

# Global study of shrimp fisheries



***Cover photographs:***

*Top image:* A double rigged shrimp trawler with nets and otterboards hanging outboard. Courtesy of the National Oceanic and Atmospheric Administration (United States of America).

*Bottom-left image:* Fishing vessels in Thailand. Courtesy of the author.

*Bottom-right image:* Shrimp being readied for market. Courtesy of the National Oceanic and Atmospheric Administration (United States of America).

# Global study of shrimp fisheries

FAO  
FISHERIES  
TECHNICAL  
PAPER

475

by  
**R. Gillett**  
FAO Consultant  
Fiji

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO in preference to others of a similar nature that are not mentioned.

The views expressed in this information product are those of the author and do not necessarily reflect the views of FAO.

ISBN 978-92-5-106053-7

All rights reserved. Reproduction and dissemination of material in this information product for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holders provided the source is fully acknowledged. Reproduction of material in this information product for resale or other commercial purposes is prohibited without written permission of the copyright holders. Applications for such permission should be addressed to:

Chief

Electronic Publishing Policy and Support Branch

Communication Division

FAO

Viale delle Terme di Caracalla, 00153 Rome, Italy

or by e-mail to:

copyright@fao.org

© FAO 2008

---

## Preparation of this document

Following the publication of a recent FAO study which showed that tropical shrimp trawl fisheries have high discard rates and account for over 27 percent of total estimated discards in all the marine fisheries of the world, the FAO Fisheries and Aquaculture Department commissioned a global review of shrimp fisheries. After completing a preliminary literature review and some in-country work, it was decided to examine shrimp fishing in a sample of ten countries, representing various geographic regions, as well as a variety of important shrimp fishery conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. The ten countries selected for the study were: Australia, Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria, Norway, Trinidad and Tobago and the United States of America. Fifteen topics related to shrimp fisheries were studied in each of the ten countries. Country studies were prepared and written with the assistance of national experts. The results of the studies are consolidated by topic and combined with specialized reviews.

This technical paper, containing both the global analysis and country reviews, is divided into two parts. Part 1 summarizes the results of the global study on the development and current status of shrimp fisheries, with a focus on direct and indirect social, economic and environmental impacts. Part 2 consists of the case studies of the countries reviewed. Finally, it includes some recommendations, using the FAO Code of Conduct for Responsible Fisheries as a reference. This report was initially reviewed internally by the FAO Fisheries and Aquaculture Department and then externally by several shrimp fishery specialists with a final review conducted by Serge M. Garcia.

## Abstract

This report summarizes the results of a global study on the development and present status of shrimp fisheries, with a focus on direct and indirect social, economic and environmental impacts. The study reviews the current situation, problems and issues, as well as the solutions found and the trade-offs made. Important topics related to shrimp fisheries are examined in ten countries representative of geographic regions, together with their various significant shrimp fishing conditions. The ten countries selected are: Australia, Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria, Norway, Trinidad and Tobago and the United States of America. The results of the country reviews are combined with specialized studies on important topics related to shrimp fisheries to produce the major findings of the overall study.

The recent world shrimp catch is about 3.4 million tonnes per year, with Asia as the most noteworthy area for shrimp fishing. World production of shrimp, both captured and farmed, is about 6 million tonnes, of which about 60 percent enters the world market. Shrimp is now the most important internationally traded fishery commodity in terms of value. In many tropical developing countries, it is the most valuable fishery export; the employment aspect is also significant. The economic importance of shrimp needs to be reconciled with considerable concern about the environmental impacts of shrimp fisheries.

Observations are made about many aspects of shrimp fisheries. These include: the development of shrimp fishing; structure of the shrimp fisheries; target species; catch/effort; economic contributions; trade; bycatch; fuel; biological aspects; impacts on the physical environment; impacts of large-scale shrimp fishing on small-scale fisheries; management; enforcement; research; data reporting; and the impacts of shrimp farming on shrimp fishing.

A major conclusion of the study is that there are mechanisms, instruments and models to enable effective mitigation of many of the difficulties associated with shrimp fishing, taking a precautionary and ecosystem approach to fisheries. The inference is that, with an appropriate implementation capacity, shrimp fishing, including shrimp trawling, is indeed manageable. In many countries, however, weak agencies dealing with fisheries, lack of political will and inadequate legal foundations cause failures in the management of shrimp fisheries. The report makes specific recommendations in a few key areas: the management of small-scale shrimp fisheries, capacity reduction; and access to the fishery.

Gillett, R.

Global study of shrimp fisheries.

*FAO Fisheries Technical Paper*. No. 475. Rome, FAO. 2008. 331p.

# Contents

Preparation of this document	iii
Abstract	iv
Acknowledgements	viii
Foreword	ix
Acronyms and abbreviations	xi
Executive summary	xv
<b>Introduction</b>	<b>1</b>
<b>Development of the study</b>	<b>3</b>
Methodology	3
Other considerations	4
<b>PART 1 MAJOR ISSUES IN SHRIMP FISHERIES</b>	<b>7</b>
<b>1. History and development of shrimp fishing</b>	<b>9</b>
<b>2. Structure of shrimp fisheries</b>	<b>15</b>
Main features at the national and global levels	15
Main fishing gear	15
Alternatives to trawl gear	24
<b>3. Shrimp species, catches and fishing effort</b>	<b>25</b>
Catches by shrimp species	25
Catches by country	28
Shrimp fishing effort and capacity	29
<b>4. Economic contribution of shrimp fishing</b>	<b>33</b>
<b>5. Trade aspects</b>	<b>37</b>
Major features of the shrimp trade	37
Major shrimp markets	38
Important issues in the shrimp trade	40
<b>6. Bycatch issues</b>	<b>45</b>
General	45
Quantifying bycatch	46
Major bycatch issues	47
The FAO Discards Study	53
Bycatch species	54
International initiatives to reduce bycatch	55
Biological research on bycatch	56
Bycatch reduction devices	59
Effectiveness of bycatch reduction efforts	63
Bycatch in non-trawl shrimp fisheries	64
Bycatch management	64

---

<b>7. Fuel use in shrimp fisheries</b>	<b>69</b>
General	69
Country experience	70
Mitigation of fuel cost increases	72
Fuel subsidies	72
<b>8. Profitability of shrimp fishing and resource rent</b>	<b>75</b>
Country experience	75
Improving profitability	77
Resource rent	79
<b>9. Biological aspects of shrimp</b>	<b>81</b>
Basic biology and life histories	81
Important issues relating to shrimp resources and biology	83
Stock assessment	84
<b>10. Impacts of shrimp fishing on the bottom habitat</b>	<b>89</b>
General	89
Describing the impact	90
Developed vs developing countries	91
Results of research on physical impacts	92
Mitigation	95
Impact on biodiversity	96
<b>11. Interactions between large- and small-scale fisheries</b>	<b>99</b>
Importance of the interaction	99
Types of interactions	100
Mitigation of negative interactions	101
<b>12. Management of shrimp fisheries</b>	<b>105</b>
General	105
Main shrimp fishery management issues in the ten study countries	105
The shrimp fisheries management framework	105
Management interventions	109
Open and limited access	112
Management of small-scale shrimp fisheries	113
Ecosystem approach to fisheries	114
Legislation for shrimp fisheries management	116
Management costs	117
Difficulty in managing shrimp fisheries	117
Cold-water shrimp fishery management	118
<b>13. Enforcement</b>	<b>121</b>
Enforcement issues in shrimp fisheries	121
Enforcement issues in small-scale shrimp fisheries	122
Electronic vessel monitoring	123
Enforcement costs	124



---

<b>14. Shrimp fishery research issues</b>	<b>125</b>
Past and current research	125
Important national issues in shrimp research	126
GEF/UNEP/FAO project research	127
Research on small-scale shrimp fisheries	127
Research costs	128
<b>15. Data reporting</b>	<b>131</b>
<b>16. Impacts of shrimp farming on shrimp fishing activities</b>	<b>133</b>
General information on shrimp farming	133
General impacts	135
Economic impacts in the marketplace	136
Destruction of mangrove forests	137
Postlarvae and broodstock	139
Escapes of cultured shrimp	140
Other impacts of shrimp farming on shrimp fishing	141
Other considerations	142
<b>17. Conclusions</b>	<b>145</b>
Is shrimp fishing manageable?	145
Management of small-scale shrimp fisheries in developing countries	146
Benefits and costs	147
Australia	149
Some suggestions	149
<b>PART 2 SHRIMP FISHERIES IN SELECTED COUNTRIES</b>	<b>153</b>
<b>Shrimp fishing in Australia</b>	<b>155</b>
<b>Shrimp fishing in Cambodia</b>	<b>177</b>
<b>Shrimp fishing in Indonesia</b>	<b>193</b>
<b>Shrimp fishing in Kuwait</b>	<b>215</b>
<b>Shrimp fishing in Madagascar</b>	<b>223</b>
<b>Shrimp fishing in Mexico</b>	<b>235</b>
<b>Shrimp fishing in Nigeria</b>	<b>247</b>
<b>Shrimp fishing in Norway</b>	<b>259</b>
<b>Shrimp fishing in Trinidad and Tobago</b>	<b>273</b>
<b>Shrimp fishing in the United States of America</b>	<b>289</b>
<b>REFERENCES</b>	<b>313</b>

## Acknowledgements

The author wishes to acknowledge the invaluable assistance and advice of the staff of the FAO Fisheries and Aquaculture Department and, in particular, the professional, consultant and general staff in the Fish Products and Industry Division, without whose help this study could not have been undertaken. Jeremy Turner provided superb support throughout, while several national consultants were involved in the preparation of Part 2 of the study, including M. Badrudin (Indonesia), Mohsen Al-Husaini (Kuwait), Zbigniew Kasprzyk (Madagascar), B.B. Solarin (Nigeria), Øystein Hermansen (Norway), Suzuette Soomai (Trinidad and Tobago), D. Aguilar (Mexico) and J. Grande-Vidal (Mexico). The cooperation and inputs from FAO's regional officers and field staff, together with the directors and staff of numerous regional fisheries organizations, are gratefully acknowledged. Special assistance and comments were provided by Serge M. Garcia, John Ward, Rohana Subasinghe, Kieran Kelleher, Ian Cartwright, Hans Båge, Jason Clay, Steve Trent, Stephen Hall, Hope Kearney, Mike King, Purwito Martosubroto, John Willy Valdemarsen and David Sterling.

## Foreword

A global review of shrimp fisheries was overdue for several reasons. Shrimp and prawns are an extremely interesting group of resources, with complex life cycles, occurring everywhere from tropical estuarine ecosystems to shallow shelves, continental slopes and deep seas, as well as the open ocean; they provide thought-provoking opportunities for comparison. They are also one of the most important internationally traded fishery products, and one of the few that can be considered a “commodity”, with a value of US\$10 billion (or 16 percent of world fishery exports), which generates substantial economic benefits, especially for many developing countries. They contribute substantially to the livelihoods of poor vulnerable communities, particularly as a source of cash.

Their “discovery” by industrial fisheries raised immense economic hopes in the 1960s, followed by concern as overcapacity and economic problems increased. Many of the fisheries could be considered as a metaphor of the global fishery crisis, with their long trail of sectoral, cross-sectoral and ecosystem issues. Overfishing is rampant, but no collapse has been reported, despite heavy fishing pressure. Attempts to control fishing efforts have been largely defeated by fishers’ inventiveness and technological progress. Conflicts between artisanal and industrial fisheries, exploiting two different phases of the life cycles for penaeids are widespread, raising – sometimes violently – the issue of allocation between endowed modern exploitation systems and vulnerable coastal communities. To make things worse, the explosive development of shrimp culture has exacerbated conflicts related to the use of wild broodstock and postlarvae and to significant competition on the global market.

On the environmental side, shrimp is strongly influenced by climatic drivers, but also often affected by coastal habitat degradation, such as the destruction of mangroves by aquaculture or of seagrass beds by illegal trawling in coastal areas. Coastal shrimp ecosystems have experienced a decrease in their average trophic level from which, shrimp, as prey, has probably benefited (resisting to collapse). Exploiting high-biodiversity ecosystems, specialized industrial shrimp fisheries capture large quantities of bycatch, consisting to a large extent of “trash fish”. Having limited storage capacity, these fisheries have been the world champions for discarding and, despite significant improvements in the last decade, still contribute about 25 percent to world discards. Little progress has been made in many countries to manage these multispecies fisheries more efficiently. Of the bycatch species, turtles have caused major problems; shrimp fisheries are an example here of the difficulty and also of the success in introducing bycatch reduction devices (BRDs). Last but not least, the use of trawls leads to an ecological impact on the superficial fauna and on the benthos, the extent and reversibility of which remain controversial.

Given both the economic and ecological importance of shrimp resources and the numerous concerns associated with shrimp fishing, it is surprising that it has been almost two decades since the last attempt was made to examine the major issues associated with shrimp fishing in the world. At a time when conventional governance is questioned and a shift to an ecosystem approach to fisheries (EAF) has been adopted, global shrimp fisheries are an excellent example of what should have been avoided but, also, in some areas, of what can be achieved with fishers’ collaboration.

It is important that necessary future action be based on complete and reliable knowledge. The *Global study of shrimp fisheries* contributes to this knowledge by examining available information on fisheries: the main issues, research achievements and gaps, as well as the management solutions and difficulties encountered in various parts of the world. The document gives several perspectives on the many areas of controversy, placing them, where appropriate, in the framework of the FAO Code of Conduct for Responsible Fisheries and

EAF. It should not be surprising that, by doing this, the review offers more open questions than definite answers.

I believe that this compilation and the reflections it contains will be particularly useful for the next generation of scientists and managers who will try to tackle the issues raised, with the additional benefit of new tools from slowly emerging modern governance.

**Serge M. Garcia**

Director (retired)

Fisheries and Aquaculture Management Division

FAO Fisheries and Aquaculture Department

## Acronyms and abbreviations

<b>ABARE</b>	Australian Bureau of Agricultural and Resource Economics
<b>ABS</b>	Australian Bureau of Statistics
<b>ACP</b>	African, Caribbean and Pacific Group of States
<b>AFMA</b>	Australian Fisheries Management Authority
<b>AFZ</b>	Australian Fishing Zone
<b>ASIC</b>	Australian Seafood Industry Council
<b>ASMFC</b>	Atlantic States Marine Fisheries Commission
<b>BED</b>	Bycatch exclusion device
<b>BRD</b>	Bycatch reduction device
<b>CARICOM</b>	Caribbean Community
<b>CFRAMP</b>	CARICOM Fisheries Resource Assessment and Management Programme
<b>CITES</b>	Convention on International Trade in Endangered Species of Wild Fauna and Flora
<b>CNP</b>	<i>Carta Nacional Pesquera</i> (National Fisheries Chart, Mexico)
<b>CNRO</b>	<i>Centre national de recherches océanographiques et des pêches</i> (National Oceanographic and Fisheries Research Centre)
<b>CONAPESCA</b>	<i>Comisión Nacional de Acuicultura y Pesca</i> (National Aquaculture and Fisheries Commission)
<b>CPUE</b>	Catch per unit effort
<b>CRFM</b>	Caribbean Regional Fisheries Mechanism
<b>CSIRO</b>	Commonwealth Scientific and Industrial Research Organization
<b>CSO</b>	Central Statistical Office
<b>DANIDA</b>	Danish International Development Agency
<b>DFO</b>	Department of Fisheries and Oceans
<b>DKP</b>	<i>Departemen Kelautan dan Perikanan</i> (Indonesian Ministry of Marine Affairs and Fisheries) (see also MMAF)
<b>DPRH</b>	<i>Direction de la pêche et des ressources halieutiques</i>
<b>EAF</b>	Ecosystem approach to fisheries
<b>EBM</b>	Ecosystem-based management
<b>EEZ</b>	Exclusive economic zone
<b>EJF</b>	Environmental Justice Foundation
<b>EU</b>	European Union
<b>FAO</b>	Food and Agriculture Organization of the United Nations
<b>FMP</b>	Fishery management plan
<b>FMSEU</b>	Fisheries Monitoring Surveillance and Enforcement Unit
<b>FRDC</b>	Fisheries Research and Development Corporation
<b>GAPCM</b>	<i>Groupement des aquaculteurs et pêcheurs de crevettes de Madagascar</i> (Madagascar Shrimp Fishers' and Farmers' Cooperative)
<b>GBRMP</b>	Great Barrier Reef Marine Park
<b>GDP</b>	Gross domestic product
<b>GEF</b>	Global Environment Facility
<b>GJ</b>	Gigajoule
<b>GMFMC</b>	Gulf of Mexico Fishery Management Council

---

GSA	Gulf of Mexico and South Atlantic
GSP	Generalized System of Preferences
G(R)T	Gross (registered) tonnage
HMS	Highly migratory species
HP	Horsepower
ICES	International Council for the Exploration of the Sea
ICLARM	International Center for Living Aquatic Resources Management
IHHNV	Infectious hypodermal and haematopoietic necrosis virus
IIED	International Institute for Environment and Development
ISSCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
IUCN	World Conservation Union
JTED	Juvenile and trash excluder device
LPUE	Landings per unit effort
LTPY	Long-term potential yield
MAFCONS	Managing Fisheries to Conserve Groundfish and Benthic Invertebrate Species Diversity
MCSU	Monitoring, Control and Surveillance Unit
MMAF	Ministry of Marine Affairs and Fisheries (see also DKP)
MSC	Marine Stewardship Council
MSY	Maximum sustainable yield
NAFO	Northwest Atlantic Fisheries Organization
Nei	Not elsewhere included
NFC	National Fisheries Company
NGO	Non-governmental Organization
NIOMR	Nigerian Institute for Oceanography and Marine Research
NITOA	Nigerian Trawler Owners Association
NMFS	National Marine Fisheries Service (United States)
NOAA	National Oceanic and Atmospheric Administration
NOM	<i>Normas Oficiales Mexicanas</i> (Mexican Official Standards).
NORMAC	Northern Prawn Fishery Management Advisory Committee
NPF	Northern Prawn Fishery
NRC	National Research Council (United States)
NSW	New South Wales
OECD	Organisation for Economic Co-operation and Development
OIE	World Organisation for Animal Health
OPEC	Organization of the Petroleum Exporting Countries
PAAF	Public Authority for Agriculture and Fish Resources
PICES	North Pacific Marine Science Organization
PL	Postlarvae
PNRC	<i>Programme national de recherche crevettière</i> (National Shrimp Research Programme, Madagascar)
QDPI	Queensland Department of Primary Industries and Fisheries
SAGARPA	<i>Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación</i> (Mexican Agriculture, Livestock, Rural Development, Fisheries and Food Secretariat)
SEAFDEC	Southeast Asian Fisheries Development Center

---

<b>SEMARNAT</b>	<i>Secretaría del Medio Ambiente y Recursos Naturales</i> (Environment and Natural Resources and Fisheries Secretariat)
<b>SFR</b>	Statutory fishing right
<b>SMC BRD</b>	Square-mesh codend bycatch reduction device
<b>SSA</b>	Southern Shrimp Alliance
<b>TAC</b>	Total allowable catch
<b>TED</b>	Turtle excluder device
<b>TPWD</b>	Texas Parks and Wildlife Department
<b>TSV</b>	Taura syndrome virus
<b>UNEP</b>	United Nations Environment Programme
<b>USCG</b>	United States Coast Guard
<b>VAT</b>	Value-added tax
<b>VMS</b>	Vessel monitoring system
<b>WASI</b>	Wild American Shrimp
<b>WECAFC</b>	Western Central Atlantic Fishery Commission
<b>WWF</b>	World Wide Fund for Nature





## Executive summary

As the debate over the economic and social costs and benefits associated with shrimp fisheries increases in intensity, FAO has recognized that it has an important role in the discussion process. Although this role could take several forms, it is likely that at this point, FAO's most appropriate contribution would be a description of situations, problems and issues, as well as solutions and trade-offs that have been made.

It is simply not possible in a short study to examine shrimp fisheries in all countries where they are located. Accordingly, the present study of shrimp fisheries examines important aspects of shrimp fisheries in ten countries. These countries represent the various geographic regions as well as the variety of important shrimp fishing conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. The ten countries selected for the study are Australia, Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria, Norway, Trinidad and Tobago, and the United States of America.

Sixteen topics were identified for close examination: the history and development of shrimp fishing; the structure of shrimp fisheries; the target species of shrimp fishing and fisheries catch and effort; the economic contribution of shrimp fishing; trade aspects; bycatch issues; the profitability of shrimp fishing; energy input aspects; biological aspects; impacts on the physical environment; impacts of shrimp fishing on small-scale fisheries; management; enforcement; research; data reporting; and the impacts of shrimp farming on shrimp fishing.

### TRAWL GEAR

A major characteristic of most large-scale shrimp fishing is the use of trawl gear. Although the number of shrimp trawlers in the world is not known, it was estimated that in the late 1990s there were about 140 000 trawlers of all types in the world's fisheries. There has been considerable interest in developing an alternative to shrimp trawling. Nevertheless, no substantial progress has been made in replacing trawl gear and, after nearly a century, it remains the main producer of important commercial shrimp species. Because of the lack of promising, industrial-scale alternatives to shrimp trawling, most shrimp gear technology efforts in recent decades have been channelled into improving trawl gear and techniques, rather than developing new industrial shrimp fishing technologies.

### SHRIMP SPECIES

Slightly less than 300 species of shrimp are of economic interest worldwide; of these, only about 100 comprise the principal share of the annual world catch. Six shrimp species groups account for 83 percent of the global shrimp catch. The most important single species in the world by weight is the akiami paste shrimp (*Acetes japonicus*).

### PENAEIDS, CARIDEANS AND SERGESTIDS

Unlike most previous global reviews of shrimp fisheries, the present study attempts to cover the fisheries for the three major groups of shrimp: penaeids, carideans and sergestids. One of the reasons for this approach is that many of the controversial topics associated with shrimp fishing transcend the boundaries between the three groups. It should be recognized, however, that there are major differences among the penaeids, carideans and sergestids that should be borne in mind when considering the results of this study.

### SHRIMP CATCHES

The recent world catch of shrimp is about 3.4 million tonnes per year. Asia is the most important area for shrimp fishing; China, together with four other Asian countries, accounts

for 55 percent of the world catch. Globally, about 60 percent of shrimp production in the world comes from fishing, while 40 percent is from farming.

### **BYCATCH**

Shrimp fishing, especially trawling in tropical regions, produces large amounts of bycatch, which is one of the most controversial aspects of the fishing; much of the management attention associated with shrimp fisheries is focused on reducing bycatch. The term “bycatch” is relatively clear in industrial shrimp fisheries of developed countries, but becomes increasingly irrelevant in the progression from large-scale fisheries in the developed world to small-scale fisheries in poor tropical countries – where almost all components of the catch have some economic value and may therefore become a target.

### **WHY WORRY ABOUT BYCATCH?**

Bycatch, particularly when discarded, is a serious concern for a number of interconnected reasons that are not specific to shrimp fishing. First, the lack of identification of the animals killed and rejected (many of which are vulnerable or threatened emblematic species), impedes a proper assessment of their status and trends and any direct management, which raises the risk of depletion or outright extinction. Second, bycatch creates interactions with other fisheries targeting the same species, complicating assessment and management. Third, bycatch, like directed catch, affects the overall structure of trophic webs and living habitats. Finally, the discarding of killed animals raises the ethical issue of wastage of natural production.

### **DIFFICULTIES IN ESTIMATING THE AMOUNT OF BYCATCH**

There are widely differing estimates for the amount of bycatch in the various shrimp fisheries, partly resulting from the different definitions of bycatch, different systems of measurement and the low level of actual monitoring. Even in relatively regulated fisheries in developed countries, it is not simple to estimate and subsequently compare levels of bycatch in a straightforward manner.

### **TOTAL GLOBAL CATCH BY SHRIMP FISHERIES**

Developing a reliable estimate of the total global catch of all species (shrimp and non-shrimp) from every shrimp fishery is beyond the scope of this report. Relatively few regions have reliable data on total species captured (shrimp, finfish and other marine invertebrates). In addition, spatial and temporal variations of species associated with shrimp habitats and differences in fishing operations prevent even a rough approximation of the total global catch of shrimp fisheries.

### **THE FAO DISCARDS STUDY**

Bycatch that is discarded is especially troublesome. A recent FAO study (Kelleher, 2005) indicated that shrimp trawl fisheries are the single greatest source of discards, accounting for 27.3 percent (1.86 million tonnes) of estimated total discards. The aggregate or weighted discard rate for all shrimp trawl fisheries is 62.3 percent and is extremely high compared with other fisheries.

### **BYCATCH OF JUVENILES OF COMMERCIAL FISH SPECIES**

A fundamental bycatch issue in both warm- and cold-water shrimp trawl fisheries is the catch of juveniles of important commercial fish species. This is significant in several fisheries, including: the bycatch of cod off Norway; rockfish off Oregon; red snapper and Atlantic croaker in the Gulf of Mexico; king mackerel, Spanish mackerel and weakfish off the southeast United States; and plaice, whiting, cod and sole in the southern North Sea.

## **BYCATCH OF SEA TURTLES**

The bycatch of sea turtles by warm-water shrimp trawling is a contentious issue. The subject has generated considerable publicity and subsequent management action has had a major effect on most of the large shrimp fisheries in the tropics. The means to reduce turtle mortality are well known, but they come with a price.

## **BIOLOGICAL RESEARCH ON SHRIMP BYCATCH**

Biological research on shrimp bycatch has consisted of determining bycatch quantities, species composition and impacts on the bycatch species and on the ecosystem. Shrimp bycatch studies appear to be most advanced in Australia. Two Australian studies are especially relevant and provide an indication of what has been achieved in shrimp bycatch research. Important areas for future research are: recovering seabed fauna after depletion; examining ways to assess the sustainability of the harvest of bycatch species; and measuring the recruitment, growth, mortality and reproduction of vertically dominant large seabed organisms.

## **BYCATCH MANAGEMENT**

A variety of measures has been used to reduce bycatch in the various shrimp fisheries. These include: a complete ban on trawling; bans on fishing in areas and/or periods when bycatch is known to be high; reduction of overall fishing effort; and, most commonly, modifications to fishing gear, mainly through the use of bycatch reduction devices (BRDs) and other modifications to the trawl net. Other measures used to reduce bycatch are catch quotas, discard bans and limits in the shrimp-to-bycatch ratio. Measures to make better use of bycatch are also considered to be part of shrimp bycatch management; several large shrimp bycatch initiatives are at least partially based on the concept of bycatch enhancement. Included in bycatch enhancement are improvements in bycatch handling and marketing, as well as product development.

## **LESSONS LEARNED IN BYCATCH MANAGEMENT**

Several authors comment on the lessons learned from successful efforts to manage bycatch, including: the setting of targets/requirements and allowing innovation; the importance of follow-up evaluation; the importance of bycatch management plans; the role of fisheries extension; and avoidance of having to “reinvent the wheel”.

## **BYCATCH CHALLENGES**

There have been some remarkable reductions in shrimp bycatch from large- and medium-scale shrimp fisheries. The situation appears manageable, and it is likely that further reductions in bycatch levels could be made, albeit with some sacrifices by fishers. One of the main challenges is to determine the acceptable levels of bycatch, taking into consideration the costs and benefits of reaching these levels. The objective of reducing bycatch in many small-scale shrimp fisheries of developing countries is challenging and perhaps even unattainable. Economic incentives do not favour bycatch reduction, and enforcement of any requirements for bycatch reduction can be extremely difficult.

## **ECONOMIC BENEFITS OF SHRIMP FISHING**

Information on simplistic indicators of benefits from shrimp fishing is presented for ten representative shrimp fishing countries: contribution to gross domestic product (GDP), shrimp consumption, employment, gross value of the catch and value of exports. Comments are made on the availability and reliability of the indicator data. Information on resource rent appears to be important, but has been estimated for only a few of the world's shrimp fisheries.

## TRADE

World production of shrimp, both captured and farmed, is around 6 million tonnes, about 60 percent of which enters the world market. Shrimp is now the most important internationally traded fishery commodity in terms of value. Annual exports of shrimp are currently worth more than US\$10 billion, or 16 percent of all fishery exports. Although over 100 countries export substantial quantities of shrimp, the international shrimp markets are concentrated in just three areas: the United States, Japan and Europe. Three current issues affecting the shrimp trade are especially important: the United States trade measures relating to turtle conservation, United States anti-dumping tariffs and ecocertification of shrimp fisheries.

## FUEL ISSUES

The three most important fuel issues for shrimp fisheries are the relatively large amount of fuel expended for the amount of food obtained, the impact of rising fuel prices on the economics of shrimp fishing, and the use of fuel subsidies. Fuel use by shrimp trawling is large compared with other fisheries, but other types of shrimp fishing such as stow nets are much more energy-efficient. A wide range of measures have been taken to reduce the impacts of fuel price increases on shrimp fishing. These can be placed in two general categories: measures that reduce fuel use and those that increase profitability to compensate for fuel cost increases. A recent study showed that, of the 34 largest shrimp-producing nations, 19 countries had fuel subsidies and seven had no subsidies; there was no information for the remaining eight countries.

## PROFITABILITY

In examining shrimp fishing in ten countries, one of the main features to emerge is the current low profitability of many commercial shrimp fishing operations. The typical situation consists of rising costs (mainly fuel) and falling revenue from shrimp sales (resulting to a large degree from competition with lower-cost farmed shrimp) in an environment where there is overcapacity. A number of measures to improve the current situation of poor profitability have been implemented or recommended. The most important measures are: increased attention to fuel costs, fleet reduction, market promotion, subsidies and import barriers. The boldest move to improve the profitability of domestic shrimp fishing in recent years has been the initiative in the United States to restrict the import of farmed shrimp on the basis that it has been dumped on the market.

## RESOURCE RENT

Resource rent can be defined as the difference between the revenue from a fishery resource and the costs of exploiting it, including capital costs. In a broader sense, if non-monetary costs and benefits are taken into account, rent can be considered as the net economic return from a fishery to society. Good management regimes tend to increase rent; others, especially open access, can dissipate it. Unfortunately, information on the amount of resource rent available appears to have been estimated for only a few of the world's shrimp fisheries.

## STOCK ASSESSMENT

Stock assessment in the shrimp fisheries of the world ranges from simple trends in catch per unit effort (CPUE) to extremely complex stock assessment and simulation models. Assuming that surreptitious increases in capacity are understood and accounted for, CPUE trends have the advantage that they are simple, easy for developing country managers to use and readily understood by fishers and the general public. The more sophisticated models are able to integrate many different types of information on shrimp resources, to give potential yields from a fishery and to be used for projections. Despite the limitations of using CPUE to gauge the conditions of shrimp resources, the reality is that many, if not most, shrimp fisheries in developing tropical countries are heavily dependent on CPUE trends for their management and are likely to continue to be so in the foreseeable future.

## PHYSICAL IMPACTS OF SHRIMP FISHING

The effects of shrimp fishing on benthic habitats can be divided into several categories: alteration of physical structure; sediment suspension; changes in chemistry; and changes to the benthic community, resulting in changes to the ecosystem. The degree to which shrimp fishing, specifically trawling, alters the seabed and the associated effects on biodiversity have generated an enormous amount of discussion and controversy, echoing and contributing to the more general and controversial debate on trawling. The factors complicating this debate include: the difficulty in clearly separating fishing impacts from environmental variability; lack of information on the original state of some fishing grounds; a lack of agreement on the level and quality of the evidence of impacts; doubts about the reversibility of these impacts; the objective difficulty in assessing the more insidious impact of the overall flattening of the ground and the less visible impacts on the benthic and microbial fauna; and the relative importance attached to the ecological, social, economic and societal costs and benefits of fishing.

## IMPACTS OF SHRIMP FISHING ON SMALL-SCALE FISHERIES

Large-scale shrimp fishing interacts in several ways with small-scale fisheries, including: physical interactions; safety at sea; targeting the same resources; interaction through bycatch; habitat disturbance; and market interactions. To reduce the physical impacts of large-scale shrimp fishing on small-scale operations, the most common measure is simply to move the large boats offshore. There is a general feeling among fisheries managers in several regions of the world that the various approaches to reduce negative interactions would be effective if only they were enforced. The irony is that, in developing countries where the conflicts generated by shrimp fishing are the greatest, the required governance and enforcement are the weakest, either because of a lack of capacity in monitoring, control and surveillance, or because the social costs of the measures, if enforced, are perceived as dangerously high.

## OBJECTIVES OF SHRIMP FISHERY MANAGEMENT

Management objectives are not always clearly stated and are rarely prioritized. The long-term conservation of the resource is an important management objective in most shrimp fishery management schemes. Maximum economic yield is a further important objective in the management of many shrimp fisheries in developed countries. Maximum sustainable yield (MSY) is also common, with Indonesia as a good example. The reduction of bycatch/discards and physical impacts is becoming increasingly important, especially in developed countries. In addition, conflict reduction plays a significant role as a management objective in shrimp fisheries, especially in developing countries. Achieving an equitable allocation of shrimp resources among the various users is important in the penaeid fisheries because of the movement of shrimp between shallow inshore and deep offshore areas. Maximizing employment is sometimes de facto the most important management objective in some of the poorer countries. Generation of government revenue through licence fees is often an unstated objective in the management of shrimp fisheries in countries ranging in development from Cambodia to the United States.

## PRIORITIZING OBJECTIVES

It is difficult to prioritize the incongruous and conflicting objectives that are often set for shrimp fisheries. On a practical level, one situation is especially common – attempting to maximize economic yield in an open access regime. An important objective of open access shrimp fisheries, probably more common in the world than restricted access, is often to maximize employment. This is, however, incompatible with the economic efficiency needed to generate maximum economic yield.

### **DIFFICULTY IN MANAGING SHRIMP FISHERIES**

Compared with other fisheries, warm-water shrimp fishery management is relatively easy as a result of several factors: growth and mortality have been determined for many of the important species; shrimp is highly fecund; and abundance is largely climate-driven. Furthermore, because most warm-water shrimp fisheries utilize more than one shrimp species, it is unlikely that bad year classes will occur in all species in one year. Because of the short life cycle, overfishing is immediately apparent, and if management mistakes are made, they can often be rectified in one year. Specific difficulties are encountered, however, in sequential fisheries (where artisanal fishers take immature shrimp, impacting directly on the recruitment to industrial fisheries), and through strong multispecies interactions with all coastal fisheries.

### **MANAGEMENT MEASURES**

There are a variety of measures available to shrimp fisheries managers. Some of the main management issues and associated interventions are the following.

- Economic overfishing in shrimp fisheries has been addressed by catch limits, limiting/reducing participation, restrictions on gear, stock enhancement, monetary measures and subsidies.
- Growth overfishing has been dealt with by closed seasons, closed areas, mesh sizes and minimum shrimp landing sizes.
- Discards/bycatch have been addressed by BRDs, turtle excluder devices (TEDs) , mesh sizes, other net modifications, gear restrictions, no discards policies, closed areas, limits on bycatch of particular species, unilateral trade measures and awareness raising of fishers.
- Physical impacts and ecosystem damage have been dealt with by gear restrictions, closed areas and fishing effort reductions. Total bans on trawling have been proposed.
- Conflicts with small-scale fishers have been addressed by zonation, BRDs, reduction of large-scale fishing effort, time-sharing of fishing grounds and total bans on trawling.
- Resource allocation between groups of fishers has been dealt with by closed areas, closed seasons, gear restrictions and mesh sizes.
- Habitat degradation of the inshore nursery ground has been addressed by controls on coastal zone development and land reclamation, restricting pollution, and watershed management.

### **MANAGEMENT IN OPEN ACCESS REGIMES**

A fundamental problem for many of the world's shrimp fisheries is open access – i.e. the right for the public to participate in a fishery. In general, if there are no barriers to entry, fisheries typically end up producing at the point where total revenue equals total costs or even beyond, when subsidies are provided. The history of shrimp fishery management shows that management interventions that do not control access and/or removals (e.g. catch limits, closed seasons) are usually ineffective at preventing economic overfishing in the long term.

### **ELEMENTS OF EFFECTIVE FISHERIES MANAGEMENT LEGISLATION**

In countries with effectively managed shrimp fisheries, legislation often requires or encourages certain positive features. These include fisheries management plans; bycatch management plans; collaboration among the various stakeholders; provisions for keeping management interventions at arms' length from the political process; ecosystem-based management; and the flexibility to intervene quickly, as a result of research findings or changing fishery conditions. Many of these features are important for fisheries management in general and not strictly specific to shrimp fishery management.

## ENFORCEMENT COMPLEXITY

In general, the management of shrimp fisheries is associated with a more complex enforcement environment than most other fisheries, although there is a large range of national conditions. The complicating factors for shrimp fisheries include:

- the use of numerous types of management measures, many of which require enforcement activities at sea;
- large incentives to circumvent restrictions on inshore trawling;
- the fact that many restrictions are counter to the short-term economic interests of fishers;
- some management measures that infuriate fishers;
- the huge problems of enforcing requirements in small-scale shrimp fisheries.

## ENFORCEMENT ISSUES

Some important enforcement issues that emerged are the following.

- Poor enforcement appears to stem from insufficient operational budgets, inadequate enforcement infrastructure, weak institutions, political considerations affecting enforcement priorities, and corruption.
- In many cases where there is efficient enforcement, the fishing industry itself has at least some enforcement responsibilities.
- If penalties for non-compliance are harsh enough, then the actual detection efforts do not need to be so great.
- A reasonable degree of compliance with some of the technical measures (mesh sizes, BRDs) requires at least some onboard observer coverage.
- Enforcement of regulations in small-scale shrimp fisheries is often considered too difficult.
- Not all cases of good enforcement of shrimp fisheries management requirements occur in wealthy, developed nations. The importance of a fishery to the national economy and effective national institutions appear at least as important as national wealth.

## RESEARCH ON SHRIMP FISHERIES

Much of the past research associated with shrimp fisheries has involved biological research on shrimp in support of stock assessment. Overall, this has been successful – researchers have made considerable progress in gaining an understanding of the life histories and other aspects of the biology of the most important species of shrimp. Currently, much of the shrimp research in the various shrimp fisheries around the world can be placed into several categories:

- ongoing monitoring and stock assessment of fisheries;
- interdisciplinary research involving biology, sociology and economics, addressing issues such as reduction of conflicts and improvement of economic efficiency, e.g. by developing bioeconomic models and determining optimal exploitation strategies;
- gear technology, especially for reducing bycatch and impacts on the benthic environment;
- topics of special concern – impacts on non-target species and effects of trawling on the sea bottom.

## MAJOR RESEARCH ISSUES

Several issues related to research that emerged in the study include:

- the identification of shrimp stock assessment models that are appropriate for use in many developing tropical countries – a persistent issue;
- the degree to which the research agenda should be driven by the information required to intervene effectively and achieve important management objectives;
- the need for greater involvement of socio-economic research in small-scale shrimp fisheries, particularly for the development of integrated assessments.

## IMPACTS OF SHRIMP FARMING ON SHRIMP FISHING

The main effects of shrimp farming on shrimp fishing are:

- economic impacts in the marketplace;
- the destruction of mangrove forests for shrimp aquaculture operations;
- the capture of shrimp postlarvae and broodstock for farming;
- escapes of cultured shrimp into the wild;
- the “trash fish” issue.

Overall, shrimp farming has had a substantial impact on shrimp fishing activities, from the fishery level to the international level. Interaction in the marketplace seems to have the most effect, at least during the present period of low profitability. The total impact of shrimp farming cannot be quantified, but the net result has been lower prices.

## IS SHRIMP FISHING MANAGEABLE?

Single-species tools and models are available for the management of shrimp fishing. This does not mean that shrimp fishery management practices are problem-free. In many countries, weak agencies dealing with fisheries, lack of political will and an inadequate legal foundation cause failures in management. These factors, which can be encountered in all fisheries across the world, are largely responsible for the lack of success, rather than any inherent unmanageable qualities of shrimp fishing gear or practices. This suggests that efforts to improve shrimp fishery management in these countries should pay more attention to such factors as agency effectiveness, awareness raising and the provision of adequate legislation to support rights-based and dedicated access systems, among others.

The findings of this study suggest that shrimp fishing, including trawling, is indeed an activity that can be managed to attain objectives, even though the management of many small-scale shrimp fisheries in developing countries presents an extremely difficult challenge.

## SMALL-SCALE SHRIMP FISHERIES IN DEVELOPING COUNTRIES

Opinions on how best to deal with the challenges of small-scale shrimp fisheries and improve their management seem to fall into three categories: a *laissez-faire* approach – i.e. recognizing difficult realities, yet giving low or no priority to the management of these fisheries; a strategy to favour management measures that are to some degree easy to enforce, such as marine-protected areas or total bans; and a comanagement approach, in which communities and government are jointly involved in the management process.

Despite the differences in dealing with the complexities of small-scale shrimp fisheries, many shrimp specialists agree that much more attention should be focused on what is desirable, possible and practical in the management of these fisheries.

## BENEFITS AND COSTS OF SHRIMP FISHING

In the process of managing shrimp fisheries, some mechanism for balancing the benefits of fishing with the various costs incurred is required. Considering the scarcity and limitations of the data on both shrimp fishing benefits and costs, it seems as if there is not enough information on benefits in most countries to determine whether costs incurred are justified, at least not in a quantitative sense. Although it is recognized that it is extremely difficult to compare benefits and costs for most shrimp fisheries, in effect, they are being compared and trade-offs are being made in the fisheries management process. The subsequent controversy appears to stem partially from a lack of stakeholder consensus on the mechanisms for making trade-offs and on the adequacy of the information used.

## AUSTRALIA

The experiences acquired and lessons learned from Australia’s large investment in shrimp fishing research and management could be used as a guide, saving fishery managers in other countries much time and expenditure from having to “reinvent the wheel”.



**RECOMMENDATIONS**

Since this has been the first attempt in several decades to review the world's shrimp fisheries, some effort has been made to provide specific recommendations in selected key areas such as the management of small-scale shrimp fisheries, capacity reduction, open access and multispecies issues – in the perspective of the FAO Code of Conduct for Responsible Fisheries and the precautionary and ecosystem approaches.



---

# Introduction

Shrimp resources are highly diversified and support a large range of fisheries. Shrimp fishing takes place in equatorial, subpolar and most intermediate ocean regions. Much of the global catch of shrimp is taken by large industrial fishing operations, but some of the largest shrimp fisheries are based on small-scale fishing, including non-motorized operations. The top ten shrimp-producing nations include both some of the richest and poorest nations in the world. The management of some shrimp fisheries is carried out effectively and illustrates the potential benefits of conventional fisheries management as well as its limits. However, other important national shrimp fisheries are textbook examples of how unmanaged fisheries can dissipate benefits.

Shrimp fishing is exceptional in the amount of controversy it generates. A recent FAO study (Kelleher, 2005) showed that tropical shrimp trawl fisheries generally have high discard rates and account for over 27 percent of total estimated discards in all the marine fisheries of the world, amounting to some 1.8 million tonnes per year. Trawling, including shrimp trawling, has been compared to forest clear-cutting and accused of being the world's most wasteful fishing practice. Garcia (1989) states that shrimp fisheries are the major source of fisheries conflict and problems in the tropical zone.

In spite of the above, it is difficult to deny that shrimp fisheries are vital and produce substantial benefits. About 3.4 million tonnes of wild shrimp are currently caught annually and shrimp is now the most important internationally traded fishery commodity – in recent years, about 18 percent of the total value of all this trade. In many tropical developing countries, shrimp is the most valuable fishery export. The employment aspect is also significant. Several years ago when Indonesia, for example, banned shrimp trawling in its waters, an estimated 25 000 people lost their jobs.

Shrimp fishing is associated with numerous benefits but also with various high costs. A review of the recent shrimp fisheries literature suggests that many of the discussions on the costs and benefits of shrimp fishing have been to some extent polarized to support a particular point of view and there is no comprehensive perspective.

This report summarizes the results of a global study on the development and current status of shrimp fisheries, with a focus on direct and indirect social, economic and environmental impacts.



# Development of the study

## METHODOLOGY

In mid-2005, FAO recruited the author to undertake a global review of shrimp fisheries and associated issues. One of his first tasks was to identify and articulate the most suitable approach for a study of shrimp fishing on a global basis. Discussions at FAO, together with a preliminary literature review and some in-country work, led to several conclusions concerning the study's methodology and scope. Because of the limited time and means available, it was decided to base the review on a sample of ten countries, representing various geographic regions, as well as a variety of important shrimp fishery conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. The ten countries selected for the study were: Australia, Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria, Norway, Trinidad and Tobago and the United States of America (Figure1).

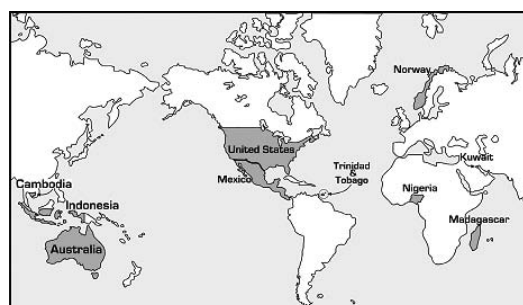
Numerous topics related to shrimp fisheries were studied in each of the ten countries. Specifically, the following 15 topics were identified for close examination.

1. History, development and structure of shrimp fisheries: types of fishing, numbers of vessels, ownership of vessels.
2. Target species of shrimp fishing; catch and effort of fisheries for these species.
3. Economic contribution of shrimp fishing in terms of employment, nutrition and contribution to gross domestic product (GDP).
4. Trade aspects, including amount and value of exports of shrimp from the various fisheries.
5. Bycatch issues associated with shrimp fishing.
6. Profitability of shrimp fishing and information on resource rent.
7. Energy input aspects.
8. Biological aspects.
9. Impacts of shrimp fishing on the physical environment.
10. Impacts of shrimp fishing on small-scale fisheries.
11. Types of management of shrimp fisheries.
12. Enforcement of management measures.
13. Research on shrimp fisheries.
14. Data reporting.
15. Impacts of shrimp farming on shrimp fishing activities.

A key element of the methodology of the study is that the results of the ten country reviews (Part 2 of this report), with respect to these 15 topics, are combined with specialized studies on these topics to produce the major findings of the overall report. Finally, some recommendations are made, using the FAO Code of Conduct for Responsible Fisheries as a guide.

This report was initially reviewed internally by the FAO Fisheries and Aquaculture Department and then externally by several shrimp fishery specialists. Serge M. Garcia conducted a final review of the document.

FIGURE 1  
The ten study countries



Certain limitations of the study should be acknowledged. It relies to some degree on national fisheries statistics or a form of these statistics given to FAO. In several countries the quality of the statistics is questionable and, in some cases, could be described as indicative at best. Nevertheless, these statistics are the best available and are consequently used in this report out of necessity. It will also be noted that several important shrimp fishing countries are not included in the study. Their exclusion, however, allows inclusion of some countries that may be more representative of global or regional conditions. China is an extreme case – many more months of work would be necessary for the country to be covered adequately. Additional limitations of the study are the following.

- Several national consultants assisted in the work. In some respects, the degree of coverage and the perspectives on the various shrimp fishing topics may have been affected by the backgrounds of these consultants. Efforts were made to “triangulate” some of the key findings, but some bias is likely to remain.
- In some countries, significant documentation related to shrimp fishing is readily available in an international language while, in others, this is not the case. Consequently, the detail of reporting in some of the developing countries included in the study may have been affected.
- Because there are significant interlinked issues in shrimp fisheries, a degree of repetition is inevitable, in order to ensure that each chapter may be read and understood independently of the full report.

#### OTHER CONSIDERATIONS

Most previous global reviews of shrimp fisheries have focused on a subset of the world’s fisheries, usually for penaeid shrimp (Gulland and Rothschild, 1984; Garcia, 1989). There is ample justification for this approach – the three major shrimp groups (penaeids, carideans and sergestids; see Chapter 3, Catches by shrimp species) differ greatly with respect to their biology, the fisheries that catch them, and other factors. Nevertheless, the present study attempts to cover the fisheries for all three groups because many of the controversial topics associated with shrimp fishing transcend the boundaries between the groups. By examining all major types of shrimp fisheries, it is possible to gain greater insight into these sensitive issues. Other justifications for the study being so inclusive are set out below.

- Developments in important aspects of the fisheries for one type of shrimp have often affected other aspects, inter alia, net designs, bycatch reduction devices (BRDs) and enforcement.
- Many of the management issues and the manner in which they have been addressed have common elements across the major groups.
- The available statistics on shrimp harvests in the world are often not disaggregated in sufficient detail to determine the specific contribution from each of the three major groups of shrimp. A quarter of the global shrimp catch in FAO statistics is dedicated to “Natantian decapods” (i.e. shrimp) alone.

It should be recognized, however, that there are major differences between the penaeid, caridean and sergestid fisheries, which should be borne in mind when considering the results of this study.

In order to avoid dispersion, the focus is on marine shrimp fisheries. Shrimp farming is only considered to the extent that it interacts with shrimp fishing. Freshwater shrimp fishing is not included, nor are activities associated with brine shrimp (*Artemia*).

Some nomenclature also requires clarification. The relationship between “shrimp” and “prawn” causes considerable confusion (Box 1). For simplicity, this report uses “shrimp” as the more inclusive term, to cover prawns as well. The terms “discards”, “bycatch” and “fishery” follow the convention of Kelleher (2005).

## BOX 1

**Shrimp or prawn?**

Two authorities on shrimp taxonomy comment on the shrimp/prawn debate.

- Because of confusion in the use of the terms “shrimp” and “prawn”, it seems useful to draw some attention to the problem. It is impossible to give a short definition of either name, since in different regions of the world these terms are used for different animal groups and even within a single region usage is not consistent. Both terms originated in the United Kingdom, where “shrimp” is used for members of the family Crangonidae, while “prawn” is used for species of Palaemonidae. However, Crustacea, which do not belong to these two families, are also often termed “shrimp” and “prawn”, which is where the difficulty begins (Holthuis, 1980).
- Chan (1998) indicates that the terms “shrimp” and “prawn” have no definite reference to any known taxonomic group. Although “shrimp” is sometimes applied to smaller species, while “prawn” is more often used for larger ones, there is no clear distinction between them and their usage is often confused or even inverted in different countries or regions.

Some references use the cumbersome term “shrimps and prawns” throughout the text but, for simplicity, this report uses “shrimp” except in the case of specific names (e.g. Australia’s Northern Prawn Fishery, Kuruma prawn).

- Discards, or discarded catch, are those portions of the total organic material of animal origin in the catch that are thrown away or dumped at sea, for whatever reason.
- Discard rate is the percentage of total catch that is discarded.
- Bycatch is the total catch of non-target animals. Discards are not a subset of bycatch since the target species is often discarded.
- A fishery is defined as a combination of a fishing area plus a fishing gear plus a target species (or group of species). The term “fishery” is considered to be equivalent to the French term *métier*.

In some countries, because of restrictions on trawling, this fishing technique sometimes assumes other names. In the present report, the definition of “trawl” is that of Nedelec and Prado (1990): a towed net consisting of a cone-shaped body, closed by a bag or codend and extended at the opening by wings. Unless otherwise specified, “trawling” here refers to bottom trawling.

Terms for the various scales of fishing are as defined by FAO (2005f).

- Industrial fisheries. Capital-intensive fisheries using relatively large vessels with a high degree of mechanization, and that generally have advanced fish finding and navigational equipment. Such fisheries have a high production capacity and the catch per unit effort (CPUE) is normally relatively high.
- Small-scale fisheries. Labour-intensive fisheries using relatively small craft (if any), and little capital and equipment per person on board. These are mostly family-owned. They may be commercial or for subsistence, are usually low in fuel consumption, and are often equated with artisanal fisheries.





**PART 1**  
**MAJOR ISSUES IN SHRIMP**  
**FISHERIES**



# 1. History and development of shrimp fishing

Shrimp has been caught by traditional gear for centuries in many parts of the world. In numerous regions this small-scale fishing continues today, as in China (stow nets), Indonesia (lift nets, push nets, beach seines, gillnets), Mexico (barriers across estuaries), and Madagascar (nets, weirs and traps). Such small-scale fishing is responsible for a surprisingly large proportion of the world's shrimp catch (see Chapter 3, section *Catches by shrimp species*).

The history of modern industrial shrimp fishing is closely related to the development of mechanized trawling. Trawling from sailing vessels in Europe has been carried out for hundreds of years. Two events in the latter part of the nineteenth century caused an increase in trawling activity in Britain: the invention of the otter trawl and the increasing use of steam propulsion in fishing vessels. Until the mid-1800s, most large-scale trawling used beam trawl gear, which relied on a heavy beam to keep the net open. Because all fishing vessels at that time used the wind for their towing power, the weight of this beam was a major constraint on the size of net that could be towed. Boards using the force of passing water to hold open the net were invented in Britain in about 1860. The use of these boards (later called otter boards<sup>1</sup>) did not become widespread until the late 1880s, when Danish fishers used them to spread their plaice seines. Steam propulsion for fishing vessels began in about 1880. In 1893 there were 480 steam trawlers working from English and Welsh ports; in 1899, there were over a thousand (Anon., 2004b).

Much of the European trawling in the late 1800s could be considered large scale and used otter trawl gear, but the target species were groundfish rather than shrimp. Adapting otter trawling to shrimp fishing occurred in several places and followed very different courses, including development led by inspired individuals; expansion of successful national fisheries into the waters of neighbouring countries; promotion by aid projects; and vessels from overexploited fisheries searching for alternatives.

Modern shrimp trawling began in Norway in the 1890s, when the renowned fisheries researcher Johan Hjort collaborated with Danish researchers and introduced trawl technology for shrimp fishing. The fishery started as a coastal fishery in the southern part of Norway and, by the 1930s, had spread all along the Norwegian coast.

On the other side of the Atlantic, the otter trawl was adapted to a subtropical fishery. In 1906, Solicito "Mike" Salvador, who was born in Italy but became a leader in the American shrimp industry, rigged his boats based in Fernandina, Florida, with otter trawl nets modified for shrimp fishing. He was able to increase the daily shrimp catch tenfold. By 1921, the Salvador Fish Company was shipping shrimp as far away as Los Angeles, Canada and Denmark (Anon., 2004b).

By 1930, the new trawls in the United States of America produced about 90 percent of the American shrimp catch, which was mostly canned or air-dried. In subsequent decades, trawling and the use of larger vessels allowed fishing in deeper water further from the shore where bigger catches could be made. Box 2 describes the evolution of

---

<sup>1</sup> One theory about the origin of the term "otter boards" is that it came from fishing trout and pike in Ireland, where otters hunted in pairs to herd fish to a point where they were easy prey. The doors played the same herding role as the otters and the name stuck (J. Fitzpatrick and the Scottish Fishermen's Museum, personal communication, June 2006).

## BOX 2

**Evolution of shrimp trawlers in the United States of America**

Early shrimp trawlers were open skiffs 5 to 8 m long, powered with gasoline engines. By the 1920s, they were decked over, the engine placed forward, and a pilothouse added forward. This arrangement remains the standard for today's shrimp trawlers in the United States. In the 1930s, the diesel engine was introduced and the average size increased to some extent. During the 1940s and 1950s, the need for larger vessels to exploit offshore grounds resulted in the construction of much larger vessels. Average vessel length increased to about 60 ft (approximately 18 m), with many vessels in the 21–27 m range. Of particular interest during this period was the success of production line model shrimp vessels, built to standard specifications with design emphasis on minimum cost. They had 20 m-hulls, were powered by 150 to 200 HP engines and characterized by a very high freeboard. This, together with the ample sheer fore and aft, provided a very dry working deck. During the 1960s, the trend was towards larger, better equipped and more powerful vessels, capable of long-distance operations. Most vessels are well fitted with electronic equipment.

*Source:* Kristjonsson, 1968.

American shrimp trawl vessels. By about 1950, most of the potential fishing grounds in waters adjacent to the southeastern states had been discovered. The United States shrimp fleet then expanded operations to the east coast of Mexico and the western Caribbean Sea. From the early 1960s to the early 1970s, between 632 and 860 United States vessels fished off Mexico. In 1976, a treaty between the United States and Mexico resulted in the phasing out of United States shrimping in Mexican waters by the end of 1979. From 1959 to 1979, up to 207 United States shrimp vessels fished off the northeastern coast of South America (Iversen, Allen and Higman, 1993). Vendeville (1990) reports that in the 1960s these industrial shrimp fishing developments in Latin America were extended to Africa and other tropical regions. He concludes that at the end of the 1980s, “shrimp trawlers used in industrial fisheries were relatively homogenous. The American Gulf of Mexico double-rig model has been widely adopted in all regions” (Figure 2).

Many aspects of American shrimp fishing in the Gulf of Mexico have had profound impacts on shrimp fisheries in other regions. Starting in the mid-1960s, experiments were conducted on devices that reduce the bycatch of shrimp trawling. In the early

1980s, substantial gear technology work began to address the issue of reducing the capture of sea turtles in shrimp trawls. The pioneering work of John Watson should be acknowledged. In the mid-1970s, he developed a selective shrimp trawl design for the Gulf of Mexico and, in 1980, the first prototype turtle excluder device (TED). Because the work in bycatch reduction and turtle exclusion eventually led to changed shrimp fishing techniques in many countries, these topics are covered in more depth in Chapter 6. The United States was considered to be the epicentre of biological research on warm-water shrimp in the world until the 1960s, when priorities shifted to research for shrimp farming (Watson and

**FIGURE 2**  
**A Gulf of Mexico-style shrimp trawler**  
**in the United States**



Photograph courtesy of the United States National Marine Fisheries Service

## BOX 3

**Development of the Thai trawl fishery**

When mackerel catches in the Gulf of Thailand declined in 1958 and 1959, perhaps for reasons that had little to do with fishing, the Government became very concerned. Thus, in 1958, when Klaus Tiews – who had been undertaking fisheries research in the Philippines where the otter trawl had been widely adopted in the late 1940s and early 1950s – recommended that trawling might open an untapped source of fish, the Government responded enthusiastically. In 1961, under a bilateral aid agreement between the Federal Republic of Germany and Thailand, Tiews and other German fisheries experts worked with Thai fisheries officers to introduce the otter trawl as part of the Sarit Government's National Economic and Social Development Plan. The project's first task was to design an otter trawl net that would not get stuck in the soft mud that characterizes the bottom of much of the Gulf of Thailand. The German net maker who was part of the team designed a suitable net in just four weeks. At an early stage in the project, it became clear that trawling offered the potential for huge profits. Thai fishers began converting their purse seiners to trawling. From 1960 to 1966, the number of trawlers soared from 99 to 2 700, and the catch by trawlers increased from 59 000 to 360 000 tonnes.

*Source:* Butcher, 1999.

McVea, 1977; Watson, Mitchell and Shah, 1986; S. Garcia, personal communication, October 2005).

Unlike Latin America and Africa, shrimp trawling appears to have evolved somewhat differently in Southeast and South Asia. Industrial shrimp fishing in Southeast Asia appears to have started from fish trawling. The profitability of steam trawlers in Europe in the late 1800s planted the idea in the minds of a few entrepreneurs and officials that trawling might prove just as successful in Southeast Asia. During the first three decades of the twentieth century, the governments of the United Kingdom, France and the Netherlands individually sponsored exploratory trawling in their Southeast Asian colonies using old steam trawlers from Europe. None of these expeditions was particularly successful. The Japanese began fishing in Manila Bay in about 1900, using trawlers powered by sail. In the 1920s, these vessels adopted diesel engines. Japanese trawlers began basing in Singapore in 1935 and ranged as far as the Arafura Sea. These operations started scaling down in 1937 as a result of pre-war animosity created by Japan's invasion of China and ceased entirely during the Second World War. In the late 1960s, a German-sponsored project led to the establishment of a trawl fishery in the Gulf of Thailand (Box 3). Although not specifically targeting shrimp, it was the buoyant shrimp prices that kept the Thai trawl fleets in business when catch rates for fish fell dramatically. Another way in which the trawling operations survived as catches declined was by moving to new areas. Thai trawlers began fishing in the waters off Burma (now Myanmar) in the late 1960s, and then in Malaysia and other countries in the region (Butcher, 2004).

Priyono and Sumiono (1997) recount the developments that led to the establishment of shrimp trawl fishing in Indonesia. Trawl fisheries started up commercially in 1966 in the Malacca Strait. The development of the trawl fisheries may have been influenced by earlier trawling in western Peninsular Malaysia. The ancestors of many Chinese fishers in Riau Province, Indonesia, had migrated from there and contact was still maintained with relatives in Malaysia. The original fishery was characterized by wooden sampan-like motorized vessels of 5–20 gross tonnage (GT). The fishery developed rapidly and, by the end of 1971, over 800 vessels were being used. In the 1970s, with the oil

production boom in the country, fuel subsidies were lavished on almost all sectors of the country's economy, including fisheries. In subsequent years, the trawl fishery spread throughout western Indonesia, via southeastern Sumatra to the north and south coasts of Java and to southern Sulawesi.

Chen (1999) gives a short history of shrimp trawling in China. Before 1970, shrimp was caught mainly by stow nets (see Chapter 2, section *Main fishing gear*). Exploited species were mainly coastal ones, particularly *Acetes chinensis* (70–80 percent of landings). There was some coastal trawling for finfish by mainland Chinese and Taiwanese trawlers, but catch rates were low. By the mid-1970s, the stock size of coastal demersal fish species had declined. Fishers started exploratory shrimp fishing using beam trawls. Subsequently, shrimp fisheries expanded rapidly and extended further seawards; beam trawls were the main gears used, typically 24–26 m in length, although some exceeded 30 m. Before 1984, prawn fishing activity was concentrated in the northern waters of Zhejiang Province and the coastal waters near the mouth of the Yangtze River. After 1984, the fishery rapidly extended to the southern and offshore waters. Catches increased in the Province, reaching 40 000 tonnes in 1986, 100 000 by 1990 and 530 000 in 1995. Vessels from other provinces also fished in these waters. Shrimp production from all vessels in the East China Sea increased to 780 000 tonnes in 1995.

In India, small-boat shrimp trawling started on the west coast in the early 1970s. The fleet grew very rapidly and catch rates declined within a short period. Although the penaeid species were many, their stocks were small. With the decline on the west coast, shrimp trawling on the southeast coast began out of Chennai Port. However, this fishery did not stay in operation for long and quickly shifted its emphasis to finfish and cephalopods. Towards the end of the 1970s, shrimp trawler operators became interested in the Sand Head area of the upper Bay of Bengal. In this area there was a serious problem in operating small-sized trawlers, which were commonly used on the west or southeast coast, because there were no suitable harbours close to the fishing grounds for unloading and processing shrimp catches. The nearest harbour with basic facilities was in Vizakhapatnam, where cold storage facilities were established for processing and exporting frozen shrimp. To operate from Vizakhapatnam, the shrimp trawling companies requested authorization from the Indian Government to import industrial-scale vessels. The Government readily provided foreign currency loans for the import of larger trawlers with outriggers for twin-trawling. These vessels were able to stay at sea for long periods and bring in the preserved shrimp to Vizakhapatnam for processing and exporting (K. Sivasubramaniam, personal communication, March 2006).

In Pakistan, the development of the shrimp fishery appears to have preceded that of India. According to officials of the Pakistan Marine Fisheries Department (M.M. Khan, Marine Fisheries Department, personal communication, April 2006), in 1951, an American-sponsored project conducted experimental trawling with an 11-m vessel. Van Zalinge, Kaliluddin and Khan (1987) state that "commercial shrimp trawling began in 1958 after FAO recommended to the Central Fisheries Department that some of the larger fishing craft be mechanized". There were three commercial trawlers in 1958, 450 vessels in 1970, 897 in 1980 and 1 070 in 1985. FAO (2003e) indicated 2 564 trawlers in 2002, and that the rapid development of the shrimp trawl fishery was a result of tax concessions, credit schemes and export incentives.

In examining the development of shrimp trawl fisheries in several countries, several patterns emerge. One is the influence on the development process of innovative individuals such as J. Hjort in Norway, M. Salvador in Florida and K. Tiews in Thailand. Another is that many of the present-day trawl fisheries that target shrimp were originally oriented towards finfish and only switched to targeting shrimp when finfish became depleted. Declining catch rates of shrimp and finfish have played an

important role in expanding trawl fisheries into neighbouring countries. Government industry promotion through tax concessions, credit schemes and export incentives has been a major factor in the development of shrimp fishing in many countries. In many places around the world, such as in West Africa, shrimp resources were discovered and mapped by scientific surveys before the development of a fleet. A final point is that, although much has been written about the sustainability (or lack of sustainability) of shrimp trawling, a review of the history of shrimp trawling in regions around the world does not uncover many examples where a shrimp trawl fishery has been abandoned as a result of the exhaustion of shrimp resources.





## 2. Structure of shrimp fisheries

### MAIN FEATURES AT THE NATIONAL AND GLOBAL LEVELS

In this study a number of countries were chosen to be representative of various geographic regions, as well as the variety of important shrimp fishing conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. The structure of the fishing industry and related issues in these countries are given in Part 2. The major features are summarized in Table 1.

Figure 3 places the recent annual shrimp catches of the ten study countries in perspective with each other. From Figure 4 it can be seen that combined catches of the study countries form about 17 percent of the global shrimp catch in recent years.

Although there are large differences among countries in the structure of shrimp fisheries, some generalizations can be made. Major distinctions occur between warm- and cold-water shrimp fisheries regarding species, scale of fishing operations, fishing gear/strategies and management measures. In most countries where shrimp fishing occurs, there are both large- and small-scale segments of the industry. While most shrimp fisheries focus on producing food, shrimp fisheries also exist in both tropical and temperate region for bait. Moreover, recreational shrimping is a significant activity in some developed countries. In addition, the capture of broodstock and postlarval shrimp for shrimp farming is important in several countries.

### MAIN FISHING GEAR

A major characteristic of most large-scale shrimp fishing is the use of trawl gear. FAO (2005f) has estimated that in the late 1990s there were about 140 000 trawlers of all types in the world's fisheries, but the number of shrimp trawlers is not known.

#### Otter trawl

Many types of trawls are used to catch shrimp, but because the otter trawl is the most important commercial gear in many countries, it deserves special mention. Figure 5 shows the major parts of a shrimp otter trawl and Figure 6 shows the gear used.

FAO (2005f) describes some important characteristics of the otter trawl gear, which is also used in many fisheries apart from shrimp fisheries.

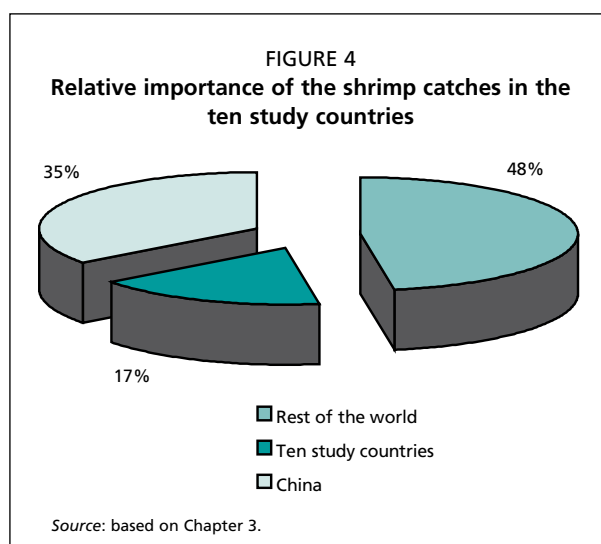
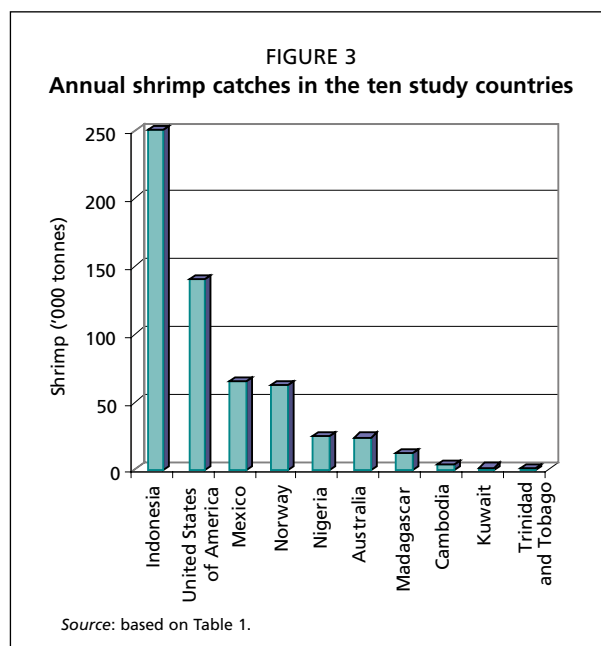


TABLE 1  
Main characteristics of the shrimp fisheries in the study

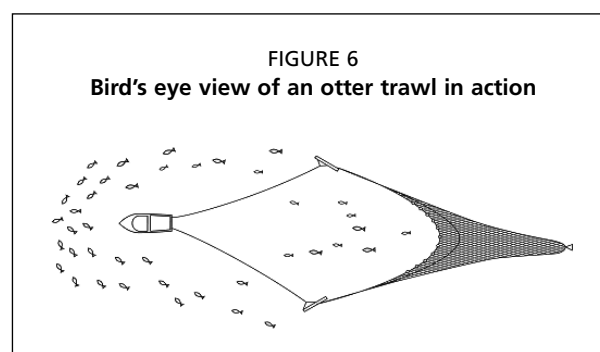
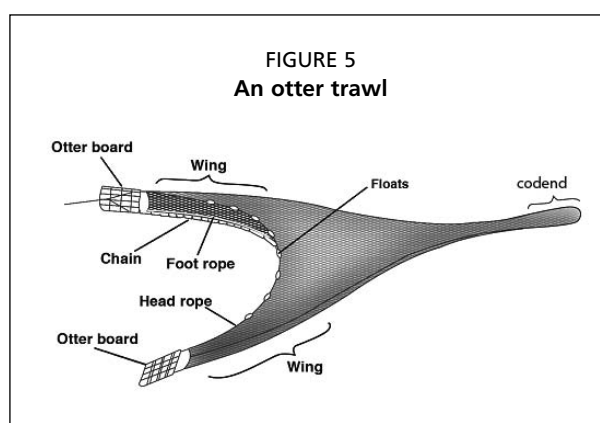
Country and annual catch <sup>1</sup>	Shrimp fishery characteristics
Australia 24 000 tonnes	Australia has a significant involvement with shrimp fishing and its associated activities. Shrimp fishing produces about 24 000 tonnes of shrimp, occurs in the tropical, subtropical and temperate waters of the country, and ranges in scale from recreational fisheries to large-scale operations using vessels up to 40 m in length. Australia also produces shrimp from aquaculture and is involved in both the export and import of shrimp in various forms. Some Australian shrimp fisheries are considered to be very well managed and a model for other countries to emulate. The availability of recent information on Australian shrimp fishing and management issues is excellent.
Cambodia 3 500 tonnes	Although marine fisheries in Cambodia are of minor importance compared with freshwater fisheries, shrimp fishing is important along its short coast. Trawling, and to a lesser extent other gears, take from 3 000 to 4 000 tonnes of shrimp annually. Shrimp is important for domestic consumption and is the most important fishery export of the country. Its shrimp fisheries management faces major challenges, including: the paucity of biological information on shrimp resources; the few legal instruments available for the management of shrimp fishing; their poor enforcement; and the open access nature of all coastal fisheries in the country.
Indonesia 250 000 tonnes	After China and India, Indonesia's shrimp catch is the largest in the world. Shrimp farming is also of great significance in the country, with over 65 000 participating households. Shrimp production, from both fishing and aquaculture, has reached over 400 000 tonnes per year, and shrimp is by far the country's most valuable fishery export. Shrimp fishing in Indonesia is not without its problems, however. A multitude of conflicts have been generated, most of which involve small-scale fisheries. The 1980s trawl ban is cited as the most significant fisheries management measures ever to have taken place in the country, but its effectiveness has been eroded over the years. As in many parts of the world, industrial-scale shrimp trawling operations are having major problems coping with the recent rise in fuel prices. The structure of the shrimp industry is complex. There are countless boats that catch shrimp and many types of fishing gear, as well as their being illegal activity and poor statistical information.
Kuwait 1 500 tonnes	The shrimp fleet of Kuwait has two components: 35 steel-hulled double-rigged Gulf of Mexico-type trawlers and 34 dhow trawlers. Only three species of shrimp are economically important: green tiger prawn ( <i>Penaeus semisulcatus</i> ) (60 percent of catches), Jinga shrimp ( <i>Metapenaeus affinis</i> ) (30 percent of catches) and Kiddi shrimp ( <i>Parapenaeopsis stylifera</i> ) (10 percent of catches). The landed value of shrimp is at present about 39 percent of that of all marine capture fisheries in the country. Total shrimp catches for the 2003/04 and 2004/05 seasons were low, at 1 577 and 1 420 tonnes respectively. In the previous decade, the average annual catch was about 1 900 and shrimp catches fluctuated between 1 012 tonnes and 5 125 tonnes from the 1960s through the 1980s. The present low catches, high level of effort and low CPUE seem to indicate that the stock has been overexploited since 1993.
Madagascar 12 000 tonnes	In recent years, industrial, artisanal and traditional fishers in Madagascar have captured from 10 000 to 13 000 tonnes of shrimp. Employment associated with shrimp fishing is vital to the country, and shrimp (both captured and farmed) is the most valuable fishery export. In past years, about 5 000 tonnes of shrimp were produced by farming operations. Shrimp from Madagascar has a special identity in Europe and commands a higher price than similar products from Asia or Latin America. About two-thirds of the shrimp landings come from the export-oriented industrial trawl fleet comprised of 70 trawlers. About 8 000 to 10 000 people are involved in traditional shrimp fishing, which is aimed primarily at domestic markets. The relationship between these two sectors is important in the management of shrimp fishing in Madagascar. A substantial amount of biological, economic and social research associated with shrimp fishing is carried out in the country. The major fall in shrimp catches in 2005 is likely to be the subject of much future research.
Mexico 65 000 tonnes	Shrimp fishing in Mexico takes place in the Pacific, Gulf of Mexico and Caribbean, by both artisanal and industrial fleets. A vast number of small fishing vessels use many types of gear to catch shrimp. The larger offshore shrimp vessels, numbering about 2 212, trawl using either two nets (Pacific side) or four nets (Atlantic side). In 2003, shrimp production in Mexico of 123 905 tonnes came from three sources: 21.26 percent from artisanal fisheries, 28.41 percent from industrial fisheries and 50.33 percent from aquaculture activities. Shrimp is the basis of the most important fishery commodity in Mexico in terms of value, exports and employment. Catches of Mexican Pacific shrimp appear to have reached their maximum. It is generally recognized that overcapacity is a problem in the various shrimp fleets.
Nigeria 25 000 tonnes	Nigeria has an annual shrimp catch of between 15 000 and 30 000 tonnes. Shrimp fishing is carried out by about 225 industrial shrimp trawlers and a very large number of fishers inshore using small trawls, beach seines and stow nets. As the most important agricultural export of Nigeria, shrimp is responsible for a substantial amount of employment and is a significant source of food in coastal areas. Major difficulties associated with shrimp fishing are the damage that industrial operations cause to small-scale fishers and overcapacity of the trawl fleet. Good data on shrimp catches, shrimp fishing effort and shrimp exports are not readily accessible and, when available, are often conflicting.

Country and annual catch <sup>1</sup>	Shrimp fishery characteristics
Norway  62 000 tonnes	Between 60 000 and 70 000 tonnes of shrimp are caught annually in Norway, which is the 14th largest producer of shrimp in the world. Fishing for shrimp, however, is not nearly as important as for other species such as herring, blue whiting, cod and saithe. In 2003, shrimp represented about 4 percent of the value of all Norwegian fishery product exports. The main shrimp stocks exploited by fishers from Norway are in the Barents Sea, Skagerrak and the North Sea. In addition, many Norwegian fjords have small local stocks. The poor profitability of many types of shrimp vessels in Norway is at present a major problem. This has probably arisen from a combination of factors, including excess capacity, increasing fuel costs and falling market prices for shrimp. Much of the management of Norwegian shrimp fishing, both domestically and internationally, is driven by the need to avoid both overfishing and bycatch of cod and other important species.
Trinidad and Tobago  800 tonnes	Shrimp fishing is currently carried out in Trinidad and Tobago by about 102 artisanal trawlers, ten semi-industrial trawlers and 20 to 25 industrial trawlers. From 1999 to 2004, annual shrimp catches averaged about 825 tonnes. In 2004, there was an estimated 785 tonnes of shrimp landed, valued at US\$2.72 million, and 703 tonnes of groundfish bycatch valued at US\$0.65 million. At present, 96 percent of exports go to the states of the Caribbean Community (CARICOM). There is a high incidental fish catch associated with shrimp trawling, which is one of the most important sources of conflict between the trawl fishery and other fisheries in the country. Other areas of concern are the full or overexploited condition of shrimp stocks as well as that of bycatch, the high levels of bycatch/discards and the degree of overcapitalization in the trawl fishery.
United States of America  140 000 tonnes	Two main types of shrimp fisheries operate in the United States of America: those that target warm-water shrimp off the southeast Atlantic coast and the Gulf of Mexico, and those for cold-water shrimp in the northeast and northwest of the country. In terms of value, shrimp is the second most important fishery in the United States after crab. The combined landings for United States domestic shrimp fisheries have been about 140 000 tonnes annually in recent years, with the warm-water fisheries responsible for over 90 percent in 2004. United States domestic production is dwarfed by shrimp imports of 500 000 tonnes per year, over 80 percent of which are from aquaculture. The domestic shrimp market has greatly expanded in recent years. Shrimp is the most important seafood item for United States consumers – currently 1.9 kg edible weight per year. The United States market is now the largest in the world for shrimp, followed by the European Union. Despite record demand for shrimp in the United States, real and nominal prices for shrimp have declined, primarily as a result of cheaper imported shrimp. This downward pressure on dockside prices and increasing operational costs of domestic shrimp vessels have resulted in severe financial difficulties in many United States shrimp fisheries.

<sup>1</sup> These are the average annual catches from 2000 to 2005, rounded to the nearest thousand tonnes.

*General description.* A bottom otter trawl (Figures 5 and 6) is a cone-shaped net consisting of a body, normally made from two, four and sometimes more panels, closed by a codend and with lateral wings extending forwards from the opening. A bottom trawl is kept open horizontally by two otter boards. Bottom trawls usually have an extended top panel (square) to prevent fish from escaping upwards over the top of the net. The mouth of the trawl is framed by a headline with floats to open the trawl vertically, and a ground gear, which is designed according to bottom conditions at the fishing ground, so as to maximize the capture of targets living close to the bottom while protecting the gear from damage and facilitating movements across an uneven bottom.

*Specific equipment.* The horizontal opening of the net is obtained by two otter boards. The vertical opening is obtained with floats and/or hydrodynamic devices (kites) on the



upper edge (floatline) and weights on the groundrope. The groundrope may be chain or weighted rope, or equipped with rubber discs, bobbins or spacers, etc. to shield the lower leading margin of the trawl from ground damage while maintaining ground contact. The horizontal opening of the trawl is obtained by two otter boards. There are many models of otter board: relatively heavy, made of wood, aluminium and steel or a combination of the three. Otter boards may be rectangular or oval-shaped, and equipped with a steel sole designed for good contact with the ground. Instruments to monitor gear performance are common in modern bottom otter trawling using large vessels. Such instruments monitor geometry (door distance, vertical opening, bottom contact, trawl symmetry), water temperature in trawling depth, catch and trawl speed with selective grid devices such as angle and speed of water flow through the device.

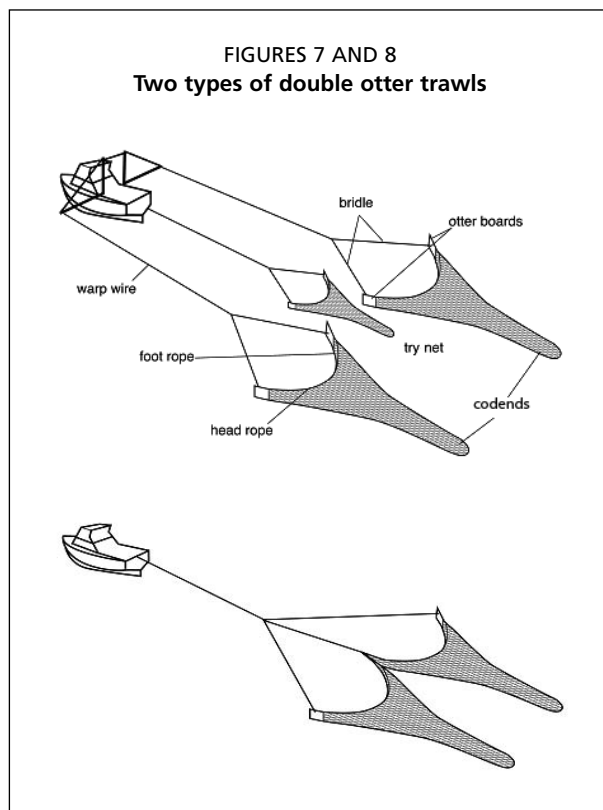
*Specific handling equipment.* The main handling equipment of a trawler is a powerful winch with two drums (or two or more split winches, each consisting of one drum) for shooting, hauling and storing the trawl warps. The trawlers operating otter trawls have galleys, gantries or derricks to handle the heavy otter boards. The net hauling system varies greatly, depending on the size of the vessel and the type of trawl used. A large net drum can be used for shooting, hauling and storing the trawl (including spare ones for additional trawls). Light wing trawls may be hauled in by power blocks. Heavy bobbin trawls may be lifted aboard with gilson winches or quarter ropes. Larger trawlers are arranged with a horseshoe deck layout for handling the trawl.

*Fishing vessels using the gear.* Otter bottom trawls can be used by side trawlers (being gradually phased out), stern trawlers and outrigger trawlers. Vessels range from small open boats to large factory trawlers.

*Fishing operations.* The trawl is designed and rigged to have bottom contact during fishing and, depending on the bottom substrate, is equipped with different kinds of groundrope for shielding the lower leading margin of the trawl from ground damage while maintaining ground contact.

In general, trawlers tow a single otter trawl. However, the use of more than one otter trawl per vessel is common (Figures 7 and 8) in shrimp fisheries. Where two nets are towed from a single warp wire, a sledge is used between them to preserve net geometry and maintain bottom contact. Two single nets, each with a set of otter boards, may be towed from outriggers, which are characteristic of larger prawn trawlers in tropical shrimp fisheries. Some fisheries use three or four nets per boat, two from each outrigger.

Multiple nets are more usually used by larger fishing operations in relatively shallow water and where the bottom is relatively smooth. Single or double nets (towed over the stern from one warp) are more easily manoeuvred around topographical obstructions and are also more suitable than quad gear for use in deep water. In recent years, there has been considerable interest in



using multiple nets for improved catches and fuel conservation (see Chapter 7, section *Mitigation of fuel cost increases*).

Vendeville (1990) reviews the technical aspects of tropical shrimp fishing gear and recognizes eight variations of the general Florida-type otter trawl. One is an arrangement with two trawls towed at the ends of two outriggers. Each net is towed by a single warp and the outrigger booms are at an angle of 20 to 30 degrees from the horizontal.

The otter trawl has also been used for large-scale shrimp fishing operations. In the North Atlantic, nets can have a footrope of 70 m in length and a vertical opening of 20 m. These trawls, which can cost over US\$100 000, are used in water up to 400 m in depth. Some of the technical improvements made on these sophisticated nets have been applied to much smaller-scale trawls for use in other regions.

Over the years, in various regions, the otter trawl has been modified for increased selectivity, total catch maximization, improved ease of handling, improved swept area, increased fuel efficiency, greater durability in rough terrain, reduction of effects on the sea bottom, and other purposes. One of the major modifications from the original Florida-type otter trawl design is a considerable reduction in size to enable use by small outboard open boats. Iversen, Allen and Higman (1993) state that shrimp trawls and the method of rigging have been undergoing change since the original shrimp trawl was developed.

Recent innovations in otter trawling in Australia and Norway are indicative of the evolution of this gear in warm- and cold-water shrimp fisheries, respectively.

- In Australia, the most obvious innovations in shrimp otter trawling in recent years relate to the imperative to introduce TEDs and BRDs. The use of both these devices is now mandatory in all Australian shrimp fisheries and has led to innovations by fishers to make things “practical” or, in other words, not causing hassles or loss of shrimp catch. Included in this category are downward TEDs with split flaps and near-vertical grids, and “fisheye” BRDs (see Chapter 6, *Effectiveness of bycatch reduction efforts*) (D. Sterling and I. Cartwright, personal communication, June 2007).

In Norway, a recent trend in otter trawling for shrimp is increased fishing width by individual trawlers. This is either achieved by increasing the length of the footrope and thus the horizontal wing spread of the trawl, or by using two or three parallel trawls. Over the last ten years, nearly all large shrimp trawlers have converted to twin trawling, whereas triple trawling was introduced in 2002 and is increasingly common (J. Valdemarsen, personal communication, June 2007).

Box 4 describes the markedly different behaviour of shrimp and fish to trawls. These differences are well known to prawn fishers and net makers, who have designed their gear accordingly. Since prawns tend to be found close to the seabed, nets generally have low openings, with the wings of the trawl attached directly to the top and bottom of the otter board. This also reduces catches of fish. Otter boards are connected directly to the “wing” of the trawl, since prawns, unlike fish, cannot be herded by using a wire between the otter board and the net. Nets tend to be short since prawns do not actively swim in the direction of the tow and are washed quickly down into the codend. The different behaviour of fish and prawns is also exploited in the design of devices to reduce unwanted fish bycatch (see Chapter 6, *Bycatch reduction devices*).

### Other trawl gear

Although the otter trawl is the most common form of shrimp trawl, several other similar types of gear are used to catch shrimp on a large scale; two common types are the beam trawl and the pair trawl.

The *beam trawl* (Figure 9) consists of a cone-shaped body ending in a bag or codend, which retains the catch. In these trawls, the horizontal opening of the net is provided by a beam, made of wood or metal, up to 12 m in length. The vertical opening

## BOX 4

**Behaviour of shrimp and fish in a trawl**

*Shrimp.* As the trawl approaches, shrimp is located either on the seabed or swimming in the water column. Shrimp on the seabed generally responds to the approaching trawl by remaining motionless. This behaviour is thought to be used to avoid detection by predators. Shrimp that is swimming does not respond to the trawl until contact is made or imminent. Shrimp escape response is rapid swimming or contraction of the abdomen and rapid propulsion (tail flicks) away from the trawl. Since this response is not sustained, the animals are eventually overrun by the trawl and enter the codend. There is no herding of shrimp into the trawl. Shrimp on the seabed responds to ground chain contact with rapid tail flicks backwards and upwards. This response may be repeated several times to a height of several metres. The combined influence of the towing speed and the height of the net ensures that many of the shrimp are unable to escape from the trawl. Shrimp that does escape the approaching trawl may swim within the water column for several minutes before returning to the seabed. Shrimp that enters the trawl mouth have limited swimming capability, particularly if it has responded several times to trawl contact. It usually enters the codend passively, although some shrimp may first be impinged on the netting for a period of time. If shrimp is then contacted by other animals, the trawl or bycatch reduction device (BRD), it may take evasive action and tail flick several times. There is no evidence that shrimp is capable of deliberately swimming through openings designed for fish escape. Shrimp enter the codend at any height, but is usually exhausted and unable to swim with the trawl.

*Fish:* Fish in the water column may escape over or around the approaching trawl or enter the trawl mouth. These fish in the trawl mouth may attempt to swim with the trawl for a period of time. This is linked to a desire to swim with an object that has a strong visual contrast with the background. If the towing speed is higher than the sustained swimming speed of the fish (cruising), they attempt to maintain their position with the trawl by repeatedly using short bursts of acceleration followed by a gliding movement. This is the “kick-and-glide” response, which is used by fish to conserve energy and avoid predation. The fish in the trawl mouth eventually tire and either attempt escape around or through the meshes of the trawl, or they enter the trawl. Many small fish will also swim with the trawl in the same direction. Since they are weak swimmers, they do not have the luxury of using a kick-and-glide response. To keep up with the trawl, they must swim at a speed that rapidly leads to exhaustion, and they are soon overrun by the trawl. Other fish do not respond by swimming with the trawl. Instead, they enter the trawl mouth either passively or with burst-speed swimming manoeuvres in random directions. Those that enter the trawl passively are quickly overrun and are collected in the codend. Fish that are burst-speed swimming typically contact the trawl netting at high speed. Some become gilled in the netting and some may escape through the meshes. Others will rebound off the netting and swim in another direction. This may continue until they make their way into the codend. Many schooling pelagic fish may attempt an upward escape by swimming through the meshes in the top panel of the trawl as they become tired. Fish on the seabed usually remain motionless until contact is made or imminent. They may react with a kick-and-glide response to keep ahead of the approaching trawl, or may even settle back on the seabed before being contacted by the trawl. This may be repeated several times before they either escape (usually over the lower sweep or under the footrope) or enter the trawl.

*Source:* Eayrs, 2005.

is provided by two hoop-like trawl heads mostly made from steel and equipped with weighted shoes designed to maintain seabed contact. No hydrodynamic forces are needed to keep a beam trawl net open. Beam trawls are the primary gear used to catch northern shrimp in Alaska and banana prawns in estuaries off the east coast of Australia. They are also the predominant gear used by the 650 vessels in the fishery for

*Crangon* in the shallow coastal waters of the southern North Sea (Figure 10).

The *pair trawl* consists of a cone-shaped body, normally made of two or four (and sometimes more) panels, closed by a codend and with lateral wings extending forwards from the opening. The bottom pair trawl is operated by two vessels, each towing a trawl warp attached to the bridles in front of the two trawl wings.

A pair trawler may be an open boat with an outboard engine or a vessel up to 60 m in length. The pair trawlers are normally of similar power and sizes. This fishing practice is often used by non-powered vessels. Pair trawling for shrimp takes place in Southeast Asia, but is prohibited in Cambodia and Indonesia's Arafura Sea. Owing to the ability of pair trawl gear to "sweep" large areas of the seabed (relative to the width of the trawl mouth) and thereby herd demersal species of fish, its use is more common in fisheries targeting finfish.

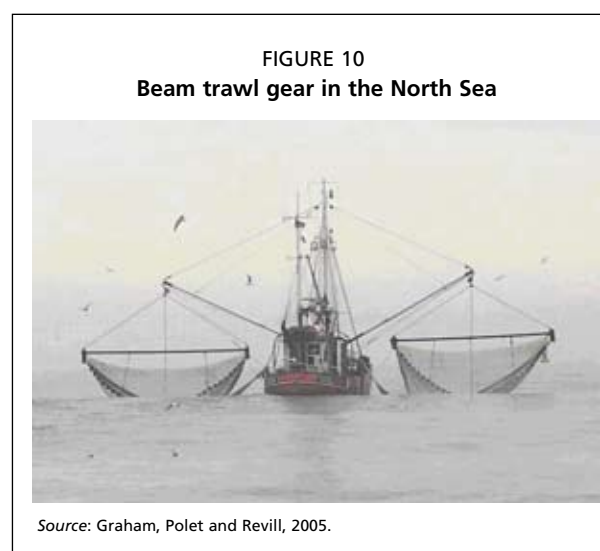
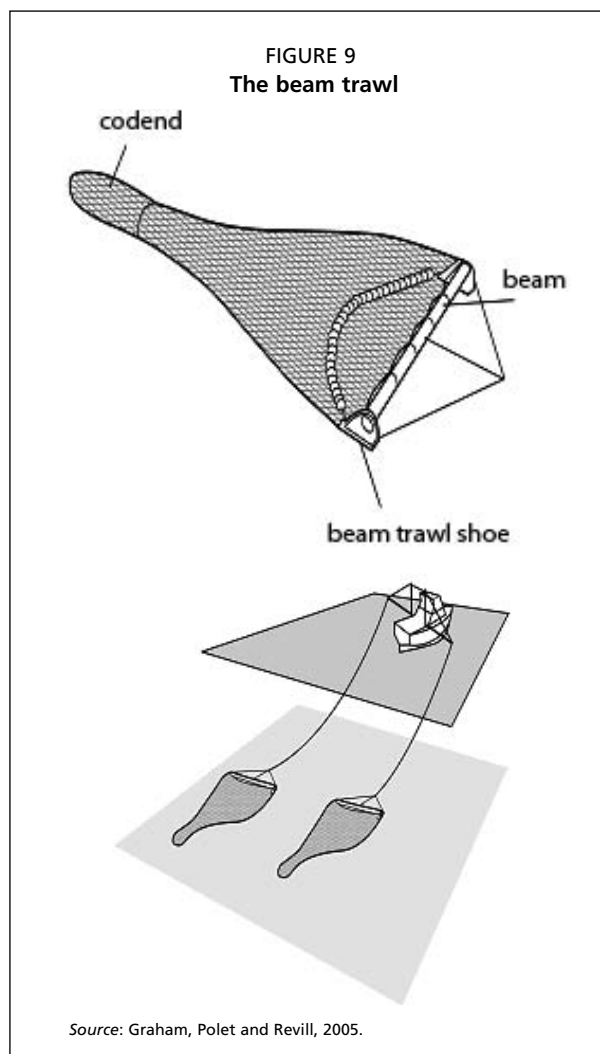
### Non-trawl gear in large-scale fisheries

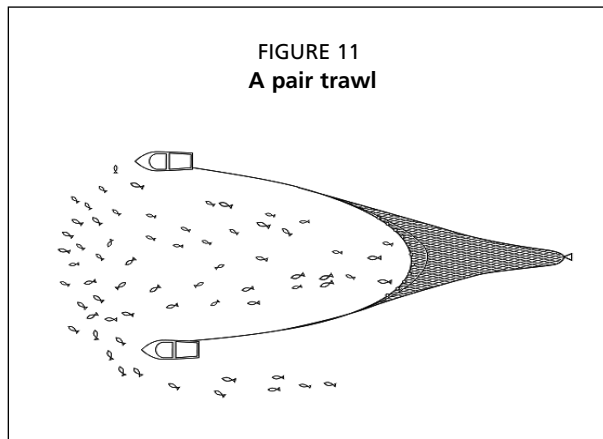
Most of the industrial shrimp fishing in the world is done by trawling (primarily otter trawling but, to a lesser degree, also beam trawling), yet there are some large-scale shrimp fisheries that use other gear. Vessels that participate in the spot prawn fishery off the coast of California use up to 500 pots and those that fish from southeast Alaska use traps (Roberts, 2005). Some of the shrimp gillnets used in Asia could be considered industrial in scale. Sun and Yin (no date) indicate that in China, 135 horsepower (HP) vessels use shrimp gillnets of 2 500 m in length. In Indonesia, there are almost 28 000 fishing units in the gear categories "shrimp nets and fishnets" and "demersal Danish/lampara seines", some of which are industrial in scale.

Iversen, Allen and Higman (1993) state that one of the reasons for using non-trawl gear in large-scale fishing operations is bottom topography; rocky bottoms are mostly unsuitable for trawling.

### Small-scale fisheries: trawl and non-trawl gear

Many other types of gear are used to capture shrimp. The diversity of shrimp fishing gear in some of the Asian countries is remarkable. In Indonesia, shrimp is caught by some 137 000 units of shrimp nets, fishnets, demersal Danish seines, lampara seines, beach seines, shrimp gillnets, drift nets, trammel nets, stow nets and guiding





barrier nets. As mentioned above, almost 28 000 fishing units make up the categories “shrimp nets and fishnets” and “demersal Danish/lampara seines”. This represents an interesting collection of gear types, many of which function as trawls. The vessels that use the small trawls are sometimes referred to as “mini-trawlers”.

Small-scale gear used to catch tropical penaeids is generally operated in estuarine waters and lagoons to catch larvae, juveniles and migrating subadults. This fishing often affects large-scale shrimp fisheries that target more mature shrimp.

In terms of tonnage, it is likely that the most important non-trawl gear in the world for catching shrimp is the stow net. This gear, sometimes known as a stake net, set net or filter net, is configured in various forms (Figure 12), but all rely on the current to carry the shrimp into the nets. Liu-Xiong (1995) indicates that there are 350 000 units of this gear in just four coastal provinces of China and the main targets are five species of shrimp, of which *Acetes* is the most important. In European waters, substantial quantities of crangonid shrimp are caught by stow nets.

Non-trawl gear is also used in the shrimp fisheries of developed countries. For example, the largest pandalid shrimp, the spot prawn, is captured on the west coast of the United States entirely by traps, and there is a substantial shrimp pot fishery in southeast Alaska (Roberts, 2005). Iverson, Allen and Higman (1993) describe the use in the United States of channel nets (gear similar to stow nets), push nets, dip nets, cast nets and seines for catching shrimp for bait.

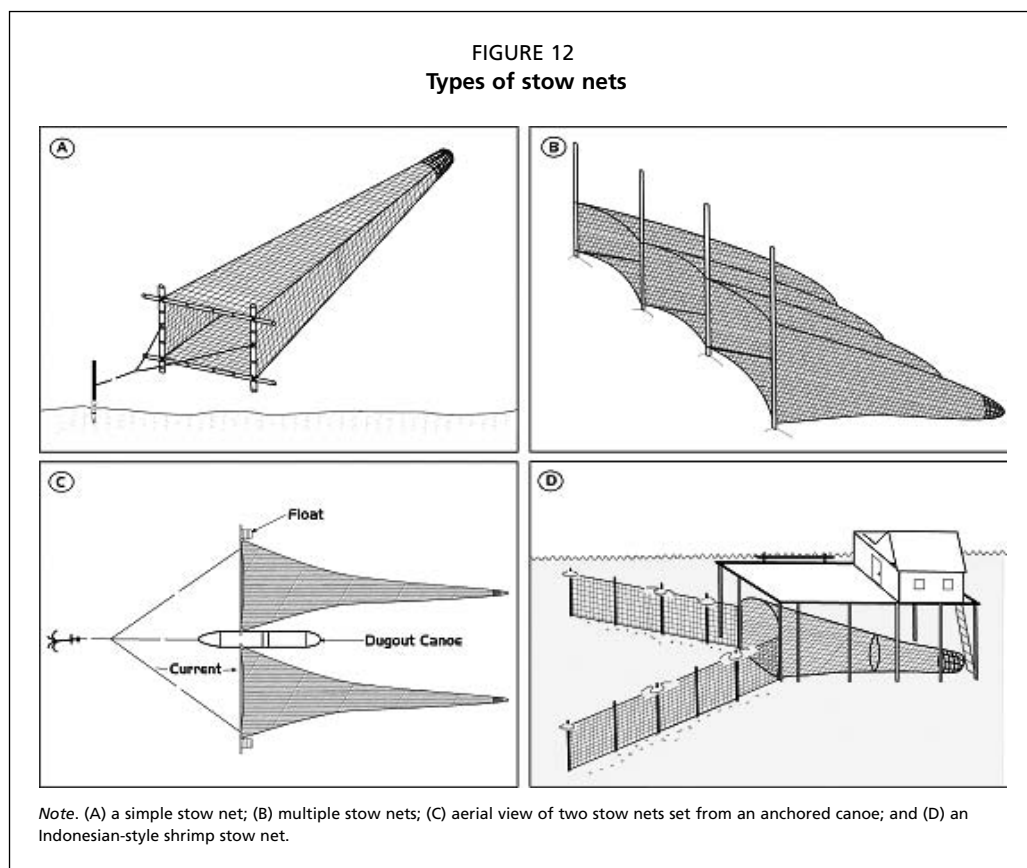




Figure 13 shows a motorized push net, a type of gear used in several Asian countries to catch shrimp in inshore areas. Box 5 gives an example of the variety of small-scale fishing gear used within the relatively small geographic area of Negombo Lagoon, Sri Lanka. Postlarval shrimp for shrimp farming is caught with small-scale gear in Bangladesh and a few other Asian countries.

Vendeville (1990) gives other types of small-scale shrimp fishing gear.

- *Beach seines* (with and without bags).

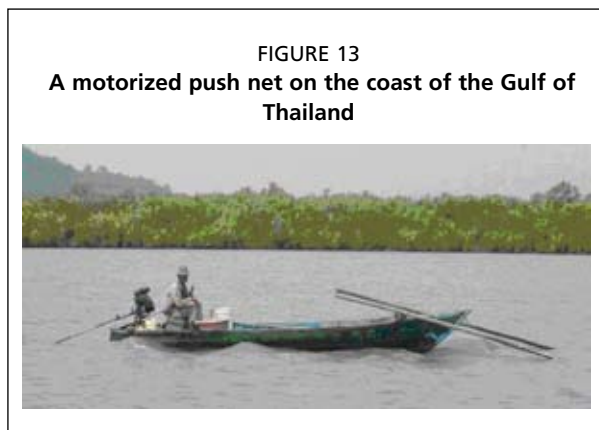
These are used in many areas of the world, including West Africa, Madagascar, the northeastern coast of South America, Central America, India, Bangladesh, Sri Lanka and Indonesia. In most cases, they are used in shallow waters and hauled on to the shore.

- *Lift nets*. These are used either from small craft or from a platform built on stilts in shallow protected areas. They are common in India and several countries of Southeast Asia.
- *Cast nets*. These are used from small craft or from the shore. They are common in South and Southeast Asia, Central America and Brazil.
- *Traps*. Large traps, 12–13 m in length and of various shapes, are used in the intertidal zones of many countries in South and Southeast Asia,

The use of small trawl-like gears is common in small-scale fisheries of developing countries, but these gears often go by different names. Because there is even debate over whether some of these gears should be considered as trawls or are small-scale, the following definitions are used.

- *Trawlers*. Vessels that tow a net consisting of a cone-shaped body, closed by a bag or codend, and extended at the opening by wings.
- *Small-scale fisheries*. Labour-intensive fisheries using relatively small craft, little capital and equipment per person on board, mostly family-owned, and with low fuel consumption.

Small-scale trawlers thus defined are very common in Asia (Figure 14). Many of them make a substantial amount of non-shrimp catches and cannot therefore be considered strictly shrimp fishing gear. In Latin America, the use of small trawls to



#### BOX 5

#### Shrimp fishing in Negombo Lagoon, Sri Lanka

The most common gears are trammel nets. These, together with cast nets, are operated across the central portion of the lagoon. Stake nets are operated immediately inside the entrance at the northern end; they are set at night during the outgoing tide and target species aggregated at the entrance and migrating to sea. The gears used in the shallower waters are lagoon seines and brush pile. Brush piles are dead tree branches, each encompassing an area of 5–10 m in diameter. The fish and shrimp aggregate within the branches and are periodically removed with surrounding nets. The other gears used in the lagoon for catching shrimp are fyke nets. These are set at the southern end adjacent to the marsh. Outside the lagoon, there are non-mechanized shrimp trawlers operating north of the entrance and mechanized shrimp trawlers operating 5–10 km to the south.

*Source:* Sanders, Jayawardena and Ediriweera, 2000.

FIGURE 14  
Small trawlers in Southeast Asia



catch shrimp is also very common, often with outboard-powered open boats. In West Africa, 8–12 m wooden canoes propelled by 15–40 HP outboard engines are often used with tow nets in inshore waters to catch mainly subadult shrimp.

#### ALTERNATIVES TO TRAWL GEAR

There has been considerable interest in developing alternative gears that could replace existing shrimp trawling operations. Despite this attention, no substantial progress has been made in replacing trawl gear and, after nearly a century, it remains the main producer of the important commercial shrimp species. Chapter 10 explores this subject further.

Because of a lack of promising industrial-scale alternatives to shrimp trawling, most shrimp gear technology efforts in recent decades have been channelled into improving trawl gear and trawl techniques, rather than developing new industrial shrimp fishing technologies. It is important to note that some of the shrimp trawl gear innovations, especially those concerning bycatch reduction, have also been adopted by other trawl fisheries.

### 3. Shrimp species, catches and fishing effort

#### CATCHES BY SHRIMP SPECIES

Shrimp, known taxonomically as Natantian decapods, comprises about 3 000 species. Figure 15 shows the features often used by taxonomists to differentiate among the various species; the development of the legs (pereiopods) and whether the plates on the abdomen overlap are particularly important for distinguishing the main groups.

Shrimp is subdivided into several groups, three of which have major fisheries importance (Chan, 1998).

- Penaeoidea (about 376 species in total) or the penaeid shrimp, which include the genera *Penaeus*, *Metapenaeus*, *Parapenaeopsis* and *Trachypenaeus*.
- Caridea (at least 2 517 species), which include the genera *Pandalus* and *Heterocarpus*.
- Sergestoidea (about 94 species); the only group of significant economic importance is the genus *Acetes* – the paste shrimp.

The above taxonomic classifications correspond roughly to the three major categories of shrimp fisheries: warm-water, cold-water and paste shrimp. As mentioned in the earlier chapter on *Development of the study*, the three major groups of shrimp differ greatly with respect to their biology, the fisheries that catch them, and other factors. The biological differences are elaborated upon in Chapter 9, section *Basic biology and life histories*. Despite the rationale for including all three groups in this global study, the differences should be borne in mind when comparing the various shrimp fisheries.

About ten species of shrimp have been commercially raised in captivity. All current commercial shrimp farming involves penaeid shrimp.

Slightly fewer than 300 species of shrimp are of economic interest worldwide, out of which 100 species provide the bulk of the annual world catch. FAO statistics on marine shrimp catches cover 66 “species items”, which represent a taxonomic group, most often at the species level, but sometimes at the level of genus, family or suborder. Table 2 gives annual landings for several years for the 25 most important shrimp species items.

It can be seen from Table 2 that in 2005 six shrimp species items (four species and two aggregated groups) accounted for 82 percent of the global shrimp catch. The most important single species in the world by weight (19 percent of global total shrimp catch in 2005) is the akiami paste shrimp, which belongs to the genus *Acetes* (Box 6). The “all other species items” category in the Table (37 species items in 2005) accounts for less than 1 percent of the global shrimp catch.

The species item “Natantian decapods nei” represents about a quarter of the world’s shrimp catch and is therefore highly significant. If this category is excluded, the remaining six most important species items in the Table account for 80 percent of the

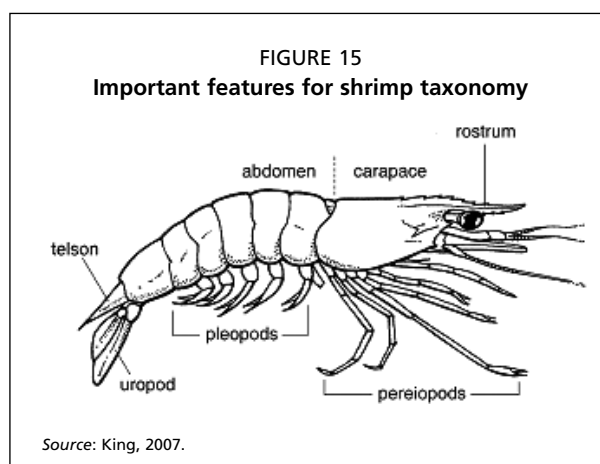


TABLE 2  
Catches of shrimp

FAO Name	Scientific Name	1965	1975	1985	1995	2005
Natantian decapods nei	Natantia	239 028	524 096	629 327	542 552	887 688
Akiami paste shrimp	<i>Acetes japonicus</i>	104 000	13 524	222 608	406 495	664 716
Southern rough shrimp	<i>Trachypenaeus curvirostris</i>		5 278	93 028	154 623	429 605
Northern prawn	<i>Pandalus borealis</i>	25 503	63 557	235 587	275 601	376 908
<i>Penaeus</i> shrimp nei	<i>Penaeus</i> spp.	194 009	261 450	277 565	296 483	230 297
Giant tiger prawn	<i>Penaeus monodon</i>	9 981	12 940	12 195	207 097	218 027
Fleshy prawn	<i>Penaeus chinensis</i>		34 297	33 191	44 449	106 329
Banana prawn	<i>Penaeus merguensis</i>	22 400	39 269	39 023	71 150	83 392
<i>Metapenaeus</i> shrimp nei	<i>Metapenaeus</i> spp	10 927	30 410	36 690	51 536	63 211
Atlantic seabob	<i>Xiphopenaeus kroyeri</i>	8 000	13 093	17 900	18 802	52 411
Northern white shrimp	<i>Penaeus setiferus</i>	32 141	26 802	44 573	39 959	50 253
Common shrimp	<i>Crangon crangon</i>	52 200	35 902	27 328	30 761	44 852
Northern brown shrimp	<i>Penaeus aztecus</i>	57 250	44 736	70 852	57 126	44 692
Sergestid shrimp nei	Sergestidae		26 229	52 602	60 377	23 259
Deep-water rose shrimp	<i>Parapenaeus longirostris</i>	12 700	18 099	39 896	15 833	19 938
Southern pink shrimp	<i>Penaeus notialis</i>	1 900	6 744	6 896	21 484	14 648
Pacific shrimp nei	<i>Xiphopenaeus, Trachypenaeus</i> spp.	9 113	63 564	15 222	15 130	12 125
West African estuarine prawn	<i>Nematopalaemon hastatus</i>					11 700
<i>Parapenaeopsis</i> shrimp nei	<i>Pandalus</i> spp. <i>Pandalopsis</i> spp.	7 927	6 085	8 486	12 919	10 412
Redspotted shrimp	<i>Penaeus brasiliensis</i>	100	774	8 006	6 565	9 390
Northern pink shrimp	<i>Penaeus duorarum</i>	11 048	18 955	15 512	11 121	7 720
Argentine red shrimp	<i>Pleoticus muelleri</i>	300	190	9 835	6 705	7 510
Caramote prawn	<i>Penaeus kerathurus</i>	1 000	3 505	2 879	4 880	6 655
Chilean nylon shrimp	<i>Heterocarpus reedii</i>	5 900	7 934	2 949	10 620	3 880
Aristeid shrimp nei	Aristeidae				2 551	3 174
All other species items		24 395	54 111	71 933	83 023	33 741
<b>Total</b>		<b>829 822</b>	<b>1 311 544</b>	<b>1 974 083</b>	<b>2 447 842</b>	<b>3 416 533</b>

nei – not elsewhere included.

Source: FAO, 2007.

Note: units: tonnes.

global shrimp catch. “Natantian decapods nei” has an unknown species composition, but the countries that contribute to this species item can be determined from the FAO FISHSTAT database. Five countries (China, India, Viet Nam, Indonesia and India) contribute 68 percent of this category, while no contribution from a major cold-water shrimp fishing nation is more than 1 percent. It can also be concluded from the Table that the category comprises almost exclusively penaeid and sergestid shrimp.

FAO English names<sup>2</sup> for some of the species are often different from regional usage, which can lead to confusion. For example, in the United States three different species are known as pink shrimp and two species as northern shrimp. Cascorbi (2004b) indicates that the species *Pandalus borealis* may be marketed as pink shrimp, northern shrimp, Alaska pink shrimp, northern pink shrimp, Pacific pink shrimp or salad shrimp. It is therefore understandable why scientific names for shrimp (rather than common names) are used so often in the literature.

After the akiami paste shrimp (*Acetes japonicus*), the five most important single shrimp species are northern prawn (*Pandalus borealis*), southern rough shrimp (*Trachypenaeus curvirostris*), giant tiger prawn (*Penaeus monodon*), fleshy prawn (*Penaeus chinensis*) and banana prawn (*Penaeus merguensis*). The distribution of catches of these species by country is listed in Table 3.

Table 3 could be misleading because the large size of the several unspecified “nei” categories in Table 2 (over a million tonnes in 2005, 35 percent of total shrimp catches)

<sup>2</sup> This is based on the ASFIS list of species for fishery statistics purposes. (Available at <http://www.fao.org/fi/statist/fisoft/asfis/asfis.asp>)

## BOX 6

**The small but important *Acetes* shrimp**

*Acetes* shrimp is not well known in many regions outside Asia but is actually important in terms of global catches – and the basis for the largest shrimp fishery in the world.

The genus *Acetes* contains several species of shrimp which, although small in size (adult body length varies from 1 to 4 cm), support substantial fisheries, especially in Asia. Most shrimp is caught with very small-scale fishing gear such as stow nets, triangular nets, lift nets, scoop nets, push nets, bag nets and seines and is marketed mainly dried, boiled, salted, fermented with salt or processed into paste or sauce (Chan, 1998).

Huge quantities of *Acetes* shrimp are captured. The most recent FAO statistics indicate that more *Acetes* is captured than any other shrimp in the world;<sup>2</sup> in 2005, it amounted to 664 716 tonnes. Furthermore, the North Pacific Marine Science Organization (PICES, 2001) indicates that world landings of paste shrimps are likely to be grossly underestimated. Almost all the reported *Acetes* catches are from China (673 485 tonnes in 2003), but other important fisheries occur in the Republic of Korea, Japan and throughout Southeast Asia. *Acetes* is the most important shrimp caught in China, where the fishery has been of major significance for over 300 years. *Acetes* is largely responsible for the Chinese landings of shrimp being close to the combined total of all of the rest of the world. In terms of relative importance of fisheries production, Sugiyama, Staples and Funge-Smith (2004) report that a type of *Acetes* (akiame paste shrimp<sup>3</sup>) is the fourth most important species group by weight in the entire Asia-Pacific region fisheries after hairtails, anchovies and scads.

<sup>2</sup> The exception is the miscellaneous category “Natantian decapods, nei”.

<sup>3</sup> PICES (2001) indicates that the akiame paste shrimps (*Acetes chinensis* and *Acetes japonicus*) overlap in their geographic ranges and are generally not distinguished in landing statistics. Carpenter and Niem (1998) report seven species of *Acetes* in the Indo-Pacific area: *Acetes erythraeus*, *A. indicus*, *A. intermedius*, *A. japonicus*, *A. serrulatus*, *A. sibogae* and *A. vulgaris*.

could affect the absolute quantities and relative importance of the various species. Several countries, from both developed and developing areas, report over half of their shrimp catches not identified by species, but at higher taxonomic levels or under the “nei” category.

For example, FAO statistics for Australia show half of the 2005 catches as “*Penaeus* shrimp nei”. Nevertheless, some observations can be made on the significance of the various shrimp species. The northern prawn is the most important cold-water shrimp, with Canada and Greenland taking almost 70 percent of the catch in recent years. China dominates the catch of many of the most important shrimp species: akiame paste shrimp, southern rough shrimp and fleshy prawns.

Although fishing for the northern prawn could be considered a single shrimp species fishery, almost all the important tropical shrimp fisheries produce significant amounts of more than one species of shrimp (Box 7). This has important fisheries management implications. The factors that cause fluctuations in the abundance of each species are usually different, and it is therefore unlikely that all important shrimp species in a fishery will be in low abundance at the same time.

Garcia (1989) points out a sequential progression in species targeting during the development of shrimp trawl fisheries. In the early stages, fishing tends to begin on more coastal and valuable white shrimp of the genus *Penaeus* caught during the day. As effort increases and abundance decreases, additional night fishing develops on deeper brown and tiger shrimp. As overall profitability decreases further and the useful fishing season shortens, fisheries tend to develop on more coastal and smaller and less valued shrimp of the genus *Xyphopenaeus*, *Trachypenaeus*, *Lithopenaeus*, *Metapenaeus*, etc. At this stage, in

TABLE 3  
Catches of important shrimp by country

Species	Country	2005 landings
Akiami paste shrimp	China	657 364
	Republic of Korea	7 352
Southern rough shrimp	China	425 643
	Republic of Korea	3 364
	Taiwan Province of China	598
Northern prawn	Canada	136 209
	Greenland	134 895
	Norway	48 310
	Iceland	12 381
	Estonia	8 659
	Russian Federation	8 658
	Faeroe Islands	7 432
	Denmark	7 183
	Lithuania	5 860
	Latvia	2 356
Sweden	2 145	
	United States	1 884
Giant tiger prawn	India	178 146
	Indonesia	32 910
	Australia	4 337
	Thailand	1 678
	Philippines	654
	Pakistan	147
	Papua New Guinea	117
	Taiwan Province of China	38
Fleshy prawn	China	105 340
	Republic of Korea	989
Banana prawn	Indonesia	65 710
	Thailand	13 352
	Australia	3 320
	Papua New Guinea	1 000
	Solomon Islands	10

Source: FAO, 2007.

many countries, shrimpers start keeping more and more of the fish bycatch on board. In the process, the progressive depletion of offshore adult shrimp tends to attract shrimp trawlers inshore, where they enter into serious conflict with coastal and small-scale fisheries.

### CATCHES BY COUNTRY

Table 4 gives shrimp catches from 2000 to 2005 for the 35 most important producing countries. Figure 16 shows the relative importance of the ten most important producers.

Figure 17 gives world shrimp catches for the past half-century. Since it could be argued that akiami paste shrimp is distinct from most other species (magnitude of production, fishing technique, product form, end market), world catches of shrimp less akiami paste shrimp are given. For comparison purposes, the production of farmed shrimp is also shown.

A number of observations can be made on the production information given in Table 5.

- Sixty percent of shrimp production in the world is from fishing; 40 percent is from farming. The relative proportion by fishing has been decreasing since the mid-1980s, and sharply so in the last decade.
- Even allowing for the fact that fisheries production statistics for China may be too high (FAO, 2004), China has a dominant role in shrimp fishing; about one-third of the world shrimp catch is taken by this country.

### BOX 7

#### The shrimp species of the fisheries of Negombo Lagoon, Sri Lanka

Fourteen species of shrimp are identified in the catch from Negombo Lagoon, six of which are major contributors to the catches. *Penaeus indicus* and, to a lesser extent, *P. semisulcatus*, were the most important in the trammel net and cast net catches. *P. indicus* was also the main species from brush piles. The stake nets set at the entrance caught mainly *Metapenaeus dobsoni* and *M. moyebi*. The latter were the major component of the catches with lagoon seines. The other important species caught in the lagoon was *M. elegans*. The main species in the trawl catches were *M. dobsoni* and *Parapenaeopsis coromandelica*. The former was the only major contributor to both the lagoon and outside catches. *P. indicus* and *P. semisulcatus* were relatively scarce in the trawl catches.

Source: Sanders, Jayawardena and Ediriweera, 2000.

TABLE 4  
Shrimp catches by country, 2000–05

	2000	2001	2002	2003	2004	2005	Av. 2000–05
China	1 023 877	909 083	911 838	1 451 990	1 481 431	1 471 575	1 208 299
India	343 860	328 941	400 778	417 039	369 153	366 464	371 039
Indonesia	252 914	266 268	242 338	240 743	246 014	235 050	247 221
Canada	139 494	129 774	139 061	144 495	178 743	139 829	145 233
United States of America	150 812	147 133	143 694	142 261	139 830	118 446	140 363
Greenland	86 099	86 451	105 946	84 764	137 009	137 009	106 213
Viet Nam	96 700	94 282	94 977	102 839	107 069	107 900	100 628
Thailand	84 625	85 115	80 996	79 082	71 889	67 903	78 268
Malaysia	95 976	77 468	76 020	73 197	78 703	52 788	75 692
Mexico	61 597	57 509	54 633	78 048	62 976	66 968	63 622
Norway	66 501	65 225	69 148	65 564	58 960	48 310	62 285
Philippines	41 308	48 398	43 386	46 373	46 132	45 101	45 116
Argentina	37 188	79 126	51 708	53 310	27 293	7 654	42 713
Brazil	39 185	28 025	29 100	34 013	32 504	38 497	33 554
Republic of Korea	36 035	30 800	29 634	31 117	19 345	21 116	28 008
Iceland	33 539	30 790	36 157	28 787	20 048	8 659	26 330
Nigeria	20 446	19 714	30 489	28 205	22 915	28 549	25 053
Japan	27 345	25 682	25 751	24 265	23 069	22 981	24 849
Australia	23 773	27 329	25 670	23 090	23 745	20 336	23 991
Pakistan	25 130	24 936	22 532	24 411	24 774	18 923	23 451
Myanmar	23 000	22 500	22 000	21 500	21 000	20 404	21 734
Guyana	19 329	26 851	20 564	22 584	18 605	18 391	21 054
Germany	17 423	12 571	15 966	16 269	19 222	22 616	17 345
Russian Federation	36 926	20 921	13 299	11 544	11 646	9 144	17 247
Suriname	10 606	13 340	13 522	16 330	26 204	22 309	17 052
Spain	21 508	27 105	17 212	14 241	10 375	8 392	16 472
Taiwan Province of China	20 603	17 403	13 545	6 491	14 415	26 297	16 459
Netherlands	11 497	14 084	11 458	14 834	14 502	16 227	13 767
Estonia	12 819	11 241	14 240	12 966	13 586	12 381	12 872
Mozambique	11 195	11 139	10 913	14 964	13 395	14 779	12 731
Madagascar	12 127	11 776	13 223	13 314	11 315	10 900	12 109
Faeroe Islands	12 611	15 930	13 141	14 083	9 314	7 183	12 044
Venezuela (Bolivarian Rep. of)	9 882	12 128	9 981	11 480	11 480	11 480	11 072
Italy	12 333	9 499	8 619	9 262	6 716	17 671	10 683
Cambodia	5 000	8 800	10 000	12 300	12 600	13 500	10 367

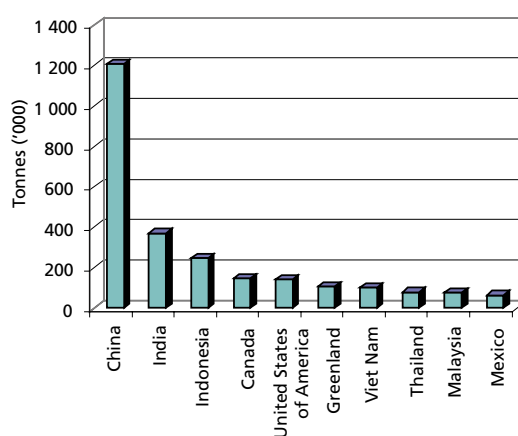
Source: FAO, 2007.

- Asia is the most important area for shrimp fishing. China and four other Asian countries (India, Indonesia, Malaysia and Thailand) account for 55 percent of the world shrimp catch.
- The major species of cold-water shrimp, the northern prawn, accounts for only 12 percent of the world's shrimp catch.

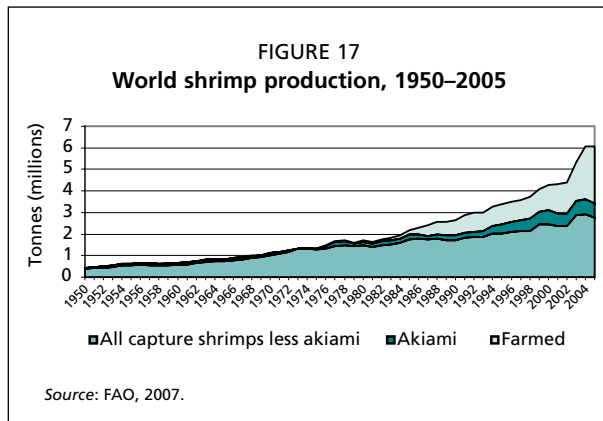
### SHRIMP FISHING EFFORT AND CAPACITY

Various schemes for quantifying fishing effort are used in the different shrimp fisheries. In the ten countries examined closely in this study (Part 2), several measures of fishing effort are used, including the number of hours of trawling, hours at sea, hauls, vessel days, vessel trips, vessel seasons and vessel years.

FIGURE 16  
Recent average annual shrimp catches, by country



Source: FAO, 2007.  
Note: Dates as per Table 4 (average of 2000–05).



In theory, shrimp fishing effort for industrial and semi-industrial fishing operations should be relatively easy to collect. Information is routinely collected from most of the larger fishing operations in both developing and developed countries. There are, however, some surprises. Cascorbi (2004b) states that estimating total fishing effort in United States shrimp fisheries is not easy. The exact number of vessels taking part in Gulf and Atlantic shrimp fisheries is not known to management authorities: there is currently no federal licensing requirement

for the South Atlantic region; state licensing regulations vary; and, because shrimpers follow the shrimp across state water boundaries, many shrimp vessels are licensed in several states simultaneously.

On the other hand, nominal shrimp fishing effort is known precisely, for example, in Australia's Northern Prawn Fishery, where the use of electronic logbooks is becoming increasingly more common. In this fishery, effort is often expressed in vessel fishing days but, for management purposes, the measurement of effective effort is complex (based partially on net headrope length) and is evolving over time. Effective effort is regularly calculated for stock assessment purposes, allowing for a range of technological innovations and skipper skills that have also evolved over time.

For small-scale shrimp fishing operations, fishing effort is more difficult to monitor. The number of gears available may be known, but information – the proportion used every day, the time during which they are used and the place in which they are used, etc. – is not often understood. This significantly influences the relation between effort and the resulting fishing mortality. In the relatively few cases where such data are collected, this is usually done by sampling a subset of the gear and extrapolating the results. However, in the small-scale shrimp fisheries of developing countries, there is usually no more than a vague idea of the number of units of a particular type of gear.

**TABLE 5**  
**Shrimp catches by FAO fishing area**

Area	2000	2001	2002	2003	2004	2005
Pacific, Northwest	1 119 007	991 004	980 880	1 519 867	1 551 715	1 555 183
Pacific, Western Central	411 121	459 725	429 965	422 344	439 031	417 360
Indian Ocean, Western	311 715	290 315	315 842	329 481	303 587	315 166
Atlantic, Northwest	269 565	263 515	288 334	285 725	360 509	304 268
Indian Ocean, Eastern	275 944	229 384	206 171	218 468	246 060	205 107
Atlantic, Western Central	204 315	212 185	188 365	217 827	218 824	193 289
Atlantic, Northeast	172 670	142 017	148 919	127 780	123 304	114 576
Atlantic, Eastern Central	59 818	69 021	66 514	67 349	58 351	65 366
Asia – inland waters	42 954	49 933	114 239	123 406	61 884	64 817
Pacific, Eastern Central	59 851	54 287	51 821	66 854	55 000	53 543
Atlantic, Southwest	76 985	109 990	93 839	92 816	59 919	46 233
Mediterranean and Black Sea	35 273	29 047	31 402	31 892	30 707	42 308
Pacific, Southeast	14 793	15 592	12 242	13 495	13 464	17 863
Pacific, Northeast	20 381	22 952	29 973	18 272	12 813	14 690
Atlantic, Southeast	10 421	13 329	6 097	5 045	3 189	3 004
Africa – inland waters	2 100	2 400	2 400	2 400	2 250	2 250
Pacific, Southwest	2 842	3 034	2 308	2 288	1 831	1 510
<b>Total</b>	<b>3 089 755</b>	<b>2 957 730</b>	<b>2 969 311</b>	<b>3 545 309</b>	<b>3 542 438</b>	<b>3 416 533</b>

Source: FAO, 2007.



## BOX 8 Fishing capacity

Different groups of people generally have a different understanding of capacity. Fishing technologists often consider fishing capacity as the technological and practical feasibility of a vessel achieving a certain level of activity – be it days fishing, catch or processed products. Fisheries scientists often think of fishing capacity in terms of fishing effort and the resultant rate of fishing mortality (the proportion of the fish stock killed through fishing). Fisheries managers generally have a similar view of fishing capacity, but often link the concept directly to the number of vessels operating in the fishery. Many managers express fishing capacity in measures such as gross tonnage or as total effort (e.g. standard fishing days available). Most of these ideas reflect an understanding of capacity primarily in terms of inputs (an input perspective). In contrast, economists tend to consider capacity as the potential catch that could be produced if the boat were operating at maximum profit or benefit (an output perspective). To reflect these different views of fishing capacity, an FAO technical consultation developed a definition of fishing capacity that is both input-based (e.g. effort, boat numbers, etc.) and output-based (catch).

*Fishing capacity is the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition (FAO, 2004).*

Ward *et al.* (2004) point out that an important feature of shrimp fishing effort, as in all fishing efforts, is plasticity. Even if a limit is imposed on the number of licences, effort can continue to expand as vessels grow in length, increase their net size or their engine power, improve the quality of their electronic fishing aids and/or establish communication networks, etc. As in almost all economic activities, shrimpers are profit maximizers and are extremely resourceful when it comes to improving their profits. The tendency for fishing vessels to increase their fishing power is referred to as “capital stuffing” or “effort creep”.

A concept related to fishing effort is “fishing capacity”. Box 8 provides a simple explanation of a topic that is sometimes elusive because of multiple interpretations.

The important fishing capacity issues in shrimp fisheries appear to be the quantification of capacity and the ability to manage capacity.

Quantification of shrimp fishing capacity and any overcapacity is not common in most shrimp fishing countries, except in some of the fisheries in developed countries such as Australia. The more common situation is that fisheries managers sense that overcapacity exists, that it is at least partially responsible for poor fleet profitability, and that steps should be taken to reduce fleet size in order to improve economic performance. The situation in Nigeria exemplifies the typical developing country situation.

*Economic revival in the Nigerian shrimp trawl fleet will depend upon either prices rising or catch rates improving, as there is little scope to reduce costs. If prices do not rebound, then the principal option facing the industry must be to reduce overall capacity to allow unit catch rates to increase for the remaining vessels (Chemonics, 2002).*

Fishing capacity problems in shrimp fisheries are not limited to developing countries. FAO (2005b) states that about half the current shrimping effort by United States vessels in the Gulf of Mexico could produce about the same yield. In Australia’s Northern Prawn Fishery, despite almost continuous management interventions including limited entry and effort adjustments during the life of the fishery, overcapacity remains a problem (Cartwright, 2003). These United States and Australian examples illustrate two very different difficulties in managing shrimp fishing capacity, as described below.

- *The lack of mechanisms for limiting entry.* Most federally managed shrimp fisheries in the United States are open access, and there are few, if any, legal instruments available to prevent new entries into fisheries and associated growth of capacity. Many other countries, especially developing ones, also lack the required legal framework and management tools to limit entry.
- *Effort creep.* The Australian example illustrates the “effort creep” mentioned above. Although the managers of the Northern Prawn Fishery have been able to restrict entry into the fishery since 1977, capacity has nevertheless grown through improved technology and fishing strategies.

Another important fishing capacity issue associated with shrimp fisheries concerns small-scale fisheries. Even the shrimp fishing nations that are able to limit entry in large-scale fishing operations are often unable to restrict participation by small-scale fishers. These fisheries represent a challenge where a solution is likely to be found in participatory management through decentralized processes, improving incentives and legitimacy and involving the social sciences in the design of management schemes, etc. A characteristic of several countries in this study – including Cambodia, Indonesia, Madagascar and Nigeria – is the large and rising number of small-scale shrimp fishers who have few non-fishing alternatives.

Another important issue mentioned above is the sequential nature of small- and large-scale fisheries. Small-scale effort has a greater plasticity than industrial effort in many cases. Closing tropical lagoons with multiple series of nets can eliminate entire year classes before maturity, leading to a practical shutdown of large-scale fisheries.

## 4. Economic contribution of shrimp fishing

It is widely assumed that shrimp fisheries contribute substantial benefits to national economies. To obtain more information on this subject, attempts were made to collect data on some economic indicators across the ten study countries. Table 6 summarizes the readily available information.

The above information represents a heterogeneous assemblage of facts, collected in different ways and with varying degrees of rigour. As such, any summaries or comparisons among countries are difficult. Despite the limitations of the data, it is possible to make certain comments.

The contribution of shrimp fishing to GDP is not readily available in most countries. Where it is available, the general perception is that the shrimp fishing GDP contribution is small. This may be a distortion of the actual situation,<sup>3</sup> but nevertheless, in many countries, it results in the view that shrimp fisheries do not have a great importance in the overall economy. Other observations related to shrimp and GDP are given below.

- The greatest GDP contribution noted in Table 6 is for Madagascar (1 percent), but this figure does not include the component of important traditional shrimp fishing.
- In many countries/regions in this study, a large petroleum industry tends to overwhelm the economic importance of shrimp fishing. Study countries in this category are Indonesia, Kuwait, Nigeria, Norway, Trinidad and Tobago, Mexico and, to a lesser extent, the United States of America.

With regard to the consumption of shrimp, per capita intake in the developed countries (Australia, Norway, United States) is, as might be expected, considerably higher than in most developing countries. Relatively high consumption in the United States, combined with its large population, translates into the world's biggest market for shrimp. In several countries in the developing world (e.g. Indonesia, Nigeria), a great deal of the shrimp is used as a condiment and thus has a greater importance than might be suggested by the weight of the product alone. It should also be noted that, in order to obtain accurate shrimp consumption information for a developing country, there must be good data on small-scale shrimp catches, which is not often available. With regard to overall nutritional benefits from shrimp fisheries, the consumption of the bycatch from shrimp fisheries is important in most shrimp fishing countries in the developing world.

Of the information on economic benefits given in Table 6, the employment data seem to be the least reliable and least comparable across countries. Where reasonable employment data are available, they are usually confined to formal onboard jobs on industrial trawlers. In many cases, the number of jobs associated with small-scale shrimp fisheries is probably vastly greater than those on board large vessels. This is the

<sup>3</sup> It is important to note that, although a fishing subsector contribution to national GDP may seem small, it can be crucially important to a national economy. Iceland is a good example: its economy is highly dependent on fish and fishing, and fishery products contribute to 70 percent of exports. Despite this importance, the fishing sector contributes only 13 percent of GDP. This is because of the way that sector contributions are calculated – many fishing-related activities are accounted for in other sectors, such as manufacturing. Furthermore, it is a result of significant economic activity generated by fishing, such as retail trade and government, which is counted as value added in other sectors.

TABLE 6  
Some indicators of the economic contribution of shrimp fisheries (data from the early 2000s)

	Contribution to GDP	Consumption (kg/person/yr)	Employment	Catch value (US\$/yr)	Exports
Australia	Not readily available	2.2 kg	1 040 people in shrimp fishing; about 5% of all fishing employment	US\$240–292 million	US\$128 million; net importer
Cambodia	Not readily available	Not readily available	No data available; crude estimate of 8 000 people involved in trawling	Official estimate not readily available; US\$2/kg catch valued at US\$7.4 million	1 578 tonnes (no official information on value); US\$4/kg exports valued at US\$6.3 million; most valuable fishery export
Indonesia	Not readily available	About 0.5 kg	2 900 people on industrial trawlers; small-scale employment unknown, but very much larger	US\$558 million	US\$887 million; most valuable fishery export
Kuwait	About 0.01% of GDP	Not readily available	335 on board; almost all expatriates	US\$7 million	US\$1 million; net importer
Madagascar	Industrial and artisanal sectors contributed 1%; traditional sector contribution not readily available	0.1 kg is a crude estimate	Industrial/artisanal shrimp fishing employed 3 970 people; traditional (part-time) varies from 8 000 to 10 000 people.	US\$70.2 million	US\$68.2 million; most valuable fishery export
Mexico	Not readily available	0.66 kg	One estimate indicates 190 884 fishers employed	US\$300 million	US\$346 million; most valuable fishery export
Nigeria	Not readily available	Not readily available	One estimate indicates 1.2 million people have formal or informal jobs associated with shrimp fishing and post-harvest	US\$70 million from industrial vessels	US\$49 million; most valuable fishery export
Norway	0.25% of GDP	1.7 kg	998 people on board	US\$228 million	\$125 million; important export
Trinidad and Tobago	About 0.2% of GDP	Not readily available	324 fishers directly involved in shrimp trawling	US\$2.72 million	US\$800 000; most valuable fishery export
United States of America	Not readily available	1.9 kg	Not readily available	US\$425 million	Exports are 15 000 tonnes; imports 500 000 tonnes

Source: based on Part 2 of this report; further details (specific source, date) available in the individual country studies.

case in Cambodia, Indonesia, Madagascar, Nigeria and Mexico (see Part 2). In some countries, such as Nigeria, the downstream employment figures are impressive, but the methodology used to estimate the number of jobs is not clear, and consequently the credibility is uncertain.

In addition to shrimp fishing for food, the capture of broodstock and postlarval shrimp for shrimp farming purposes employs a considerable number of people; Clay (2004) estimates a million people worldwide.

The gross value of the shrimp catch is known in most cases. Gross landed values vary widely in the study countries: from US\$2.72 million to US\$558 million. Despite the shortcomings of these statistics, it appears that these figures are often used by fisheries managers for making decisions, such as trade-offs between fisheries when they interact, simply because the numbers are available and comparable.

Shrimp is clearly an important export in the study countries. It is the most valuable fishery product export in Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria and Trinidad and Tobago, and an important – although not the most important – fishery export in Australia and Norway. A complicating factor (and one that also affects shrimp consumption data) is that in most cases where shrimp fishing and shrimp farming exist within the same country, it is often difficult to distinguish between the two – and shrimp exports are a combination of farmed and captured products.

Although not listed in Table 6, the resource rent in a shrimp fishery is a kind of benefit that is available to the private and/or public sectors in various forms. Information on the amount of resource rent available is not known for most shrimp fisheries. In fact, resource rent calculations are only readily available for a few of the world's shrimp fisheries: that of Australia's Northern Prawn and Torres Strait, the Gulf of Mexico, the Gulf of Thailand, Greenland's Davis Strait and the European *Crangon*.

Some observations can be made in reflecting on the economic benefits for the shrimp fisheries in the study.

- The entry "not readily available" often appears in Table 6 and the subsequent text. In many cases, information could in fact be obtained, albeit through considerable research. In another sense, the data readily available reflects to some degree the economic information on hand for fisheries managers to use in decision-making.
- In the management of shrimp fisheries, some mechanism for balancing the benefits of fishing with environmental and other costs incurred is required. Given the scarcity and limitations of data on shrimp fisheries, there does not seem to be enough information on benefits in most countries to determine whether the costs incurred are justified, at least not in a quantitative sense.



## 5. Trade aspects

### MAJOR FEATURES OF THE SHRIMP TRADE

World production of shrimp, both captured and farmed, is around six million tonnes (Chapter 16, section *General information on shrimp farming*), about 60 percent of which enters the world market. Shrimp is now the most important internationally traded fishery commodity in terms of value. Annual exports of shrimp are currently worth more than US\$10 billion, or 16 percent of all fishery exports.

Currently, about 40 percent of the world production of shrimp is from farming; however, the proportion of farmed shrimp in international trade appears to be much higher. Although the precise composition is not known with certainty (farmed and capture shrimp are combined in export statistics), it appears that about 60 percent of internationally traded shrimp is from aquaculture. Ward *et al.* (2004) review the reasons for the greater popularity of the farmed product (Chapter 16). Another consideration is that the most important single species of capture shrimp in the world, the akiame paste shrimp, characteristically does not enter international trade, hence lowering the importance of the captured product in this trade.

Trade often amplifies the various effects of fishing practices, whether they are beneficial, such as employment, or harmful, such as environmental damage. Because most shrimp fisheries, especially those in the developing world, depend upon international trade for their continuation (EJF, 2003b), there is an opportunity to use trade for improving aspects of shrimp fisheries. To do so, however, requires an understanding of the shrimp trade.

Shrimp marketing is complex, with different markets requiring different product forms, methods of preservation, species and sizes. Clay (2004) indicates that in the United States alone, there are more than 70 classifications based on size and degree of processing. Chemonics (2002) and Cascorbi (2004b) describe the various characteristics.

- *Product forms.* There are several categories, with different markets:
  - green headless: the standard market form. It includes the six tail segments, with vein, shell and tail fin. "Green" does not refer to shell colour but to the uncooked, raw state of the shrimp. Also called "shell-on" or "headless";
  - peeled: green headless shrimp without the shell;
  - PUD: peeled, undeveined, tail fin on or off, raw or cooked. The vein, running the length of the tail, is the intestine, also called the "mud vein" or "sand vein";
  - tail-on round: undeveined shrimp with tail fin on;
  - P&D: peeled, deveined, tail fin on or off, raw or cooked;
  - cleaned: shrimp that is peeled and washed, a process that removes some or all of the vein but not thorough enough to warrant the P&D label;
  - shell-on cooked: cooked tail, with vein, shell and tail fin;
  - split, butterfly, fantail: tail-on shrimp cut deeply when being deveined.
- *Preservation methods.* The main types are fresh, frozen raw, semi-processed or fully processed (i.e. as breaded shrimp). The great bulk of internationally traded shrimp is sold frozen, graded, as whole or tails, with fully processed tails representing the balance.
- *Sizes.* These have a great impact on the price that shrimp receives – the larger the shrimp, the better the price, by a substantial margin. Shrimp is graded by "count",

i.e. the number per pound or kilogram. The important point is the significant price differential between grades; on average 15–18 percent per size grade.

- *Species*. Different shrimp species trade into different markets: cold-water northern pandalids, tropical white (mostly *Penaeus vannamei*), pink and brown penaeids and black tiger (*P. monodon*) all have distinct market niches, as do scarcer specialized species.

From the mid-1990s to 2005, a major feature in the world shrimp market was generally falling prices. Ward *et al.* (2004) indicate that from 1997 to 2002 in the United States, ex-vessel prices declined by 27 percent in the Gulf of Mexico and 24 percent in the Southern Atlantic States Shrimp Fishery, as imports increased by 300 percent. In Japan, there was a general downward trend in prices from the mid-1990s. In the European Union (EU), combined penaeid import prices mostly declined from 2000, but prices for some captured species increased. Cold-water shrimp prices, as judged from *Pandalus borealis* prices in the United Kingdom, show a downward trend from the mid-1990s. Although increased aquaculture production is the main cause of the fall in prices, Globefish (2003) also notes other causes in the early 2000s.

*Demand weakened in key markets, particularly the United States of America, following the events of 11 September. Difficult economic conditions in Japan, as well as the weak yen, meant reduced demand and downward pressure on prices in that market. In the EU, the appreciation of the euro vis-à-vis the dollar effectively reduced import prices for shrimp products normally quoted in dollar terms.*

Since late 2005, the shrimp price situation has changed. Because of higher demand and lower expected aquaculture production, especially in Thailand, shrimp prices have been increasing. At least part of the increased demand is from Thailand and China where domestic consumption is rising.

## MAJOR SHRIMP MARKETS

Although over 100 countries export substantial quantities of shrimp, the international shrimp markets are concentrated in just three areas: the United States, Japan and Europe.

The United States represents the world's largest country shrimp market and United States Government shrimp import policies have a critical effect on major shrimp exporting countries throughout the world. In recent years, the country has produced commercially about 145 000 tonnes of shrimp per year, of which only about 4 000 tonnes are from aquaculture. The United States imports about 500 000 tonnes annually, over 80 percent of which are from aquaculture.

There have been important changes in the United States shrimp trade in recent years. The total supply of shrimp on the domestic market has increased dramatically over the past 20 years. Domestic production plus imports were about 200 000 tonnes in the early 1980s, but increased to over 650 000 tonnes in 2004. There has also been a large increase in shrimp imports. The United States market share supplied by imports increased from 48 percent in 1978 to 80 percent in 2004. The rise in low-cost imports has led to a fall of shrimp prices on the domestic market. Two decades ago, the major exporters of shrimp to the United States were Latin American countries (Ward *et al.*, 2006). United States markets are greatly affected by unilateral action of the government, including measures relating to turtle conservation (see Chapter 5, section *Measures relating to turtle conservation*), anti-dumping action (see Chapter 5, section *United States anti-dumping action*), and the June 2007 blocking of farmed shrimp from China because of contamination with unapproved animal drugs and food additives (FDA, 2007). The latter action resulted in shrimp from China being diverted to other markets (e.g. Japan, EU), and more Thai and Indonesian shrimp going to the United States market. In addition, at least some shrimp shipments bound for the United States are being routed through other Asian countries to avoid the appearance of originating in China (i.e. "shrimp laundering").



The Japanese shrimp market was formerly the largest in the world, but economic stagnation in the last decade led to its reduced importance. At present, shrimp imports into Japan are about 300 000 tonnes annually, or about 60 percent of United States imports. In 2006, Japanese imports of frozen raw shrimp were at a six-year record low of 229 952 tonnes, but the market now supports more

imports of prepared products; in 2006, there was a 15 percent increase in imports of frozen value-added shrimp compared with 2005 (Eurofish, 2007). Again in 2006, there was a notable increase in imports of cold-water shrimp, with imports from Argentina increasing fivefold to 3 400 tonnes (O'Sullivan, FAO, personal communication, 2007). Asian countries are the major suppliers to Japan, with Viet Nam recently overtaking Indonesia as the most important provider. African nations, such as Madagascar, Mozambique and Nigeria, also export significant amounts to Japan, with Australia catering to some speciality niches. In the ten country studies (Part 2), several suppliers expressed the opinion that Japan is an important alternative shrimp market to the United States during periods of United States unilateral action affecting the shrimp trade.

The EU imports almost as much shrimp as the United States, with Spain as the main market, followed by France, the United Kingdom and Italy. In 2006, the six major supplying nations in terms of volume were Greenland, Ecuador, India, Canada, China and Brazil. (O'Sullivan, FAO, personal communication, 2007). With respect to shrimp marketing, the EU is not homogenous since each country has different suppliers and preferences.

Table 7 gives some of the important characteristics of the main international shrimp markets.

The various tariffs are important in the major shrimp markets Josupeit (2004; personal communication, 2007) reviews the situation in the United States, EU and Japan.

- In the United States, there is no tariff on frozen shrimp products. A 5-percent tariff is applied when shrimp is canned with fish meat. Anti-dumping tariffs apply to shrimp from specific countries (see Chapter 5, section *Important issues in the shrimp trade*).
- The EU tariffs are 18 percent for frozen *Crangon crangon*, 12 percent for other frozen shrimp and 20 percent for canned shrimp. The zero tariffs for the African, Caribbean and Pacific (ACP) Group of States are likely to expire in the coming years. There are also substantial tariff reductions for certain developing countries outside the ACP agreement. One important group, the Generalized System of Preferences (GSP)<sup>4</sup> countries, has a reduced duty of 14.5 percent for *Crangon crangon*, 7 percent for canned shrimp and 4.2 percent for frozen shrimp other than *Crangon crangon*. Brazil has been excluded from this tariff reduction. In July 2007, tariffs on cooked and peeled *Pandalus borealis* going for further processing in the EU were reduced from 20 to 6 percent for a 20 000-tonne quota (H. Josupeit, FAO, personal communication, October 2007).

TABLE 7  
Characteristics of the main shrimp markets

	Main shrimp groups in imports			Preferred product
	White <sup>a</sup> (%)	Black tiger <sup>b</sup> (%)	Cold water (%)	
United States	26	72	2	Frozen shell-on tails (51%) Peeled tails (31%)
Japan	7	80	13	Frozen shell-on tails
Europe	34	33	33	Spain – whole shrimp France – whole shrimp United Kingdom – small peeled tails Netherlands – tails Italy – whole shrimp

Source: Chemonics, 2002.

a. Mostly *Penaeus vannamei*.

b. *Penaeus monodon*.

<sup>4</sup> GSP: a grouping of 115 countries and territories.

- In Japan, tariffs are 1.8 percent for fresh, 4.8 percent for cooked and 6 percent for frozen and canned shrimp. Tariffs on Mexican shrimp have been eliminated under a trade agreement.

Josupeit (2004) concludes that tariffs have been reduced and are relatively unimportant in the United States and Japan. Tariffs are still high in the EU.

### IMPORTANT ISSUES IN THE SHRIMP TRADE

Three important issues in the shrimp trade deserve special attention: the United States trade measures relating to turtle conservation, United States anti-dumping tariffs and ecocertification of shrimp fisheries.

#### Measures relating to turtle conservation

According to the United States Department of State, Chapter 609 of United States Public Law 101–162 provides that shrimp or products from shrimp harvested with commercial fishing technology that may adversely affect certain species of sea turtles protected under United States laws and regulations may not be imported into the country unless the President certifies to Congress by 1 May 1991, and annually thereafter. The foundation of the United States programme governing the incidental taking of sea turtles in the course of shrimp harvesting is the requirement that commercial shrimp trawl vessels use TEDs, approved in accordance with standards established by the United States National Marine Fisheries Service (NMFS), in areas and at times when there is a likelihood of intercepting sea turtles. The goal of this programme is to protect sea turtle populations from further decline by reducing incidental mortality in commercial shrimp trawl operations. The chief component of the United States sea turtle conservation programme is a requirement that commercial shrimp boats use TEDs to prevent the accidental drowning of sea turtles in shrimp trawls.

On 1 May 2007, the United States Department of State certified that 16 nations had adopted programmes to reduce the incidental capture of sea turtles in their shrimp fisheries, similar to the programme in effect in the United States. The Department also certified that the fishing environments in 24 other countries and one economy – China, Hong Kong Special Administrative Region – do not pose a threat of incidental taking of sea turtles. Shrimp imports from any nation not certified were prohibited, effective 1 May 2007 (Federal Register, 2004). The various categories and certified countries are on the basis that:

- national sea turtle protection programmes are comparable with that of the United States: Belize, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Madagascar, Mexico, Nicaragua, Nigeria, Pakistan, Panama, Suriname and the Bolivarian Republic of Venezuela;
- national fishing environments pose no danger to sea turtles because shrimping grounds are only in cold waters: Argentina, Belgium, Canada, Chile, Denmark, Finland, Germany, Iceland, Ireland, the Netherlands, New Zealand, Norway, Russian Federation, Sweden, the United Kingdom and Uruguay; and
- national fishing environments pose no danger to sea turtles because shrimp is only harvested using small boats with crews of fewer than five people, who use manual rather than mechanical means to retrieve nets, or catch shrimp using other methods that do not threaten sea turtles: the Bahamas, China, the Dominican Republic, Fiji, Hong Kong SAR, Jamaica, Oman, Peru and Sri Lanka.

The United States policy on TEDs is not without its critics. Many shrimp fishers outside the country are unclear as to the actual requirements, while others complain that they simply cannot afford gear similar to that used by relatively rich United States fishers. At a higher level, the Government is sometimes faulted for adopting unilateral measures that aim to compel other governments to alter their national policies to be more in line with United States objectives (Joyner and Tyler, 2000).

Country experience in compliance with United States TED requirements is reviewed in Part 2. The main observation that can be made from examining the situation in ten countries in several regions is that, if the intention of the TEDs policy is to change fishers' behaviour so that fewer turtles are killed in shrimp trawling, more effort needs to be made by the United States promoters of the programme to raise awareness among vessel operators as to the specific requirements and status of national compliance with the United States law. Currently, the confusion associated with TEDs seems to engender considerable animosity, limiting the potential benefits for turtle conservation. One important factor of success in the United States, where important reductions of turtle mortality have been achieved, seems to be the move from technological solutions developed and imposed by the administration to solutions developed by the fishing industry itself, in an enabling environment where conservation incentives are provided by the establishment of some sort of resource entitlement (Melvin, 2007).

Sea turtle conservation measures in shrimp trawl fisheries were originally promoted by the United States, but are now fundamental in many countries. All seven species of sea turtle are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

### United States anti-dumping action

Another United States intervention affecting shrimp imports concerns anti-dumping action. While it directly affects only aquaculture shrimp exported to the United States by certain countries, it was designed to benefit United States shrimp fishers and certainly has an impact on the global shrimp trade because of the size of the United States shrimp market.

The rise in imports and, in particular, of farmed warm-water shrimp from low-cost producers has, over time, led to a fall in shrimp prices in the United States market, resulting in fishers becoming less competitive. This has led United States shrimpers to accuse foreign producers of dumping. On 31 December 2003, the Southern Shrimp Alliance, a lobbying organization formed by shrimp fishers and processors in eight southern states, filed an anti-dumping petition with the United States Department of Commerce against shrimp farms in Brazil, China, Ecuador, India, Thailand and Viet Nam. On 6 July 2004, the Department imposed duties varying up to 113 percent on these countries. Some commentators see it from a different perspective (Box 9). Thailand and Ecuador are taking action with the World Trade Organization to protest against the United States duties.

#### BOX 9

##### **An alternative view of shrimp dumping in the United States**

Shrimp farming has proliferated for one simple reason: efficiency. Trawling for shrimp is costly, and the harvest often varies considerably from year to year with changes in weather and ecological conditions. Shrimp farms not only produce shrimp at much less cost, but also produce a steady and reliable volume. Seafood processors value the reliable volume: these companies buy harvested shrimp and produce finished products for consumers whose desire for shrimp does not fluctuate with weather and ecological conditions. As shrimp farming has expanded, world shrimp production has increased and shrimp prices have fallen. Shrimp prices are now so low that they threaten the market survival of United States shrimp trawlers. The trawlers have therefore turned to the United States Government and its anti-dumping law to protect themselves, not from dumping, but from market competition with their more efficient foreign competitors (Mathews, 2004).

In the short term, some market specialists feel this action resulted in higher shrimp prices to consumers. Internationally, supplies directed away from the United States market led to falling prices elsewhere. In the long term, however, the impacts of the anti-dumping measures have been mitigated by the creativity of foreign supplier of shrimp and by the action of the United States Government (see Chapter 8, section *Improving profitability*).

### Ecocertification of shrimp fisheries

The concept that some consumers wish to buy marine products that do not contribute to overfishing or other destructive practices is behind “certifying” certain seafood and marine products as “sustainable”. Organizations that are currently actively involved in certifying marine products include the Marine Aquarium Council, the Global Aquaculture Alliance and the Marine Stewardship Council (MSC). The MSC is the most widely known example of an independent organization certifying capture fisheries based on standards for sustainable management (Kura *et al.*, 2004).

Leadbitter and Oloruntuyi (2002) review the development of the MSC. A marriage of economics and ecology between Unilever and World Wide Fund for Nature (WWF) International resulted in the creation of an ecolabelling programme and an overseeing authority. Now independent of its founders, the MSC operates as a non-profit, standard-setting body, which accredits independent certifiers to evaluate fisheries against its standard. The standard, called the *Principles and Criteria for Sustainable Fishing*, is based on the FAO Code of Conduct for Responsible Fisheries. It was derived from a two-year international consultation programme that involved stakeholders from fisheries economics, stock assessment, marine ecosystem analysis, conservation and the social and legal aspects of fisheries, and represented industry, environment groups, consumer and regional interests. The standard looks at sustainable fishing from three perspectives: the state of the fish stock, the impact of the fishery on the associated ecosystem and the performance of the management system.

If a fishery is certified as sustainable, its products are eligible to bear a distinctive logo or statement certifying that the fish has been harvested in compliance with conservation and sustainability standards. The logo or statement is intended to make provision for informed decisions of purchasers whose choice can be relied upon to promote and stimulate the sustainable use of fishery resources (FAO, 2005c).

As of September 2007, there were no MSC-certified shrimp fisheries. In 2005/06, the Oregon Pink Shrimp Fishery in the United States (a trawl fishery) entered into the process of full MSC assessment and, in October 2006, the Canadian Northern Prawn Fishery (another trawl fishery) did the same (MSC, 2007). The possibility of certification has been cited for several other shrimp fisheries, including the British Columbia Spot Prawn Fishery, the Industrial Shrimp Trawl Fishery in Madagascar, and Australia’s Spencer Gulf Fishery. In the ten study countries (Part 2), the possibility of obtaining MSC certification was mentioned by shrimp fishery stakeholders in Australia, Madagascar and the United States as having the potential to exert a positive influence on shrimp fishing practices.

Would ecolabelling promote greater sustainability in shrimp fisheries?

- In support of ecolabelling for shrimp fisheries, Leadbitter and Oloruntuyi (2002) cite studies that show consumer interest in ecolabelled seafood in the United States, Hong Kong SAR and the United Kingdom, but state that studies of consumer purchasing intentions do not necessarily reveal actual purchasing decisions.
- Ward *et al.* (2004) study ways to increase the shrimp price for fishers in the United States and critically examine the contention that fisheries that operate on a “sustainable” basis can be rewarded by a higher price. They indicate that the crucial questions are: whether there is a significant consumer preference for

certified seafood among a certain segment of the population; and whether this segment will vote for this preference by paying a premium for the product. The report indicates that because ecolabelling is a relatively new concept, there is little empirical information to assess how individuals have responded to the label in the market.

- One fisheries management specialist has expressed the view that the MSC bar is set relatively high and almost all shrimp fisheries would struggle to reach it. Because only relatively well-managed, sustainable fisheries are likely to make the grade to MSC certification, the real impacts of certification on poor practices in most of the world's shrimp fisheries are likely to be limited (I. Cartwright, personal communication, May 2007).
- EJF (2003b) discusses shrimp trawling and argues that, in addition to the economic incentives provided by ecolabelling, the practice also acts as a starting-point in raising consumer awareness of fisheries sustainability issues.
- Clay (2004) points out that the most efficient way to address many of the issues related to the sustainability of fisheries is by consulting the few institutional buyers in the United States who decide which shrimp will be subsequently purchased by millions of consumers.



## 6. Bycatch issues

### GENERAL

Most fishing results in catching species other than the target ones. Shrimp fishing, especially in the tropical shrimp trawl fisheries, is a very specialized activity producing large amounts of bycatch that is either discarded or partially kept on board. Where vessel technology allows for it, the proportion of bycatch landed tends to increase when shrimp catch rates decrease. Landed bycatch also tends to be much higher in poor tropical countries than in developed ones. Bycatch is one of the most pressing and controversial aspects of shrimp fishing and much of the management attention associated with shrimp fisheries is focused on reducing it. The shrimp bycatch issue has generated a great deal of literature; it appears that more has been written on this subject than on any other aspect of shrimp fishing.

Why worry about bycatch? Bycatch, particularly that which is discarded, is a serious conservation problem because valuable living resources are wasted, populations of endangered and rare species are threatened, stocks that are already heavily exploited are further impacted and ecosystem changes in the overall structure of trophic webs and habitats may result (Harrington, Myers and Rosenberg, 2005).

As for several other aspects of shrimp fishing, public discussion on bycatch is polarized. For example, the Environmental Justice Foundation (EJF, 2003b) states that commercial shrimp trawling involves dragging the trawl along the bottom, and scraping up shrimp and everything else in the net's path. On the other hand, Eayrs (2005) indicates that there is a common perception among stakeholders that shrimp trawls sweep large expanses of the ocean, catching all animals in the path of the trawl, but that this is not an entirely correct generalization. Many shrimp fishers have used selective fishing methods for a long time, including trawls with a low headline height to minimize fish catches; ground chain arrangements that reduce the amount of seabed debris taken; avoidance of fishing grounds where bycatch is known to be high; mesh sizes large enough to allow some small animals to escape; and TEDS and BRDS.

As pointed out by Poseidon (2003), much confusion dealing with bycatch stems from uncertainty of the terminology used. In this report, terms related to bycatch and discards of shrimp fisheries follow the convention of Kelleher (2005).

- Discards, or discarded catch, are that portion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea, for whatever reason.
- Discards are not a subset of bycatch as the target species is often discarded.
- Discard rate is the percentage of the total catch that is discarded.
- Bycatch is the total catch of non-target animals.

It is important to note that there are other types of bycatch nomenclature. For example, in Australia, the part of the "catch" that does not reach the deck of the fishing vessel but is affected by interaction with the fishing gear is considered bycatch. The nomenclature used in the United States is also quite different, as shown by the NMFS terms in the section below and in Box 10.

The terms "target" and "bycatch" are relatively clear in industrial shrimp fisheries of developed countries, but become increasingly irrelevant in the progression from large-scale fisheries in the developed world to small-scale fisheries in poor tropical countries where almost everything of economic value can become a target. In these cases, the term "trash fish" is often used. In this report, "trash fish" is defined as fish that have a low

## BOX 10

**Various estimates of bycatch and discards in the United States warm-water shrimp fisheries**

The exact ratio of non-shrimp bycatch in Gulf and Atlantic shrimp trawl fisheries remains difficult to quantify. NMFS data suggest that there was a ratio of 10:1 in the 1970s, before measures were put in place to reduce growth overfishing of shrimp. Estimates of the bycatch ratio for Florida shrimp trawls range from 6:1 to 1:1. Studies in the late 1990s by the Texas Department of Parks and Wildlife found ratios in Texas State waters of approximately 4:1. In 2003, an industry representative asserted that the Gulf and South Atlantic Fishery had reduced the bycatch ratio from 10:1 to 3:1 since the mid-1980s. The best recent, non-industry estimates (NMFS in the late 1990s) suggest that for every pound (0.45 kg) of shrimp caught, about 4.5 pounds of bycatch are discarded in the United States South Atlantic and about 5.25 pounds of bycatch in the Gulf. BRDs are believed to reduce finfish bycatch by as much as 30 percent, which means that since 1997 (when BRD requirements were put into place), ratios could have reached 2.8:1 in the United States South Atlantic and 3.5:1 in the Gulf.

*Source:* summarized from Cascorbi, 2004b.

commercial value because of their low quality, small size or low consumer preference. In some small-scale fisheries (e.g. Cambodia) trash fish is sometimes targeted.

**QUANTIFYING BYCATCH**

The amounts of bycatch and discards in shrimp fisheries have been the focus of discussions related to conservation and sustainability for many decades. Even for specific shrimp fisheries, there are widely varying estimates of the amount of bycatch. At least some of the variation is caused by different systems of measurement and the low level of actual monitoring. However, part of the problem lies with how bycatch is defined. For example, while Kelleher (2005) defines bycatch in terms of non-target animals, the NMFS in the United States adopts a more expansive definition that includes the retained incidental catch. Because retained incidental catches are at least secondary targets, bycatch estimates may differ by several orders of magnitude depending on the definition used. From an ecological and global perspective, the NMFS definition would appear to be the most suitable to facilitate an estimate of the total capture of all species in shrimp fisheries.

Even in relatively regulated fisheries in developed countries, estimating and subsequently comparing levels of bycatch is not straightforward (Box 10). The Box also illustrates the point made in the section above concerning differences in bycatch nomenclature.

Lack of effective and uniform monitoring of bycatch in many shrimp fisheries creates difficulties for determining the success of efforts to reduce bycatch (see section *Bycatch reduction devices*) and for the important task of estimating global bycatch from shrimp fisheries.

Although quantifying all bycatch from shrimp fisheries on a global level is crucial for gauging the overall bycatch situation, it is an extremely difficult task. Relatively few regions have reliable data on total species captured (shrimp, finfish and other marine invertebrates). In addition, spatial and temporal variations of species associated with shrimp habitats and differences in fishing operations prevent even a rough approximation of the total global catch. In general, bycatch is low and managed in cold-water shrimp trawl fisheries, but it is high and often unmanaged in tropical



shrimp trawl fisheries. Combining these two generalities on a global scale to arrive at a total is fraught with difficulties. Furthermore, there is little quantitative bycatch information on non-trawl shrimp fisheries.

## MAJOR BYCATCH ISSUES

### Inferences from the national studies

In this study, a number of countries have been chosen as representative of various geographic regions, as well as for their variety of important shrimp fishing conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. These ten countries are examined in Part 2. The major shrimp bycatch issues in the ten countries are thought to reflect the global situation and are summarized in Table 8. In many respects, the bycatch issues are different in warm- and cold-water shrimp fisheries. In Table 8, the shrimp fisheries operate in cold waters (Norway); in both cold and warm<sup>5</sup> waters (United States) or in warm waters (the remaining eight countries).

Some observations can be made on the issues in Table 8. The shrimp bycatch issues highlighted in the national studies are distinctly different between developed and developing countries, large- and small-scale fisheries, and warm- and cold-water shrimp fisheries. In developed countries, compliance with legislation and management plans appear to underpin many bycatch issues. In developing countries, it appears as though economic incentives, including trade sanctions (to encourage bycatch reduction), food security and other requirements (to encourage bycatch landing and reduction of discards) are the main drivers of the bycatch/discards issue. In the small-scale fisheries, many bycatch issues are associated with bycatch utilization and with conflict generated by the bycatch of large-scale shrimp fishing operations.

In addition to the main national bycatch issues highlighted in Table 8, specialized studies examining the bycatch of shrimp fisheries point to other important issues. These include the following:

- *Effects on individual species.* If shrimp bycatch removes a large proportion of the abundance of a particular species, the effect is the same as if the species were a target. Beyond a certain level of removal, that species can be threatened. It makes no difference whether the bycatch is landed or discarded. For example, in the 1980s and 1990s, the bycatch of juvenile red snapper in shrimp trawl fisheries of the Gulf of Mexico was identified as the reason why the commercially valuable red snapper could not recover from overfishing (Cascorbi, 2004b). Sharks, skates and rays are common in the shrimp trawl catch and are particularly vulnerable.
- *Effects on endangered species.* The effect described above is a particular source of concern when the species is already endangered by direct fishing or other threats such as pollution and the destruction of nesting beaches. The mortality of turtles in shrimp trawls is well known (see section *Warm-water shrimp trawl bycatch issues* below), but other threatened or charismatic species are also impacted, including dolphins, seahorses, dugongs, albatrosses and penguins.<sup>6</sup>
- *Effects on ecosystems.* If the abundance of key species is reduced through bycatch, major and unpredictable changes may occur in food chains. This impact is similar whether the removal results from targeted catch or bycatch. One aspect of this issue is the removal of shrimp predators by trawling that can result in profound changes in the food chain, such as increased abundance of prey, including squid and shrimp. This has been observed in both warm- and cold-water shrimp fisheries.

<sup>5</sup> Eighty-five percent of United States shrimp production is from warm-water fisheries.

<sup>6</sup> Gandini *et al.* (1999) studied the Shrimp Beam Trawl Fishery for Argentine red shrimp (*Pleoticus muelleri*) in Golfo San Jorge, Argentina and reported that 0.33 percent of the breeding population of Magellanic penguins is incidentally killed by the shrimp fishery every summer.

TABLE 8  
Main bycatch issues of the ten shrimp fishing countries in the study

Country	Bycatch issues
Australia	<p>Bycatch issues in northern Australian prawn trawl fisheries focus predominantly on unwanted fish bycatch and the incidental capture and mortality of sea turtles in trawl nets. Bycatch issues in southern Australian prawn trawl fisheries focus predominantly on unwanted fish and crustacean bycatch. There are several reasons why bycatch issues in Australian prawn trawl fisheries have received considerable attention over the past decade, including the following.</p> <ul style="list-style-type: none"> <li>• Australian fisheries management agencies have a legislative mandate to ensure that trawl fisheries comply with the principles of ecologically sustainable development (ESD).</li> <li>• Many Australian prawn trawl fisheries also have legislation or policies that require a reduction in the take of non-target species and a minimization of the impact of trawling on the ecosystem.</li> <li>• The drowning of sea turtles in trawls of northern Australia has received considerable attention.</li> <li>• “World Heritage” status has brought increased scrutiny of commercial fishing practices, especially trawling operations, to ensure that the exploitation of fisheries resources do not occur at the expense of the quality of the ecosystem.</li> <li>• All export fisheries require accreditation through a strategic assessment process, which, <i>inter alia</i>, gives consideration to levels of bycatch (Robins, Campbell and McGilvray, 1999).</li> </ul>
Cambodia	<ul style="list-style-type: none"> <li>• There are few, if any, measures in place to manage, control or reduce bycatch.</li> <li>• Unlike in many other countries, trash fish is a major bycatch issue here; trash fish could be considered together with shrimp as an actual target of trawling. The proportion of trash fish in the trawl catch is increasing.</li> </ul>
Indonesia	<ul style="list-style-type: none"> <li>• There is a high discard level of industrial shrimp trawlers in the Arafura Sea.</li> <li>• The adverse biological impacts of industrial bycatch on the small-scale shrimp fisheries are significant.</li> <li>• There is a scarcity of appropriate measures to mitigate bycatch problems, and enforcement of bycatch legislation is extremely difficult.</li> <li>• The trash fish situation is complex, characterized by: an increasing use of trash fish for aquaculture and other animal feeds; competition between the use of trash fish for fishmeal and for human food; sustainability of the current system; and the amount of fish that becomes trash through poor handling and post-harvest strategies.</li> </ul>
Kuwait	<ul style="list-style-type: none"> <li>• Although some studies show a high discard rate, the issue is not often raised here.</li> <li>• At present, there is a lack of incentives for using BRDs.</li> </ul>
Madagascar	<ul style="list-style-type: none"> <li>• The reduction of bycatch results in some economic losses to the industrial shrimp fishery – there is a requirement that each kilogram of landed shrimp be accompanied by at least a half a kilogram of fish.</li> <li>• The retained bycatch of shrimp trawling represents a significant amount of the national supply of fish.</li> <li>• The possibility of obtaining ecocertification appears to be providing an incentive for further reducing bycatch and discards.</li> </ul>
Mexico	<ul style="list-style-type: none"> <li>• The amount of discards from Mexico’s shrimp fisheries, 133 000 tonnes, is considered to be large.</li> <li>• Mexico is among the 13 countries that currently meet the standard set by the NMFS with respect to the use of TEDs. A major shrimp bycatch issue in Mexico is retaining this status.</li> </ul>
Nigeria	<ul style="list-style-type: none"> <li>• All shrimp trawlers operating in Nigerian inshore waters are required to land 75 percent of the shrimp bycatch. There is much evidence that there is a thriving business of bycatch transfer to canoes.</li> <li>• The use of TEDs on shrimp trawl nets has been a requirement since September 1996, but is still not fully implemented, as documented by the United States import ban.</li> <li>• Traditional small-scale fishing gear catches large quantities of juvenile shrimp.</li> </ul>
Norway	<ul style="list-style-type: none"> <li>• Bycatch of juvenile cod, haddock and redfish (1–1.5 year-old fish) on shrimp grounds in the Barents Sea, as such small fish are not released by the Nordmøre grid. Shrimp grounds are closed for shrimp trawling when bycatch of these species exceeds a preset level.</li> <li>• Capture of small-sized shrimp (&lt; 15 mm carapace length).</li> </ul>
Trinidad and Tobago	<ul style="list-style-type: none"> <li>• The incidental fish catch associated with shrimp trawling may be as high as 90 percent for the artisanal trawl fishery and most of these fish are juveniles of other important coastal fisheries. The high discard rate of the shrimp trawl fisheries is one of the most important sources of conflict between the trawl fishery and other coastal fisheries in national waters.</li> <li>• Implementation of management actions to improve selectivity and limit discards has been hampered by the lack of capacity to monitor activities at sea, limited data on catches and on economics of the fishery, and limited alternative technological options in the harvest sector.</li> <li>• The imposition of TED requirements on the semi-industrial and industrial trawl fleets has not been well accepted by the industry.</li> </ul>
United States	<ul style="list-style-type: none"> <li>• The major bycatch issues are: estimation of bycatch in the various fisheries; the impacts of shrimp fishing on protected species, non-protected species and the environment; and various initiatives to reduce this impact, both domestically and internationally.</li> <li>• Kelleher (2005) notes that with respect to general bycatch issues in the United States, three features are especially noteworthy: (i) the growing impact of the incidental catch of charismatic species in fisheries management and in trade; (ii) the emerging influence of civil society with regard to bycatch and incidental catch issues; and (iii) the importance of fisheries management plans in bycatch management.</li> <li>• The incidental take of juvenile red snapper has been a significant bycatch problem in the Gulf of Mexico Shrimp Fishery, the resolution of which has challenged fishery managers for many years.</li> </ul>

Indeed, in the Mediterranean, fishers have allegedly “cleaned” upper slope grounds from predators (e.g. sharks, chimeras, etc.) to turn them into shrimp and hake fishing grounds.

- *Impacts on scavengers.* Seabirds and dolphins are known to consume discarded shrimp fishing bycatch. This may result in improvement of the reproductive rate of these animals, but may also lead to difficulties if they become dependent on the discards or are injured in the process of taking the bycatch.
- *Decomposition of discards.* The impact of the discards on the bottom detritus feeders and microbial fauna is not well known. The oxygen depletion that may occur when discards sink to the sea bottom of shallow, poorly circulated inshore areas may cause effects on the benthic community.
- *Conflict through bycatch.* The bycatch of large-scale shrimp trawling is often comprised of juveniles and adults of species important to small-scale fisheries, leading to reduced availability in the latter. In this situation, discarding is especially controversial.

Although shrimp bycatch creates various environmental problems, it is an important source of food in many communities. In Madagascar, consumption of the bycatch of shrimp fisheries constitutes about 6 percent of the national intake of fishery products. In Nigeria, trawler bycatch retained and sold ashore is an important food. In a review of a global programme to reduce bycatch from shrimp trawling, Westlund (2006) states that bycatches appear to play an important role in food security for poorer population groups in some countries, but their exact role is not yet well understood. A related issue, mentioned by ICES/FAO (2005), is the suboptimal situation in which communities become dependent on consumption of juvenile fish in the shrimp bycatch.

### Warm-water shrimp trawl bycatch issues

Two issues are particularly important in warm-water shrimp fisheries: turtles and trash fish.

#### *Turtles*

The bycatch of sea turtles by warm-water shrimp trawling is one of the most contentious topics related to shrimp fishing. The subject has generated considerable publicity and subsequent management action has had a major effect on most of the large shrimp fisheries in the tropics.

There are seven species of sea turtles in the world. These are the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), flatback (*Natator depressus*), leatherback (*Dermochelys coriacea*) and Kemp’s ridley (*Lepidochelys kempii*). All seven species are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).<sup>7</sup> Three species are classified as “critically endangered” on the World Conservation Union (IUCN) Red List: the leatherback, hawksbill and Kemp’s ridley.

<sup>7</sup> Appendix I includes species that are threatened with extinction and that may be affected by international trade. These species are prohibited from being traded internationally for commercial purposes, but some trade is allowed for non-commercial purposes (e.g. for educational facilities or scientific purposes).

FIGURE 18  
Sorting shrimp from the bycatch



Photo courtesy of NOAA Fisheries Service.

The role of shrimp trawling as one of the threats to sea turtles has been recognized for some time. Hillestad *et al.* (1981) stated that “worldwide the shrimp trawling industry seems to capture more sea turtles than any other commercial fishery. Many of the most intensely trawled waters are adjacent to major sea turtle nesting beaches or feeding grounds”. Some alarming reports<sup>8</sup> of turtle mortality have generated considerable publicity.

- In 1990, the Committee on Sea Turtle Conservation of the National Research Council (NRC) published a report on the capture of sea turtles. An important finding of the study was that shrimp trawling in the United States results in the deaths of 5 000–50 000 loggerhead turtles and 500–5 000 Kemp's ridley annually. Collectively, all other fishing activity is responsible for an additional 500–5 000 loggerhead deaths and 50–500 Kemp's ridley deaths annually. The incidental capture of sea turtles in shrimp trawls was identified by the committee as the major cause of mortality associated with human activities – killing more sea turtles than all other human activities combined (NRC, 1990).
- Twenty thousand turtles, mainly olive ridleys, are taken by Costa Rican trawlers each year, around half of which die from the trauma (Arauz, 1998).
- Over 35 000 olive ridleys were recorded dead on Orissa beaches in India from 1993 to 1998, most of which were killed by trawling (Pandav and Choudhury, 1999).
- A project conducted in 1989 and 1990 estimated that 5 000–6 000 turtles were caught by trawlers annually in Australia's Northern Prawn Fishery (Poiner and Harris, 1996).

The NRC study cited above concluded that the best method currently available to mitigate the effects of trawling on turtles (short of preventing trawling), would be the use of TEDs. Subsequent legal action under the Endangered Species Act resulted in the requirement for TEDs on all United States shrimpers operating in the Gulf of Mexico and South Atlantic. In 1992, as a result of lobbying by United States shrimp fishers and environmentalists, the TED provision was broadened to include foreign fleets. The saga of the United States extending the TED requirement abroad is given in Chapter 5, section *Important issues in the shrimp trade*.

Since a TED is considered to be any modification to a shrimp trawl aimed at reducing the capture of turtles, there are consequently several designs. Much of the original TED design work was undertaken by the NMFS in the Gulf of Mexico Fishery, starting in the mid-1970s. In 1980, John Watson of NMFS introduced the first prototype TED and, in 1983, NMFS started a formal programme urging voluntary introduction of TEDs. Since that period, TED designs have evolved considerably (Watson and McVea, 1977; Watson, Mitchell and Shah 1986; Hogan, 2004).

The most common TED designs use an inclined grid to prevent large animals from entering the codend (Figure 19). The animals are guided by the grid towards an escape opening located either in the top or bottom of the codend. Smaller animals (including shrimp) pass through the bars of the grid and enter the codend. A less common TED design uses an inclined netting panel instead of a grid (Eayrs, 2005).

Gauging the effectiveness of TEDs in reducing sea turtle mortality is not straightforward. The efficiency of a TED is affected by the design, operational conditions, effectiveness of the rigging, maintenance of the device and skill of the crew. Furthermore, some turtles may die after contact with a trawl even if excluded by the TED, and many turtles survive even if captured in the trawl. Despite these difficulties, some estimates of sea turtle mortality reduction have been made for tropical fisheries in developed countries.

<sup>8</sup> Although the number of turtles killed appears large, the importance as a proportion of the populations concerned is not known.

- Studies of Australia's Northern Prawn Fishery prior to the TED requirement indicated that an average of 0.0509 and 0.0754 turtles per trawl were captured for the tiger prawn and banana prawn season, respectively. Since TEDs became mandatory in 2000, the catch of sea turtles is estimated to have decreased to 0.0072 and 0.0092 for the two seasons (Robins *et al.*, 2002).
- In the United States, in order to be approved by NMFS, a TED design must prove to be 97 percent effective in excluding sea turtles during testing based upon specific testing protocols (Federal Register, 2004). Some studies, however, have suggested that the actual exclusion is considerably less, especially for larger turtles.

TEDs also have costs – mostly because they inadvertently reduce the capture of the target shrimp. The most common causes of shrimp loss are grid blockage and delayed exclusion of large animals from the trawl (Eayrs, 2005b). The actual reduction is hotly debated. Cascorbi (2004b) reviews the situation in the warm-water shrimp trawl fisheries of the United States and reports that some fishers claim that TEDs reduce the shrimp catch by as much as 30 percent, although federal government tests indicate an average of 10 percent. Samonte-Tan (2000) assumes that shrimp loss from TED use is 14 percent and calculates that it costs shrimp trawl fishers in the Gulf of Mexico US\$37.2 million annually.

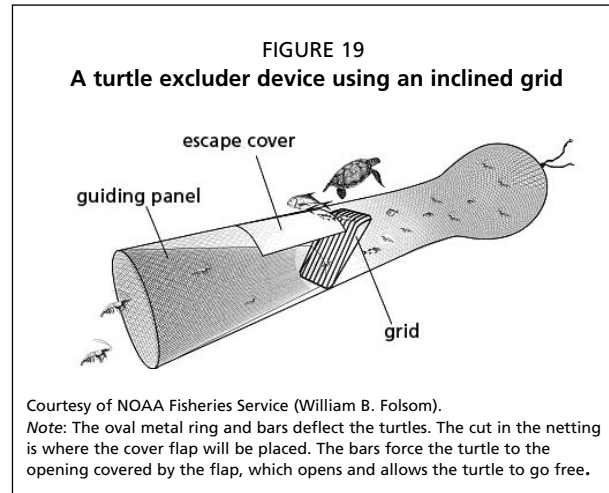
There can be a number of advantages in using TEDs, which can offset costs, particularly where they have been modified to exclude large animals including sharks, rays and other large bycatch species and fish (Eayrs, Buxton and McDonald, 1997). These include:

- ability for gear to stay longer on the bottom, decreasing the time wasted during sorting and hauling;
- possible reduction of damage to the net caused by large animals;
- quicker sorting time;
- reduced injuries to the crew from dangerous animals; and
- higher quality of shrimp catch.

The means to reduce turtle mortality by shrimp trawling are well known, but come with a price. Justification for the extra costs is probably better understood by fishers in developed countries than in small-scale fisheries of the developing world. During periods of low profitability such as the present (Chapter 8), all shrimp fishers, regardless of location, are more likely to be critical of factors affecting their income.

### *Trash fish*

Discards in the small-scale shrimp fisheries of most tropical developing countries are low or negligible. As indicated in the first part of this chapter, it is often difficult to distinguish between target species and bycatch in multispecies, small-scale and large-scale fisheries (e.g. non-specialized trawl fisheries) that catch shrimp. The low-value catch, which is sometimes a target (e.g. by small Cambodian trawlers) is often referred to as “trash fish”. The term has recently been defined as *fish that have a low commercial value by virtue of their low quality, small size or low consumer preference. They are either used for human consumption (often processed or preserved) or used for livestock/fish, either directly or through reduction to fishmeal/oil* (Funge-Smith, Lindebo and Staples, 2005). Although the improved use of trash fish reduces discards, in turn



reducing the ethical issue of waste, some other issues arise in trash fish-producing fisheries, including shrimp fisheries.

- *Direct versus indirect human consumption.* Trash fish is increasingly used directly for human food in many countries, as discussed above. It is also increasingly used indirectly for human food through aquaculture and other animal feeds, either in fresh form or after reduction to fishmeal. Key issues behind this competition are the loss of yield for human consumption because of the low conversion rate of fish to human food through culture and the diversion of trash fish food from poor customers in producing countries to rich aquaculture species consumers in the developed world. The effect of this transfer is not known
- *Sustainability of the current system.* The high risk stemming from landings that are usually not properly registered, leading to unknown removals of non-identified species has already been stressed above, particularly the risk of growth overfishing through harvesting of juveniles of commercial species.
- *Processing performance.* The amount of fish that becomes trash as a result of poor handling and post-harvest strategies is an ongoing issue.

The management of trash fish in capture fisheries is a significant challenge in Southeast Asia, even compared with that of managing other types of fisheries. Trash fish generally comes from non-target (multi-target) fisheries, using relatively unselective gear. The landings are particularly difficult to monitor since they are often far from major landing sites. There is a strong demand for trash fish that is also changing rapidly as markets evolve. These market drivers are also occurring on a local scale, which is difficult to monitor or influence (WorldFish, 2005).

A critical issue is that the increasing demand for trash fish in some regions of the world creates economic incentives for bycatch increases, rather than bycatch reduction. If shrimpers would “unspecialize”, returning to the pre-shrimping original function of multispecies fishing boats, with multiple targets and reduced discarding, the specific bycatch/discard problem would become less acute. In addition, it would be subsumed under the general (and not easier) issue of exploitation and management of multispecies resources in data-poor situations. This is in fact happening in many developing countries where, because of higher demands for human consumption and other uses, shrimp fishery discards are now close to zero.

### **Cold-water shrimp trawl bycatch issues**

In general, bycatch problems are less severe in cold-water shrimp trawl fisheries than in those of the tropics. Although the cold-water fisheries can also produce large amounts of bycatch, efforts to promote bycatch reduction and utilization have enjoyed considerable success. The shrimp trawl fisheries of the northeast Atlantic are sometimes cited as positive examples of what can be done in bycatch reduction. Roberts (2005) reviews the bycatch situation in North American shrimp fisheries.

*All the major trawl fisheries for cold-water shrimp in the United States and Canada have plans in place to reduce bycatch. Both countries' northern shrimp fisheries have mandatory Nordmore grate requirements. The Oregon and Washington pink shrimp fisheries have mandatory grate or soft BRD requirements. These and other measures such as seasonal closures and trawl modifications have reduced bycatch to less than 5 percent of the total catch, and so are deemed effective.*

Another important feature is that the capture of sea turtles is not a major issue in the shrimp fisheries of temperate regions. In reviewing the issue in North America, Roberts (2005) indicates that no sea turtles have been caught in cold-water shrimp fisheries in Canada or the United States. With respect to restrictions placed on imports of shrimp into the United States, the Government has certified that 16 nations have shrimp fisheries only in cold waters, where the risk of taking sea turtles is negligible: Argentina, Belgium, Canada, Chile, Denmark, Finland, Germany, Iceland, Ireland,

the Netherlands, New Zealand, Norway, the Russian Federation, Sweden, the United Kingdom and Uruguay.

One of the most important bycatch issues in the cold-water shrimp trawl fisheries is the effect on non-target commercial species. In the North Atlantic, the use of the Nordmøre grid has had a major effect on reducing the quantities of bycatch of the important cod, haddock, Greenland halibut and redfish. The grid is not very effective at reducing the capture of small individuals, however, and significant numbers of the young of these commercially important species are vulnerable to capture by shrimp trawls. In many cases, the management strategy to address this problem has been to close areas when and where such small fish occur. A similar issue relates to the capture of small-size individuals of the target shrimp species.

Estimating the quantities of bycatch is an important issue in some fisheries, especially those that involve fishers from more than one country. Compatible bycatch estimation and verification techniques are required if results are to be meaningful. In 2006, Russian and Norwegian fishery scientists continued to work on developing a common methodology for determining quantities of bycatch and discards in the shrimp fishery of the Barents Sea (IMR, 2007). Much of the work of fishery observers on board cold-water shrimp trawl vessels consists in estimating bycatch levels.

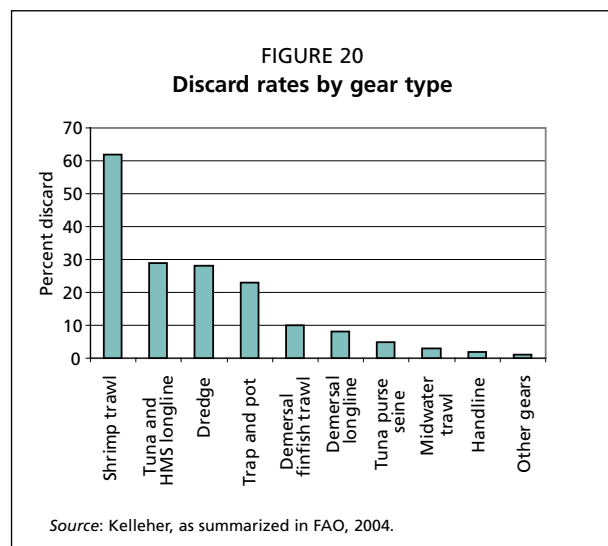
Kelleher (2005) states that a number of countries that participate in cold-water shrimp fisheries of the North Atlantic pursue a “no discards” policy, which is one of the factors responsible for relatively low discard rates in the major fisheries of the region. The Norwegian discards ban, discussed in Part 2, means that when commercially important species are captured as bycatch and as juveniles of the target species, the catch must be taken ashore and deducted from the total allowable catch of the concerned species. The “discard ban” does not mean that Norwegian fisheries, including the shrimp fisheries, discard unwanted fish, but rather, stipulates that important species are not to be discarded.

### THE FAO DISCARDS STUDY

Bycatch that is discarded results in waste of ecological and economic resources and, as such, is especially troublesome. In a major study, Kelleher (2005) estimates the quantity of discards in the world’s marine fisheries from 1992 to 2001. Kelleher’s results indicate that the shrimp trawl fisheries, and tropical shrimp trawl fisheries in particular, are the single greatest source of discards, accounting for 27.3 percent (1.86 million tonnes) of estimated total discards. The aggregate or weighted discard rate for all shrimp trawl fisheries is 62.3 percent and is very high compared with other fisheries (Figure 20).

Kelleher indicates that shrimp trawl fisheries have consistently high discard rates because of a range of factors.

- Shrimp is often less than 20 percent of the demersal biomass on many shrimp fishing grounds.
- The relatively small mesh size required to capture shrimp inevitably results in large quantities of bycatch.
- Vessels are designed for shrimp retention and have limited freezing and hold capacity for bycatch.
- Transshipment at sea is often discouraged by vessel owners, or prohibited by authorities because of concerns over theft or illegal/ unrecorded transshipment.



- Shrimp grounds are often at a considerable distance from the markets for bycatch, rendering its retention and transport to market uneconomical.
- Bycatch species are often of small size and their relatively low value makes bycatch retention uneconomical;
- Enforcement of regulations on minimum landings of bycatch and on discard reduction may be deficient.

The tropical shallow-water shrimp fisheries account for 70 percent of total estimated discards from shrimp trawl fisheries. Almost all of these fisheries target penaeid shrimp and have an average discard rate of 55.8 percent. Three countries, China, India and Thailand, all with low or negligible discard rates, account for over half of the penaeid shrimp catch. Most shrimp trawl fisheries in South and Southeast Asia have insignificant discards, with the notable exception of the Arafura Sea Shrimp Fishery. The latter, as well as the fisheries in the Gulf of Mexico, United States Atlantic, Ecuador and on the Guiana shelf, accounts for a large proportion of the discards from tropical shrimp fisheries. Several smaller shrimp fisheries have discard rates in excess of 80 percent: those of Kuwait, French Guiana, Panama and Suriname.

The cold-water shrimp trawl fisheries exhibit an even greater variety than tropical shrimp in terms of fishing gears, fishing depths and substrates. In aggregate, they have a weighted discard rate of 39 percent and contribute approximately 220 000 tonnes to the global discard estimate. The highest recorded discards occur in the fishery of Peru (74 000 tonnes with a discard rate of 81 percent). The fisheries for Pandalidae (*Pandalus*, *Heterocarpus* sp.) concentrated in the North Atlantic (Canada, Norway, Iceland) account for approximately 13 000 tonnes of discards. The mandatory use of Nordmøre grids and other BRDs in most of these fisheries results in a relatively low discard rate (weighted discard rate of 5.4 percent).

Kelleher indicates that a complex of biological, economic and regulatory factors determine fishers decisions to discard. These factors are generally specific to each fishery and the decision to discard may vary according to fishing trip, fishing operation, season or fisher. Consequently, discard information has a high level of inherent variability, often requiring extensive discard sampling to generate accurate assessments of quantities.

### BYCATCH SPECIES

In the subtropical and tropical regions of the world, the bycatch from shrimp fisheries includes a large number of finfish species characteristic of warm-water tropical fauna, such as: small jacks (Carangidae), pompanos (Carangidae), goatfishes (Mullidae), lizardfishes (Synodontidae), mojarras (Gerridae), threadfins (Nemipteridae and Polynemidae), tooth ponies (Leiognathidae), flounders (Bothidae), rays (Dasayatidae), sea trouts and croakers (Sciaenidae), catfish (Siluridae), snappers (Lutjanidae), lizardfish (Sauridae), scads (Decapterridae), tonguesoles (Cynoglossidae), grunts (Pomadasidae), barracudas (Sphyrenidae), squids and cuttlefish (cephalopods), as well as hairtails, ribbon fish, sardines, anchovies, shads and groupers. Discards are mostly made up of species maturing at sizes under 20 cm and weighing less than 100 g (Villegas and Dragovitch, 1984; Van Zalinge, 1984; Clay, 1996).

A substantial amount of invertebrate species is also taken by shrimp trawls. In Australia's Northern Prawn Fishery, 234 species of invertebrates have been noted in the bycatch; other crustaceans make up 4–5 percent of all bycatch and cephalopods about 1–2 percent (NORMAC, 2002). In Indonesia's Arafura Sea Shrimp Trawl Fishery, research from 1990 to 1998 showed that organisms other than shrimp or fish represented from 3 to 6 percent of the total catch (ICES/FAO, 2005).

The bycatch species composition is very different in cold-water shrimp fisheries. For example, in the Canadian Northern Shrimp Trawl Fishery, Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes* spp.) and



Greenland halibut (*Rheinhardtius hippoglossoides*) account for 90 percent of the bycatch (Koeller *et al.*, 2000). In a non-trawl fishery, the Southeast Alaska Pot Fishery for spot prawns and coonstripe shrimp, invertebrates – mainly squat lobster (*Munida quadrispina*) – and several species of crab, molluscs and echinoderms made up over 90 percent of the bycatch (Roberts, 2005).

An important bycatch issue in both warm- and cold-water-shrimp trawl fisheries is the catch of juveniles of important commercial fish species. Several fisheries are involved, for example: the bycatch of cod off Norway; rockfish off Oregon; red snapper and Atlantic croaker in the Gulf of Mexico; king mackerel, Spanish mackerel and weakfish off the southeast United States and plaice, whiting, cod and sole in the southern North Sea. This is a very important driver of management interventions related to shrimp bycatch.

### INTERNATIONAL INITIATIVES TO REDUCE BYCATCH

Several international efforts are currently under way to reduce shrimp trawl bycatch. These include assistance from international organizations, trade requirements and international legal instruments. All three types of initiatives are applicable to the bycatch of warm-water shrimp fisheries, while the international legal instruments are relevant to cold-water shrimp fisheries.

Starting in 2002, FAO implemented a five-year global project: the United Nations Environment Programme (UNEP)/Global Environment Facility (GEF) project *Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management*. This project, funded by GEF, concentrates on four main tropical regions. Eleven countries and one regional organization participated fully in the project: Cameroon, Colombia, Costa Rica, Cuba, Indonesia, Islamic Republic of Iran, Mexico, Nigeria, Philippines, Trinidad and Tobago, the Bolivarian Republic of Venezuela and the Southeast Asian Fisheries Development Centre (SEAFDEC). The overall objectives of the project are to reduce bycatch taken by shrimp trawlers, reduce capture of juvenile fish, particularly of species used for human consumption, and increase knowledge of the impact of shrimp trawling on marine habitat. The project was reviewed in late 2006. Box 11 gives some of the important findings of the review.

Another international initiative to reduce trawl bycatch (partially supported by the GEF project) is being carried out by SEAFDEC, an intergovernmental body established to promote fisheries development in Southeast Asia. Current members are Brunei Darussalam, Cambodia, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam. SEAFDEC started work on BRDs in 1996 and has been involved in developing the Thai turtle-free device and four types of juvenile and trash excluder devices (JTEDs) for shrimp trawls: the rectangular shaped, the circular shaped, the rigid sorting grid and the semi-curved rigid sorting grid JTEDs. The development and testing of the devices have continued in collaboration with the GEF project, including support to the Philippines and Indonesia with practical demonstrations and sea trials and experiments. Several collaborative workshops and training events have also been organized jointly by SEAFDEC and the GEF project. SEAFDEC's efforts have been especially valuable in the development and production of promotional and information material on bycatch reduction (Westlund, 2006).

Because of its broad geographic scope, the United States unilateral policy with regard to the use of turtle excluder devices (see Chapter 6, section *Warm-water shrimp trawl bycatch issues*) could be considered a bycatch reduction initiative that is international in its impact. Thirteen countries meet the United States TED requirements and 24 countries and one economy are certified as having fishing environments that do not pose a danger to sea turtles.

## BOX 11

**Major findings of the mid-term review of the UNEP/GEF project on *Reduction of Environmental Impacts from Tropical Shrimp Trawling***

Substantial results have been produced with regard to data collection, and testing and demonstration of BRDs and improved gear. Outputs produced to date include:

- tests on BRDs and decision on what devices should be promoted/recommended for regulations completed for some fisheries (e.g. in Calbayog in the Philippines, Colombia, Pacific coast of Mexico, etc.) and trials well under way in most other countries. Probable bycatch reductions are estimated at around 30-40 percent;
- revised or new legislation adopted in Nigeria and Mexico; work started on legal reviews in others; recertification of Nigeria for shrimp exports to the United States through the reintroduction of TEDs;
- recognition of the need for a reinforced, wider fisheries management approach, including, for example, effort controls through closed seasons/areas and limits on number of trawlers;
- extensive technical regional and global collaboration established, cooperation initialized and steps taken towards harmonization of bycatch reduction at the subregional level (Nigeria/Cameroon/Gulf of Guinea countries, Mexico/Latin America and the Caribbean, SEAFDEC/Southeast Asia);
- knowledge of bycatch composition and quantities, and improved information collected on the socio-economic role of bycatches (Nigeria, and Trinidad and Tobago);
- cooperation between governments (officials and researchers) and the shrimp trawl industry/private sector established or strengthened in countries where it existed pre-project;
- awareness of the importance and usefulness of BRDs and the knowledge of possible technical solutions enhanced among relevant national institutions and administrations, as well as within the fishing industry;
- an FAO manual/guide on BRDs published, *A guide to bycatch reduction in tropical shrimp-trawl fisheries* (Eayrs, 2005); training materials on juvenile and trash fish excluder devices developed by SEAFDEC; and project Web site set up.

Source: Westlund, 2006.

Several international legal instruments and agreements also focus on bycatch in general (Box 12).

## **BIOLOGICAL RESEARCH ON BYCATCH**

### **Warm-water shrimp fisheries**

In order of increasing complexity, biological research on shrimp bycatch has consisted of determining bycatch quantities, species composition, impacts on the bycatch species and impacts on the ecosystem.

In shrimp fisheries in tropical developing countries, bycatch research is most often limited to estimating bycatch quantities. Although Kelleher (2005) asserts that “on-board observer reports are considered indispensable for accurate estimation of discards”, not many tropical developing countries have comprehensive observer programmes on shrimp vessels, and there are few, if any, such programmes on small trawlers. The bycatch research situation in many developing countries is in the same category as Bangladesh where ICES/FAO (2005) state: *There has not been much research so far on shrimp fisheries in general and on shrimp trawling in particular. Valid*

## BOX 12

**Global attempts to reduce discards**

*The United Nations General Assembly Resolution 49/118 (1994)* concerns fisheries bycatch and discards, and their impact on the sustainable use of the world's living resources. In this resolution, the United Nations promotes the issue of bycatch and discard reduction in FAO's development of a Code of Conduct for Responsible Fisheries and suggests its inclusion in the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. It also urges regional fisheries organizations to review and, where possible, address specific jurisdictional issues in bycatch and discard reduction.

*The United Nations Fish Stocks Agreement* states that signatories should "...minimize pollution, waste, discards, catch by lost or abandoned gear, catch of non-target species ... and impacts on associated or dependent species ... through measures including, to the extent practicable, the development and use of selective, environmentally safe and cost-effective fishing gear and techniques".

*The Kyoto Conference on Sustainable Contribution of Fisheries to Food Security* in 1995 produced a declaration intended to "promote fisheries through research and development aimed at [...] (iii) reduction of discard mortality; (iv) development and use of selective, environmentally safe and cost effective fishing gear and techniques".

The FAO Code of Conduct for Responsible Fisheries, Article 7.6.9 addresses bycatch and discards.

*States should take appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular endangered species. Where appropriate, such measures may include technical measures related to fish size, mesh size or gear, discards, closed seasons and areas and zones reserved for selected fisheries, particularly artisanal fisheries.*

Source: Poseidon, 2003.

*scientific information in this regard is still lacking. No estimate of the type and amount of bycatch has ever been made.*

Shrimp bycatch studies appear to be most advanced in Australia; certainly the country has the most sophisticated research involving bycatch for tropical shrimp fisheries. Two Australian studies are especially relevant and can provide an indication of what has been achieved in shrimp bycatch research.

***Environmental effects of prawn trawling in the far northern section of the Great Barrier Reef: 1991–96.*** This was undertaken by the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Queensland Department of Primary Industries and Fisheries (QDPI) on the environmental effects of trawling in a 10 000 km<sup>2</sup> area closed to fishing in the northern Great Barrier Reef region. The report of the study had many conclusions related to bycatch, some of which are summarized by CSIRO (1998).

- *Fish.* A total of 243 species of fish were captured in prawn trawls. These trawls mainly capture small species of fish that are associated with the seabed. Many larger species of epibenthic and pelagic fish are not taken, so prawn trawls impact on only part of the fish community. Although recreationally and commercially important species of fish occur in the study areas, prawn trawls seldom catch juveniles or adults of these species. There is little overlap, therefore, between recreational or commercial line fisheries and prawn trawl fisheries in this part of

the Great Barrier Reef. The results suggest that for species that can be captured by a prawn trawl, with the exception of two species (*Diagramma pictum* and *Scolopsis taeniopterus*), all size/age stages are vulnerable. The extent of the impact of prawn trawling on fish populations is probably low, given the generally low fishing effort in the study area.

- *Birds.* The only species of seabird apparently affected by feeding on discards is the crested tern. Populations of this species have increased by two orders of magnitude over the time of the trawl fishery. This increase may have been the result of greater availability of discards for young birds.

*Ecological sustainability of bycatch and biodiversity in Prawn Trawl Fisheries: 1996–99.* This was undertaken by CSIRO and QDPI for Australia's Northern Prawn Fishery, the Torres Strait Prawn Fishery and the Queensland Banana Prawn Fishery. The Northern Prawn Fishery Management Advisory Committee (NORMAC, 2002) gives the main results.

- *Species vulnerability.* Since the 1980s, 411 fish species have been recorded in the Northern Prawn Fishery (NPF) bycatch. The species ranked as least likely to be sustainable, and therefore the priority for management, monitoring and research, were highly susceptible to trawls. They are benthic or demersal, their main habitat is soft sediments and their diet may include prawns. Their recovery capacity is low. In applying this process, important gaps in current knowledge of bycatch species have been highlighted, but the ranking must be used with caution. Future research should be aimed at developing a greater understanding of the biology of these species and their distribution in the region of the fishery. The biology of elasmobranchs makes them more susceptible to overfishing than bony fishes because they are long lived, slow growing, reach maturity at a later age and have few young. Fifty-six species of elasmobranchs have been recorded in the bycatch of the NPF. Most are dead when landed on deck (56 percent), and survival is lower for smaller individuals. Most elasmobranchs caught by trawlers are small and would fit through TEDs. The biology of sea snakes also makes them more susceptible to overfishing than bony fishes. The fishing mortality of the 13 species of snakes in the NPF bycatch is about 49 percent. TEDs and BRDs appear to be effective in reducing sea snake catch.
- *Effects on fish bycatch.* The vertebrate bycatch community was compared between areas open to trawling and areas that have been protected for 15 years, in the western Gulf of Carpentaria. If trawling had a large impact on biodiversity, there would be fewer species, lower catch rates and smaller individuals in the open areas. This was not the case; there was no consistent difference in the number of species between open and closed areas or in catch rates between these areas. In general, the mean size of species was greater in the open areas. Although the results were equivocal with regard to the impact of trawling on biodiversity, this does not imply that trawling has no impact. Any differences between open and closed areas may be reduced by the low commercial effort in the open area, aggregated trawling, potential trawling in the closure and the mobility of species. This, combined with high natural variation, may obscure any trawling impacts.
- *Future research and monitoring.* The high diversity of the bycatch of these tropical prawn fisheries and the fact that most species are rare mean that managing the sustainability of the bycatch is a significant challenge. There are clearly some species that are more susceptible to trawling and are unlikely to recover if depleted; these species are the least likely to be sustainable. Consequently, future research and management should concentrate on them. A monitoring programme will be critical to assess whether the bycatch mortality is sustainable or not.

Poiner *et al.* (1998) indicate important areas for future shrimp trawl bycatch research. They indicate that the priorities should be to document the recovery of seabed fauna after depletion, examine ways to assess sustainability of the harvest of bycatch species, and measure the recruitment, growth, mortality and reproduction of structurally dominant large seabed organisms.

### Cold-water shrimp fisheries

There is a significant amount of research on bycatch for cold-water shrimp fisheries. Poseidon (2003) indicates that from 1994 to 1998 the EU alone funded 50 studies related to discards, bycatch and selectivity as part of its Biological Studies Programme, and 14 projects (at a combined cost of €11.2 million) as part of its Programme of Research and Technological Development; many of these involved European shrimp fisheries. The considerable bycatch research cooperation of Denmark, the Faeroe Islands, Greenland, Iceland, Norway and Sweden has been facilitated by the Nordic Council of Ministers. A substantial amount of shrimp bycatch research is also being carried out in Canada and the United States.

Two types of biological research on the bycatch of cold-water shrimp fisheries are especially important: studies on the effects on commercially important fish and studies on the dynamics between target and bycatch species.

Recent research has provided some insight on the effects that taking bycatch will have on other commercially important fish. Graham, Polet and Revill (2005) indicate that numbers of discarded fish may have little meaning unless they are suitably modelled in order to determine their detrimental effects upon the affected stocks; a high discard rate of very young fish may not be problematic if most would die from natural mortality. Revill *et al.* (1999) estimated that a complete reduction of bycatch in the Crangon Beam Trawl Fishery of the southern North Sea may result in an additional 2 000 tonnes of cod, 1 500 tonnes of whiting, 12 000 tonnes of plaice and 600 tonnes of sole being landed annually by North Sea whitefish fishers.

### BYCATCH REDUCTION DEVICES

The large amount of bycatch generated by shrimp trawl fisheries has resulted in worldwide attention. Various programmes and mechanisms have been introduced to reduce the unwanted and wasted portion of the catch.

Although bycatch issues can be quite different with regard to warm- and cold-water shrimp trawl fisheries, many devices to reduce bycatch are shared between the two. Developments in one group have had impacts on the other, especially those of cold-water on warm-water shrimp trawl fisheries. In general, BRDs in the latter are required to deal with a more heterogeneous group of animals than those of cold-water fisheries and, consequently, there is a greater variety of devices.

Broadhurst (2000) reviews the evolution of bycatch reduction through technological changes to trawl gear. Innovation in bycatch reduction is examined in 47 prawn trawl fisheries around the world, starting with the efforts in cold-water European shrimp trawl fisheries in the mid-1960s. The Broadhurst study indicates that, despite the wide variety of BRDs, most can be classified under the following two broad categories.

- *BRDs that separate species by behaviour.* These BRDs operate by exploiting behavioural differences between shrimp and fish, using strategically placed funnels, horizontal and/or vertical panels and escape windows. They take advantage of the principle that fish, unlike slow-moving benthic invertebrates, have certain characteristic responses to towed trawls.
- *BRDs that separate species by size.* These BRDs use relatively simple oblique panels or grids, usually located within or immediately forward of the codend. Such features tend to partition the catch mechanically, according to size, and exclude individuals that are larger than the openings in the panels/grids. TEDs (see section above, *Warm-water shrimp trawl bycatch issues*) are in this category.

## BOX 13

**The Nordmøre grid**

The Nordmøre grid is the most widespread gear-related technical measure used in the North Atlantic Shrimp Fishery to reduce bycatch. The concept came from a shrimp fisherman, Paul Brattøy, who lived in the Nordmøre area of Norway, hence the name. He developed the grid, which had comparatively large bar spacing initially used to exclude the bycatch jellyfish often found in shrimp grounds.

In 1989, after a few months of testing and modification, the Nordmøre grid was introduced to the shrimp fishery. Fishing grounds that were closed because of high bycatch of juvenile cod and haddock were opened for shrimp trawling when a grid was installed in the trawl. Fishers were at first reluctant to use the device, but when a few skilled shrimpers proved that they managed both to handle the grid and to access shrimp grounds yielding extremely good catches, the grid was a success. Soon a large proportion of the coastal fleet used the grid voluntarily.

Following the success of this device, a series of formal experiments was undertaken in Norway, with a grid system having narrower bar spacing (19 mm). The research demonstrated considerable reductions in the bycatches of cod, haddock, redfish, Greenland halibut and polar cod with a minimum loss of shrimp (approximately 5 percent). In 1991, Canadian researchers tested grid technology on the Gulf of St Lawrence Fishery. A number of vessels were fitted with 19-mm Nordmøre grids with retaining bags fitted to the escape opening; the catch retained was used to estimate the quantity of bycatch escaping from the trawl as well as monitor potential shrimp loss. On average, the reduction of bycatch was 97 percent, with only a 2 percent loss of shrimp. Other experiments in the Eastern Scotian Shelf showed bycatch reductions of 97, 100, 95 and 100 percent for plaice, cod, redfish and haddock, respectively (Graham, 2005; Isaksen, 1997).

The Nordmøre grid, a BRD that separates species by size, is very important in the North Atlantic Shrimp Fishery and in several other fisheries. Box 13 describes the development of this gear.

A great deal of work has been done to improve the efficiency of BRDs with regard to excluding bycatch and minimizing impact on the target shrimp. It is generally acknowledged that, because of the large diversity in shrimp trawl fisheries, no particular design is appropriate for all fisheries, but rather, the most effective design for a fishery depends largely on the characteristics of that fishery. Broadhurst (2000) indicates that important factors to consider include size of trawls, location of use, handling of gear, species to be excluded and regulations governing the fishery. Considerable testing and adjustment are often required to arrive at a suitable design for a particular fishery.

The Nordmøre grid remains the most important BRD in cold-water shrimp fisheries. In 2005, regarding warm-water fisheries, FAO produced a manual on reducing bycatch in tropical shrimp trawl fisheries. The guidebook (Eayrs, 2005) was designed for fishers, net makers and fishing technologists, as well as fishery managers and policy-makers interested in a practical guide to the design, use and operation of BRDs. Some of the most important devices and modifications in the guidebook are given in Box 14.

An important aspect of BRDs is the fate of the excluded animals. If they suffer high mortality as a result of their contact with the BRD and/or fishing gear, then the bycatch reduction may not produce the desired benefits. Eayrs (2005) states that, with few exceptions, there has been little work in tropical shrimp trawl fisheries to assess the survival of fish that have escaped from a BRD. An FAO study of the mortality of fish

## BOX 14

**Devices and modifications to reduce bycatch**

*BRD.* A “bycatch reduction device” is any modification designed principally to exclude fish bycatch from a shrimp trawl. These devices may also exclude other animals and non-living material, but because fish usually dominate the bycatch, most research has attempted to exclude these animals from the trawl. Most BRDs are located in the codend of the trawl since this is where the catch is accumulated and the opportunity to escape is high.

*TED.* A “turtle excluder device” is any modification to a shrimp trawl designed to reduce the capture of turtles. These devices are sometimes called “trawl efficiency devices” because they can also prevent the capture of other large animals including sharks, stingrays, jellyfish and some large fish. The most common TED designs use an inclined grid to prevent large animals from entering the codend (Figure 19).

*JTED.* A “juvenile and trash excluder device” is designed to exclude small fish – usually juvenile or trash fish – from the trawl and maintain the catch of shrimp and large fish. The JTED was designed by SEAFDEC and has been tested in shrimp fisheries in several Southeast Asian countries.

A *square-mesh codend* is constructed entirely from square-mesh netting, which can allow a substantial amount of small fish and other bycatch to escape. This is because square-mesh netting stays open for the duration of the tow, unlike diamond-mesh netting, which closes under the weight of the catch.

A *square-mesh window* is usually a panel of square-mesh netting located in the top panel of the codend or trawl body. As fish pass through the trawl, they move towards the device and swim through the square escape openings. The selection of mesh size is vital, and trial and error are needed to find the mesh size that maximizes fish exclusion and prevents shrimp loss. Like the fisheye, the size and location of the square-mesh window are also important. The top of the codend is the favoured position, since this reduces shrimp loss; it should not be too close to the catch in the codend or shrimp will be lost (Figure 21).

A *fisheye* is an elliptical steel or aluminium frame fitted to the codend through which fish swim to escape. Fisheyes are usually placed in the top or sides of the codend so that only strong swimming fish can escape, while shrimp passively enters it (Figure 21).

A *fishbox* is designed to alter the movement of water in the codend. It is a box-like device fitted to the top of the codend with an opening through which fish can swim and escape. A metal plate or foil generates water turbulence adjacent to the escape opening, and many fish species actively seek this region because swimming is easier. Fish then move from there out of the trawl.

*Other modifications to reduce bycatch.* A range of simple rigging modifications to the trawl may be used to reduce the capture of bycatch. These modifications include a triangular or diamond-shaped cut in the top of the codend, changes to the ground chain settings, longer sweeps between the otter board and trawl,<sup>1</sup> headline height reduction, a length of twine stretched between the otter boards to frighten fish away from the trawl, a large mesh barrier across the trawl mouth and large cuts in the top panel of the net ahead of the codend.

Source: Eayrs, 2005.

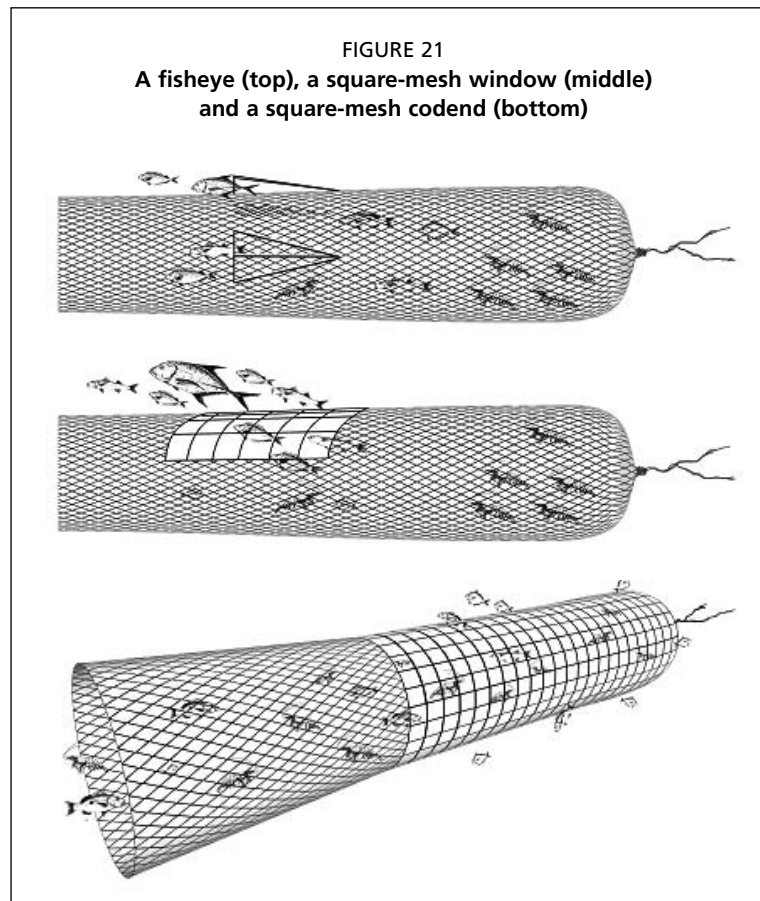
<sup>1</sup> This can be used to reduce the capture of small sea urchins, other benthic animals and seabed debris, although it may sometimes increase fish catches.

escaping trawl gears (Suuronen, 2005) makes the following observations on improving the survival of escapees.

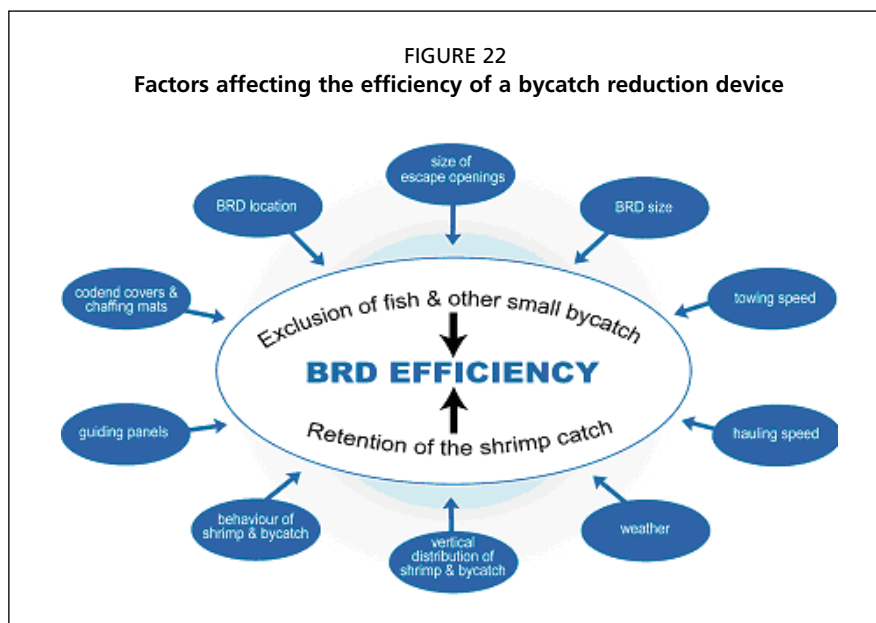
*First, fish that escape from a fishing gear should do so quickly and, in the case of towed gears, should not enter into the aft part of the codend, where the risk of serious injury is greatest. Installing escape panels or other sorting devices at strategic positions in a fishing gear can enhance escape and the survival of juveniles and non-target species. Furthermore, facilitating the voluntary escape of fish through various constructional and operational solutions would increase the likelihood of their survival. The use of non-abrasive netting materials, the exclusion of debris and large objects from codends, and better design, operations and rigging of nets could improve survival.*

Hill and Wassenberg (1990) studied the fate of teleosts, non-commercial crustaceans and cephalopods discarded from trawlers in Australia's Torres Strait. These groups make up about 80 percent of discards by weight, have a high mortality rate and are therefore the most likely animals to be eaten by scavengers. The remaining 20 percent of discards consists of animals such as turtles, sharks, bivalves and sponges, which are caught in low numbers and appear to have a low mortality from trawling. Fish make up 78 percent, non-commercial crustaceans 18 percent and cephalopods 3 percent, by weight of the material studied. Nearly all fish were dead when discarded, and about half sank. Approximately half of the non-commercial crustaceans were alive when discarded, and all sank. Few cephalopods (2 percent) were alive when discarded, and about 75 percent sank.

The use of BRD devices, as with the more specialized TEDS (described in the section above, *Warm-water shrimp trawl bycatch issues*), is not without costs. Expenditure must be made for the devices themselves and there is at least some loss of target shrimp. In many small-scale shrimp trawl fisheries, the reduction of bycatch is relatively more expensive because of the practice of selling the available bycatch.







### EFFECTIVENESS OF BYCATCH REDUCTION EFFORTS

Numerous factors affect the efficiency of a BRD, many of which are shown in Figure 22 (Eayrs, 2005).

Despite their considerable differences, almost all BRDs reduce bycatch when deployed in the environment for which they are developed. The reductions achieved in various fisheries are well-documented, as shown by the following authors.

- Graham (2005) states that the widespread use of Nordmøre grids in the Northern Shrimp Fisheries of the North Atlantic has resulted in large-scale reductions in the levels of bycatch that typified the fisheries in earlier years.
- Parsons *et al.* (1998) acknowledge the reduction in bycatch by the mandatory use of sorting grids in the North Atlantic, but indicate that the capture of small fish (which pass through the bar spacings) is still problematic and that it is difficult to assess the efficacy of the grids in reducing the bycatch of these fish.
- Cartwright (2003) indicates that TEDs and BRDs have reduced the turtle bycatch by up to 99 percent, bycatch of small fish by 8 percent and sea snakes by 12 percent in Australia's NPF. This has occurred at the cost of a loss of prawn catches of around 6 percent.
- Harrington, Myers and Rosenberg (2005) cite three different studies on the effectiveness of BRDs in reducing the finfish catch in the Gulf of Mexico shrimp trawl fisheries; the devices reduced the catch of finfish by 43 percent, 45 percent and 16.5 percent.

The above examples of bycatch reductions come from relatively large-scale fisheries and reflect the situation around the world, i.e. the most successful examples of bycatch reduction are from large-scale fisheries. This observation is consistent with that of Kelleher (2005) who studied the global discard situation and commented on shrimp bycatch reduction.

*Bycatch reduction devices are used in a wide range of shrimp fisheries with apparent discard reductions in Pandalus fisheries (0.2–29 percent discards), less impact in other cold-water fisheries for Nephrops and other species (44–50 percent discards), and even less impact in tropical fisheries (67–89 percent discards). The low impact in some tropical fisheries may be due to poor enforcement of BRD regulations, as experimental results clearly indicate significant reductions in unwanted bycatch. Reduction in discards in developing countries is more likely to arise from increased utilization of bycatch, rather than reduction of bycatch. Many shrimp trawl fisheries in developing countries are*

*marginally profitable and any reduction in shrimp catch through the use of BRDs may result in significant economic losses.*

### BYCATCH IN NON-TRAWL SHRIMP FISHERIES

The above discussion of bycatch from shrimp fisheries is largely focused on shrimp trawling, which produces most of the bycatch. Other types of shrimp fishing produce varying amounts of bycatch, at levels generally well below those of trawl fisheries.

The stow net fishery for paste shrimp (*Acetes* sp.) in China is one of the world's largest shrimp fisheries (Chapter 3, section *Catches by shrimp species*). Liu-Xiong (1995) reviews the catch composition of the stow net fishery in several coastal provinces of China. In Fujian Province, stow nets caught 241 species, including 190 species of fish, 42 species of crustaceans and nine species of cephalopods. *Acetes* made up 19.7 percent of the catch, with the next most important components being the hairtail *Trichiurus haumela* (18.7 percent) and cods Bregmacerotidae (4.07 percent). Chen Amoa (1994) analysed the sampling results of five stow net monitoring stations in the waters of Zhejiang Province from 1987 to 1993; shrimp accounted for 44.7 percent of the catch by weight; small fish 37.4 percent; and hairtail and other economical species, 17.9 percent.

Other examples of bycatch composition in non-trawl shrimp fisheries are given by the following authors.

- Badrudin, Sumiono and Murtoyo (2001) report that tidal trap nets in Riau Province, Indonesia, catch over 40 groups of fish/invertebrates, including four groups of shrimp. The combined shrimp catch is less than 10 percent of the total, but virtually nothing is discarded.
- Roberts (2005) states that cold-water shrimp trap fisheries are generally considered to have low rates of bycatch. The bycatch rate as a percentage of target catch in the Southeast Alaska Shrimp Pot Fishery is 10 percent or lower in terms of numbers. Bycatch rates in the British Columbian and Washington Pot Fisheries also appear to be low. A study of the Californian Pot Fishery found higher levels of bycatch in terms of weight, but no tally of the number of species was carried out. In addition, bycatch in pot fisheries for cold-water shrimp generally consists of invertebrates that are released alive.

### BYCATCH MANAGEMENT

“Bycatch management” is defined as interventions to reduce bycatch in order to reduce waste and threats to vulnerable or endangered species, and make better use of bycatch, to reduce waste.

In the various shrimp fisheries, several measures have been taken to reduce bycatch, including: complete bans on trawling; bans on fishing in areas and/or periods when bycatch is known to be high; reduction of overall fishing effort; and the most common modifications of fishing gear, mainly through the use of BRDs. Other measures to reduce bycatch are bycatch quotas, discard bans and limits in the shrimp-to-bycatch ratio. Some observers feel that because most shrimp fisheries in the world are overexploited, fishing effort reduction would have the dual benefit of improving catch rates and reducing bycatch. EJF (2003b) shows that, conceptually, the means for reducing bycatch can be placed into two categories (Box 15).

An important issue is that bycatch enhancement is not always compatible with bycatch reduction; in some circumstances, the improved use of bycatch could result in greater demand and consequently more bycatch. It is important that bycatch enhancement (for improving food availability, economic efficiency, reducing waste) be compatible with sustainable use.

Several authors comment on lessons learned from successful efforts to manage bycatch in both warm- and cold-water shrimp trawl fisheries.

## BOX 15

**Concepts of reducing bycatch**

*Total bycatch = bycatch per unit effort x fishing effort.* Accordingly, in order to decrease total bycatch of shrimp fisheries, one or both of the following factors needs to be reduced:

- *bycatch per unit effort.* This can be reduced by: technological changes (e.g. installation of TEDs/BRDs); operational changes (e.g. reduction of speed and duration of trawling); training (e.g. to avoid areas of high bycatch); and management actions (e.g. setting of bycatch limits for individual vessels);
- *fishing effort.* This can be reduced by: regulatory bans (e.g. use of spatial and temporal closures); regulatory limits (e.g. use of quotas), trade-related measures (e.g. reducing fishing subsidies); consumer behaviour (e.g. establishment of ecolabelling schemes); and gear changes (e.g. use of passive fishing gear).

Source: EJF, 2003b.

*Setting targets/requirements and allowing innovation.* In Australia's NPF, an important lesson learned is that, rather than government research on bycatch reduction technology and its promotion, a better approach is for regulators to set the targets/requirements and allow industry to innovate them (I. Cartwright, Australian Fisheries Management Authority [AFMA] personal communication, January 2006). This is similar to the sentiment expressed by Harrington, Myers and Rosenberg (2005) in a recent review of United States bycatch and its reduction.

*Clearly, management programmes need to be adaptive and make continuous improvements rather than consist of fixed regulations that are not performance-based. Regulations are needed to provide incentives to reduce bycatch and disincentives to continue fishing practices with high bycatch rates.*

Robins, Campbell and McGilvray (1999) review the history of prawn bycatch reduction efforts in Australia and comment that the greatest advances in the rates that fishers adopt TEDs and BRDs have occurred after respected individuals within the fishing industry have developed or modified gear that reduces bycatch.

*The importance of follow-up evaluation.* Graham (2005) describes the process of developing effective discard mitigation measures for use in the North Sea *Crangon crangon* Fisheries: the compilation of a detailed fleet and effort inventory (1995/96); the quantification of discard levels (1996/97); the modelling of discards to determine the impacts on affected stocks (1999); the development of mitigation measures (1999/2001); the modelling of the potential benefits to the affected stocks of introducing mitigation measures; the introduction of appropriate legislation; and the undertaking of follow-up evaluation of effectiveness of technical measures and legislation. AFMA (2002) states that there are two main elements in the process of managing bycatch in Australian shrimp fisheries. First, industry needs to adopt measures to reduce the amount taken and second, the management agency will have to monitor the success of the measures.

*The importance of bycatch management plans.* In the recent FAO discards study (Kelleher, 2005) the global situation was reviewed. The study makes several recommendations, including advocating the development of bycatch management plans. Poseidon (2003) notes the importance of bycatch management plans in Australia, Japan and the United States. ICES/FAO (2005) examine bycatch management in several countries and state that one of the important lessons learned is that at the local, regional and national levels, bycatch/discard action plans should be developed for shrimp fisheries. These plans should identify objectives and goals with regard to the

## BOX 16

**Australia's checklist for developing a bycatch management plan**

The most important consideration in the development of bycatch reduction plans is that they should be developed consistently and transparently, and implemented effectively. The basic steps are the following.

- Determine the availability of data and their usefulness.
- Decide what the bycatch issue is.
- Look at all the options available (utilize, avoid or reduce).
- Decide on the way(s) to address the problem (strategies) and determine whether new ways need to be developed.
- Outline practical and effective actions to achieve the objectives of the policy.
- Review progress or evaluate the effectiveness of the programme.

*Source:* Australian Government, 2006.

use or reduction of bycatch/juveniles/trash fish, suggest strategies for achieving them, and identify key performance indicators. Box 16 gives a summary of the Australian Government's checklist for developing a bycatch management plan.

*The role of fisheries extension.* In reviewing TED/BRD requirements, Eayrs (2005) indicates that compliance rates are linked to effective extension programmes that keep fishers well informed about developments. In this way, fishers are given up-to-date information about TED/BRD regulations, as well as operational details of performance, and are able to make informed decisions on their fishing operations.

*Learning from experience.* In reviewing the many attempts to reduce shrimp bycatch, Robins, Campbell and McGilvray (1999) comment that, in hindsight, Australia has benefited greatly from overseas experiences in the development and implementation of technology that reduces fishery bycatch, thereby avoiding "reinventing the wheel".

From the fisher's perspective, the disincentives to use the most common method of reducing shrimp bycatch, BRDs, are: the expense of the device; the loss of some shrimp from using the device; the extra work in deploying and maintaining the device; and, mainly for small-scale fisheries, the loss of income or food from selling or consuming the bycatch. The main incentives for using a BRD can include: improved quality of the shrimp catch; less bycatch, enabling longer tows; concern over prosecution for non-use; concern that more restrictive regulations will be imposed; less effort needed to sort bycatch; greater fuel efficiency; and the possibility of ecocertification with its enhanced marketing opportunities. In balancing the disincentives/incentives for reducing bycatch, it can be observed that the small-scale fisheries have more disincentives (i.e. more reasons to keep their bycatch) and fewer incentives to bring in only shrimp than the larger operations.

There have been some remarkable reductions in the shrimp bycatch from large- and medium-scale shrimp fisheries. The situation appears manageable and it is likely that further reductions to bycatch levels could be made, albeit with some sacrifices by fishers. One of the main challenges at this point is to determine the acceptable levels of bycatch, considering the costs and benefits once they are reached.

The objective of reducing bycatch in many small-scale shrimp fisheries<sup>9</sup> of developing countries is particularly challenging. The food security and economic incentives do not favour bycatch reduction, and enforcement of any requirements for reduction can

<sup>9</sup> Included in "small-scale fisheries" are the very large number of "mini-trawlers" that are common in tropical developing countries.

be extremely difficult considering the large numbers of vessels and landing sites, the impracticality of placing observers on board and the expanding markets for bycatch. Some fisheries specialists feel that creating awareness of the problems caused by taking bycatch will alter the behaviour of small-scale shrimp fishers, taking them in the right direction, but others consider this to be “wishful thinking”, especially in the open access situations in which small-scale shrimp fisheries characteristically operate.

With regard to attempts at bycatch reduction in small-scale shrimp trawl fisheries, two especially relevant concepts emerged during the course of the present study.

- Much of the work on bycatch reduction in these fisheries is focused on BRD gear technology but, for reasons cited above, regulations relating to technical innovations are difficult or impossible to enforce. Furthermore, in many situations, the better the devices function (excluding valuable bycatch), the more they will be resisted.
- If enforcement is such a difficult problem for any regulations dealing with bycatch in small-scale fisheries, then management interventions that are easier to enforce should be encouraged. Accordingly, protected areas where no shrimp fishing (or no fishing of any kind) is allowed may overcome some of the chronic compliance problems. Eayrs (2005) points out additional advantages: area or seasonal closures, particularly in locations that are nursery grounds for juvenile fish and other animals, afford total protection to all bycatch while it remains within boundaries, and it is unlikely that BRDs will ever achieve a comparable level of protection.

Where reducing bycatch in small-scale shrimp fisheries is extremely difficult (and in any case, counter-intuitive when all catch is used), efforts should concentrate on using a participatory ecosystem approach to fisheries to ensure sustainability of the species mix in its ecosystem. Future bycatch reduction efforts, where justified (e.g. in high discarding practices, emblematic species, endangered species), should concentrate largely on medium- and large-scale shrimp fisheries, following an ecosystem approach to fisheries.



## 7. Fuel use in shrimp fisheries

### GENERAL

Fuel use is as central an issue in the economics and dynamics of many fisheries as it is in the production of similar food items, such as beef and poultry. With regard to food, fisheries globally dissipate 12.5 times the energy they provide in the form of edible protein energy (Tyedmers, Watson and Pauly, 2005). The issue of fuel use in fisheries has increased in prominence in recent years to the point of being covered in the FAO Code of Conduct for Responsible Fisheries, quoted below.

*States should promote the development of appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and post-harvest activities within the fisheries sector.*

Recent reviews of energy use in fisheries that have special relevance to the capture of shrimp are: Wilson (1999), Tyedmers (2004), Tyedmers, Watson and Pauly (2005), and Smith (2007).

Tyedmers (2004) indicates that energy input into fishing operations includes direct inputs, such as those used to move the vessel through the water and deploy fishing gear, as well as indirect inputs used in building vessels and providing gear, bait and ice. General points on fisheries energy inputs include the following.

- Regardless of the scale of total energy inputs to commercial fisheries, direct fuel inputs typically account for 75–90 percent of the total industrial energy<sup>10</sup> inputs to fishing.
- It is evident that the energy performance of many fisheries, and in particular those targeting species for human consumption, has deteriorated over time as abundance and catch rates have decreased and technology sophistication increased.
- Total energy use in commercial fisheries can range over three orders of magnitude. Some industrial fisheries dissipate as little as 1.5 gigajoules (GJs)<sup>11</sup> per tonne of fish landed. In contrast, fisheries for high-value species for direct human consumption commonly dissipate energy in excess of 1 000 GJs per tonne.
- Relative fuel consumption still compares favourably with other animal protein production systems. With an energy used/energy produced ration of 0.095 (about 10 percent), the fuel consumption in 29 North Atlantic fisheries appears to be about five times more efficient than beef production, 4.5 times more than lamb production, three times more than chicken production, 1.5 times more than swine production and much more efficient than most aquaculture systems (Tyedmers, 2004).

There are many sources of differences in fuel efficiency that are relevant to shrimp fisheries.

- Some species require more fuel than others to be captured. Capturing deep-sea species far offshore usually takes more fuel than for coastal penaeid shrimp.
- Some areas, with high ocean dynamics (e.g. off Somalia or Mauritania) or dangerous ecosystems (Arctic, Antarctic), will require larger vessels for safety reasons and more fuel per tonne caught than, for instance, coastal areas and estuaries.

<sup>10</sup> It should be noted that fuel used for primary fish “production” usually includes catching, on-board processing, storage and transportation to concentrated landing points. This must be taken into account when making comparisons within the sector (i.e. between large- and small-scale fisheries) and between sectors (i.e. comparing with other sources of protein).

<sup>11</sup> One GJ is equal to 950 000 British thermal units.

- Smith (2007) cites another study (Institute of Fishery Technology in Trondheim, Norway), which indicates that otter trawlers used four times as much weight of fuel to catch 1 tonne of fish as local coastal gillnet and line vessels. A recent World Wide Fund for Nature (WWF) report (Binet, 2007) cites a French study that shows proportionally greater fuel costs for fishing gear that is towed. Fuel represented 24 percent of total costs for vessels over 12 m in length using towed gear, but only 11 percent for those using set gear.

The combination of these factors leads to differences in fuel efficiency among ecosystems, areas or countries. Tyedmers, Watson and Pauly (2005) state, for example, that purse seine fisheries for species such as herring and menhaden that are for reduction to fishmeal and oil typically use under 50 litres of fuel per tonne of fish landed, whereas fisheries for shrimp, tuna and swordfish frequently consume over 2 000 litres per tonne. Smith (2007) cites two studies that compare fuel usage in Malaysia and the North Sea (Table 9).

The above studies indicate that fuel use by shrimp trawling is greater than in other fisheries. Some other types of shrimp fishing are, however, much more energy-efficient. More paste shrimp (*Acetes*) is captured than any other shrimp in the world (Chapter 3, section *Catches by shrimp species*) and most of the catch is by passive fishing gear, especially stow nets in China (Chan, 1998), which are very fuel-efficient. On the other hand, the use of outboard engines in several small-scale shrimp fisheries is likely to be more fuel-intensive than industrial-scale shrimp trawling.

The fuel use by various forms of shrimp trawling can differ vastly, even in the same general area. Clay (1996) shows that offshore shrimp vessels in Texas, United States use more than ten times the amount of fuel per kg of shrimp than do inshore vessels. Where fuel consumption of a particular fishery is high, that fishery usually produces relatively valuable shrimp. In the Texas example, the offshore vessels catch large shrimp, valued at about four times that of the small inshore shrimp.

It is clear that such broad comparisons are useful if they underline an alternative way of obtaining the same benefits with less fuel. In this respect, it seems obvious that the technique used to produce menhaden fishmeal cannot be easily used for deep-sea shrimp or tuna; that swordfish and deep-sea shrimp cannot be caught with stow nets; and that inshore United States shrimpers could hardly target offshore shrimp with their fuel-efficient boats.

Krampe (2006) examines fishing fuel and gives a history of the price increase (Box 17). In summary, crude oil prices increased 400 percent from 1998 to 2005, and rose further in the first half of 2006. Smith (2007) considers the fuel price increases in 2006

TABLE 9  
Comparing fuel usage by method

Area	Fishing method	Fuel (kg) per catch (kg)
Malaysia	Lines	0.16
	Traps	0.20
	Gillnets	0.19
	Purse seines	0.21
	Trawls	0.33
North Sea	Beam trawling	2.42
	Bottom trawling	1.19
	Shrimp trawling	1.17
	Mid-water trawling	0.57
	Gillnetting	0.67
	Danish pair seining	0.68
	Danish seining	0.17

Source: Smith, 2007.

and concludes that much is caused by the lack of capacity in most of the elements of the fuel supply process, especially the low amounts of critical elements. These include exploration carried out in the 1990s; present production capacity; super-tankers; and oil-refining capacity caused by hurricane damage in the Gulf of Mexico. Additional crude oil price increases occurred in 2007. Crude oil hit a record high of US\$78.77 a barrel in early August 2007 in the United States. Reuters (2007) indicates that various factors were responsible: real and threatened disruptions to crude oil supplies; constraints at refineries in consuming countries; resilient global fuel demand; and a flow of investor money into oil.

## COUNTRY EXPERIENCE

In the ten study countries (Part 2), a number of energy issues emerged. Rising fuel prices for shrimp fishing and



### BOX 17 Oil price increases

Relative to today, oil prices were very stable from 1947 to 1972. During this period, there was a surplus of oil. Then, in 1972, the continuing increase in demand began to push up the price of oil significantly, which rose from US\$3 to US\$15 a barrel. Throughout the 1970s, demand continued to rise as did oil prices. After the Iranian Revolution, from 1979 to 1980, the cycle shifted and demand for oil declined for the next several years. This marked the beginning of a 17-year period of mostly depressed oil prices, which finally bottomed out in 1998. Then, from 1998 to early 2003, as global demand expanded, nominal oil prices doubled from US\$15 to US\$30 per barrel. By 2005, nominal prices doubled again, from US\$30 to over US\$60 a barrel, and have continued to escalate into the current period – with no apparent end in upward prices in sight.

Source: Krampe, 2006.

associated financial difficulties were the most prominent energy-related feature, the only exception being Kuwait. The typical situation was in Australia, where the Australian Fisheries Management Authority (AFMA, 2005a) summarized the situation: “Fuel is a huge expense and the cost base of producing a kilo of prawns is on an upward spiral against the prices flat-lining or declining”. Other fuel issues in the country studies are described below.

- There have been numerous attempts to mitigate the effects of the fuel price rise.
- The actual price paid for fuel for fishing in a particular country often depends more on taxes/subsidies than on whether that country is a net importer or exporter of fuel.
- The fuel price increase produces an incentive to reduce bycatch in order to reduce costs, because less bycatch means less drag and associated fuel consumption.
- The fuel price increase may also produce an incentive to increase revenues, reducing discards when they can be properly marketed instead.
- A rise in fuel cost has minimal effect on non-motorized shrimp fishing and may make it relatively more profitable.
- Many small-scale shrimp fisheries depend on outboard motors, a form of propulsion that is not very fuel-efficient.
- Because many shrimp capture fisheries are more fuel-intensive than shrimp aquaculture, rising fuel prices can create additional problems for captured shrimp in its competition with the farmed product.

When fuel cost increases coincide with subsidy reductions, the effects can be devastating. In Indonesia, the average annual fuel cost for an industrial otter trawl shrimp vessel operating in the Arafura Sea tripled in 2005, from about US\$210 000 to US\$625 000 (Part 2).

Another important feature of the ten countries studied is the difference in fuel prices. Unfortunately, there is no readily available source of information on current fishing fuel prices. Figure 23 is taken from

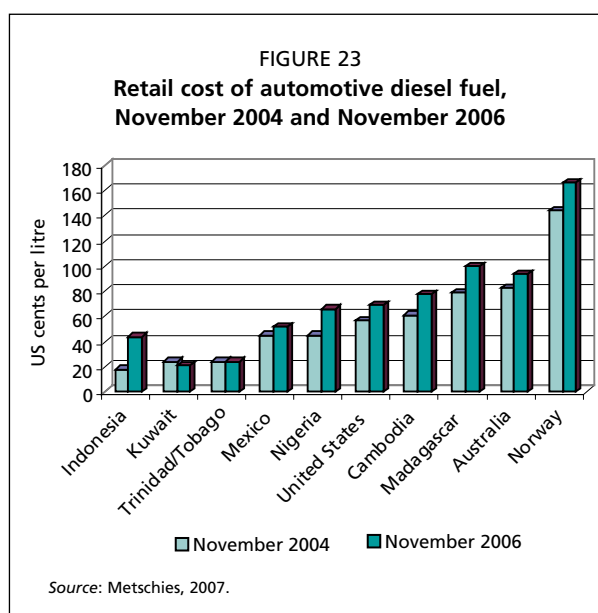
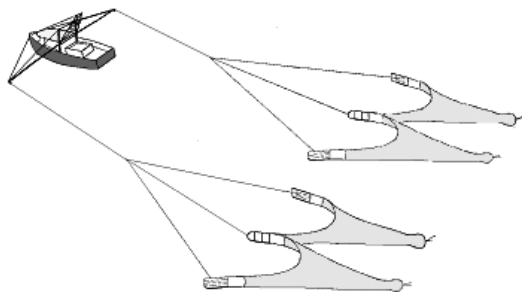


FIGURE 24  
A quad-rig trawl arrangement



Source: Sterling, 2005.

a worldwide study of the retail price of automotive diesel. The cost of this diesel can differ from that for fishing vessels, especially in Europe, where automotive fuel is significantly higher than that for fishing operations. Nevertheless, there is a general impression that many of the countries that compete with each other in international shrimp markets have vastly different fuel costs.

### MITIGATION OF FUEL COST INCREASES

A wide range of measures has been taken to reduce the impacts of fuel price increases on shrimp fishing, which can be classified in

two general categories: measures that reduce fuel use (through operational and policy approaches), and measures that increase profitability to compensate for fuel cost increases. The latter are covered in Chapter 8, section *Improving profitability*.

The policy-level interventions to reduce fuel costs in shrimp fisheries (either mooted or implemented) include: subsidizing the cost of fishing fuel; reducing fuel taxation; allowing activities that have a result similar to reducing taxation (e.g. offshore fuelling); ensuring that the fuel cost benefits of currency appreciation are passed on to fishers; relaxing fishery management arrangements that cause greater fuel use; and providing low-interest loans for improving the fuel efficiency of vessels.

With regard to operational measures that reduce fuel consumption, Smith (2007) covers several generic measures applicable to many fisheries. These include optimization of vessel speed, hull shape/condition and propeller. Wilson (1999) indicates that on a typical fishing vessel, only about one-third of the energy reaches the propeller and, for a small trawler, only one-third of the energy reaching the propeller is useful for work such as dragging a net. Consequently, there is room for considerable improvement.

According to the ten countries studied, operational measures used in shrimp fisheries to mitigate fuel cost increases include: using multiple nets (Figure 24); lightening the fishing gear; using sled-type doors for otter trawling; switching from otter trawling to pair trawling; reducing bycatch; using improved netting material; avoiding trawling against tidal currents; basing shrimp vessels closer to fishing grounds; fuelling offshore; smuggling fuel; and remaining in port until the fuel and/or catch situation improves.

### FUEL SUBSIDIES

Fuel subsidies deserve special mention. They appear to be the most important policy-level measure for mitigating the rising cost of fuel to the shrimp fleets, although in most cases the policy involved is much broader than shrimp fishing or even the fishing sector. Unfortunately, as mentioned above, there is no good up-to-date source for worldwide comparative information on fuel costs and associated subsidies for fishing activities. The retail price for retail automotive fuel is sometimes taxed at a higher rate than that for agriculture/fishing use. If it is assumed that there is at least some relationship between the taxes/subsidies on retail automotive fuel and that for fishing, then the global study of fuel prices (Metschies, 2007) can provide some insight into fuel taxes/subsidies for shrimp fishing.<sup>12</sup>

According to Metschies (2007), countries can be placed in four categories, from having very high diesel subsidies to very high diesel taxation. Countries with diesel

<sup>12</sup> In Europe, where fuel costs for automobiles are significantly higher than those for fishing operations, the results of a global study on automotive fuel have the least applicability to the fishing fuel situation.

TABLE 10  
Fishing fuel subsidies of the major shrimp-producing countries

Countries with fishing fuel subsidies		Countries without fishing fuel subsidies		Countries with no information on fishing fuel subsidies	
Country	Cents	Country	Cents	Country	Cents
United States	0.06	Viet Nam	0	Greenland	N/A
Indonesia	0.07	Pakistan	0	Myanmar	N/A
Taiwan Province of China	0.09	Nigeria	0	Suriname	N/A
Spain	0.10	Guyana	0	Faeroe Islands	N/A
India	0.11	Germany	0	Estonia	N/A
Malaysia	0.11	Netherlands	0	Madagascar	N/A
Brazil	0.11	Mozambique	0	Venezuela (Bolivarian Republic of)	N/A
Thailand	0.13			Cambodia	N/A
Philippines	0.15				
China	0.18				
Canada	0.18				
Norway	0.18				
Mexico	0.18				
Argentina	0.18				
Iceland	0.18				
Republic of Korea	0.18				
Russian Federation	0.18				
Australia	0.20				
Japan	0.25				

Source: Sumaila *et al.*, 2006.

Note: units: US\$ per litre.

subsidies or very high diesel subsidies on automotive diesel (which is assumed above to have at least some relationship to subsidies on fishing fuel) produce a substantial amount of the world's shrimp catch. Combining the information in Metschies (2007) with that of Table 4 (Chapter 3, section *Catches by country*), it can be seen that about half of all shrimp landings come from countries with subsidies or very high subsidies on automotive diesel.

Sumaila *et al.* (2006) report on a global study of fishing fuel subsidies in 144 coastal countries in 2000. A fishing fuel subsidy is defined in the study as the price differential, if any, enjoyed by the fishing sector in each country relative to other economic sectors. Of the 34 largest shrimp-producing countries (Table 4 in Chapter 3), the study shows that in 2000, 19 countries had fuel subsidies (from US\$0.06 to US\$0.25 per litre), seven had no subsidies and there was no information for eight countries. Table 10 shows the results.

The overall conclusions of Sumaila *et al.* (2006) also apply to shrimp fishing.

*It is generally accepted that global fisheries are grossly overcapitalized, resulting in overfishing in most of the world's fisheries. Fuel prices have recently seen significant increases. Given that fuel constitutes a significant component of fishing costs, it is obvious that, other things being equal, increasing fuel prices will reduce overcapacity and overfishing, because they will reduce the profits that can be made, thereby driving marginal fishers out of fishing. But other things are hardly equal. Here, the willingness of governments to provide the fishing sector fuel subsidies reduce, if not completely negate, the conservation value of increasing fuel costs.*

Despite numerous oil shocks during the last three decades, fishing capacity in many shrimp fisheries has continued to grow. A significant part of the effect of rising oil prices has been passed directly to the consumer through price increases and indirectly to society through subsidies.



## 8. Profitability of shrimp fishing and resource rent

### COUNTRY EXPERIENCE

One of the main features to emerge in the examination of shrimp fishing in ten countries (Part 2) is the current low profitability of many commercial shrimp fishing operations. The typical situation is rising costs (mainly fuel) and falling revenue from shrimp sales (to some degree as a result of competition with lower-cost farmed shrimp) in an environment where there is overcapacity. Of the study countries, only Kuwait appears to be unaffected by the generally poor profit situation: fuel costs are low and stable; the Government provides subsidies to trawlers; and prices paid for shrimp on the domestic market are rising. Several other countries lie at the other end of the profitability spectrum, including the United States.

*The current economic crisis faced by the domestic shrimp industry in the United States is unprecedented – in scope, magnitude and duration. Declining real and nominal prices, along with increasing costs of operation, have created large difficulties in maintaining financial solvency for commercial shrimp vessels in the Gulf of Mexico and southern Atlantic states region (Ward et al., 2004).*

In a general sense, profitability of commercial shrimp is affected by several factors, the most important of which are fuel costs, catch rates, the price received for shrimp, and any subsidies. Over the last 25 years, fuel costs have generally risen (Chapter 7). Catch rates in open access fisheries (most of the world's shrimp fisheries) have tended to fall. Shrimp prices are more complex, with both rises and falls. The situation with respect to government subsidies is dynamic, with some being eliminated (e.g. fuel subsidy in Indonesia) and other schemes being instigated (e.g. “anti-dumping” duties in the United States).

Determining the profitability of shrimp fishing operations can be difficult, just as in many other fisheries. In countries where shrimp fishing profitability has been formally evaluated, many or perhaps most studies are hampered by using unverified vessel-supplied data in an environment where there are numerous incentives to under-report profits. The situation in Indonesia (Part 2) is typical of many developing countries: “A limited amount of information is available of the profitability of shrimp fishing in Indonesia. Where it is available, it is often not possible to establish the reliability of the sources, rigorousness of methodology used to calculate profit, and consequently the credibility of the results”. On the other hand, work on profitability in Australia (Box 18) and Norway could be considered as a model for emulation.

In the absence of good data on the profitability of shrimp fishing, some conjecture on the financial health of various shrimp fleets is given on the basis of indirect indicators, such as fleet size, condition of vessels and CPUE.

- In Mexico, the change in number of vessels in each shrimp fleet is sometimes used as a crude indicator of profitability. It can be inferred from this that there has been no great change in profitability in the 1990s of the industrial shrimp fleets based in the states of Sonora, Sinaloa and Tampico.
- In Cambodia, despite the paucity of economic data, there are indications that the profitability of individual shrimp fishing operations is low. This assertion is based on several features of the shrimp fisheries in the country, including the open access nature of Cambodian coastal fisheries, rising coastal populations, low barriers to

## BOX 18

**Determining the profitability of shrimp fishing in Australia**

The Australian Bureau of Agricultural and Resource Economics (ABARE) has been undertaking economic surveys of selected Commonwealth fisheries since the early 1980s and on a regular basis for particular fisheries since 1992. In 2005, ABARE surveyed two shrimp fisheries: the Northern Prawn Fishery and the Torres Strait Prawn Fishery. Galeano *et al.* (2006) describe the methodology and give the results of the 2005 work. Between February and June, an ABARE officer interviewed the owner of each shrimp boat selected in the sample to obtain physical and financial details of the fishing business for the survey years. Further information was subsequently obtained from accountants, selling agents and marketing organizations. This has enabled various indicators of financial performance, including boat business profit, profit at full equity and rate of return to boat capital to be determined.

*Source: Galeano et al., 2006.*

participation, lack of non-fishing sources of livelihoods, rising proportion of trash fish in the catch and falling CPUE.

- In Nigeria, shrimp trawling in 2002 was close to break-even at best. The exit of many players from the industry that year supports the contention of low profitability.
- In Australia, despite decades of intense management, profitability remains elusive, with an excess of capacity, partly created by effort creep.

It is interesting to note that many current shrimp trawl fisheries were established when other forms of trawling became unprofitable. Chemonics (2002) stated that in Nigeria the original focus of trawlers was finfish for the domestic market, with shrimp featuring as a bycatch. After a currency devaluation, fish sold locally could not even cover operational costs. Shrimp, which used to be a bycatch, became the focus because of its high export earnings. A switch from trawling for fish to trawling for shrimp also occurred without any devaluation in several Southeast Asian countries, as well as in some of the former French territories in West Africa. In China, in the mid-1970s, because the stock size of coastal demersal fish species was depleted by trawling, fishers started exploratory shrimp fishing using beam trawls, which proved successful. Shrimp fisheries expanded rapidly and extended further seawards (Chen, 1999).

The “discovery” of coastal shrimp fisheries may be a case of ecological relationships assisting the profitability of shrimp trawling. The removal of large predatory fish by trawling during the years preceding the shrimp fishing boom appears to have resulted in less predation on shrimp, reducing its fishing mortality and increasing its abundance. Although this phenomenon can have a positive effect on profitability and development, it can also result in important changes in the marine ecosystem brought on by trawling.

In the shrimp industry, the harvesting sector is not the only segment to experience low profitability. IntraFish (2005) reports financial difficulties in processing cold-water shrimp in the main producing countries: Canada, Greenland, Iceland and Norway. There is increasing competition from tropical species that are generally larger. In recent years, a major shrimp processor closed nine cold-water shrimp processing plants, including three in Norway. Hempel (2001) indicated that eight shrimp peeling plants in Norway also closed recently. It should be noted, however, that non-fisheries factors (such as high labour costs in a labour-intensive industry) could also be responsible for these shrimp processing difficulties.

## IMPROVING PROFITABILITY

A number of measures to improve the current situation of poor profitability have been implemented or suggested. The most important are increased attention to fuel costs (discussed in Chapter 7), fleet reduction, market promotion, subsidies and import barriers.

Considerable optimism is shown by both fishery managers and commercial operators in many parts of the world that reducing the number of vessels participating in a fishery will increase the profitability of the remaining vessels. This is often expressed in general terms but, in Nigeria and the United States, there has been some quantitative work.

- *Economic revival (of the shrimp fisheries in Nigeria) will depend upon either prices rising or catch rates improving, as there is little scope to reduce costs. If prices don't rebound, then the principal option facing the industry must be to reduce overall capacity to allow unit catch rates to increase for the remaining vessels, a situation that may be faced by much of the world's shrimp fisheries. This is already happening with the Nigerian fleet – and an indication of the eventual impact on the fleet if prices remain at current levels can be estimated as follows: to restore profitability, catch rates would need to increase by 50 percent (i.e. from 60 to 90 tonnes per boat per year). This would imply a fleet reduction of at least 35 percent, or reducing the fleet to around 100–110 boats (Chemonics, 2002).*
- Ward *et al.* (2004) examined the economics of the Gulf of Mexico and Southern Atlantic States Shrimp Fishery. Simulation analysis found that with low shrimp prices, economic profits are negative and, at the end of 2004, a reduction of 30 percent of permits/licences of the large vessels would be needed to yield positive economic profits in 2005. For small vessels, positive economic profits can be achieved only for the 50 percent fleet reduction.

Reductions in shrimp fleet sizes to improve profitability have been undertaken in several locations, including Australia and the industrial fisheries in Madagascar. On the other hand, small-scale shrimp fisheries are often unprofitable, but there are few cases, if any, where management has reduced small-scale shrimp fishing fleets to improve economic performance.

Reduction in fleet size or capacity (e.g. through vessel numbers or gear restrictions) will not necessarily increase profitability in the long term. In input-controlled fisheries, which cover most shrimp fisheries, the incentive remains to innovate and rearrange inputs to become relatively more effective. Each operator introducing an innovation (e.g. a new net or otter board design) will enjoy a short-term benefit, but this will diminish as others adopt the new technology and effort creeps forwards, eroding profitability as fishing capacity increases and CPUE falls or seasons shorten.

Market promotion exercises have been carried out in several countries to improve profitability. The Mexican Shrimp Council (*Consejo Mexicano del Camarón*) and Ocean Garden Products of San Diego, the largest Mexican shrimp importer in the United States, launched a marketing campaign in March 2004 to promote the flavour and texture of shrimp from Mexico. The campaign, touted as “The Naked Truth About Shrimp”, is designed to give farmed and wild Mexican shrimp the brand recognition that products such as Colombian coffee and Mexican tequila already enjoy.

*When you've got something this good, why cover it up? Our south-of-the-border beauties come from the most pure ocean waters of a sun-drenched climate. This nutrient-rich environment paired with the VIP treatment means our happy swimmers come to you perfect in taste and texture – as is. All you'll ever really need are a few culinary essentials to bring out their natural flavor. Simple is good. Naked is best (www.mexicanshrimp.org).*

At least some of the premium price paid for Madagascar shrimp in Europe has been obtained through market promotion exercises. The Norwegian Seafood Export Council has also carried out some effective publicity work for cold-water shrimp (Figure 25).

FIGURE 25  
Promoting Norwegian shrimp



Source: Courtesy of Alf Boerjesso, Norwegian Seafood Export Council.

Some market promotion exercises are quick to take advantage of new opportunities. In September 2007, the marketing group Wild American Shrimp (WASI, affiliated with the Southern Shrimp Alliance [Chapter 5, section *United States anti-dumping action*]) launched a marketing campaign and fund-raising activities associated with new concern in the United States over the safety of Chinese seafood products. WASI feels that this is creating a new selling opportunity for shrimp caught in the United States. To take advantage of this situation, WASI indicates that it needs additional funds to the US\$10 million in federal grants received over the last four years for the marketing campaign (IntraFish, 2007).

When profits collapsed in the United States shrimp fishing industry, several measures

were proposed by NMFS, including a major marketing programme. Analysis of this proposal (Ward *et al.* 2004) showed that market promotion efforts would have to result in a 15 percent increase in ex-vessel price to eliminate the negative economic profits for smaller vessels. A 5 percent increase in ex-vessel price would increase revenues by 2.25 percent and employment by 2.24 percent. Significantly, the analysis concluded that market promotion and other attempts to improve prices would not be successful unless the number of vessels participating in the shrimp fisheries is limited.

Subsidies are another mechanism that has been used to improve the profitability of shrimp fishing. Most of the obvious subsidies are related to fuel costs (Chapter 7), but others are granted on a per vessel basis, or consist of measures such as tax waivers, low interest loans or provision of infrastructure. Many, but not all, subsidies are harmful (Box 19). Several types of subsidy interventions have been used for shrimp fishing, including those to reduce costs of shipbuilding (Australia), to import vessels (India) and to fit out vessels (Nigeria). In general, the fully or overexploited nature of many shrimp fisheries has tended to reduce government enthusiasm for subsidies, while shocks such as fuel prices and competition with farmed shrimp have resulted in more pressure on governments to grant subsidies.

Subsidies to shrimp fisheries are especially sensitive. Kura *et al.* (2004) make a strong case that government fishing subsidies are a leading factor in the excess capacity of the world's fleets. It is well known that many, if not most, of the world's shrimp fisheries suffer from overcapacity. It is therefore ironic that many of these fisheries continue to receive various types of subsidies.

The boldest move to improve profitability of shrimp fishing in recent years has probably been the initiative in the United States to restrict the import of farmed shrimp on the basis that it has been dumped on the market. In December 2003, the Southern Shrimp Alliance (SSA), a lobbying organization formed by shrimp fishers and processors in eight southern states, filed an anti-dumping petition with the United States Department of Commerce against shrimp farms in Brazil, China, Ecuador, India, Thailand and Viet Nam. In July 2004, the Department imposed duties varying up to 113 percent on these countries. SSA claimed it was seeking protection from an unfair trade practice, but some commentators saw it as a form of unfair protection from foreign competition. The United States shrimp industry is likely to have profited in three ways from the tariff: from reducing the quantity of imported product on the United States market; from a United States law (the "Byrd Amendment"), which gives the duties



## BOX 19

**The good, the bad and the ugly of fisheries subsidies**

It is often unclear which specific subsidies are harmful and to what extent, particularly in the case of indirect subsidies such as port improvements or government-sponsored trade promotions. But there are a few types of subsidies that clearly contribute to overfishing. One is the group of subsidies that encourages continued growth of fishing fleets, even when fish stocks are already overexploited by existing capacity. These subsidies often consist of grants or low-interest loans to purchase or upgrade fishing vessels. They were originally conceived by governments as incentives to develop their industrial fishing sectors, but have not been withdrawn even though most national fleets in the developed world suffer from overcapacity. Some fishing subsidies doled out in developed countries actually have a negative effect on small-scale fishers in developing countries. In contrast to these harmful subsidies, some government-subsidized programmes clearly contribute to better fisheries management. For example, well-designed “vessel buy-back” programmes, where the government pays fishers to retire fishing vessels, can help shrink the size of the fishing fleet and reduce pressure on fish stocks. Government-sponsored research on fishing gear and methods can improve the selectivity of the gear and determine how best to deploy it in order to cut down on bycatch and waste.

Source: Kura *et al.*, 2004.

collected to the aggrieved United States party (some US\$150 million); and from a deal between SSA and foreign producers (worth several million) to avoid reappraisal of the dumping duties (The Economist, 2006).

Although SSA efforts were initially successful, subsequent analysis shows that foreign entrepreneurs reacted creatively to thwart the United States restrictions. Shrimp buyers in the United States switched to new suppliers of frozen shrimp, and foreign producers subject to the tariff switched production to shrimp products exempt from the tariff. The amount of shrimp imported into the United States actually increased – including that from many countries subject to the anti-dumping measures.<sup>13</sup> Action by the United States Government also reduced the impact: in February 2007, the “Byrd Amendment”, was repealed and in August 2007, Ecuador was removed from the list of countries subject to the extra duty (Mathews and Dunaeva, 2007).

**RESOURCE RENT**

Resource rent can be defined as the difference between the revenue from a fishery resource and the total costs of exploiting the resource. In a broader sense, if non-monetary costs and benefits are considered, rent can be considered as the net economic return from a fishery to society. In limited access fisheries, resource rent can be kept by fishers (as super profits) or collected by management authorities (and returned to the public) through licence fees.

Good management regimes tend to increase rent; others, especially open access, can dissipate it. Accordingly, changes in rent can be an indicator of the economic performance of a fisheries management agency. For example, the performance of the AFMA in managing several shrimp fisheries under its jurisdiction is to some extent determined by changes in resource rent levels of these fisheries.

<sup>13</sup> O’Sullivan (2005) states that the United States import share by the six countries affected by the anti-dumping measures actually increased from 62.4 percent in 2003 to 65.4 percent in 2005.

Resource rent has not been determined for many shrimp fisheries in tropical countries. The situation in Indonesia seems typical where, according to the Director of the Centre for Marine and Fisheries Socio-Economic Research, there have been few rent studies on any of the fisheries (A. Purnomo, personal communication, December 2005). Elsewhere, many fishery managers encountered during the present study are only vaguely aware of the concepts related to resource rent. Few managers appear to use the amount of rent when managing shrimp fisheries. Chapter 4 indicates that in many countries, the gross value of the shrimp catch is often used by fisheries managers for making decisions, such as trade-offs between fisheries, simply because the numbers are available and comparable. This is unfortunate, because resource rent is in many respects a better indicator of the value of a fishery to society.<sup>14</sup>

Information on resource rent is readily available for several shrimp fisheries in developed countries.

- Galeano *et al.* (2004) give the rent in the NPF (\$A33 million of resource rent in the 2001/01 season), the Torres Strait Prawn Fishery (\$A2.8 million in the 2001/01 season), and the Southeast Trawl Fishery (\$A2 million average for several years).
- Ward (2006) determines the resource rent level for the Gulf of Mexico shrimp fishery in the United States at US\$2.11 billion. By introducing optimal yield management strategies and property rights into the fishery, a rent of US\$4.19 billion could be obtained.
- Christensen and Vestergaard (1993) state that in 1991 the rent in the Greenland Shrimp Fishery in the Davis Strait was between US\$33.8 million and US\$104.8 million.

<sup>14</sup> Between the mid-1980s and the early 1990s, FAO promoted the use of bioeconomic models (and related software) for this purpose, developing pilot applications in Mexico, Madagascar and Kuwait (Willmann and Garcia, 1985; Sparre and Willmann, 1992).

## 9. Biological aspects of shrimp

Fisheries biologists have made considerable progress in understanding the life histories of many of the important species of shrimp. In the early days of shrimp fishing, biologists had poor knowledge of shrimp biology, including the complex larval life, growth and mortality rates, life span, migration and habitat requirements (Iversen, Allen and Higman, 1993). After many decades of research, “most of the big unknowns were solved” (S. Garcia, personal communication, 2006), which contributes greatly to the improvement of the assessment and elaboration of advice for the management of shrimp fisheries.

### BASIC BIOLOGY AND LIFE HISTORIES

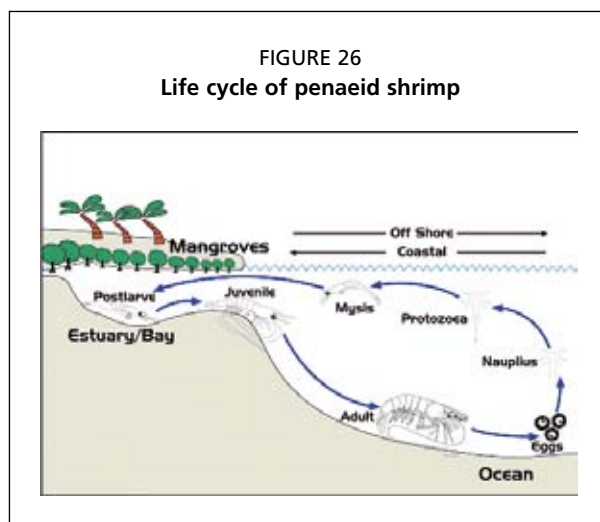
There are major biological differences between the main groups of shrimp. For the purpose of this discussion, economically important shrimp is divided into three groups:

- penaeid shrimp (primarily the genera *Penaeus*, *Metapenaeus*, *Parapenaeopsis* and *Trachypenaeus*);
- caridean shrimp (primarily the families Pandalidae and Crangonidae; and
- sergestid shrimp (the genus *Acetes*).

Drawing upon a variety of sources, Cascorbi (2004b), reviews the major biological characteristics of the three major species of *penaeid shrimp* in the Gulf of Mexico, much of which are applicable to warm-water shrimp in other regions. Most shrimp is omnivorous, catching or scavenging whatever plant or animal material is readily available. The sexes are separate and females tend to be larger than males. Males and females clasp to copulate and then the female broadcasts fertilized eggs into the water column. All three major penaeid shrimp in the Gulf are extremely prolific, releasing between 500 000 and 1 million eggs per spawning. The eggs drift with the plankton and may settle to the seafloor. They hatch within 24 hours. Newly hatched shrimp larvae bear little resemblance to their elders; in the three important penaeids of the Gulf, larvae must undergo 11 moults to attain final form as a juvenile shrimp. The tiny shrimp larvae drift with the plankton, where they are important food for many fishes and invertebrates. Postlarvae (PL) individuals – tiny but shrimp-like – seek sheltered estuaries in which to grow to adulthood, making estuarine habitat very important to penaeid species. The annual abundance of penaeid shrimp is closely tied to natural factors such as average temperature, amount of rainfall and the number and intensity of storms, which affect the survival and recruitment of the larvae. Young penaeids are sensitive to changes in water salinity. The main Gulf shrimp is short-lived, completing its life cycle in 18–24 months and reaching sexual maturity in 6–12 months.

Roberts (2005) and Iversen, Allen and Higman (1993) have reviewed the literature of caridean shrimp biology (the genus *Pandalus*). The main commercially important pandalid shrimp is nearly all protandrous

FIGURE 26  
Life cycle of penaeid shrimp



hermaphrodites: juveniles usually mature as males, breed as males for one or two years, and then transform and breed as females for another year or two. The males transfer sperm to the females, who may store the sperm for some time. The females then extrude the eggs, fertilizing them as they lay them. Clutch size ranges from a few hundred eggs to about 4 000, very few compared with the tens of thousands or more eggs released by warm-water shrimp. The female pandalid attaches her fertilized eggs to her abdominal appendages, where they remain, protected by the mother and aerated by her swimming, until the larvae break free. Newly hatched shrimp larvae bear little resemblance to their elders; each must undergo up to 12 moults to attain final form as a juvenile shrimp. Pandalid shrimp generally live much longer than penaeid shrimp – many important species live for about six years and enter fisheries at about two years of age. Many marine species prey on pandalid shrimp. Several authors have suggested that the collapse of Atlantic cod populations off Canada and in the Barents Sea may have led to an increase in biomass of *Pandalus borealis*, but results of studies to date are equivocal.

PICES (2001) summarizes the basic biological features of the genus *Acetes* of sergestid shrimp. Spawning occurs twice a year, with spring/summer and summer/autumn generations, and most of both broodstocks die after reproduction. During the spring, gonads mature after wintering, and spawning begins in June. The spring stock grows quickly in the summer and reproduces to form the autumn generation. In akiame shrimp, the longest life span is only one year; the sex ratio is about 1:1; the body length of mature male and female individuals ranges from 17 to 32 mm and 18 to 43 mm, respectively; and size frequency structures of two generations are different. Female body lengths of the spring stock range from 25 to 40 mm and the range is dominated by 31 to 32 mm shrimp. Female body lengths of the autumn stock range from 12 to 30 mm and are dominated by 20–30 mm shrimp. Mating activity takes place about 15 days prior to spawning, in batches and always at night. Typical spring females produce 7 700 to 8 700 eggs, while a 30-mm autumn female would produce 6 800 eggs. Akiame shrimp is a weak swimmer and does not make long-distance migrations, but there is a seasonal movement between shallow (summer) and deep waters (winter). The shrimp filters feed on phytoplankton (diatoms) and detritus, but also actively preys on zooplankton. The diet composition changes with habitat and seasons.

Some biological characteristics of shrimp have important fisheries management implications. Penaeid shrimp fisheries generally exploit a single year class. The annual yield is therefore largely a function of the importance of annual recruitment, which is widely influenced by environmental conditions (often rainfall or temperature during a critical period). The consequences are highly variable annual catches. This fact has many consequences for stock assessment, modelling, effort control and management strategy (Garcia, 1989). The postlarvae of many penaeids move to inshore areas where they grow to maturity and subsequently move back to deeper water. As small-scale shrimp fishing is often done in shallow, sheltered, inshore areas, fishing on different size shrimp often equates to competition between industrial and small-scale fleets. Management measures based on shrimp size also have some tendency to partition the resource between the various scales of fishing operations.

Cold-water shrimp has attracted less biological investigation, but nevertheless, some of the research findings affect management strategies. Pandalid shrimp are fast-growing and early-maturing and produce several thousand young. These and other life history characteristics, such as environmental sex determination, make them inherently resistant to fishing pressure (Roberts, 2005).

With regard to *Acetes* shrimp, much less biological information is available. Because the shrimp has a short life span, its abundance may be easily affected by natural conditions and human activities. As a result, its annual abundance and landings fluctuate extensively (PICES, 2001).

TABLE 11  
Some differences in the main groups of shrimp

Aspect	Penaeid	Caridean	Sergestid
Species items of commercial importance (groups with more than 3 000 tonnes in the 2005 FAO statistics)	Many in several genera	<i>Pandalus borealis</i> , <i>Crangon crangon</i> , <i>Pandalus</i> spp., <i>Pandalopsis</i> spp., <i>Heterocarpus reedii</i>	Sergestidae, <i>Acetes japonicus</i> <sup>1</sup>
Percentage of global commercial catch	Slightly more than half	Slightly less than one fifth	Slightly more than one quarter
Body size	Small to large	Very small to large	Small to microscopic; body strongly compressed laterally
Sex	Separate sexes	Nearly all protandrous hermaphrodites	Separate sexes
Reproduction	Eggs released directly into water – fertilized on release	Females carry eggs until hatching	Eggs released directly into water
Life cycle	Short (<3 years)	Mostly long (3–8 years)	One year or less
Habitat zone	Mainly tropical and temperate	Mainly temperate and arctic	Mainly tropical and temperate

<sup>1</sup> PICES (2001) indicates that the akiami paste shrimp (*Acetes chinensis* and *Acetes japonicus*) overlaps in its geographic ranges and is generally not distinguished in landing statistics.

The three main economically important groups of shrimp are distinct with respect to biological and other attributes, some of which are given in Table 11. These differences have major implications for the strategies used in their management.

### IMPORTANT ISSUES RELATING TO SHRIMP RESOURCES AND BIOLOGY

In the ten study countries in Part 2, a number of issues related to shrimp biology and biological research were identified. One of the most striking features is the generally poor biological condition of the shrimp resources in developing tropical countries. The information in Part 2 can be summarized as follows.

*Indonesia.* There does not appear to be much potential for expansion of shrimp catches in the country. In many areas, shrimp resources appear to be considerably overexploited. A decade ago, an FAO project suggested that effort should be reduced by about 50 percent of the effort in 1993 in order to keep the catch around MSY.

*Cambodia.* Despite the paucity of data, overexploitation of shrimp resources is suggested by several indicators, including the open access nature of Cambodia's coastal fisheries, the rising coastal population, low barriers to participation, lack of non-fishing sources of livelihood, low profitability, rising proportion of trash fish and perceptions of falling CPUE.

*Madagascar.* A large decrease in landings in 2004 and 2005 indicates a need for a new and detailed analysis of shrimp stocks.

*Mexico.* For Mexico's Pacific coast shrimp resource, it has been concluded that catches of Mexican Pacific shrimp have reached their maximum and that fishing effort should not be increased in any region or on any species. Some of the stocks are at a biomass level below maximum productivity.

*Nigeria.* An FAO report (FAO, 2000c) concludes that it is clear that current output level of the shrimp fishery is considerably beyond potential long-term yield estimates.

*Trinidad and Tobago.* Brown shrimp is one of the dominant species exploited by both the trawl fleets of Trinidad and Tobago and the Bolivarian Republic of Venezuela in the Orinoco-Gulf of Paria region. A study using 1973–2001 data indicates that the *Farfantepenaeus subtilis* resource is severely overfished and that overfishing has been taking place since the 1970s.

Another prominent issue is the lack of research, or even basic data collection, in many countries where the resource is important (see Chapter 14).

## BOX 20

**Assessment of Australia's Northern Prawn Fishery**

Assessments of the dynamics and status of the Northern Prawn Fishery target species is undertaken by the Northern Prawn Fishery Assessment Group on an ongoing basis. Logbook and research data are used in the assessments with extensive modelling work developed for the major prawn species. Results of each assessment are published annually and include an analysis of previous and current stock assessments, implications for management, economic status and environmental factors affecting prawn stocks. Catch, effort and CPUE trends for target prawn species are monitored, and persistent downward trends over three or more years are investigated to determine whether there is a biological problem with stocks. Research into improved stock assessment techniques is ongoing. Extensive modelling is used, in particular for tiger prawns, where there is a clear stock recruitment relationship. These models are regularly peer-reviewed.

*Source:* Department of the Environment and Heritage, 2003.

**STOCK ASSESSMENT**

The biological condition of various shrimp fisheries is currently being assessed to varying degrees, ranging in sophistication from little, if any, data collection and virtually no assessment in some countries, to the assessment process for Australia's NPF (Box 20), which has been described as the most comprehensive for any shrimp population assessment in the world (AFMA, 2001a).

Because of the great differences in assessment between warm- and cold-water shrimp fisheries, they are discussed separately below.

**Warm-water shrimp**

Stock assessment on warm-water shrimp resources ranges from simple trends in CPUE to extremely complex stock assessment models. CPUE trends have the advantage of being simple, easy for developing country managers to use, and readily understandable by fishers and the general public. However, as noted earlier, they are prone to error and need frequent adjustment to account for effort creep driven by technical innovation. The more sophisticated models are able to integrate many different types of information on shrimp resources and can give potential yields from a fishery.

Garcia (1989) notes that because seasonal and age-specific fishing patterns have marked consequences on annual yield in weight and value, an important role of stock assessment for warm-water shrimp is to determine the most appropriate age at first capture to reach a specific management objective. This implies the use of bioeconomic yield-per-recruit modelling with pre-season surveys. Gulland and Rothschild (1984) place the various models used for resources assessment in general, and shrimp stock assessment in particular, into two general categories.

- *Production models.* As generally applied, these relate the catch to fishing effort in one season. These models do not take explicit account of the effect of fishing on different size groups, but demand fewer data than age- or length-structured models, and are therefore widely used.
- *Age- or length-structured models.* These are based on the yield-per-recruit calculations of such researchers as Ricker and Beverton and Holt and are essential to study the effects of changes in fishing practices that involve changes in the pattern of distribution of fishing mortality with age. Yield-per-recruit or other measures of output (catches by age or size class) can be obtained for a particular input.

## BOX 21

**Modelling of the shrimp fishery in Negombo Lagoon**

A model was formulated to investigate the likely outcomes from changes in the fisheries inputs, particularly the consequences to catch weights and CPUEs from applying different fishing efforts. The model is of the length-based “Thompson and Bell” type. The biological inputs concern growth in length, the conversion of length to individual weight, and the natural mortality at age constants, among others. The outputs from the model were estimated catch numbers, catch weights and catch values, the associated CPUEs and the shrimp length frequencies. These outputs are for each of the six main shrimp species and eight gear types. Three hypothetical scenarios were examined with the model.

- In the first scenario, the fishing effort with stake nets was varied, while the efforts for the other gears were maintained at the contemporary levels. The results indicated that substantially increased catches were likely from increased stake net effort. Reducing the stake net effort produced near-proportional reductions in stake net catch, associated with very marginally increased CPUEs (in the trawl fisheries).
- In the second scenario, the fishing effort with trammel nets was varied. The estimated decrease in trammel net CPUEs from increased effort was judged as likely to be unacceptable. The loss of catch from reduced effort was found to be greater than the increase in catch from the other gears.
- In the third scenario, the combined fishing efforts for the trawl fisheries were varied. The findings indicated that the potential to increase the mechanized trawler catch is negligible. There seems to be some scope to increase the catch from non-mechanized trawlers.

Source: Sanders, Jayawardena and Ediriweera, 2000.

For example, a length-structured model was developed for the shrimp fishery in Negombo Lagoon, 40 km north of Colombo in Sri Lanka. Sanders, Jayawardena and Ediriweera (2000) describe the model and its application (Box 21).

Despite the limitations of using CPUE to gauge the conditions of shrimp resources, the reality is that many, if not most, shrimp fisheries in developing countries (almost all of which are warm-water fisheries) are heavily dependent on CPUE trends for their management. In these situations, two avenues of enhancement should be considered:

- the use of the somewhat more sophisticated yield-per-recruit analysis (“the next step up from using CPUE”), which is sometimes cited as a characteristic of an effectively managed penaeid fishery (R. Shotton, personal communication, 2006);
- the use of some index of recruitment success (i.e. related to rainfall or based on pre-season surveys), which can significantly improve any forecasting of future yields (S. Garcia, personal communication, 2006).

**Cold-water shrimp**

Roberts (2005) and Koeller *et al.* (2000) review stock assessment for cold-water shrimp fisheries. Because of its commercial importance, pandalid shrimp has received considerable attention from fisheries organizations such as the International Council for the Exploration of the Sea (ICES), the Northwest Atlantic Fisheries Organization (NAFO), and the North Pacific Marine Science Organization (PICES). Assessments of cold-water shrimp stocks generally consist of monitoring population changes using catch rate series and, in some cases, research surveys. They provide general information on population structure and recruitment, significant changes in which are used to identify when a change in quota or effort is needed. Biological reference points and formal yield projections are not common.

TABLE 12  
Year class strength of the northern shrimp stock for the 2006 season

Year class	Year class initial year class strength (based on prior assessments)	Current year class strength (based on 2005 assessment)
2000	Virtually absent	Have passed out of 2006 fishery
2001	Moderate	Strong Assumed to be 5-year old females
2002	Virtually absent	Very weak Assumed to be 4-year old females
2003	Weak to moderate	Strong Assumed to be 3-year old males and transitionals
2004	Not available	Strong Juveniles

Source: ASMFC, 2006

TABLE 13  
Assessment of northern shrimp in Canada's Hopedale and Cartwright Channels

Index	Observation	Interpretation
<b>Fishery data</b>		
Spatial pattern	The offshore component of fisheries expanded to shelf edge.	This reflects discovery of high concentration of shrimp along shelf slope during exploratory fishing in 1992 and 1993, areas previously thought unproductive.
Temporal pattern	A winter/spring fishery for the offshore fleet since 1995; previously a summer/fall fishery. Inshore vessels fish during summer/autumn.	High concentration of shrimp available throughout the year.
Male abundance	Catch rates of males increased during the 1990s. The 1991 year class dominated the males in 1995 and 1996; the 1993 year class in 1997 and 1998; and the 1994 year class in 1999.	Good recruitment of year classes produced in the early 1990s resulted in high catch rates of males over the past several years.
Female abundance	Catch rates of females increased from around 1993 to 1997, and stabilized in 1998 and 1999.	Continued good recruitment since the late 1980s is responsible for the increase in spawning stock throughout the 1990s. Spawning component remains healthy.
Sex inversion	The mean size of females and the median size at sex change have declined since 1996; these data are from the offshore vessels only.	This likely reflects a change in growth and size at sex change.
<b>Research data</b>		
Biomass/ abundance index	Estimate declined from 1996 to 1998 and increased in 1999. Broad 95 percent confidence intervals in this area, especially in 1996.	There is greater uncertainty because distribution is continuous with another area (area 6), but more patchy in the northern channels.
Spatial pattern	Shrimp is distributed widely throughout the management area, but very high catches occur in some locations.	With the current low survey coverage and the relationship with the southern area, results must be interpreted cautiously.
Recruitment (male age structure)	Males dominated by the 1993 year class in 1996 and 1997 surveys. The 1994 year class was prominent in the 1998 survey and the 1994 and 1995 year classes were prominent in the 1999 survey. No recruitment estimate.	Most of the 1994 year class will recruit to the female group in 2000.
Spawning stock (females)	Females in 1999 were composed of year classes produced prior to 1994, but most were assumed to belong to the 1993 year class.	Female biomass/abundance will be maintained in 2000.
<b>Other factors</b>		
Predation	Abundance of known predators in the offshore areas such as cod, redfish, skate and American plaice remains low.	Predation mortality remains low relative to periods of high predator abundance.
Environment	Positive correlation was observed between ice cover and CPUEs six years later.	Catch rates could decline gradually or remain stable over the next several years, assuming predator abundance remains low.
Industries perspectives	Catch rates from the 2000 fishery over a broad area for January/February are reported to be higher than for the same months in previous years.	Stock remains healthy.

Source: DFO, 2007.



Christensen and Vestergaard (1993) comment on aspects of stock assessment of the large *Pandalus borealis* fishery between Canada and Greenland. They state that ageing the shrimp constitutes one of the major tasks of assessment of the stock. Ageing difficulties have been a hindrance for the application of analytical assessment models and, as a consequence, the annual catch quotas have been based on logbook information of commercial fishery catches.

Unlike many of the penaeid fisheries, which typically involve shrimp species with short life cycles, northern shrimp populations can be tracked by year class. Table 12 provides a comparison of year class strength in the Gulf of Maine northern shrimp stock, as determined by prior assessments and the 2005 assessment. It shows how fishing pressure and environmental conditions can affect the stock over time. Changes in the 2001 and 2003 year classes are indicators of a recovering stock. These, together with increase in biomass, were the basis for increasing the fishing season to 140 days for the 2006 season.

Canada's Northern Shrimp Fishery is one of the most thoroughly assessed cold-water shrimp fisheries in the world. DFO (2007) indicates that fishery data, research data and other factors are used to assess the stock status. Table 13 summarizes the factors that have led to the conclusion that the stock of northern shrimp in the Hopedale and Cartwright Channels is in a favourable condition.



## 10. Impacts of shrimp fishing on the bottom habitat

### GENERAL

Concerns over the impacts of fishing gear on the sea bottom and benthic fauna have been around for a long time and have often been expressed by fishers themselves ever since mobile bottom gears were introduced. In 1376, a commons petition to the King of England complained “that the great and long iron of the wondyrchoun runs so heavily and hardly over the ground when fishing that it destroys the flowers of the land below water there ...” (Austers, Malatesta and Babb, 1994). The “wondyrchoun” (wonderful machine) was a beam trawl (Sharp, 2000). The King’s response, although couched in antiquated terms, is essentially the same as that still being used today, “Let commission be made by certain qualified persons to inquire and certify to the truth of the allegation made, and thereon let right be done in the Court of Chancery”. In other words, let’s do an environmental impact assessment before we act (BoFEP, 2000).

The degree to which shrimp trawling alters the seabed has generated a substantial amount of polarized discussion and controversy. On the one hand, scientists have shown the strong impact of trawling on the bottom, and advocacy institutions have equated trawling “to harvesting corn with bulldozers that scoop up topsoil and cornstalks along with the ears”, and stated that “bottom trawling is the most important human source of physical disturbance on the world’s continental shelves” (Safina, 1998).

Regarding more specifically tropical shrimp fisheries, participants at regional workshops on reducing the impact of tropical shrimp trawl fisheries in Latin America, Africa, the Middle East and Southeast Asia, recognized the lack of knowledge in participating countries, the possible importance of such an impact in some areas and the need for more research (FAO, 2000a). This lack of information (and potentially of consensus) could complicate the agreement needed for a participative ecosystem approach to fisheries.

It is obvious, however, that there must be some physical impact and, as stated by Hall (1999), “it would be quite foolish to deny that benthic communities are substantially altered by towing a fishing gear over them”. However, agreeing on the seriousness of the impact in different habitats and on the objective assessment of the long-term consequences on target productivity as well as on biodiversity is complicated by the diverse perspectives of the stakeholders (ecologists, conservationists, gear technologists, fishery scientists, fishery managers, fishing industry and the general public). These include different appreciations of the short- and long-term societal costs and benefits of shrimp fishing, different concepts of economic development and different views about intangible values of the ecosystem.

From a purely technical perspective, there are debates over: the scientific rigour of past impact studies; the frequent absence of non-impacted ground to be used as control; the chronic difficulty in separating fishing effects from other environmental impacts; the need to quantify an impact prior to raising concern (giving due consideration to the precautionary approach, however); and the impact of trawling in relation to that of natural phenomena such as waves (e.g. on shallow soft bottoms). On a different level, Leadbitter and Oloruntuyi (2002) cite a likely major philosophical difference causing the divide: “Given the fact that the modification of terrestrial habitats is vital to both agriculture and human settlement, the concern over the modification of

benthic marine/estuarine habitats is often difficult for many to understand". Whatever the cause, the fact remains that there are indeed major differences of opinion over the physical impacts of shrimp trawling.

An overriding fact, however, is that governments have committed themselves to sustainable development, responsible fisheries and sustainable use of biodiversity, and there is moral pressure to do so. The different aspects of the question are discussed below.

### DESCRIBING THE IMPACT

Johnson (2002) proposes a scheme for categorizing the various types of physical effects of fishing gear in general on benthic habitats.

- *Alteration of physical structure.* Physical effects of fishing gear can include scraping, ploughing, burial of mounds, smoothing of sand ripples, removal of stones or dragging and turning of boulders, removal of taxa that produce structure, and removal or shredding of submerged aquatic vegetation.
- *Sediment suspension.* Resuspension of sediments occurs as fishing gear is dragged along the seafloor. Effects of sediment suspension can include: reduction of light available for photosynthetic organisms; burial of benthic biota; smothering of spawning areas; and negative effects on feeding and metabolic rates of organisms.
- *Changes in chemistry.* Fishing gear can result in changes to the chemical makeup of both the sediments and overlying water mass through mixing of subsurface sediments and interstitial water. This could facilitate the remobilization of contaminants.
- *Changes to the benthic community.* Benthic communities are affected by fishing gear through damage to the benthos in the path of the gear and disturbance of the seafloor to a depth of up to 30 cm. Many kinds of epibenthic animals are crushed or buried, while infauna is excavated and exposed on the seabed, often damaged.
- *Changes to ecosystem.* The use of some types of fishing gear can affect benthic community composition and habitat. It is possible that these changes at the community level in turn result in effects on harvested populations and ecosystems.

Prado and Valdemarsen (2001) describe in general terms the bottom impacts of different types of fishing gear, five of which are sometimes used for shrimp fishing (Table 14).

Barnette (2001) gives a general synopsis of the physical effects of otter trawling. Otter trawl doors, mounted ahead and on each side of the net, spread the mouth of the net laterally across the seafloor. The spreading action of the doors results from the angle at which they are mounted, which creates hydrodynamic forces that push them apart and, in concert with the trawl door's weight, also push them towards the seabed.

TABLE 14  
Bottom impacts of various types of fishing gear

Fishing gear	Bottom impact
Bottom otter and beam trawls	<ul style="list-style-type: none"> <li>• Compress and penetrate the upper sediment layers</li> <li>• Scour the sediment</li> <li>• Flatten existing surface structures</li> <li>• Disturb the surface structures, including burrows</li> <li>• Break up sedimentary layering</li> </ul>
Seine net <sup>1</sup> (Danish/Scottish)	<ul style="list-style-type: none"> <li>• Minor: seines normally have light bottom contact</li> </ul>
Traps/pots	<ul style="list-style-type: none"> <li>• Minor: mainly effects of ropes and anchors on the seabed</li> </ul>
Beach seine	<ul style="list-style-type: none"> <li>• Minor: some impacts on the habitat of juveniles in shallow waters</li> </ul>

<sup>1</sup> In Southeast Asia, the use of seines for shrimp fishing is common: there are over 18 000 units of "demersal Danish/lampara seines" in Indonesia, much of which are used for shrimp fishing.

Source: Modified from Prado and Valdemarsen, 2001.

The doors, because of their design and function, are responsible for a large proportion of the potential impact inflicted by a trawl. The footrope runs along the bottom of the net mouth and may be lined with lead weight, rollers and other devices that may or may not reduce bottom impact. On a relatively flat bottom, it is often expected that the footrope will not have a major effect on the seabed and its fauna, but the impact of tickler chains may not be insignificant. However, in areas of complex, three-dimensional benthic habitat, with elevated animal colonies, the footrope has more impact. Additionally, even though the footrope may cause little physical substrate alteration on relatively flat bottoms, aside from smoothing and minor compression, it can lead to sediment “packing” after repeated trawling activity. Such compression can also result from the dragging of a loaded net (codend) along the bottom. The remaining path of the trawl is influenced by the ground warps which, while not in direct contact with the seabed, can create turbulence that resuspends sediments. Trawl gear, particularly the trawl doors, penetrates the upper layer of the sediments, which liquefies the affected sedimentary layers and suspends sediment in the overlying water column. This sediment “cloud” generated by the interaction of the trawl gear with the benthos and the turbulence created in its wake contributes to fish capture.

*The State of World Fisheries and Aquaculture* (FAO, 2004) describes the impact of the beam trawl, another shrimp fishing gear that causes concern over its effects on the sea bottom. Beam trawls are used to catch species that stay on the bottom or are partly buried in the seabed. Accordingly, beam trawls have tickler chains designed to disturb the seabed surface and penetrate the upper few centimetres of the sediment. The most noticeable physical effects of beam trawling are a flattening of irregular bottom topography and the elimination of natural features such as bioturbation mounds and faunal tubes. The penetration depth of the tickler chains of beam trawls varies from 1 to 8 cm. Løkkeborg (2005) compares the physical impacts of otter trawling and beam trawling. Furrows and berms created by the trawl doors are the most conspicuous physical impacts from otter trawls. The doors of otter trawls probably penetrate deeper into the sediments than beam trawls, but the area disturbed by the trawl doors comprises only a small proportion of the total area swept by the trawl. The main physical impact of beam trawling seems to be a flattening of the bottom topography, whereas the doors of otter trawls create irregular features on the seabed. Figure 27 shows the difference in sediment disturbance between a standard flat otter board (left) and that of a new design. Larger and heavier gear will obviously have much greater impact than small ones.

There is not much information in the literature concerning the effects of non-mobile shrimp fishing gear on the seabed. In examining the situation in the North Pacific, Roberts (2005) states that it is generally accepted that pots and traps have relatively little impact on the seafloor, but impacts are not completely benign, especially in cases where the gear is used in coral or hard bottom areas, as is the case in spot prawn traps. In Indonesia, there is widespread use of shrimp gillnets. The potential impact of these entangling nets in the country where 30 690 units of the gear are used (unpublished 2003 statistics, Ministry of Marine Affairs and Fisheries) is unknown.

### DEVELOPED VS DEVELOPING COUNTRIES

In examining shrimp fishing closely in ten countries (Part 2), a striking feature is that

FIGURE 27

#### Sediment disturbance by two otter board types



Source: Sterling, 2005.

issues and concerns related to the physical impacts of shrimp fishing gear lead to different reactions in developed and developing countries. In general, in developed countries there is a large and growing awareness and concern over the physical impacts, accompanied by a substantial amount of research aiming at assessing and reducing the impact. This is not usually the case in developing countries. Despite a general awareness that shrimp trawls and associated dragging gear may result in some damage to the bottom, research on the subject and mitigation issues typically receive low priority. Examples from Australia and Nigeria highlight the differences.

- In Australia, the subject of the impact of shrimp trawling on the physical environment is addressed in many reviews of specific Australian fisheries and in targeted research. Several reviews indicate that shrimp trawling is most definitely having an impact, but that the effects are mitigated to some extent by the fact that the actual trawling only covers a portion of the fishery area, and the intensity of trawling is decreasing as management measures reduce fishing activity.
- In Nigeria, there have been no specific studies on the effects of shrimp trawling on the ocean bottom, but there is a general perception that the groundropes, tickler chains and doors of shrimp trawl nets that are dragged over the sea bottom to catch shrimp disturb the soft bottom. The shrimp industry acknowledges that some problems exist and indicates a willingness to work with the government to address environmental concerns.

### RESULTS OF RESEARCH ON PHYSICAL IMPACTS

The otter trawl is probably the most studied fishing gear type in history. Much of the research concerns the effects of the gear when it contacts the seabed, a subject that many acknowledge as being extremely difficult to study. Despite this difficulty, it is important to review some of the significant and/or representative studies in order to put into perspective the various conflicting statements with actual research findings. Furthermore, from a fisheries management perspective, NRC (2002) points out that it is both possible and necessary to use the available information, however rudimentary, to manage the effects of trawling on the seabed more effectively.

CSIRO and QDPI carried out five years of research on the environmental effects of trawling on the far northern Great Barrier Reef Marine Park (GBRMP) (CSIRO, 1998). The study covered 10 000 km<sup>2</sup> in an area closed to trawling since 1985, known as the Green Zone. The project surveyed the physical and biological makeup of the study area, conducted experiments to simulate the physical impact of trawling on seabed animals and plants, compared the biology of areas open to trawling with those closed to trawling, and investigated prawn trawl bycatch. Because this work represents the world's largest and most comprehensive study of the environmental effects of trawling and the first study on the effects of prawn trawling in the tropics, the results deserve special mention. With respect to the physical impacts of trawling, the research undertook a repeat-trawling experiment that indicated that a single trawl removes from 5 to 25 percent of the benthos, depending on the species. Repeated trawling has a cumulative effect; for example, around seven trawls over the same ground will remove about half the benthos. Although, over the last 20 years, 50 to 70 percent of trawled grids have been trawled only lightly each year, the cumulative effect is severe depletion of vulnerable types of fauna (i.e. those easily removed and/or slow to recover). This has probably caused substantial changes in the composition of the faunal community. The overall faunal biomass may have been reduced by about 20 percent and may now be dominated by "weedy" species (CSIRO, 1998).

Although concerns have been expressed over the methodology of the above CSIRO/QDPI research, in many respects it represents the state of knowledge gained from a study on the physical impacts of shrimp trawling in the tropics. It is interesting to note that the results of this particular study have been selectively used

both to support claims of vast destruction by trawlers (e.g. comparisons with forest clear-cutting) and to refute these claims.

Barnette (2001) considered approximately 600 studies on the fishery-related habitat impacts of fishing gear and subsequently carried out a major review of the fishing gear utilized within the Gulf of Mexico and off the southeast coast of the United States, and their potential impacts on essential fish habitat. With respect to otter trawling, the report concluded that the fishing method has the potential to reduce or degrade structural components and habitat complexity by removing or damaging epifauna, smoothing bedforms that reduce bottom heterogeneity and removing structure-producing organisms. Trawling may change the distribution and size of sedimentary particles, increase water column turbidity, suppress growth of primary producers and alter nutrient cycling. The magnitude of trawling disturbance is highly variable. The ecological effect of trawling depends upon site-specific characteristics of the local ecosystem such as bottom type, water depth, community type and gear type, as well as the intensity and duration of trawling and natural disturbances. Several studies indicate that trawls have the potential seriously to impact sensitive habitat areas such as submerged aquatic vegetation, hard bottom and coral reefs. In regard to hard bottom and coral reefs, it should be recognized that trawlers do not typically operate in these areas because of potential damage to their gear. However, during the last decade, as a response to decreased biomass on conventional grounds, technological innovations have been adopted that allow trawls to be used over very rough bottoms. Although trawl nets have been documented to impact hard coral reefs, typically resulting in lost gear, these incidents are usually accidental. Low profile, patchy hard bottom as well as soft coral (including cold corals) and sponge habitat areas are more safely accessible to trawls and therefore more impacted.

It may be concluded that trawls have a minor overall physical impact when employed on shallow, bare, sandy and muddy substrates (the three-dimensional fauna of which might have been eliminated decades ago), but the impact of this physical perturbation on the infauna and productivity merits further clarification (see Chapter 9). In addition, even if the local impact is easy to imagine and has been documented, the overall impact on regional ecosystem productivity (considering the patchiness of fishing) remains to be assessed. In general, few studies document recovery rates of habitat after trawl perturbation and those available did so only after a single perturbation, not reflecting the reality of ongoing and cumulative fishing impacts.

The NRC was asked by the NMFS to study the effects of bottom trawling and dredging on seafloor habitats. The review was conducted by 12 eminent specialists over a period of 18 months. The resulting report (NRC, 2002) was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. In summary, the report indicates that a complete assessment of the ecosystem effects of trawling requires three types of information: gear-specific effects on different habitat types (obtained experimentally); frequency and geographic distribution of bottom tows (trawl fishing effort data); and physical and biological characteristics of seafloor habitats in the fishing grounds (seafloor mapping). The report acknowledges the lack of much required data in the three areas. Within the limitation of the available data, the report concludes that:

- trawling and dredging reduce habitat complexity;
- repeated trawling and dredging result in discernible changes in benthic communities;
- bottom trawling reduces the productivity of benthic habitats;
- the effects of mobile fishing gear are cumulative and are a function of the frequency with which an area is fished;

- fauna living in low natural disturbance regimes are generally more vulnerable to fishing gear disturbance;
- fishing gears can be ranked according to their impacts on benthic organisms; and
- benthic fauna can be ranked according to their vulnerability.

An overall management-related conclusion is that available data are not sufficient to optimize the spatial and temporal distribution of trawling and dredging to protect habitats and sustain fishery yields.

In a report prepared at FAO's request, Løkkeborg (2005) examines the impact of trawling and dredging by reviewing published studies. Major emphasis was placed on critically examining the various methodologies used. The report promotes the concept that few general conclusions can be drawn regarding responses of benthic communities to the impacts of trawling disturbances.

*This lack of knowledge is due to the complexity and natural variability of these communities, and to the fact that it is very difficult and demanding to conduct studies of them. With respect to the methodology used by previous studies, trawl impacts are investigated either by conducting experimental trawling and assessing the responses of the benthic community, or by using historical effort data and comparing fishing grounds that are subjected to low and high fishing intensities. The former approach provides exact data on the disturbance regime, but does not replicate real fisheries, whereas the latter method seldom provides suitable control sites.*

Although there are many differences, the research cited above and several other studies seem to agree on a few topics. Most researchers in this field would agree that it is difficult to design and implement studies on the physical impact of trawling gear that could lead to clear conclusions. Other apparent sources of agreement include the following.

- The various researchers studying the physical effects of trawl gear tolerate very different levels of inconclusiveness in their results, conclusions, and proclamations.
- The impacts of trawling depend on many factors, principally bottom type, water depth, community type and gear type, the frequency and intensity of trawling, and concurrent natural disturbances. The habitats least affected are those with soft substrates and areas affected by natural impacting forces such as wave action. Hard bottoms with large sessile organisms seem to be most affected.
- It is especially difficult to come to conclusions concerning recovery rates of trawl-disturbed habitats.

The considerable research on the physical impacts of trawling has yielded mixed results with different degrees of reliability. Many areas of debate remain and more research is needed. In a different sense, the level of concern and advocacy associated with this issue can be conducive to consensus-building. The situation is not uncommon in environmental impact analysis and has led to the adoption of the precautionary and adaptive approaches as a means to proceed towards management while minimizing risk to the ecological system and the human communities depending on them.

In his review of the physical impacts of fishing gear, Hall (1999) stressed that "putting experimental results into the appropriate context will always be difficult". An important issue arising from available knowledge is the ways and means to incorporate it into the fisheries management process, given its uncertainty. Johnson (2002) cites five reviews: Kenchington, 1995; Lindeboom and de Groot, 1998; Watling and Norse, 1998; Gray, 2000; and NRC, 2002 to support the contention that since some negative impacts from mobile fishing gear are likely to occur, management decisions need to be made without waiting for more scientific evidence. The precautionary approach adopted by FAO precludes waiting for definitive conclusions before taking action when a clear risk has been identified. The ecosystem approach also adopted by FAO offers the framework needed to research while managing, using planned experiments in an adaptive and participative process of decision-making.



## MITIGATION

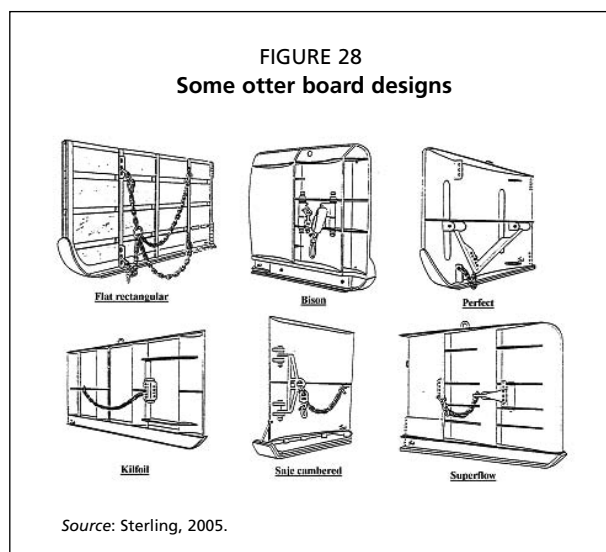
There are many measures, both applied and proposed, to reduce the physical effects of trawling. The report by the National Research Council (NRC, 2002) presents the most common interventions. It states that the effects of trawling should be managed according to the specific requirements of the habitat and the fishery through a balanced combination of the following management tools.

- *Fishing effort reductions.* Effort reduction is the cornerstone of managing the effects of fishing, including, but not limited to, effects on habitat. Both of the other management tools (gear restrictions or modifications and closed areas) can also require effort reduction to achieve maximum benefit. The success of fishing effort reduction measures will depend on the resilience and recovery potential of the habitat.
- *Modifications of gear design or gear type.* Gear restrictions or modifications that minimize bottom contact can reduce habitat disturbance. Shifts to different gear types or operational modes can be considered, but the social, economic, and ecological consequences of gear reallocation should be recognized and addressed. In shrimp fisheries with output controls, more efficient gear could lead to less fishing and less contact with the seabed.
- *Establishment of areas closed to fishing.* Closed areas are necessary to protect a range of vulnerable, representative habitats. Closures are particularly useful for protecting biogenic habitats (corals, bryozoans, hydroids, sponges, seagrass beds) that are disturbed by even minimal fishing effort. Because area closures could displace effort to open fishing grounds, effort reductions could be necessary in some cases to reduce habitat effects.

In addition to the common categories above, other mitigation measures are often mentioned in the literature. Total bans on trawling have been proposed, but implemented in only a few countries (discussed in Chapter 12). There is considerable mention of market-based methods, such as certification by the MSC. These are based on the premise that some consumers wish to buy marine products that do not contribute to destructive practices, which may result in higher prices for products that come from fisheries that, for example, do not have negative impacts on the sea bottom. Another mitigation mechanism is zonation, which allows for fixed gear-only areas in which trawling and other mobile gear are prohibited.

Kennelly and Broadhurst (2002) discuss the gear technology approach to mitigating physical impacts. They state that an alternative to management strategies such as closures involves the development of new technologies that reduce the impacts of fishing on ecosystems – similar to those to reduce bycatch problems. Recent trawl gear innovations to reduce physical impacts have emphasized otter board design to some extent. Sterling (2005) states that otter boards are responsible for much of the physical interaction with the sea bottom and, consequently, the gear technology approach to mitigation is largely focused on improving the performance of the boards. Figure 28 shows various otter board designs. Other shrimp trawl otter boards are designed to “fly” over the bottom. The use of canvas boards, popular some years ago, is being revived. Other gear-type physical impact mitigation measures include:

- the use of electric impulses to reduce the amount of tickler chains required;
- the use of drop chains, rather than weights integrated into groundrope, to reduce contact of the ground gear with the seabed;
- the use of wheels on the groundrope to reduce abrasion on the seabed;
- the use of semi-pelagic shrimp trawls in the Gulf of Maine and Newfoundland in which much of the gear is kept off the bottom (boards, lower bridles); and
- the proposed use of artificial reefs that would interfere with trawling to protect sensitive seagrass areas in Cambodia.



Some observations can be made on the various measures to mitigate the physical impacts of trawling. There appears to be considerable faith in the possibility of developing an alternative to shrimp trawling and trawling in general, especially among environmental groups. The reality is that, despite this interest, no substantial progress has been made in replacing trawl gear and, after nearly a century, it remains the main producer of the important commercial shrimp species. On the other hand, some feel that a total shrimp trawl ban could provide a powerful incentive to develop such gear (J. Clay, WWF, personal communication, 2006).

There is considerable advocacy on the part of environmental groups to ban trawling in especially vulnerable areas. Hall (1999) takes the issue further, stating that "... it is incumbent upon us to identify, not only sensitive areas, but also areas for which concerns are fewer".

Some of the more important mitigation mechanisms (e.g. effort reductions, protected areas) are also associated with management of other main areas of concern regarding shrimp trawling, such as bycatch/discards and impacts on biodiversity. This appears to provide additional justification for their implementation.

### IMPACT ON BIODIVERSITY

Biological diversity is often defined as the variety of life in all its forms, levels and combinations, and includes ecosystem diversity, species diversity and genetic diversity. The important relationship between biodiversity and fisheries is emphasized by the attention given to it in the FAO Code of Conduct for Responsible Fisheries. With respect to biodiversity, the Code states *inter alia* that biodiversity of aquatic habitats and ecosystems be conserved and endangered species protected; and selective and environmentally safe fishing gear and practices be further developed and applied, to the extent practicable, in order to maintain biodiversity and to conserve population structure and aquatic ecosystems as well as to protect fish quality.

Biodiversity is an important issue in shrimp fishing; it is often claimed that shrimp trawling significantly reduces it. The fact is that shrimp are short-lived. Many species of the same assemblage have longer life cycles and are therefore more vulnerable to a fishing effort than would be sustainable for shrimp. This raises the issue of sustainably managing a mix of species with different ecological resiliencies (Sainsbury, Punt and Smith, 2000).

While it is obvious that indiscriminate trawling can easily threaten biological diversity (vulnerable species, endangered species, corals, sponges), the conclusions of some targeted research are often less than clear. From 1996 to 1999, research was carried out in the north of Australia on the ecological sustainability of bycatch and biodiversity in shrimp trawl fisheries. The Northern Prawn Fishery Management Advisory Committee (NORMAC, 2002) summarizes the results of a study in Australia involving shrimp trawling in the tropics, which is especially illustrative in this regard.

*The vertebrate bycatch community was compared between areas open to trawling and areas that have been protected for 15 years, in the western Gulf of Carpentaria. If trawling had a large impact on biodiversity, we would expect to see fewer species, lower catch rates and smaller individuals in the open areas. This was not the case; there was no consistent difference in the number of species between open and closed areas*

or in catch rates between open and closed areas. In general, the mean size of species was greater in the open areas. Although the results were equivocal with respect to the impact of trawling on biodiversity, this does not imply that trawling has no impact. Any differences between open and closed areas may be reduced by the low commercial effort in the open area, aggregated trawling, potential trawling in the closure, and the mobility of species. This, combined with high natural variation, may obscure any impacts of trawling.

In this particular study, which was carried out in a country that has high scientific capacity, the simple change in the number of species proved problematic to study and highlights the difficulty in gauging the impacts of shrimp trawling on species diversity beyond the obvious impact on elevated structures. The comprehensive review by Løkkeborg (2005) also stressed the inconclusiveness of many similar analyses. The assessment of the impact on other components of biodiversity such as ecosystem and genetic diversity seem even more elusive. While the overall quality of the analyses might not always be adequate, some comprehensive and convincing analysis is available. The northwest shelf of Western Australia, for instance, provides a well-documented example of the impact of the demersal trawl fishery on the ecosystem. Sainsbury *et al.* (1997) show a 15-year decrease in *Lethrinus* and *Lutjanus* fish species and a change in the fish species composition and economic value of the community as a result of a complete erosion of their habitat by intense trawling. As a consequence, even though the original state of most fishing grounds is often unknown, the global scale of trawling and the available evidence of physical impact on hard bottoms and tridimensional faunas, and the impact of fishing on the food chain are such that Løkkeborg's review conclusions are not universally accepted (Sheppard, 2006; Gray *et al.*, 2006).

Considering this situation, Enticknap (2002) makes an appropriate observation that is applicable to many trawl fisheries: the debate over the effects of bottom trawling is shifting away from whether or not it reduces marine biological diversity and habitat complexity and now focuses on where and to what degree the reduction in diversity is socially acceptable.

Reconciling the various points of view is essential in order to progress with enough scientific and social legitimacy. But it is most important to underline the fact that, even in the absence of global consensus, guidance is indeed available on how to proceed on a case-by-case basis, using the precautionary and ecosystem approaches to fisheries and, more specifically, the environmental impact assessment and the risk assessment methods that they provide.



# 11. Interactions between large- and small-scale fisheries

## IMPORTANCE OF THE INTERACTION

Large- and small-scale fisheries interact in many ways, resulting in synergies as well as conflicts. Synergies may appear, for instance in the development of land-based infrastructure and the market, which facilitates small-scale fisheries development and profits in the wake of industrial development. Sources of conflict are numerous and generally relate to competition for resources and space. Synergies are usually ignored. Conflicts tend to be more visible (sometimes violent) and therefore better known. A recent report of the World Resources Institute (Kura *et al.*, 2004) reviews the major fisheries dilemmas of the world and asserts that in marine environments, the most documented conflict between large- and small-scale fishers occurs when industrial trawlers encroach upon near-shore fishing grounds where small-scale fishers operate. For shrimp fishing, the situation is especially difficult. Garcia (1989) states that shrimp fisheries are the major source of fisheries conflict and problems in the tropical zone.

Numerous cases of conflicts generated by shrimp trawling can be cited. Indeed, many of the international campaigns against the negative aspects of trawling focus on the interactions of this gear with small-scale fisheries. Box 22 is from the pamphlet “Squandering the seas: how shrimp trawling is threatening ecological integrity and food security around the world”.

### BOX 22

#### Some trawl conflicts with small-scale fisheries

In the Bay of Bengal, as a result of sustained (but not sustainable) shrimp trawling, the numbers of higher-value species such as red snappers, groupers and large croakers have fallen, leaving artisanal and subsistence fishers struggling to sell lower-value fish. Some can no longer make a living from fishing. Given that the fisheries sector contributes about 78 percent of animal protein intake in Bangladesh, coastal communities may well suffer from lowered dietary protein in the long term. In the Philippines, the encroachment of trawlers into prohibited zones has resulted in uneven catch and income for small-scale and subsistence fisheries. Equally striking stories come from the Bolivarian Republic of Venezuela, where growing shrimp trawling fleets often illegally fish in shallow coastal areas that had been reserved for artisanal fisheries. Again, these waters often serve as nursery sites for commercial species. Similarly, fishing for shrimp in equivalent zones in Cameroon has resulted in high bycatch of juvenile fish, causing conflict between trawlers and artisanal fishers. Shrimp trawlers not only remove fish biomass, but also damage local people’s fishing gear, especially when it is fixed to the seabed (such as fish traps). This causes intense antagonism since fishers lose equipment needed to sustain their livelihoods.

Source: EJE, 2003b.

## TYPES OF INTERACTIONS

Large-scale shrimp fishing, predominantly trawling, interacts with small-scale fisheries in several ways which, together with the associated impacts, includes the following.

- *Physical interactions.* Small-scale fishing gear may be destroyed by larger trawlers. For example, in Cambodia, much of the trawling is done illegally in areas where there is considerable small-scale fishing activity. Thus, trawlers often destroy the small-scale fishing gear and do not pay compensation to the fishers (Sour, 2005).
- *Sea safety.* Collisions between industrial shrimp vessels and small craft are a major cause of fatal accidents in small-scale fisheries. This is especially prevalent in West and East Africa (Båge, 2003a; Nageon de Lestang, 2007).
- *Targeting the same resources.* Various scales of fishing often compete in many regions. In most tropical countries, sequential fishing takes place at various stages in the shrimp life cycle (e.g. postlarvae, subadults, adults, mature females) in different environments, using different fishing gear and scales of fishing. As a result, there is a strong interaction between shrimp fisheries operating in the open sea, the bays and the estuaries (INP, 2000). In San Miguel Bay, the Philippines, for example, there are intense economic interactions between scales of fishers targeting the same resources: trawlers consisting of 89 units and belonging to only 40 households obtain 85 percent of pure profit, 42 percent of catch value and 31 percent of the total catch in the San Miguel Bay Fishery. The rest goes to 2 300 small-scale fishing units owned by 3 500 households and employing about 5 100 fishers (Silvestre and Pauly, 1997).
- *Interaction through bycatch.* The large bycatch characteristic of shrimp trawl fisheries is often a target of small-scale finfish fisheries (see Part 2, Nigeria).
- *Habitat disturbance.* Trawls, particularly when operating illegally close to the shore, can cause significant disturbance to the seabed. In Southeast Asia, trawling is held responsible for much of the degradation of seagrass areas, which are crucial for juveniles of species important to coastal fishers (Department of Fisheries, 2005).
- *Market interactions.* These can occur when industrial-scale shrimp fishing operations offload large quantities of shrimp and finfish on local markets and depress prices. In some countries (e.g. Papua New Guinea), this is the justification for not requiring the landing of bycatch from shrimp trawling ashore.

To be fair, it should be noted that not all negative interactions involving shrimp fisheries concern powerful industrial operators impacting weak small-scale fishers. Some of the small-scale shrimp fisheries (e.g. push netting in Southeast Asia) are likely to have major negative effects on other small-scale fisheries, either through habitat destruction or catches of juvenile fish. In some countries, there is a contention that small-scale shrimpers who catch juvenile shrimp in inshore areas negatively impact medium- and large-scale operations and markedly reduce the overall value of the fishery. Nageon de Lestang (2007) reports that in Madagascar, a major cause of accidents at sea is collisions between shrimp trawlers and small artisanal vessels with no lights, even though regulations require them.

In some cases, a symbiosis between scales of fishing occurs. Much of the bait shrimp for small-scale recreational fishing in some countries comes from large-scale operations. In the Gulf of Mexico, about 2 200 tonnes of shrimp for bait are caught each year. Large-scale shrimp trawlers often sell their bycatch to small-scale fishers at sea for resale ashore.

There are several other aspects of the impacts of large-scale shrimp fishing. In developed countries, the issue often concerns the impact on recreational fisheries, rather than on small-scale commercial or subsistence fisheries. The scales of fishing that interact are relative: the vessels used in the small-scale shrimp fisheries of coastal Norway are much larger than, for example, the shrimp trawlers of Southeast

Asia (Figure 29) that are causing many of the problems with small-scale fisheries. Another notable aspect is that, despite the worldwide significance of these shrimp fishery interactions, careful analysis of conflict situations is not a prominent feature of shrimp fishery literature. One of the few exceptions is the trawl ban in Indonesia (Box 23). The ban was imposed primarily to reduce the impacts of trawling on small-scale fishing and has been extensively analysed.

#### MITIGATION OF NEGATIVE INTERACTIONS

The management of fisheries in general can have a number of different objectives. The role that conflict reduction plays as a management objective in shrimp fisheries

is relatively large, much of which concerns the negative interactions between large- and small-scale fishing operations. This is not surprising considering the inherently political nature of the fisheries management process and the amount and type of conflict generated by shrimp fishing. As expressed by one Asian shrimp industry participant, “suboptimal shrimp resource use often gets a yawn, but violence between fishers gets the politicians moving”. Bailey (1997) reports that in Malaysia, small-scale fishers responding to being pushed out of their traditional fishing grounds in the 1970s sunk over 60 boats and killed 23 fishers. He also reports that in Indonesia’s Malacca Straits, the favourite weapon of small-scale fishers was the Molotov cocktail, which proved quite effective against wooden-hulled trawlers. “In the final analysis, it was the willingness of small-scale fishers to resort to violence that prompted decisive action on the part of the Indonesian Government.”

A number of management interventions are used to mitigate conflict generated by shrimp fisheries. To reduce the physical impacts of large-scale shrimp fishing on small-scale operations, the most common measure is simply to move the large boats offshore. The measure tends to be ineffective and not complied with when offshore resources are already depleted by chronic overcapacity. Nonetheless, in West Africa, nearly all countries have passed laws giving artisanal fishers exclusive fishing rights to coastal waters within a fixed distance from the shore (1–12 nautical miles, depending on the country), and have prohibited industrial trawlers from operating in these waters (Kura *et al.*, 2004). Båge (2003a; 2003b) proposes the installation of artificial reefs that physically hinder trawling in prohibited areas.

Other measures are used to mitigate impacts on small-scale fisheries. Seasonal “time-sharing” of fishing grounds off Florida has been used as a partial solution to the conflict between shrimp trawlers and trappers fishing for stone crab and blue crab: trawl nets bring up traps and entangle trap buoy lines (Cascorbi, 2004b). When conflicts involve competition for resources, they can be reduced by stricter requirements for BRDs and mesh sizes. Schemes that reduce the fishing effort of the larger fishing operations can be an effective mitigation measure.

There is a general feeling among fisheries managers in several regions of the world that the various approaches mentioned above for reducing negative interactions would be effective if enforced. The irony is that, in the developing countries where the conflicts generated by shrimp fishing are the greatest, the required enforcement is the weakest. One of the more extreme examples of weak enforcement comes from Cambodia.

*To reduce conflict between trawlers and small-scale fishers in Cambodia, the fishery law bans trawling in the area between the shore and the 20-m isobath. A major difficulty*

FIGURE 29  
Small-scale trawlers in the Gulf of Thailand



## BOX 23

**Origin and outcome of the Indonesian trawl ban**

Butcher (2004) indicates that the conflict and even violence generated by shrimp trawlers were greatest along the north coast of Java, because shrimp was concentrated relatively near to shore, and because so many fishers depended on these waters for their livelihood. During the 1960s and 1970s, the government introduced a multitude of regulations to restrict the number of trawlers and to prevent them from operating within various distances from shore, but these proved ineffective for various reasons. In 1977, fishers in seven sailboats attacked a trawler operating off the east coast of Sumatra and killed its captain; there were similar clashes on the south coast of Java.

In July 1980, following many unsuccessful attempts to restrict trawling, President Suharto issued a decree banning trawling from the waters surrounding Java and Bali as of October of that year, and from the waters surrounding Sumatra as of January 1981. As the Director-General of Fisheries explained, the banning was a “political decision”, made with the “aim of reaching social peace and stability by providing better protection to poor traditional fishermen masses”. The All-Indonesia Fishermen’s Association, a functional group within the Golkar, the government’s main electoral vehicle, had put considerable pressure on the government to ban trawling. At the same time, many in the government believed that various programmes to help improve the welfare of fishing communities would be in vain unless the resources on which they depended were protected from trawlers. Unlike earlier attempts to restrict trawling, issued as ministerial decrees, the ban carried the full weight of the President and the military. Moreover, it was much easier to enforce a total ban on trawling than to restrict it. Anyone operating a trawl could no longer claim to have been fishing outside areas where trawling was restricted.

Chong *et al.* (1987) and Bailey (1997) summarize the outcome of the trawl ban. The immediate impact of the ban was seen in the reduction of violence, loss of human lives, property destruction and tension in the coastal areas and at sea. This in itself was very positive for a country such as Indonesia, which places a high value on peace and coexistence. However, close to 25 000 trawl fishers (owner, captain and crew) were immediately thrown out of work because of the ban. The aggregate income foregone at the minimum was Rp462.5 million, or US\$1.11 million per month (US\$13.4 million per year). The government realized the economic hardships confronting the displaced fishers and took the necessary actions to soften the impact of the ban in the form of a large credit programme for trawl crew fishers to purchase new boats and nets; much of the credit was used in already overexploited inshore areas. There was also an immediate interruption in shrimp and fish landings in Indonesia: a 5 percent drop in shrimp landings and a 22-percent drop in shrimp exports.

Bailey (1997) also noted the impact on small-scale fishing. Following the ban, there was a rapid increase in the number of small-scale enterprises. Despite this growth, demersal stocks increased dramatically from 1980 onwards and landings in the Malacca Straits increased by 124 percent over the 1980–93 period. With the elimination of trawlers as a source of supply, shrimp exporters increased their efforts to collect shrimp from scattered rural fishing communities. Prior to 1980, many shrimp exporters had little incentive to seek sources of supply among small coastal villages; it was far easier to take delivery of large volumes of shrimp brought to the exporter’s dock by a trawler. After 1980, however, shrimp packers/exporters quickly established marketing channels into rural areas. These efforts by the private sector were complemented by government credit programmes to motorize small-scale fishing boats and to purchase gear specifically designed to exploit demersal resources.



*arises because most of the trawlers are relatively small and are unsuitable for use in offshore areas. This results in a situation where most of the trawling is done illegally in areas where there is considerable small-scale fishing activity. This is the major source of conflict between groups of marine fishers in Cambodia. Despite the fact that inshore trawling is clearly illegal, the Department of Fisheries is reluctant to enforce the ban due to various reasons, including the perceived financial difficulties it would cause the operators of trawlers (Gillett, 2004).*

In recognition of the difficulties of enforcing spatial separation, a number of countries have opted for the bolder measure of complete trawl bans in order to reduce trawl-generated conflict. The Indonesian example in Box 23 is perhaps the most notable example, but other countries have such bans covering smaller areas.

Another avenue to improve enforcement is given by the Environmental Justice Foundation (EJF, 2003). In Margarita Island, the Bolivarian Republic of Venezuela, local fishers have claimed that their catches have increased significantly since the implementation of a new fishing law, which has raised fines for shrimp trawlers caught illegally within six nautical miles of the coastline. Juvenile fish are now being given the opportunity to reach commercial size and replenish local stocks.

A more fundamental mitigation measure (and one that does not rely on non-existent enforcement) is to strengthen the political power of fishers negatively affected by large-scale shrimp fishing. This was indeed the driving force behind the Indonesia trawl ban (Chong *et al.*, 1987; Bailey, 1997). In March 2005, Madagascar cooperative management zones were created with the objective of reducing conflict generated by large trawlers in inshore areas. Although the management zone scheme was an initiative of the trawlers, the catalyst for action was the concern that any open conflict between the different shrimp fishery subsectors would probably be resolved in favour of the traditional fisheries, as a result of the prevailing political and social environment.



## 12. Management of shrimp fisheries

### GENERAL

*Most shrimp fisheries throughout the world face similar problems. The stocks are fully exploited, with little opportunity of increasing total catches. Fishing effort continues to increase, giving rise to serious economic or social problems even when the stocks themselves may be in no danger.*

This remark was made in 1981 by the keynote speakers at a major international meeting on the management of shrimp fisheries (Gulland and Rothschild, 1984), but the comment is still applicable today. In the last 25 years, much has been learned about the biology of shrimp and its reaction to regulatory interventions, but many problems relating to the management of shrimp resources remain.

In the various shrimp fisheries of the world today, there are considerable differences in the quality of their management. For some shrimp fisheries, management is state of the art and used to demonstrate the benefits of effective conventional fisheries management. Conversely, some important national shrimp fisheries are textbook examples of how unmanaged fisheries can dissipate benefits. Box 24 compares two vastly different management regimes.

The Spencer Gulf-Cambodia comparison is somewhat imbalanced in that it contrasts what is probably the best example of shrimp fishery management in a country that has characteristically strong institutional governance in the fisheries sector with what goes on in an extremely poor nation. Nevertheless, it emphasizes the huge range in outcomes when a shrimp fishery is effectively managed.

### MAIN SHRIMP FISHERY MANAGEMENT ISSUES IN THE TEN STUDY COUNTRIES

In this study, a number of countries were chosen to be representative of various geographic regions, as well as the variety of important shrimp fishing conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. The major shrimp fishery management issues of the ten countries examined in Part 2 are summarized in Table 15.

In brief, the issues encountered in the study countries reflect the whole array of issues characterizing fisheries management today: open access; overfishing; effort creep and fishing capacity control; low economic returns; insufficient research and management aggravated by low compliance; unsustainable management costs; bycatch reduction and other multispecies concerns; and conflicts between small- and large-scale fisheries for shrimp. A few more issues existing elsewhere have not clearly emerged from this sample, but could be mentioned: conflict between national and foreign fleets; conflicts with aquaculture; and the impact of pollution and other coastal developments on shrimp production, particularly in heavily urbanized estuaries and deltas.

### THE SHRIMP FISHERIES MANAGEMENT FRAMEWORK

#### Definition

An essential prerequisite for an analysis of shrimp fisheries management is a concise understanding of “fisheries management”. Many definitions of this term can be found in the literature. In the *FAO Technical Guidelines for Responsible Fisheries* (FAO, 1997), fisheries management is defined as: *the integrated process of information*

## BOX 24

**Effective and weak management of shrimp fisheries**

**Australia.** In October 1967, commercial shrimp fishing began in South Australia's Spencer Gulf and, in March 1968, a programme of restricted entry was introduced to prevent overexploitation of the resource and overcapitalization within the fishery. Today, the fishery has a limited entry consisting of 41 licence holders. The fishery is managed jointly by the government and industry through the Prawn Fisheries Management Committee headed by an independent chair. The fishers themselves take an active role in research by participating in stock assessments using their vessels and crew. Industry pays 100 percent of the attributable management and research costs through annual licence fees. Management measures include limited entry, gear restrictions, and temporary and permanent closures. These controls result in Spencer Gulf fishers enjoying a unique and enviable lifestyle – fishing only 55 to 60 nights per year. The fishery provides jobs for some 150 people on board vessels and a significant number of jobs in processing and support industries (Palmer and Miller, 2005).

**Cambodia.** The number of shrimp trawlers operating in Cambodia increased rapidly from the early 1990s, and today the 1 500 trawlers operating represent about 3.4 vessels per linear kilometre of coastline. For coastal fisheries in general, there are no formal management plans and the objectives of fisheries management must be inferred by the various legal instruments and past government interventions. Although the basic fisheries law prohibits trawling between the shore and the 20-m isobath, most small trawlers operate illegally in shallow inshore areas and cause substantial conflict with smaller-scale fishers. There is at present no legal mechanism in the fisheries law for limiting fish catches or fishing effort. Despite the lack of economic data on shrimp fishing, there are indications that both the profitability of individual shrimp fishing operations and the rent from the various shrimp fisheries are low, including: the open access nature of Cambodian coastal fisheries; poor enforcement of the few legal instruments for management; the rising coastal population; low barriers to participation; lack of non-fishing sources of livelihoods; the rising proportion of trash fish; and falling CPUE.

*Source:* Gillett, 2004.

*gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of other fisheries objectives.*

A definition of fisheries management developed specifically from practices in the shrimp fisheries was proposed by Gulland (1984) in his essay on shrimp fisheries management: "Fisheries management can be defined in a broad sense as the manipulation of factors to achieve societal goals from a stock of fish". The important elements of the Gulland definition are goals (or objectives) and associated manipulations (or interventions) in support of these goals. In many cases, the prevention or mitigation of the various problems associated with a particular fishery forms the management objectives for that fishery.

Shrimp fisheries management developed from the 1960s to the 1980s and, in general, needs to be adapted by taking into account the agreed framework offered by the 1995 FAO Code of Conduct for Responsible Fisheries and the FAO Ecosystem Approach to Fisheries (FAO, 2003b).

TABLE 15  
Main shrimp fishery management issues in the ten study countries

Country	Main issues
Australia	The management of shrimp fisheries is strongly affected by two general trends in Australian fisheries: a move to a "user pays" system where participants in each fishery are increasingly responsible for funding management, research and compliance costs that support the fishery; and the broadening of management away from a "single-species" approach to include more general ecosystem management issues. In many of the important shrimp fisheries, despite almost continuous management interventions and effort adjustments, overcapacity remains a problem – "effort creep" defeats capacity limits based on numbers of boats.
Cambodia	Considering the paucity of biological information on shrimp resources, the few legal instruments available for management of shrimp fishing, their poor enforcement, and the open access nature of all coastal fisheries in the country, the obstacles to deriving greater benefits from the shrimp fisheries by management interventions are indeed considerable.
Indonesia	The prevention of negative impacts of trawling on small-scale fishers is a dominant objective in the management of shrimp fisheries. The trawl ban to safeguard the interests of small-scale fisheries has been referred to as the boldest fisheries management intervention ever to be implemented in Southeast Asia, but it has been undermined by the renaming of trawl gear and poor enforcement. Protection of shrimp fisheries from overexploitation is a less prominent objective. With regard to the large amount of small-scale shrimp fishing, the open access nature of coastal fisheries in Indonesia makes it very difficult to restrict fishing effort.
Kuwait	The present low catches, high level of effort and low CPUE seem to indicate that shrimp stocks have been overexploited since 1993. Although shrimp fishing overcapacity has been generally recognized for some time and there has been an attempt to halt its increase, the number of industrial fishing vessels was allowed to increase in the mid-1990s.
Madagascar	The main issues are: (i) the protection of the interests of the traditional shrimp fishers from negative interaction of industrial/artisanal shrimp fishing, with appropriate consideration given to the benefits to the national economy from larger-scale operations; (ii) the control of effort increases in the traditional shrimp fishery; and (iii) the importance of reconciling the need to reduce bycatch with the economic benefits of selling bycatch.
Mexico	The main issues are: (i) the declining CPUE and overcapacity in many of the shrimp fleets; (ii) improvement of shrimp fishing profitability, which may require structural adjustment, but whose effort restrictions face strong resistance from fishers; and (iii) management of the interactions between the three different types of shrimp fisheries in Mexico (high seas, bays, estuaries), which often equates to allocation of shrimp resources among very different groups of fishers.
Nigeria	A major issue is the interaction between large- and small-scale shrimp fishing, including the encroachment of industrial shrimp trawlers into areas reserved for small-scale fishing, and the competition for the same fishery resources. Another important issue is the current low profitability of commercial shrimp fishing caused by piracy, falling catch rates and increasing fuel costs.
Norway	Important issues are: (i) the "discard ban" for all commercially important species, which results in the need to avoid cod and other important species; (ii) the need to avoid capture of undersized shrimp; and (iii) the current low profitability of most shrimp fishing operations.
Trinidad and Tobago	There is a high incidental fish catch associated with shrimp trawling, causing considerable conflict between the trawl fishery and other fisheries in the country. Other areas of concern are the full or overexploited condition of shrimp stocks as well as that of bycatch, the high levels of bycatch/discards and the degree of overcapitalization in the trawl fishery. There is a great need to reduce shrimp fishing effort, but a lack of political will and legal tools to do so.
United States of America	There has been increased attention paid to overcapacity in the various United States shrimp fisheries. Many problems facing shrimp fishery managers result from the use of an open access management regime that ignores economic efficiency criteria and implicitly stresses economic impacts in the form of state revenues from licence sales, taxes and low-paying jobs. Other important issues are a decrease in recent profitability in the industry as a result of overcapacity and growing environment concerns.

Source: based on Part 2.

### Ranking objectives

Successful fisheries management is characteristically based on a clear definition of objectives and their ranking. Prioritizing management objectives is a central responsibility of fisheries governance. Staples, Satia and Gardiner (2004) stress that: *policy is the starting-point that sets out the broad objectives and framework to guide relevant decisions, actions and institutional arrangements impacting on small-scale fisheries. It should be recognized that policy is required to address many, often competing, objectives that relate to the conservation and sustainable use of resources, and to economic and social (equity) needs. The main issue is that policy is often poorly articulated both within and outside of the fisheries sector.*

In the various shrimp fisheries around the world, a wide variety of management objectives have been explicitly adopted to various extents. Garcia (1989) states that the long-term conservation of the resource is usually given top priority, at least

rhetorically. Maximum economic yield is an important objective in the management of many shrimp fisheries. Maximum sustainable yield is also common, with Indonesia being an important example. Reduction of bycatch/discards and physical impacts are becoming increasingly important objectives, especially in developed countries. Chapter 11 stresses the significant role that social peace (through conflict reduction) plays as a management objective in shrimp fisheries, especially in developing countries. Achieving an equitable and sustainable allocation of shrimp resources between the various users is important in the penaeid fisheries because of the movement of shrimp between shallow inshore areas and deep offshore areas. Maximizing employment is sometimes the de facto most significant management objective in some of the poorer countries. Generation of government revenue is often an unstated objective in the management of shrimp fisheries in countries ranging in development from Cambodia to the United States.

Garcia (1989) and Gulland (1984) recognize both the importance of and the difficulty in prioritizing and balancing shrimp fishery management objectives.

- *It is generally recognized that the ranking of shrimp fisheries management objectives are rarely clearly defined in reality and at best expressed as a list of broad and often conflicting goals. Ideally, management in this context must offer mechanisms allowing acceptable compromises on basic objectives (Garcia, 1989).*
- *There is unlikely to be a magic formula to enable balancing objectives. Managers must accept that they are pursuing multiple objectives. Policies must be chosen to achieve some acceptable and balanced degree of progress towards the objectives as a whole. The first step is to identify objectives so that they can at least be borne in mind when making decisions. In the ideal world, it might be possible to express all objectives on some common scale, or at least provide some quantitative weighting between different objectives. This is too much to ask – in practice, the choice must be made by a policy-maker, in light of national objectives and political/social pressure (Gulland, 1984).*

The above comments dating back over two decades on the underlying difficulties of prioritizing shrimp fishery objectives still remain valid today. It is difficult to rank the incongruous and conflicting objectives that are often set for shrimp fisheries. On a practical level, two common situations of objective ranking are especially problematic. One is the maximizing of economic yield in an open access regime. An important objective of open access shrimp fisheries, probably more common in the world than restricted access, is often maximizing employment. This is incompatible with the economic efficiency needed to generate maximum economic yield. The other difficult prioritization issue is the increasingly frequent situation of reconciling maximizing fleet profitability with minimizing bycatch and physical impacts on the seabed.

### Issue-based framework

Many different management frameworks can be considered:

- time – e.g. operational versus strategic;
- space – e.g. local, national, regional, integrated;
- resources – e.g. stocks, populations, ecosystems;
- sectoral considerations – e.g. large-scale, small-scale and cross-sectoral); and
- conventional dimensions of sustainable development – ecological, social (including cultural), economic and governance (including institutional).

In this report, it was found convenient to use an issue-oriented conventional framework for analysing the problems of shrimp fisheries, as provided by Poffenberger (1984). He establishes two broad categories of issues to be addressed by shrimp fisheries management: overfishing and issues not relating to overfishing. The latter category includes such considerations as bycatch/discards and physical effects on the seabed. The three types of overfishing problems addressed by Poffenberger are the following.

- *Growth overfishing*. Shrimp is harvested when individuals are small and growth is not yet completed, leading to a loss in total yield-per-recruit or yield. This type of overfishing is common in many of the world's shrimp fisheries.
- *Recruitment overfishing*. Spawning biomass and recruitment to the exploitable stock become significantly reduced because of the level of fishing. This type of overfishing, detected through a stock-recruitment analysis, is particularly difficult to identify in shrimp fisheries where the relation is blurred by significant environmental effects. In general, it seems that shrimp stocks are more driven by environmental oscillations than stock size, although reducing the stock to very low levels could cause recruitment to collapse without notice, particularly in the presence of adverse environmental conditions.
- *Economic overfishing*. The amount of fishing effort increases to the point where the fisheries operate beyond maximum economic yield. Under open access, fisheries can develop to the point that the rent is lost, profitability becomes negative and subsidies are needed to maintain the fisheries. This is a situation that threatens many or most of the world's shrimp fisheries.

Poffenberger (1984) concludes that penaeid shrimp fisheries tend to have more serious problems dealing with economic overfishing than other types of overfishing. The author did not, however, consider *ecosystem overfishing*, a situation widespread in shrimp fisheries, which occurs when the species composition and dominance are significantly modified by fishing, with reductions of large, long-lived, demersal predators and increases of small, short-lived species at lower trophic levels.

The above scheme for classifying shrimp fishery problems can be used to consider the common problems identified in earlier chapters of this report. Overcapacity-related problems include declining shrimp catches and some aspects of deteriorating profitability. Other problems, not related or indirectly related to overcapacity, include excessive bycatch/discards, physical impacts of shrimp fishing, other aspects of declining profitability, impacts on small-scale fisheries and other conflicts. The mitigation or prevention of these difficulties forms the objectives for the management of many shrimp fisheries. It should be noted that many of the "other problems" mentioned above would find at least a substantial solution in the reduction of excessive capacity.

Conventional shrimp fisheries management must be reconsidered in light of the FAO Code of Conduct for Responsible Fisheries and the related approaches, including the progress being made in the management of small-scale fisheries. Many of the issues mentioned above, particularly those of prioritizing objectives, call for more transparent and participative forms of management than those used conventionally for shrimp fisheries in the past. The overriding issue of introducing market incentives in the form of user rights needs to be seriously considered since limited entry and effort controls have demonstrated their limits. The complexity of shrimp fisheries as socio-ecological systems needs to be better taken into account, with a stronger application of social sciences and the adoption of adaptive management processes.

## MANAGEMENT INTERVENTIONS

The management issues encountered in the preceding sections relate to three interrelated central issues: capacity control, allocation and conservation. Allocation appears as the overriding issue since it conditions the control of capacity, the incentives for conservation and the level of compliance. All other issues (overfishing, poor selectivity, low economic returns, aggravated environmental issues), with few exceptions, tend to be subsidiary causes or consequences. A central problem of managing by solving recurrent crises, as opposed to planning to avoid them in the first instance, is the general tendency to lump consequences and symptoms together instead of dealing with root causes, resulting in ineffective governance.

Nonetheless, taking an issue-oriented approach – perhaps more familiar to managers, the variety of measures and interventions available for dealing with the most frequently mentioned goals are the following.

- *Economic overfishing.* Improvement of the economic performance of shrimp fisheries has been attempted by using catch limits, controlled access (limiting/reducing participation), restrictions on gear, stock enhancement, monetary measures (taxation of inputs, high licence fees, fractional licensing),<sup>15</sup> reduction/withdrawal of subsidies and buyout programmes. The infrequent use of market incentives (fishing rights) in shrimp fisheries is noteworthy.
- *Growth overfishing.* Improvement in yield and productivity has been attempted by reducing fishing effort and through technical measures such as closed seasons, closed areas, mesh size regulations and minimum landing sizes.
- *Discards/bycatch.* A reduction in the impact on biodiversity and of waste has been addressed by adopting BRDs and TEDs, larger mesh sizes, other net modifications (e.g. square-mesh, codend, fisheye), prohibition of certain gear, no-discards policies, temporary or permanent closed areas, limits on bycatch of particular species, unilateral trade measures, raising fishers' awareness and increased collaboration.
- *Physical impacts and other ecosystem damage.* This has been tentatively controlled by restrictions on the use of certain gear, gear design regulations (benthic-friendly trawl), closed areas (protected areas) and fishing effort reductions. Total bans on trawling have been proposed and adopted (as in the General Fisheries Commission for the Mediterranean), where the banning of all trawling beyond 1 000 m reduces impacts on deep-sea shrimp populations and habitats.
- *Conflicts between large-and small-scale fisheries.* These have been tentatively reduced by zonation schemes, BRDs, reduction of large-scale fishing effort, time-sharing of fishing grounds and, in some cases, total bans on trawling.
- *Resource allocation between groups of fishers.* This has been dealt with by closed areas, closed seasons, gear restrictions and mesh sizes. As noted above, the scarce use of market incentives (fishing rights) for resource allocation in shrimp fisheries is noteworthy.
- *Inshore nursery ground habitat degradation.* This has been attempted through closed areas, artificial reefs, integrated coastal zone development and control of mangrove exploitation and land reclamation, restriction of pollution and watershed management.

These management measures can be broadly grouped into input and output controls. Input controls act on the quantity and quality of the fishing inputs, e.g. restrictions of effort and capacity, gear restrictions and specifications and closed seasons. Output controls act on the quantity and quality of the fishing output, e.g. total allowable catches and quotas, and minimum landing sizes. Input controls are generally more common in shrimp fisheries, but in some of the highly regulated shrimp fisheries (e.g. the NPF in Australia), there is a movement towards complementing effort regulations with output controls, which aims at counterbalancing the effect of “effort creep”. Similarly, one of the world's largest shrimp fisheries in terms of volume, Canada's East Coast Northern Shrimp Fishery, is managed by limited entry and a total allowable catch (Box 29).

Input and output controls can be decided upon and implemented top-down, in the conventional and poorly effective manner, or in a participative manner. The latter

<sup>15</sup> A fractional licence programme reduces effort in a fishery by eliminating a portion of each licence and retaining the requirement for a full licence. For example, each licence for a fishery is converted to a half-licence and all fishers are required to buy another half-licence from another fisher in order to fish.



is strengthened if implemented within a decentralized system of decision-making or within a system of formal restricted use rights.

Some general comments should be made on the effectiveness of the above management measures. To be effective, an intervention must be capable of producing the expected result: to be efficient, it must do so at reasonable cost. Compliance with the measure is essential and relates both to the nature of the measure (e.g. its simplicity), how it is perceived by fishers (legitimate or otherwise) and how it is enforced (deterrence). Some measures are not very effective (e.g. mesh sizes to reduce the catch of undersize shrimp), some are inefficient (e.g. poorly implemented buy-back schemes) and others are difficult to enforce (e.g. gear restrictions/requirements for small-scale fishers). On a different level, the capacity of national institutions to manage has a great influence on the effectiveness of the various interventions.

Several of the management interventions mentioned above are discussed in other chapters of this report: interventions dealing with bycatch (Chapter 6), physical impacts (Chapter 10), and interactions with small-scale fishers (Chapter 11). Other measures such as the regulation of mesh sizes and trawl bans deserve particular attention.

### Mesh size regulations

Mesh sizes are regulated in most of the world's shrimp fisheries, both trawl and non-trawl. Although stipulating mesh sizes can have considerable value, it is not without problems. The main use of mesh sizes is for regulation of catch-age composition to prevent growth overfishing and optimize yield from a cohort. The principal problems of using mesh sizes are the following.

- (i) *Imperfect selectivity*. A wide range of shrimp sizes and species are often retained by a given mesh.
- (ii) *Difficult enforcement*. Dockside controls are easy in large-scale fisheries but less so in small-scale ones.
- (iii) *Easy to circumvent*. Fishers are clever at reducing the real selectivity of the mesh while apparently complying.
- (iv) *Perceived as illogical*. This occurs when the larger animals purported to be retained by the net do not exist in the fishing area or are extremely rare because of overfishing.

As a result, the use of "too small" mesh sizes is often a consequence and not a root cause of poor fisheries. Mesh size regulations would be more effective in a context of effective capacity control and not, as too often considered, as a replacement for it. An additional complication of mesh regulations is that most shrimp fisheries exploit a mix of shrimp species, and adjusting mesh sizes to the most profitable shrimp species leads to underexploitation of other shrimp species. Furthermore, for the protection of fast-growing juvenile shrimp, closed seasons and closed areas are generally thought to be more appropriate than mesh sizes (Garcia, 1989; Gulland and Rothschild, 1984; Iversen, Allen and Higman, 1993).

### Trawl bans

Although complete bans on trawling are not common at present, they are often promoted by environmental groups and have been occasionally implemented in the past. The use of trawls was prohibited in Flanders in 1499; the Dutch banned the use of trawls in 1583; and trawling was made a capital offence in France in 1584. In 1631 in Britain, the use of "traules" was prohibited (Fogarty, 2002). In more recent times, shrimp trawling has been banned on at least two occasions in Southeast Asia. In early 1964, the Malaysian Government banned trawling on the grounds that it would deplete the fish stocks in inshore waters and ruin the livelihoods of traditional fishers. The highly profitable nature of trawling, together with the need to increase landings to meet the growing demand for food, made it impossible to enforce the ban, which was

## BOX 25

**Lessons learned from the Indonesian trawl ban**

An important lesson learned from Indonesia's trawl ban appears to be that regulations that restrict trawlers from certain zones are far more difficult to impose than a complete ban, which can be enforced from shore at a limited number of fishing ports. Imposition of a gear ban is possible, but requires substantial political will. No other country has shown such resolve or ability to reallocate access to an important resource to small-scale fishers. A second important lesson learned is that demersal stocks in the tropics appear to be capable of rebuilding after being overexploited. A third lesson learned is that elimination of trawlers does not necessarily mean a long-term decline in either landings or exports. Small-scale fishers using relatively simple gear appear able to utilize demersal resources as fully as trawlers. This capacity is, of course, a two-edged sword, since eliminating trawlers will not solve problems of resource management. The need for rural and national development to attract labour and capital away from the fishery remains.

*Source:* Bailey, 1997.

lifted in October 1964 (Talib and Alias, 1997). In 1980, the Indonesian Government imposed a ban on trawling along the Malacca Straits and off the north coast of Java, and extended it nationwide in 1981. The trawl ban has been extensively documented and analysed (Butcher, 2004; Chong *et al.*, 1987; Bailey, 1997). The original objective of the ban, reduction of negative impacts of trawling on small-scale fishers, was accomplished (Chapter 11), but its effectiveness has decreased over the years by renaming trawl gear and poor enforcement. Bailey (1997) reviews the ban and extrapolates some lessons learned for other developing countries in the region (Box 25).

**OPEN AND LIMITED ACCESS**

A fundamental problem of many of the world's shrimp fisheries is open access – the right for the entire public to participate in a fishery. In general, if there are no barriers to entry, fisheries typically end up producing to the point where total revenue equals total costs (profitability shrinks to zero) and beyond if subsidies are provided. The history of shrimp fishery management shows that management interventions (e.g. catch limits, closed seasons) that do not address participation are usually ineffective at preventing overcapacity and economic overfishing in the long term.

Limiting access is often difficult but, if implemented in the early stages of a fishery, the transition can be less expensive and more effective. Two examples illustrate the difference. In 1967, commercial prawn fishing began in South Australia's Gulf of St Vincent. Limited entry was introduced in 1968 and participation in the fishery was further reduced in 1987. Indicators show that the management objectives of "optimizing economic returns to stakeholders" are being achieved (Zacharin, 1997). In Texas, United States, shrimp fishing developed rapidly after 1920 and in the 1930s a closed season and gear restrictions were implemented, but increased participation in the fishery created economic problems for the shrimp fleets. To improve the economic performance of the shrimp fishing, in 1995 the Texas Legislature enacted the first bay and bait shrimp vessel licence limited entry programme. Since the implementation of the licence buy-back programme, the Texas State Government has purchased and retired 815 commercial shrimp boat licences (422 bay and 393 bait) at a cost of approximately US\$4.3 million. This represents 25 percent of the 3 231 licences of 1995. Since the buy-back programme was not entirely successful at restoring profitability, additional management measures were implemented in 2002 (TPWD, 2002).

In a comprehensive study of the economic problems experienced by the United States shrimp fleets in the Gulf of Mexico and off the southeastern coast (Ward *et al.*, 2004), a number of options for improving profitability were offered. A notable point is that the study concluded that “none of these options would provide the estimated improvement in present value or profitability for the fishing fleet if some form of limited entry is not adopted”.

Garcia (1989) reviews other considerations of limiting access. He stresses the advantages of limited entry in shrimp fisheries, but notes some complications. One of the most controversial features of limited access is, ironically, that it may generate large rents. If these rents accrue to fishery participants, social tension can be created. Another difficulty with limited entry is that it tends to transfer excess effort into neighbouring fisheries or stocks, creating a need to restrict access at those locations (a domino effect). Limited entry management is considered more challenging and dependent on community- or territory-based strategies for small-scale fisheries, especially in developing countries where identification of eligible fishers and exclusion of others are difficult and where numerous practical problems arise in enforcement.

One mechanism for limiting entry into a fishery consists of the government granting a long-term right to participate in a fishery to a restricted number of fishers, allowing them to transfer the right to fish to others. This effectively creates a property right that assumes tradable value. Since this value can increase, should the profitability of the fishery increase, the participants have an interest in the effective management of the fishery. The use of such property rights is becoming increasingly common in the management of shrimp fisheries.

## MANAGEMENT OF SMALL-SCALE SHRIMP FISHERIES

The vast majority of success stories in the management of shrimp fisheries come from medium- and large-scale fishing operations in developed countries. In the literature, cases of successful management<sup>16</sup> of small-scale shrimp fisheries in developing countries are not common in modern times. An important issue is whether, under the present management systems, small-scale fisheries can indeed be managed to prevent overfishing, reduce discards and avoid environmental damage while achieving other livelihood objectives.

There are several perspectives on the small-scale shrimp fisheries management challenge, most of which are conditioned by the various national circumstances. Some of the ideas are the following.

- *“Laisser-faire” strategy.* Because the management of small-scale shrimp fisheries is considered extremely difficult or unrealistic, it has been suggested that management attention should be focused on the larger scales of fishing. As one fishery manager put it: “Don’t attempt to manage the unmanageable”. The implication of this strategy is that it is hoped that the worse will not happen but that, if it does, small-scale fisheries will have enough resilience to adapt.
- *Transfer of benefits.* An alternative view is that in cases where large-scale shrimp fisheries take most of the shrimp catch, they should be managed for the benefit of the mainly disadvantaged small-scale fishers.
- *Alternative employment.* There is also the opinion that development of other sectors, not necessarily limited to those in coastal areas, should be undertaken to reduce fishing pressure in these areas, offering alternative employment to fishers. An example is the development of the oil-palm plantation industry in Malaysia, which has been able to absorb an appreciable number of fishers in coastal areas, thus reducing fishing pressure (P. Martosubroto, personal communication, May 2007).

<sup>16</sup> “Management success” is taken to mean that objectives have been set and to some degree achieved through interventions.

- *Participatory management.* Much of the current discussion on shrimp fisheries management concerns interventions by centralized government agencies. Some fisheries specialists argue that the management of small-scale fisheries is more successful if undertaken through participative processes (e.g. comanagement, community-based management), with local communities and government agencies contributing where they have strength. It follows that, if their use can be shown to fulfil the needs of the fishery, protected areas where no shrimp fishing (or fishing of any kind) is allowed may simplify the chronic compliance problems if they have been established in a participatory process.
- *Awareness and education.* It is contended that if small-scale fishers know the implications of some of their fishing practices, then they may tend to refrain from those that have negative effects.

### ECOSYSTEM APPROACH TO FISHERIES

In the management of shrimp fisheries, increasing attention is being focused on the ecosystem approach to fisheries (EAF). In general terms, the fisheries management policies in several countries are widening away from a “single-species” approach to include more general ecosystem issues. Specifically with respect to shrimp management, there is increasing recognition of the range of impacts outside the shrimp fishery in question, hence more emphasis on managing the effects of the fishery on the ecosystem and vice versa. Box 26 describes some important aspects of the ecosystem approach.

The principles of EAF are the following. It is science-based and uses both qualitative and quantitative information and traditional knowledge. Within pragmatically defined ecosystem boundaries, EAF aims at human and ecosystem well-being, maintaining the potential for maximum biological production as well as ecological relations, and

#### BOX 26

##### Some important aspects of the ecosystem approach

An ecosystem approach entails taking careful account of the condition of ecosystems that may affect fish stocks and their productivity. It also means taking equally careful account of the ways that fishing activities may affect marine ecosystems. This means, where necessary (e.g. within agreed levels of impact), changing the way in which the fishery operates, adjusting the type of gear used, or imposing closed areas to protect biodiversity or habitats critical to the whole fishery or to the biodiversity of the region. Furthermore, it means taking an inclusive approach to setting goals and objectives for harvested fish and the fish ecosystem, recognizing ecosystem interactions, possibly integrating activities across a range of other users and resource sectors, and respecting the broad range of society’s values for the marine environment.

The ecosystem approach aims at environmental and human well-being by:

- maintaining the natural structure, function, biodiversity and productivity of natural systems;
- accounting for human needs and values of ecosystems when establishing objectives;
- recognizing that ecosystems are dynamic with attributes and boundaries constantly changing and that consequently, interactions with human uses are also dynamic;
- accepting that natural resources are best managed within a management system based on a shared vision and a set of objectives developed among stakeholders;
- adopting adaptive management procedures, based on scientific knowledge, continual social learning and recurrent audit and evaluation of the management performance.

Source: based on Ward *et al.*, 2006.

minimizing the impacts of use. It also aims at equity, transparency and participation as a means to ensure them. Furthermore, it acknowledges uncertainty and develops precaution and foresight. It integrates information building, assessment and management within the ecosystem area. Finally, it addresses transboundary impacts and ensures compatibility of management measures across the entire ecosystem (Garcia *et al.*, 2003).

EAF cannot be developed in a vacuum. It can only be sustainably implemented within supporting national economic, policy, institutional and juridical frameworks operating as an enabling environment. This requires the existence or establishment of local democratic institutions, a pragmatic decentralization of equitably distributed rights and duties, the adoption of a system of indicators and a set of minimal environmental norms. It also requires good coordination among ministries.

Garcia *et al.* (2003) and FAO (2005f) state that the ecosystem approach to fisheries, blending ecosystem and fisheries management, requires: (i) a definition and scientific description of the ecosystem in terms of scale, extent, structure and functioning; (ii) assessment of its state in terms of health or integrity as defined by what is acceptable to society; (iii) assessment of threats; and (iv) maintenance, protection, mitigation, rehabilitation, etc., using (v) adaptive management strategies. An especially useful comparison between conventional fisheries management and ecosystem management is given in Table 16.

An ecosystem approach is perhaps particularly appropriate for the management of shrimp because of its important role as prey in most ecosystems; its sensitivity to climatic factors as drivers of its life cycle and recruitment success; its sensitivity to the quality of coastal habitat; its impact on other fisheries through bycatch; and the potential impact of trawling on the bottom and bottom fauna.

TABLE 16  
Comparison between fisheries and ecosystem management

Criteria	Fisheries management	Ecosystem management
Paradigm	Sector-based. Vertically integrated. Focusing on target resource and people.	Area-based. Holistic. Loosely cross-sectoral. Focusing on habitats and ecosystem integrity.
Objectives	Not always coherent or transparent. "Optimal" system output. Social peace.	A desired state of the ecosystem (health, integrity).
Scientific input	Formalized (particularly in regional commissions). Variable impact.	Less formalized. Less operational. Often insufficient. Stronger role of advocacy science.
Decision-making	Most often top-down. Strongly influenced by industry lobbying. Growing role of environmental NGOs and fishing communities.	Highly variable. Often more participative. Strongly influenced by environmental lobbies. Stronger use of tribunals
Role of the media	Historically limited.	Stronger use of the media.
Regional and global institutions	Central role of FAO and regional fishery bodies.	Central role of United Nations Environment Programme (UNEP) and the Regional Seas Conventions.
Geographic basis	A process of overlapping and cascading subdivision of the oceans for allocation of resources and responsibilities.	A progressive consideration of larger-scale ecosystems for more comprehensive management, e.g. from specific areas to entire coastal zones and large marine ecosystems.
Stakeholder and political base	Narrow. Essentially fishery stakeholders. Progressively opening to other interests.	Much broader. Society-wide. Often with support from recreational and small-scale fisheries.
Global instruments	1982 UN Convention on the Law of the Sea, UN Fish Stocks Agreement and the FAO Code of Conduct.	Ramsar Convention, 1992 United Nations Conference on Environment and Development Agenda 21, Convention on Biological Diversity, and the Jakarta Mandate.
Measures	Regulation of human activity inputs (gear, effort, capacity) or output (removals, quotas) and trade.	Protection of specified areas and habitats, including limitation or exclusion of extractive human activities. Total or partial ban of some human activities.

Source: Garcia *et al.*, 2003.

In moving towards an ecosystem approach to shrimp fisheries a number of steps should be taken to:

- delineate the practical boundaries of the shrimp fishery ecosystem inland and at sea;
- identify critical habitats (e.g. lagoons, mangroves, seagrass beds, mudflats, spawning grounds), their state and existing threats (agriculture, urbanization, etc.);
- identify the species assemblage and information available on it, predators and preys;
- identify all stakeholders and catalogue the different values of the ecosystem for them;
- identify potential partners, e.g. in the Ministry of the Environment, Non-governmental Organizations (NGOs), etc.;
- assess, at least qualitatively, the bycatch issue, looking for threats to protected/endangered species;
- identify institutional zones such as reserves and exclusion zones for industrial fishing;
- identify potential external drivers such as climate oscillations, rainfall and market forces, etc.;
- identify potential sources of threats such as pollution sources, competing sectors, urban development, and oil industry and dumping activities;
- identify patterns of variability and change; and
- identify explicit and implicit objectives.

To be particularly effective, the steps towards improved management will need to be participatory and include a risk assessment analysis (Fletcher, 2005). Any management plan might also benefit from establishing recurrent audit and evaluation processes to guarantee adaptive improvements; and programmes of stakeholder awareness raising and education to ensure a common platform of understanding.

The task may sound daunting for the shrimp fisheries of most developing countries (and perhaps also for some developed ones), but can be implemented stepwise, with a direction and speed to be jointly decided by stakeholders and with the collaboration of international institutions, NGOs and institutions with converging interests, etc., sharing the burden and pooling competencies and resources. For example, guidance is available in Garcia *et al.* (2003); FAO (2003b) and Cochrane, Augustyn and Cockcroft (2004).

To a certain extent, the progression to an ecosystem approach to the management of shrimp fisheries is well under way in some countries. This is evidenced by increased management attention to bycatch reduction; the introduction of estuarine and watershed aspects into shrimp fishery management plans; efforts to mitigate negative effects on the seabed; and the use of marine protected areas in shrimp fisheries management. The incorporation of the principles of an ecosystem approach into shrimp management appears considerably more advanced in developed countries, such as Australia and Norway (Part 2).

### LEGISLATION FOR SHRIMP FISHERIES MANAGEMENT

Globally, legislation for fisheries management reflects the variety of legal systems in the world. For shrimp fisheries, a key aspect of national fisheries legislation is whether or not there is a legal mandate to restrict participation in fisheries. Other features of legislation that are important for effective shrimp fisheries management include the authority to reduce participation, limit catches, restrict gear, establish closed seasons/areas and collect data.

In countries with effectively managed shrimp fisheries, legislation often requires or encourages certain positive features. These include fisheries management plans, bycatch management plans, collaboration among the various stakeholders, provision for keeping management interventions at arms' length from the political process, an ecosystem approach to management and the flexibility to intervene quickly, based on

## BOX 27

**Modernizing fisheries legislation in Trinidad and Tobago**

The Fisheries Act of 1916 does not provide a legal basis for controlling access by nationals of Trinidad and Tobago to fisheries resources under the national jurisdiction. Efforts to limit fishing effort in the trawl fishery have subsequently been attempted through a 1988 Cabinet decision to restrict entry of new vessels, both artisanal and industrial. This measure is effective to a greater extent for the semi-industrial and industrial fleet, where permission for the importation of any new fishing vessel must be obtained from the Minister with responsibility for fisheries. The Fisheries Management Bill prepared in 1995, to be known on finalization as the Marine Fisheries Management Act, will repeal the Fisheries Act of 1916. The new Act will provide for the preparation of fishery management plans and, in accordance with these plans, will control and limit access to fish resources through the establishment of a licensing system for both local and foreign fishing vessels. Currently, however, there appears to be insufficient political will to enact the proposed legislation.

*Source:* based on Part 2.

research findings or changing fishery conditions. Many of these features are, however, important for fisheries management in general and not strictly specific to shrimp fishery management.

There are numerous complications and difficulties in the legislation for shrimp fisheries management. Problems associated with revising antiquated legislation are common. The case of Trinidad and Tobago is similar to that of many countries (Box 27). Jurisdictional issues whereby a shrimp fishery occurs in the geographic area of more than one management authority plague many countries. In the United States, multiple jurisdictions result in the inability even to determine the number of operational shrimp vessels in the major shrimp fishery of the country, making implementation of effective management difficult. The prevention of inshore nursery ground habitat degradation is important for shrimp fisheries, but does not usually fall within the legal mandate of the government agency responsible for fisheries management.

The greatest difficulty with legislation for shrimp fisheries management often involves enforcement, especially in developing countries. The situation of “relying on non-existent enforcement” is covered in Chapter 13.

**MANAGEMENT COSTS**

An important consideration is the cost-effectiveness of fisheries management. Management costs are not, however, readily available for most of the world's shrimp fisheries. The typical situation is when the budget of a government fishery agency is known but is partitioned by administrative section, rather than by function, such as research or management. It is even more uncommon to disaggregate government fishery budgets to the level of the management of a specific fishery. In some countries, however, industry is responsible for at least a portion of management costs associated with the fisheries in which they participate, and consequently management expenditure is carefully accounted for on a fisheries basis (Box 28). Since industry is paying for a service, cost efficiency is encouraged.

**DIFFICULTY IN MANAGING SHRIMP FISHERIES**

It should be emphasized that shrimp fishery management is *not that difficult*. Compared with other fisheries, warm-water shrimp fishery management is relatively easy because of several factors: growth and mortality have been determined for many

## BOX 28

**Management costs in Australia's Northern Prawn Fishery**

Current government policies for fisheries managed by the National Government are that the fishing industry pays for management costs directly attributed to fishing activity on a full cost-recovery basis, with the government paying for, or contributing to, activities that may benefit the broader community as well as industry. Recoverable management costs include the running costs of management committees, the fisheries management agency's day-to-day fisheries management activities, costs of developing and maintaining management plans, and logbooks and surveillance, but do not include enforcement costs (Cartwright, 2003). From 1995 to 2002, annual management costs attributed to the Northern Prawn Fishery ranged from \$A1 million to \$A2.2 million.<sup>1</sup>

Source: Galeano *et al.*, 2004.

<sup>1</sup> In 2002, the average exchange rate was US\$1 = \$A1.84.

of the important species; shrimp is highly fecund; and abundance is largely climate-driven. Furthermore, since most warm-water shrimp fisheries utilize more than one shrimp species, it is unlikely that bad year classes will occur in all species in one year. Because of the short life cycle of shrimp, overfishing is immediately apparent and, if management mistakes are made, they can often be rectified in one year (S. Garcia, FAO, personal communication, 2007).

On the other hand, the management of a shrimp fishery can be more complex if it involves small-scale fishers (Chapter 11), is open access or occurs in a poor country with weak institutional arrangements for management. Overall, some of the best-managed fisheries of any type (invertebrate, finfish or other) are the commercial-scale shrimp fisheries in the countries that limit fisheries access. Even in these cases, there is considerable room for improvement.

### COLD-WATER SHRIMP FISHERY MANAGEMENT

The discussion of shrimp management issues in the sections above is focused to some extent on the warm-water or penaeid shrimp fisheries. To a certain degree, this reflects the greater international attention currently given to the management of warm-water shrimp fisheries rather than to that of cold-water ones.

In general, the management of cold-water shrimp fisheries is more simple. Cold-water fisheries are most often limited entry, industrial-scale operations carried out by fleets from developed countries. They do not characteristically have the management difficulties associated with small-scale fisheries and the generally larger vessels involved allow more options to deal with bycatch issues. In relative terms, the fisheries are closely regulated and there is better compliance. Much of the cold-water shrimp fishing occurs in countries whose fisheries policies stress the importance of an ecosystem approach to fisheries management. On the other hand, the international nature of many of the cold-water shrimp fisheries requires bilateral and multilateral arrangements that introduce considerable management complexity.

Nevertheless, the management of cold-water shrimp fisheries is usually less complex and consequently more successful than that of warm-water fisheries in terms of achieving common management objectives, such as maximizing rent or reducing bycatch. As an indication of the easier management situation, most of the shrimp fisheries in consideration for certification by the MSC (Chapter 5, section *Important issues in the shrimp trade*) are cold-water fisheries (Leadbitter and Oloruntuyi, 2002).



## BOX 29

**Canada's management interventions for northern shrimp**

Access to northern shrimp stocks is regulated through fishing licences, shrimp fishing areas, seasons, quotas, enterprise allocations and gear specifications.

- For 2007, a total northern shrimp quota of 164 244 tonnes was established for the eight shrimp fishing areas. This quota is partitioned among the eight areas and then allocated to participants.
- Nordmøre grids continue to be mandatory in shrimp trawls to reduce bycatches of other species including Atlantic cod, Greenland halibut, wolffish, skates, seals and snow crab.
- The fishery is monitored by extensive at-sea observer coverage paid for by licence holders. Vessels over 100 ft (30.5 m) carry 100 percent observer coverage. This is based on 10 percent coverage on inshore vessels. At-sea observers monitor for compliance with management measures, including bycatches, dumping and high-grading, gear restrictions, area and closed time provisions. Observers also collect valuable scientific information including size composition, temperature data and bycatch composition.
- Dockside monitoring by a certified dockside monitoring company is conducted on all landings from vessels less than 100 ft in length. Dockside monitoring of shrimp landed from vessels of over 100 ft in length is not currently required.
- Completion and submission of accurate fishing and production logbooks as well as fish purchase slips are required.

All vessels fishing shrimp must be equipped with a government-approved electronic vessel monitoring system. Offshore vessels fishing northern shrimp must report to the government their position and catch on a daily basis in the prescribed format. Fishery officers conduct surveillance of fishing activities through periodic aerial and dockside surveillance and by conducting at-sea boarding of fishing vessels. From time to time, vessels may be subject to audit of reported landings and catch information.

*Source:* DFO, 2007.

Management objectives in the main cold-water shrimp fisheries reflect the characteristically high quality of governance in the fisheries sectors of the important countries involved (Canada, Greenland, Iceland and Norway). Objectives are often the maximization of economic efficiency and reduction of environmental costs, using a variety of management interventions to achieve these goals. For example, Box 29 describes the management interventions used in 2007 in Canada's Northern Shrimp Fishery off northeast Newfoundland, the Labrador Coast and in the Davis Strait.



## 13. Enforcement

Enforcement is defined as ensuring the observance of laws. Fisheries enforcement includes not only the process of recording violations of fisheries laws, but also the legal processes and penalties applied (Kelleher, 2002).

### ENFORCEMENT ISSUES IN SHRIMP FISHERIES

Enforcement is an important aspect of any fisheries management regime. For the purpose of the present study, it is important to identify the issues and elements of enforcement that are specific to shrimp fisheries or are of particular significance.

Because of the variety of life cycles, fishing gear and practices, and the communities involved, the management of shrimp fisheries is associated with a complex enforcement environment within a large range of national conditions. The complicating factors for shrimp fisheries include: the use of many types of management measures, many of which require enforcement activities at sea; substantial incentives to circumvent restrictions on inshore trawling (i.e. productive near-shore fishing grounds); the fact that many restrictions are counter to the short-term economic interests of fishers (some measures dealing with bycatch/discards); the management measures that infuriate fishers (unilateral TED requirements imposed on developing country fishers by the United States); and the huge problems, or even futility, of enforcing requirements in small-scale shrimp fisheries.

Although there are a multitude of measures employed in the management of the world's shrimp fisheries (Chapter 12), the main areas of concern regarding fisheries enforcement and its associated considerations are the following.

- *Gear measures.* These include mesh sizes, other net specifications, TEDs and BRDs. Although some form of gear control is in force in most of the world's shrimp fisheries, it is relatively difficult to enforce in port and often requires observers or boarding at sea to ensure compliance.
- *Restricted areas.* These include both permanent and temporary closures for protecting juvenile shrimp, sensitive areas and small-scale fishers. Enforcement is generally easier than for gear measures and the use of electronic vessel monitoring further facilitates enforcement.
- *Catch restrictions.* These include requirements (quantities, sizes of individuals) on retaining and discarding target species and bycatch. Some aspects can be monitored in port, but others require on-board observers at sea.
- *Participation.* In restricted access fisheries, fishers that are legitimate participants often effectively contribute to the enforcement process. Even in open access fisheries, domestic fishers have incentives to report illegal foreign fishers.

In the ten country studies of Part 2, a number of issues related to enforcement of regulations emerge. As expected, enforcement matters differ greatly between developed and developing countries, but there are also major differences in enforcement between warm- and cold-water shrimp fisheries, with the latter more involved in compliance with shrimp size regulations and quotas. Enforcement of turtle excluder requirements is confined to warm-water fisheries, which also have greater involvement in the complexities of enforcement in small-scale fisheries.

Other enforcement issues that became apparent in the national studies are given below.

## BOX 30

**Enforcement in Madagascar**

Fisheries surveillance and enforcement are carried out by the Centre de surveillance des pêches, which was created by the Minister in charge of fisheries by Decree No. 4113/99 of 23 April 1999. The objective of the Centre is to oversee compliance with regulations, at sea as well as on land. Twenty provincial agents are deployed along the coast to inspect boats and to verify fishing gear, which for shrimp fishing involves the following criteria: the length of the backrope, the mesh size of the trawl and installation of TEDs and BRDs. Thirty-five observers dedicated to the shrimp fisheries allow for observation of fishing operations at sea. A vessel monitoring system has been used since the beginning of the 2001 fishing season to regulate the fishing areas of industrial shrimp trawlers. All vessels are equipped with ARGOS or INMARSAT transmitters. The Centre has several funding sources, both national and international. The annual budget is about US\$1.4 million.

*Source:* based on Part 2.

- Poor enforcement appears to stem from a number of factors: insufficient operational budgets, inadequate enforcement infrastructure, weak institutions, political considerations affecting enforcement priorities and official corruption.
- Much or most of the corruption associated with shrimp fisheries seems to involve payments to circumvent enforcement of regulations.
- In many cases where efficient enforcement exists, the fishing industry itself has at least some enforcement responsibilities; this applies to both developed and developing countries.
- If penalties for non-compliance are harsh enough, then the actual detection efforts do not need to be as great to be a deterrent.
- A reasonable degree of compliance with some of the technical measures (mesh sizes, BRDs) requires at least some on-board observer coverage.
- Enforcement of regulations in small-scale shrimp fisheries is often considered to be too hard a prospect.
- Not all cases of good enforcement of shrimp fisheries management requirements occur in wealthy developed nations (Box 30). The significance of a fishery for the national economy and effective national institutions appear to be at least as important as national wealth in whether adequate resources are dedicated to enforcement.

Another aspect of enforcement that emerges from Part 2 concerns unilateral attempts of a single country, the United States, to extend its shrimp fishery management requirements overseas. This is an issue whereby the United States requires an equivalent monitoring and enforcement programme for the use of TEDs in countries wishing to export shrimp to the United States. In effect, the harvesting country must document its enforcement of the laws of another country. Currently, this is only a TEDs/United States issue, but the concept could conceivably be adopted by other major shrimp markets in relation to turtle conservation or other matters.

### **ENFORCEMENT ISSUES IN SMALL-SCALE SHRIMP FISHERIES**

Enforcement of regulations in small-scale shrimp fisheries deserves additional attention. In Chapter 12, section *Difficulty in managing shrimp fisheries*, it is noted that in many countries, even modest regulatory interventions dealing with small-scale shrimp fisheries do not succeed as a result of enforcement problems: the large numbers

of vessels, the impracticality of placing observers, the many landing sites and reluctance to place demands on poor people.

As discussed in Chapter 12, section *Management of small-scale shrimp fisheries*, there appear to be three main types of small-scale fishery management strategies, each of which has its enforcement problems: (i) the *laissez-faire* strategy, which gives low priority to imposing or enforcing regulations; (ii) bans and protected areas, which are expected to require less enforcement (a less than obvious assumption in many situations); and (iii) participative management involving the communities and the government in the management process, including enforcement.

Funge-Smith, Lindebo and Staples (2005) refer to enforcement restrictions on small-scale trawling in Southeast Asia and observe that such regulations are unfortunately difficult to enforce and success has been rather limited, unless supported by local communities and administrations. Increasingly, small-scale fishers are the main endorsers of responsible fishing practices in small-scale fisheries, through community-based and comanagement programmes, often with strong support from the local government.

### ELECTRONIC VESSEL MONITORING

The introduction of electronic vessel monitoring has a very positive effect on some aspects of shrimp fishery enforcement. A vessel monitoring system (VMS) provides accurate geographic information on participating fishing vessels to the monitoring agency. VMS alone does not provide evidence of a standard likely to satisfy most criminal courts of an offence that involves fishing activity. VMS can, however, indicate probable fishing activity and provides a good and sufficient basis for further investigation by one or more of the conventional enforcement measures (FAO, 1998).

There are now requirements in most countries that large-scale shrimp trawlers be equipped with VMS. This mitigates one of the most serious problems of shrimp fishing – large trawlers encroaching on banned inshore areas and creating conflicts with small-scale fishers. As in many other fisheries, the introduction of VMS for shrimp fishing was initially resisted by industry. After VMS use became mandatory and part of normal shrimp fishing operations, the fishing industry became aware of some peripheral benefits: companies can more accurately track the movements of their fleets and legitimate companies can more easily demonstrate compliance of their vessels with geographic restrictions.

In many countries, there is a general perception that VMS reduces overall enforcement costs. Yet VMS places additional demands on monitoring agencies to deal with a substantial amount of information from vessels equipped with VMS transponders, and fishers usually pay at least the cost of the on-board transmitting unit.

Experience has shown that VMS can make a valuable contribution to fishery enforcement effectiveness when:

- states do not have adequate monitoring of the fishery or when they do, they require access to data that are close to real time, which other monitoring tools cannot provide. VMS allows some measure of fishing effort and can rapidly and precisely allow a fishery manager to see spatial and temporal distribution of effort;
- there are industrial-type foreign fishery agreements;
- there are conflicts between fishery sectors or between neighbouring countries, in which case VMS can provide a mechanism for dispute resolution;
- there are limited human and financial resources in the country and fisheries are remotely located;
- it is combined with other control activities, such as dockside monitoring;
- improved efficiency is desired since it reduces the surface/aerial patrol costs without sacrificing part of the evidence of a violation; and

- a state's infrastructure can accommodate VMS demands: operational, legal, etc.

The use of VMS information is not confined to enforcement. In some shrimp fisheries, VMS provides valuable information for researching aspects of the fishery, such as the fine-scale distribution of effort and logbook validation.

### **ENFORCEMENT COSTS**

Kelleher (2002) discusses enforcement costs and places them into two categories: capital costs (buildings, infrastructure, communications systems, patrol platforms, etc.) and recurrent costs (personnel, administration, patrolling, etc.). The reality is, however, that enforcement costs are not readily available for most of the world's shrimp fisheries. This is partly because of the way that budgets for fisheries administrations are organized and partly because external enforcement agencies (e.g. military, police, coast guard) do not usually partition their budgets or expenses by fishery or even by category (e.g. smuggling, sea safety, fisheries).

By contrast, the enforcement costs of some shrimp fisheries are well known. The annual compliance budget for the relatively small Gulf St Vincent Prawn Fishery in Australia is currently about US\$25 000 and accounts for costs incurred for checking on bycatch, maximum trawl headline length and the landed prawn catch. This equates to enforcement costs of about 1 percent of the value of the fishery. In 2005, in Kuwait, the total annual cost for all fisheries enforcement was KD1 091 532 (US\$3 714 600), of which an estimated 40 percent related to shrimp fishery management. This equates to enforcement costs of about 21 percent of the value of the shrimp fishery.

Government policies vary considerably as to who bears the burden of enforcement expenses. Generally, for fisheries management, many countries are moving towards a policy of "user pays", but this is not always extended to enforcement costs. Participants in nationally managed shrimp fisheries in Australia pay for most management costs, but not those related to enforcing regulations. In Canada's east coast Northern Shrimp Fishery, harvesters pay only the costs of observer coverage and dockside monitoring.

## 14. Shrimp fishery research issues

### PAST AND CURRENT RESEARCH

The purpose of fishery research is to provide a basis for management decisions. An important point concerning shrimp research is that past efforts have resulted in major advances in knowledge. As mentioned in Chapter 13, researchers have made considerable progress in gaining an understanding of the life histories and other aspects of the biology of the important species of shrimp. In the early days of shrimp fishing, biologists had poor knowledge of shrimp biology, including shrimp's complex larval life, growth and mortality rates, life span, migration and habitat requirements. *After two decades of research, most of the big unknowns regarding population dynamics and interactions between small- and large-scale fisheries were reduced by the end of the 1980s* (S. Garcia, personal communication, 2006). This provided a strong foundation for conventional management strategies fisheries that were tested for four decades and are still evolving.

Much of the past research associated with shrimp fisheries has involved biological and economic research on shrimp in support of stock assessment. Another research area that has received considerable attention is bycatch: quantities, species, resilience to fishing pressure and reduction. Several decades ago, the most advanced research on tropical shrimp was carried out in the United States. Policy decisions resulted in transferring much research effort to shrimp culture by the end of the 1960s. During the 1970s, with substantial support from FAO, tropical shrimp research developed on shrimping grounds in West Africa, Latin America, the gulfs between the Islamic Republic of Iran and the Arabian Peninsula, and Southeast Asia. Since the end of the 1970s, Australia has, in many respects, led the world in research on warm-water shrimp. From the 1990s onwards, there seems to have been a slump in this type of research as the world has shifted from single-species to ecosystem perspectives for fisheries.

Substantial research work on cold-water shrimp fisheries is currently being carried out in Canada and northern Europe. One of the most effective national shrimp research programmes in a developing country is the National Shrimp Research Programme of Madagascar (Box 31).

At present, much of the shrimp research in the various shrimp fisheries around the world can be placed into several categories:

- ongoing monitoring and stock assessment of existing fisheries;
- socio-economic research, including for reduction of conflicts and improving economic efficiency;
- research that encompasses both socio-economics and biology, such as the development of bioeconomic models and determining optimal exploitation strategies;
- gear technology, especially for reducing bycatch and impacts on the benthic environment; and
- topics of special concern: impacts on non-target species and effects of trawling on the sea bottom.

The specific research needed to bring shrimp fisheries management into an ecosystem approach framework is still limited, except in Australia, as shown in the discussions on discards and the biological impact of shrimp trawling.

## BOX 31

**Madagascar's National Shrimp Research Programme**

Madagascar's National Shrimp Research Programme (PNRC) began in September 1997. The programme has taken over the objectives of some previous shrimp research projects, including that of FAO, to become the focal point of Madagascar shrimp research. PNRC was initially focused on shrimp research in three areas.

- *Socio-economic research*: the importance of traditional shrimp fishing, the economics of the industrial/artisanal shrimp fisheries and analysis of the types of management.
- *Biological research*: sound justification for the period of closure of shrimp fishing; considerations related to the proposed trawl ban within two miles of the coast; the relationship between fishing and the environment; sites and importance of nursery grounds; determination of migration/growth/mortality from shrimp tagging; comparisons of biological cycles for the different fishing areas; stock identification; and evaluation of resource potential in the various fishing areas.
- *Research that encompasses both socio-economics and biology*: the study of economic and biological interactions between the three shrimp fishing subsectors – industrial, artisanal, traditional; and bioeconomic modelling to simulate the various management schemes.

The PNRC is now in a transitional phase. Following the workshop on the results of scientific studies in October 2004, several proposals for future shrimp research were made, including: extending the work carried out at Baie d'Ambaro and other important areas on the traditional shrimp fishery; pursuing shrimp stock assessment in the various fishing areas using cohort analysis and yield per recruit analysis; integrating the catch data of the three shrimp fishing subsectors; bioeconomic modelling of the fisheries by fishing area; and undertaking simulations to determine optimal exploitation strategies.

*Source*: based on Part 2.

**IMPORTANT NATIONAL ISSUES IN SHRIMP RESEARCH**

In the ten study countries, a number of issues related to shrimp research were identified. One of the most prominent features is the lack of research, or even basic data collection, in many countries where the shrimp resource is important. In Bangladesh, for instance, there has not been much research so far on shrimp fisheries in general and on shrimp trawling in particular. Valid scientific information in this regard is still lacking. The Cambodian fisheries statistical system is oriented towards collection of production information, while even the most basic indicators useful for stock assessment (e.g. CPUE) are not included (Gillett, 2004). ICES/FAO (2005) state that, in Cameroon, no proper research has been carried out so far regarding stock assessment and the actual level of exploitation.

Several other important matters related to research emerge from the national studies. One persistent issue concerns the identification of shrimp stock assessment models that are appropriate for use in developing tropical countries. As expressed by an Asian shrimp fishery manager: "The next step up from using trends in CPUE is unclear". An African fisheries specialist expressed a similar sentiment: "*With respect to shrimp stock assessment, there is a general lack of knowledge in moving from the theoretic/experimental to the recipe book*". The statements could indicate a decrease in assessment capacity from the 1980s when FAO, in collaboration with the Danish International Development Agency (DANIDA) trained more than 1 500 scientists in techniques adapted to various situations.

Other prevalent research issues and concerns are given below.



- Non-penaeid tropical shrimp (e.g. sergestoid shrimp of the genus *Acetes*) is important in the global shrimp catch (Chapter 3, section *Catches by shrimp species*) but little, if any, stock assessment information is readily available for fishery managers on these species.
- Some countries that carry out little research on shrimp are adjacent to those where substantial research has been undertaken. The high degree of applicability of shrimp research conclusions across areas offers considerable opportunities for knowledge transfer.
- With respect to research priorities related to shrimp fisheries, there is some debate in several countries on the amount of attention to give to biological research with respect to other types of research, such as socio-economics or gear technology. The latter should be a priority since it is an area in which differences across countries are more likely.
- Most research on shrimp is oriented towards large commercially important fisheries, with much less work on the shrimp resources that are exclusively targets of small-scale fishing. Although the latter is often responsible for large quantities of shrimp, there is uncertainty as to whether such research is cost-effective, considering the difficulties of data collection (on multiple-gear fisheries with a large number of fishing units in isolated areas) and management.
- In many developing tropical countries, some sophisticated stock assessment has been carried out on shrimp resources by externally funded projects, using expatriate expertise. The lack of continuity after the departure of project staff is an issue in many of these countries.

### GEF/UNEP/FAO PROJECT RESEARCH

Some form of research on shrimp bycatch reduction is carried out in most countries that have shrimp fisheries. Bycatch reduction research is also promoted on a global basis by a GEF/UNEP/FAO project, “Reduction of the Environmental Impact from Tropical Shrimp Trawling Fisheries, through the Introduction of By-catch Technologies and Change of Management”.

Research is a major component of the project, justification for which is given in the project document (FAO, 1999).

*With the problem of fish bycatch, particularly of juvenile food-fish, identified as a priority area for mitigation, research aimed at developing efficient and practical solutions has been started in several countries (including the United States, Australia, Mexico and Thailand), and is likely to continue in these countries, but because research and development require substantial financial and human resources they will tend to be restricted to those countries with a strong economy. The intervention of GEF is therefore required to support efforts by a number of less fortunate developing countries in all four major regions of the world in order to resolve a common problem.*

In addition to supporting national research efforts, the project is striving to increase cooperation in shrimp bycatch research among countries, the success of which will be demonstrated by the number of agreements made by governments on fishery research.

### RESEARCH ON SMALL-SCALE SHRIMP FISHERIES

Small-scale fisheries, including those for shrimp, have special research needs. In recognition of both the unique research requirements and the lack of sufficient attention in the past, FAO convened a meeting on small-scale fisheries research in November 2003. This meeting was charged with examining the role and importance of small-scale fisheries, elaborating a research agenda for the sector, and reviewing strategies and mechanisms to bridge the gap between research and action. An important finding of the meeting concerned the placement of emphasis in small-scale fisheries research.

*In order for research to have more impact on small-scale fisheries, the more traditional biotechnical approaches of many fisheries agencies must be augmented by substantial contributions from socio-economic research. In many cases, government fishery agencies are structured and staffed with an emphasis on northern hemisphere approaches to stock assessment. While resource assessment and monitoring remain key functions, the emphasis of a research agenda more appropriate for small-scale fisheries should be on policy formulation and socio-economic research (Staples, Satia and Gardiner, 2004).*

This general statement above is especially applicable to small-scale shrimp fishery research in developing countries. Currently, many aspects of conducting shrimp fisheries research in these countries were either learned in, or borrowed from, developed countries where large-scale shrimp fishing and associated stock assessment dominate the agenda. In the fisheries research agencies of some countries, research on issues of critical importance to small-scale shrimp fisheries, such as conflict with other scales of fishing, is dismissed as not being “scientific” and thus being inappropriate as a subject.

Overall, it seems that socio-economic research on issues of importance to small-scale fisheries should receive greater attention in the fisheries research agendas of many countries. Furthermore, it appears that the results of past socio-economic research have often been inadequately considered in the fisheries management process. This suggests the importance of developing mechanisms for incorporating the findings of socio-economic research in management plans, perhaps similar to what routinely occurs in many countries to obtain the results of stock assessment.

## RESEARCH COSTS

Research costs are not readily available for most of the world’s shrimp fisheries. Research budgets of fisheries agencies are known, but costs are not often disaggregated to the level of research on a particular fishery. In the countries where little or no research on shrimp fisheries is carried out, the budgets are obviously small or zero. In countries where one agency/programme is responsible for all shrimp research, the associated costs are well known.

As an example of the latter case, Madagascar’s National Shrimp Research Programme (PNRC) is a multidonor initiative with the participation of Agence française de développement, the Madagascar Government (the Aquaculture and Fisheries Development Fund and the Fisheries Agreement with the EU), the Institut de recherche pour le développement, and the Madagascar Shrimp Fishers and Farmers’ Cooperative. The original budget was about €2.0 million and about €1.8 million for the second phase.

The Madagascar situation also highlights another issue dealing with shrimp research funding in developing countries: reliance on donor support. It can be risky using the sometimes volatile aid funds to finance an ongoing activity. There can also be difficulties should the donors wish to exert influence over research priorities.

Comparison of funding levels among countries is complicated by several factors, including: definitions of “research”; apportioning agency administrative costs; and dealing with donor funding and purely academic research. Nevertheless, some indication of the magnitude of funding for research on shrimp fisheries can be obtained from the country studies in Part 2.

- The cost of shrimp-related research in *Indonesia* is not readily available. Estimating the cost of such research is rendered difficult by the large number of government, academic and donor agencies involved, and the difficulties associated with partitioning budgets by species groups. Nevertheless, some understanding of the financing available can be gained by considering the Research Institute for Marine Fisheries. Much of the government biological research on shrimp is undertaken at

the Institute, which has an annual budget of approximately US\$350 000. About 20 percent of its work could be considered to be focused on shrimp.

- In *Kuwait*, in recent years, it is estimated that the annual cost of research projects on the shrimp fishery averages US\$340 000.
- In *Norway*, the cost of shrimp research is not easily quantified, but a leading shrimp researcher estimated it at about US\$1 million for 2004.
- The average annual budget for research in the Fisheries Division of *Trinidad and Tobago* is estimated at US\$170 000. The budget supports the ongoing catch and effort, biological sampling programmes, participation in regional scientific working groups and counterpart funding for the GEF trawl project. It is estimated that 35 percent of the annual research budget is focused on the demersal trawl fishery (shrimp and groundfish resources), and another 35 percent on the pelagic fisheries. The remaining 30 percent covers information services shared equally between pelagic and demersal fisheries.

In some countries there has been a move to the concept of “user pays” for shrimp fishery research. This can be positive in terms of encouraging cost-efficiency. In South Australia’s Spencer Gulf Prawn Fishery, industry pays 100 percent of the attributable research costs through an annual research levy per licence holder, based on the production value of the fishery.



## 15. Data reporting

Most countries collect information on the total catch of industrial shrimp fisheries. Developed countries with effectively managed shrimp fisheries typically and routinely collect data on catch, effort and size of the important shrimp species. These data are verified by a number of means, including observers, boarding at sea and port sampling. Developing countries often collect information on shrimp catches as simply a component of an overall national fisheries statistical system, in which case, features that are important for shrimp assessments, such as shrimp size and species, may not always be included. In some developing countries, shrimp research projects (often established and initially operated with donor funds) collect information that is important for shrimp to augment the catch information of the overall fisheries statistical systems. In some developing countries where shrimp fishing is relatively important in the national economy, a specialized national statistical system for shrimp fishing has been established.

Given the considerable diversity of the various systems around the world for reporting data on shrimp fishing, only a few overall generalizations can be made on their functioning. In many of the better systems, industry is involved with collecting and reporting data. In Norway, all shrimp is sold through fishers' sales organizations. Catch information is obtained from the sales agreements between buyer and vessel. The fishers' organizations report the sales documents to the Directorate of Fisheries, which compiles the Norwegian catch statistics. In Australia's NPF, logbook design has involved continuous industry involvement and input, since the accuracy of the data is a function of industry satisfaction and commitment to the process (Cartwright, 2003).

Many of the poorer systems for collecting information on shrimp fisheries are in a situation similar to what Coates (2002) described for fisheries data in one region.

*The countries of Southeast Asia in general struggle with limited resources to compile information that, in many cases, they do not themselves trust, need or use. At the same time, most of those countries are aware of what information it would be more logical to collect, but lack the methods and support to obtain it.*

In general, the data systems that have input by industry and multiple verification mechanisms seem to be the most accurate. Box 32 gives examples of two very different situations.

Previous chapters of this report have stressed the importance of small-scale shrimp fishing in many countries. The large number of special problems of these fisheries has also been noted, including difficulties in management, enforcement and bycatch reduction. Data reporting is also problematic – most countries have considerable trouble collecting information on small-scale shrimp fisheries. In countries where such fishing is significant, there are often questions about the costs and utility of collecting information on potentially a huge number of types of shrimp fishing units, and also about the accuracy of such information once collected. In some countries, information collected outside the fishing sector (i.e. from national nutrition surveys or household income/expenditure surveys) is the best or only data available on small-scale shrimp fisheries.

Gulland (1984) reports on a global meeting of shrimp specialists held in the early 1980s and discusses many features related to the management of shrimp fisheries, including the importance of catch and effort statistics. The conclusions of the meeting in this regard are still applicable today – and suggest that many aspects of reporting data on shrimp fisheries did not change in the last quarter century.

## BOX 32

**Data from Indonesia and Shark Bay, Australia**

Venema (1996) indicates that over the previous decade in Indonesia, shrimp stock assessments were undertaken with data from various sources, including: (i) survey data from research vessels; (ii) data collected by scientists on commercial fishing boats; (iii) logbook data; (iv) data collected at landing places; (v) data collected by interviewing captains and crews of commercial fishing vessels at fishing harbours; and (vi) government fishery statistics at the provincial and regency level. After a thorough scrutiny of the data, it was concluded that all assessments need to be redone with independent data, including data on catch rates by different types of gear. Even rudimentary shrimp assessments were only possible in three areas and were based on focused research results, rather than the official statistics.

In the Shark Bay Prawn Fishery of Western Australia, data are obtained through compulsory monthly logbooks, which all operators voluntarily complete on a daily basis. Commercial logbooks are validated against processor records and against VMS data. The logbooks contain information on daily and shot-by-shot target and by-product catch, hours trawled and areas of operation. Data on protected species interactions have been collected through the observer surveys operating in the fishery since 1998.

*Source:* Environment Australia, 2002.

- Adequate data collection is crucially important, comprising at least comprehensive statistics on catch and fishing effort, distinguishing catches of different species of shrimp and some data on the sizes of shrimp caught.
- Although statistics on total catch are readily available for most of the main industrial shrimp fisheries, if not all, there is concern that information has not been collected on significant catches in sport, subsistence and artisanal fisheries.
- Since complete catch data are basic to many analytical approaches, omissions of potentially large components of the total catch can be a serious problem. Because the size of these unreported components may vary radically over time, the inability to address or even detect such changes could create a very biased picture of the condition of the stock.
- The practice of discarding fish in the shrimp fisheries is well known, but it has been pointed out that in several fisheries, small shrimp is also discarded but the amounts are not often recorded; this may seriously affect the results of stock assessments.
- Since otter trawls are not the only gear in many shrimp fisheries, a broad consideration of shrimp fishing effort would need to take various other gears into account.

A recent technological innovation is improved data reporting in some shrimp fisheries. The use of electronic logbooks is being contemplated or introduced in some of the more advanced countries. In the last few years, many of the vessels participating in Australia's NPF reported using electronic notebooks. Studies related to modifying the Gulf of Mexico Shrimp Fishery Management Plan suggest that the use of 100 percent coverage with electronic logbooks is one option to enforce a trip/days quota system.

## 16. Impacts of shrimp farming on shrimp fishing activities

### GENERAL INFORMATION ON SHRIMP FARMING

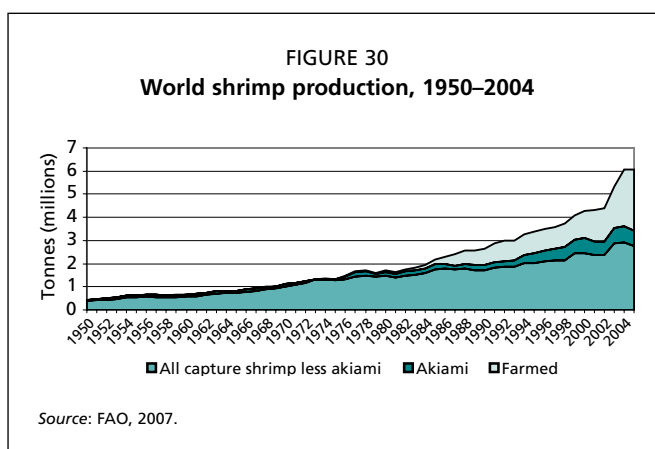
Briggs *et al.* (2004) review the history of shrimp aquaculture.<sup>17</sup> Modern shrimp farming began in the late 1960s and early 1970s when French researchers in Tahiti developed techniques for intensive breeding and rearing of various penaeid shrimp species, including *Penaeus japonicus*, *P. monodon* and later *P. vannamei* and *P. stylostris*. At the same time, in China, *P. chinensis* was produced in semi-intensive ponds, while *P. monodon* was produced in small intensive ponds in Taiwan Province of China. In North America, the NMFS began funding research on shrimp farming.

Until the early 1980s, world shrimp harvests were comprised almost exclusively of catches in oceans and bays. In 1982, cultured harvests accounted for only 5 percent of total shrimp production. By 1990, shrimp aquaculture was credited with 25 percent of world shrimp harvests and about half of all shrimp exports. In 2000 and 2001, new shrimp farming projects came on line all over the world, particularly in Viet Nam, Brazil and China. Brazil quickly became the low-cost producer in the Western Hemisphere, while shrimp farmers in Asia learned to produce large yields of shrimp at very low prices. Governments throughout Asia encouraged the development of shrimp farming with land concessions, tax breaks, easy loans and technical assistance. Consequently, from 1999 through 2004, production of farmed shrimp doubled, from approximately 1 million to an estimated 2 million tonnes (Shrimp News International, 2004). Clay (2004) estimates that 1 to 1.5 million people are directly employed in shrimp farming, with another million dependent on the industry for a major portion of their livelihoods.

Figure 30 gives the evolution of shrimp harvesting in the world and the proportion of capture<sup>18</sup> and culture shrimp production.

Today, world annual production of shrimp, both capture and farmed, is about 6 million tonnes. Currently, just over 40 percent of world shrimp production is from farming, or about 2.6 million tonnes per year. With respect to exports, the precise composition is not known with certainty (capture and farmed shrimp is combined in export statistics), but it appears that about 60 percent of internationally traded shrimp comes from aquaculture.

The leading shrimp farming countries are shown in Table 17. It can be seen that the five largest Asian producers are responsible for about 80 percent of world cultured shrimp.



<sup>17</sup> Shrimp aquaculture in this report is confined to marine and brackish-water operations.

<sup>18</sup> Since it can be argued that the capture of akiami paste shrimp is distinct from most other species (magnitude of production, fishing technique, product form, end market), the world catches of akiami paste shrimp are given separately.

TABLE 17  
Leading producers of farmed shrimp

Country	2000	2001	2002	2003	2004	2005
China	217 994	304 182	384 141	789 373	935 944	1 024 949
Thailand	309 862	280 007	264 924	330 725	360 292	375 320
Viet Nam	89 989	149 979	180 662	231 717	275 569	327 200
Indonesia	138 023	149 168	159 597	191 148	238 567	279 539
India	96 715	102 930	114 970	113 240	117 589	130 805
Mexico	33 480	48 014	45 853	45 857	62 361	72 279
Brazil	25 388	40 000	60 000	90 190	75 904	63 134
Bangladesh	59 143	55 499	56 020	56 503	58 044	63 052
Ecuador	50 110	45 269	46 735	55 500	56 300	56 300
Myanmar	4 964	5 473	6 550	19 181	30 000	48 640
Philippines	41 812	42 390	37 479	37 033	37 947	39 909
Malaysia	15 894	27 014	25 582	26 180	30 838	33 364
Colombia	11 390	12 000	14 000	16 503	18 040	18 040
Venezuela (Bolivarian Republic of)	8 500	10 512	12 000	14 259	16 500	16 500
Saudi Arabia	1 961	4 150	4 650	9 160	8 705	11 259
Belize	3 630	4 460	4 400	10 160	11 042	10 433

Source: FAO, 2007.

Currently, all significant commercial shrimp farming operations are based on the penaeid species. Table 18 shows the important cultured shrimp species.

The increasing popularity of farmed shrimp is attributable to several factors:

- the farm-raised product has greater consistent quality than the wild product;
- the farmed product is less seasonal in nature and production is more reliable than its wild counterpart;
- the species and sizes can be controlled better in a farm-based system than in a wild-based one; and
- the current trend towards vertical integration in the farming system lends itself to better adaptation to consumer needs (Ward *et al.*, 2004).

On the other hand, aquaculture operations are unable to produce larger sizes of shrimp economically, which are especially valuable. In some markets, there is a preference for the taste of captured shrimp.

Shrimp farming is not without major problems; FAO *et al.* (2006) review some of them. Rapid expansion of shrimp farming has generated substantial income for many developing countries, as well as developed ones, but has been accompanied by rising concerns over the environmental and social impacts of development. Major

TABLE 18  
Production of farmed shrimp

English name	Scientific name	Farmed production in 2005 (tonnes)
Whiteleg shrimp	<i>Penaeus vannamei</i>	1 594 039
Giant tiger prawn	<i>Penaeus monodon</i>	710 806
<i>Penaeus</i> shrimp – nei	<i>Penaeus</i> spp.	125 025
Banana prawn	<i>Penaeus merguensis</i>	81 105
Fleshy prawn	<i>Penaeus chinensis</i>	51 300
Kuruma prawn	<i>Penaeus japonicus</i>	43 181
Indian white prawn	<i>Penaeus indicus</i>	31 875
Metapenaeus shrimp - nei	<i>Metapenaeus</i> spp.	14 600
Blue shrimp	<i>Penaeus stylirostris</i>	3 170

nei – not elsewhere included

Source: FAO, 2007.

issues raised include the ecological consequences of conversion of natural ecosystems, particularly mangroves, for the construction of shrimp ponds; effects such as salination of groundwater and agricultural land; the use of fishmeal in shrimp diets; pollution of coastal waters through pond effluents; biodiversity issues arising from the collection of wild brood and seed; and social conflicts in some coastal areas. The sustainability of shrimp aquaculture has been questioned by some in view of self-pollution in shrimp-growing areas, combined with the introduction of pathogens, leading



to major shrimp disease outbreaks and significant economic losses in producing countries. Béné (2005) indicates that the social impacts of shrimp farming include: loss of access to mangrove resources and services; marginalization and increased vulnerability of local communities; social unrest, conflicts and harassment leading, in some extreme cases, to loss of life and ultimately, a widening gap between the poorest and the more affluent.

Rising concerns over the environmental and social impacts of shrimp farming led to the formation in 1999 of the Consortium on Shrimp Farming and the Environment, whose purpose is to analyse and share experiences on these impacts, and on the management of sustainable shrimp farming. The Consortium consists of representatives of FAO, the Network of Aquaculture Centres in Asia-Pacific, the Coordination Office of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities of UNEP, the World Bank and WWF. The Consortium formulated the International Principles for Responsible Shrimp Farming from studies and consultations involving a wide range of stakeholders, from government, private and non-governmental organizations. These principles provide the basis upon which stakeholders can collaborate for a more sustainable development of shrimp farming. The eight principles cover farm siting, farm design, water use, broodstock and PL, feed management, health management, food safety and social responsibility (FAO *et al.*, 2006).

### GENERAL IMPACTS

Shrimp farming affects shrimp fishing in several ways, giving rise to some controversy as a result. In a review of shrimp farming and shrimp fishing, Iversen, Allen and Higman (1993) indicate that the competition between the two sectors is both real and imagined. Aquaculture industry representatives refute many of the accusations against shrimp farming, including some that impact unfavourably on shrimp fishing. Overall, most stakeholders would agree that interactions between shrimp farming and shrimp fishing are fluid, not well established or understood, and therefore open to considerable speculation.

The impacts of shrimp farming on shrimp fishing are different in the various regions. Interaction appears to be most intense in Southeast Asia, with many elements apparent in Indonesia (Box 33).

The economic effects that aquaculture in general has on fishing have been well studied. Ye and Beddington (1996) in their study of bioeconomic interactions between capture and culture fisheries found that the entry of aquaculture lowers market price, increases total supply, reduces fishing effort and raises natural fish stocks. When culture costs are reduced, the fish price will decrease and fishing effort will decline. Willmann (2005) states that capture fisheries and aquaculture produce fish and supply the same processing industries, markets and consumers. Capture fisheries and aquaculture therefore compete in these markets, and the supply of cultured fish will influence the price of wild fish and vice versa.

The main effects that shrimp aquaculture has on shrimp fishing can be classified in several categories:

- economic impacts in the marketplace;
- destruction of mangrove forests for shrimp aquaculture operations; and

FIGURE 31  
A shrimp farm in New Caledonia



Courtesy of B. Ponia, Secretariat of the Pacific Community.

## BOX 33

**Impacts of shrimp aquaculture on shrimp fishing in Indonesia**

Shrimp aquaculture in Indonesia affects shrimp fishing in several ways.

- Many shrimp farms in Indonesia are situated in former mangrove forests. In Sumatra, large sections of mangrove forests have been transformed into shrimp ponds from Aceh to Lampung, where the world's largest shrimp farm (18 000 ponds) was constructed in the 1990s.
- Although there is considerable hatchery production of fry for shrimp farming, there is still some collection of fry in the wild. Official fishery agency data indicate that 27.5 million tiger prawn fry (valued at US\$275 000) were collected in 2003, mostly from Sulawesi.
- The large increase in farmed shrimp production has led globally to a decline in prices for all shrimp, including captured shrimp. The shrimp price fall and the rise in fuel prices are the main components of the present financial problems. This is having a major effect on commercial shrimp fishing in Indonesia and is likely to result in fewer Indonesian shrimp fishing operations and a lower shrimp catch.

*Source:* based on Part 2.

- capture of shrimp PL and broodstock for farming;
- escapes of cultured shrimp into the wild;
- other impacts, including “trash fish” and symbiosis.

These aspects are dealt with in more detail below.

**ECONOMIC IMPACTS IN THE MARKETPLACE**

The best studied example of economic interaction between shrimp fishing and shrimp farming occurred a few years ago, when large amounts of cheap imported farmed shrimp came on the market in the United States. In simplistic terms, the supply of shrimp on the world market soared mainly as a result of farming operations; prices decreased; imports into the United States increased; and prices paid to domestic fishers fell, causing a demise of warm-water shrimp fishing in the country. According to Ward *et al.* (2004), major impacts are the following.

- Since 1980, much of the growth in world shrimp production has been the result of successful farming activities throughout the world, particularly in Asia and, to a lesser extent, in South and Central America. World production of farmed shrimp in 1980 was about 160 million pounds<sup>19</sup> (live weight), which accounted for approximately 5 percent of total world production at the time. By 2001, farmed production had advanced to 2.8 billion live-weight pounds, or more than 35 percent of total world warm-water shrimp output.
- There was an 11 percent increase in world farmed shrimp production from 2000 to 2001, representing an additional 280 million pounds of shrimp (live weight) on the world market.
- From 1997 to 2001, import prices (in constant United States dollars) declined from US\$5.20 to US\$4.25; shrimp imports into the United States increased by about 50 percent; and prices paid to domestic fishers declined from US\$2.13 to US\$1.73.
- Analysis shows that the ex-vessel shrimp price should decline 84 cents per pound for every hundred million pounds of shrimp imported into the United States.

<sup>19</sup> Seafood weights in the United States are expressed in pounds; 1 pound = 0.453 kg.

- Although farmed shrimp imports were responsible for much of the price decrease, other factors could have contributed, including the varying conditions of national economies, tariff structures and tolerance levels for banned chemical substances.<sup>20</sup>

Shrimp price declines, at least partially a result of the increased availability of low-cost farmed shrimp, were not confined to the United States. From the mid-1990s to 2005, a major feature in the shrimp markets was that prices were generally falling. In Japan, there has been a general downward trend in prices from the mid-1990s. In the EU, combined penaeid import prices mostly declined from 2000 to 2005.

Since late 2005, the shrimp price situation has changed, with farmed shrimp once again responsible to some degree. Lower than expected aquaculture production, especially in Thailand, together with increased Asian domestic consumption, have been causing shrimp prices to increase.

Globally, the effects of cheap farmed shrimp are felt in most shrimp fishing fleets, especially those that target the major international markets. The resultant income declines are a major component of the current worldwide shrimp fishing “profit squeeze”. The typical current situation for shrimp vessels is rising costs (mainly fuel) and falling revenue from shrimp sales (competition with lower-cost farmed shrimp being a major component) in an environment where there is overcapacity.

Several measures are being discussed or implemented to mitigate the adverse economic effects of shrimp farming on shrimp fishing. At the level of the individual vessel, low shrimp prices (from whatever cause) reduce profitability and, consequently, the means to increase revenue (e.g. higher catch rates) or lower expenses (e.g. fuel efficiencies) are pursued. At the fleet level, capacity reduction is often attempted in restricted access fisheries. At the national level, subsidies, trade promotion and trade restrictions are used.

The boldest example of such a trade restriction was the initiative in the United States to restrict the import of farmed shrimp, on the basis that it had been dumped on the market (Chapter 5, section *Important issues in the shrimp trade*). In December 2003, the Southern Shrimp Alliance, a lobbying organization formed by shrimp fishers and processors in eight southern states, filed an anti-dumping petition with the United States Department of Commerce against shrimp farms in Brazil, China, Ecuador, India, Thailand and Viet Nam. In July 2004, the Department imposed duties varying up to 113 percent on farmed shrimp from these countries.

## DESTRUCTION OF MANGROVE FORESTS

The destruction of mangrove forests for shrimp farming operations is well known and acknowledged even by aquaculture industry representatives. There is considerable disagreement, however, over the amount of this destruction in the past caused directly by shrimp farming. For the present discussion, the important issue is the degree to which mangrove destruction caused by shrimp farming affects shrimp fishing.

Clay (1996) cites various sources to summarize the mangrove/shrimp issue. Mangroves are estimated to have once lined as much as 75 percent of the world’s tropical coasts, but perhaps half of the mangrove areas have been destroyed for various reasons, including urbanization, commercial logging, unrestricted firewood collection, charcoal making, river impoundment and shrimp pond collection. Globally, shrimp farming is not responsible for even a quarter of the mangrove clearings that have taken place since 1960 but, in the last ten to 20 years, mangrove destruction has been accelerated by shrimp farming. Much of the information on mangrove destruction is vague, general and contradictory. Specific data from one region are generalized for a whole country and the

<sup>20</sup> These chemicals are mainly chloramphenicol and nitrofurantoin in shrimp imported from Thailand. The EU had a lower tolerance level, resulting in shrimp being redirected to the United States.

FIGURE 32  
Shrimp pond in a former mangrove area



Courtesy of B. Ponia, Secretariat of the Pacific Community.

relative importance of multiple causes is not identified. Current use of areas that were once mangroves is often assumed to be the cause of the destruction, when in many cases, this was not so. Examples of original causes are milkfish and rice cultivation in many places of the Philippines and India, respectively. In assessing the overall situation, it appears that mangrove destruction is a complex subject. There is no useful purpose in hiding this fact, but there is little doubt that shrimp aquaculture poses the most serious threat to mangroves in regions that are considered suitable for shrimp ponds.

There are contrasting views on the amount of mangrove destruction caused by shrimp farming. An environmental group states:

*We can reasonably estimate that more than one-third of total mangrove loss has been due to shrimp farming, which appears to be clearly the greatest single threat to mangroves worldwide (Greenpeace, 2004).*

A paper by a representative of the Global Aquaculture Alliance states that less than 3 percent of the loss of world's mangrove resource is a result of shrimp farm development, and indicates that this figure puts shrimp farming impacts into perspective as a minor cause of global mangrove losses (Chamberlain, 2001). Boyd and Clay (1998) estimate that shrimp farming is responsible for some 5 to 10 percent of the global loss of mangrove habitat. FAO (2006c) reviews various studies and concludes that "aquaculture globally accounts for less than 10 percent of the loss of this important habitat".

Despite the controversy over the amount of past mangrove destruction by shrimp farming, there now appears to be a consensus among stakeholders that there is a declining trend. Factors contributing to less mangrove destruction include government action banning mangrove removal and the realization that the acidic soil found in mangrove areas is unfavourable for shrimp farming. In addition, the movement towards intensive shrimp farming has limited the clearance of large areas that took place in previous years (S. Funge-Smith, personal communication, April 2007).

How does mangrove destruction affect shrimp fishing? Clay (1996) states that postlarval and juvenile stages of shrimp depend on mangroves for survival. Primavera (1995) studied mangroves as shrimp nurseries in one area of the Philippines. The author's report concluded that the nursery use of mangroves by shrimp is well defined and year-round in a riverine mangrove area; limited to peak recruitment periods in an island mangrove area; and absent in a non-vegetated tidal flat. The report also cites a variety of other studies that show a positive correlation between mangrove area and near-shore fish and shrimp catches in the Philippines, Malaysia, Indonesia and Australia. EJF (2003) indicates that in Malaysia, a study estimated that from each hectare of mangrove, 600 kg each of finfish and shrimp are produced annually. Naylor *et al.* (2001) estimate that in areas of Thailand where shrimp farms have been carved out of mangrove forests, a total of 400 g of wild fish and shrimp are lost from near-shore catches for every kg of shrimp farmed. On the other hand, many shrimp farming experts feel that the relationship between mangrove destruction and shrimp fishing has not been well researched and many of the quantitative findings would not stand up under close scrutiny (R. Subasinghe, FAO, personal communication, 2007).

Figure 33 shows schematically the life cycle of penaeid shrimp and its association with mangroves. A possible location for a shrimp farm in the mangrove area is also given.

In recognition of the need to address mangrove destruction by shrimp farming, the Consortium on Shrimp Farming and the Environment (this chapter, section *General information on shrimp farming* above) included mangrove issues in its International Principles for Responsible Shrimp Farming. It stipulated that there should be no net loss of mangroves or other sensitive wetland habitats; and that existing farms should be improved in intertidal and mangrove areas through mangrove restoration, retiring unproductive ponds and increasing the productivity of remaining farm areas above the intertidal zone.

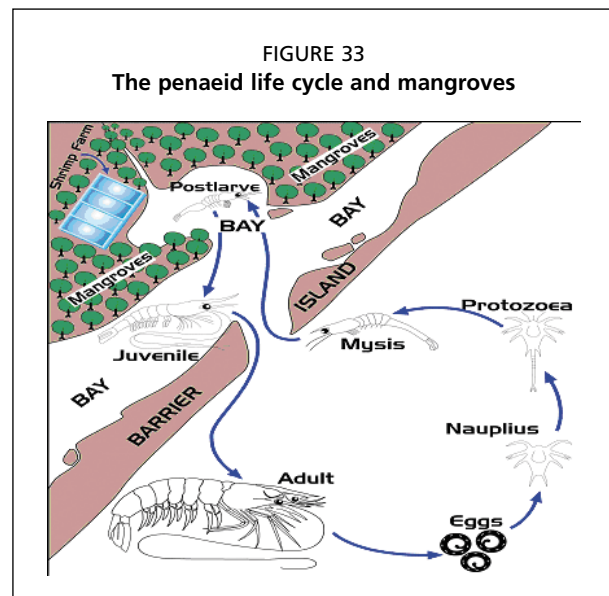
### POSTLARVAE AND BROODSTOCK

The capture of shrimp PL and broodstock for shrimp farming is likely to have had negative effects on shrimp fishing. Although there are diverse impacts from these capture practices, the main problems for shrimp fishing appear to be that the capture of PL may result in considerable bycatch (including juvenile shrimp) and the capture of adult broodstock may result in overfishing of shrimp.

Garcia (1989) indicates that the collection of PL from natural sources is a major source of conflict between shrimp culture and capture. Clay (1996; 2004) reviews the collection of PL for shrimp culture. Traditionally, shrimp farmers relied on wild shrimp for the production of seedstock. Currently, they either capture wild juveniles, which are stocked directly in a nursery or growout pond, or they spawn egg-laden or gravid females at a hatchery. Unfortunately, there is good evidence that the bycatch from capturing wild PL is even higher than from the shrimp trawling industry. Two studies are cited in support of the statement, “for every single shrimp grown in a pond, almost a hundred other fish or shrimp are killed”.

The situation is changing. Most of the shrimp seed used in the world today no longer relies on wild-caught larvae, but comes from hatcheries. Clay (2004) indicates that globally, some 98 percent or more of PL used by farming operations are produced in hatcheries. Wild-caught PL are most common in Bangladesh, India and Ecuador, where hatcheries are not required by law. Kura *et al.* (2004) state that even farmers in countries such as Ecuador, who favoured the use of wild seed for shrimp farms, are now shifting to hatchery-reared seed because it is perceived to harbour fewer diseases. Because of hatcheries, the capture of wild PL has become much less of an issue in many countries, but continues to be problematic in some places. Shrimp farmers in Bangladesh are currently partly dependent on wild fry and its collection contributes to the livelihood of several hundred thousand poor people (Nautilus Consultants and IIED, 2003). In Indonesia, there is considerable hatchery production of fry for shrimp farming, but a significant amount of fry in the wild is still collected (Box 33). Cascorbi (2004a) points out a dilemma: while the capture of larvae is still a cottage industry in some economically disadvantaged coastal communities, larva fishing takes a heavy toll on bycatch of the youngest stages of many fish and invertebrates.

Some facilities now specialize in breeding shrimp in captivity to raise broodstock. While this takes some of the pressure off wild shrimp populations, there is not enough broodstock cultivated to supply worldwide demand (Cascorbi, 2004a). The shrimp farming industry, especially in Asia, remains highly dependent on the capture of wild broodstock for hatchery spawning. Although substantial progress has been made in



Latin America with regard to captive breeding programmes for *Penaeus vannamei* and *P. stylirostris*, similar success has not occurred in Asia for *P. monodon* (Nautilus Consultants and IIED, 2003).

The high value of wild shrimp broodstock for farmers can cause fishers to target it. There is the contention that prices received may enable fishing effort to increase to a level above that of normal (non-broodstock) shrimp fishing, thereby increasing the possibility of overfishing. Alternatively, some shrimp farming specialists feel that there is a lack of evidence about this and such interaction is largely speculation.

The Consortium on Shrimp Farming and the Environment included this issue in its International Principles for Responsible Shrimp Farming in recognition of the need to address the wild capture of PL and broodstock for shrimp farming. It stipulated that, where possible, domesticated selected stocks of disease-free and/or disease-resistant shrimp broodstock and PL should be used to enhance biosecurity, reduce disease incidence and increase production, while reducing the demand for wild stocks.

In general, there appears to be a consensus that there is a decreasing trend for PL and broodstock collection in the world. The controversy seems to be whether the much diminished quantities are still a problem or are “next to nothing”, as currently stated by some shrimp farming specialists. Of relevance to the present study is whether what is taken has a significant effect on shrimp fishing.

#### ESCAPES OF CULTURED SHRIMP

Escapes of cultured shrimp into the wild affect shrimp fishing in both positive and negative ways. Shrimp has been introduced (transported and released outside the present species range) and transferred (transported and released within the present species range) for shrimp farming purposes (Clay, 1996). This has raised two issues for shrimp fishing: the establishment of non-native shrimp populations and the dissemination of pathogens.

Chemonics (2002) states that an important and interesting feature of recent shrimp fishing in Nigeria has been the arrival of wild *Penaeus monodon* specimens in trawler catches. *P. monodon* (tiger shrimp) appeared four years ago, mainly in the Calabar/eastern delta zone of Nigeria, where it comprises as much as 10 percent of trawler catches. It is an Asiatic exotic that could only have arrived through human agency (African current patterns preclude natural introduction), and presumably escaped from a West African (Gambian, Senegalese or Cameroonian) shrimp farm. This occurrence is important for shrimp farming for two reasons. First, it forestalls the question of introducing an exotic farm species to an existing economically important shrimp ecosystem – obviously, *P. monodon* already exists in Nigerian waters. Second, hatcheries that are essential for commercial shrimp culture still mostly depend on wild-caught gravid (egg-bearing) females for a source of eggs. This is particularly true for *P. monodon*, so that the presence of a viable population in Nigerian waters ensures a local supply of these gravid females for farming purposes. What remains unclear is which species, if any, has been displaced by the invasion of *P. monodon*.

Cascorbi (2004) indicates that as a result of escapes from shrimp farms, Pacific white shrimp (native to the west coast of the Americas) is now found in the Gulf of Mexico. Briggs *et al.* (2004) state that a total of nine penaeid species has been introduced for farming purposes into the Pacific Islands (mainly Tahiti and New Caledonia) but, of these, only the banana prawn (*Penaeus merguensis*) has become established in the wild (in Fiji).

These species introductions could have complex ecosystem and genetic implications. Their effects on shrimp fishing appear to be mixed. At least in the short term, the arrival of a new and valuable shrimp species in Nigeria is appreciated by the country's shrimp fishers. In Fiji, where there is no commercial shrimp fishing, the new species goes virtually unnoticed by coastal residents or even fishery researchers.

There is considerable uncertainty over the possibility that shrimp pathogens may be disseminated through shrimp that has escaped from farms. Clay (2004) states that the impact of disease pathogens on wild stocks is not documented, but anecdotal information suggests that it may be serious. In 1992–93, for example, when diseases reduced shrimp farming production by 60 to 70 percent, the production of wild-caught shrimp in China also declined by 90 percent. Briggs *et al.* (2004) review various studies on wild shrimp populations affected by viruses from shrimp farming.

- Overstreet *et al.* (1997) and JSA (1997) report that pathological viruses could be transmitted to native wild penaeid shrimp populations; thus, introduced alien shrimp viruses may be capable of infecting these shrimp populations.
- Taura syndrome virus (TSV) has been detected in wild *P. vannamei* escapees in the United States, but appears to have had minimal impact on wild shrimp populations (Brock, 1997; Global Monitoring for Food Security [GMFS] Web site; World Organisation for Animal Health [OIE] Web site). TSV appears to occur largely as a subclinical infection in populations of wild shrimp (Brock *et al.*, 1997).
- There is also some evidence of TSV in the wild populations of *P. monodon* around the southwest coast of Taiwan Province of China during 2000, although pathological effects on its new host were not noted and they appear largely unaffected (IQ2000 Web site, cited in Briggs *et al.*, 2004).
- There are speculations that another virus, infectious hypodermal and haematopoietic necrosis virus (IHHNV), originating from United States culture facilities, may have caused the closure of the Mexican shrimp fishery from 1987 to 1994 and the loss of millions of dollars, since wild *P. stylirostris* (and other less prevalent native species) proved highly susceptible to IHHNV (Lightner, 1996; JSA, 1997). The virus is commonly found in wild shrimp on the Pacific coast of Latin America and throughout Asia, from where it probably originated (OIE Web site; Lightner, 2002).

An alternative view of the situation is provided by some shrimp farming specialists. They feel that because good data on any wild population declines and subsequent catch reduction are mostly absent, the relationship of escapes of cultured shrimp to shrimp fishing is largely conjecture.

#### **OTHER IMPACTS OF SHRIMP FARMING ON SHRIMP FISHING**

“Trash fish” has been defined as “fish that have a low commercial value by virtue of their low quality, small size or low consumer preference. They are either used for human consumption (often processed or preserved) or used to feed livestock/fish, either directly or through reduction to fishmeal/oil” (Funge-Smith, Lindebo and Staples, 2005). The composition of trash fish is highly diverse, with over 97 fish families represented in the trash fish of Southeast Asia and China. This is because of the numerous types of fisheries that contribute to trash fish and the fact that most comes from trawl fisheries (WorldFish, 2005). Funge-Smith, Lindebo and Staples (2005) review trash fish issues in the Asia-Pacific region. The continued expansion of aquaculture in the region has resulted in dependency on capture fisheries for trash fish. There is general concern that the rapid expansion of aquaculture may ultimately be constrained by dependence on trash fish and fishmeal, popularly referred to as the “fishmeal trap”. A dangerous spiral has evolved where the demand for trash fish has supported increased fishing pressure on already degraded resources.

There is some debate as to the amount of trash fish from shrimp trawling used in shrimp farming operations. FAO (2006c) cites an example of up to 140 000 tonnes of trash fish being used annually in the mid-1990s for farming *Penaeus monodon* in Viet Nam. However, some shrimp specialists feel that trash fish use in shrimp farming is not important. If it is indeed significant or increasing, it may be an important issue

because: (i) increasing demand for trash fish may create economic incentives for bycatch increases by shrimp trawling and other fishing techniques, rather than bycatch reduction; and (ii) in some developing countries, trash fish previously used for human consumption is now being used to feed farmed shrimp exported to affluent countries.

Shrimp farming and shrimp fishing each have public relations problems. In the minds of consumers, some of the stigmas of farming can affect the image of fishing and vice versa. One of these is that the use of chemicals in shrimp aquaculture can negatively affect the perception of captured shrimp in the marketplace. Two references, which may be only applicable to the United States situation, illustrate a negative attitude towards farmed shrimp that has caused concern in the shrimp capture industry.

- *Nearly 80 percent of the shrimp that American consumers eat in restaurants or buy at the grocery store are imported and farm-raised. Chances are, the delicious shrimp cocktail you're splurging on is loaded with antibiotics and chemicals because that's what goes into the cramped, dirty ponds made to mass-produce shrimp. Doesn't sound yummy, does it? ([www.foodandwaterwatch.org/fish/shrimp](http://www.foodandwaterwatch.org/fish/shrimp))*
- *Consumer health risks associated with eating imported farmed shrimp have been given little attention in the United States. While shrimp tops the list of popular seafood choices, consumers are usually unaware of the health impacts. By the time shrimp arrive in grocery stores or are served in a restaurant, it has been injected with antibiotics, doused in pesticides and fed chemical-laden food. Imagine what this chemical cocktail does to your health (Public Citizen, 2004).*

Nevertheless, shrimp farming and shrimp fishing can form a favourable symbiosis in marketing, as shown by an example from Madagascar. There, the limited shrimp farming specializes in the production of *Penaeus monodon* and is almost all owned by industrial and artisanal shrimp vessels. This situation illustrates the potential for combining resources for effective monitoring of international markets and associated exporting. By combining marketing for both wild and farmed shrimp, clients can be offered a large range of shrimp: different species, different sizes and wild/farmed options.

There seems to be an additional, yet more subtle impact of shrimp farming on shrimp fishing. Both sectors have their difficulties: for example, farming has problems with mangrove destruction and fishing with bycatch and other issues. Generalization is difficult but, in many fishery agencies, it appears to be felt that the problems of shrimp farming are more manageable than those of shrimp fishing. Although this difference in perception may not be great, the implications could be significant in terms of government support. In some places, this could result in shrimp farming receiving relatively more subsidies, development attention, research allocation and favourable treatment in management schemes. For example, in the 1970s in the United States, there was a remarkable shift in research priorities by the Federal Government from shrimp fishing to shrimp farming.

## OTHER CONSIDERATIONS

It can be seen from the above discussion that shrimp farming has had a substantial impact on shrimp fishing activities, with some quite definite forms of interaction and others more open to debate. Interaction in the marketplace seems to be the most certain, with the most effect, at least during the present period of low profitability.

There is frequent debate as to whether past trends will continue in the future and whether farmed shrimp will largely displace capture shrimp. Despite the considerable uncertainty, this seems unlikely to happen.

Farmed shrimp is likely to acquire a larger market share of global shrimp production, especially in view of rising fuel costs for the energy-intensive capture sector and limited opportunities for expansion of catches; however, a complete displacement is improbable for various reasons. Historically, production trends (Figure 30) show that



shrimp production from both capture and farming increased over the last 20 years; hence, farming increases have not been at the expense of capture declines (i.e. the market is growing). Without increasing demand, conditions for captured shrimp would be more difficult, but several authors have commented that, in such a competitive environment, shrimp fishing fleets will probably become more profitable as the less efficient operators drop out. In addition, the various subsidies enjoyed by shrimp fishers (including for fuel) are likely to continue. It should also be remembered that aquaculture operations have great difficulty in producing economically the large-size shrimp so valued in many markets.

Finally, a great deal of shrimp farming (and its expansion) is largely related to international markets while, domestically, the captured product has certain advantages, including the low production costs of small-scale fishers and important markets not suitable for aquaculture, such as the large domestic demand in Asian countries for condiments made of paste shrimp.



## 17. Conclusions

Since the observations on the main shrimp fishery issues made in the preceding chapters are actually summaries of those subjects, they do not require further repetition. However, some other findings of the present study could be considered cross-cutting since they emerge in discussions of several different topics. A few deserve additional attention in this chapter: whether or not shrimp fishing is manageable; difficulties in small-scale shrimp fisheries; and benefits/costs of shrimp fishing. Some general suggestions for improvement are also given here.

### IS SHRIMP FISHING MANAGEABLE?

In the course of collecting information for the present study, the question of whether or not shrimp fishing is manageable arose on several occasions, both in the literature and in discussions. On reflection, the prospect of “manageability” seems to depend on perceptions of the management process and of its outcomes.

The recent history of shrimp fishing, especially that of warm-water shrimp trawling where many difficulties lie, shows that much of associated management activity is aimed at mitigating perceived problems. This characteristically involves reducing negative interactions with small-scale fishers, alleviating overfishing of target and non-target species, decreasing bycatch and/or discards, and lessening impacts on the seabed and ecosystem.

Sufficient technology and management experience now exist to mitigate these major problems. Substantial advances have been made in understanding the biology of the main shrimp species and their resilience to fishing pressure, and indeed such work has been commendable in showing the benefits of biological fisheries research in general. Spatial separation methods, enhanced by new technologies (e.g. VMS), can be used to reduce or eliminate industrial shrimp trawlers from interfering with inshore fishers. A great deal of work has been done on bycatch reduction, which has shown the way to successful interventions, by gear modifications and restrictions on fishing. Although the study of impacts on the seabed and the wider ecosystem is challenging, our understanding of these disturbances is increasing and several effective mechanisms to reduce physical impacts have been developed.

Fisheries management institutions in some countries are able to take advantage of these mechanisms and knowledge and alleviate many of the identified difficulties in shrimp fishing. Some of the best managed fisheries in the world of any type (invertebrate, finfish or otherwise) are shrimp trawl fisheries. Australia’s Northern Prawn Fishery and Spencer Gulf Prawn Fishery are global models for many aspects of fisheries management, including stakeholder participation, flexibility/responsiveness of interventions, verifiable achievement of objectives and the use of rights-based approaches. Some of the cold-water shrimp trawl fisheries are also exemplary for similar reasons.

It is therefore apparent that there are tools and models that can effectively mitigate the difficulties associated with shrimp fishing. The inference is that shrimp fishing, including shrimp trawling, is certainly manageable. This does not mean that shrimp fishery management practices are problem-free; in many countries, weak agencies dealing with fisheries, lack of political will and inadequate legal foundations cause failures in management. It is these factors that are largely responsible for lack of success, rather than any inherent unmanageable qualities of shrimp fishing gear or

shrimp fishing practices. Statements such as “shrimp fishing in this country is far more damaging than all other fishing put together” reveal more about the quality of the management regimes in that country than about shrimp fishing.

The above has implications for the improvement of the management of shrimp fisheries. It suggests that, in many countries, initiatives to enhance management should focus on these institutional aspects. Formerly, the agenda for improving the management of shrimp fisheries in many countries was oriented towards biology and technology, which in many cases was successful. At present, the weakest link – at least in many developing tropical countries where much of the shrimp management difficulty occurs – relates to institutional problems and in understanding the need for and benefits of management intervention. This suggests that efforts to improve shrimp fishery management in these countries should include more attention to such factors as agency effectiveness, awareness raising and the adequacy of legislation to support rights-based and dedicated access systems. For developed countries, much of the challenge lies in improving economic conditions within shrimp fisheries to deal with competition from aquaculture and rising fuel prices.

Another aspect of the question concerns management objectives. Many of the misunderstandings among the various concerned stakeholders are not fundamentally about shrimp fishing gear or fishing activities, or whether they can be controlled or not. Rather, they relate to differing ideas on acceptable costs transferred (externalized) by the gear/activities to non-target species, other fisheries, the environment and society. After all, management tools and experience are currently available to attain almost any level of costs. Perceived lack of success at achieving management objectives (i.e. the inability to manage shrimp fishing) often results from a lack of consensus over these objectives. This suggests that another key aspect for the enhancement of shrimp fishery management is an improvement in the participatory processes needed to generate greater stakeholder agreement on acceptable costs.

The conclusion here is that shrimp trawling is indeed an activity that can be managed to achieve objectives. In contrast, the management of many small-scale shrimp fisheries in developing countries appears to be extremely difficult.

## MANAGEMENT OF SMALL-SCALE SHRIMP FISHERIES IN DEVELOPING COUNTRIES

Small-scale shrimp fishing is very important in many regions and is responsible for a large portion of the total shrimp catch, especially in Asia. The number of small-scale shrimp fishers in the world is not known, but is likely to exceed by far those working on industrial shrimp vessels.

Various chapters of this report cite difficulties dealing with small-scale shrimp fisheries. In Chapter 6, it is argued that the objective of reducing bycatch in many small-scale shrimp fisheries of developing countries is challenging and perhaps even impossible. In Chapter 12, it is suggested that access restriction is necessary to prevent economic overfishing, but this is not practical in many small-scale shrimp fishery situations for several reasons. Other chapters mention the additional difficulties of small-scale shrimp fisheries: concerns over the cost/benefits of research; carrying out stock assessment; and obtaining reasonable catch data. It is also cited that management of these fisheries often “relies on non-existent enforcement”. In many countries, even modest top-down regulatory interventions dealing with small-scale shrimp fisheries do not succeed because of enforcement practicalities: large numbers of vessels; the impracticality of placing observers on board; many landing sites; and reluctance to place demands on poor people. A further complication is that many of the concerned small-scale fisheries are not really “shrimp fisheries”, but multispecies fisheries in which shrimp is caught.

The net result of the above is an extremely challenging situation which, in many cases, may approach what Pauly (1993) refers to as “Malthusian overfishing”, i.e. the inability of fishery resources to support large and rising numbers of fishers who have few non-fishing alternatives.

An important issue in these circumstances is whether management interventions can be effective and worthwhile. Chapter 12 gives the many views on this topic, some of which are only applicable to specific national conditions. Most of these opinions on how best to deal with the challenges of small-scale shrimp fisheries and improve their management seem to fall into three categories: a *laissez faire* approach – to recognize the difficult realities and give low or no priority to management; a strategy to favour management measures that are easy to enforce to some degree, such as marine protected areas or total bans; and participatory management, in which communities and government are jointly involved in the management process.

Despite these differences in dealing with the complexities of small-scale shrimp fisheries, many shrimp specialists agree that much more attention should be focused on the issue of what is desirable, possible and practical in their management.

### BENEFITS AND COSTS

Shrimp fishing has numerous benefits, but also considerable costs. In Chapter 4, the economic benefits of shrimp fishing are discussed. As regards costs, since there are so many associated with shrimp fishing, they are dealt with in several chapters.

Table 19 gives the benefits and costs of shrimp fishing. The list is not intended to be exhaustive and nor do all benefits/costs apply to every shrimp fishery.

As regards the benefits of shrimp fishing, Chapter 4 provides information for ten representative shrimp fishing countries on simplistic indicators of benefits: contribution to GDP, shrimp consumption, employment, gross value of the catch and value of exports. This information is summarized in Table 6, followed by a number of observations on the availability and reliability of the indicator data. Particularly relevant comments are the following.

- Employment associated with shrimp fishing is often thought to be one of the main benefits. In the ten countries studied, data on employment seem to be the least reliable and least comparable across countries. Where reasonable employment data are available, they are usually confined to formal jobs on board industrial trawlers but, in many cases, employment in small-scale shrimp fisheries is probably much greater than it is on board large vessels.
- Resource rent for a fishery represents the net benefits available to the private and/or public sectors in various forms. Unfortunately, estimates of resource rent appear to have been made for only a few of the world’s shrimp fisheries.
- With a view to exploiting the information gleaned, it should be noted that the available benefits information for the ten countries studied represents a heterogeneous assemblage of facts, collected in different ways, with varying

TABLE 19  
Some of the benefits and costs of shrimp fishing

Benefits	Costs
Income from direct employment	Physical impacts on sea bottom
Company profits	Overexploitation of target resources
Spin-off benefits (profits/income indirectly generated)	Ecosystem impacts
Nutrition	Conflicts with other fisheries
Export earnings	Cost of subsidies
Government revenue	Management costs (including research, enforcement and costs of exclusion)
Social stability	

degrees of rigour. As such, summations or comparisons of most types of benefit are difficult.

There is often less information available on shrimp fishing costs than benefits and, in many cases, it is considerably less precise. In some well-studied fisheries, several types of shrimp fishing costs are known and readily available to fishery managers. Examples are the financial impact of bycatch in the *Crangon* Beam Trawl fishery of the southern North Sea, and the cost of fisheries management in Australia's Spencer Gulf Prawn Fishery. However, these examples appear to be exceptions – costs in most shrimp fisheries are elusive. For some collateral costs (e.g. physical and ecosystem impacts), neither the methodology for determining impact has been developed, nor that for valuing detected impacts. With respect to costs in developing countries, government fishery agency officials are typically fairly aware of the many types of costs associated with shrimp fishing, but focus, to some degree, only on those that affect the agency's budget (often subsidies and management costs) and involve conflict. Some important observations on shrimp fishing costs are the following.

- A large proportion of shrimp fishing costs appears to be associated with trawling, or at least there is far less information on the costs of other types of shrimp fishing.
- Discards are substantial in many shrimp trawl fisheries, yet Kelleher (2005) states that few comprehensive studies have been carried out on the cost of discards to society and on who bears these costs.
- Costs associated with shrimp fishing, as for most fisheries, occur mainly out of sight and are not visible to the general public.
- Many costs are external to shrimp fishing operations and are borne by society. These externalities represent indirect, and in most cases unconscious, incentives to pursue an irresponsible and altogether uneconomic use of goods.
- There are often significant political costs involved in implementing management.

Both benefits and costs are difficult subjects to quantify and compare, but somehow costs appear more suited to colourful metaphors, such as: “*clear-cutting a forest in order to catch songbirds*” and “*using a bulldozer to harvest corn*”. Benefit information, such as income, seems more mundane in proclamations and brochures. Many of the benefits cited in Table 19 are promoted by strong economic forces; some appear transitory. Several costs appear more enduring and some may even be irreversible, such as the eradication of three-dimensional biological structures.

Based on the information in this report, some conclusions can be drawn as to the benefits and costs of shrimp fishing. In the process of managing shrimp fisheries, some form of balancing the benefits of the fishing with the various costs incurred is required. Considering the scarcity and limitations of data on shrimp fishing benefits/costs, it does not seem that there is enough information on benefits in most countries to determine whether costs incurred are justified, at least not in a quantitative sense. Although it is recognized that it is difficult to compare benefits and costs for most shrimp fisheries, in effect they are being compared and trade-offs made in the fisheries development and management processes. The controversy that often results appears to be partially a result of lack of stakeholder consensus over the mechanisms for making the trade-offs, and the adequacy of the information used.

In fisheries where this is indeed the case, information from resource rent studies may improve the process. Estimates of resource rent can be formulated to include both monetary and non-monetary benefits and costs. Considering the advantages, it is ironic that rent information is unavailable for many of the world's shrimp fisheries, just as for most fisheries in the world.

## AUSTRALIA

Throughout this report, constant reference to Australia has been unavoidable. The country is a convenient source of positive shrimp fishery examples, including quantity and relevance of research on shrimp/bycatch, bycatch reduction, mitigation of the physical effects of trawling, stakeholder participation in management, “user pays” and management cost-recovery arrangements, data reporting and the use of property rights in management. While a few other shrimp fishing countries can also provide good experience and models, Australia’s knowledge is especially valuable for two reasons. First, it concerns warm-water shrimp fisheries, where the interests of developing countries lie and which have the greatest management challenges. Second, Australia’s shrimp-related information is internationally available.

In one sense, Australia is a wealthy developed country with well-developed fishery institutions and processes that cannot simply be replicated by a developing country. In addition, Australia does not have a poor and growing population of fishers, and limited access is the norm. Nonetheless, the experience and lessons learned from Australia’s large industry and government investment in shrimp fishing research and management could be used as a model to strive towards and could save fishery managers in other countries much expenditure and time, and from having to “reinvent the wheel”.

## SOME SUGGESTIONS

Many important issues related to the world’s shrimp fisheries are highlighted in this report. The findings show that there are many opportunities for improving the sustainable benefits from shrimp fisheries and considerable potential for reducing their negative impacts.

Deficiencies and possible solutions at the fishery and national levels are far better known by individuals and agencies at these levels. Because the present study has some advantage in looking at issues globally, it is appropriate that attention be focused on those subjects that are generally applicable and where there is potential for international cooperation. Another factor in favour of generalizations is that, because shrimp is one of the few real fishery “commodities”, the improvement of shrimp fishery management is simply often not compatible with local solutions, because of global demand and prices.

### Shrimp fisheries in developing countries

Of all shrimp fisheries, those in developing countries present the greatest challenges. They typically have the major problems of overcapacity, overexploitation, conflict with small-scale fishers and high discard rates for industrial-scale trawl vessels. In addition, these countries characteristically have weak fisheries institutions for researching and managing such difficulties. In short, there are many problems and few affordable solutions. Ironically, many of the countries in this unfortunate category are highly dependent on the economic benefits of shrimp fishing.

More could, and should be done to improve this bleak situation, by both national governments and the international community. In general, means to improve shrimp fisheries should be oriented towards the institutional aspects of fisheries management, such as agency effectiveness, awareness raising and adequacy of legislation. On the technical side, priority should be given to:

- ensuring minimal administrative capacity (in data collection, staff with management capacity, minimal scientific support, extension officers), including at the decentralized level;
- recognizing the limitations of single-species management and, where possible, and appropriate, moving towards an ecosystem approach to management;

- promoting fisheries management regimes that grant secure resource rights to the stakeholders in these fisheries, focusing on the usefulness of collective rights and responsibilities as an alternative to centralized fisheries institutions and processes;
- “democratizing” important types of analysis that are often not carried out because of their complexity. This includes establishing processes for simplified resource and fisheries integrated assessment to the level where they are suitable for less sophisticated users; and
- promoting fisheries management tools appropriate for difficult environments, specifically marine protected areas, because of their potential enforcement, bycatch and ecosystem advantages.

Some suggestions for improvement in management of shrimp fisheries in developing countries depend on the scales of fishing. With respect to small-scale shrimp fisheries, a major recommendation is that greater attention be paid to socio-economic aspects.

- Research on socio-economic issues should receive greater attention in the fisheries research agendas of fisheries agencies.
- Mechanisms should be developed to incorporate the findings of socio-economic research in the management process.
- Special emphasis should be placed on the fundamental question of whether additional net benefits can be produced by management intervention (“What kinds of management attempts will be worthwhile?”) and the practicalities of small-scale shrimp fishery capacity reduction.

For large- and some small-scale shrimp fisheries where there is open access (the right for the public to participate in a fishery), an overriding recommendation of this study is that serious consideration be given to introducing a regime to restrict access effectively and subsequently provide secure tenure, either collectively or individually, to participating stakeholders.

### Capacity reduction

Many or most of the world’s shrimp fisheries are overexploited, at least in an economic sense. Reduction of effort, or the more fundamental reduction of capacity, is likely to have positive effects on the profitability of fishing operations and on the wider net benefits from these fisheries. Such reductions would also serve to moderate some of the major negative impacts of trawling, such as bycatch and physical disturbances to the seabed.

In view of these benefits, shrimp fishing capacity reduction efforts need to be reinvigorated, by publicizing the benefits of capacity reduction, highlighting the various schemes in shrimp fisheries that have been successful, drawing attention to innovative mechanisms for capacity reduction (e.g. fractional licensing) and addressing the issue of open access.

### Open access

Following on from the last section, a key observation of this study is that open access management regimes plague shrimp fisheries in both developing and developed countries – from Cambodia to the Gulf Coast of the United States. Conversely, in restricted access regimes where participants have secure tenure, there is a long-term relationship between fishers and the fishery resource, hence a powerful incentive for conserving the resource for the future.

The history of shrimp fishery management shows the futility of attempts to maximize economic yield over the long term in an open access environment. Considering that many, or even most, of the world’s shrimp fisheries are open access, it appears that economic overfishing will continue to plague the global shrimp fishing industry for a long time.



Reduction of bycatch and mitigation of impacts on the seabed are also important objectives in the management of shrimp fisheries in an EAF framework. Reducing capacity is important to do this, but to do so efficiently necessitates the ability to restrict effort.

One of the most important overall recommendations of a global study of shrimp fisheries is that the open access nature of a large number of shrimp fisheries around the world should be addressed. This would include raising public awareness of the benefits of a change to restricted access, generating the political will to transform, establishing mechanisms for a transition process and accommodating any windfall in benefits.



**PART 2**  
**SHRIMP FISHERIES IN SELECTED**  
**COUNTRIES**



# Shrimp fishing in Australia

## AN OVERVIEW

Australia is greatly involved in shrimp<sup>21</sup> fishing and its associated activities. Shrimp fishing occurs in the tropical, subtropical and temperate waters of the country, and ranges in scale from recreational fisheries to large-scale operations using vessels of up to 40 m in length. Australia also produces shrimp from aquaculture and is involved in both the export and import of shrimp in various forms. Many Australian shrimp fisheries are considered to be extremely well managed and a model for other countries to emulate. Moreover, the availability of recent information on Australian shrimp fishing and management issues is excellent.

## DEVELOPMENT AND STRUCTURE

The main Australian shrimp fisheries can be roughly divided by area and management responsibility.<sup>22</sup> Ten major shrimp fisheries are recognized in the national fisheries statistics (ABARE, 2005). Summary details on these fisheries are given in Table 20. The nomenclature of the main species of Australian shrimp is given in Table 21.

Some of the more significant or interesting Australian shrimp fisheries are described below.



TABLE 20

**Main shrimp fisheries in Australia**

Fishery	Species listed	Main method	Fishing units
Commonwealth Northern Prawn	Banana, tiger, endeavour and king prawns	Otter trawling	96 vessels
Commonwealth Torres Strait Prawn	Prawns	Otter trawling	70 vessels
New South Wales Ocean Prawn Trawl	Eastern king prawns	Trawling	304 licence holders
Queensland East Coast Otter Trawl	Tiger, banana, red spot, king, endeavour, eastern king, bay prawns	Otter trawling	478 licence holders
Queensland River and Estuary Trawl	Banana, bay and tiger prawns	Beam trawling	160 licence holders
Western Australia Shark Bay Prawn	King, tiger and endeavour prawns	Trawling	27 licence holders
Western Australia Exmouth Prawn	King, tiger and endeavour prawns	Trawling	13 licence holders
Western Australia Nickol Bay Prawn	King and banana prawns	Trawling	13 licence holders
South Australia West Coast Prawn	Western king prawn	Trawling	3 licence holders
South Australia Spencer Gulf Prawn	Western king prawn	Trawling	39 licence holders

Sources: ABARE, 2005.

<sup>21</sup> Although the term “prawn” is more often used than “shrimp” in Australia, “shrimp” is used in this chapter to be consistent with other chapters and international usage. (See Box 1 for information on the use of shrimp versus prawn.)

<sup>22</sup> Most of the larger offshore fisheries in the country are managed by the Australian Commonwealth, while most of the coastal and inshore fisheries fall under the jurisdiction of the Australian states or territories.

TABLE 21  
Main shrimp species in Australia

Scientific name	Common name in Australia
<i>Penaeus merguensis</i>	White banana prawn
<i>Penaeus indicus</i>	Indian banana prawn
<i>Penaeus longistylus</i>	Red spot king prawn
<i>Penaeus latisulcatus</i>	Blue-legged king prawn
<i>Penaeus plebejus</i>	Eastern king prawn
<i>Penaeus esculentus</i>	Brown tiger prawn
<i>Penaeus semisulcatus</i>	Grooved tiger prawn
<i>Penaeus monodon</i>	Leader prawn, giant tiger prawn
<i>Metapenaeus ensis</i>	Red endeavour prawn
<i>Metapenaeus endeavouri</i>	Blue endeavour prawn
<i>Metapenaeus macleayi</i>	School prawn
<i>Metapenaeus bennettiae</i>	Greasyback prawn
<i>Trachypenaeus</i> spp.	Hardback prawn

1960s. Initially, NPF was a banana prawn fishery, with vessels targeting the abundant schools or “boils” of prawns in the southeast corner of the Gulf. The numbers of vessels rose dramatically in the mid-1970s, partly as a result of huge catches in 1974, when more than 12 500 tonnes were landed. The open access nature of the fishery, shipbuilding subsidies and government development priorities for the Northern Territory resulted in a rapid buildup of vessels and an expansion of effort across the NPF area. The banana prawn season shrank from year-round in the 1960s to only a few months a year in the 1970s and to just a few weeks in the 1980s. In recent years, a poor banana prawn season, usually associated with reduced rainfall, may last little more than two weeks. This decline was exacerbated by a particularly dry decade in the 1980s that forced vessels to seek new fishing opportunities, leading to an increase in effort in the tiger prawn fishery. As the banana prawn fishery began to decline, attention turned more and more towards tiger prawns. The tiger prawn fishery rapidly expanded until it too began to suffer from an excess of capacity and declining catches in the late 1970s. In September 2005, the fishing fleet comprised 85 purpose-built steel trawlers from 13 m to 29.2 m in length, most of which are “company” boats. These trawlers are capable of sorting, grading, packing and freezing catches at sea and are serviced by mother ships that accept the frozen products and supply fuel, gear and other provisions. At present, the NPF has two components, as described below.

- A banana prawn fishery, which commences when the NPF season opens and usually lasts for a few weeks in April/May. The fishery generally operates during daylight hours and targets prawn aggregations, frequently using spotter aircraft. Fishing is extremely intense with vessels often working in close proximity and in strong competition. Very large catches can be taken in a short time.
- A tiger prawn fishery, which operates from September to December, generally at night, and is more widespread across the NPF area than the banana prawn fishery.

The Commonwealth Torres Strait Prawn Fishery is located between the tip of the Cape York Peninsula and the south coast of Papua New Guinea. About 70 vessels participate in the fishery and the operators target tiger and endeavour prawns. The value of the shrimp catch was about \$A19.2 million in the 2002/03 season. Since the 1998/99 season, harvests have decreased each year, contributing to the fall in value of the fishery. Fishing is carried out at night using otter trawls. Few vessels fish exclusively in the Torres Strait area; most move between the Queensland East Coast Trawl Fishery and the NPF. The fishing season in the Torres Strait Prawn Fishery is from March to December (Galeano *et al.*, 2004).

At the South Australia Spencer Gulf Prawn Fishery, western king prawns were first trawled in 1909, but it was not until the mid-1960s that fisher trials showed their

The Commonwealth Northern Prawn Fishery (NPF) is the most important shrimp fishery in the country and in the 2003/04 period produced about 6 000 tonnes of shrimp worth \$A74 million. Cartwright (2003) provides information on its history and structure. The fishery covers a large geographic area of some 700 000 km<sup>2</sup>, extending across much of the northern coastline, from Queensland to Western Australia. Surveys in the mid-1960s, by the Commonwealth Scientific and Industrial Research Organization (CSIRO), resulted in the establishment of a commercial prawn fishery in the Gulf of Carpentaria in the late

commercial potential. By the late 1960s, a small industry had been established. At present, commercial fishing is undertaken using otter trawling. This trawling takes place at night for nine to 13 hours, depending on the hours of darkness (daylight trawling is prohibited). The Spencer Gulf Prawn Fishery (and the nearby west coast area) is the largest in the world for western king prawns, with an average annual catch of 1 800 to 2 000 tonnes, which in recent years has been worth from \$A35 million to \$A40 million. The fishery (including the west coast) has a limited entry consisting of 42 licence holders, with the average vessel fishing 60 days per year (Palmer and Miller, 2005).

The New South Wales (NSW) Estuary Prawn Trawl Fishery involves the harvesting of prawns and, in some estuaries, squid and fish, by licensed commercial operators, using prawn trawl nets. The practice of trawling for prawns in NSW began in 1926 in Port Jackson. A single net connected to a pair of otter boards to spread it out was towed behind a small boat. In the 1940s, prawn trawling spread to four other estuaries (Clarence, Hunter and Hawkesbury Rivers and Botany Bay), following improvements in transport, the development of markets and the advent of motorized vessels. The introduction of mechanical winches on prawn trawling boats allowed the boats to trawl in deeper waters. In 1984, a freeze on the issue of new boat licences was introduced and, in 1988, the number of vessels operating in the fishery was limited to 309. Prawn trawling is currently permitted in four estuaries in NSW: the Clarence, Hunter and Hawkesbury Rivers and Port Jackson. At present, the fishery uses a single otter trawl net to target school prawns and eastern king prawns and, in the case of the Hawkesbury River, squid. With the exception of the Hawkesbury River, the fishery operates in defined seasons (generally October to May) and, within each estuary, is confined to specific times and a specific area (around 50 percent of the tidal area of each estuary). Most prawn catches are landed during the dark of the moon. In 2002–03, 322 tonnes of prawns, squid and other fish were harvested from the four estuaries, with a total estimated value at the first point of sale of \$A2.9 million. Approximately 220 fishers are currently entitled to operate in the fishery (DPI, 2005).

The Queensland East Coast Trawl Fishery extends from Cape York to the NSW border and is divided into three components: (i) the northern portion (mainly the Great Barrier Reef lagoon), which harvests tiger, endeavour and red spot king prawns; (ii) the southern portion (south of 220°S), which takes eastern king prawns and saucer scallops; and (iii) Moreton Bay, which harvests eastern king prawns, squid and blue swimmer crabs. From 6 000 to 9 000 tonnes of prawns are harvested annually by the Queensland East Coast Trawl Fishery. In recent years, the number of boats participating in the fishery varied from 700 to 800. King prawns are the major component of the trawl harvest, historically contributing 27 percent, with tiger prawns accounting for 21 percent (Williams, 2002).

A small Northwest Slope Trawl Fishery extends from 114°E to about 125°E off the Western Australian coast between the 200 m-isobath and the outer limit of the Australian Fishing Zone (AFZ). Seven vessels catch pink prawn (*Haliporoides sibogae*), red prawn (*Aristaeomorpha foliacea*), striped prawn (*Aristeus virilis*), scarlet prawn (*Plesiopenaeus edwardsianus*), red carid (*Heterocarpus woodmasoni*) and white carid (*Heterocarpus sibogae*). In the 2003/04 season, 61.6 tonnes worth \$A1 149 100 were landed.

Recreational fishing for shrimp is important in Australia. A national recreational survey showed that the largest component of recreational fishing in terms of numbers caught was the prawn shrimp fishery. This type of fishing occurs mainly in the estuaries of northern NSW and Queensland (Morgan, 2004a).

#### TARGET SPECIES, CATCH AND EFFORT

The annual catches of shrimp by political entity in Australia are given in Table 22.

The various shrimp fisheries catch different species of shrimp. Three examples are given below.

TABLE 22  
Australian shrimp catches

Area/fishery	Catch	2001/02	2002/03	2003/04
		Tonnes		
New South Wales	King prawns	1 113	1 180	849
	School prawns	522	563	635
	Other prawns	277	258	155
	Total prawns	1 912	2 001	1 639
Victoria	Total prawns	126	91	56
Queensland	Endeavour prawns	933	965	1 128
	King prawns	3 372	3 858	3 329
	Tiger prawns	1 527	1 861	2 242
	Other prawns	944	936	1 551
	Total prawns	6 775	7 620	8 250
Western Australia	Total prawns	3 555	3 934	3 689
South Australia	Total prawns	2 610	1 740	2 126
Northern Prawn Fishery	Tiger prawns	1 958	1 969	2 186
	Banana prawns	5 419	3 325	3 516
	Endeavour prawns	1 132	395	418
	King prawns	2	3	1
	Other prawns	7	6	71
	Total prawns	8 518	5 699	6 192
Torres Strait Fishery	Tiger prawns	706	665	630
	Endeavour prawns	889	750	681
	King prawns	167	122	81
	Other prawns	3	5	4
	Other	73	52	37
	Total	1 838	1 594	1 432

Source: ABARE, 2005.

- NPF is a multispecies fishery that catches at least nine species of prawns. Three species (the white banana prawn *Fenneropenaeus merguensis*, the brown tiger prawn *Penaeus esculentus* and the grooved tiger prawn *P. semisulcatus*) account for almost 80 percent of the total annual landed catch weight from the fishery. Endeavour prawns (*Metapenaeus endeavouri* and *M. ensis*) and red-legged banana prawns (*F. indicus*) constitute most of the remainder of the catch. Other components of the commercial catch include the giant tiger prawn (*P. monodon*), western king prawn (*Melicertus latisulcatus*) and the red spot king prawn (*M. longistylus*) (NORMAC, 2002).
- Robins, Campbell and McGilvray (1999) give the species in the Queensland East Coast Otter Trawl Fishery: eastern king prawn (*Penaeus plebejus*), banana prawn (*P. merguensis*), red spot king prawn (*P. longistylus*), brown tiger prawn (*P. latisulcatus*), brown tiger prawn (*P. esculentus*), grooved tiger prawn (*P. semisulcatus*), giant tiger or leader prawn (*P. monodon*), red endeavour prawn (*Metapenaeus ensis*), blue endeavour prawn (*M. endeavouri*), school prawn (*M. macleayi*), greasyback prawn (*M. bennettiae*) and hardback prawn (*Trachypenaeus* spp.).
- Broadhurst, MacBeth and Wooden (2005) indicate that, in NSW, three species of shrimp account for more than 98 percent of the total annual production: eastern king prawn (*Penaeus plebejus*), school prawn (*Metapenaeus macleayi*) and greasyback prawn (*M. bennettiae*).



TABLE 23  
Catch and effort in the Northern Prawn Fishery, 1980–2004

Year	Banana prawns (tonnes)	Tiger prawns (tonnes)	Endeavour prawns (tonnes)	King prawns (tonnes)	Total prawns (tonnes)	Number of vessels	Banana fishery effort (days)	Tiger fishery effort (days)
1980	2 835	5 124	1 891	111	9 964	269	8 391	30 594
1981	5 672	5 559	2 073	95	13 400	286	11 524	31 895
1982	3 875	4 891	2 124	144	11 036	271	8 751	32 956
1983	2 382	5 751	1 488	207	9 831	254	6 856	34 551
1984	3 770	4 525	1 714	83	10 095	252	5 932	32 447
1985	4 469	3 592	1 671	77	9 811	231	6 946	26 516
1986	2 935	2 682	748	85	6 451	238	7 132	26 669
1987	4 257	3 617	772	65	8 713	234	7 954	22 478
1988	3 381	3 458	669	81	7 591	222	6 655	26 264
1989	5 466	3 173	909	85	9 636	223	7 439	27 036
1980–89 average	3 904	4 237	1 406	103	9 653	248	7 758	29 141
1990	2 221	3 550	735	128	6 636	200	5 044	25 525
1991	6 605	3 987	879	81	11 554	172	6 515	20 744
1992	2 254	3 084	880	47	6 267	170	5 132	21 789
1993	4 292	2 515	733	35	7 572	127	6 299	16 019
1994	2 157	3 162	872	72	6 263	128	4 955	18 592
1995	4 961	4 125	1 150	58	10 294	125	4 880	16 834
1996	4 078	2 311	1 235	41	7 665	127	5 525	16 635
1997	4 587	2 694	1 870	51	9 202	129	5 476	15 385
1998	3 569	3 218	1 322	20	8 123	130	5 301	18 003
1999	3 904	2 136	885	21	6 947	129	5 639	12 675
1990–99 average	3 863	3 078	1 056	55	8 052	144	5 477	18 220
2000	2 195	2 190	958	13	5 355	121	3 697	12 736
2001	7 245	1 983	1 157	4	10 389	118	6 247	10 440
2002	4 577	1 943	411	5	6 936	114	4 148	8 718
2003	3 238	2 222	435	4	5 898	97	4 114	8 503
2004	3 520	1 767	396	3	5 686	96	3 985	7 793
2000–04 average	4 155	2 021	671	6	6 849	109	4 438	9 638

Source: Perdrau and Garvey, 2005.

The issues of catch and effort are discussed in more detail below for Australia's most important shrimp fishery, the NPF. Catch and effort information for this fishery for 1980 to 2004 is given in Table 23.

Although effort is given in the Table in terms of vessel days for the two fisheries, in practice the measurement of effort is complex and is evolving over time. The issues of effort, effort creep and capacity for the NPF are discussed in the section *Management of the Northern Prawn Fishery* below.

### ECONOMIC CONTRIBUTION OF SHRIMP FISHING

The values<sup>23</sup> of shrimp catches in Australia are given in Table 24.

Since 2002, the total annual catch of shrimp for Australia has been between 22 000 and 26 000 tonnes, valued between \$A300 and \$A365 million. In a national perspective, the value of total annual Australian fisheries production is about \$A2.2 billion. The shrimp fisheries are therefore roughly responsible for about 15 percent of the value of production from Australian fisheries. Gross domestic product (GDP) calculations by fishery or fishery commodity do not feature prominently in Australian shrimp literature; however, the contribution of all Australian fisheries to GDP is less than 0.3 percent.

<sup>23</sup> Values given are the assessed values at the point of landing and exclude transport and marketing costs.

TABLE 24  
Australian shrimp catch value, by season (\$A'000)

Area/fishery	Catch	2001/02	2002/03	2003/04
New South Wales	King prawns	23 258	24 109	17 795
	School prawns	3 907	5 801	4 973
	Other prawns	1 336	1 231	538
	Total prawns	28 501	31 141	23 306
Victoria	Total prawns	1 644	1 159	730
Queensland	Endeavour prawns	11 192	11 583	13 542
	King prawns	39 061	44 884	39 469
	Tiger prawns	22 904	27 908	33 635
	Other prawns	6 830	6 961	11 962
	Total prawns	79 986	91 336	98 607
Western Australia	Total prawns	47 068	45 807	44 782
South Australia	Total prawns	47 405	32 459	43 423
Northern Prawn Fishery	Tiger prawns	48 321	34 640	32 072
	Banana prawns	71 910	42 797	36 043
	Endeavour prawns	13 130	4 543	4 388
	King prawns	31	47	12
	Other prawns	42	21	610
	Total prawns	133 434	82 048	73 126
Torres Strait Fishery	Tiger prawns	13 510	10 700	8 511
	Endeavour prawns	8 221	6 902	5 194
	King prawns	2 109	1 586	932
	Other prawns	22	17	9
	Other	710	582	378
	Total	24 572	19 787	15 023

Source: ABARE, 2005.

Employment data for the fishing industry are collected by the Australian Bureau of Statistics (ABS). The data are gathered from the population census survey every five years. The most recently available ABS employment data for the Australian fishing industry (2001) indicate that 1 040 people were employed in shrimp fishing, geographically distributed as follows: New South Wales, 223 people; Victoria, six; Queensland, 472; Western Australia, 150; South Australia, 109; and Northern Territory, 80. These 1 040 people in shrimp fishing represent about 5 percent of those employed in the fishing industry as a whole.

A national nutrition survey of 13 858 Australians in 2004 indicated that the national consumption of shrimp is about 75 g/day, or 20.8 kg/year, for people over two years of age (Anon., 2004a).<sup>24</sup> Simplistically, if shrimp production from commercial capture fisheries is assumed to be 25 000 tonnes per year, aquaculture production 3 500 tonnes, shrimp exports 9 000 tonnes, shrimp imports 25 000 tonnes, and the Australian population 25 million, then an approximate estimate of annual per capita consumption of commercial shrimp in the country is about 2.2 kg.

## TRADE ASPECTS

Table 25 gives Australian shrimp exports for several years by product form.

<sup>24</sup> This seems unreasonably large in view of the results of Australian fish consumption studies that show that per capita consumption of all types of seafood in Australia was about 20 kg/ year in the mid-1990s (Gillett and Preston, 1997).

TABLE 25  
**Australian shrimp exports, by product form**

Product	2001/02		2002/03		2003/04	
	Tonnes	\$A'000	Tonnes	\$A'000	Tonnes	A\$'000
Headless	785	18 607	580	12 002	307	5 353
Whole	10 870	239 367	8 739	192 567	8 852	151 488
Other	270	4 853	213	3 676	237	3 762
Total	11 925	262 827	9 532	208 245	9 396	160 603

Source: ABARE, 2005.

The most important export destinations in 2003/04 in terms of weight were Japan (34 percent), Spain (18 percent) and China (12 percent). Australia also imports shrimp from various countries – 24 448 tonnes in the 2003/2004 period. The main supplying countries were China, India, Indonesia, Thailand and Viet Nam. It should be noted that import/export data include shrimp from capture fisheries as well as from aquaculture.

The data above show that Australia is a net importer of shrimp. In 2003/04, shrimp imports were 2.6 times that of exports.

In May 1996, the Government of the United States of America placed an embargo on the import of prawns from countries not implementing sea turtle conservation measures required by United States law. Australian shrimp exports were included in the embargo. The trade ban did not appear to have much direct effect on Australia because, prior to the embargo, it exported only a small proportion of its shrimp to the United States. The embargo could have had some indirect effects because Japan, the main Australian export shrimp market, may have experienced some oversupply since embargoed shrimp from other countries was diverted there. In July 2000, the general United States embargo on Australian shrimp was lifted.

At present, the United States position is that because the Australian Government maintains good governance over specific fisheries and keeps separate shrimp harvested in specific fisheries apart from specific fisheries labelled separately, the United States certifies Australian shrimp on a fishery basis. In early 2006, Australia had five fisheries certified: Torres Strait, Exmouth Gulf, Spencer Gulf, Northern Prawn and Queensland East Coast. Only shrimp from these five fisheries is allowed to enter the United States.

## BYCATCH ISSUES

Commonwealth policy defines bycatch as: (i) that part of a fisher's catch that is returned to the sea either because it has no commercial value or because regulations preclude it from being retained; and (ii) that part of the catch that does not reach the deck of the fishing vessel but is affected by interaction with the fishing gear (NORMAC, 2002).

Robins, Campbell and McGilvray (1999) give an overview of bycatch issues in Australian shrimp trawl fisheries. Bycatch issues in northern Australian prawn trawl fisheries focus predominantly on unwanted fish bycatch and the incidental capture and mortality of sea turtles in trawl nets. Bycatch issues in southern Australian prawn trawl fisheries focus predominantly on unwanted fish and crustacean bycatch. There are several reasons why bycatch issues in Australian prawn trawl fisheries have received considerable attention over the past decade:

- Australian fisheries management agencies have a legislative mandate to ensure that trawl fisheries comply with the principles of ecological sustainable development;
- many Australian prawn trawl fisheries also have legislation or policies that require a reduction in the take of non-target species and a minimization of the impact of trawling on the ecosystem;
- the drowning of sea turtles in trawl nets of Northern Australia has been given wide exposure;
- “World Heritage” status has meant increased scrutiny of commercial fishing practices, especially trawling operations, to ensure that the exploitation of fisheries

TABLE 26  
Bycatch issues in some Australian shrimp trawl fisheries

Fishery	Bycatch issue	Key initiators
Queensland East Coast*	Sea turtle and fish, since the late 1980s	Conservation-driven but supported by industry
Torres Strait	Sea turtles, unwanted fish bycatch	Conservation-driven
Northern Prawn	Sea turtle, unwanted fish bycatch since the late 1980s	Conservation-driven but supported by industry
Western Australia: Kimberley coast	Jellyfish	Industry-driven
Western Australia: Exmouth Gulf	Fish, seaweed and crabs since 1996	Industry-driven
Western Australia: Shark Bay*	Sea turtles and crabs since 1996	Industry-driven
South Australia: Spencer Gulf and West Coast	Crabs and fish since the mid-1980s	Industry-driven
South Australia: Gulf of St Vincent	Small prawns and fish since 1995	Industry-driven
New South Wales: estuaries	Fish since the 1980s	Government-driven, supported by industry
New South Wales: oceanic	Fish since the late 1980s	Government-driven, supported by industry

Source: Robins, Campbell and McGilvray, 1999.

\* Fisheries either entirely or partially within a "World Heritage Area".

resources does not occur at the expense of the quality of the ecosystem – two Australian prawn trawl fisheries occur within "World Heritage Areas"; and

- all export fisheries require accreditation through a strategy (environment) which, among other issues, gives consideration to levels of bycatch from a fishery.

The bycatch issues and associated initiators are different in the various Australian fisheries. Table 26 summarizes the situation in ten Australian shrimp trawl fisheries.

Reducing fishery bycatch in Australia had been addressed primarily through the use of technological gear solutions, such as TEDs and BRDs. Additional ways to reduce the overall bycatch of prawn trawl fisheries have been the reduction in the number of days fished, restrictions on fishing areas or specifications of allowable fishing gears.

Kelleher (2005) comments on discard rates from some Australian shrimp fisheries. Three northern shrimp fisheries (Northern Prawn, Torres Straits and Queensland East Coast Trawl Fisheries) jointly discard approximately 80 000 tonnes. The NSW Ocean Prawn Trawl Fishery has a high discard rate (88.7 percent), generating approximately 16 000 tonnes of discards. Progressive implementation of bycatch action plans for the various fisheries is likely to reduce the discards and discard rates presented above.

Many of the shrimp fisheries in Australia are covered by bycatch management plans. The NPF has a comprehensive bycatch management plan that covers bycatch issues; bycatch caught in trawls; cause of the bycatch problem; extent of the issues; stock status; strategies for managing the issues; and management of bycatch. With respect to the management of bycatch, the plan states: "There are two main elements to managing bycatch. First, industry needs to adopt measures to reduce the amount taken. Second, the management agency must monitor the success of the measures" (NORMAC, 2002). With respect to the success of efforts to reduce prawn trawl bycatch in Australia, the following observations are especially significant.

- In reviewing the history of prawn bycatch reduction efforts in Australia, Robins, Campbell and McGilvray (1999) comment that the greatest advances in the rates whereby fishers adopt TEDs and BRDs have occurred after respected individuals within the fishing industry have developed or modified gear that reduces bycatch. In hindsight, Australia has benefited greatly from overseas experiences in the development and implementation of technology to reduce fishery bycatch.
- Robins *et al.* (2002) give the results of a study of the effectiveness of TEDs in reducing sea turtle bycatch in the NPF. The study showed that prior to the use of TEDs, an estimated 5 000 sea turtles were caught annually by the trawl fleet. Since TEDs have been installed, the catch of sea turtles is estimated to have fallen possibly to fewer than 200 turtles per year. In addition, turtle mortality is estimated to have decreased from close to 40 percent in earlier years to around 22 percent in recent years. In summary, since the introduction of TEDs, few turtles are expected

to die as a result of capture in trawl nets in the NPF. Recent catch data (2004) from the Australian Fisheries Management Authority (AFMA) show the annual catch of turtles as 27, of which 24 were released alive (Perdrau and Garvey, 2005).

- An important lesson learned is that rather than governments researching and driving bycatch reduction technology, a better approach seems to be for regulators to set targets/requirements (and perhaps initial style), and allow industry to innovate them. In the NPF, TEDs were originally seen as a necessary evil but, since they also removed large animals such as bull rays and sharks, they also increased prawn quality and crew safety. Now, they would be a matter of choice rather than of obligation (I. Cartwright, personal communication, January 2006).

### PROFITABILITY AND RESOURCE RENT

The Australian Bureau of Agricultural and Resource Economics (ABARE) has been undertaking economic surveys of selected Commonwealth fisheries since the early 1980s and, on a regular basis for particular fisheries, since 1992. ABARE surveyed four individual Commonwealth fisheries in 2003, including NPF and the Torres Strait Prawn Fishery. Galeano *et al.* (2004) describe the methodology and give the results of the 2003 work. Between February and June, an ABARE officer visited the owners of each shrimp boat selected in the sample to interview them in order to obtain physical and financial details of the fishing business for the survey years. Further information was subsequently obtained from accountants, selling agents and marketing organizations.

The results of the studies (Tables 27, 28 and 29) provide insight into the economic performance from the perspective of fishing vessel operators as well as that of the overall fishery. The latter is especially useful in gauging how well AFMA is performing against their legislated objectives of maximizing economic efficiency and providing efficient and cost-effective management. According to a former senior Australian fisheries manager (R. Kearney, personal communication, January 2006), rent in fisheries is not calculated for taxation purposes, which is against current government policy.

Galeano *et al.* (2004) summarize the performance of the two fisheries.

#### *Northern Prawn Fishery*

- The real (2002–03 \$A) gross value of NPF production reached a record \$A175 million in 2000–01 before falling to \$A140 million in 2001–02 and to under \$A83 million in 2002–03.
- Average prawn receipts per boat fell by 21 percent in 2001–02 to \$A1.17 million; this partly reflected lower catches.

TABLE 27

**Financial performance of the Northern Prawn Fishery**

	Revenue	Operating costs	Capital	Net returns (excl. management costs)	Management costs	Net returns (incl. management costs)	Number of vessels
\$A million*							
1990–1991	149.4	110.7	98.1	22.3	n.a.	22.3	169
1991–1992	115.8	94.5	80.3	10.0	n.a.	10.0	160
1992–1993	128.6	99.1	68.5	21.3	n.a.	21.3	129
1993–1994	140.8	108.0	59.7	21.9	n.a.	21.9	132
1994–1995	173.8	116.6	77.8	44.0	n.a.	44.0	133
1995–1996	147.7	111.1	92.3	21.1	1.6	19.5	134
1996–1997	139.1	101.3	80.6	24.1	1.9	22.2	128
1997–1998	167.4	109.5	77.1	43.8	1.7	42.1	130
1998–1999	153.0	105.0	73.2	35.6	1.4	34.2	133
1999–2000	121.9	89.2	58.3	22.1	1.1	21.0	130
2000–2001	185.7	114.3	52.7	62.4	1	61.4	118
2001–2002	139.3	97.1	45.4	34.0	1.1	33.0	118

\* At 2002/03 value.

TABLE 28  
Financial performance of the Torres Strait Prawn Fishery

	Revenue	Cash costs	Capital	Net returns (excl. management costs)	Management costs	Net returns (incl. management costs)	Number of vessels
\$A million*							
1992–93	17.6	14.9	11.4	1.4	n.a.	n.a.	61
1993–94	17.6	14.8	10.1	0.8	n.a.	n.a.	64
1994–95	19.1	16.0	11.2	1.1	n.a.	n.a.	60
1995–96	18.2	15.9	9.5	0.6	n.a.	n.a.	60
1996–97	19.9	16.9	8.6	1.5	n.a.	n.a.	80
1997–98	22.3	17.6	7.0	3.3	0.2	3.1	83
1998–99	26.9	21.5	12.0	3.3	0.2	3.1	82
1999–00	26.8	20.8	10.6	4.0	0.2	3.8	79
2000–01	28.6	21.4	11.9	5.1	0.3	4.8	78
2001–02	24.7	19.7	10.0	3.1	0.3	2.8	75

\* At 2002/03 value.

- The fall in average prawn receipts per boat was slightly greater for small boats and, while there were some cost reductions across the fleet, profit at full equity for all boats fell on average by 35 percent to \$A305 000 per boat.
- On large boats, cost reductions were not as large and profit at full equity fell by 44 percent to an average of \$A337 000 per boat in 2001–02.

Estimated real net returns (including management costs) to the NPF resource fluctuated substantially since 1990–91, averaging around \$A29.4 million annually (in 2002–03 \$A). Net returns (assuming constant stocks) were estimated at \$A61.4 million in 2000–01 and \$A33.0 million in 2001–02.

#### *Torres Strait Prawn Fishery*

- Despite a relatively stable harvest of prawns between 2000–01 and 2001–02, average prawn receipts per boat for the fleet as a whole are estimated to have fallen by 15 percent in the second season to \$A671 000.
- Fuel and crew costs were the main contributors to an estimated 9 percent fall in costs across the fleet between 2000–01 and 2001–02. Boat cash income across the fleet fell by an estimated 45 percent between 2000–01 and 2001–02 while, according to specialists, it fell by an estimated 17 percent.
- Net returns to the fishery (including management costs and assuming constant stocks), are estimated to have fallen in real terms from \$A4.8 million in 2000–01 to \$A2.8 million in 2001–02.
- These net returns are much lower than the estimated average long-term net returns to the NPF (\$A38.3 million), yet higher than the average for the Southeast Trawl Fishery (\$A2 million) over the same period.

#### **ENERGY INPUT ASPECTS**

Fuel is a major cost component of shrimp fishing. In the 2001/02 season, fuel accounted for 23.5 percent of all costs in the Torres Strait Fishery and 20.6 percent in the NPF (Table 29). Fuel costs have increased considerably since that period and, in 2006, constituted a much larger portion of total costs. According to the summary of the December 2005 meeting of the Northern Prawn Fishery Management Advisory Committee (NORMAC), “Fuel is a huge expense and the cost base of producing a kilo of prawns is on an upward spiral against the prices flat-lining or declining” (AFMA, 2005a).

- Many opinions have been expressed on how to cope with rising fuel costs. For some time it was thought that one of the incentives for reducing bycatch is that fuel costs would be less (reduced net drag) (Robins, Campbell and McGilvray, 1999). A Fuel Sales Grants Scheme (FSGS) has provided relief to fuel users in regional and remote Australia in the recent past, cutting the price of fuel, including

TABLE 29  
Estimated financial performance of an average vessel\*

	Torres Strait Fishery		Northern Prawn Fishery	
	2000/01	2001/02	2000/01	2001/02
Prawn receipts	788 649	671 429	1 486 473	1 167 646
Other fishing receipts	134 419	68 343	23 644	25 363
Non-fishing receipts	28 225	20 276	26 689	28 638
Total cash receipts	951 293	760 048	1 536 807	1 221 647
Administration	13 005	11 148	18 435	15 621
Crew costs	285 095	225 279	377 240	303 194
Freight and marketing expenses	21 490	14 717	35 344	27 992
Fuel	158 212	140 891	201 300	184 868
Insurance	15 492	18 877	37 380	38 043
Interest paid	9 919	16 782	15 070	14 495
Leasing			23 129	17 548
Licence fees and levies	13 578	15 911	23 887	29 651
Packaging	10 644	11 456	13 903	15 920
Repair and maintenance	102 615	111 948	188 922	192 673
Other costs	21 407	28 556	56 059	50 009
Total costs	651 458	595 564	990 671	890 014
Boat cash income	299 835	164 484	546 136	331 633
less depreciation	29 549	27 830	42 614	42 403
Boat business profit	270 286	136 655	503 521	289 230
plus interest leasing and rent	10 703	23 465	38 906	32 468
Profit at full equity	280 989	160 120	542 428	321 698
Capital				
– excluding quota and licences	530 026	584 584	1 129 929	1 101 816
– including quota and licences	n.a.	2 242 396	n.a.	4 547 864
Rate of return to boat capital	53%	27.4%	48%	29.2%
Rate of return to full equity	n.a.	7.1%	n.a.	7.1%

Source: Galeano *et al.*, 2004.

\*All vessels in the fisheries.

Note: units, unless otherwise specified, are in \$A.

diesel, used on fishing vessels by up to 2 cents/litre, thus reducing the fuel bill in the NPF alone by around \$A1 million a year. This scheme, however, was abolished in January 2006 (Australian Seafood Industry Council [ASIC] Web site information). ASIC has formulated a three-point proposal to address fuel costs and help mitigate the loss of the FSGS:

- extend relief from the 2 cents/litre ultralow sulphur diesel levy to the seafood industry;
- cut another 4 cents/litre by applying goods and service tax to the net cost of fuel after diesel fuel rebate, not to the gross cost; and
- ensure that oil companies pass on the full benefit of the 35 percent revaluation of the Australian dollar.

Currently, twin gear (two nets) is used in the NPF. This gear is considerably less fuel-efficient than the quad rig (two nets per warp), which was used until it was banned as part of new management arrangements. With spiralling fuel prices, it is becoming increasingly attractive to seek ways of reducing fuel use, including revisiting the quad-rig ban, and the development and use of more fuel-efficient trawl boards and netting material (I. Cartwright, personal communication, January 2006).

## BIOLOGICAL ASPECTS

The status of most significant fisheries in Australia is assessed and reported on annually by the management agency to state and national governments through formal “state of

the fisheries” reports (Morgan, 2004a). As such, most of the important shrimp fisheries have been assessed in terms of their biology, and many have undergone economic and environmental evaluations. From a biological perspective, because most of the country’s shrimp fisheries are fully or overexploited, there is not much potential for the expansion of shrimp catches.

Although a full account of the biological aspects of all of Australia’s shrimp fisheries is beyond the scope of this brief review, summary biological information from one large shrimp fishery (NPF) and one small one (Exmouth Gulf) are given below.

The biological status of the target species in the NPF, as given by several authors, is summarized by Galeano *et al.* (2004).

- *Banana prawns.* Banana prawn catches in the NPF are made up of white banana prawns and red-legged banana prawns. The sustainable long-term average annual catch for both species of banana prawns is estimated at around 4 000 tonnes, approximately the average annual catch over the past ten years. The catch of banana prawns from the NPF is considered likely to be sustainable, but the reliability of the assessment is moderate. The annual productivity of banana prawns has been linked to rainfall levels. Expected catches based on these levels are compared with observed catches to give an assessment of the banana prawn fishery. Preliminary results from an age-structure model indicate that, at least in certain areas, there may be a relationship between stock size and subsequent recruitment for white banana prawns.
- *Tiger prawns.* In 2001, an independent expert was contracted to review the 1999 tiger prawn assessment. It was concluded that brown tiger prawn stocks were at 42 to 54 percent and grooved tiger prawn stocks at 66 to 86 percent of target levels in 2001; tiger prawn stocks were overfished; and levels of effort were too high to promote recovery. The model used to assess the status of tiger prawns has been updated in recent years but still shows brown tiger prawns as overfished. However, effort levels in 2002 are thought to have been below the level needed to achieve the stock associated with maximum sustainable yield (MSY) and projections suggest that rebuilding of the target spawning stock size will occur within a couple of years if 2002 effort levels are maintained. The stock is considered fully exploited and is projected to remain at this level, based on the assumption that the 2002 levels are maintained and not increased.

The Australian Department of Fisheries (2002) summarizes the biological information on the Exmouth Gulf Prawn Fishery in Western Australia.

- The breeding stock level for tiger prawn stock in the Exmouth Gulf is currently above the agreed reference point.
- The historical catch and effort trends over the past 40 years indicate that there has been no decline in the production levels for king prawn in the Exmouth Gulf, which is consistent with there being sufficient ongoing levels of spawning biomass for this species.
- Historical catch trends indicate that production levels for endeavour and banana prawns remain within natural environmental levels, which is consistent with the recruitment potential of these species that have not been affected by the fishery.
- The level of capture of other by-product species by this fishery is too small to have a significant impact on their dynamics.
- The two main target species for the Exmouth Gulf, the tiger and king prawns, are both classified as fully exploited.

## IMPACTS ON THE PHYSICAL ENVIRONMENT

The subject of the impact of shrimp trawling on the physical environment is addressed in many of the reviews on particular Australian fisheries. Several of the reviews indicate that shrimp trawling is definitely having an impact, but that the effects are mitigated to some extent by the fact that the actual trawling only covers a portion of the fishery



area and the intensity of trawling is decreasing as management measures reduce fishing capacity. Some specific observations are given below.

- *Gulf St Vincent*. Like all trawling methods used in the fishing industry, the demersal otter trawl technique used in Gulf St Vincent may cause some damage to the benthos. This results from the very nature of the operation, which requires contact with the seabed in order to catch bottom-feeding crustaceans. There are, however, some mitigating factors that tend to minimize adverse effects on the ecology of the regions fished. Prawn trawling can only take place where the water is relatively deep (more than 10 m in depth) and seagrass beds are avoided. The sand and mud bottom is generally smooth and free of snags. Furthermore, as a result of long-term management strategies that have reduced fishing times, disturbance to the benthos has been reduced by progressive reductions in the actual number of annual fishing hours (Zacharin, 1997).
- *NPF*. The disturbance and mortality of benthic communities as a result of interaction between the otter boards and the groundchain of trawl nets are issues here. These impacts are mitigated by the fact that a relatively small proportion of the area is trawled (around 14 percent) and that areas containing sensitive seagrass communities have been closed to trawling since 1983 (Cartwright, 2003).
- *Spencer Gulf*. Trawling does not cover all the area available to the fishery. Research has demonstrated that less than 15 percent of this area is trawled, with over 60 percent of the catch taken in two areas that cover less than 8 percent of the Gulf (Palmer and Miller, 2005).
- *Exmouth Gulf*. The potential impact on the mud and sand habitat on Exmouth Gulf as a result of prawn trawling operations was considered unlikely to have even a minor consequence (which provides a low risk), because of the following:
  - only around 35 percent of the area permitted to be trawled is actually trawled (through targeting of known favourable grounds);
  - twenty-eight percent of the area is permanently closed to trawling;
  - studies of actual impacts from prawn trawling suggest only minimal impacts on infaunal communities; and
  - the mud substrate in Exmouth Gulf is generally comprised of coarser and heavier sediments and is therefore thought to be more resistant to disturbance by trawling activities. Moreover, such exposed seabeds are naturally dynamic as a result of environmental influences (Department of Fisheries, 2002).
- *New South Wales Estuary*. Although there is some uncertainty associated with the assessment of trawling on biodiversity and habitat of estuaries, the damage from trawl gear to benthic habitats has been well documented. An environmental impact statement concluded that the precautionary measures adopted ensure a relatively high confidence that most habitats, especially seagrass beds, will be sufficiently conserved. The fishery has been impacting its areas for 60 years and species found within the trawled areas have probably adapted to frequent disturbance from trawling activity (Department of the Environment and Heritage, 2004a).

CSIRO and the Queensland Department of Primary Industries and Fisheries (QDPI) carried out five years of research on the environmental effects of trawling on the far northern Great Barrier Reef Marine Park (GBRMP) (CSIRO, 1998). The study covered 10 000 km<sup>2</sup> in an area closed to trawling since 1985, known as the “Green Zone”. The project surveyed the physical and biological makeup of the study area; conducted experiments to simulate the physical impact of trawling on seabed animals and plants; compared the biology of areas open to trawling with those closed to trawling; and investigated prawn trawl bycatch. Because this work represents the world’s largest and most comprehensive study of the environmental effects of trawling, and the first study on the effects of prawn trawling in the tropics, the results deserve special mention.

- *Biology.* The lagoon and inter-reef areas of the GBRMP had been thought to be flat, muddy and relatively barren of life, but the study recorded more than 1 000 seabed species revealing a high biodiversity. It showed that while there are extensive bare, muddy or sandy areas, there are also seagrass and algal meadows, diverse sponge and coral garden patches, and deeper coral reefs.
- *Comparisons of areas closed to trawling (Green Zone) versus areas open to trawling.* Few differences were found between the areas that were clearly a result of trawling, for which there are several explanations. The effects of earlier trawling and/or current illegal trawling may have masked any differences between open and closed areas. In addition, the open areas next to the untrawled areas were not trawled heavily and some parts were not trawled at all, making these open areas similar to the closed areas. Furthermore, the two open areas studied were found to be either as different from each other as they were from the Green Zone, or more different from each other than from the Green Zone, making it difficult to detect differences resulting from trawling.
- *Physical impact.* Commercial trawling typically targets aggregations of prawns by repeatedly trawling patches of productive seabed before moving to another aggregation. In a series of experiments to simulate commercial trawling activities, the study showed that the pass of a single trawl has less impact than previously thought, i.e. that a trawl would remove nearly everything from the seabed, but research showed that each pass of a trawl along the seabed removes about 5 to 25 percent of seabed life. However, there is a cumulative effect: seven trawls over the same area of seabed removed about half of the seabed life, while a total of 13 trawls removed 70 to 90 percent.
- *Vulnerability.* Research shows that different seabed species exhibit different levels of impact. For example, large sponges and flowerpot corals are particularly susceptible to trawling, whereas seaweeds and gorgonians are more resistant.
- *Recovery.* Recovery rates of damaged seabed life are poorly known but are thought to range from one to 20 years, depending on the species. It is estimated that over the last 20 years, trawling in the GBRMP has depleted the most vulnerable fauna (those easily removed and slow to recover) in trawled areas by more than half, with the result that less vulnerable species (those difficult to remove and/or quick to recover) dominate the seabed community.

The study concluded that there is potential for environmentally sustainable management of prawn trawling in the GBRMP, although there are important information gaps that need to be filled.

### IMPACTS ON SMALL-SCALE FISHERIES

In Australia, the interaction between large-scale and small-scale shrimp fisheries does not appear to be a major issue. Unlike many other tropical countries, subsistence fishing is not extremely important in Australia. Recreational fisheries are, however, significant. A survey undertaken in 2000/01 showed that in the states of New South Wales, Victoria, Queensland, Tasmania and South Australia, approximately 2.7 million people undertook marine recreational activities during the study period (Morgan, 2004a).

The precise degree to which large-scale shrimp fishing affects recreational fishing is not known; however, the study on the effects of trawling in the GBRMP (previous section) produced some results relevant to the issue. This study had a component on the effects of shrimp trawling on other fisheries (Poiner *et al.*, 1997), which concluded the following.

- A comparison of the catch from 122 paired fish and prawn trawls showed that, although there were recreational or commercially important fish in intershoal areas, extremely few were caught by the prawn trawl.

- With the single exception of the painted sweetlips (*Diagramma pictum*), the prawn trawl did not catch significant numbers of juveniles of any recreationally or commercially important fish species.

There have been environmental assessments on many of the Australian shrimp fisheries, which usually contain information on interactions with small-scale fisheries.

Examples are the following.

- For the NPF area, it has been concluded that the take of prawns by the indigenous and recreational sectors is insignificant; however, some species caught as by-product and/or bycatch in this fishery are targeted by these users and by other commercial fisheries (Department of the Environment and Heritage, 2003).
- The harvest of western king prawn by recreational fishers in South Australia is minimal and there is no known harvest by the indigenous sector (Department of the Environment and Heritage, 2003).
- In Western Australia's Shark Bay, there is no significant take of prawns by the indigenous and recreational sectors; however, some species caught as by-product and/or bycatch in this fishery are targeted by these users and by other commercial fisheries (Environment Australia, 2002).
- In the NSW Estuary Prawn Trawl Fishery, there is both commercial and non-commercial Aboriginal fishing activity, which is affected to some degree by non-Aboriginal fishing and by fishery management restrictions.

### MANAGEMENT REGIMES AND LEGISLATION

In general, the management of fisheries in Australia, including that for shrimp, is highly developed and is characterized by a collaborative approach between the Australian Government and industry. All major fisheries are limited entry in nature, although entry entitlements are generally freely tradable. In recent years, two significant trends have emerged: first, the move to a "user pays" system, where participants in each fishery are increasingly responsible for funding management, research and compliance costs that support the fishery; and second, the broadening of management objectives away from a "single-species" approach to include more general ecosystem management issues. This second trend has been driven by Australia's more general commitment to the principals of ecological sustainable development (Morgan, 2004a). There has been a move towards comanagement approaches, as already practised in Spencer Gulf, incorporating management advisory committees and other industry/government/research collaborative mechanisms.

Fisheries resources within the AFZ are managed under either Commonwealth or state/territory legislation. The demarcation of jurisdiction and responsibilities among these various governments has been agreed to under the Offshore Constitutional Settlement, which was needed to clarify the complex fisheries management arrangements after the establishment of the AFZ in 1979. Under this settlement, the states and territories have jurisdiction over localized, inshore fisheries; the Commonwealth has jurisdiction over offshore fisheries or fisheries extending to waters adjacent to more than one state or territory. Each government has separate fisheries legislation and differing objectives (FAO, 2003a).

The most important fisheries legislations at the national level are the Fisheries Administration Act (1991) and the Fisheries Management Act (1991), while the fisheries objectives of Torres Strait are contained in the Torres Strait Fisheries Act (1984). At the national (Commonwealth) level, fisheries legislation is reviewed on an annual basis and necessary amendments made. At the state level, legislation is reviewed on a regular basis, according to need, and major legislative reviews are undertaken every five to ten years (Morgan, 2004a).

The management of shrimp fisheries is generally good in Australia, but there is some variability. One shrimp specialist (D. Leadbitter, personal communication, October

2005) commented on the quality of management of shrimp fisheries in the country:

*Some of the prawn trawl fisheries are very sophisticated in terms of management. Spencer Gulf and Exmouth Gulf are two examples. Some are good (e.g. Northern Prawn), some are in transition (Queensland East Coast Trawl) and some limp along (NSW Offshore Prawn Trawl).*

Although a full account of the management of all Australia's shrimp fisheries is far beyond the scope of this review, summary management information from one large shrimp fishery (NPF, managed by the Commonwealth) and one small one (Spencer Gulf, managed by the South Australia State Government) can provide some insight into the management processes.

### MANAGEMENT OF THE NORTHERN PRAWN FISHERY

The fishery is managed under the Northern Prawn Fishery Management Plan (1995) (as amended), which obtains its authority from the Fisheries Management Act (1991) and the Fisheries Administration Act (1991). The Management Plan sets out the range of management measures, objectives and performance criteria for the fishery. Under the plan, AFMA is required to develop, and industry to implement, a Bycatch Action Plan for the fishery. The Northern Prawn Fishery Bycatch Action Plan (2003) contains clear objectives, strategies and actions to address ongoing bycatch issues. A new Bycatch Action Plan for the fishery is currently being developed. In addition, NORMAC produces Five Year Strategic Plans for consideration by the AFMA Board. The Northern Prawn Fishery Strategic Plan (2001–06) contains detailed objectives and strategies that AFMA and NORMAC intend to pursue over the period of the plan. Strategies and performance measures are reported in NORMAC's annual report to AFMA, fishers and other stakeholders. NORMAC also produces a Five Year Research Plan (Department of the Environment and Heritage, 2003; W. Whitelaw, personal communication, January 2006).

Cartwright (2003) reviews the evolution of management arrangements for the NPF. The fishery was established in the 1960s and developed rapidly throughout the 1970s. By 1977, when limited entry regulations were introduced, concerns with overcapitalization and stock declines had begun to be expressed. In 1985, measures were taken to address the capacity issue through "unitizing" the fleet, by issuing all NPF licence holders with two forms of tradable rights and implementing boat replacement policies aimed at limiting and reducing capacity. The two forms of unit were: Class-A units (vessel capacity) related to vessel characteristics, and Class-B units (a licence to fish), which gave each holder the right to fish in the NPF.

As operators rearranged inputs and utilized new technology, effective effort continued to increase. In order to combat this situation, a range of effort-reduction strategies was implemented in the 1980s and 1990s, including two major buy-back programmes. These schemes cost US\$28 million, of which industry paid more than 80 percent. They were eventually effective in removing capacity, reducing the number of NPF vessels by 55 percent and capacity in terms of A-Class units by 70 percent, by 1993. In 1995, the two classes of NPF fishing rights became statutory fishing rights (SFRs), providing operators with strong, long-term access rights to the fishery. These rights, combined with industry "investment" in the fishery through funding for the buy-backs, have tended to encourage operators' strong interest in the longevity and sustainability of the fishery. In 2000, vessel-based (Class-A) units in the NPF were replaced with gear SFRs based on net (headrope) length, combined with a 15 percent cut in capacity. Gear SFRs were considered to provide the basis for a more flexible gear-based management regime.

Despite almost continuous management interventions and effort adjustments during the life of the fishery, overcapacity has remained a problem. The annual NPF stock assessment in 2001 reaffirmed that tiger prawn stocks were overfished; consequently,

industry reacted strongly by agreeing to a major (40 percent) reduction in capacity, implemented during the 2002 season. The reduction was achieved through removing gear SFRs (25 percent) and reducing season length in an effort to restore tiger prawn biomass to target levels. A further cut of 25 percent of gear units in the fishery was agreed in November 2005 for the start of the 2006/07 season.

The programme of capacity reduction in the NPF has not been easy and has at times required difficult negotiations between differing sectoral interests. These interests have usually been divided between larger corporate fleet owners and generally smaller, more “lifestyle”-oriented operators.

In the future, there are likely to be major changes in management of the NPF. In the past, management using input controls resulted in decades of “effort creep” and excess capacity, and contributed to the present low profitability of the fishery. Recent studies have suggested that output controls would be more effective (Kompas and Gooday, 2006).

Galeano *et al.* (2004) indicate that, from 1995 to 2002, annual management costs attributed to the NPF ranged from \$A1 million to \$A1.9 million (Table 27).

### MANAGEMENT OF THE SPENCER GULF FISHERY

Palmer and Miller (2005) review the management of the South Australia Spencer Gulf Prawn Fishery. In October 1967, commercial shrimp fishing began in the Gulf and, in March 1968, the Director of Fisheries introduced restricted entry in an attempt to prevent overexploitation of the resource and overcapitalization within the fishery. Today, the fishery has a limited entry of 39 licence holders, while the adjacent West Coast Fishery has three licence holders.

The fishery is managed jointly by the Australian Government and industry through the Prawn Fisheries Management Committee, headed by an independent chair. This comprises representatives from primary industries (fisheries), a senior prawn biologist from the South Australian Research and Development Institute, ten fishers elected to the committee by other fishers, a processor’s representative (who provides information related to prawn sizes and marketing), and the South Australian Recreational Fishing Advisory Council.

Current gear restrictions on licence holders include:

- vessel size limited to 22-m overall length;
- engines restricted to 365 HP;
- mesh size – codend (4.5 cm); wings and body (5 cm);
- gear configuration and net size limited to a double rig (two nets) with a maximum headline length of 14.63 m per net.

Other controls are also used in managing the Spencer Gulf Prawn Fishery:

- permanent closures to protect small prawns that occur in particular areas of the Gulf;
- temporary area closures to allow prawn growth and/or spawning;
- temporary full closure of the fishery to reduce overall effort and allow spawning (e.g. in January and February); and
- rotation of grounds.

The above controls result in an average of 55 to 60 nights per year, and trawling taking place on only 15 percent of the entire Gulf. Each fishing trip varies in length from ten to 16 days. Usually, only six trips occur each year, with one for each vessel in November, December, March, April, May and June.

An innovative management arrangement that has been used effectively is the Committee at Sea made up of fishers elected to the Prawn Fisheries Management Committee. During harvesting periods, the Committee at Sea monitors all areas open to fishing. With up-to-date communication systems, the committee can very quickly relay information in order to close areas that were initially open, so as to protect small

prawns that may have moved into them. These changes are then immediately broadcast to the fleet and accepted as a rule. By focusing on landing large prawns of very high quality, the fishery is able to differentiate its product in the market from aquaculture products, and is thus more insulated (but not isolated), from the price pressures being experienced in the NPF.

The fishers themselves take an active role in research by participating in stock assessments using their vessels and crew, capturing tagged prawns and recording information, providing high-resolution catch and effort data in logbooks, and measuring samples of prawns from the catch. Industry pays 100 percent of the attributable management and research costs by way of annual licence fees. An annual research levy per licence holder, based on the production value of the fishery, is also included in the levy.

### ENFORCEMENT

Surveillance and enforcement arrangements differ between the shrimp fisheries managed by the Commonwealth and those managed by the states.

AFMA develops a compliance plan for each major Commonwealth fishery, including the Northern Prawn and Torres Strait Prawn Fisheries. Compliance plans contain strategies to manage the potential risks for non-compliance and details of compliance activity, performance measures and proposed budgets.

The Northern Prawn Fishery Compliance Plan identifies the risks to compliance and presents a programme detailing the compliance tasks, agency responsibilities and related performance indicators. Compliance and enforcement tools implemented in the fishery include the mandatory installation and use of a vessel monitoring system (VMS) and random at-sea and port inspections. AFMA also provides educational material and holds port meetings to ensure that operators are aware of the rules and regulations that apply in the fishery. The NPF Compliance Plan requires that a minimum of 65 percent of vessels in the fleet be subject to regular and random at-sea inspections, combined with a programme of aerial surveillance. At-sea inspections check net lengths, ensure compliance with TED and BRD regulations, check logbook and transshipment records, and inspect catch to ensure compliance with size and catch limits. In-port measuring of all nets is conducted, and involves the measuring and tagging of nets, making at-sea inspection easier (Department of the Environment and Heritage, 2003).

The VMS requirement was introduced into the NPF in 1998. The system has reduced compliance costs and allowed for more efficient means of opening the fishing season, enforcing closed areas and targeting compliance activity. It has also improved the flow of information to the fleet from AFMA, and provided details to researchers and managers concerning the fine-scale distribution of effort in the fishery. While initially resisted by some operators, VMS is now well accepted, with company vessel managers using it to monitor the activity of their fleet (Cartwright, 2003).

As an example of enforcement in a state-managed fishery, Western Australia's Exmouth Gulf Prawn Fishery has sea patrols and radar watches on a random basis during the season. Aerial compliance checks are also conducted. Compliance operations are mainly focused on maintaining the integrity of the nursery areas within the fishery. Enforcement staff also conduct licence and gear inspections both at sea and in port. Given the value of the licences, fishers themselves are also a source of information on illegal activities. VMS requirements were introduced in 2002, and random patrol activities are decreasing overtime, while targeted patrols investigating specific incidences will become the major focus of patrol activities (Department of Fisheries, 2002).

In general, expenditure on surveillance and enforcement of management rules is considered a management cost in Australia. Current government policies for Commonwealth-managed fisheries provide that the fishing industry pays for costs

directly attributed to fishing activity on a full cost-recovery basis, with the Australian Government paying for or contributing to activities that may benefit the broader community as well as industry. Recoverable management costs include the running costs of management committees, AFMA's day-to-day fisheries management activities, costs of developing and maintaining management plans, and logbooks and surveillance, but do not include enforcement costs (Cartwright, 2003).

## RESEARCH

At the Commonwealth and state levels, fisheries research priorities are identified both as part of fisheries-specific management plans and as more strategic, long-term priorities. Research is carried out by a variety of Commonwealth and state research agencies. These include fisheries research laboratories that are part of each state's fisheries management agency, CSIRO and various universities in Australia. Generally, research is carried out by the agencies that also have legislative responsibility for a specific fishery so that, for example, research on state-controlled fisheries is carried out by that state. The Fisheries Research and Development Corporation (FRDC), created in 1991, is Australia's main funding agency for fisheries and aquaculture research. FRDC aims to improve the production, processing, storage, transport and marketing of fish and fish products, and to achieve sustainable use and management of fisheries resources. The Australian Government contributes 0.5 percent of the gross value of fisheries production to FRDC, with fishers also contributing, which attracts further government support in the form of matching funding. State governments also contribute directly to the funding of research undertaken by their own agencies, which in many cases, is the most significant part of total research funding (FAO, 2003a).

In Australia, much of the research related to shrimp fishing is focused on stock assessment of target species; impacts on non-target species; effects of trawling on the seabed; improvement of economic efficiency; optimum harvesting strategies; and gear technology, especially for reducing bycatch. Recently, there has been a considerable shift towards researching the bioeconomic aspects of shrimp fisheries, in response to cost/price pressures. The research requirements and resources available for research are obviously greater for the larger shrimp fisheries. The NPF receives substantial research effort, while most of the smaller state-managed fisheries enjoy less attention.

According to the Northern Prawn Fishery Five Year Research Plan (2001–06) (AFMA, 2001b), the high and medium research priorities are:

- assessment of the fishery status, including management strategies for the fishery (target and by-product species);
- effects of fishing – improved efficiency in fishing gear and techniques to reduce bycatch and discarding, increased survivorship of bycatch and environmental impacts on the benthos;
- improved knowledge of environmental factors of importance to the fishery;
- improved efficiencies in the economics of fishing; and
- utilization of bycatch species.

With respect to research in a state-managed shrimp fishery, the main objective of recent prawn research in the Spencer Gulf of South Australia has been to obtain information that can be used to determine optimum harvesting strategies. This requires an understanding of the mechanics of the fishery, including the grounds and the movement of prawns over the grounds; size composition of prawns over the grounds; growth; juvenile movement and behaviour; recruitment patterns over the regions; natural mortality; fishing mortality; catchability; and the effects of lower water temperature and the full moon phase. Fishers themselves take an active role in research by: (i) undertaking stock assessments using their vessels and crew; (ii) capturing tagged prawns and recording information; (iii) providing high-resolution catch and effort data in logbooks; and (iv) measuring samples of prawns from the catch (Palmer and Miller, 2005).

## DATA REPORTING

In the NPF, catch and effort data reporting plays a vital role in underpinning research and management decisions. Although costly, face-to-face contact with fishers has been pivotal to good logbook data, especially through the work of logbook officers in the 1980s and early 1990s. Data are at present collected in two main areas: from vessels via logbooks, and landing returns from owners and processors. Logbooks have undergone an adaptive process, reflecting the development of this fishery towards tiger prawns in the 1970s; since 1977 their completion became compulsory. The evolution of logbook design has involved continuous industry involvement and input since the accuracy of the data is a function of industry satisfaction and commitment to the process (Cartwright, 2003). Twenty-one operators used electronic logbook reporting in 2004 (Perdrau and Garvey, 2005).

Fishers in the NSW Estuary Prawn Trawl Fishery are required to submit records on a monthly basis, detailing their landings and fishing effort. The information includes landings for each species, the effort expended (for each method) to take the catch, and the area/s fished. This information is entered in a database by NSW fisheries and allows for analysis of fishing activity, reported landings and effort levels. The accuracy of the data provided on catch returns is variable, particularly with respect to fishing effort data. There are a number of management responses to improve the quality and reliability of the information provided on catch returns, including a review of the current monthly catch return and validation of landings and effort data under the scientific monitoring programme (NSW Fisheries, 2003).

In the Shark Bay Prawn Fishery of Western Australia, data are obtained through compulsory monthly logbooks, which all operators voluntarily complete on a daily basis. Commercial logbooks are validated against processor records and against VMS data. The logbooks contain information on daily and shot-by-shot target and byproduct catch, hours trawled and areas of operation. Data on protected species interactions have been collected through the observer surveys operating in the fishery since 1998 (Environment Australia, 2002).

In general, because of the involvement of fishers in the management process and the nature of the right to fish in a limited entry fishery, information supplied by shrimp fishers in Australia is considered to be of reasonably good quality, especially for the target species.

## IMPACTS OF SHRIMP FARMING ON SHRIMP FISHING

Shrimp production from Australian commercial capture fisheries is roughly 25 000 tonnes per year; aquaculture production, roughly 3 500 tonnes; shrimp exports, roughly 9 000 tonnes; and shrimp imports, roughly 25 000 tonnes (ABARE, 2005). Aquaculture production constitutes therefore about 8 percent of the Australian shrimp market, much of which is exported. As a result of its small market share, it seems that domestic aquaculture production does not have a major effect on Australian domestic shrimp prices, nor much impact on domestic shrimp fishing.

A large portion of shrimp imports into Australia are from aquaculture. Because of its low price, this imported farmed shrimp is having a downward effect on prices for Australian captured shrimp. The prices for imported farmed shrimp, especially *P. vannamei* from China, are a fraction of those for shrimp from Australian fishing operations. Although species/sizes are very different in domestic fishing and overseas aquaculture, there is some flow-on effect to all segments of the Australian shrimp market. According to the Australian Prawn Farmers Association:

*Over the past 18 months the industry has been devastated by a flood of cheap imported Penaeus vannamei prawns from China and Asia. Chinese P. vannamei prawns land in Australia for between \$A5.50 and \$A6.50, and retail for between \$A9.00 and \$A14.00 (www.apfa.com.au).*



### **MAJOR ISSUES RELATED TO SHRIMP FISHING**

The major issues related to shrimp farming in Australia are:

- the low current profitability of many of the shrimp fisheries;
- increased attention to bycatch reduction;
- overcapacity resulting from effort creep, even in shrimp fisheries with relatively good management; and
- increased scrutiny of the physical effects of trawling, especially within “World Heritage Areas”.



# Shrimp fishing in Cambodia

## AN OVERVIEW

Although marine fisheries in Cambodia are of minor importance compared with freshwater fisheries, shrimp fishing is significant along Cambodia's short coast. Annually, trawling and, to a lesser extent, other gears take from 3 000 to 4 000 tonnes of shrimp. Shrimp is important for domestic consumption and is the most valuable fishery export of the country.

The management of shrimp fisheries in Cambodia faces major challenges. The obstacles to deriving greater benefits from shrimp fisheries by management interventions are considerable, with regard to the paucity of biological information on shrimp resources; the few legal instruments available for managing shrimp fishing; the poor enforcement of those that do exist; and the open access nature of coastal fisheries in the country.



## DEVELOPMENT AND STRUCTURE

The coast of Cambodia is 435 km in length, located along the Gulf of Thailand from the Thai border in the northwest to the Vietnamese border in the southeast. The coastal area includes several large bays and extends across the provinces of Koh Kong and Kampot, and the municipalities of Sihanoukville and Kep. The offshore marine area has numerous islands. The exclusive economic zone (EEZ) covers approximately 55 600 km<sup>2</sup> and is relatively shallow, with an average depth of about 50 m.

The most important marine shrimp fishing gears in Cambodia are trawls, gillnets, push nets and stow nets. Table 30 gives information on these four gear types.

Trawling in Cambodia was first attempted in the mid-1920s when the Oceanographic Institute of Indochina started a trawling survey of French Indochina in 1925. It was concluded that catches were too small to permit the use of a European trawler. Developments in Thailand (which shares the Gulf of Thailand with several countries,

TABLE 30  
Fishing gear in Cambodia that catches shrimp

Gear	Target species or group	Bycatch
Shrimp trawls	Penaeid shrimp ( <i>Penaeus semisulcatus</i> , <i>P. canaliculatus</i> , <i>P. latisulcatus</i> , <i>P. merguensis</i> )	Black tiger shrimp ( <i>Penaeus monodon</i> ); <i>P. silasi</i> , Swimming crabs (Portunidae), Trash fish
Shrimp gillnets	<i>Penaeus merguensis</i>	Trash fish; squid (Loliginidae); <i>Penaeus merguensis</i>
Push nets	Mixed fish species; peregrine shrimp ( <i>Metapenaeus</i> sp.); sepiolid squid (Sepiolidae sp.); octopus ( <i>Octopus</i> sp.); very small shrimps	Multispecies juvenile fish and shrimp
Stow nets	Mixed fish species; Sepiolid squid (Sepiolidae); squid (Loliginidae); Penaeidae and metapenaeid shrimp	

Source: Touch and Todd, 2002.

TABLE 31  
Number of trawlers on the Cambodian coast

Province/ municipality	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Kep							5	7	52	52	52	52	10
Kampot	31	16	5	186	186	20	30	22	89	89	89	89	120
Sihanoukville	227	242	276	262	244	226	296	283	656	756	807	783	787
Koh Kong	164	184	268	186	130	214	214	342	719	413	651	322	322
Total	422	442	549	634	560	460	545	654	1 516	1 310	1 599	1 246	1 186

Source: Official statistics, Department of Fisheries.

including Cambodia) resulted in the introduction of trawling to Cambodia. In the late 1950s, a fisheries scientist from (the former Federal Republic of) Germany began to advise the Government of Thailand on increasing fishing landings. In 1961, a trawl was designed that did not get stuck in the soft mud that characterizes the Gulf of Thailand. Between 1960 and 1966, the number of trawlers in Thailand soared from 99 to 2 700, and the catch from 59 000 to 360 000 tonnes. Rising prices for shrimp and for trash fish enabled operators to persist and flourish. In 1964, fleets began to expand out of Thailand into Malaysia, Cambodia and Viet Nam (Butcher, 2004).

Later, during the Khmer Rouge period (1975–78), additional trawlers from Thailand began fishing in Cambodia. In the 1980s, small trawlers became popular because of their relatively low costs and ability to fish shallow productive inshore areas. The boom in the shrimp market also encouraged further trawling. Table 31 shows the distribution of trawlers along the Cambodian coast. About a quarter of all motorized marine fishing vessels in Cambodia are trawlers.

There are two main types of Cambodian trawlers, although not distinguished in official statistics. Small trawlers (defined as vessels with engines of less than 30 HP) fish mainly inshore areas and catch both shrimp and fish. They usually fish at night and return to port each morning. Another class of trawler is characteristically about 20 m in length. Fishing from the latter is in offshore areas and trips usually range from one to four weeks. The catch is predominantly fish and squid, which is often transhipped at sea rather than being landed in a Cambodian port.

Most small trawlers operate in shallow inshore areas, but the basic fisheries decree (Fiat-Law No. 33 on Fisheries Management and Administration, 1987) prohibits trawling between the shore and the 20-m isobath, which is often located 10 km offshore. Many trawlers are inappropriate for fishing so far offshore and, consequently, a great deal of trawling takes place in illegal areas. Another important feature of trawling in Cambodia is excess capacity: 1 500 trawlers represent 3.4 vessels per linear km of coastline. A major fisheries management issue is the need to reduce the number of small trawlers.

There is a significant amount of foreign trawling in the Cambodian zone. The Department of Fisheries indicates that about 150 trawlers (mainly from Thailand) are licensed to fish in the offshore “overlap zones” with Thailand.

With respect to non-trawl shrimp fishing, gillnets are the second most important gear type. They tend to catch larger shrimp than trawls and are used most commonly in the rainy season (June to September). The International Center for Living Aquatic Resources Management (now WorldFish) (ICLARM, 1999) reports fewer shrimp trawlers in the late 1990s, while the number of shrimp gillnetters increased. Table 32 gives shrimp gillnet numbers in the four coastal areas of Cambodia.

TABLE 32  
Number of shrimp gillnets

Province/ municipality	2003	2004
Kep	0	1 500
Kampot	21 000	16 500
Sihanoukville	252 600	239 500
Koh Kong	594 776	515 250
Total	868 376	772 750

Source: Official statistics, Department of Fisheries.

TABLE 33  
Shrimp fishing gear in Thmor Sor village, Kompong Som Bay

Gear type	Engine HP (daily fuel consumption)	Net size <sup>1</sup> (m)	Mesh size (cm)	Fishing grounds	Catch	Catch (kg/day)	% of catch
Single trawl	8	8 x 7	5	In front of village, 2–3 km	Shrimp	6	26
					Squid	2	9
					Mixed fish	15	65
Single trawl	18	11 x 3	4	In front of village, 1–2 km at 4 m depth	Shrimp	10	31
					Squid	2	6
Single trawl	8 (30 litres)	4 x 2	4	4 km from village, at 6 m depth	Mixed fish	20	63
					Shrimp	8	35
					Crab	4	17
					Squid	1	4
Single trawl	30 (45 litres)	11 x 11	4	5 km from village, at 2–3 m depth	Mixed fish	10	43
					Shrimp	20	38
					Squid	2	4
					Mixed fish	30	58
Single trawl	18 (30 litres)	12 x 8	5	In front of village, 4–5 km	Shrimp	20	38
					Crab	5	10
					Squid	2	4
					Mixed fish	25	48
Single trawl	18 (30 litres)	12 x 8	4	km In front of village, 1–2	Shrimp	8	25
					Crab	2	6
					Squid	2	6
					Mixed fish	20	63
Single trawl	8	9 x 3	4	In front of village, 5–10 km	Shrimp	10	27
					Crab	3	8
					Squid	4	11
					Mixed fish	20	54
Push net	8 (30 litres)	8 x 7	4	In front of Thmor Sor, Chamkar Leur	Shrimp	20	38
					Crab	3	6
					Mixed fish	30	57
Shrimp gillnet	5	1200 x 2	4	In front of Chamkar Leur, 2–3 km	Shrimp	3	
Shrimp gillnet	11	720 x 2	4	In front of Thmor Sor, Chamkar Leur	Shrimp	2	
Shrimp gillnet	13	900 x 2	3.8	In front of Thmor Sor, Chamkar Leur 1–2 km	Shrimp	3	
Shrimp gillnet	17	1 800 x 2	3.8	Koh Rong, Chrouy Svay	Shrimp	4	
Shrimp gillnet	18	400 x 2	3.8	Chamkar Leur	Shrimp	2	
Shrimp gillnet	7	600 x 2	3.8	Chamkar Leur, Phum Thmey, Ta Meak	Shrimp	3	
Shrimp gillnet	7	700 x 2	3.8	2 km from village	Shrimp	3	

Source: Chu *et al.*, 1999.

<sup>1</sup> It is assumed that these dimensions are net opening x length of net, but the report does not clarify this.

Although stow netting used to be widespread, it is now confined to estuaries in Koh Kong Province (Touch and Todd, 2002). Total production from stow nets (shrimp and fish) is only about 50 to 100 tonnes per year.

A study on the fishing practices of eight villages around Kompong Som Bay, Koh Kong Province (Chu *et al.*, 1999), describes the various gears used to catch shrimp. Results obtained by interviewing fishers from one of the villages are given in Table 33.

- The motorized, therefore illegal, push net has a daily fuel consumption about the same as a trawler.
- All trawling takes place in waters less than 20 m deep and is therefore illegal.
- Shrimp gillnets appear to be the most selective of the three gear types, but the daily catch is relatively low.

#### TARGET SPECIES, CATCH AND EFFORT

The Department of Fisheries (I. Try and O. Vibol, personal communication, December 2005) says that there is considerable uncertainty as to the taxonomy of the shrimp catch in Cambodia. Table 30 shows that the major species of shrimp caught with the

TABLE 34  
Shrimp catches, 2003 and 2004 (tonnes)

	Kep	Kampot	Coastal area		Total
			Sihanoukville	Koh Kong	
2003	54	325	2 209	1 265	3 853
2004	50	316	2 546	783	3 695

Source: Official statistics, Department of Fisheries.

two main Cambodian shrimp fishing gears are *Penaeus semisulcatus*, *P. canaliculatus*, *P. latisulcatus* and *P. merguensis*, with *P. monodon* as a bycatch. Try (2003) states that ten species of shrimp are known in Cambodia: *P. canaliculatus*, *P. semisulcatus*, *P. merguensis*, *P. latisulcatus*, *P. monodon*, *P. japonicus*, *Metapenaeus affinis*, *M. spinulatus*, *Parapenaeopsis sculptilis* and *Parapenaeopsis* sp. He adds that “*Metapenaeus affinis* and *M. spinulatus* comprise around 60 percent of the total catch”.

Shrimp of the genus *Acetes* is not mentioned above but is probably significant in Cambodia; it is extremely important in other Southeast Asian countries, where its main use is for shrimp paste, which is also popular in Cambodia.

Annual shrimp catches for 2003 and 2004 are given in Table 34.

In the 1996 to 2001 period, Try (2003) states that annual shrimp catches ranged from 2 721 to 4 061 tonnes. National fisheries statistics on shrimp catches have not been reported to FAO since 1993. The Organization estimates that, on the basis of increased marine total catches in recent years, 12 600 tonnes of shrimp were captured in Cambodia in 2004 (FAO *Cambodia fishery country profile*, FAO, 2005a) (L. Garibaldi, FAO, personal communication, March 2006).

With respect to the accuracy of the Cambodian shrimp catches given above, three difficulties should be noted: the inherent problems of the fisheries statistical system; catches by Cambodian vessels landed outside the country; and legal/illegal catches by foreign vessels.

- There is compelling evidence that the official catches for the Cambodian coastal zone are a major underestimate of actual catches (FAO, 2005a).
- Further offshore, Flewelling and Hosch (2004a) estimate that 25 percent of the volume of total marine catch by Cambodian vessels is landed outside Cambodia, and is therefore not accounted for in official statistics.
- Little accurate information is available on shrimp production by legal or illegal foreign vessels fishing offshore. Gillett (2004) states that, according to Department of Fisheries internal reports, total catches (shrimp and non-shrimp) from licensed Thai vessels in Cambodian waters are estimated to be from 26 500 to 37 500 tonnes. If this were the case, such an amount would approach the total marine catch recorded for all Cambodian vessels. Furthermore, it is thought that there is a substantial amount of illegal fishing by non-licensed vessels from both Thailand and Viet Nam. Butcher (1999) studied the situation of illegal Thai trawlers and indicated that between 40 and 60 percent of the total catch of these vessels came from outside Thai waters; it appeared that Thai trawlers had long fished in Cambodian waters under unofficial agreements. Butcher concluded that Thailand has a huge number of trawlers and not many fish, while there are far more fish in the waters of nearby countries.

Because of the above factors, Gillett (2004) concludes:

*Many of the studies of marine fisheries in Cambodia rely to some extent on the statistics produced by the Department of Fisheries. The rudimentary nature of the statistical system for marine fisheries, the fact that fish are not landed at a central location, direct exports are made to foreign vessels, and other factors all contribute to inaccuracies. The landing data for marine fisheries given in this report should therefore be treated with caution and be considered indicative at best.*

This statement is also applicable to the present report.

Gillett (2004) comments in a general sense on increasing fishing effort in Cambodia: *Excess fishing effort and associated declines in abundance of target species are thought to be serious problems for most of Cambodia's marine fisheries. The major causes appear to be population increases coupled with: (i) an economy that is not expanding rapidly enough to cater to rising needs; and (ii) the government policy of not denying to anyone the opportunity to fish for subsistence or income. Unregulated foreign fishing activity is another cause. Improved management in the forestry sector, however desirable, has produced an increase in migration of people to the coastal zone where many become involved in fishing where entry costs are low. Export demand also encourages additional fishing effort, especially the high-value species in overseas markets.*

Effort data are not collected from shrimp fisheries in Cambodia, according to the Department of Fisheries. Consequently, the following should be noted.

- There is a general theory among observers of the fisheries situation in Cambodia that the catch rate from inshore trawlers has decreased in the last two decades, but there are few data to back up this assumption.
- Although CPUE data have not yet been collected for the marine fisheries in Cambodia, surveys from its neighbouring country, i.e. Thailand, may give some leads (Try, 2003).
- Kongprom *et al.* (2003) state that CPUE from trawl surveys in the Thai portion of the Gulf of Thailand declined from 298 kg/hour in 1961 to around 20 kg/hour in the early 1990s, and that, in 1961, the trawlable biomass in the Gulf declined to only about 8.2 percent of the biomass level.
- Try (2003) mentions a 1999 socio-economic survey in Kep, which showed that from 1996 to 1998, the collection of shrimp by small boats fell from 20 kg of shrimp/night to 5 kg/night.
- In the survey of trawl fishing in eight villages around Kompong Som Bay, Koh Kong Province, mentioned earlier (Chu *et al.*, 1999), some anecdotal information on CPUE was obtained. Fishers using all kinds of equipment are reporting declines of up to 90 percent in CPUE over the last ten years. This decline is likely to result from both overfishing and habitat destruction. There are two elements to the overfishing problem: an increase in the total number of fishers and a shift in fishing gears towards more modern and efficient methods.

### ECONOMIC CONTRIBUTION

Lamberts (2001) gives seven estimates of the contribution of both inland and marine fisheries to Cambodia's GDP. The Planning and Accounting Office of the Department of Fisheries states that the contribution of all fisheries to the Cambodian GDP is 11.4 percent. The contribution of marine fisheries to GDP has not been assessed accurately; it would require a good estimate of production, the value of this production at the producer level, and an estimate of the value added by the producer. The specific contribution of shrimp fishing to GDP is therefore unknown at present.

The March 1998 census indicated that the population of the two coastal provinces and two coastal municipalities was about 840 000, or about 7 percent of the country's total population. Although population density in the coastal provinces is low in relation to other parts of the country, the number of people in coastal areas increased by about 25 percent in the five-year period ending in 1998. Touch and Todd (2002) estimated that about 10 000 people are employed in the marine fishery sector, including fishing, gathering, processing, and marketing but this figure is not further broken down into employment associated with shrimp fishing. More recent data (2004 official statistics) from the Department of Fisheries give the number of people involved in marine "medium-scale fishing", which approximates to the number of people working on motorized fishing vessels in the country: 50 workers in Kep, 2 100 workers in Kampot, 5 764 workers in Sihanoukville and 25 300 workers in Koh Kong, i.e. a total

of 33 214 workers. Considering that trawlers make up about a quarter of the motorized vessels on the Cambodian coast, employment related to shrimp fishing is obviously important to Cambodia's coastal region.

There is also employment associated with the post-harvest aspects of shrimp fisheries. In late 2005, there were two export-oriented shrimp processing facilities in Sihanoukville. ICLARM (1999) states that one of these factories (Sun Wah Fisheries Co. Ltd) employed 780 people. Small-scale processing for domestic consumption is also important; the most popular products are dried shrimp and shrimp paste (Sok, 2005). Touch and Todd (2002) state that, in 2000, about 185 tonnes of dried small shrimp and 92 tonnes of shrimp paste were produced.

There is little documentation with respect to shrimp consumption in Cambodia. Of the shrimp consumed (3 892 tonnes annually in the early 1990s), 97.5 percent was consumed fresh and 2.5 percent dried (Touch and Todd, 2002).

### TRADE ASPECTS

Official statistics of the Department of Fisheries give export information on four types of shrimp products (Table 35). In the statistics, shrimp produced by aquaculture operations (90 tonnes in 2004) is combined with that from shrimp fishing. Shrimp caught offshore and directly transhipped to foreign countries is not included.

These official statistics are available for volumes of exports and not for value. Nevertheless, shrimp is the most valuable fishery export commodity (Touch and Todd, 2002).

The Department of Fisheries indicates that the primary export destinations for shrimp products are Taiwan Province of China (fresh) and China (processed).

Currently, Cambodia cannot export shrimp to the United States, under Section 609 of United States Public Law 101–162, which stipulates that shrimp or products from shrimp harvested with commercial fishing technology that may adversely affect certain species of sea turtles protected under United States laws and regulations may not be imported into the United States. At the root of the United States prohibition is the requirement that commercial shrimp trawl vessels use TEDs – approved in accordance with standards established by the United States NMFS – in areas where there is a likelihood of intercepting sea turtles.

There is yet another aspect to shrimp trade with the United States. Quick Frozen Foods International (QFFI, 2005) reports that Cambodian exports of shrimp to the United States were zero in 2003 but soared to 5 330 tonnes in 2004. Exports of shrimp from China to Cambodia also soared from zero in 2003 to 2 664 tonnes in 2004. Because China's shrimp exports to the United States have been subject to anti-dumping duties since July 2004, a possibility is that Chinese producers have begun exporting shrimp to the United States via Cambodia to evade punitive duties.

TABLE 35  
Shrimp product exports of Cambodia, 2003 and 2004 (tonnes)

	Item	Coastal Area				Total
		Kep	Kampot	Sihanoukville	Koh Kong	
2003	Fresh shrimp	0	120	23	1 022	1 165
	Dried shrimp	0	30	30	1	61
	Peeled/frozen shrimp	0	0	308	17	325
	Dried shells	0	0	0	0	0
2004	Fresh shrimp	0	35	557	600	1 192
	Dried shrimp	0	12	40	9	61
	Peeled/frozen shrimp	0	0	365	24	389
	Dried shells	0	5	48	0	53

Source: Official statistics, Department of Fisheries.



## BYCATCH ISSUES

Kelleher (2005) states that discards in Cambodian marine fisheries are small:

*An arbitrary discard rate of 1 percent was assigned to the fisheries of Thailand, Malaysia and Cambodia, which are considered to generate combined discards of less than 50 000 tonnes.*

With discards from fisheries not a concern in Cambodia, the major bycatch issues in shrimp fishing are related to trash fish and endangered species.

The term “trash fish” has recently been defined as “fish that have a low commercial value by virtue of their low quality, small size or low consumer preference” (Funge-Smith, Lindebo and Staples, 2005). In Cambodia, according to Fisheries Department officials, trash fish normally means the part of the catch that is not for human consumption; trawling produces most of this commodity. Several reports on Cambodian marine fisheries mention trash fish.

- Try (2003) states that, after the opening of the fertilizer factory in 1993, trawlers changed their target species to trash fish for fertilizer. This trash fish is composed of small-size fish that have no market value, non-edible species, and unacceptable juveniles of economically important species. During the 1980s, fish caught by trawl fisheries contained 30–40 percent trash fish, but it now comprises 60–65 percent of the total catch.
- The study on the fishing practices of the villages around Kompong Som Bay, Koh Kong Province (Chu *et al.*, 1999), states that trawlers catch shrimp, squid and crabs as well as fish in the bay. Mixed fish, much of which is trash fish (*trey chi*, made into fertilizer), makes up to 50–60 percent of the catch.
- The Department of Fisheries and National Institute of Statistics (2003) state that 70 percent of the catch landed by trawlers in Cambodia’s marine area is considered to be trash fish, which amounted to 10 867 tonnes in 1999.

A senior officer in the Fisheries Department (O. Vibol, personal communication, December 2005) provides information on the current use of trash fish. Most of the fish comes from large trawlers, with much less from the huge number of small trawlers. Trash fish is used for reduction in factories; as bait in crab traps; (iii) animal farming operations (aquaculture, crocodiles and ducks); and export to Thailand. The price given to fishers fluctuates seasonally and recently varied from US\$0.12 to US\$0.30 per kg.

Cambodia is somewhat unusual in Southeast Asia with respect to trash fish and its use because there is significant targeting of the fish, particularly for fertilizer, unlike other neighbouring countries where it is mostly processed into animal feed.

Another facet of shrimp fishing bycatch in Cambodia is the catch of endangered species: trawlers are capable of taking large marine mammals and sea turtles in their nets. Bycatch is thought to be one of the main threats to Cambodia’s marine mammals and accidental catches of these species are usually discovered after the animal has died. Other countries have been testing devices to reduce capture of sea turtles with some success. However, Cambodia’s trawler vessels are not required to be equipped with devices such as TEDs which, in any case, are not suitable for Cambodian fishing vessels because the boats are too small.

Cambodia participated in a five-year bycatch reduction project sponsored by the Southeast Asian Fisheries Development Center (SEAFDEC). The aim was to reduce incidental catch of turtles and minimize the catch of small juvenile fish.

## PROFITABILITY

The Department of Fisheries has undertaken very little economic analysis on aspects of marine fisheries. Available information on the profitability of shrimp fishing in Cambodia appears to be confined to anecdotes and a single externally funded project of the Department of the Environment.

TABLE 36  
Profitability of shrimp fishing in Kompong Som Bay

	Type of gear (number of units analysed)	Average income (US\$)	Average costs (US\$)	Average profit (US\$)
Koh Sdach	Trawl (6)	127.03	21.12	105.91
	Shrimp gillnet (3)	1.69	2.53–7.47	.79–5.78
Chrouy Svay Commune	Trawl (9)	21.20	10.11	11.09
	Shrimp gillnet (7)	2.82	1.06	1.77
Thmor Sor Commune	Trawl (1)	20.60	8.91	13.30
	Push net (5)	31.31	–	–
	Shrimp gillnet (24)	3.13	1.15	1.98
Chikkar Kraom Commune	Push net (1)	23.76	7.92	15.84
	Shrimp gillnet (12)	2.32	1.08–1.58	0.71–1.24

Source: Chu *et al.*, 1999.

Note: US\$1 = B37.88 (Thai baht).

With regard to marine fisheries in Cambodia, Sour (2005) states that there is “very limited information about profitability/economic return of fishing. However, this economic return seems to be very low.”

The study of the villages around Kompong Som Bay, Koh Kong Province (Chu *et al.*, 1999) produced some information on the profits<sup>25</sup> of three types of shrimp fishing at four locations on the bay (Table 36).

Bearing in mind that all trawling in the bay is illegal because the water is shallower than 20 m and all motorized push nets are banned in Cambodia, the study concludes:

*It is clear why trawlers and push netters are unwilling to give up their illegal activities and switch to gillnetting. Their profits would decrease by up to 90 percent.*

Despite the few economic data, it appears that both the profitability of individual shrimp fishing operations and the rent from the various shrimp fisheries are low, as a consequence of the open access nature of Cambodian coastal fisheries; the rising coastal population; low barriers to participation; lack of non-fishing sources of livelihood; indications of low profitability, the rising proportion of trash fish; and falling CPUE. This is a stark example of the inability of fishery resources to support large and increasing numbers of fishers with few non-fishing alternatives – or what Pauly (1993) terms “Malthusian overfishing”.

### ENERGY INPUT ASPECTS

Operators of fishing vessels indicated that, in late 2005, diesel fuel for their vessels cost US\$0.75 per litre whereas, in late 2004, it cost US\$0.55 per litre. Fuel smuggled from Thailand reportedly cost US\$0.55 per litre in late 2005.

No studies on fuel consumption in Cambodia’s marine fisheries have been undertaken. Some data on fuel consumption by trawlers and push netters are given in Table 33. To summarize, small trawlers at Thmor Sor village, Kompong Som Bay, use between 30 and 45 litres of fuel/day, and push netters 30 litres/day.

If a small trawler uses 38 litres of fuel/day and the cost of fuel rises by US\$0.20/litre, then the daily fuel cost would increase by US\$7.60/fishing day. This would have a significant effect on the daily profits of small trawlers, which range from US\$11.09 to US\$105.91, as shown in Table 36.

The effects of a rise in fuel cost would be minimal for non-motorized shrimp fishing with small push nets and short shrimp gillnets.

<sup>25</sup> It appears that the study considered operating expenses and gross income from sales of fish, so the difference between the two is actually the net operating income. In addition, it should be remembered that information was obtained from interviews rather than from verified documentation.

## BIOLOGICAL ASPECTS

Few biological studies have been undertaken on the shrimp resources of Cambodia. This has been mentioned in several general reviews of the marine fisheries of the country, including the following.

- Very little is known about the status of fish stocks in Cambodia's marine waters (Try, 2003). There are concerns about stock depletion in the marine fishery, but substantial stock assessments are needed to substantiate these concerns.
- Stock states and exploitation rates are relatively unknown (Flewwelling and Hosch, 2004a). Data are mostly production-oriented and fail to include basic information for the computation of essential indicators for stock assessment (e.g. CPUE).
- Since there are no data related to CPUE, it is difficult to identify trends of specific fishery commodities, impact on any specific species, or impact of a particular gear (FAO, 2005a).

With little biological information available on specific Cambodian marine fishery resources, one option is to look at assessments of shrimp resources in the Gulf of Thailand. Janetkitkosol *et al.* (2003) review the fishery resources of the Gulf and, with regard to shrimp, conclude that penaeid resources have been overexploited since 1982 (MSY of 22 000 tonnes and an optimal fishing effort of 25 million hours). Small-sized shrimp (*Trachypenaeus* spp. and *Metapenaeopsis* spp.) have also been overexploited, with an estimated MSY of 110 000 tonnes and an optimal fishing effort of 44 million hours. Kongprom *et al.* (2003) used trawl surveys (1961–95) and annual production statistics (1971–95) to examine the status of demersal fishery resources in the Gulf. Results showed that, by 1995, the trawlable biomass had declined to only about 8.2 percent of the biomass level in 1961.

## IMPACTS ON THE PHYSICAL ENVIRONMENT

Although there have been no specific studies in Cambodia on the effects of shrimp fishing on the physical environment, there is considerable mention of damage by trawling in the country's fisheries literature, much of which relates to the destruction of seagrass beds. This may either reflect the general feeling of coastal communities or the priorities given to seagrass by external agencies, which have funded much of the work on marine resources in the country.

The report on the situation in Kompong Som Bay, Koh Kong Province (Chu *et al.* 1999) states that the bay probably used to support extensive seagrass beds, which acted as nursery areas and habitat for shrimp, crabs, juvenile fish and other marine fauna, including globally endangered dugongs and turtles. Trawlers and push nets destroy seagrass beds by dragging the seagrass out by its roots and damaging the muddy sea bottom; it is not known how much seagrass is left. The decrease in seagrass may be a contributing factor to the decline in fisheries catch, particularly shrimp and crabs.

A national report on seagrass (Department of Fisheries, 2005) found that the total area of seagrass in Cambodia's waters was 32 492 ha. These seagrass beds typically occur in water depths of 3–4 m and are mostly damaged by trawling, leaving seagrass shoots and leaves floating on the sea surface.

O'Brien (2003) proposes a National Marine Fisheries Management and Development Policy and Action Plan, noting that seagrass beds are being damaged by trawlers, push net boats and other bottom-weighted fishing methods. Seagrass habitats are important nursery areas for a range of marine species; up to nine species of seagrass beds have been identified in Cambodian waters, with most beds located in waters near Kampot and Kep. Destruction of seagrass beds may be contributing to the decline of some marine animal species, including dugongs. Trawling is one of the most destructive fishing methods used in Cambodia but it is also the source of significant income and employment. A major objective of marine fisheries management in Cambodia should

be “to reduce the impact of trawlers on the environment”, and two activities should be supported to obtain this objective: research on ways to reduce the impact of trawling; and education of fishers on the effects of destructive fishing methods.

### IMPACTS ON SMALL-SCALE FISHERIES

Shrimp fishing in Cambodia, especially trawling and motorized push netting, causes considerable conflict with small-scale fishers. Trawlers destroy the fishing gear of small-scale fishers and often do not pay compensation (Sour, 2005). The fishers cannot claim compensation because the trawler crews are often banned and are usually under the protection of high-ranking military, police or political officials. Between 1989 and 2002, trawler crews killed 22 fishers along the coast (Weinberger and Chou, 2003).

To reduce conflict between trawlers and small-scale fishers, a fishery law bans trawling in the area between the shore and the 20-m isobath but, because most of the trawlers are relatively small, they are unsuitable for use in offshore areas. This means that much of the trawling takes place illegally in areas with considerable small-scale fishing activity. Despite the fact that inshore trawling is clearly illegal, the Department of Fisheries is reluctant to enforce the ban for various reasons, including the perceived financial difficulties that it would cause trawler operators. On the other hand, those that suffer from the trawling are frustrated by the lack of government action to halt the illegal activity.

Chu *et al.* (1999) describe the situation in Kompong Som Bay, Koh Kong Province.

*Trawlers and family fishers are fishing in the same areas. This has led to conflict between the two groups. Trawlers catch their nets on the fishing gear of gillnetters and squid trappers, and the nets of both break. The gillnetters and squid trappers cannot afford to buy new nets. The trawlers sometimes pay compensation but often do not, and may even threaten small-scale fishers with guns if approached. Family fishers have boats that are only equipped to travel a maximum of approximately 2–3 km from shore. Trawlers can travel further, but only the largest trawlers consider it safe to go out past the 20-m line. Trawlers in Chrouy Svay consider themselves too small to leave Kompong Som Bay and usually trawl within the 10-m line. This leads to inevitable overlaps in fishing grounds and the damage or loss of nets of both trawlers and fishing families. Although it is illegal for any trawlers to trawl in shallow water, it is not possible to force small boats out past the 20-m line. There is potential for this conflict to be solved by direct talks between family fishers and trawlers to try to agree on boundaries within which each can fish safely.*

### MANAGEMENT

In July 2005, the Government of Cambodia made a statement on the National Fisheries Sector Policy, in which the main overall objectives of management and development of fisheries were enhancement of food security and contribution to poverty alleviation.

The legal basis for the management of shrimp fisheries in Cambodia is Fiat-Law No. 33 on Fisheries Management and Administration, 1987. The text consists of 44 articles divided into six chapters: Interpretation; Exploitation in inland fishery domain, aquaculture and processing freshwater fishery product; Exploitation in marine fishery domain; Aquaculture and processing sea product; Competent authorities for solving the fishery law violation; Penalty; and Final order. There are several other legal instruments for fisheries management in Cambodia, but most are applicable only to inland fisheries. The Department of Fisheries has been revising the existing Fisheries Law to apply better to the present social and economic situation. The revised law will reflect the need for community participation in fisheries management and emphasize the need for environmental protection and preservation (FAO, 2005a). The new law will have no provisions specifically targeted at shrimp fishing.

Shrimp fisheries are not managed separately in Cambodia, but rather as a component of all coastal fisheries, for which there are no formal management plans; the objectives of fisheries management must be inferred from the various legal instruments and past government interventions. Fiat Law No. 33 does not specifically cite the objectives of marine fisheries management, but they may be construed from its provisions, which are:

- generation of government revenue;
- production of information on the quantity of fish catch;
- avoidance of obstructing the passage of vessels;
- protection of mackerel;
- protection of the gear of inshore fishers and/or bottom habitats; and
- elimination of the use of destructive fishing gear.

To understand the management of shrimp fishing in Cambodia, it should be clear that other objectives of the present management regime are also important but not specifically articulated in the Fiat Law or in fisheries management planning documents. A major objective is to retain the possibility for all Cambodians, especially those too poor to enter other economic sectors, to participate in marine fisheries. This cannot be underestimated in a country that has been torn by decades of civil war and with limited economic opportunities for an expanding population. Although this objective has negative implications for marine resource sustainability, the political reality is that at this stage in Cambodia's history, it is difficult to deny poor people access to what is perceived as a low entry cost occupation. The legitimacy of this poverty alleviation is not disputed here, but an important point should be made: if the fisheries management system is charged with the responsibility for ensuring economic opportunities for a very large number of poor people, major restrictions are placed on the achievement of other management objectives (Gillett, 2004).

The following are current fisheries management measures relevant to shrimp fishing.

- All fishing, except family-scale operations, must be licensed. In addition, if fishing takes place from a vessel, the vessel must be licensed by both the fisheries agency and the police.
- Fishers must record on a daily basis the quantity of fish caught and report this monthly to the provincial/municipal fishery agency.
- Trawling between the shore and the 20-m depth line is prohibited.
- Certain fishing gear is specifically prohibited (explosives, electrical fishing gear and modern fishing gear have not yet been mentioned in a ministerial proclamation). This prohibition presumably covers motorized push nets and pair trawling, which fisheries officers often cite as illegal.
- Fishing is banned in designated marine protected areas.

Nevertheless, the present law does *not* specify any provision for limiting fish catches or fishing effort. The Department of Fisheries recognizes that the large number of small trawlers is a major threat to the sustainability of fisheries resources but, because of the open access situation in all Cambodian marine fisheries, there are few legal measures that can be taken to limit the numbers. The Department's strategy to limit efforts has been to explore the potential of limiting/reducing vessel numbers by comanagement with fishing communities and by promoting alternative livelihoods. Fisheries officials also report that they discourage – albeit with no legal basis – the construction of new small trawlers and the repair of older ones (e.g. by non-endorsement of requests for bank loans, discussions with trawler owners).

Considering the lack of biological information on shrimp resources, the few legal instruments available for shrimp fishing management, the poor enforcement of those that do exist, and the open access nature of all coastal fisheries, there are considerable obstacles to deriving greater benefits from the shrimp fisheries by management interventions.

## ENFORCEMENT

The Marine Inspection Unit, based at Sihanoukville, employs some 80 people and is responsible for monitoring the compliance of fishing activities along the coastline. The unit operates two fairly old 45-ft (13.7-m) vessels and is charged with actively enforcing gear, season and zone restrictions, with appropriate penalties applied when necessary. A VMS is in place, and random and routine dockside/landing site inspections are carried out. Resources are lacking to monitor the national and foreign fleets in the 55 600 km<sup>2</sup> EEZ. Capacity within the Department of Fisheries is insufficient, however, to be able to enforce the law effectively (Flewwelling and Hosch, 2004).

The major issue in the enforcement of legislation relating to shrimp fishing concerns the ban on trawling in waters less than 20 m deep. The ban was intended to safeguard the interests of small-scale fishers but enforcement is selective at best. The result is that most of the shrimp landings in Cambodia are from trawling in prohibited areas. As stated previously, there is a reluctance to enforce the ban for various reasons, including the financial difficulties that it would cause trawler operators, who are perceived to be poor.

Some of the “concern for the poor” arguments for non-enforcement do not seem to hold up under close scrutiny (Gillett, 2004). Observations along the coast suggest that those who suffer the effects of non-enforcement are the small-scale inshore fishers who appear even poorer than the trawl fishers.

Chu *et al.* (1999) make an observation concerning problems in enforcement in Koh Kong Province:

*Trawlers are supported by senior police and military and are owned by wealthy Thai and Cambodian businessmen. All trawlers pay bribes to police and military, as well as to fisheries officials, district and commune leaders. Because of the protection of high-level officials, lower-level officials cannot enforce the law prohibiting trawling.*

Try (2003) concludes:

*The lack of consistent enforcement within the Department of Fisheries is resulting in inequitable access to fisheries resources, community conflicts, a reduction in fish stocks through overfishing and habitat degradation by allowing fishing activities to continue in protected areas.*

The costs of enforcing legislation relating to shrimp fisheries, or even to coastal fisheries in general, are not readily available. Calculations are complicated by the various agencies involved and the fact that most of the agencies have enforcement responsibilities outside the fisheries sector.

## RESEARCH

An Inland Fisheries Research and Development Institute exists within the Department of Fisheries, but there is no equivalent for marine fisheries. Similarly, the Royal University of Agriculture has a faculty for fisheries research but focuses almost exclusively on inland fisheries. There is no formal research structure for marine fisheries in Cambodia and consequently the authorities rely almost entirely on donor-funded activities for research programmes or projects (Flewwelling and Hosch, 2004).

In recent years, externally funded research projects relevant to shrimp fisheries have included studies on trawling, seagrass, turtles, socio-economic status of coastal fishing communities, marine mammals, mangroves and marine biodiversity. Sponsors of these studies have included DANIDA, FAO, conservation NGOs, UNEP, SEAFDEC and GEF. The studies were mostly undertaken in cooperation with the Department of Fisheries or the Ministry of the Environment. The costs of these projects are not available.

Marine fisheries research conducted in neighbouring countries, such as Thailand, could have some applicability to Cambodia, as was mentioned in the section *Biological aspects* with regard to shrimp resources in the Gulf of Thailand.

## DATA REPORTING

Much of the descriptive information on shrimp in this report relies to a certain extent on the statistics produced by the Department of Fisheries. Gillett (2004) states that numerous reviews of the fisheries sector in Cambodia highlight the deficiencies in the fisheries statistical system, mainly emphasizing the following points.

- Important elements of marine fisheries are not included: catches by subsistence fishers, and catches by Cambodian and foreign vessels (both licensed and illegal) that are landed outside Cambodia.
- As a result of the methodology, estimates for even those components covered by the statistical system could be inaccurate.
- The statistical system is oriented towards collection of production information, while even the most basic indicators useful for stock assessment (e.g. CPUE) are not included.

It should be acknowledged that collection of fisheries statistics is inherently difficult and expensive in a location such as the Cambodian coast. In this respect, the situation in Cambodia may be similar to that of many neighbouring countries. A study on inland fisheries statistics across Southeast Asia (Coates, 2002) came to a conclusion that could apply to the marine fisheries statistics of Cambodia:

*The countries of Southeast Asia in general struggle with limited resources to compile information that, in many cases, they do not themselves trust, need, or use. At the same time, most of those countries are aware of what information it would be more logical to collect, but lack the methods and support to obtain it.*

Senior staff of the Department of Fisheries (I. Try and O. Vibol, personal communication, December 2005), indicate that there have been recent improvements in Cambodia's marine fisheries statistics. They state that SEAFDEC has provided assistance to improve both the training of statistical staff as well as the procedures for collecting statistics.

## IMPACTS OF SHRIMP FARMING

The Agriculture Productivity Improvement Project (APIP, 2001) reviews the history of shrimp farming in Cambodia. Coastal aquaculture began with shrimp culture, using technology from neighbouring countries, particularly Thailand. The culture was started extensively in Koh Kong Province, and was then expanded to Sihanoukville and Kampot Province. The main marine species cultured in the coastal area were *Penaeus monodon* and *P. merguensis*. Shrimp culture production rose remarkably, from 500 tonnes in 1993 to peak at 731 tonnes in 1995, but then dropping to just 63 tonnes in 1999. This decrease in production was caused by disease, which killed thousands of tonnes of shrimp and caused many farmers to become bankrupt.

Shrimp farm production from 1993 to 2004 is given in Table 37; location of production from 2001 to 2004 in Table 38.

There is a lack of economic data on shrimp fisheries (see section *Profitability*), including information on decreases in prices for shrimp on the domestic or international markets. However, price declines are unlikely to be related to the effects of shrimp farming in Cambodia because of the small quantities of shrimp produced. Worldwide, the large increase in farmed shrimp production has led to a fall in prices for all shrimp, including captured shrimp, and this could affect shrimp prices in Cambodia.

TABLE 37  
Shrimp production in Cambodia,  
1993–2004

Year	Production (tonnes)
1993	500
1994	560
1995	731
1996	600
1997	266
1998	197
1999	63
2000	21
2001	143
2002	53
2003	90
2004	75

Source: Official statistics, Department of Fisheries.

TABLE 38  
Shrimp production by location

	2001	2002	2003	2004
Kep	3	1	2	0
Kampot	50	0	8	20
Sihanoukville	60	25	53	37
Koh Kong	30	27	27	18
Total	143	53	90	75

Source: Official statistics, Department of Fisheries.

There are other impacts of shrimp farming on shrimp fishing.

- Fisheries officers have heard complaints from trawl fishers that the destruction of mangrove forests, including those for shrimp farms, is negatively affecting their catches.
- Work in Koh Kong Province (Chu *et al.*, 1999) warns of pollution associated with shrimp farming. Development of shrimp aquaculture without adequate thought to the environment could be a disaster for the ecosystem of Kompong Som Bay and could have long-term detrimental effects on the environment and economy of the area.

The relationship of trash fish to shrimp aquaculture is not as close in Cambodia as in other Southeast Asian countries, where a major use of trash fish is for feed for shrimp farming. This also occurs in Cambodia, although trash fish is more often used for fertilizer and for bait.

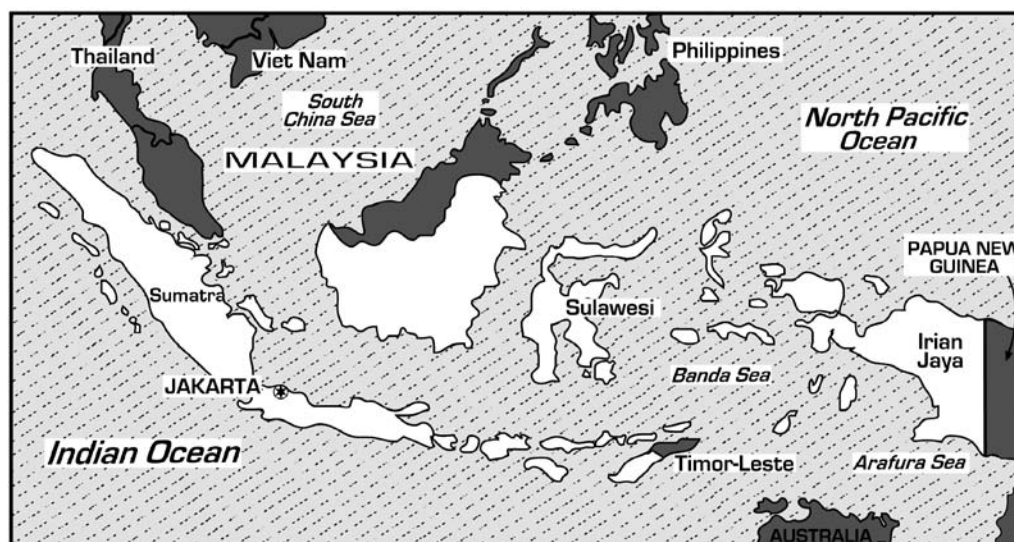
### MAJOR ISSUES

The major issues related to shrimp fishing in Cambodia are that:

- trawling for shrimp and demersal fish produces most of the fisheries-related conflict along the coast;
- small trawlers are numerous and fish illegally in shallow waters, but they are unsuitable for offshore fishing;
- the relatively simple ban on trawling in shallow water cannot be enforced;
- there is an urgent need to reduce coastal fishing effort, especially by small trawlers, but this is extremely difficult because of the lack of enabling legislation and political will;
- there is a lack of biological knowledge of the shrimp captured and even considerable uncertainty as to what species are being fished; and
- considering the paucity of biological information on shrimp resources, the few legal instruments available for managing shrimp fishing, poor enforcement of those that do exist, and the open access nature of coastal fisheries in the country, the obstacles to deriving greater benefits from shrimp fisheries by management interventions are considerable.



## Shrimp fishing in Indonesia



### AN OVERVIEW

Shrimp fishing is of major importance to Indonesia. After China and India, Indonesia's shrimp catch is the largest in the world. Shrimp farming is also of great significance, with over 65 000 participating households. Shrimp production, from both fishing and aquaculture, has reached over 400 000 tonnes per year, and shrimp is by far the country's most valuable fishery export.

Shrimp fishing in Indonesia is not without its problems. A multitude of conflicts are generated, most of which involve small-scale fisheries. The 1980s trawl ban is cited as the most significant fisheries management measure ever to have taken place in the country, but its effectiveness has eroded over the years. As in many parts of the world, industrial-scale shrimp trawling operations are having major problems coping with the recent rise in fuel prices.

The structure of the shrimp industry is complex and problematic. There are a large number of boats that catch shrimp, many types of fishing gear and illegal fishing and trade activities. Moreover, poor statistical information and inadequate enforcement of regulations do not help to resolve the difficulties.

### DEVELOPMENT AND STRUCTURE

Shrimp fishing has been important in Indonesia for centuries. Lift nets, push nets, beach seines, set nets, gillnets and a multitude of other gear have been used to catch shrimp for generations by small-scale fishers across the country. The development of larger-scale methods to catch shrimp was a slow process. From 1907 to 1911, in the hope of decreasing Java's dependence on imported fish, the Netherlands Indies Government undertook development work with trawling in the Java Sea, using a converted hopper barge from the Netherlands. The operation experienced problems with the soft mud and the large amount of sponges. Although the work dispelled the idea of being able to make significant catches on the bottom, some good trawling areas were found in the Madura Straits and off the south coast of Borneo. Japanese trawlers began basing in Singapore in 1935 and ranged as far as the Arafura Sea. These operations started scaling

down in 1937 as a result of pre-war animosity created by Japan's invasion of China. The next significant attempt to introduce trawling in Indonesia occurred in the 1950s when the Directorate-General of Fisheries carried out trawling trials. Although they were regarded as successful, "local fishermen did not respond, due to the difficulty of obtaining engines and spare parts" (Butcher, 2004).

Priyono and Sumiono (1997) recount the developments that led to the establishment of shrimp trawl fishing in Indonesia. Trawl fisheries started commercially in 1966 in the Malacca Straits, particularly in the area surrounding the estuary of the Rokan River, with Bagansiapiapi as its base. The fishery was characterized by wooden sampan-like motorized vessels of 5–20 GT, employing a single gulf-type shrimp trawl of 12–15 m headrope length. The fishery developed rapidly, engaging over 800 vessels by the end of 1971. The development of trawl fisheries in Indonesia may have been influenced by western Peninsular Malaysia. The ancestors of many Chinese fishers in Riau Province, Indonesia, have migrated from there and still maintain contact with their relatives in Malaysia. The number of Chungking trawlers (of type 15 GT) operating from Bagansiapiapi increased to 227 in 1976. In the following years, the trawl fishery spread throughout western Indonesia via southeastern Sumatra to the north and south coasts of Java, and to southern Sulawesi. The sizes of the trawlers gradually increased from 15 to 35 GT, and their engines from 66 to 120 HP. Polyethylene nets were used, with headrope length ranging from 13.5 to 22.5 m, and a codend mesh size of 2 cm. Data from the provincial fisheries offices of the Malacca Straits provinces of Aceh, North Sumatra and Riau showed that, in the early to mid-1970s, about 20 percent of trawler catch was shrimp. Trawling for shrimp in the Arafura Sea began in 1969 with nine trawlers, ranging in size from 90 to 600 GT and from 260 to 1 200 HP. By the end of 1982, the number of shrimp trawlers in the Moluccas and Irian Jaya in eastern Indonesia had peaked at 188 units. In the 1990s, there were only 87 trawlers.

Butcher (2004) provides information on the business aspect. Investment in trawling was fuelled by Chinese entrepreneurs who wished to diversify investment and take advantage of the foreign and domestic capital investment laws of 1967 and 1968, with their tax holidays and duty-free import of equipment. In 1969, the Indonesian Government tightened up considerably and foreign companies had to have a joint venture partner. Typically, foreign partners put up capital and local partners facilitated the connections. In 1970–71, 50 trawlers moved from Sumatra to the north coast of Java. Between 1967 and 1971, one wholly Japanese and ten joint ventures began operating in the Malacca straits, off Kalimantan and in the Arafura Sea. Catches of shrimp rose as new shrimping grounds were opened faster than older ones were overfished. Cold-storage plants were constructed; by 1976, there were 51 shrimp cold-storage plants in Indonesia.

Substantial conflict was generated between small-scale fishers and trawler operators. Trawling was subsequently banned in most of Indonesia by Presidential Decree No. 39/1980, which was implemented incrementally (see section *Impacts on small-scale fisheries*).

Shrimp fishing in Indonesia is a complex mixture of industrial and smaller-scale operations. The situation is complicated by the large number of units and gear types; the fact that many small-scale fishers catch shrimp with multispecies gear, and also that various types of trawl gear have been renamed to circumvent the trawl ban.

Large-scale shrimp trawling is, in principle, confined to the Arafura Sea and adjacent areas of eastern Indonesia. Purwanto (2005) gives the evolution of the fleet structure in the Arafura Sea in recent years (Table 39).

Industry sources (Sukirdjo, Association of Indonesian Shrimp Catching Companies, personal communication, December 2005) state that, in late 2005, there were about 140 Association shrimp trawlers fishing in eastern Indonesia (Arafura, Aru, Maluku) and about an equal number of non-Association vessels operating in the same area. A much

TABLE 39  
Number of shrimp trawl vessels in the Arafura Sea

	Vessel size (GT)				Total
	<50	51–100	101–200	>200	
1992	n.a.	n.a.	n.a.	n.a.	250
1996	39	59	280	53	431
2000	70	207	198	51	526
2004	2	126	174	34	336

Source: Purwanto, 2005.

TABLE 40  
Main small-scale fishing gear used to catch shrimp

Gear type	Number of fishing units	Distribution of gear
Shrimp nets and fishnets*	10 002	65% of units located in East Kalimantan
Demersal Danish/lampara seines	17 893	56% in North Java
Beach seines	18 925	
Shrimp gillnets	30 690	26% in North Java; 16% in the Malacca Straits; 18% in Bali-Nusatenggara; 14% in South Java
Trammel nets	42 131	47% in North Java
Stow nets	7 887	83% in East Kalimantan
Guiding barrier nets	9 482	
Total	137 010	

Source: 2003 statistics, Ministry of Marine Affairs and Fisheries.

\*This category presumably includes the industrial trawlers operating in eastern Indonesia.

larger number of these vessels (perhaps a total of 500) had been operating, but most returned to China in 2003.

The size of the Association's vessels ranges from 150 to 200 GT, fishing trips average 60 days in length, and vessels are based in the ports of Ambon, Sorong, Kendari and Kupang. The 140 Association vessels are owned by 14 different companies, eight of which are joint ventures with foreign entities (seven Japanese, one Australian). All trawlers are "Florida type" with twin trawl nets and carry a crew of 15 to 20.

According to ICES/FAO (2005), three types of trawl gear are used in the Arafura Sea:

- double-rig shrimp trawl: the headrope length is between 15 and 26 m; the mesh size of the codend is generally 30 mm and made of polyethylene;
- single-rig stern trawl: the headrope length is between 26 and 35 m; and
- quad trawl where two trawls on each side are towed: headrope length of each trawl is between 20 and 25 m.

To complicate the Indonesian industrial shrimp fishing situation further, there is reportedly a substantial amount of illegal trawling by foreign vessels, as well as by Indonesian vessels, in areas of the country where trawling is, in principle, banned.

The structure of non-industrial shrimp fisheries in Indonesia is considerably more complex than the industrial operations. According to an Indonesian fishery scientist (M. Badrudin, personal communication, December 2005), many types of gear are used by small-scale fishers to catch shrimp; the major ones for which official statistics have been collected are given in Table 40. As can be seen from the Table, there are a considerable number of fishing units. An important point is that most of the gear types listed make substantial amounts of non-shrimp catches and therefore they cannot be considered strictly shrimp fishing gear. The most important non-trawl gears for catching shrimp are trammel nets and shrimp gillnets.

Almost 28 000 fishing units make up the categories "shrimp nets and fishnets"<sup>26</sup> and "demersal Danish/lampara seines". This represents an interesting collection of gear types, many of which function as trawls and are sometimes referred to as "mini-

<sup>26</sup> The name that appears in the official statistics and documents is always "BED-equipped shrimp nets/fishnets".

trawlers”. At least some of the Indonesian trawl gear terminology arose to circumvent the ban on using trawl gear in most areas of the country. Endroyono (2000) lists 25 named types of trawls used in the seven fishing areas of Indonesia:

- Arafura, Aru and Banda: two types of trawl gear, both used by industrial-scale vessels (more than 5 GT);
- Indian Ocean: four types of trawl gear, two of which are used by industrial-scale vessels;
- Malacca Straits: seven types of trawl gear, three of which are used by industrial-scale vessels;
- Java Sea: 15 types of trawl gear, one of which is used by industrial-scale vessels;
- Karimata Strait and South China Sea: five types of trawl gear, all of which are used by industrial-scale vessels;
- Makassar Strait and Flores Sea: six types of trawl gear, none of which is used by industrial-scale vessels; and
- Seram Sea, Tomini Bay, Sulawesi Sea, Pacific Ocean and Bituni Bay: four types of trawl gear, two of which are used by industrial-scale vessels.

In general terms, industrial-scale shrimp fishing takes place mainly in southeast Indonesia, while small-scale shrimp fishing occurs mainly in western Indonesia. Small trawlers operate in many parts of the country, but predominate in the west. Illegal foreign shrimp fishing activity is reportedly common in the good shrimping grounds in the southeast and in the South China Sea area, close to Indonesia’s Southeast Asian neighbours. Foreign shrimp fishing is allowed under licence in certain areas, but the Indonesian Government has indicated that it would be phased out in late 2006. In addition to marine catches, about 15 000 tonnes of freshwater shrimp<sup>27</sup> are taken per year.

#### TARGET SPECIES, CATCH AND EFFORT

Of the 81 species of penaeid shrimp found in Indonesia, at least 46 species are caught, of which just 14 are economically important. The banana shrimp group (*Penaeus merguensis*, *P. indicus*, *P. chinensis*), the tiger shrimp group (*P. monodon*, *P. semisulcatus*, *P. latisulcatus*) and the endeavour shrimp group (*Metapenaeus endeavouri*, *M. monoceros*, *M. affinis*) account for almost 95 percent of Indonesian shrimp export (Venema, 1996).

Further clarification is given by Priyono and Sumiono (1997). The most important shrimp caught by trawl is:

- banana, or *jerbung* (*Penaeus merguensis*, *P. indicus*, *P. chinensis*);
- tiger, or *windu* (*P. monodon*, *P. semisulcatus*, *P. latisulcatus*);
- endeavour (*Metapenaeus monoceros*, *M. ensis*, *M. elegans*);
- rainbow, or *krosok* (*Parapenaeopsis sculptilis*, *P. stylifera*);
- pink (*Solenocera subnuda*, *Solenocera* spp.).

The first three groups are well defined in official fisheries statistics, while rainbow and pink shrimp belong to the “other shrimp” category.

The various shrimp fisheries in Indonesia catch different species.

- Industrial shrimp trawling in the Arafura Sea trawl catches 19–35 percent tiger shrimp, 29–43 percent banana shrimp and 21–31 percent endeavour shrimp (ICES/FAO, 2005).
- Small-scale shrimp fishing in Cilacap on the south coast of Java catches (i) banana/white shrimp; (ii) endeavour shrimp; (iii) *krosok* or a mixture of small species of shrimp; and (iv) *rebon* or small shrimp of Sergistidae and Mysidaceae. The first two categories are exported to Japan and the United States, the third group is used for canning and local consumption, and the fourth group is used for making shrimp paste (Naamin and Martosubroto, 1980).

<sup>27</sup> Since the present study is concerned with marine shrimp, freshwater shrimp is not considered further.

TABLE 41  
Indonesia's shrimp catches, 1993–2003 (tonnes)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003*
Giant tiger prawns	16 116	16 960	24 501	19 393	25 929	30 047	34 223	40 987	43 759	38 088	34 190
Banana prawns	43 925	47 237	50 477	53 913	53 924	62 192	64 179	66 644	65 269	69 508	66 501
<i>Metapenaeus</i> shrimp	15 814	20 364	22 863	22 285	32 588	40 717	33 847	38 925	36 358	33 570	34 178
Other shrimp	79 714	91 152	81 261	89 215	95 790	87 200	103 372	98 880	113 161	95 561	100 221
<b>Total</b>	<b>155 569</b>	<b>175 713</b>	<b>179 102</b>	<b>184 806</b>	<b>208 231</b>	<b>220 156</b>	<b>235 621</b>	<b>245 436</b>	<b>258 547</b>	<b>236 727</b>	<b>235 090</b>

Source: 2003 statistics, Ministry of Marine Affairs and Fisheries.

\* The 2003 shrimp catches, as reported to FAO, are 265 980 tonnes. For other years, the Ministry and FAO statistics are identical.

TABLE 42  
Indonesia's shrimp catches by area, 2003 (tonnes)

Area	Giant tiger prawns	Banana prawns	<i>Metapenaeus</i> shrimp	Other shrimp	Total
West Sumatra	1 483	2 040	1 440	1 992	6 955
South Java	1 194	450	213	1 823	3 680
Malacca Straits	6 643	23 622	10 835	27 670	68 770
East Sumatra	940	6 038	6 598	20 943	34 519
North Java	1 833	7 159	1 547	15 890	26 429
Bali-Nusatenggara	166	178	144	346	834
South/West Kalimantan	1 690	6 702	2 596	10 154	21 142
East Kalimantan	9 114	13 114	7 191	10 777	40 196
South Sulawesi	3 427	4 241	1 025	2 432	11 125
North Sulawesi	17	156	0	151	324
Maluku-Papua	7 683	2 801	2 589	8 043	21 116
<b>Total</b>	<b>34 190</b>	<b>66 501</b>	<b>34 178</b>	<b>100 221</b>	<b>235 090</b>

Source: Ministry of Marine Affairs and Fisheries unpublished data, 2003.

- Tidal trap nets in Riau Province catch over 40 groups of fish/invertebrates, as well as the shrimp *Penaeus merguensis* (2 percent of total catch by weight), *Metapenaeus lysianasa* (1 percent), *Parapenaeopsis styliifera* (7 percent), *P. sculptilis* (3 percent) and *Acetes* spp. (1 percent) (Badrudin, Sumiono and Murtoyo, 2001).

The Indonesian Ministry of Marine Affairs and Fisheries (DKP) publishes statistics each year<sup>28</sup>. Information on shrimp catches in Indonesia from 1993 to 2003 are given in Table 41 and the 2003 shrimp catch is divided by area in Table 42.

It can be seen from the tables that:

- production of shrimp in Indonesia generally increased during the 1993–2001 period, but fell during the following two years;
- the Malacca Straits, followed by East Kalimantan and East Sumatra, are the major shrimp-producing areas;
- the industrial-scale shrimp fishing in Maluku-Papua catches considerably less shrimp than the total of the smaller operations to the west; and
- the production of non-export shrimp (*Metapenaeus* and other shrimp) is greater than that of the export species (banana and tiger).

Some catch and effort data are available for industrial-scale shrimp trawling in the Arafura area, but similar data for the enormous number of smaller-scale shrimp fisheries are less available, accurate and comparable.

Purwanto (2005) summarizes recent CPUE data on industrial-scale shrimp trawling in the Arafura Sea:

- Biological studies indicate a decreasing trend in shrimp CPUE in recent years. In 1993, catch averaged 90 tonnes of shrimp/vessel/year, but this generally decreased to just over 60 tonnes in 2000.

<sup>28</sup> Cautions on data quality are given in Chapter 15, Data reporting.

- Industry data show much more variability between years, but a decrease from 63 tonnes of shrimp/vessel/year in 1993, to 32 tonnes in 2000, followed by an increase to 48 tonnes in 2001. The shrimp catch/vessel/day decreased from about 270 kg in 1993 to 160 kg in 2002.

Other sources give additional information on CPUE in industrial-scale shrimp trawling in the Arafura Sea.

- An industry source (Sukirdjo, Association of Indonesian Shrimp Catching Companies, personal communication, December 2005) stated that the catch/vessel/day has decreased from 300–350 kg per day two decades ago to the present 250–300 kg.
- The National Committee for Reducing the Impact of Tropical Shrimp Trawling Fisheries in the Arafura Sea (National Committee, 2001) gives the change in fishing effort from 1990 to 1998 and states that: (i) in 1990, the fishing effort in the Arafura Sea was estimated at 86 640 operational days or 632 472 hauls; and (ii) in recent years, even though the amount of effort increased, the CPUE (kg/haul) remained stable at between 25 and 37 kg. In 1990, the catch per haul was 33 kg but, in 1974, during the early days of the fishery, it averaged 95 kg.
- An Indonesian fishery scientist (M. Badrudin, personal communication, December 2005) has said that the current thinking among researchers is that the Arafura shrimp CPUE has been slack in the last few years, but that the species composition has changed, with the high-value species decreasing. Badrudin and Nurhakim (2004) use two different measures of CPUE (based on 1991–2002 data). The first is in the form of catch/vessel/year, while the second index is the catch/vessel/day. The trend of both indices from 1991 to 2002 is almost horizontal.

## ECONOMIC CONTRIBUTION

Each year the Ministry of Marine Affairs and Fisheries publishes fisheries statistics, including the value of species groups. Tables 43 and 44 give the values<sup>29</sup> by type of shrimp, area and year.

DKP statistics also give the value of all marine fishery capture production in 2003 as Rp26 641 072 151 000, or about US\$3.1 billion. Therefore, the official statistics indicate that the landed value of marine shrimp capture fisheries is about 18 percent of that of all marine capture fisheries in the country.

The fisheries sector is responsible for about 2.9 percent of Indonesia's GDP. If the value added for shrimp fishing is about average for all fishery subsectors, then shrimp fishing represents about 0.52 percent of the country's GDP (DKP, 2005a).

According to the Director of the Center for Marine and Fisheries Socio-Economic Research in Jakarta, information on employment in shrimp fishing and other fisheries is not readily available in Indonesia (A. Purnomo, personal communication, December 2005). An appreciation of the importance of employment in shrimp fishing can be seen from Table 40. There are approximately 137 000 fishing units using the seven most important types of gear. The employment associated with these units completely overshadows employment on vessels of the industrial-scale shrimp fishery in the Arafura Sea – about 2 900 people on 280 boats.

Data on the consumption of shrimp in Indonesia are not readily available. Naamin and Martosubroto (1980) report that the two statistical categories “*Metapenaeus* shrimp” and “other shrimp” are consumed domestically, while the other categories are exported. In 2003, DKP statistics show that 134 000 tonnes of “*Metapenaeus* shrimp” and “other shrimp” were landed. An Indonesian fishery scientist (M. Badrudin, personal communication, December 2005) expressed the opinion that about half of Indonesia's shrimp catch, or about 118 000 tonnes, is consumed domestically. If it is assumed that

<sup>29</sup> Values given are those at the landing site.

TABLE 43  
Value of shrimp capture production, 2003

	Giant tiger prawns	Banana prawns	<i>Metapenaeus</i> shrimps	Other shrimp	Total (Rp '000)	Total (US\$)
Sumatra	384 604 184	701 161 521	323 253 500	386 944 501	1 795 963 706	209 027 433
Java	190 978 025	292 954 834	37 684 824	184 967 768	706 585 451	82 237 599
Bali-Nusatenggara	4 503 500	3 361 800	2 699 100	6 712 350	17 276 750	2 010 795
Kalimantan	530 860 176	556 099 553	145 870 233	185 208 440	1 418 038 402	165 041 713
Sulawesi	79 308 000	53 627 760	13 133 830	43 438 867	189 508 457	22 056 385
Maluku-Papua	309 279 500	96 163 140	89 277 500	172 175 900	666 896 040	77 618 254
<b>Total ('000 Rp)</b>	<b>1 499 533 385</b>	<b>1 703 368 608</b>	<b>611 918 987</b>	<b>979 447 826</b>	<b>4 794 268 806</b>	
<b>Total (US\$)</b>	<b>174 526 698</b>	<b>198 250 536</b>	<b>71 219 621</b>	<b>113 995 324</b>		<b>557 992 180</b>

Source: Ministry of Marine Affairs and Fisheries, unpublished data, 2003.

Note: 2003 rupiah/dollar conversion at 8 592 (www.oanda.com).

TABLE 44  
Value of shrimp capture production, 2000–03

	2000	2001	2002	2003
Giant tiger prawns	2 047 310 085	2 502 407 356	2 055 284 615	1 499 533 385
Banana prawns	1 701 405 234	1 688 705 550	1 812 160 747	1 703 368 608
<i>Metapenaeus</i> shrimp	618 150 159	619 325 594	631 191 513	611 918 987
Other shrimp	612 662 797	764 473 882	846 072 386	979 447 826
<b>Total ('000 Rp)</b>	<b>4 979 528 275</b>	<b>5 574 912 382</b>	<b>5 344 709 261</b>	<b>4 794 268 806</b>
<b>Total (US\$)</b>	<b>591 744 299</b>	<b>541 621 722</b>	<b>571 626 659</b>	<b>557 992 180</b>

Source: 2003 statistics, Ministry of Marine Affairs and Fisheries.

Note: 2003 rupiah/dollar conversion at 8 592; 2002 at 9 350; 2001 at 10 293; and 2000 at 9 350 (www.oanda.com).

125 000 tonnes are consumed domestically and the population of Indonesia in 2003 was 240 million, then the per capita consumption in 2003 was about 0.5 kg. Shrimp is consumed fresh as well as in processed forms such as cakes, balls, rolls and paste.

## TRADE ASPECTS

As already mentioned, shrimp is Indonesia's largest fishery export. DKP (2005) gives the volumes and values of the 2003 and 2004 exports (Table 45). It can be seen that, in 2004, shrimp represented 15 percent of all Indonesian fishery exports by volume and 50 percent by value. By contrast, tuna (the second most important fishery export) represented 14 percent by volume and 13 percent by value.

The shrimp export situation is complicated by the fact that aquaculture shrimp is not distinguished from captured shrimp in the published DKP statistics. The total production of aquaculture shrimp in Indonesia was about 179 000 tonnes in 2003, much of which was exported. An additional difficulty is that, in 2005, both the United States and the EU made allegations that a substantial amount of shrimp from China was being repackaged in Indonesia for re-export in order to circumvent trade sanctions.

Suboko (2001) reports that 89 percent of all shrimp exports are frozen, 9 percent fresh chilled, and the remainder canned. With respect to shrimp exports that originate only from capture fisheries, a representative of the Association of Indonesia Shrimp

TABLE 45  
Volumes and values of fishery exports, 2003 and 2004

	2003		2004*	
	Volume (tonnes)	Value (US\$)	Volume (tonnes)	Value (US\$)
Shrimp	137 636	850 222	139 450	887 127
Tuna	117 092	213 179	94 221	243 937
Other fishery products	603 055	580 141	668 687	649 769
<b>Total fishery exports</b>	<b>857 783</b>	<b>1 643 542</b>	<b>902 358</b>	<b>1 780 833</b>

\* This is a provisional estimate.

Source: DKP, 2005.

Catching Companies (Sukirdjo, personal communication, December 2005) says that most of their shrimp production is exported frozen, with the product being specific to national markets: tiger shrimp (head-on) and banana shrimp (headless) are sold to markets in Japan; banana shrimp (head-on) are sold to China; small peeled shrimp are sold to the EU; and all shrimp sold to the United States is headless.

For 2000, the main shrimp export destinations (both capture and aquaculture products), were Japan (42 percent by value) and the United States (14 percent) (Suboko, 2001). A representative of the Association of Indonesian Shrimp Catching Companies (Sukirdjo, personal communication, December 2005) says that, in late 2005, the situation was quite different; virtually all captured shrimp exports were sold to markets in Japan and China, with little going to the EU and none to the United States.

Various forms of sanctions have been applied to Indonesian shrimp imports and exports.

- From December 2001 to July 2003, the EU banned imports of cultivated shrimp from Indonesia because they were found to contain the antibiotic chloramphenicol. The EU had previously warned Indonesia that it should comply with an EU directive prohibiting the use of this antibiotic. Indonesia itself had issued a ban on the distribution of chloramphenicol as early as 1982 (Down to Earth, 2002).
- In December 2004, in an effort to combat shrimp transshipments from China through Indonesia to the United States and the EU, the Government of Indonesia banned the import of *Penaeus vannamei*, *P. monodon* and *P. stylirostris* shrimp (United States Embassy press release, December 2005).
- In May 2002, the United States Government banned imports of shrimp from Indonesia and Haiti on the basis of the fact that that these countries are not certified by the United States Department of State as having met the requirement that shrimp entering the United States market are harvested so as to cause no harm to threatened turtle species (Caribbean Update, 2002).

There is considerable confusion in Indonesia with regard to the United States embargo on sea turtles. In late 2005, independent discussions with several Indonesian shrimp industry participants gave the impression that no embargo of Indonesian shrimp was in place, but rather that the United States had issued a warning a few years before, requiring greater compliance should Indonesia wish to continue exporting shrimp to the United States. On the other hand, a United States official (C. Stanger, personal communication, Office of Marine Conservation, United States Department of State, October 2005) said that Indonesian captured shrimp is not certified and cannot be imported into the United States.

The Center for Marine and Fisheries Socio-Economic Research in Jakarta is carrying out a study of non-tariff barriers in the main countries that import Indonesian shrimp. Although the study report has not been released, the authors state that the main result is that non-tariff barriers are more important than tariff barriers for the United States market while, for the EU, the converse is true (A. Purnomo, personal communication, December 2005).

### BYCATCH ISSUES

The major bycatch issues in Indonesian shrimp fisheries are the high discard levels of industrial shrimp trawlers in the Arafura Sea; the adverse biological impacts of bycatch in the small-scale shrimp fisheries; appropriate measures to mitigate these bycatch problems; and enforcement difficulties associated with bycatch legislation.

Kelleher (2005) comments on discarding in Indonesia. With the notable exception of the Arafura Sea Shrimp Trawl Fishery, most Southeast Asian fisheries have been given a discard rate of 1 percent. While some discarding undoubtedly takes place, the volumes are so low as to be considered insignificant by most experts from the region. The Arafura Sea Shrimp Trawl Fishery discards over 80 percent of the total catch, around



230 000 tonnes per year. Despite the introduction of BEDs, the total discards remain high as a result of weak enforcement of regulations and lack of local markets for the bycatch, since the fishery is located at a considerable distance from major population centres. Kelleher concludes that:

*Discards in Indonesia are considered insignificant as everything is used for home consumption or for commercial purposes, except for the Arafura Sea Shrimp Trawl Fishery.*

The National Committee (2001) provides additional information on the Arafura fishery. The landings of bycatch (compared with discarding bycatch) are rather low as a result of operational factors and local socio-economic conditions. The operational factors include the small size of vessels (which do not have enough room for storage of bycatch); the time required to handle the bycatch; and short sailing times between fishing grounds and landing sites (Ambon, Sorong). Socio-economic factors include the decrease in the price of bycatch fish on the local market and costs for its storage and transportation.

Funge-Smith, Lindebo and Staples (2005) quote the legislation relevant to bycatch in the Arafura Sea. Presidential Decree No. 85/1982 requires that BRDs be used on shrimp trawlers. The same decree also stipulates that all bycatch be handed over to the state-owned company. Decree No. 561 of the Minister of Agriculture stipulates that all entities fishing shrimp are required to use the fish from their fishing activities as foodstuff for the population. Fisheries Decree No. IK.010/S3.80.75/1982 requires that trawlers in the Arafura area deploy TEDs, and Fisheries Decree No. 868/Kpts/IK.340/II/2000 requires that a BRD be installed on the body of the trawl (Zainudin and Pet-Soede, 2005).

According to industry sources, a common practice is for Arafura shrimp trawlers to stop using any BRDs about ten days before the end of fishing trips (60-day trips are average), so that the crew can have fish for consumption and sale. The National Committee carried out a survey to evaluate stakeholders' perception of shrimp exploitation. Around 38 percent of respondents from shrimp fishing companies stated that they always use BRDs as required by Presidential Decree No. 85/1982; 25 percent stated that they use them only occasionally or did not know whether they should use them or not. Only 25 percent believed that the use of a BRD is an obligation, while almost 38 percent believed that it is not. Twelve percent stated that they do not use BRDs for technical reasons (National Committee, 2001). It can be concluded from this survey that awareness and enforcement of bycatch legislation are major difficulties.

The catch of turtles in the shrimp trawls of the Arafura Sea has attracted the attention of United States authorities (see section *Trade aspects*), as well as that of Indonesian environmental NGOs. The latter have recently placed observers on shrimp trawlers in the Arafura Sea (Zainudin, 2005).

Measures that have been suggested to decrease the discard rate in the Arafura Sea include: larger minimum mesh requirements; development of a more appropriate BED; stricter enforcement of bans on trawling in inshore areas; increased use of mother ships for bycatch collection at sea; and reduced fishing effort. In addition, Indonesia participates in the GEF/UNEP/FAO shrimp bycatch reduction project.

Discards in the small-scale shrimp fisheries are low or negligible (Kelleher, 2005). Much of the bycatch fisheries is considered "trash fish", which has recently been defined as:

*... fish that have a low commercial value by virtue of their low quality, small size or low consumer preference. They are either used for human consumption (often processed or preserved) or used for livestock/fish, either directly or through reduction to fishmeal/oil (Funge-Smith, Lindebo and Staples, 2005).*

Some of the issues arising from catch of trash fish by various fisheries, including shrimp fisheries, are:

- the increasing use of trash fish for aquaculture and other animal feeds;
- competition between the use of trash fish for fishmeal versus use for human food;
- sustainability of the current system;
- amount of fish that becomes trash through poor handling and post-harvest strategies;
- growth overfishing – harvesting of juveniles of commercial species.

WorldFish (2005) comments on trash fish and its associated management in Southeast Asia. The management of trash fish in capture fisheries is a significant challenge, even in comparison with that of managing other types of fisheries in the region. Trash fish generally comes from non-target fisheries using relatively unselective gear. Landings are particularly difficult to monitor since they are often far from major landing sites. There is a strong demand for trash fish that is also changing rapidly as markets evolve. These market drivers are occurring on a very local scale, making it difficult to monitor or influence them. Developing management strategies that will be effective, given the combination of these factors, should be a focus of future discussion.

Indonesia is participating in two international projects focused on reducing bycatch in shrimp fisheries.

- FAO is executing a GEF-funded project “Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management”. In Indonesia, the main emphasis is on selection and testing of suitable technologies to reduce bycatch (BRDs, mesh sizes, square meshes, towing time and towing speed) and collection, processing and marketing more of the unavoidable bycatch (FAO, 2000a).
- The Training Department of SEAFDEC is promoting the use in Indonesia and other Southeast Asian countries of devices that exclude large animals from trawls and those that exclude small fish.

### PROFITABILITY

A limited amount of information is available on the profitability of shrimp fishing in Indonesia. Where available, it is often not possible to establish the reliability of the sources, rigorousness of the methodology used to calculate profit and, consequently, the credibility of the results.

Purwanto (2005) gives summary details of the profitability of shrimp trawling in the Arafura Sea, which are presumed to be for 2004.

The Association of Indonesian Shrimp Catching Companies (Sukirdjo, personal communication, December 2005) has a model to calculate break-even costs for shrimp trawling in the Arafura Sea. At specified fuel costs – set at Rp5 480 (US\$.56) per litre in December 2005 – the model can calculate break-even points for Association shrimp trawlers, using as variables:

- catch per day (range: 270 to 390 kg/day);
- percentage of days fished (range: 75 to 85 percent); and
- revenue per kg of shrimp (range: US\$6 to US\$7).

The model indicates that, for example, at a shrimp price of US\$6.50/kg operating 80 percent of days, the average Association trawler must catch 329 kg of shrimp/day to break even. If the price of shrimp increases to US\$7, then 306 kg of shrimp must be caught.

Officials representing several companies that trawl for shrimp in the Arafura Sea have indicated that because of the fuel price increase in Indonesia (see next section), few vessels were profitable in late 2005. Similarly, an Indonesian fisheries management specialist commented:

*In short, fuel subsidy removal combined with an open access management system in the management has resulted in the collapse of some fisheries in the country. This policy*

TABLE 46  
Arafura Sea shrimp trawler profitability

	Vessel size (GT)			
	100–150	151–200	201–300	>300
Income	268 986	329 846	363 535	277 364
Expenditure	93 735	292 966	192 575	272 527
Profit before taxes	175 252	36 020	125 897	-28 414
Profits after taxes	124 633	25 748	42 629	-28 414
Price received per kg of shrimp	5.61	4.76	5.94	5.87
Cost of production per kg of shrimp	2.12	4.48	3.53	7.03
Profit per kg of shrimp	3.49	0.29	2.41	-1.15

Source: Purwanto, 2005.

Units: US\$; 2004 rupiah/dollar conversion at 8 945 (www.oanda.com).

TABLE 47  
Cost and returns of Java Sea gear that catches shrimp

	Arad seine	Small Danish seine	Large Danish seine ( <i>dogol</i> )
Tonnage of boat (GT)	23	5	23
Income (Rp million/yr)	82.62	30.21	80.43
Cost (Rp million/yr)	65.46	26.33	60.02
Margin (Rp million/yr)	17.16	3.88	20.42

Source: Purwanto, 2003; recalculated from a 1999 study.

Note: 1999 rupiah/dollar conversion used: US\$1 = Rp10 000.

has resulted in bringing many fishing companies to the brink of failure, especially those operating vessels larger than 30 GT in the Arafura Sea (P. Martosubroto, personal communication, May 2007).

With regard to small-scale shrimp fisheries, there is little information available on profitability. Bailey and Marahudin (1987) state that, despite the overwhelming importance of the small-scale fisheries sector in Indonesia, few cost and earnings studies have been attempted. The data available are either from a small number of case studies or from a series of extensive surveys conducted by the government, both of which have inherent limitations.

Cost and returns information on several types of fishing gear used in the Java Sea are given by Purwanto (2003). The results of the analysis of these gears that occasionally catch shrimp are shown in Table 47.

Purwanto concludes that the large Danish seine, a modification of traditional fishing gear called *dogol*, is the most economically viable fishing gear of those studied.

In 1999, a similar study of fisheries in central and northern Java (Priyono, 2003) concluded the following:

*... assuming that fisheries activities have a medium risk factor of 10 percent and the existing interest rate is 27 percent, then beach seine, stationary lift net, monofilament gillnet, Danish seine (dogol) and set gillnet are profitable and feasible for investment.*

A somewhat different conclusion was reached by a fisheries stock assessment meeting. In early 1995, the Indonesia/FAO/DANIDA Workshop on the Assessment of the Potential of the Marine Fishery Resources in Indonesia reviewed all available information on the shrimp fisheries and other important fisheries of the country. The report of the workshop stated:

*In the light of the overall uncertainty, no further investment or effort increase in any shrimp fishery should be considered.*

Chong *et al.* (1987) give the results of a 1984/85 study on costs and returns analysis for shrimp trammel net fishers in four central Java north coast sites. The net profits or returns for one unit of trammel net was estimated at Rp2 072 464 (US\$2 100) per year. This profit calculation was based on a nine-month operation/year, i.e. from June to November, and from January to March. Based on the prevailing share system, this

net profit was distributed according to the following breakdown: Rp563 848 (US\$575) for the owner and Rp1 508 616 (US\$1 539) for the crew of three men (excluding the captain) or Rp502 872 (US\$513) per person.

Analysis of resource rent in various fisheries is not a prominent feature of the fisheries literature of Indonesia. According to the Director of the Center for Marine and Fisheries Socio-Economic Research, there are few, if any, studies giving rent in Indonesian fisheries (A. Purnomo, personal communication, December 2005).

### ENERGY INPUT ASPECTS

The major issue in Indonesian shrimp fisheries with regard to fuel use is the cost increase that occurred in mid-2005. Although Indonesia is a major oil producer (the only member of the Organization of the Petroleum Exporting Countries [OPEC] in Southeast Asia), increased domestic fuel consumption in concert with rising international prices (about US\$65 per barrel) created a situation where the cash-strapped Government could not continue with its long-standing generous fuel subsidies.

According to a representative of the Association of Indonesian Shrimp Catching Companies (Sukirdjo, personal communication, December 2005), fuel costs for Association vessels were Rp1 800/litre in early 2005 (US\$19.6 at a rate of 9 168), but increased to Rp6 300 in August 2005 and then settled at Rp5 340 in December 2005. Because of this increase, the average annual fuel cost for an Association vessel tripled, from about US\$210 000 to US\$625 000.

A number of measures are being contemplated by operators of Indonesian industrial shrimp vessels to mitigate the effects of a fuel cost rise, including the following.

- *Basing shrimp vessels closer to the fishing grounds.* Vessels currently have to travel considerable distances from their present bases in Sorong, Ambon, Kendari and Kupang. In future, it is expected that vessels will be based much nearer to the fishing grounds in Merauke and Aru.
- *Greater use of mother ships.* By keeping the boats working on the fishing grounds, less fuel will be spent transiting and the number of fishing days will increase.
- *Fleet reduction proposal to the government.* By reducing the numbers of fishing vessels, the profitability of the remaining vessels is expected to increase.
- *Government assistance.* Although a fuel subsidy is not likely, a reduction in licence fees and taxes would help profitability.

Most, but not all, of Indonesia's small-scale shrimp fisheries are motorized and therefore also subject to the negative effects of the recent fuel cost rise.

### BIOLOGICAL ASPECTS

Many shrimp stock assessments have been carried out in Indonesia. Activities, such as the following, which bring together the results of various studies, are of particular importance.

- In 1995, the Indonesia/FAO/DANIDA Workshop on the Assessment of the Potential of the Marine Fishery Resources of Indonesia reviewed all available information on shrimp and other major marine fishery resources across the country.
- The National Commission of Marine Fish Stock Resources Assessment is comprised of members from DKP, research institutes and Bogor Agricultural University. The Commission meets periodically and reviews the status of the major marine fisheries in nine areas.
- The National Committee for Reducing the Impact of Tropical Shrimp Trawling Fisheries in the Arafura Sea met in March 2000 and was able to summarize the results of many relevant studies.

Table 48 gives the results of the shrimp assessments of the Indonesia/FAO/DANIDA Workshop. Although somewhat dated, the workshop's conclusions are still

TABLE 48  
Shrimp assessment results of the Indonesia/FAO/DANIDA Workshop, 1995

Area	Landings 1992 or 1993	Estimated production (tonnes/km coast)	Estimate of potential, 1995	Status
West of Sumatra	2 400	0.5	3 700	Overexploited
West. of Java	5 300	0.5	5 400	Fully exploited?
Bali to Timor	900	0.1	1 100	Uncertain
Malacca Strait	19 800	11.9	19 800	Over- or fully exploited
South Sumatra and Kalimantan	13 800	2.0	9 500 12 200	Fully exploited Overexploited
Java Sea and East Kalimantan	21 900	6.6	17 200 6 200	Fully exploited? Fully exploited?
Makassar Strait	6 000	0.9	6 500*	Fully exploited
Banda Sea	6 300	0.0	-	No resource
Ceram, Maluku and Tomini	100	0.0	-	No resource
Arafura Sea	6 300	2.9	14 700	Fully exploited
Sulawesi Sea	2 200	0.8	0	Unknown
Pacific Ocean	500	0.2	0	Unknown
Total, and status	85 500	1.5	96 300	No expansion, but management

\* This is probably from some other area, such as the Arafura Sea.

relevant because of the participation of a combination of Indonesian and international shrimp stock assessment specialists. The results (over a decade ago) are currently still of interest because they do not show much potential for the expansion of catches, whereas fishing effort has increased considerably over the past decade.

Two important conclusions of the workshop are given below.

- With regard to the industrial fishery in the Arafura Sea, the catch mostly consists of banana shrimp (*Penaeus merguensis*). The number of trawlers increased rapidly until 1973 when the catch was slightly higher than the MSY. The number of trawlers increased slightly thereafter until 1976 when effort started to stabilize at around 30 000 boat days; the optimum number of effort is about 23 000 boat days. This indicates that the shrimp resources in the Arafura Sea are overexploited. It is suggested that effort should be reduced to about 50 percent of that in 1993 to keep the catch around MSY.
- With regard to future shrimp stock assessments in Indonesia, these need to be redone with carefully scrutinized statistical data, starting at the *kabupaten* (regency) level. A detailed description of the shrimp fisheries is also necessary, with independent data to be collected on catch rates by different types of gear.

Since the Indonesia/FAO/DANIDA Workshop in 1995, there have been several meetings of the National Commission of Marine Fish Stock Resources Assessment. According to an Indonesian shrimp researcher (M. Badrudin, personal communication, December 2005), the Commission's 1999 assessment of shrimp resources is still being used largely unchanged.<sup>30</sup>

The Commission's assessments by management area are often transformed into estimates of present production, potential (a portion of a calculated MSY), and the ratio of the production over the potential, which is often assumed to demonstrate opportunity for expansion of catches. Table 49 gives the most recent summary of this for the penaeid shrimp resources of Indonesia.

In March 2000, the National Committee met for a workshop and sets out the results, which included a summary of Arafura Sea shrimp stock assessments (National Committee, 2001). Table 50 provides information on the standing stock of shrimp resources in the Arafura Sea.

<sup>30</sup> A meeting of the Commission was held in December 2005, but the shrimp stock assessment results, if any, are not available at the time of writing.

TABLE 49  
Exploitation level of penaeid shrimp by management area

	Fisheries management areas									Total
	1	2	3	4	5	6	7	8	9	
Potential ('000 tonnes)	11.4	10.0	11.4	4.8	0.0	0.9	2.5	43.1	10.7	94.8
Production ('000 tonnes)	49.5	70.5	52.9	36.9	-	1.1	2.2	36.7	10.2	259.9
Level of present exploitation (%)	433.9	705.1	463.7	769.0	-	123.3	87.2	85.1	95.7	274.2

Source: Research Centre for Fisheries, 2001; DKP, 2005.

Note: Fisheries management areas: 1 = Malacca Strait; 2 = South China Sea; 3 = Java Sea; 4 = Makassar Strait and Flores Sea; 5 = Banda Sea; 6 = Seram Sea and Tomini Bay; 7 = Sulawesi Sea and Pacific Ocean; 8 = Arafura Sea; 9 = Indian Ocean.

TABLE 50  
Standing stock of shrimp resources in the Arafura Sea

Fishing areas	Shrimp species				Total
	Tiger	Banana	Endeavour	Other shrimp	
Bintuni and Kaimana					
kg/haul	5	13	6	5.5	29.5
kg /km <sup>2</sup>	98	256	118	108	580
Tonnes	1 470	3 840	1 770	1 620	8 700
Dolak					
kg/haul	2	18	11	6	37
kg /km <sup>2</sup>	39	354	216	118	727
Tonnes	1 755	15 930	9 720	5 130	32 715
Aru					
kg/haul	9	1	6	10	26
kg /km <sup>2</sup>	177	20	9 118	197	511
Tonnes	2 301	260	1 534	2 561	6 643
Total Arafura Sea	5 526	20 030	13 024	9 491	48 058

Source: National Committee, 2001.

With regard to the Arafura Sea shrimp stock status, the National Committee (2001) concluded:

*Several assessments of shrimp resources in exploitation in the Arafura Sea have been carried out, based on the analysis of commercial fisheries. All results agree that the level of shrimp fishing has already reached a heavily exploited stage ... Shrimp and fish resources seem to have been under high pressure for the last 30 years. Indications of resource deterioration are perceived with the size of the fish and shrimp which are smaller and smaller and the reduction in average catching yield and catch per unit of effort, in general. Apart from this, the status of environment and ecosystems cannot be properly evaluated due to insufficient data.*

The comments on stock assessment in this section refer generally to penaeid shrimp. It is recognized, however, that non-penaeid shrimp (e.g. sergestoid shrimps of the genus *Acetes*) are important in Indonesia. Little, if any, stock assessment has been carried out on these species in the country.

In reviewing the above and other work on the biological status of penaeid shrimp resources in Indonesia, the following observations can be made.

- There does not appear to be much potential for expansion of shrimp catches in the country. In many areas, shrimp resources appear to be considerably overexploited.
- Although a substantial amount of biological assessment has been undertaken on the Arafura Sea Industrial Shrimp Fishery, much less has been done on the many small-scale fisheries across Indonesia that, as a whole, catch large quantities of shrimp. This is understandable, considering the difficulties of data collection and analysis in dealing with dozens of gear types and over a hundred thousand fishing units.

- In the Indonesian fisheries literature, there is little mention of the role of environmental factors in features such as shrimp stock size and optimum shrimp catch. In the Australian Northern Prawn Fishery (which is adjacent to the Arafura Sea), annual productivity of banana prawns (the main species of the Arafura Sea fishery) has been closely linked to rainfall levels.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

There have been few studies in Indonesia to examine the effects of shrimp fishing on the physical environment.

The National Committee commented on the status of knowledge on the effects of trawling on the seabed:

*The bottom habitats in the Arafura Sea have hardly been studied, after and before the utilization of the shrimp trawl. Research activities concerning bottom sediments, biological oceanography or coastal ecosystems such as mangrove were carried out at Banten Bay, Sele Strait and the Aru Islands. However, due to the inconsistency of time and space the information now available is very limited, making it difficult to analyse the impact of shrimp trawl on the seabed and habitat conditions* (National Committee, 2001).

The National Committee also carried out a survey to evaluate stakeholders' perceptions of shrimp exploitation and environmental protection (National Committee, 2001). The report of the survey stated that most of the respondents (83 percent) feel that trawling is very dangerous for the biodiversity of living marine resources, while the remaining respondents consider the damage to biodiversity to be acceptable.

Bogor Agricultural University recently carried out a study of the environmental effects of shrimp trawling in the Arafura Sea. Although the results of the study are not available at the time of writing, the researchers involved state that it was oriented towards examining the area from inside the 10-m isobath (where there is no legal trawling) to that outside the 10-m isobath (A. Purbayanto, personal communication, October 2005).

The general feeling among Indonesian fishery researchers is that trawling causes some damage to the seabed, but this has not been adequately studied because of other research priorities (M. Badrudin, personal communication, December 2005).

### IMPACTS ON SMALL-SCALE FISHERIES

Small-scale fisheries are extremely important in Indonesia. Some 94.6 percent of the total marine fish landings are taken by small coastal fishers using lines, traps, beach seines or lift nets, with pole and lines, trolling gear and mini-seines for tunas and small pelagics (Flewwelling and Hosch, 2004a). One major objective of the management of marine fisheries is to reduce conflict among various groups of fishers.

One of the greatest conflicts in Indonesian fisheries occurred in the late 1960s and 1970s, when the shrimp trawlers based in the Malacca Straits began to expand their area of operations. The origin and outcome of the trawl ban are described in Box 34. By banning trawling, the government in effect transferred inshore demersal resources from trawl owners to small-scale fishers (Butcher, 2004).

The trawl ban did not stop all conflict with small-scale fishers. Some of the effectiveness of the ban was undermined by weak enforcement and by renaming trawl gear. Endroyono (2000) lists 25 types of gear functioning as trawls that are used in Indonesian areas covered by the ban. Under the ban, trawling is allowed in certain parts of eastern Indonesia provided that it takes place in waters deeper than 10 m; nevertheless, trawling in shallow waters frequently occurs in eastern Indonesia, generating conflict with local communities.

The major critical areas with regard to conflict generated by shrimp fishing are West Kalimantan, North Sumatra and the Malacca Straits (M. Badrudin, personal

## BOX 34

**Origin and outcome of the Indonesian trawl ban**

Butcher (2004) states that the conflict and even violence generated by shrimp trawlers was greatest along the north coast of Java because shrimps was concentrated relatively near to shore and so many fishers depended on these waters for their livelihood. During the 1960s and 1970s, the Indonesian Government introduced a multitude of regulations to restrict the number of trawlers and to prevent them from operating within various distances from shore, but these proved ineffective for various reasons. In 1977, fishers in seven sailing boats attacked a trawler operating off the east coast of Sumatra and killed its captain; there were similar clashes on the south coast of Java.

In July 1980, following many unsuccessful attempts to restrict trawling, President Suharto issued a decree banning trawling from the waters surrounding Java and Bali as of October of that year, and from the waters surrounding Sumatra as of January 1981. As the Director General of Fisheries explained, the banning was a “political decision” taken to reach social peace and stability, by way of providing better protection to poor traditional fishers. The All-Indonesia Fishermen’s Association, a functional group within the Golkar, the Government’s main electoral vehicle, had put considerable pressure on the government to ban trawling. At the same time, many in the government believed that various programmes to help improve the welfare of fishing communities would come to nothing unless the resources on which they depended were protected from trawlers. Unlike earlier attempts to restrict trawling issued as ministerial decrees, the ban carried the full weight of the President and the military. Moreover, it was much easier to enforce a total ban on trawling than to restrict it. Anyone operating a trawl could no longer claim to have been fishing outside areas where trawling was restricted.

Chong *et al.* (1987) summarize the outcome of the trawl ban. The immediate impact was seen in the reduction of violence, loss of human lives, property destruction and tension in the coastal areas and at sea. This in itself was extremely positive for a country such as Indonesia, which places a high value on peace and coexistence. However, close to 25 000 trawl fishers (owner, captain and crew) were immediately thrown out of work because of the ban. The minimum aggregate income foregone was Rp462.5 million or US\$1.11 million per month, or US\$13.4 million per year. The Government realized the economic hardships confronting the displaced fishers and took the necessary steps of action to soften the impact of the ban in the form of a large credit programme to trawl crew to purchase new boats and nets; much was used in already overexploited inshore areas. There was also an immediate interruption in shrimp and fish landings for Indonesia: a 5 percent drop in shrimp landings and a 22 percent drop in shrimp exports.

communication, December 2005). The usual conflict is caused by gear used as a trawl that interferes with smaller-scale fishing activity. In general terms, in attempting to resolve conflict among various scales of fishing activity, the Indonesian Government often relies on the principle of keeping larger vessels further offshore.

It is probable that certain small-scale shrimp fishing gears, such as push nets, have a negative effect on other small-scale gear through catching juveniles or habitat disturbance. These effects, if any, do not appear to be well documented or studied in Indonesia.

**MANAGEMENT**

Fisheries management in Indonesia is under the joint responsibility of the Ministry of Marine Affairs and Fisheries (DKP) and the provincial and district governments. Law No. 22/1999 devolves authority for government management, including fisheries, to the



provincial (0–12 nautical miles) and district levels (0–4 nautical miles). This devolution of authority occurred fairly recently, and policies and legislation are still evolving. Law No. 31/2004 concerning fisheries has replaced Law No. 9/1985 on fisheries.

Priyono and Sumiono (1997) summarize a major fisheries management dilemma in Indonesia. Although the importance of effective fisheries resource management is clearly understood in the country, nonetheless most government efforts have been directed towards resource development through the expanded use of more productive fishing gear and boats, rather than through effort controls. The most serious management problem facing policy-makers is related to the coastal resources exploited by the vast majority of fishers. Current management regulations attempt to protect both vulnerable resources and small-scale fishers' rights of access to fishing grounds. In the long term, these objectives will turn out to be incompatible, and critical choices will have to be made.

Fisheries management plans and their specified objectives are not a general feature of fisheries management in Indonesia. Objectives often have to be inferred by fisheries legislation. The legislation given below regarding shrimp fisheries gives some idea of the de facto objectives.

The various legal instruments related to shrimp trawling are listed by Endroyono (2005).

- Presidential Decree No. 39/1980, which bans trawling in some areas of Indonesia.
- Other decrees/instructions from 1980 to 1982 that implement the ban.
- Minister of Agriculture Decree 769/1988, which concerns the use of bottom seine nets.
- Director General of Fisheries Decree 340/1990, which stipulates that the mesh size on foreign trawlers may not be less than 5 cm.
- Director General of Fisheries Decree 340/1997, which provides specifications on the permitted gear that is similar to trawling gear.
- Minister of Agriculture Decree No. 1039/1999, which requires vessels using fish trawl nets in the Indian Ocean EEZ of Indonesia to be based in specific ports.
- Director General of Fisheries Decree 868/2000, which concerns specifications for TEDs.
- Ministry of Marine Affairs and Fisheries Decree No. 10/2003 allowing foreign fishnet vessels and shrimp trawl vessels to fish in Indonesia.

Legislation related to shrimp trawl bycatch is repeated from the *Bycatch issues* section and given below.

- Presidential Decree No. 85/1982, which includes provisions that (i) BRDs are to be used on shrimp trawlers; (ii) all bycatch be handed over to the state-owned company; and (iii) in areas of Indonesia where shrimp trawling is permitted, it must be undertaken beyond the 10-m isobath.
- Decree No. 561 of the Minister of Agriculture, which stipulates that all entities fishing shrimp are required to use the fish from their fishing activities as foodstuff for the population.
- Fisheries Decree No. IK.010/S3.80.75/1982, which requires that trawlers in the Arafura area deploy TEDs.
- Fisheries Decree No. 868/Kpts/IK.340/II/2000, which requires that a BRD be installed on the body of the trawl.

Other relevant legislation is the following.

- Minister of Agriculture Decree No. 02/Kpts/Um/1/1975, which prohibits all shrimp fishing activities in Irian Jaya waters with pair trawl gear.
- Minister of Agriculture Decree No. 392/1999 on Fishing Zones, which establishes three fishing zones, with the intention of keeping larger vessels further offshore; it also establishes a minimum mesh size of 1 inch (2.54 cm) (Article 7).

It can be inferred from this legislation that prevention of negative impacts on small-scale fishers is a major objective of shrimp fishery management in Indonesia. The trawl ban to safeguard the interests of small-scale fisheries has been referred to as the boldest fisheries management intervention ever to be implemented in Southeast Asia.

Protection of shrimp fisheries from overexploitation is a less prominent objective. With regard to large-scale shrimp fishing, attempts to restrict access to the trawl fishery of the Arafura Sea by using an established total allowable catch (TAC) to determine the number of vessels to be licensed (Minister of Agriculture and Fisheries Decree No. 995/1999) have not met with much success (ICES/FAO, 2005). With regard to small-scale shrimp fishing, the open access nature of coastal fisheries in Indonesia makes it very difficult to restrict fishing effort.

Industry sources indicate that at the lower levels of government (districts have management authority in the zone from zero to four nautical miles offshore), the main management objective appears to be the generation of government revenue and, to a lesser extent, mitigation of conflict. Resource protection does not appear to be prominent.

In terms of desirable changes in the future management of shrimp fisheries in Indonesia, shrimp trawl industry representatives suggest that the Arafura shrimp trawl fleet be reduced in size to increase the profitability of each vessel. They would also like to see greater resource management measures and stronger enforcement. With regard to small-scale shrimp fisheries management, several DKP staff have expressed the view that, because the management of fisheries – including shrimp fisheries – has been devolved to lower levels of government, these levels should acquire greater skill in fisheries management. Several shrimp researchers would like to see larger minimum mesh sizes for shrimp trawls. There is some discussion about relaxing the trawl ban, or at least modifying it so that it is consistent with present shrimp fishing practices (i.e. acknowledging the use of trawl-like gear).

## ENFORCEMENT

Enforcement of fisheries legislation is characteristically weak in Indonesia, which has been noted in several reviews of the country's fisheries sector.

- Many of the problems in the management of fisheries in the country relate to enforcement difficulties. Furthermore, improvements in other aspects of fisheries management will have little positive effect unless this weak link in the system is improved (Gillett, 2001).
- Effective management of fisheries is difficult to achieve, particularly because of the lack of enforcement capabilities in Indonesia. An additional problem is that, at the provincial level, fisheries management matters tend to be dealt with by staff in production divisions as an additional rather than a prime responsibility (FAO, 2000b).
- Licensing and registration mechanisms are weak and lack enforcement. Enforcement of current laws by law enforcement agencies with appropriate penalties being handed down to violators is almost negligible for the national fleets. Lack of attention to these three key inputs to sustainable and responsible fisheries management significantly increases the challenge for DKP to meet its mandate, while reducing its probability for success (Flewwelling and Hosch, 2004a).

With regard to legislation related to shrimp fishing, enforcement is ineffective. While the major enforcement problems appear to be primarily associated with the trawl ban and the prohibition on fishing in shallow waters, these seem to be simply the areas where lack of enforcement is most noticeable. Enforcement is also a major difficulty in other areas, such as those concerned with bycatch and mesh size requirements.

As mentioned previously, Bogor Agricultural University recently carried out a study of the environmental effects of shrimp trawling in the Arafura Sea, oriented towards

examining the area from inside the 10 m-isobath (where there is no legal trawling) to that outside the 10-m isobath. A summary of the study (Monintja *et al.*, 2005) found a substantial amount of trawling in shallow waters, storage of TEDs on deck during fishing, and the use of pair trawl gear.

DKP (2005b) indicates that of the 559 fishnet and shrimp net vessels of Indonesian registry, 182 are equipped with VMS transponders. Full fleet VMS coverage was targeted for 2006.

The cost of enforcing shrimp fishing regulations is not available. Such a calculation would be complicated by the various agencies involved, and by the fact that all of the involved agencies have enforcement responsibilities outside the fisheries sector.

While identifying weaknesses of enforcement related to fisheries management in Indonesia is relatively easy, the challenge is to identify mechanisms to improve the situation. Tan *et al.* (1996) suggest that the political will to improve the dismal management/enforcement situation could be generated by demonstrating in clear terms to high-level policy-makers the financial costs of poor enforcement of legislation in the fisheries sector.

## RESEARCH

With regard to Indonesian fisheries research in general, Flewwelling and Hosch (2004b) give a summary of the institutional aspects. The Indonesian Institute of Science and Technology, the Central Fisheries Research Institute and three other research institutes (Research Institute for Marine Fisheries, Research Institute for Freshwater Fisheries and Research Institute for Coastal Aquaculture) are the official agencies that provide research assistance to the Ministry of Marine Affairs and Fisheries. Universities, such as Bogor Agricultural University, often become involved in fisheries research to assist the Ministry in the development of policies and strategies in capture fisheries management.

The National Committee (2001) reviewed the research on the Arafura Sea Shrimp Fishery.

- *Living resources.* Research activities have consisted of obtaining information on: (i) shrimp species caught; (ii) size composition of shrimp in the various fishing grounds; (iii) distribution of effort and catch per species according to water depth and seabed conditions; (iv) population parameters; (v) reproduction parameters (e.g. spawning season, recruitment pattern); and (vi) stock assessment, sustainable yield and level of exploitation. In 1982, after the introduction of regulations concerning BRDs, research related to bycatch was undertaken, which included differences in compositions of trawl catch with and without BRDs, ratio of shrimp and fish catch with BRDs, bycatch species composition with and without BRDs, and ratio of utilized and discarded bycatch.
- *Fishing gear.* Research began in 1982 with the introduction of TEDs on shrimp trawls in the Arafura Sea. In 1997, more gear research was carried out to improve the earlier TED model (i.e. the introduction of super-shooter TED).
- *Oceanographic conditions.* Research was carried out on the mangrove community in Tanimbar Island, fertility levels and the hydrology condition of mangrove waters in Bintuni Bay, and the fish community in waters surrounding mangrove in the bay. In January 1996, a preliminary study was carried out on plankton and chlorophyll distribution patterns in the waters of Kai, and sediment composition in Sorong waters, Sele Strait, Irian Jaya.
- *Socio-economics of shrimp fisheries and bycatch utilization.* Research on the socio-economic aspects of shrimp fisheries in the Arafura Sea has been limited. Some analysis of technical economic parameters regarding shrimp trawl fishing units show more profitability, with increased number of days of fishing operation. Other studies have been carried out on fish handling, marketing and bycatch

utilization, including: (i) identification of the intermediates within the marketing process from producers to consumers, and benefits from bycatch; (ii) catch handling methods according to catch composition and characteristics; and (iii) processing/technology for bycatch value adding.

- *Future research.* Several topics should be considered: improving the accuracy of fisheries data; continuous monitoring of environmental conditions; product development based on unavoidable bycatch; bycatch reduction technology; and improvements in fisheries monitoring and control.

In addition to work in the Arafura Sea, a significant amount of research has been carried out on other shrimp fisheries in Indonesia. Most has been geared to estimating MSY using surplus production models (M. Badrudin, personal communication, December 2005). In addition, specific research has been undertaken on determining the effects of the trawl ban (Chong *et al.*, 1987), monitoring biomass levels (summarized in Priyono and Sumiono, 1997), and the impacts of development projects on shrimp resources and shrimp fishing.

With the support of SEAFDEC, Indonesia is a very active participant in the GEF/UNEP/FAO shrimp bycatch reduction project. The research goals are to find appropriate BRDs for industrial vessels to reduce the bycatch of juvenile fish.

The cost of shrimp-related research in Indonesia is not readily available. Again, estimating the cost is complicated by the large number of government, academic and donor agencies involved and by the difficulties associated with dividing budgets by species groups. Nevertheless, some understanding of the magnitude of financing available can be gained from the Research Institute for Marine Fisheries. Much of the government biological research on shrimp is undertaken at the Institute, which has an annual budget of about Rp3.5 billion (US\$350 000). Approximately 20 percent of the Institute's work is focused on shrimp (M. Badrudin, personal communication, December 2005).

## DATA REPORTING

Official DKP fisheries statistics cover production, production units and socio-economic data for marine, inland open water and aquaculture operations. The statistical system in use was established by FAO in 1974/75 and has been described as one of the world's largest national fisheries statistical systems.

A major and chronic problem in the general management of fisheries in Indonesia is the quality of the official fisheries statistics. In the past decade, virtually all missions visiting Indonesia to review marine fisheries resources, stock assessment or fisheries management have concluded that there is an urgent need for better data from existing fisheries. Especially relevant comments have been made by the following.

- Project Concern International (PCI) (2001) mentions the questionable quality of the data and statistics on fisheries currently being compiled, which rely upon an obsolete data collection system based on a sampling framework and methodology developed about 30 years ago.
- Willoughby, Monintja and Badrudin (1999) suggest that the size of Indonesia's non-recorded fish deficit is more than a million tonnes per year – one-third of the total recorded catch.

Specifically with regard to shrimp fisheries, Venema (1996) records that shrimp stock assessments have been undertaken with data from various sources, including: (i) survey data from research vessels; (ii) data collected by scientists on commercial fishing boats; (iii) logbook data; (iv) data collected at landing sites; (v) data collected by interviewing captains and crews of commercial fishing vessels at fishing harbours; and (vi) government fishery statistics at the provincial and regency levels. After a thorough scrutiny of the data, it has been concluded that all assessments need to be redone with independent data, including those on catch rates by different types

TABLE 51  
Shrimp pond area and shrimp production

	1998	1999	2000	2001	2002	2003
Area (ha)	357 331	393 186	419 282	438 010	458 107	478 570
Production (tonnes)	353 750	412 035	430 017	454 710	473 128	500 000
Shrimp	121 042	148 673	152 541	154 555	169 915	179 500
Milkfish	158 666	209 758	222 228	209 525	210 000	265 781
Others	35 203	12 543	14 554	37 417	33 836	35 758
No. of households	144 411	183 173	186 485	190 872	193 877	196 500

Source: Ministry of Marine Affairs and Fisheries, unpublished data, 2003.

of gear. Even rudimentary shrimp assessments were only possible in three areas, which were based on focused research results rather than the official statistics.

### IMPACTS OF SHRIMP FARMING

Indonesia is a major shrimp farming country. Table 51 gives the shrimp pond area and production of shrimp and other species produced in association with shrimp. Indonesia's production of farmed shrimp is about 15 percent of the world total.

Shrimp farming is concentrated in certain areas of Indonesia. From Table 52 it can be deduced that 60 percent of present production is concentrated in Sumatra and Java. Kalimantan and Maluku-Papua have considerable potential for future production. DKP plans to increase the production of farmed shrimp to 300 000 tonnes per year, or an increase of almost 70 percent over the 2003 level.

The future of shrimp aquaculture in Indonesia is dependent to some extent on relative production costs, profitability and competition with Indonesia's Asian neighbours. Agbayani, Belleza and Agbayani (1997) give the results of a comparative study of these factors, which shows that China is a major competitor and that Indonesia enjoys some advantages in semi-intensive shrimp culture. Indonesia faces strong competition from other Asian countries in intensive and extensive shrimp culture.

Shrimp farming has several effects on shrimp fishing, including:

- the effects of mangrove destruction;
- the effects of shrimp fry collection;
- trash fish utilization;
- contribution to the profit squeeze of shrimp fishing.

Many of the shrimp farms in Indonesia are situated in former mangrove forests. A survey conducted in 12 Asian countries (ADB/NACA, 1997) shows that, across the region, 41.6 percent of shrimp ponds are sited in ex-mangrove areas. In Sumatra, large sections of mangrove forests have been transformed into shrimp ponds, from Aceh to Lampung, where the world's largest shrimp farm (18 000 ponds) was constructed in the 1990s (Butcher, 2004). The precise impact of mangrove clearing on shrimp fishing in Indonesia is not known, but there is likely to be some effect because of the importance of inshore areas in the life cycle of shrimp.

Although there is considerable hatchery production of fry for shrimp farming, there is still some collection of fry in the wild. DKP data indicate that 27.5 million tiger prawn fry (worth US\$275 000) were collected in 2003, mostly from Sulawesi. The effect of this collection on shrimp fishing in Sulawesi has not been studied.

TABLE 52  
Current and potential production of shrimp and associated species, by area

	Current production (2003)	Potential production
Sumatra	99 926	204 200
Java	150 874	110 100
Bali-Nusatenggara	8 128	26 300
Kalimantan	60 178	318 100
Sulawesi	129 370	44 900
Maluku and Papua	9 631	209 400
Total	458 107	913 000

Source: Research Institute for Marine Fisheries, unpublished data.

The growth in aquaculture production in Indonesia has been associated with increases in the demand for feed, much of which comes from trash fish. Trash fish is most often used for shrimp farming in the form of pellets. Of Indonesia's total aquaculture production of 900 000 tonnes (all species), it is estimated that about 20 000 tonnes are dependent on trash fish feed, requiring about 96 000 tonnes of trash fish. The demand for trash fish in Indonesia has grown about 22 times since 1993. The largest source of trash fish is from trawl bycatch. Although the large amount of bycatch from the industrial fishery in the Arafura Sea is mostly discarded, much of the bycatch from various small trawls in other areas of the country is considered trash fish and used for aquaculture, including shrimp aquaculture. Shrimp farming in Indonesia is therefore dependent to some degree on trawling and its bycatch (Funge-Smith, Lindebo and Staples, 2005; WorldFish, 2005).

The large increase in farmed shrimp production globally has led to a decline in prices for all shrimp, including captured shrimp. The shrimp price decline plus the rise in fuel prices are the main components of the price squeeze noted in the *Profitability* section. This is having a major effect on commercial shrimp fishing in Indonesia and is likely to result in fewer Indonesian shrimp fishing operations and a lower shrimp catch. Another capture/culture market interaction relates to the species being cultured. Indonesia is substantially expanding the farming of *Penaeus vannamei* and decreasing the farming of *P. monodon*. This should result in a price increase for catches of *P. monodon*, especially the larger sizes.

### MAJOR ISSUES

The major issues related to shrimp fishing in Indonesia are summarized below.

- Many of the problems in fisheries management relate to enforcement difficulties. Improvements in other aspects of fisheries management will have little positive effect unless this weak link in the system is improved. With regard to shrimp fishing, there are few regulations and poor enforcement of those that do exist.
- The trawl ban to safeguard the interests of small-scale fisheries has been referred to as the boldest fisheries management intervention ever to be implemented in Southeast Asia, but its effectiveness has been eroded by poor enforcement.
- Unlike Australia and the United States, there is little mention of the concept that changes in environmental conditions produce much of the variability in shrimp stock sizes, and that stocks can quickly recover with favourable conditions.
- The recent rise in fuel costs is having a devastating effect on the profitability of fishing operations, especially trawling.
- Although there are indications that the quality of data has improved in the last decade, there are still problems with fisheries statistics, which has major implications for understanding shrimp fishing in Indonesia.
- It can be seen from workshop results, discussions and reports that there are many local names for small-scale shrimp trawlers; however, some are not very small in scale.
- The results of socio-economic studies show that shrimp fishing is important to Indonesia but causes substantial conflict, and that bycatch issues are equally important and involve many aspects (trade, food security, aquaculture).
- There appears to be a negative feeling that BEDs reduce the shrimp catch and result in less fish for the crew. Simply demonstrating the use of BEDs without creating incentives may not result in much bycatch reduction.
- Fisheries enforcement in Indonesia is weak. A favourable environment for change could be created if the groups negatively affected by slack enforcement had a reasonable influence on government fisheries institutions.
- Despite the large importance of small-scale fisheries in Indonesia, there is relatively little biological or economic research on these fisheries.

- The lower levels of government have little capacity to take on their new management responsibilities, including those for shrimp.
- There is much wishful thinking in the literature published by DKP. Both a booklet and workshop were entitled *Discover the ecofriendly trawl in Indonesia waters* (Endroyono, 2000). In the official statistics, a gear type “BED-equipped shrimp nets” crops up.





# Shrimp fishing in Kuwait

*Based on the work of Mohsen Al-Husaini*

## AN OVERVIEW

The shrimp fleet of Kuwait has two components: 35 steel-hulled double-rigged Gulf of Mexico-type trawlers and 34 dhow trawlers. Only three species of shrimp are economically important: green tiger prawn *Penaeus semisulcatus* (60 percent of catches), jinga shrimp *Metapenaeus affinis* (30 percent of catches) and kiddi shrimp *Parapenaeopsis stylifera* (10 percent of catches). The landed value of shrimp is currently about 39 percent of that of all marine capture fisheries in the country. Total shrimp catches for the 2003/04 and 2004/05 seasons were low, at 1 577 and 1 420 tonnes, respectively. In the previous decade, 1996–2006, the average annual catch was about 1 900 tonnes. Shrimp catches fluctuated between 1 012 and 5 125 tonnes from the 1960s through the 1980s. The present low catches, high level of effort and low CPUE seem to indicate that the stock has been overexploited since 1993.



## DEVELOPMENT AND STRUCTURE

Kuwait is situated in the northwestern corner of the Persian Gulf, which separates the Islamic Republic of Iran from the Arabian Peninsula, and has a small coastline on the Gulf. The sea area and coastline of Kuwait are characterized by extreme meteorological and hydrological conditions, with water temperatures reaching over 33°C during summer months (air temperatures of over 50°C), high evaporation rates and high salinities (Morgan, 2004b).

Abdul-Ghaffar and Al-Ghunaim (1994) review the development of shrimp fisheries in Kuwait. Commercial exploitation of Kuwait's shrimp resources started in the late 1950s (Boerema, 1969). Dhow boats, wooden-hulled sailing craft employed for fishing and trading, served as the first commercial shrimp vessels using scope nets. Their efforts were soon joined by purpose-built shrimp vessels when the Gulf Fishing Company, established in August 1961, imported Gulf of Mexico-type shrimping vessels to exploit stocks off Iran. By the mid- to late 1960s, dhow boats were fitted with diesel engines to make them more competitive with the introduction of industrial vessels, whose numbers increased in the mid-1960s with the formation of additional fishing companies: the Kuwait National Fishing Company and the International Fishing Company. The increase in the number of shrimp vessels, from 36 in 1964/65 to 124 in 1968/69, suggests that shrimp fishing was extremely good in those early years.

The industrial shrimp fleet is comprised of 35 steel-hulled double-rigged Gulf of Mexico-type trawlers, from 20 to 32 m in length, a beam of 3.7–7.3 m, GT of 79–159

tonnes and a draft of 2.4–3.5 m. The industrial fleet is owned by two fishing companies: the United Fishing Company (20 boats) and the National Fishing Company (15 boats).

The artisanal fishing fleet is comprised of 34 dhows with an average length of 19 m (ranging from 14 to 23 m), a beam of 5.7 m (3.7–6.6 m), a draft of 2.4 (1.8–3 m) and a GT of 45 tonnes (13–95 tonnes).

The landing sites for the industrial fleet are Doha (Kuwait Bay) and Shuaiba (south) ports, while the landing sites for the artisanal fleet are Sharque (Kuwait Bay) and Fahaheel (south) harbours. The catches of the industrial fleet are both processed and exported, and sold on the local market. The shrimp catch by the industrial fleet has declined in recent years, from 80 percent to less than 50 percent of total shrimp landings.

The standard industrial shrimp trawl nets are a four-seam design and operated in a dual-rig configuration (one net towed from each side of the boat). The nets are constructed from polyamide (nylon) material and have a nominal stretched mesh size

of 51 mm in the main body of the net and 45 mm in the codend. Typical net specifications are: 57.4-m headrope, 30.5-m footrope, and 50 kg of 5/16 chain with five plastic oval-shaped floats of 20 x 17 cm.

The dhow standard trawl nets are similar in design to the industrial nets but with different specifications: 30.5 m headrope, 33-m footrope, 50-kg chain, 16 plastic oval-shaped floats of 15 x 11 cm, 32 x 45 mm stretched mesh size belly and 2 545 mm stretched mesh codend.

The fishing season usually starts on 1 September and ends in January or February (five to six months later), depending on the catch rates towards the end of the season. However, fishing in the 2004/2005 season started on 15 August and on 1 August in the 2005/06 season.

#### TARGET SPECIES, CATCH AND EFFORT

Nine species of penaeid shrimp are found in Kuwait's waters. At least four species are caught, of which just three are economically important. These are the green tiger prawn *Penaeus semisulcatus* (60 percent of catches), jinga shrimp *Metapenaeus affinis* (30 percent of catches) and kiddi shrimp *Parapenaeopsis stylifera* (10 percent).

Shrimp catches in Kuwait fluctuated between 1 012 and 5 125 tonnes from the 1960s through the 1980s. The highest catches occurred in the 1988/89 season, followed by the second highest of 4 057 tonnes in the 1989/90 season, through the highly favourable environmental conditions (Siddeek *et al.*, 1994) and regulated low fishing effort. The catches dropped to a level between 1 420 and 2 727 tonnes in the years after the Gulf war (after 1991) and have continued at this level. Fishing effort increased from around 3 000 boat days in the 1960s and early 1970s to more than 10 000 boat days after the war. Fishing effort for the 1993/94 season peaked at 14 600 fishing days and for the 2000/01 season, at 11 510. This high fishing effort with low catches resulted in the low CPUE (134 to 153 kg/day). Total catches for the 2003/04 and 2004/05 seasons were low, at 1 576 and 1 420 tonnes, respectively, and the fishing effort was 8 353 and 8 202 fishing days, respectively.

TABLE 53  
Catch, effort and CPUE for Kuwait's shrimp fishery, 1965–2004

Year	Catch (tonnes)	Fishing effort (fishing days)	CPUE (kg/fishing day)
1965	2 747	3 100	886.1
1966	3 158	3 300	957.0
1967	2 697	3 600	749.2
1968	2 357	3 000	785.7
1969	1 772	4 000	443.0
1970	1 104	2 800	394.3
1971	1 804	3 400	530.6
1972	1 985	4 700	422.3
1973	1 437	2 500	574.8
1974	1 595	3 700	431.1
1975	1 012	2 400	421.7
1976	1 968	3 900	504.6
1977	1 084	3 300	328.5
1978	1 402	6 600	212.4
1979	1 215	6 500	186.9
1980	1 515	3 200	473.4
1981	1 699	9 400	180.7
1982	2 156	9 300	231.8
1983	3 140	13 300	236.1
1984	1 684	10 700	157.4
1985	1 778	11 500	154.6
1986	2 065	10 400	198.6
1987	2 455	7 200	341.0
1988	5 126	5 200	985.8
1989	4 057	4 000	1 014.3
1990			
1991	582	1 500	388.0
1992	2 530	5 700	443.9
1993	2 727	14 600	186.8
1994	1 461	10 200	143.2
1995	1 657	12 400	133.6
1996	2 031	9 200	220.8
1997	2 252	5 360	420.1
1998	2 289	7 620	300.4
1999	1 575	10 236	153.9
2000	2 394	11 510	208.0
2001	2 309	9 338	247.3
2002	2 002	13 115	152.6
2003	1 576	8 353	188.7
2004	1 420	8 202	173.1

TABLE 54  
Species composition of shrimp catches of the artisanal fleet, 1995/96–2004/05

Season	<i>Penaeus semisulcatus</i> Green tiger shrimp		<i>Metapenaeus affinis</i> Jinga shrimp		<i>Parapenaeopsis stylifera</i> Kiddi shrimp	
	Catch (tonnes)	Percentage	Catch (tonnes)	Percentage	Catch (tonnes)	Percentage
1995/96	440.716	50.27	199.150	22.72	234.227	26.72
1996/97	476.019	61.83	219.005	28.45	72.981	9.48
1997/98	603.839	82.99	119.316	16.40	4.386	0.60
1998/99	534.204	73.26	154.522	21.19	40.131	5.50
1999/00	409.849	58.34	268.728	38.26	23.802	3.39
2000/01	628.796	65.69	234.937	24.55	65.319	6.82
2001/02	695.818	72.44	239.420	24.92	21.022	2.19
2002/03	797.445	77.46	221.376	21.50	10.666	1.04
2003/04	577.644	72.77	200.400	25.25	15.759	1.99
2004/05	592.215	81.14	134.251	18.39	3.308	0.45

TABLE 55  
Value of shrimp landings, 2000–04

	2000	2001	2002	2003	2004
Total (US\$)	11 709 811	8 512 979	8 657 722	6 140 551	7 192 476

Source: Central Statistical Office, Kuwait.

Kuwait's shrimp fishing grounds are small. Because the artisanal and the industrial fleets have been fishing in the same area, species composition of the shrimp catch is believed to be similar. Precise monitoring of species composition of the catches for the industrial sector has not been undertaken in the last ten years. For the artisanal sector, such monitoring was carried out until the 1997/98 season. Since then, the species composition for the artisanal fleet has been estimated from fisher interviews (Table 54).

### ECONOMIC CONTRIBUTION

Although shrimp trawling is a very important component of fishing in Kuwait, the contribution of the industry to Kuwait's economy is small in comparison with the oil industry. Morgan (2004b) states that fisheries in general are insignificant from an economic point of view in the country and therefore of a low political significance.

Kuwaiti nationals own all vessels and supporting infrastructure of the fishing industry, but almost all employees are expatriates. The main nationalities engaged in the fishing industry are Bangladeshi, Indian, Egyptian and Iranian (FAO, 2003c). With regard to shrimp fishing, there are 612 fishers employed on board the industrial fleet and 274 on board the dhow boats.

Each year the Central Statistical Office (CSO) of the Ministry of Planning publishes fisheries statistics, including the value of species groups. Table 55 shows shrimp values by year.

CSO indicates that the landed value of all marine fishery capture production in 2004 was KD5 342 864, or about US\$18 297 480; Therefore, the landed value of shrimp was about 39 percent of that of all marine capture fisheries in the country.

The contribution of shrimp fishing to GDP in 2003 was US\$4 728 224. This represents about 0.01 percent of Kuwait's total GDP of US\$47.15 billion.

Subsidies are an important economic aspect of shrimp fishing in Kuwait. The industry receives direct subsidies from the government through the Public Authority for Agriculture and Fish Resources. The present value of subsidy is KD2 000 for a steel trawler (US\$6 850.00) and KD750 (US\$2 570.00) for a dhow trawler.

### TRADE ASPECTS

Information on Kuwait's shrimp import and export is given in Table 56, which shows that Kuwait both imports and exports shrimp, with the inward trade being about

TABLE 56  
Import and export of shrimp, 1995–2004

	Export quantity (tonnes)	Export value (US\$1 000)	Import quantity (tonnes)	Import value (US\$1 000)
1995	263	3 266	193	1 384
1996	468	5 665	226	1 369
1997	839	9 802	191	1 062
1998	611	6 894	254	1 253
1999	570	4 366	169	818
2000	510	5 014	284	1 522
2001	403	3 096	282	1 305
2002	151	1 783	77	219
2003	215	1 381	100	422
2004	154	1 171	379	2 332

Source: FAO, 2006b.

twice that of outward trade. In the late 1980s, about 90 percent of the shrimp landings were exported (FAO, 2003c).

The largest market for Kuwaiti shrimp is the Middle East. The export shrimp data for 2004 showed that 186.9 tonnes were exported to Middle East countries such as Lebanon, the Syrian Arab Republic and Jordan. Shrimp exports to these countries in 2005 were 117.5 tonnes. Shrimp imports come mostly from Thailand.

The artisanal shrimp catches are landed at the main wholesale fish market and sold at local fish markets and retail shops. On some occasions, industrial catches are landed at the wholesale market on the request of PAAF in order to stabilize local prices.

The Iranian shrimp fleet often lands its shrimp catches at Kuwait's fish markets during the shrimp fishing season. The incentive for this is the difference in shrimp prices between the two countries. This offloading is believed to lower market prices in Kuwait by 20 to 30 percent during the fishing season.

### BYCATCH ISSUES

The estimated total bycatch of the shrimp fishery in Kuwait has ranged in recent years from 34 737 to 55 495 tonnes. The amount of bycatch actually landed is small, from 1.32 to 1.61 percent of the total bycatch caught; more than 98 percent of the bycatch is discarded. In a recent standardized shrimp survey in the waters of the western Arabian Gulf (Bishop *et al.*, 2001), the fish bycatch in the waters of Kuwait was found to be higher than those of neighbouring countries to the south. On average, the capture of 1 kg of shrimp in Kuwait required the capture of 56.8 kg of fish, most of which was discarded (Bishop *et al.*, 2001).

In a study by Al-Ayoub *et al.* (2005) for only three periods during 2003, the bycatch-to-shrimp ratio was 7.2:1 in October 2003, 3.8:1 in December 2003 and 50.5:1 in February 2004. (The fishing season starts in September and ends in January/February.)

The bycatch in shrimp trawling in Kuwait includes juveniles and adult finfish, sharks, rays, crustaceans, sea snakes, turtles, soft corals, molluscs and echinoderms. Three species were responsible for half of all the finfish bycatch: *Otolithes rubber* (37.11 percent), *Saurida tumbil* (13.55 percent) and *Arius bilineatus* (6.71 percent). Thirteen other species of finfish were common.

Al-Ayoub *et al.* (2005) separately tested performance in comparison with standard nets of two types of BRDs, the fisheye and the square-mesh codend, and one type of TED. The results showed that nets equipped with TEDs caught more shrimp and less bycatch than the standard nets. Nets with the square-mesh codend retained shrimp catch and primary valuable fish bycatch species, while they significantly reduced discard species. The net with the fisheye reduced both the shrimp catch and bycatch.

There is no legislation in Kuwait requiring shrimp trawls to be equipped with BRDs or TEDs. However, the Fisheries Management Department of the Public Authority for Agriculture and Fisheries Resources (PAAF) has plans for the gradual implementation of this gear on a number of trawlers and subsequently adopting regulations and enforcement measures for the whole fleet within two years. Research to implement bycatch reduction technologies including TEDs has started in Kuwait. Because TEDs are not required in Kuwait's shrimp fishery, the country is not able to export shrimp to the United States; however, as a result of the current destination of shrimp from Kuwait, this issue is at present of little relevance to the shrimp trade.

## PROFITABILITY

Few data are available on the profitability of shrimp fishing in Kuwait. However, some observations can be made.

- Despite low shrimp catch rates, the profitability of fishing units appears to be adequate, as shown by their continuing operation.
- The profitability of shrimp fishing is significantly distorted by direct (and increasing) government subsidies, which are a government response to the recent low catch rates. The annual subsidies are KD2 000 (US\$6 850.00) for a steel trawler and KD750 (US\$2 570.00) for a dhow trawler.
- Demand for shrimp is continuously increasing while production is decreasing; domestic prices of shrimp are consequently rising significantly.

Unlike other shrimp fishing countries, profitability of shrimp fishing in Kuwait is protected to some extent by marketing arrangements (most is sold on the domestic market where prices are rising) and by the fuel cost situation (stable prices for the last five years). Although catch rates have fallen over the last decades, subsidies partially compensate. However, these subsidies also contribute to overcapitalization, lower catch rates and decrease profitability without additional subsidies.

## ENERGY INPUT ASPECTS

The fuel consumption by the 15 trawlers of the National Fishing Company for the 2005/06 season was about 900 000 litres (US\$215 750). That of the 20 trawlers of the United Fishing Company for the 2005/06 season was about 2 592 000 litres (US\$517 752). The estimated fuel consumption by the artisanal shrimp fishery for the 2005/06 season was 1 468 800 litres (US\$308 448).

Since fuel prices have not changed over the last years, fuel costs have not contributed to any instability in profits. In this respect, the profitability of Kuwait's shrimp fishery is among the few fisheries in the world unaffected by recent increases in fuel costs.

## BIOLOGICAL ASPECTS

Most research on fisheries biology of shrimp has been concentrated on the major species, *Penaeus semisulcatus*. Peak spawning of *P. semisulcatus* in Kuwait waters occurs in March. A high percentage of gravid females are observed from December to May.

The distribution of *P. semisulcatus* extends from Kuwait Bay to Kubber Island and southwards towards the border with Saudi Arabia, while distribution of *Monoporeia affinis* extends from Kuwait Bay to Failakah Island and northeastwards around Bubiyan Island and the mouth of the Shatt Al-Arab. Juveniles of *P. semisulcatus* are most abundant in shallow waters in the spring on sandy or reefal bottoms with attached vegetation, whereas *M. affinis* is found on shallow muddy bottoms during summer. Biological oceanography and juvenile surveys in the early 1980s showed that Kuwait Bay and the coastal areas are important nursery areas for *P. semisulcatus*, and hence trawling was banned in these areas. Tagging studies indicated migration movement between Kuwait Bay and outside deeper waters.

Research carried out has allowed the estimation of growth and mortality for *P. semisulcatus* and *M. affinis*.

The estimated MSY for *P. semisulcatus* and optimal effort for the seasons 1969/70 and 1986/87 was from 1 794 to 1 872 tonnes at 6 061 to 7 032 boat days (Siddeek, Abdul-Ghaffar and El-Musa, 1988). Because the fishery is characterized by low catches, high fishing effort and low CPUE, it appears that the stock has been overexploited since 1993 (Al-Foudari, 2005a; 2005b).

The estimated recruitment index shows that annual recruitment is variable. By incorporating temperature and salinity parameters, a good 1988/89 season had been predicted. The yield per recruit and biomass per recruit analyses showed that a

1 September opening and an end of February closing of fishing maximizes catches (Siddeek, El-Musa and Abdul-Ghaffar, 1989).

The results of cooperative shrimp stock assessment in 1998–2001 (Bishop *et al.*, 2001) indicated that the percentage of gravid females of *P. semisulcatus* was relatively higher in Kuwait and Saudi Arabia than in the more southern countries, such as Bahrain and Qatar. A very marked north-to-south gradient was found for growth parameters of *P. semisulcatus*; this species seems to grow larger in Kuwait than in Bahrain. Yield per recruit analysis showed that maximum biomass and yield per recruit were obtained in Kuwait in August, while the maximum biomass and yield per recruit were lower in Bahrain and occurred in June. Accordingly, the opening of the fishing season in subsequent years was stipulated to be in August in Kuwait and in June in Bahrain.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

Bycatch, discarding and the impact of trawling on the seabed and on associated animals were issues considered in the environmental impact assessment of shrimp fisheries by Al-Yamani *et al.* (1999). The study showed that information on changes in benthic communities before and after trawling is lacking and therefore, precise assessment of the physical impact is difficult. The study did, however, recommend using BRDs and TEDs to reduce the impact of shrimp trawling on fish and benthic organisms. It also urged the reduction of fishing effort to decrease the amount of discards. In addition, the study found only minimum impact of waste and fuel discharging by trawlers.

### IMPACTS ON SMALL-SCALE FISHERIES

There are some conflicts between shrimp trawlers and those who fish using traps and gillnets on fishing grounds during the shrimp fishing season. This is because of Kuwait's very limited sea area. Conflict has been minimized recently by the transfer of trap fishing operation areas beyond the territorial waters and where shrimp trawling occurs.

### MANAGEMENT

Responsibility for fisheries management in Kuwait lies with PAAF, although national and regional environmental authorities have influence in the management of marine areas. Morgan (2004b) reviews the general framework for fisheries management in Kuwait. PAAF administers the national fisheries legislation, which is held in law No. 46 of 1980 on protection of fisheries resources. This is the basic fisheries law and includes regulations that address, *inter alia*: (i) the right of fishing and exploitation of marine resources that are determined by a decree; (ii) regulation of foreign vessels that can only fish with a licence issued by the competent minister; (iii) the requirement that all fishing vessels be owned by a citizen of Kuwait; (iv) the requirement that licences be issued to fishers operating licensed fishing boats; and (v) regulating gears used in fishing, in cooperation with other departments, to enforce regulations and law.

Morgan (2004b) reviews the evolution of shrimp fisheries management in Kuwait. Because of a rapidly expanding trawl fleet in the 1960s, catches in the 1970s dropped, resulting in the introduction of management measures in 1980. These included closed seasons, protected areas (Kuwait Bay and the three nautical mile coastal zone), mesh size regulations and effort limitation in order to optimize shrimp productivity. As a result of these management measures, and particularly with the reduction in the number of industrial vessels in the mid-1980s, shrimp landings rose to between 4 000 and 5 000 tonnes in 1988 and 1989. However, after the 1991 liberation of Kuwait from Iraqi occupation, industrial fishing capacity was permitted to increase to 35 vessels (with illegal fishing by dhow vessels in the nursery areas of Kuwait Bay also being common), resulting in a reduction of catches and catch rates.

The present shrimp fishery management measures consist of the following:

- *A closed season.* This usually begins in February or March, depending on the catch rates during January, and extends to September when the fishing season begins.
- *Closed areas to protect spawning as well as recruitment.* These areas are Kuwait Bay and the zone three nautical miles from the coast.
- *Effort limitation.* Entry to the fishery is limited to 35 industrial boats and 28 artisanal dhow boats; however, the number of artisanal boats has recently increased to 33.
- *A minimum mesh size* for shrimp trawl nets of 45 mm (stretched).

## ENFORCEMENT

The enforcement of fisheries regulations in Kuwait's territorial waters is the responsibility of PAAF. Twenty-six surveillance and fisheries patrol boats are owned by PAAF and 130 people are involved in the operation of these vessels.

The total annual cost in 2005 for enforcement by PAAF for Kuwait's fisheries was KD1 091 532 (US\$3 714 600). It is estimated that the shrimp fishery is responsible for about 40 percent of all enforcement costs.

## RESEARCH

Research on the assessment of shrimp resources has been conducted by the Mariculture and Fisheries Department of the Kuwait Institute for Scientific Research since 1977. Routine catch, effort and biological data collection systems were established and annual workshops held to discuss the findings and management decisions. Systematic sea surveys, shrimp tagging experiments, selectivity studies and a juvenile distribution study were also conducted. These research projects were supported by the Kuwait Institute for Scientific Research (KISR), the Kuwait Fund for the Advancement of Science, the Public Authority for Agriculture and Fisheries, and FAO (1977–79).

A cooperative project on shrimp stock assessment in the waters of Kuwait, Saudi Arabia, Bahrain and Qatar was conducted from 1998 to 2001. It was supported by the Kuwait Fund for the Advancement of Science, the Islamic Development Bank and Arab Funds for Economic and Social Development.

A research project started in 2007 to study the relationship between the shrimp stocks in Kuwait and the international waters near Kuwait in order to evaluate the fishing power of the fleets and to assess Kuwait's stock after recent changes in the environment of the northern Arabian Gulf.

In recent years it has been estimated that the annual costs of KISR research projects on the shrimp fishery average KD100 000 (US\$340 000, early 2006).

## DATA REPORTING

There are three sources of fisheries data for Kuwait.

- The Central Statistical Office of the Ministry of Planning collects fisheries data on a daily basis. It covers the wholesale volumes of fish and shrimp by species on the local market.
- A second source of fisheries data is project-oriented. It is implemented by the Kuwait Institute for Scientific Research for fish stock assessment and other biological aspects. These data include catch, effort, species composition per sector, fishing area and month.
- In recent years, PAAF has collected catch and effort data on shrimp fishing by general census at the main wholesale fish market.

The data collection of the Institute is based on six sampling days per month. Biological samples are collected from each major fishing ground for each sampling day. The computerized database was lost by the Iraqi invasion troops in the 1990/91 war, but the data files were salvaged and secured.

### IMPACTS OF SHRIMP FARMING

At present, there is no shrimp aquaculture activity in Kuwait. The only country in the Gulf region that has shrimp aquaculture is the Islamic Republic of Iran, but Kuwait does not import farmed shrimp from this country.

### MAJOR ISSUES

The major issues related to shrimp fishing in Kuwait are the following:

- although shrimp trawling is an important component of fishing in Kuwait, in comparison with the oil industry, the contribution to the economy is small;
- present low catches, high level of effort and low CPUE seem to indicate that shrimp stocks have been overexploited since 1993;
- although shrimp fishing overcapacity has been generally recognized for some time and there has been an attempt to halt its increase, the number of industrial fishing vessels was allowed to increase in the mid-1990s;
- there is a high level of bycatch in shrimp trawling, more than 98 percent of which is discarded; and
- subsidies are an important economic aspect of shrimp fishing in Kuwait but contribute to overcapacity, which lowers catch rates and (without additional subsidies) reduces profitability.



# Shrimp fishing in Madagascar

*Based on the work of Zbigniew Kasprzyk*

## AN OVERVIEW

Industrial, artisanal and traditional fishers in Madagascar have captured between 10 000 and 13 000 tonnes of shrimp in recent years. Employment related to shrimp fishing is extremely important in the country and shrimp, both captured and farmed, is the most valuable fishery export. About 5 000 tonnes of shrimp have also been produced by farming operations. Shrimp from Madagascar is particularly appreciated in Europe and commands a higher price than shrimp products from Asia or Latin America.

About two-thirds of shrimp landings come from the export-oriented industrial trawl fleet, comprised of 70 trawlers. Eight thousand to 10 000 people are involved in traditional shrimp fishing, which is instead aimed primarily at the domestic market. The relationship between these two sectors is significant for shrimp fishing management in Madagascar.

A substantial amount of biological, economic and social research on shrimp fishing is carried out in the country. The major decline in shrimp catches in 2005 is likely to be the subject of much future research.

## DEVELOPMENT AND STRUCTURE

There are two main categories of shrimp fisheries in Madagascar: the deep-water shrimp fishery and the coastal fisheries.

The deep-water shrimp fishery has been only slightly developed, and just along the coast. Annual shrimp production has fluctuated between 100 and 150 tonnes (130 tonnes in 2003). Fishing ceased in 2005 for several reasons: the seabed caused difficulties in trawling; there were limited shrimp resources; and trawlers were in a poor condition. The fishery started operations in 1992 with just one trawler. From 1998 to 2001, there were four trawlers, but in 2004 only one remained, which operated for a mere three months. The vessels were stern trawlers of 50–55 m in length, 400–600 GRT, 1 500 HP, and they were all more than 20 years



old. The fishing zone was located between the 400-m and 750-m isobaths. The major species captured were *Plesiopenaeus edwardsianus* and *Aristeomorpha foliacea*, known as scarlet shrimp and giant red shrimp, respectively.

The fisheries for coastal shrimp are much more developed. These fisheries are the most important marine fishery activity and also provide the most valuable fishery exports for the country. They are divided into three categories: industrial (68.6 percent of landings during the period 2000–04), traditional (27.3 percent) and artisanal (4.1 percent).

The industrial shrimp fishery consists of 70 freezer trawlers, of which 64 are active on the west coast and six on the east coast. They vary in length from 23 to 30 m and in HP from 250 to 500. The fleet exploits local shrimp stocks close to the coast at a depth of 7–25 m. The fishery began in 1967 with a Japanese-financed company. Currently, all industrial shrimp fishing companies in Madagascar are local companies relying on substantial foreign capital.

The artisanal shrimp fishery has 36 “mini-trawlers”, with engines of less than 50 HP and a length of 10 m. These vessels operate on the west coast, only during the day, and usually very close to the coast in estuary and mangrove areas. They characteristically trawl in waters up to a depth of 10 m. The mini-trawler design was introduced to Madagascar in the 1970s, under an FAO programme. At that time, it was thought that motorizing traditional fishing craft was a logical and necessary step towards modernizing traditional fishing. As it turned out, the most important factor driving the acceptance of this vessel design was the financial success of the industrial fishery. Although there was the idea that mini-trawlers could offer local fishers an entry into modern shrimp fishing, the reality is that all these vessels today belong to the owners of industrial shrimp vessels.

Traditional fishing is defined as fishing undertaken individually or as a group, using non-motorized vessels (powered by paddle or sail), or on foot with a very limited fishing area. Various forms of nets, weirs and traps are used. More than 600 traditional shrimp fishing sites have been identified along the Malagasy coast and, although the precise number of fishers involved in traditional shrimp fishing is not known, it is likely to range from 8 000 to 10 000 people. This fishery, which has operated for many years, is aimed primarily at the domestic market – dried shrimp (often boiled/dried) for inland markets and fresh shrimp for markets close to the coast. Over the last 25 years, the production of the traditional shrimp fishery has increased by 400 percent – from 800 tonnes in the late 1970s to about 3 500 tonnes in 2004. Significant factors in this increase were the development of a collection network, and the substantial migration of people to coastal areas, attracted by shrimp fishing opportunities. Because access to fishery resources in Madagascar is open, anyone can be a fisher. This has led to a situation in which many villages have more immigrants than locals. Since the locals often own fishing vessels and gear, they frequently rent them to immigrants.

Two additional major characteristics of shrimp fishing in Madagascar are the following.

- The number of operational industrial trawlers has begun to decrease. This process was initiated by the vessel operators themselves in order to improve profitability by increasing the productivity of each remaining vessel. On the other hand, the number of traditional shrimp fishers and fishing units has increased.
- Capital is heavily concentrated in three groups of operators. They largely dominate the industrial and artisanal fisheries, as well as the semi-industrial farming of shrimp.

## TARGET SPECIES, CATCH AND EFFORT

Table 57 gives the shrimp species in the three fishery subsectors.

The combined Madagascar shrimp catch is dominated by *Penaeus indicus* (78 percent by weight). This species, known as the Indian white prawn, accounts for almost

TABLE 57  
Shrimp species by fishery subsector

Shrimp fishing subsector	<i>Penaeus indicus</i> (%)	<i>Metapenaeus monoceros</i> (%)	<i>Penaeus monodon</i> (%)	Other (%)
Industrial	67	24	–	9
Artisanal	97	1	1.7	0.3
Traditional	99	–	1	–

Source: Dintheer, Andriambalotiana and Razafindrakoto, 1998.

TABLE 58  
Shrimp catches by fishery subsector, 1996–2004

	Industrial	Artisanal	Traditional	Total
	(tonnes)			
1996	8 136	334	2 000	10 470
1997	8 146	609	2 000	10 755
1998	8 782	446	2 242	11 470
1999	7 888	480	2 139	10 507
2000	8 303	412	3 412	12 127
2001	7 889	437	3 450	11 776
2002	9 207	467	3 450	13 124
2003	9 370	494	3 450	13 314
2004	7 155	710	3 450	11 315
Average 2000–04	8 385	504	3 342	12 231

Source: Direction de la pêche et des ressources halieutiques (DPRH).

all of the traditional and artisanal shrimp fisheries in the country, and 67 percent of the industrial fishery. The second most important shrimp species in the catch is *Metapenaeus monoceros*, or speckled shrimp, which is taken almost exclusively by the industrial fleet. Other species taken are *Penaeus monodon* (giant tiger prawn), *P. semisulcatus* (green tiger prawn) and *P. japonicus* (kuruma prawn).

The species composition of the shrimp catch depends to some extent on the fishing area, the season and the fishing strategy (day or night fishing). For example, the east coast fishery is mainly based on *M. monoceros*, with some *P. indicus* caught at night.

The Madagascar shrimp catches by fishery subsector for recent years is shown in Table 58. It can be seen that:

- industrial production of shrimp remains dominant, with a substantial contribution by the traditional subsector;
- after good catches in 2002 and 2003, they fell 15 percent in 2004 as a result of a sharp decline in industrial production.

The 2005 statistics were not available at the time of writing, but the total shrimp catch for the year can be estimated at 9 500 tonnes or under. Industrial production fell to about 5 600 tonnes. Traditional catches also declined, mainly in the northwest of the country. There are numerous reasons for the falling catches but biological factors are likely to be the most important. Over the course of the last 30 years, it has been observed that after two, three or even four years of good catches, a fall in catch occurs. However, this decrease has never been as significant as in 2005, so other factors are likely to have contributed, which could include two cyclones at the beginning of the year, a rare occurrence on the west coast of Madagascar. Another factor could be the rapid and uncontrolled expansion of traditional shrimp fishing. The traditional fishery captures small- and medium-sized shrimp close to the coast (estuaries, mangrove areas and river mouths), which prevents growth of the shrimp offshore.

With regard to the seasonality of shrimp fishing, the industrial shrimp fleet catches more than 50 percent of its shrimp during the first three months of the season. The fishing season generally begins on 1 March and ends on 30 November. For traditional shrimp fishing, the best shrimp fishing is in March, April and May (like the industrial fleet) and then in October and November.

For the industrial and artisanal subsectors, shrimp fishing effort is limited by the number of licences allocated annually. In the 1990s, the number of licences for industrial trawlers increased from 51 to 75 and from 14 to 36 for mini-trawlers. At the beginning of the 2000 fishing season, the number of licences was frozen (Decree No. 2000-415). In 2004, the number of operational trawlers decreased to 70 due to a decision by operators themselves to improve production and profitability of the remaining vessels, as mentioned previously. “Effort creep” continues to occur in the fleet, mainly through increasing experience of the captain and crew. For the traditional shrimp fishery, there is currently no legal framework for limiting fishing effort.

The annual production of a shrimp trawler in Madagascar is relatively high compared with other countries. On the west coast, catches average about 150 tonnes of shrimp for a vessel of 500 HP, and 115 tonnes for a vessel of 270 HP. The average on the east coast is about 80 tonnes for a vessel of 500 HP. In recent years, however, the average catch has fallen dramatically in certain zones to about 100 tonnes per freezer trawler.

The catch of shrimp per hour of trawling has declined from more than 40 kg in the 1960s, to 30–35 kg in the 1980s and to 20–30 kg from 2000 to 2004.

### ECONOMIC CONTRIBUTION

In 2004, the value of the shrimp catches from the industrial, artisanal and traditional fisheries was estimated at US\$70.2 million.

Shrimp fishing is Madagascar’s second most important source of foreign currency. Shrimp accounted for 11.9 percent of all exports in 2003. Shrimp fishing by the industrial and artisanal subsectors contributed about 1 percent to Madagascar’s GDP. Contributions to GDP by fishery subsector are given in Table 59.

In 2004, industrial and artisanal shrimp fishing employed 3 970 people: 3 210 in industrial fishing and 760 in artisanal fishing.

The number of traditional fishers that do at least some shrimp fishing during a year probably varies between 8 000 and 10 000 people.

All of the landed bycatch from the shrimp fisheries (about 4 000 tonnes annually), and a portion of the shrimp catch (1 500–2 000 tonnes, mainly from traditional fishing) are sold in local markets. Consumption of the bycatch of shrimp fisheries constitutes about 6 percent of the national intake of fishery products.

Licence fees paid by the industrial and artisanal shrimp fleets amounted to US\$4.6 million in 2005.

### TRADE ASPECTS

In 2004, Madagascar exported 8 220 tonnes of products originating from shrimp fishing, valued at US\$68.2 million. About 80 percent of this came from industrial shrimp fishing, with the rest from artisanal and traditional fishing. For comparison purposes, in the same year Madagascar had exports of farmed shrimp of 5 430 tonnes, worth US\$55.7 million.

Industrial shrimp exports are dominated by whole shrimp (66 percent) and, to a lesser extent, headless shrimp (29 percent). Shrimp exports by the artisanal and traditional subsectors are largely peeled and headless. Most exported shrimp is sold whole to Europe, while the headless product (12 percent) is sold to Japan. A small portion is sold in neighbouring countries (Mauritius and Réunion). Madagascar was certified for export of wild-caught shrimp to the United States market in January 2007. This certification is conditioned by the proper use and implementation of TEDs.

TABLE 59  
Contributions of shrimp fishing to GDP,  
by subsector, 2001–03

Year	Industrial fishery (%)	Artisanal fishery (%)
2001	0.84	0.09
2002	0.91	0.07
2003	0.70	0.09

Source: Observatoire économique, 2004 and 2005.

## BYCATCH ISSUES

The bycatch in Madagascar shrimp fisheries is largely made up small fish, which are mostly discarded at sea. Previously, 15–20 percent of the bycatch was retained for sale in local markets. Since 1998, the government fishery agency has required that each kg of landed shrimp be accompanied by at least 0.5 kg of fish. Over the last few years, the amount of bycatch landed annually by the industrial fleet has been about 4 000 tonnes.

At the beginning of a shrimp fishing season (February–April), when catches are good and it is difficult to handle all the shrimp, almost all of the bycatch is generally discarded. From May onwards, more of the bycatch is retained, and most is taken in September, October and November. Over the course of a fishing season, the shrimp catch decreases while that of bycatch increases.

The ratio of shrimp to bycatch on industrial trawlers varies between 1:1 and 1:5 in Madagascar. This proportion depends on the fishing area, the season and the time of day when fishing takes place. On the west coast, the ratio of shrimp to bycatch is 1:2 in the northern part and 1:4 in the south. From a study undertaken in the late 1980s, a ratio slightly greater than 1:3 was calculated for all industrial trawlers. Applying this same ratio to all trawlers (industrial and artisanal) gives a total bycatch of about 20 000 tonnes in 2004.

Using estimates of total bycatch and data on the amounts of bycatch and shrimp landed, discard rates of the industrial shrimp fleet can be calculated. These were about 65 percent in 2003 and 55 percent in 2004. Kelleher (2005), using data from a few years earlier, states that Madagascar's industrial shrimp trawl fisheries discard over 30 000 tonnes (72 percent discard rate).

The reduction of bycatch results in some economic losses for the industrial shrimp fishery. On the other hand, benefits accrue to the industry from not harvesting fish at the juvenile stage. The possibility of obtaining ecocertification also provides an incentive for reducing bycatch.

## PROFITABILITY

Analysis by the Observatoire Économique of the economic performance of the Madagascar shrimp fisheries (industrial and artisanal) between 2000 and 2004 indicates that:

- the value of the average annual production was US\$51.9 million;
- the average annual intermediate expenses of the above production were US\$31.6 million;
- value added by the industrial and artisanal shrimp fishing activities is therefore US\$20.3 million.

Despite the positive average results from 2000 to 2004, it should be noted that, compared with 2001, 2004 was a year of crisis: the value of landings fell by 23 percent, value added decreased by 29 percent and employment fell from 5 000 in 2002 to 3 970 in 2004. Projections by the Observatoire Économique indicate that value added for the industrial and artisanal shrimp fisheries for 2005 was between US\$4.5 and US\$10.5 million, compared with US\$25.1 million in 2004. This is a decline of between US\$13 and US\$19 million.

## ENERGY INPUT ASPECTS

Trawling is a fishing technique characterized by high fuel consumption. In 2001, the cost of fuel, as a proportion of all intermediate production expenses, was about 27 percent for the industrial shrimp fishery and 21 percent for the artisanal fishery. For both subsectors, fuel is the most significant intermediate expense.

Some steps have been taken to mitigate the effects of high fuel costs. Since 2001, the industrial shrimp fleet has taken advantage of offshore fuelling. In 2004 and 2005, a

project was undertaken on fuel reduction in shrimp fishing by studying various fishing gear modifications. Moreover, subsequent to changes in the management regime (increased closed season and a ban on night fishing), which started in 2004, fuel and oil consumption has been reduced by 20 percent.

### BIOLOGICAL ASPECTS

Several assessments of MSY have been undertaken in the industrial shrimp fishery of the west coast (zones A, B and C, from the north to the south), using global production models (Schaefer and Fox). These estimates are shown in Table 60. For the east coast (Zone D), the figure represents the estimation method used by the government fisheries agency, and corresponds to the level of maximum catches over the long term.

According to the yield estimates in Table 60, the potential annual yield of Madagascar's shrimp fisheries is about 8 700 tonnes of shrimp, of which the west coast contributes 8 200 tonnes. This corresponds to the past average production of just the industrial shrimp fishery. Considering that, from 2000 to 2004, the entire annual production of shrimp from all three shrimp fishery subsectors averaged 12 231 tonnes, this suggests that Madagascar's shrimp resources are overexploited. However, it should be noted that the global models, which do not consider the biological parameters of stocks, are only able to give crude estimates of exploitation levels.

Since 2004, assessment of the principal stocks exploited by Madagascar's three shrimp fisheries has been undertaken using Pope's cohort analysis, which brings together the population and age structure, using catch data. The study consisted of an analysis of the four principal stocks at the end of the 2003 season: *Penaeus indicus* in zones A, B and C, and *Metapenaeus monoceros* in zone D. This is the first shrimp stock assessment in Madagascar to use the same geographic areas as for shrimp fisheries management. The main conclusions of the study are the following.

- The four stocks studied are largely in a condition of full biological exploitation.
- On the west coast, *Penaeus indicus* is most intensely exploited in zone A (the northernmost part of the west coast). At the end of the 2003 season, the stock was slightly overexploited.
- In zone B (on the west coast, south of zone A), the female stock is almost fully exploited, but the male stock appears to be greatly underexploited, although some caution should be attached to this finding.
- In zone C (central/south west coast), male and female stocks appear to be biologically lightly underexploited.
- The *Metapenaeus monoceros* stock of the east coast (zone D) appears to be biologically slightly underexploited.

There is some disagreement between shrimp vessel operators and fishery scientists on the status of shrimp stocks. The operators claim both economic and biological overexploitation, while the scientists feel that it is a situation of full exploitation or slight biological underexploitation of the resources. A large decrease in landings in 2004 and 2005 indicates the need for a new and detailed analysis of shrimp stocks.

TABLE 60  
Estimates of shrimp yield

Zone	MSY (tonnes)	Estimation method
A	1 490	Global production models (Schaefer and Fox)
B	1 560	Global production models (Schaefer and Fox)
C	5 147	Global production models (Schaefer and Fox)
D	500	Maximum annual production
Total	8 697	

Source: Oceanic Development, 2005.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

The fishing technique of bottom trawling is characterized by a certain amount of destruction of benthic flora and limited selectivity. In the case of traditional shrimp fishing, where passive fishing gear dominates, the selectivity varies according to gear type.

Substantial efforts have been made by shrimp vessel operators to lighten fishing gear in order to reduce fuel consumption. At the same time, this gear modification is likely to have reduced the negative effect of trawling on the seabed.

Before 2003, the principal concern was to determine the closed season in order to allow for stock recovery. The official closed period became increasingly longer; it is now three months and also applies to traditional shrimp fishing. Shrimp vessel operators have themselves extended the closed season to 4.5–5 months per year.

Studies on the environmental impact of shrimp trawling have increased since the beginning of 2003, corresponding to the start of the process of ecocertification for the Madagascar shrimp fishery. The ecocertification, promoted by the Marine Stewardship Council (MSC), is a scheme to protect the environment and natural resources, which is based on consumer preference; it guarantees the buyers of fishery products that these products have been produced from well-managed fisheries.

### IMPACTS ON SMALL-SCALE FISHERIES

In the Madagascar shrimp fisheries, there is a certain amount of competition between the industrial/artisanal fisheries and the traditional fisheries. This is a result of exploiting the same resource, often in the same area. At least some of the conflict in the past has arisen from trawlers destroying the fishing gear belonging to traditional fishers, but this situation now seems to be relatively rare. Damage should generally be compensated for by the trawler operators. The industrial fishers are trying to avoid conflict at sea and are aware that in other countries there is a coastal zone reserved for traditional fishing; however, this is not the case in Madagascar.

There is no legal restriction on trawling in the zone that extends two nautical miles out from the coast. The government fisheries agency is aware that placing a ban on trawling inside the two-mile zone, an area that encompasses 85 percent of the shrimp fishing grounds, would put an end to industrial shrimp fishing in the country, and with it an important source of national income and a principal source of foreign exchange.

Action was taken in March 2005 that may resolve the issue of the two-mile trawling ban. Cooperative management zones were created with the objectives of accommodating the various conflicting claims over marine resources; establishing long-term conflict resolution mechanisms; improving the conditions of fishing and fish processing; and adopting a participatory approach towards management action.

The creation of the cooperative management zones was an initiative of the industrial vessel operators with support from the government. The two partners wished to avoid open conflict among the different shrimp fishery subsectors, using all means possible. For political and social reasons, conflict would mostly be resolved in favour of the traditional fisheries.

There is a further negative impact of the industrial shrimp fisheries on the traditional finfish fishery. Since small-scale fishers are finding less fish in the zone around the coast where the industrial vessels trawl, they have to travel further offshore in their non-motorized canoes; this reduces their fishing time and consequently their catch. It also creates sea safety problems since the sea is fairly rough along the east and southeast coast and in all areas at certain times of the year.

### MANAGEMENT

The Ministry of Agriculture and Fisheries is responsible for the management of fishing through the intermediary of the Direction of Fishing and Fish Resources. Ordinance

93022 of 4 May 1993 concerning the regulation of fishing and aquaculture establishes the basics of the fishing management process (Soumy, 2004).

Because of their socio-economic importance, Madagascar's shrimp fisheries have for some time received considerable management attention. The process of improving shrimp fishery management is carried out by the government fisheries agency in close cooperation with:

- the Groupement des aquaculteurs et pêcheurs de crevettes de Madagascar (GAPCM – the Madagascar Shrimp Fishers and Farmers Cooperative);
- the Centre national de recherches océanographiques et des pêches (CNRO –the National Oceanographic and Fisheries Research Centre) with respect to science;
- the Programme national de recherche crevette (PNRC – the National Shrimp Research Programme);
- the Observatoire Économique, which analyses the economic performance of the three shrimp subsectors.

Workshops on Madagascar's shrimp fishery management were held in 1996, 1998, 2000, 2003 and 2005. Participants included those from the government, national and international scientists and the various types of fishers, including traditional fishers. These workshops have allowed for the regular modification of management measures.

The licensing system has evolved in recent years. Since 1971, all shrimp trawlers must have a licence (Law D71.228 of 18 May 1971). In 1986, the two largest fishing companies obtained fishing rights in certain areas. In the case of the Pêcherie de Nosy-Be, exclusive fishing rights were obtained in what is now zone A; for the Société Malgache de Pêcherie, exclusive rights were obtained for what is now zone B. Zone C remained an open access area. The exclusivity arrangements were terminated in 2000.

As a result of a shrimp stock assessment undertaken in 1998, the number of licences was frozen in 1999 for a period of two years – at 75 for industrial trawlers and 36 for artisanal mini-trawlers (Decree No. 4942/99 of 14 May 1999).

In 2000, the Madagascar Government made major changes to the system of granting licences for industrial and artisanal shrimp fishing (Decree No. 000-415 of 16 June 2000). The resulting system is still in force. The main management measures are given below.

- There is a freeze on the number of licences.
- The introduction of a new scheme of fishing areas– four zones instead of 14.
- Exclusive fishing rights in zones A and B are eliminated.
- A licence is granted for a specific engine HP.
- Each licence is valid for 20 years, starting from 2000.
- All expired licences revert to the government.
- Licences are transferable between private operators, but with the provision that the new vessel has similar characteristics to the vessel originally associated with the licence.
- Fishing companies or groups of fishing companies are prohibited from having more than 40 percent of the total number of industrial fishing licences.
- Licences may be withdrawn for certain infractions such as non-payment of licence fees; failure to report data on catches; violations of fishing gear standards; fishing in unauthorized zones; underperformance as judged by the Observatoire Économique; and in the case of a need to reduce effort, as justified by scientific studies.
- At least 8 percent of the value of the catch is withheld as a licence fee.

The current management system includes technical measures regarding the power of the trawlers and specifications of the trawl net, as described below.

- The maximum authorized HP has increased from 25 to 50 HP for artisanal vessels and to 500 HP for industrial vessels (Decree of 26 August 1993).
- Trawl specifications are given in Decree No. 2003-1101 of 25 November 2003: the total length of the headrope cannot be more than 69 m; the mesh size at the codend cannot be smaller than 25 mm, and not less than 30 mm on the wings.



Furthermore, the trawl must be equipped with a TED; for vessels operating on the west coast, the trawl gear must be equipped with a BRD.

To regulate fishing effort, two measures are used: the distribution of the industrial fishing fleet and the length of the fishing season. The total fishing effort of the industrial fleet (measured by engine power) is distributed among the fishing zones, taking into consideration the potential of each vessel. Licences are distributed by zone according to the engine power of the vessels. The measure concerning the length of the fishing season was originally established to protect the species *Penaeus indicus* during the period of recruitment on the west coast. The closing day of the season was established as 1 December and, since 2004, 1 March as the opening day.

The principal management measures for the traditional shrimp fishery are described below.

- The fishery on the west coast is closed for three months (regulation of fishing effort).
- Shrimp collection is the subject of a recent regulation. Under Decree No. 060/2005 of 17 January 2005, fishers must hold a licence that authorizes shrimp fishing in a specific area, but does not allow any processing or freezing on board. This measure came into force on 1 July 2005.
- To ensure the sustainability of fishing activities and to limit conflict between the industrial/artisanal and traditional fisheries, cooperative management zones were established on 1 March 2005. These at present consist of activities in three regions (Ambaro Bay, Antongil Bay and Morondava) where the risks of conflict are greatest.
- Measures dealing with fishing are: (i) a ban on using the *pôto* trap gear which, because of its small mesh and the method in which it is used, captures mainly small shrimp, mostly juveniles; (ii) an increase in the allowable mesh size from 12 to 15 mm for the *kaokobe*, a multifilament net used from a canoe by four fishers; and (iii) a ban on the use of beach seines.

As mentioned earlier, the ecocertification promoted by the MSC is a scheme to protect the environment and natural resources, which is based on consumer preference; it guarantees the buyers of fishery products that these products have been produced from well-managed fisheries. The first steps in the process of certification (Decree No. 2003-1101) started in 2005 for the industrial shrimp fishery, with the following requirements:

- limitation of the combined length of the headropes to 69 m (10 percent shorter);
- an increase in mesh size to 25 mm in the body (belly) of the trawls and 30 mm in the wings;
- the use of BRDs; and
- the use of TEDs.

In addition to these government interventions at the request of the fishing industry (made during the workshop on shrimp fishery management in July 2003), other voluntary measures have been adopted by some shrimp vessel operators. These included: a night fishing ban during the first 45 days of the fishing seasons in 2005 and 2006; not using tickler chains in front of the body of the net (a practice that was widespread in the past); the use of a single trawl net instead of twin; and alternation between day and night fishing during the season.

## ENFORCEMENT

Most of the fisheries management measures developed by the government with the collaboration of stakeholders have been implemented. The measures not yet in force at the time of writing are the following.

- The scheme whereby licences are withdrawn because of underperformance. The conclusions of the study on how to calculate performance were not accepted by

the vessel operators, who were opposed to the scheme even before the preparation of the decree on the subject.

- The legal framework and mechanisms for transferring licences.
- The regulation on compensating vessel operators for withdrawing licences when a need to reduce fishing effort has been demonstrated.

The use of TEDs does not appear to cause problems such as those caused by BRDs, which result in a significant loss of shrimp and probably also of fish of commercial size. The desire to avoid bycatch by the installation of BRDs on the trawl is starting to conflict with the desire to increase bycatch to supply local markets.

The original attempts to introduce BRDs suffered from the initial use of a fisheye model, which resulted in a significant loss of commercial fish. Subsequently, BRDs with square mesh windows were used and appear more effective at reducing unwanted bycatch while retaining commercial species.

Fisheries surveillance is carried out by the Centre de surveillance des pêches, which was created by the Minister in charge of fisheries by Decree No. 4113/99 of 23 April 1999. The objective of the Centre is to oversee compliance with the regulations in force at sea as well as on land. Twenty provincial agents are deployed along the coast to inspect boats and to verify fishing gear, which for shrimp fishing involves the length of the backrope, the mesh size of the trawl, and the installation of TEDs and BRDs. Thirty-five observers dedicated to the shrimp fisheries enable observation of fishing operations at sea. To regulate the fishing areas of the industrial shrimp trawlers, a VMS has been used since the beginning of the 2001 fishing season. All vessels are equipped with Argos or Inmarsat transponders. The Centre de surveillance des pêches has several funding sources, both national and international. Its annual budget is about US\$1.4 million.

## RESEARCH

The National Shrimp Research Programme (PNRC) began in September 1997. Its legal basis is Decree No. 1697/97 of 13 February 1997. The programme has taken over the objectives of some previous shrimp research projects, including that of FAO, to become the focal point of Madagascar shrimp research. PNRC was initially oriented towards shrimp research in three areas.

- *Socio-economic research*: the importance of traditional shrimp fishing, the economics of the industrial/artisanal shrimp fisheries and an analysis of the types of management.
- *Biological research*: sound justification for the period of closure of shrimp fishing; considerations related to the proposed trawl ban within two nautical miles of the coast; the relationship between fishing and the environment; sites and importance of nursery grounds; determination of migration/growth/mortality from shrimp tagging; comparisons of biological cycles for the different fishing areas; stock identification; and evaluation of resource potential in the various fishing areas.
- Research encompassing both socio-economics and biology: the study of the biological and economic interactions between the three shrimp fishing subsectors – industrial, artisanal and traditional; and bioeconomic modelling to simulate the various management schemes.

In order to carry out this research, a PNRC financing plan was formulated for an initial three-year period (February 1997 to March 2000) and a second phase of two years (March 2002 to October 2004), with a transition period from April 2000 to February 2002. PNRC is a multidonor initiative with the participation of Agence française de développement, the Madagascar Government (the Fisheries and Aquaculture Development Fund and the Fisheries Agreement with the European Union), the Institut de recherche pour le développement and GAPCM. The original budget was about €2.0 million and €1.8 million for the second phase.

At the time of writing, PNRC is in a transitional phase. Following on from its workshop on the results of scientific studies in October 2004, several proposals for future shrimp research were made:

- extension of the work carried out at Ambaro Bay and other important areas on the traditional shrimp fishery;
- pursuing shrimp stock assessment in the various fishing areas using cohort analysis and yield per recruit analysis, integrating the catch data of the three shrimp fishing subsectors; and
- bioeconomic modelling of the fisheries by fishing area and undertaking simulations to determine optimal exploitation strategies.

## DATA REPORTING

The system for collecting statistical data encompasses two different areas.

- One area is the formal sector, where data are obtained after an exhaustive census based on items such as logsheets and quarantine certificates. This is applicable to industrial/artisanal fishing, exporting, product collection and the domestic distribution of fishery and aquaculture products.
- The second area is the informal sector, where statistical data are collected using sampling methods based on surveys. This is done for traditional fisheries, inland aquaculture and fishery product distribution at the local market level.

There are various sources of data on shrimp fishing in Madagascar. Reports from various decentralized government agencies give information on fishery production, exporting, domestic distribution and local consumption. PNRC carries out surveys on production from traditional fishing. A statistical project (Système statistique national standardisé informatisé) collects statistics on inland and coastal traditional fishing, and is now working in Toamasina, Toliara, Morondava, Mahajanga, Antsiranana and Maintirano. A national database project on Madagascar shrimp fishing (BANACREM) processes fish receipts and logbook information supplied by industrial and artisanal fishing vessel operators. Reports from fishery observers on board allow for the comparison and verification of data. Quarantine and sanitation certificates produced by the national competent authority give information on exports. Finally, documentation associated with the repatriation of funds from exported products is compared with export data.

As regards quality, data for the industrial/artisanal subsectors are generally good, despite some data collection problems that affect the quality of the national shrimp database. During the process of data transmission to the vessel operators by the captains of the shrimp vessels, errors can be introduced when copying information from logbooks. Some companies send handwritten logbook information directly to the fisheries agency, which means that deciphering some of the data can require interpretation. Logsheets can be scanned at the Ministry of Agriculture and Fisheries and data entered into a database for verification before being transferred into the national database.

Statistical data for traditional fisheries is collected intermittently, according to requirements. The system of data collection tested by PNRC at the time of the study of shrimp fishing in Ambaro Bay (implemented in March 2003) proved to be effective and therefore appropriate for other sites. This system also has the advantage of providing biological information and the effects of overexploitation.

## IMPACTS OF SHRIMP FARMING

In 2004, a total of 5 430 tonnes of shrimp was produced by farming operations. In the same year, shrimp fishing catches were 11 315 tonnes (63 percent by the industrial fleet).

The impact of shrimp farming on shrimp fishing in Madagascar is favourable. Madagascar shrimp farms specialize in the production of *Penaeus monodon* and are

almost all owned by the industrial and artisanal shrimp vessel owners. This situation enables resources to be pooled for effective monitoring of the international markets and associated exporting. By combining marketing for both wild and farmed shrimp, clients can be offered a wide range of shrimp: different species, different sizes and wild and/or farmed.

As mentioned at the beginning of this review, shrimp from Madagascar, both wild and farmed, is particularly appreciated in Europe, especially in France, and commands a higher price than shrimp products from Asia or Latin America. Madagascar shrimp is even sold in large supermarkets, but targets consumers who desire high-quality products. Because the shrimp competes on the international market with the large amount of inexpensive shrimp from Asia and Latin America, its marketing requires substantial publicity, stressing both the quality of the product and the positive environmental aspects of its production (ecocertification).

### MAJOR ISSUES

The major issues related to shrimp fishing in Madagascar are:

- protecting the interests of traditional shrimp fishers from the negative interaction of industrial/artisanal shrimp fishing, with appropriate consideration given to the benefits to the national economy from larger-scale operations;
- difficulties associated with controlling effort increases in the traditional shrimp fishery;
- the need for a new and detailed assessment of shrimp stocks;
- reconciling the position of vessel operators with that of fishery scientists as to the appropriate level of fishing effort;
- the major fall in shrimp catches in 2005;
- maintaining the favourable position of Madagascar shrimp in the European market; and
- reconciling the need to reduce bycatch with the economic benefits of selling it.

# Shrimp fishing in Mexico

*Based on the work of D. Aguilar and J. Grande-Vidal*



## AN OVERVIEW

Mexico has coastlines of 8 475 km along the Pacific and 3 294 km along the Atlantic Oceans. Shrimp fishing in Mexico takes place in the Pacific, Gulf of Mexico and Caribbean, both by artisanal and industrial fleets. A large number of small fishing vessels use many types of gear to catch shrimp. The larger offshore shrimp vessels, numbering about 2 212, trawl using either two nets (Pacific side) or four nets (Atlantic). In 2003, shrimp production in Mexico of 123 905 tonnes came from three sources: 21.26 percent from artisanal fisheries, 28.41 percent from industrial fisheries and 50.33 percent from aquaculture activities.

Shrimp is the most important fishery commodity produced in Mexico in terms of value, exports and employment. Catches of Mexican Pacific shrimp appear to have reached their maximum. There is general recognition that overcapacity is a problem in the various shrimp fleets.

## DEVELOPMENT AND STRUCTURE

Although trawling for shrimp started in the late 1920s, shrimp has been captured in inshore areas since pre-Columbian times. Magallón-Barajas (1987) describes the lagoon shrimp fishery, developed in the pre-Hispanic era by natives of the southeastern Gulf of California, which used barriers built with mangrove sticks across the channels and mouths of estuaries and lagoons.

The National Fisheries Institute (INP, 2000) and Magallón-Barajas (1987) reviewed the history of shrimp fishing on the Pacific coast of Mexico. It began in 1921 at Guaymas with two United States boats. During the 1930s, 17 Californian sardine boats were modified to trawl and were incorporated into the fleet. Japanese trawlers explored the Mexican Pacific coast and located the main trawling areas in the same decade. In 1941, a fleet of 21 shrimp vessels landed 1 900 tonnes of shrimp from the area around Guaymas. During the 1940s and 1950s, the fishery expanded to the entire

TABLE 61  
Major fishing areas, industrial fleet distribution and main shrimp species

Fishing areas	Number of vessels	Main shrimp target species
Pacific coast	1 674	
West coast of Baja California	71	<i>Farfantepenaeus californiensis</i> and <i>Litopenaeus stylirostris</i>
Gulf of California	1 456	<i>F. californiensis</i> , <i>L. stylirostris</i> and <i>L. vannamei</i>
Gulf of Tehuantepec	147	<i>L. vannamei</i> , <i>F. californiensis</i> and <i>L. stylirostris</i>
Gulf of Mexico	703	
Tamaulipas	293	<i>F. aztecus</i> and <i>L. setiferus</i>
Veracruz	72	<i>F. aztecus</i> and <i>L. setiferus</i>
Tabasco	20	<i>F. aztecus</i> and <i>L. setiferus</i>
Campeche	311	<i>F. aztecus</i> , <i>L. setiferus</i> and <i>F. duorarum</i>
Yucatán	7	<i>F. aztecus</i>
Caribbean Sea	35	
Quintana Roo	35	<i>F. brasiliensis</i> and <i>Sicyonia brevirostris</i>

Source: ICES/FAO, 2005.

Gulf of California and to the Gulf of Tehuantepec. During the late 1950s, double-rig trawls were introduced. By 1960, fishing operations extended to the southwest coast of Baja California. During the late 1960s and early 1970s, fishers gradually reduced mesh size.

On Mexico's east coast, the development of shrimp fishing in the southern Gulf of Mexico and western Caribbean was greatly influenced by the United States fleet (Iversen, Allen and Higman, 1993). In the 1940s, shrimp fishing in the United States grew remarkably and, by the early 1950s, most of the potential fishing grounds in waters adjacent to the southeastern states had been discovered. The United States shrimp fleet then extended operations to the east coast of Mexico and the western Caribbean Sea. From the early 1960s to the early 1970s, 632–860 United States vessels fished off Mexico. In 1976, a treaty between the United States and Mexico resulted in United States shrimping in Mexican waters being phased out by the end of 1979.

There are four main shrimp fleets in Mexico: the offshore trawl, inshore, seabob and the Magdalena fleet.

*The offshore trawl fleet.* This comprises about 1 674 vessels on the Pacific coast and 738 in the Gulf of Mexico and the Caribbean Sea. The boats are characteristically steel, 18–25 m in length and equipped with 240–624 HP engines. The fleets operate differently in the two oceans.

- On the Pacific coast, offshore shrimp trawlers operate in waters between 9 and 64 m deep, using two trawl nets. The nets have a headline of 23–36 m, 3.81–4.13 cm mesh in the codend, and are also equipped with TEDs.
- In the Gulf of Mexico and the Caribbean Sea, the fleet operates in waters between 9 and 64 m deep, using four trawl nets. The nets have a headline of 10.6–13.6 m, 3.81–4.45 cm mesh in the codend, and are also equipped with TEDs.

*The inshore fleet.* This consists of boats that catch shrimp in waters 5–15 m deep in lagoons, estuarine systems, rivers and the coastal zone. The vessels, numbering between 75 000 and 80 000 during the fishing season, are 6–9 m in length and use 55–100 HP outboard engines. About 60 percent of the fleet is based on the Pacific coast and 40 percent in the Gulf of Mexico and Caribbean Sea. The fleet uses many different types of gear, including cast nets, enmeshing nets and various forms of small trawl nets, locally called *suriperas*, *changos*, *conos* and *bolsos*.

*The seabob fleet.* In Del Carmen city, Campeche state, 200–300 small craft target Atlantic seabob (*Xiphopenaeus kroyeri*). These vessels range from 6 to 9 m in length overall, and are equipped 45–65 HP outboard engines and trawl nets with headropes of 7.6–10.6 m.

*Magdalena fleet.* This is made up of vessels similar to those of the seabob fleet, but they are all based in southern Baja California. The boats are required by law to use a trawl net that has a 13-m headline.

TABLE 62  
Sources of shrimp production in Mexico, 2003

Origin (tonnes)	Pacific coast	Atlantic Ocean and the Caribbean	Total
Artisanal landings	15 682	10 660	26 342
Industrial landings	22 165	13 036	35 201
Aquaculture	59 260	3 101	62 361
Total	97 107	26 797	123 904

Source: SAGARPA, 2004a.

Offshore shrimp vessels are characteristically owned by the private sector. The vessels of the other three fleets usually belong to unions, cooperatives or individual fishers.

On the Pacific coast, the shrimp fishing season is from September to February, with some variations for lagoons and estuaries. In these areas, the season usually opens 15 days earlier for artisanal fishers. In the Gulf of Mexico, there is a temporary closed season from May to August for Tamaulipas and Veracruz, and from mid-May to October for the region from Tabasco to Campeche. On both coasts, the fishing season can be modified according to the results of biological research.

### TARGET SPECIES, CATCH AND EFFORT

The main commercial shrimp species on the Pacific coast are the blue shrimp (*Litopenaeus stylirostris*),<sup>31</sup> whiteleg shrimp (*L. vannamei*), yellowleg shrimp (*Farfantepenaeus californiensis*) and crystal shrimp (*F. brevirostris*).

In the Gulf of Mexico and Caribbean Sea, the main species are the northern brown shrimp (*Farfantepenaeus aztecus*), northern pink shrimp (*F. duorarum*), northern white shrimp (*Litopenaeus setiferus*), redspotted shrimp (*F. brasiliensis*), Atlantic seabob (*Xiphopenaeus kroyeri*) and the crystal shrimp (*Sicyonia brevirostris*).

Table 61 shows Mexico's major fishing areas, the industrial fleet distribution and the main target species in the various areas.

Commercial shrimp fishing in Mexico began in the 1930s. Industrial catches increased from 630 tonnes in 1930 to 5 102 in 1940, 20 373 in 1950 and 39 776 in 1960. In 1970 and 1980, total catches were 42 872 and 51 726 tonnes, respectively. A maximum industrial shrimp catch of 59 602 tonnes was attained in 1987 and, subsequently, there were considerable annual variations. The average industrial catch of 1994 to 2003 was 47 168 tonnes.

In addition to industrial shrimp catches, shrimp production in Mexico also comes from artisanal fishing and aquaculture. Table 62 gives the various sources of shrimp production in 2003, while Table 63 gives the Mexican industrial and artisanal shrimp catches from 1990 to 2004.

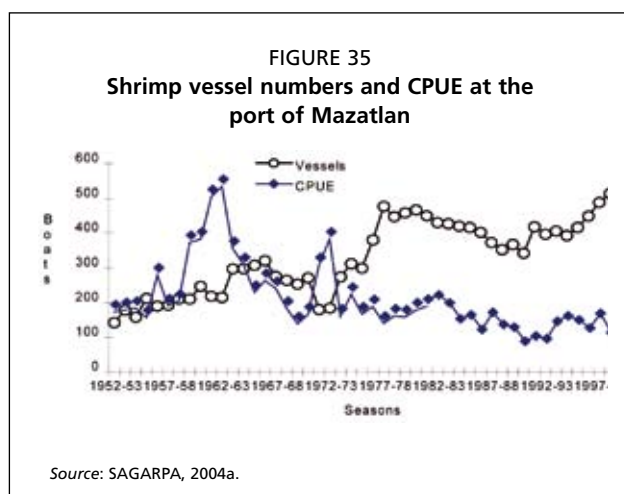
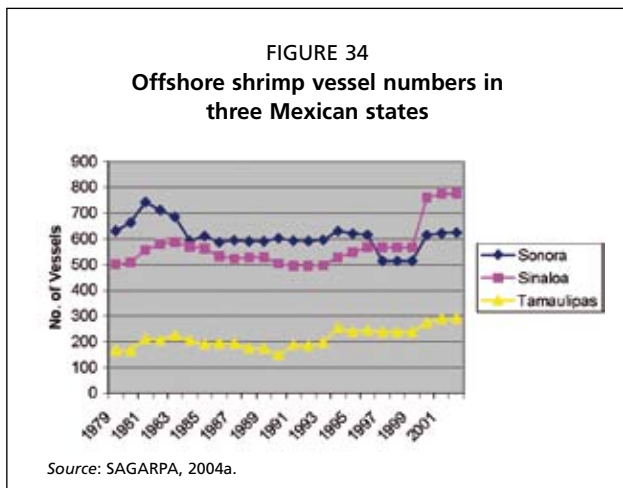
Shrimp fishing effort in Mexico is measured in a variety of ways, including the number of boats, fishing trips, days at sea or fishing days, depending on the available fleet information. For the

TABLE 63  
Shrimp catches in Mexico, 1990–2004

Year	The Gulf and Caribbean	Pacific Ocean	Total
1990	23 847	34 081	57 928
1991	29 284	36 185	65 469
1992	22 715	35 174	57 889
1993	28 058	40 280	68 338
1994	22 709	41 134	63 843
1995	23 435	46 599	70 034
1996	21 450	44 114	65 564
1997	21 984	49 083	71 067
1998	23 170	43 416	66 586
1999	20 155	46 336	66 491
2000	21 288	40 309	61 597
2001	21 847	35 662	57 509
2002	18 533	36 100	54 633
2003	23 697	37 848	61 545
2004	22 320	35 744	58 064

Source: FAO, 2006a.

<sup>31</sup> For shrimp in the Americas, many taxonomic authorities (including in Mexico) divide the genus *Penaesus* into two genera: *Litopenaeus* and *Farfantepenaeus* and the nomenclature convention is followed in this report. The English names are those used by FAO.



inshore fleet in general, the only measure of effort collected is the number of boats.

There were 104 vessels in the offshore fleet in 1930 but the fleet grew to a maximum size of 2 880 vessels in 1983. Since then, the national fleet has oscillated in size and, in 2006, the number on both coasts was 2 412. Figure 34 gives the changes from 1979 to 2002 of the number of vessels based in the states of Sonora, Sinaloa and Tamaulipas, where the major shrimp ports of Guaymas, Mazatlan and Tampico are located, respectively.

Following several years without much change in vessel numbers, fleet growth occurred in all three states in 2000. Shrimp vessel numbers and CPUE (tonnes per season) for the main shrimp port in Sinaloa, Mazatlan, are given in Figure 35. It can be seen that in the 1960s and early 1970s there was a large oscillation in CPUE, followed by a gradual decline to the present.

From 1929 to 1969, for both coasts, the CPUE for the offshore fleet increased to 60.86 kg of shrimp/hr in 1961 with some annual variation. After 1961, there was a constant decline to 16.96 kg/hr in 1981. The catch rate appears to have stabilized in recent years.

There is general recognition that overcapacity is a problem in the various shrimp fleets of Mexico. This has been noted in the shrimp fishery literature of the country since the 1970s. A recent example of government intervention to mitigate this problem occurred in mid-2005. The National Aquaculture and Fisheries Commission (CONAPESCA) allocated 27 million pesos (US\$2.54 million) to producers from Sinaloa, Tabasco and Tamaulipas as part of the framework for voluntary decommissioning of the Mexican fleet to reduce the fishing effort on shrimp.

### ECONOMIC CONTRIBUTION

Between 1995 and 2000, the total fishing activity in Mexico was responsible for 0.8 percent of the country's GDP. Fisheries have considerably greater local importance in some parts of Mexico; in Sinaloa and Sonora, they comprise nearly 4 percent and 2.3 percent of GDP, respectively (FAO, 2003d). The specific contribution of shrimp fishing to GDP is not readily available.

Fishing in general accounts for 0.31 percent of all employment in the country (Gomez, 2001). In 2002, according to official statistics, there were 246 551 people involved in fishing in inland, inshore and offshore waters. It is estimated that the shrimp fishery provides employment for 190 884 fishers and indirect employment for 573 000 others.

In 2002, according to SAGARPA, the Mexican Agriculture, Livestock, Rural Development, Fisheries and Food Secretariat (2004a), the direct consumption of all fish (including shellfish) in the country was 874 549 tonnes, equivalent to 8.3 kg per capita. The consumption of shrimp was 69 078 kg, or 0.66 kg per capita.



TABLE 64  
Mexico's shrimp trade, 1990–2004

	Export quantity (tonnes)	Export value (US\$ '000)	Import quantity (mt)	Import value (US\$ '000)
1990	17 682	202 396	35	274
1991	17 365	221 613	6	35
1992	16 968	170 872	359	1 378
1993	23 436	291 319	4 011	26 670
1994	24 434	312 753	4 240	18 083
1995	35 885	455 675	2 639	6 969
1996	35 763	368 407	2 783	7 141
1997	35 712	478 516	2 633	7 259
1998	46 584	491 364	12 175	7 998
1999	47 049	425 314	3 139	8 156
2000	37 359	455 495	5 357	10 625
2001	39 280	436 643	7 267	20 796
2002	25 335	285 228	6 218	25 586
2003	26 212	300 988	6 289	28 083
2004	30 640	346 322	4 837	24 234

Source: FAO, 2006b.

SAGARPA (2004b) comments on the importance of shrimp and shrimp fishing in Mexico.

- In terms of volume, shrimp is the most important fishery commodity.
- In terms of value, shrimp is the most important commodity after sardines and tuna.
- Shrimp is the most important fishery commodity export.
- In terms of numbers of fishing vessels, more are involved in shrimp fishing (both offshore and artisanal) than in any other type of fishing.
- Shrimp fishing is responsible for more employment than any other fishery.

At the micro level, shrimp fishing can be extremely important for coastal communities in particular areas. Ocean Garden (2005) reports that about 4 500 jobs are dependent on the shrimp business in the small towns of San Felipe, Puerto Peñasco and the Gulf of Santa Clara.

### TRADE ASPECTS

Table 64 shows Mexico's shrimp trade from 1990 to 2004. During this period, the volume of shrimp exports<sup>32</sup> almost doubled.

In 1990, shrimp exports constituted 61.8 percent of the total export of fishery products from Mexico. However, their relative importance has decreased and, in 2003, the contribution was 45.5 percent.

Some issues that are especially important for the Mexican shrimp trade are the following.

- Mexico is among the 13 countries that currently meet the standard set by the United States National Marine Fisheries Service (NMFS) regarding the use of TEDs; Mexican shrimp exports are therefore not subject to the United States embargo.
- Some Mexican fishery products have obtained greater access to the Japanese market after the signing of a Japan/Mexico economic partnership agreement in 2004. This agreement has provisions for tax exemption for yellowfin tuna, oysters, lobsters, octopus and shrimp (INFOFISH, 2004).
- Mexico's shrimp industry and Ocean Garden Products of San Diego, the largest Mexican shrimp importer in the United States, launched a marketing campaign

<sup>32</sup> Shrimp exports also include farmed shrimp.

in March 2004 to promote the flavour and texture of shrimp from Mexico. The campaign, touted as “The naked truth about shrimp,” is designed to give farmed and wild Mexican shrimp the brand recognition that products such as Colombian coffee and Mexican tequila already enjoy (Seafood Business, 2004).

- In July 2004, the United States Department of Commerce imposed duties varying up to 113 percent on shrimp from six countries. Some concern was expressed during the process of formulating this trade sanction that Mexican shrimp would be included, but fortunately this did not occur.

### BYCATCH ISSUES

The National Fisheries Institute carried out studies on bycatch from 1956 to 1996. Results were reported by Chapa (1976), Rosales (1967), Chávez and Arvizu (1972), Corripio (1979), Grande-Vidal and Díaz (1981), Grande-Vidal (1987), Aguilar and Grande-Vidal (1996) and Grande-Vidal (1996). Some of the more important findings are given below.

- The results obtained by Grande-Vidal and Díaz (1981) showed that 60–63 percent of the bycatch from the shrimp fishing fleets on both coasts was composed of various species of fish, with the remainder being crustaceans, molluscs and echinoderms. The authors found that the proportion of bycatch to shrimp was 9:1 on the Pacific coast and 3:1 in the Gulf of Mexico. Between ten to 18 of the bycatch species were abundant enough to be commercialized.
- From 1992 to 1994, experiments were carried out in the Pacific Ocean using trawl nets with five types of TEDs. The results showed that bycatch was reduced from 35.3 to 30.0 kg/hr depending on the type of TED. The loss of shrimp was from 0 to 2.14 kg/hr (Aguilar and Grande-Vidal, 1996).
- The same set of experiments showed that the average ratio of bycatch to shrimp was maintained at 9:1 in the Pacific, but there were major differences by zone: Sonora 3.9:1, Sinaloa 3.76:1 and the Gulf of Tehuantepec 24:1 (Grande-Vidal, 1996).

Bojórquez (1998) states that, without BRDs, the average ratio of shrimp to bycatch is 1:10 in the Pacific and 1:3 in the Gulf of Mexico and the Caribbean. In the Pacific, the bycatch consists of 70 percent by weight of fish, made up of 105 species. In the Gulf and Caribbean, the bycatch consists of 65 percent by weight of fish, made up of 91 species. The report claims that the use of TEDs reduced the fish bycatch by 45 percent.

Kelleher (2005), citing Bojórquez (1998), indicates that Mexico’s Gulf of Mexico shrimp fisheries generate 19 000 tonnes of discards (a discard rate of 46.2 percent) and the Pacific shrimp fisheries approximately 114 000 tonnes (a discard rate of 76.7 percent).

INP (2000) states that activities to protect sea turtles started over 30 years ago in Mexico. Since December 1993, shrimp trawlers in the Gulf of Mexico have been required to use TEDs. This has been a requirement on the Pacific coast since April 1996.

Seefoó Ramos, Sarmiento Náfate and Balmori Ramírez (2004) summarize recent developments in the use of TEDs in Mexico. The use of hard TEDs is mandatory for all vessels in the industrial shrimp trawl fleet. In 2004, a new regulation came into force, requiring a larger TED escape opening and allowing the possibility of using a single or a double cover for the opening. An assessment of this new regulation by paired fishing trials was conducted in the Gulf of Tehuantepec. Results showed that the new TED design with a single cover has similar shrimp catch efficiency to the former design, but decreases the bycatch by 3.3 percent. Double-cover TED trials showed increases of 2 percent in shrimp catch efficiency and an 11 percent decrease in bycatch.

As reported in the section above, Mexico is among the 13 countries that currently meet the standard set by the United States NMFS regarding the use of TEDs.

Mexico has actively participated in the FAO/GEF/UNDP project “Reduction of the Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Technologies and Change of Management”. This participation has included gear technology work, training of observers and transfer of technology to other Latin American countries.

### PROFITABILITY

There are few data in the public domain on the profitability of shrimp fishing in Mexico. Nevertheless, some observations can be made.

If the change in number of vessels in each shrimp fleet is a rough indicator of profitability, then Figure 34 would suggest that, in the 1990s, there has been no great change in profitability of the industrial shrimp fleets based in the states of Sonora, Sinaloa and Tampico.

INP (2000) considered all the commercial shrimp species on the Pacific coast and their main landing points. One finding was that some of the stocks are at biomass levels below that of maximum productivity, for which it is necessary to consider measures for reducing fishing effort in order to increase fishery profitability.

### ENERGY INPUT ASPECTS

Fuel consumption is an important aspect of shrimp fishing in Mexico. The average offshore vessel consumes between 20 000 and 25 000 litres of diesel per fishing trip (average trip 22–26 days), and a small craft consumes 80–150 litres of petrol per day. The April 2006 price of diesel fuel was US\$0.45/litre and regular petrol was US\$0.63.

Some issues regarding fuel use in shrimp fishing in Mexico are the following.

- There is a fuel subsidy for shrimp fishing vessels. The subsidy in 2006 was equivalent to US\$0.09/litre of the normal value for diesel and petrol for authorized fishing vessels registered with CONAPESCA.
- The price of fuel has increased steadily in recent years.
- The use of outboard engines for various forms of small-scale trawling is widespread in Mexico, but this activity is relatively fuel-intensive compared with diesel inboard engines.

### BIOLOGICAL ASPECTS

There have been many assessments of the condition of Mexico’s shrimp resources, including studies on both coasts. The main results are summarized by SAGARPA/INP (2001).

- The Pacific Ocean studies indicate that the commercial species of shrimp have a short life cycle (a maximum of two years). Juveniles are caught in estuaries and lagoons, and adults are caught offshore. In general, the shrimp populations have rapid growth and a high resilience to fishing pressure. An analysis was carried out using the dynamic pool Schaeffer model and the age-structured Deriso model. Results show that the stock of *Farfantepenaeus californiensis* is in good shape, but that stocks of *Litopenaeus stylirostris* and *L. vannamei* are depleted.
- The Gulf of Mexico and Caribbean Sea studies indicate sequential exploitation – capture as juveniles in lagoons by artisanal fisheries and then offshore by the industrial fishery. Recruitment is characterized by considerable interannual variation and is concentrated in particular times of the year, which are different for the various species. An analysis was carried out using age-structured models and yield per recruit models. Results show that the stock of *Farfantepenaeus aztecus* is good, but that stocks of *F. duorarum* and *Litopenaeus setiferus* are depleted.

As regards Mexico’s Pacific coast shrimp resource, the National Fisheries Institute (INP, 2000) considered all the commercial species and main landing points, and concluded that catches of Mexican Pacific shrimp have reached their maximum and

that fishing effort should not be increased in any region or on any species. Some of the stocks are at a biomass level below that of maximum productivity, for which it is necessary to consider measures for reducing fishing effort in order to increase fishery profitability.

Grande-Vidal (2006) examined Mexican shrimp fishing from 1929 to 2003. The study estimated MSY for all commercial species of shrimp in both oceans at 48 769 tonnes.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

There have been few, if any, studies in Mexico on the impact of shrimp fishing on the sea bottom.

A management plan for Mexico's Pacific shrimp resources (SAGRAPA, 2004c) cites several problems associated with shrimp fisheries, including their impact on the sea bottom. It also states that one of the management objectives for shrimp fisheries is to minimize the environmental impact, particularly in areas that are ecologically significant.

### IMPACTS ON SMALL-SCALE FISHERIES

INP (2000) indicates that the activity known as "shrimp fishing" is actually made up of various components of a sequential nature; shrimp are targeted at various stages in their life cycle in different environments by different fishing gear and scales of fishing. As a result, there is a strong interaction between the three different types of shrimp fisheries in Mexico – the high seas, the bays and the estuaries. There is also significant interaction between illegal fishing and these three fisheries. In addition, shrimp fisheries take considerable bycatch of high-value commercial fish, which negatively impacts fishers targeting these species.

A management plan for Mexico's Pacific shrimp resources (SAGRAPA, 2004c) states that one of the management objectives for shrimp fisheries is to mitigate the effects of the negative interactions that occur because of competition among the shrimp fishing subsectors.

### MANAGEMENT

Díaz de León (2004) reviews the institutional arrangements and legal basis for general fisheries management in Mexico. From the end of 2000, at the beginning of a new federal administration, fisheries institutions were transferred to what is now the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA). The agency responsible for fisheries management, monitoring and enforcement is CONAPESCA.

Marine fisheries are under federal jurisdiction. The Mexican Constitution establishes that the central federal government is empowered to manage all marine and inland fisheries resources found within federal national waters. Fisheries legislation and management are the responsibility of the federal government, leaving little room for local governments to manage fisheries resources.

The highest-ranking instrument of Mexican fisheries legislation is the Federal Fisheries Law (*Ley de Pesca*). It gives general guidelines to regulate fisheries and can be modified through the intervention of the Chamber of Deputies and the Senate. The Union Congress of Mexico has issued eight laws on fisheries: in 1925, 1932, 1938, 1948, 1950, 1972 and 1986, and the amended law of 1992. The Fisheries Regulations were drawn up by the Executive on the basis of the general guidelines given in the Federal Fisheries Law. They deal with particular aspects and can be modified directly by the Executive without the intervention of legislature, which results in some degree of flexibility. Particular instruments of legislation are the *Normas Oficiales Mexicanas* (NOMs, the Mexican Official Standards), which deal with specific aspects such as regulating mesh sizes, gear types used and spatial restrictions, *inter alia*, which need

to be changed from time to time and which, if included in a more general instrument, would make the regulating process cumbersome. The process that shapes or modifies NOMs involves the participation of stakeholders, NGOs and other interest groups in committees. These committees also consult on issues such as setting dates for closed seasons for selected fisheries (including shrimp). INP presents relevant research and monitoring results at these meetings to assist in the decision-making process. Decisions from the meeting are made official by being published in the Federation's Official Registry. Passing of NOMs and related decisions requires an assessment of the regulatory impacts expected from the implementation of NOMs.

INP (2000) gives some historical perspective on shrimp fishery management on the Pacific coast. From 1939, the shrimp fisheries were reserved for cooperative societies. In 1992, with the new fisheries law, the private sector was allowed to participate in the fishery. The use of a closed season for the management of shrimp resources began in 1938 in the Gulf of California. In 1960, closed seasons were established in the Gulf as a shrimp conservation measure to protect shrimp spawning. Seasonal closures were extended the following year to the west coast of Baja California and the Gulf of Tehuantepec. In 1977, regulation of mesh sizes began. After 1980, closed seasons were used to protect not only shrimp spawning, but also shrimp growth, taking into consideration economic factors.

The main regulatory measures are covered in a Mexican Official Standard (NOM-002-PESC-1993). This legal instrument has provisions for:

- control and reduction of fishing effort (number of boats);
- closed seasons;
- closed area;
- reduction of turtles and other bycatch through the use of TEDs; and
- regulation of the mesh size in the codend of the trawl nets to prevent the catch of juveniles of shrimp.

Another important aspect of fisheries management in Mexico is the National Fisheries Chart (CNP). Although the Fisheries Law initially referred to the CNP as a mere inventory, a modification made to the Fisheries Regulations (amended in September 1999) endowed it with the function of defining levels of fishing effort applicable to species and groups of species in specific areas, and providing guidelines, strategies and provisions for the conservation, protection, restoration and management of aquatic resources (Díaz de León, 2004).

The March 2004 CNP lays down strategies for the management of shrimp fisheries in four regions of the Pacific coast and four regions of the Atlantic coast. For example, in the upper Gulf of California area, the following strategies are proposed.

- With regard to the species *Litopenaeus stylirostris*, measures should be continued to maintain the reproductive biomass remaining at the end of each season and protect spawning.
- Regarding the species *Farfantepenaeus californiensis*, measures should be applied to halt the decrease in biomass and avoid lengthening the fishing season under the pretext of taking greater advantage of this species, since this will affect other species.
- The fisheries potential of new species, underexploited offshore or deep-water species should be evaluated and a scheme for their management eventually implemented.
- Alternative fishing gear should be evaluated for the shrimp fishery in the upper Gulf of California.

Díaz de León (2004) notes some major difficulties in fisheries management in Mexico that seem especially relevant to the shrimp fisheries.

- It appears that effort restrictions face the strongest resistance from fishers, who see them as “a lack of flexibility in management” and name them, together with “a

lack of investment” as one of the biggest problems in Mexican fisheries (Comisión de Pesca de la Cámara de Diputados, 2001).

- The introduction of new regulations has contributed to improving some fisheries performance in the short term, but social constraints have tended to erode their effectiveness with time. For example, in 1993, the implementation of a closed season in the Tamaulipas Shrimp Fishery doubled catches in offshore fisheries, but rigidity in its implementation (given that it restricted only the lagoon fishery, minimally affecting the industrial offshore fishery) resulted in the closed season involuntarily becoming an instrument of allocation, greatly diminishing its effectiveness (Fernández *et al.*, 2000).

Information on the costs of management of the shrimp fisheries in Mexico is not readily available.

### ENFORCEMENT

The enforcement of fishing laws is the responsibility of the federal government through CONAPESCA. The latter undertakes surveillance and enforcement with respect to such topics as closed seasons and compliance with technical measures, such as mesh size, TED usage and fishing areas by species.

Many years of work have resulted in several other government agencies cooperating with CONAPESCA in fisheries law enforcement, including the following.

- Secretaría de Comunicaciones y Transportes controls the licensing of vessel navigation at sea and carries out at-sea safety checks.
- Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT, the Environment and Natural Resources and Fisheries Secretariat) is involved with the conservation and protection of natural resources in the country. Within this agency is a further institution, Procuraduría Federal de Protección Ambiental (Federal Environmental Protection Agency), which is of relevance to shrimp fishing and is responsible for supervising the economic activities of hunting, fishing and of all natural resources.
- Secretaría de Marina is involved with surveillance of the EEZ and coasts. This agency usually works with CONAPESCA through official agreements to supervise fishing activities.

It should be noted that surveillance activities are often carried out by members of cooperatives and unions, especially on the activities of non-members.

### RESEARCH

INP bears responsibility for, *inter alia*, research on and assessment of the status of national fisheries as well as the evaluation of fishing gear. Regulations usually arise from the detection of an actual or potential problem. For example, INP research resulted in the implementation of closed seasons for the shrimp fishery in the Gulf and Pacific regions. INP carries out periodic monitoring and systematic assessments of most of the important fisheries, but it lacks the personnel and means to cover many artisanal fisheries. Although the Institute still includes 13 regional centres and some of the most experienced researchers in the country in its ranks, it has been severely downsized by at least 100 of its former 400 researchers and technicians (FAO, 2003d; Díaz de León, 2004).

Because shrimp is the basis of some of the most important fisheries in Mexico, it is the most studied fishery resource in the country and receives the largest proportion of INP human and financial resources (INP, 2000). Studies are carried out on shrimp growth, fecundity, reproduction and recruitment. Research cruises focused on shrimp are undertaken in both oceanic and lagoon areas. During the fishing seasons, landings are sampled at the principal ports for species composition, length and sex, and information is obtained on indices of abundance. Despite this large research

effort, there are still gaps in the knowledge of fishing activity, especially artisanal shrimp fishing.

INP has 100 to 125 scientists and technicians working on different aspects of the shrimp fisheries: biology, stock assessment, technology and shrimp culture. Shrimp-related activities account for 40–50 percent of the total INP budget.

### DATA REPORTING

When applying for a fishing licence, the owner of each fishing vessel must provide specifications for the vessel. This information is subsequently included in a national fishing register. The fishing vessel owners are required to report the results of each fishing trip to the fishing authorities, with specific data on catch, effort, species and fishing conditions. This information is collected on the form known as *aviso de arribo*, and is then entered into a database on the fishery.

Although the quality of information on fishing activity is generally good, mistakes do happen. For this reason, the current thinking is that data could be improved by cross-checking by port/factory inspections and by research programmes.

### IMPACTS OF SHRIMP FARMING

Shrimp farming in Mexico began in the 1980s. Official statistics on this activity show that production was 35 tonnes in 1985, 15 867 tonnes in 1995 and 33 480 tonnes in 2000. The production of farmed shrimp in 2002 of 61 283 tonnes was close to the fishing production of 61 024 tonnes.

The main farmed shrimp species in Mexico is *Litopenaeus vannamei*, but there is also production of *L. stylirostris* and *Farfantepenaeus californiensis*. *L. vannamei* is native to the Pacific coast of Central and South America, but is now being farmed in other regions and is the major farmed species in the world.

International shrimp prices have been stagnant or declining in recent years. At least some of the downward pressure on prices on many types of shrimp (farmed as well as captured) comes from the increasing amount of farmed shrimp on the world market, especially *L. vannamei* from China.

### MAJOR ISSUES

The major issues related to shrimp fishing in Mexico are:

- declining CPUE and overcapacity in many of the shrimp fleets;
- the improvement of profitability of shrimp fishing; this may require effort reduction, but effort restrictions face strong resistance from fishers;
- shrimp exports are extremely important to the country; however, since the major market is the United States, the various forms of sanctions that could conceivably be applied to the shrimp trade could have extreme negative consequences;
- incomplete knowledge of the large amount of artisanal shrimp fishing activities; and
- management of the interactions between the three different types of shrimp fisheries in Mexico: those of the high seas, the bays and the estuaries.





# Shrimp fishing in Nigeria

*Based on the work of B.B. Solarin*

## AN OVERVIEW

Shrimp fishing in Nigeria is undertaken by about 225 industrial shrimp trawlers and a large number of fishers inshore, using small trawls, beach seines and stow nets. Shrimp, the most important agricultural export of the country, is responsible for a substantial amount of employment and is a significant source of food in coastal areas.

Major difficulties associated with shrimp fishing are the damage caused by industrial operations to small-scale fishers and overcapacity of the trawl fleet. Good data on shrimp catches, shrimp fishing effort and shrimp exports are not readily accessible, and those that are available, are often conflicting.



## DEVELOPMENT AND STRUCTURE

Nigeria has a coastline of 853 km along the Gulf of Guinea in the Atlantic Ocean. The continental shelf is relatively narrow, ranging in width between 14.8 km to the west off Lagos and 27.8 km to the east off Calabar. The country has about 46 000 km<sup>2</sup> of shallow ocean area (with a depth of less than 200 m). Oceanographic conditions, including poor upwelling, limit the productivity of the waters off the Nigerian coast (FAO, 2000c).

Most Nigerian commercial shrimping grounds lie east of longitude 5°E at the Nigerian/Cameroon border, principally around the Niger Delta, river mouths and in estuaries and lagoons with soft mud deposits. Marine shrimp is caught by both artisanal and industrial trawlers. The artisanal vessels catch shrimp in the area between zero and five nautical miles offshore, while trawlers are required to fish outside this zone. Nigeria's major shrimping areas are offshore of the mouths of the Rivers Escravos, Forcados, Ramos, Pennington, Brass, San Bartholomew and Calabar.

Trawling for fish and shrimp commenced in the late 1950s after the 1950–53 Colonial Development Corporation exploratory survey (Longhurst, 1965.) Serious private sector trawl fishing in Nigeria started in 1982 with the introduction of 49 medium-size trawlers (Amire, 2003). A tremendous growth in trawl fishing took place in 1985 with the deployment of 149 fishing and shrimping vessels, harvesting a total of 23 766 tonnes of fish and 2 376 tonnes of shrimp. The original focus of trawlers brought in from Greece, Spain, Italy, Japan and the United States of America was finfish, with shrimp featuring as a bycatch (Chemonics, 2002). During this period, the Nigerian naira was strong (at about NGN1 to US\$1), so the fish catch sold profitably on the local market. In 1986, the naira devalued as a result of a structural adjustment programme. Thereafter, fish sold locally could not even cover operational costs and the Nigerian Government's appetite for foreign exchange increased. Shrimp, which used to be a bycatch, became the focus because of its high export earnings. In 1987, the fish

catch by trawlers fell by 13.2 percent to 28 411 tonnes, while shrimp production rose by 82.5 percent to 5 234 tonnes (Amire, 2003).

The industrial shrimp fleet of Nigeria consists of about 225 vessels, ranging in length from 23 to 26 m, and is operated by 28 fishing/shrimping companies. The vessels are typically Mexican-type trawlers built in the United States. They mostly use quad-rigged, four-seam trawls with headlines of 15–20 m, and have an onboard blast or plate freezer and a cold store capable of maintaining products at  $-18^{\circ}\text{C}$  to  $-20^{\circ}\text{C}$ . They operate day and night using their booms to pull either two or four otter trawl nets with tickler chains. Towing speed is between 2.5 and 3.0 knots and trawling time is about three hours. The vessels are crewed with 3 000 foreign and Nigerian crew, the latter being mainly mate certificate holders and second-class engineers. The skippers and chief engineers are mostly Asian and Ghanaian nationals. The trawling industry is represented by the Nigerian Trawler Owners Association (NITOA), the members of which operated about 250 Nigerian-flagged vessels in 2004 (Chemonics, 2002; FAO, 2000c; ICES/FAO, 2005).

Non-industrial shrimp fishing in Nigeria has three components.

- First, there are 8–12 m wooden canoes propelled by a 15–40 HP outboard engine, which tow conical filter nets for targeting/catching the estuarine prawn (*Nematopalaemon hastatus*) in inshore waters less than 5 km from the shoreline. This type of fishing is undertaken in all eight Nigerian maritime states.
- Second, there is an artisanal beach seine net fishery, which uses nets of 500–1 500 m in length and operates in shallow coastal waters. The Beach Seine Fishery started in the 1950s. Larger nets were introduced by fishers who migrated eastwards from Ghana, Togo and Benin. The large seine nets are owned by one or two families, but operated by a group of fishers referred to as “the company”, which is disbanded at the end of each annual fishing season. The beach seine fishery has been declining because of a lack of adequate labour to pull the net ashore manually. The fishery, which had been operated by previous generations, is not especially attractive to the youth of today, who prefer to work as deck hands on vessels.
- Third, conical stow nets are used passively for catching mainly submature shrimp in the sheltered brackish waters of the lagoons, creeks and estuaries.

#### TARGET SPECIES, CATCH AND EFFORT

Amire (2003) provides information on the important shrimp in Nigeria. The species<sup>33</sup> mostly exploited are: the southern pink shrimp, *Penaeus notialis*, which is most abundant and most valued economically; Guinea shrimp, *Parapenaeopsis atlantica*; caramote prawn, *Penaeus kerathurus*; and the deep-water rose shrimp, *Parapenaeus longirostris*. *P. notialis* prefers supra-thermocline muddy sand with fine particles and abundant organic matters at  $25^{\circ}\text{C}$ . Concentrations of this species are particularly high in the Niger Delta, at 20–30 m. *Parapenaeopsis atlantica* is prevalent at 10–40 m in depth, while *Parapenaeus longirostris* is found in deep waters from 60 to 400 m.

The estuarine prawn (*Nematopalaemon hastatus*) is the basis of a major fishery. Exclusively exploited by small-scale operators with passive cane or netting gear in estuaries and with small trawls in the surf zones, it constitutes about 50 percent of estuarine shrimp catches. Also harvested by artisanal fishers are the brackish water prawn (*Macrobrachium macrobrachion*), river prawn (*M. vollehovenii*) and juvenile southern pink shrimp.

Ogbonna (2001) lists the species in the inshore shrimp fishery of Nigeria, in ascending order of importance:

- *Penaeus notialis*;
- *Parapenaeopsis atlantica*;

<sup>33</sup> The English names have been modified to conform to standard FAO nomenclature.

- *Parapenaeus longirostris*;
- *Penaeus kerathurus*; and
- *Nematopalaemon hastatus*.

An important and interesting feature of late has been the arrival of *Penaeus monodon* wild giant tiger prawns in trawler catches (Chemonics, 2002). *P. monodon* appeared in the late 1990s and apparently occurs mainly in the Calabar/eastern delta zone where it comprises as much as 10 percent of trawler catches. This is an Asiatic exotic that could have only arrived through human agency (African current patterns preclude natural introduction), and presumably escaped from a West African (Gambian, Senegalese or Cameroonian) shrimp farm. FAO (2000c) states: "As reported for Cameroon, the non-native giant prawn *Penaeus monodon* is increasing in abundance".

Information on the amount of shrimp caught in Nigeria is fragmented and sometimes conflicting.

- Data reported by the Government of Nigeria to FAO during the previous decade indicate that the annual shrimp catch varied from 15 000 to 30 000 tonnes, with an average of 22 452 tonnes.
- Chemonics (2002) reports that reliable production data are scarce, but historic data show reported landings of 10 000 to 15 000 tonnes annually, although anecdotal reports mention 30 000 tonnes (as do some landings statistics that cover the 1980s). Discrepancies are usually accounted for by illegal at-sea sales that go unreported. Trade data from the Organisation for Economic Co-operation and Development (OECD) give an alternative measure – some 6 800 tonnes were imported into Europe in 1998 (which takes the great bulk of Nigerian shrimp). Adjusted for weight loss on processing, this equates to 10 000 tonnes (live-weight equivalent), so there is some corroboration for a figure of this magnitude.
- The annual catch of shrimp between 1992 and 1997 was more than 9 000 tonnes (up to 12 000 tonnes) (Ogbonna, 2001). In 1998, total shrimp exports to Europe were 8 300 tonnes.

It appears that at least some of the differences between the various estimates of shrimp catches are caused by the lower estimates mainly for licensed shrimp vessels, while the upper estimates include all forms of shrimp fishing, including small-scale.

With such uncertainty over the amount of the annual shrimp catch, information on CPUE is even more doubtful. Nevertheless, some information is available. Ogbonna (2001) gives annual CPUE on licensed shrimp vessels between 1985 and 1997 (Table 65).

Operational information from the industrial shrimp fleet in recent years indicates that between 5 and 10 tonnes of shrimp and about 40 tonnes of retained bycatch are considered typical for a 45- to 55-day fishing trip. Vessels trawl continuously, completing six to eight hauls per 24 hours (240–400 hauls during each trip), and characteristically retain 20 kg of shrimp and 150 kg of bycatch per haul. However, catches vary considerably among vessels and across areas and seasons.

### ECONOMIC CONTRIBUTION

Nigeria's shrimp fisheries, both industrial and artisanal, are a major source of both direct and indirect employment. This includes shrimp capture/production, processing for local and export markets, and jobs associated with gear sales/repair and cold-storage facilities.

It is estimated that members of NITOA provide either full- or part-time employment for about 50 000 people,

TABLE 65  
CPUE data on licensed shrimp vessels,  
1985–97

	Total shrimp catch (tonnes)	Number of shrimp vessels	Catch (tonnes/vessel/year)
1985	2 376	40	59.4
1986	2 623	54	48.57
1987	3 517	82	42.80
1988	2 868	132	21.72
1989	5 234	158	33.72
1990	3 666	195	18.80
1991	6 200	195	31.70
1992	9 373	203	46.10
1993	8 956	223	40.16
1994	8 884	230	40.16
1995	12 252	235	34.27
1996	9 551	196	48.73
1997	10 807	266	40.63

Source: Ogbonna, 2001.

including work on vessels, in processing plants and in distribution. Current estimates suggest that 1.2 million people have formal or informal employment associated with shrimp fishing and downstream activities (Federal Department of Fisheries statistics, NITOA, 1998).

Against these employment benefits, it should be noted that many of the inputs into the Nigerian shrimp industry (e.g. vessels, trawl nets and accessories) are imported.

Data on the domestic consumption of shrimp and shrimp products are not readily available. It is well known, however, that the estuarine prawn (*Nematopalaemon hastatus*) is both a major source of relatively cheap animal protein and an important condiment in food preparation. Trawler bycatch retained and sold ashore is also an important food.

According to information from the Central Bank of Nigeria, fishing is responsible for about 5 percent of agriculture's contribution<sup>34</sup> to Nigeria's GDP. The specific contribution of shrimp fishing is not readily available.

### TRADE ASPECTS

Shrimp and shrimp products are the second most important commodity export of Nigeria after petroleum. FAO (2000c) reports that about half the country's total shrimp catch (both large- and small-scale fishing) is exported. The quantity and value of shrimp exports for recent years are shown in Table 66.

Chemonics (2002) reports on shrimp processing, export and domestic sales of Nigerian shrimp.

- Most Nigerian shrimp is frozen whole at sea. It is often packed on board as a finished product for the "head-on" whole shrimp market (plate frozen in 2-kg boxes). The main role of the shore facilities in Lagos is to store and aggregate the frozen landed product prior to export by 40-foot (12.2 m), 18-tonne container. Alternatively, bulk (blast) frozen shrimp can be further processed in the Lagos plants. The shrimp is thawed and deheaded, and can either be packed as such or peeled. Since the trend in the market is towards requiring increased value added, further processing may become a more important activity in Nigeria.
- With regard to export markets for Nigerian shrimp, most is sold in Europe. In 2002, the total EU shrimp market was about 280 000 tonnes, with a value of about US\$1.75 billion. Nigeria, in effect, holds about 2 percent of the European market. Important market components are Spain (25 percent of sales), France, Belgium and the United Kingdom.
- As regards domestic shrimp marketing, the highly perishable nature of shrimp dictates that it is mostly sold smoked, unless it is sold close to the point of capture where fresh/live products can be on sale. Distribution relies upon small traders who buy and deliver small quantities of dried/smoked seafood to rural markets, using local transport. This is a trade dominated by women – the "fish mummies", who tend to control artisanal post-harvest activities throughout West Africa, often within family businesses where the men fish while the women manage and sell.

FAO (2000c) reports that Nigeria achieved harmonization in the EU market for its fish products exports, mainly shrimp, and other products such as sole fillets, cuttlefish and crab claws. The harmonization of Nigeria with EU regulations resulted

TABLE 66  
Shrimp exports from Nigeria,  
1992–2001

Year	Quantity (tonnes)	Value (US\$)
1992	3 400	13 966 526
1993	2 322	8 539 423
1994	3 368	11 163 114
1995	4 265	13 393 769
1996	3 845	14 345 623
1997	2 946	8 386 458
1998	8 028	31 163.784
1999	7 418	46 485 491
2000	6 303	39 495 886
2001	6 694	48 820 467

Source: Dada, 2004.

<sup>34</sup> This includes crop production, livestock, forestry and fishing.

in the listing of approved vessels. Responsibility for monitoring and maintenance of standards and recommendations for listing/delisting has been vested in the Federal Department of Fisheries in accordance with EU legislation.

In February 2004, the United States Government announced that it would ban imports of shrimp from Nigeria, according to Section 609 of United States Public Law 101–162, which provides that shrimp, or products from shrimp, harvested with commercial fishing technology that may adversely affect certain species of sea turtles protected under United States laws and regulations, may not be imported into the United States unless certified. The foundation of the United States programme governing the incidental taking of sea turtles in the course of shrimp harvesting is, according to the United States NMFS, the requirement that commercial shrimp trawl vessels use TEDs, approved in accordance with standards established by NMFS (C. Stanger, personal communication, Office of Marine Conservation, United States Department of State, October 2005).

Although exports to the United States only constituted a minor part of total Nigerian shrimp exports before the closure, both the Nigerian Government and the shrimp industry have been very anxious to have United States exports reopened. This is both to increase exporting flexibility and because of the concern that the EU may follow the United States in adopting turtle excluder requirements (ICES/FAO, 2005).

### BYCATCH ISSUES

In the small-scale shrimp fisheries, bycatch is minimal. Most small-scale shrimp fishing targets the estuarine prawn (*Nematopalaemon hastatus*), which has a shrimp to fish ratio ranging from 8:1 to 15:1.

Industrial shrimp trawlers catch a diverse assemblage of finfish, crustaceans and cephalopods, including juveniles of some commercially important species. The shrimp to bycatch ratio ranges from 1:5 to 1:15.

Most of the retained bycatch includes teleosts such as croakers (Sciaenidae – *Pseudolithus* spp.), threadfins (Polynemidae – *Galeoides decadactylus*, *Polydactylus quadrifilis* and *Pentanemus quinquarius*), sole (Cynoglossidae – *Cynoglossus* spp.) and grunter (Pomadasyidae – *Pomadasyus jubelini*). Some are sold sorted by species (in 20-kg bags) according to size (e.g. large, medium and small), while others are combined with various species and packaged in four categories, with a progressive decrease in fish size, as mix 1, mix 2, mix 3 and, more recently, mix 4. Fish smaller than mix 4, which can be up to 40 percent of the bycatch, are sometimes sold at sea by the trawler crews to small-scale fishers. These fish are resold ashore, resulting in the development of bycatch markets along the coast of the eight Nigerian maritime states.

Akande (2002) provides some information on the trade of shrimp bycatch. Officially, shrimp bycatch must be landed at a designated port, jetty or fishery terminal. The law stipulates that any shrimper operating in Nigerian inshore waters must land 75 percent of the shrimp bycatch. There is, however, much evidence that there is a thriving business of transfer to canoes on the high seas. Bycatch collection is now an occupation attracting an increasing number of artisanal fish traders in all the coastal states of Nigeria. Despite limitations on the size of their collector vessels (canoes), the occasionally rough sea and the technical problems of transferring bycatch at sea, the artisanal fishers find the collection of bycatch a viable alternative source of income. The first category of artisanal fishers involved in the transfer of bycatch at sea concerns those who, because of the high costs of fishing operations, opt to undertake the full-time business of accepting bycatch from shrimp trawlers. The second group normally concentrates on *bonga* and *sardinella* during the peak season, but instead chooses the bycatch transfer trade during the low season.

Irrespective of fish size, it is apparent that few of the organisms caught by Nigerian shrimp trawlers are discarded. Kelleher (2005) states that trawl fisheries in Ghana,

Nigeria and Cameroon have low discard rates since there is extensive collection at sea. Because of high demand for fish products and high coastal populations in many areas, discards in the artisanal fisheries are negligible.

Some years ago, Akande (2002) reported that BRDs are not used on any of the registered shrimp vessels and there are no plans to introduce them. A more recent ICES/FAO report (2005) states, however, that the investigation of the performance of BRDs as an attractive and environmentally friendly option to mitigate the problem of bycatch in shrimp trawling has commenced. The use of TEDs on shrimp trawl nets has been a requirement since September 1996, but was still not fully implemented until the beginning of 2006, as documented by the United States import ban.

Nigeria participates in the global FAO/GEF/UNEP project "Reduction of the Environmental Impact of Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management". The project's objective is to introduce bycatch reduction technologies in order to protect juvenile fish and marine turtles. Through the concerted action of this project, the fishing industry, the Nigerian Institute for Oceanography and Marine Research (NIOMR) and the Department of Fisheries, Nigeria was recertified for exporting wild shrimp to the United States market in January 2007 after United States inspectors had found the implementation of TEDs satisfactory during an inspection in August 2006.

In Nigeria, an important issue related to bycatch is that traditional small-scale fishing gear catches large quantities of juvenile shrimp. It is desirable that fishers using this gear change their practices to allow the shrimp to grow to maturity, contribute to recruitment and attract higher market value, thereby improving the overall value of the fishery. It has been suggested that the traditional small-scale shrimp filter/stow nets be modified so they can be more selective for larger-size shrimp.

### PROFITABILITY

Few recent data are available on the profitability of shrimp fishing in Nigeria.

In 2002, shrimp trawler production costs in Nigeria were analysed (Chemonics, 2002). It was concluded that, in former years, shrimp trawling had prospered in the country since it was both profitable and generated foreign exchange. When production costs in previous years were nearly US\$5/kg of whole shrimp, this equated to US\$7.80–8.00/kg of tails (allowing for processing weight loss). While prawn tail prices averaged US\$10/kg, the business was clearly profitable, generating margins of 30 percent. A number of events subsequently occurred in the shrimp industry, negatively affecting profitability: catch rates and shrimp prices fell, fuel costs rose and piracy increased. Consequently, in 2002, shrimp trawling in Nigeria was close to breakeven at best and the situation still remains. The exit of many players from the industry in 2002 supported the contention of low profitability. Chemonics (2002) came to several conclusions.

- Economic revival will depend on either prices rising or catch rates improving, as there is little scope to reduce costs.
- If prices do not rebound, then the principal option facing the industry must be to reduce overall capacity to allow unit catch rates to increase for the remaining vessels.
- To restore profitability, catch rates need to increase by 50 percent (i.e. from 60 to 90 tonnes/boat/yr). This would imply a fleet reduction of at least 35 percent (i.e. reducing the fleet to 100–110 trawlers).

### ENERGY INPUT ASPECTS

Each industrial shrimp trawler stays out of port for 45–55 days and requires 30–50 tonnes of fuel.

Despite its rich oil resources, Nigeria does not have the refining capacity to meet domestic demand and has to reimport consumable refined oil. For the past decade,

under pressure from donors demanding market liberalization, governments across West Africa have been calling a halt to fuel subsidies, which cost the Nigerian Government alone US\$2 billion a year. In September 2005, thousands of angry Nigerians took to the streets to protest against 30 percent rises in fuel prices (Mail and Guardian, 2005).

The current price of diesel fuel ranges from US\$0.50 to US\$0.70/litre. The price remained the same after the September 2005 increase, and the Federal Government gave assurances that the current price would be retained throughout 2006.

In addition to fuel costs, the main complaint related to fuel for trawlers has been the inadequate and irregular supply of fuel. A further problem concerns fuel bunkering. Most companies operate from private jetties within the state of Lagos, which makes bulk purchase or delivery of fuel difficult. To mitigate this problem, the Federal Government was contemplating building a fishing terminal complex in the Lagos area, funds permitting.

### BIOLOGICAL ASPECTS

Amire (2003) summarizes the results of studies on the inshore and offshore trawl fisheries.

*For the inshore fishery, Ajayi (1982), analysing the 1971–1978 catch and effort data of Nigerian shrimpers, calculated a sustainable yield of 2 008 tonnes for 12 651 days at sea. Ajayi and Adebolu (personal communication, 2006), combining shrimp catch data from Cameroonian shrimpers with those of Nigerian fishing trawlers and shrimpers, estimated an MSY ranging from 3 250 to 4 000 tonnes. Pooling all the estimates, the potential of the Nigerian inshore shrimp resources is between 3 250 and 4 016 tonnes.*

*For the offshore fishery, Tobor (1990) estimated the potential yield of Nigeria's offshore demersal resources to be 6 370 tonnes. Earlier results from the Guinea Trawl Survey estimated approximately 31 000 tonnes as the standing stock within the 50–200 m depth area. The potential of the offshore royal shrimp, *Parapenaeus longirostris*, which occurs in this zone from 50 to 200 m depth, is yet to be determined.*

A Workshop on the Assessment and Management of Shrimp and Crabs in Southwest Africa was held in 1999. The report of the workshop (Caramelo, Lamboeuf and Tandstad, 1999) indicated that because only catch and effort data were made available to the workshop, only simple production models could be used in the analysis. Regarding the shrimp resources of Nigeria, MSY for the shallow-water shrimp fisheries was calculated at 8 800 tonnes and the equilibrium effort of MSY was calculated at 48 000 fishing days. This was taken as an indication that the fishery was exploited close to the MSY level at that time. It was also concluded that the relationship between effort and CPUE in the previous nine years was not significant, which probably resulted from the limitations of data collection.

It is clear that the output level of the shrimp fishery was considerably beyond the potential long-term yield estimates (FAO, 2000c).

### IMPACTS ON THE PHYSICAL ENVIRONMENT

Although there have been no specific studies in Nigeria on the effects of shrimp trawling on the ocean bottom, there is a general perception that the groundropes, tickler chains and doors of shrimp trawl nets that are dragged over the sea bottom to catch shrimp also disturb the soft bottom. This disruption occurs by direct contact or through turbulent resuspension of sediments.

NITOA is working with the Nigerian Government to address the numerous problems of the industrial fishery sector, including environmental concerns (FAO, 2000c).

Another less obvious environmental concern relates to the harvest of fuelwood for smoking shrimp and bycatch. This is responsible for some destruction of mangrove areas, which serve as breeding and nursery grounds for fish and shrimp. It also

exacerbates coastal erosion and promotes the spread of exotic plant species, particularly the *Nypa* palm.

### IMPACTS ON SMALL-SCALE FISHERIES

Large-scale industrial shrimp fishing has a significant impact, both directly and indirectly, on small-scale fishing activity. The artisanal vessels catch shrimp in the area between zero and five nautical miles offshore, while trawlers are required to fish outside this zone. The problem is that large trawlers frequently encroach upon this zone, especially in the highly productive mouths of rivers, which often results in physical interaction with small-scale fishing gear. Many incidences of gear damaged by trawlers are not adequately redressed because of non-reporting or the apathy of industrial fishers. Coastal communities generally believe that industrial fishing has reduced the standard of living of fishing families living in coastal areas.

Large-scale industrial shrimp fishing also affects small-scale fishing activity indirectly through competition for the same resources. It has been shown that much of the industrial bycatch is finfish juveniles, which are important in small-scale fisheries. Similarly, some of the most significant shrimp species are targeted by both the large- and small-scale fisheries.

As mentioned previously, traditional shrimp stow nets in Nigeria catch large quantities of juvenile shrimp. There is the contention that fishers using this gear should change their practices to allow the shrimp to grow to maturity, contribute to recruitment and attract higher market value, thereby improving the overall value of the fishery. This seems to be a case of small-scale shrimp fishing negatively affecting large-scale fishing.

### MANAGEMENT

Amire (2003) reviews the evolution of the legal basis for fisheries management in Nigeria. The first comprehensive law, Sea Fisheries Act No. 30, was promulgated in 1971. The subsidiary Fishing and Licensing Regulations of the Act were enacted in 1972. Following lapses observed in the effectiveness of this decree over time, it was repealed and replaced by Sea Fisheries Decree No. 71 of 1992. The main decree contained general provisions for the conditions relating to the issuance of fishing and shrimping licences, vessel operations, duties and powers of authorized persons and penalties for offences. The Sea Fisheries Fishing and Licensing Regulations enacted under the new decree contain provisions similar to those of the repealed Sea Fisheries Act No. 30 of 1971. However, they provide for, *inter alia*, wider and stiffer penalties for offenders.

ICES/FAO (2005) review the sea fisheries licensing and fishing regulations that impact on shrimp trawling and associated bycatch. These provisions and justifications are the following.

- An obligatory pre-purchase assurance in writing by the licensing authority that any procured vessel entering the Nigerian shrimping business would be licensed after the due process. This is a measure to control, before investment, fishing effort and prevent overcapitalization.
- A requirement for a vessel survey and tonnage measurement, by the Nigerian Government Inspector of Shrimping from the Federal Ministry of Transport, to ensure that only suitable and permissible vessels enter the Nigerian shrimping or fishing fleet.
- Restriction in size of a shrimp trawler to less than 23.2-m length overall and 130 GT, to prevent oversized vessels from entering the trawl shrimp fishery.
- Delimitation of a non-trawling zone of five nautical miles, which places restrictions on trawling in a sea water area covering about 7 900 km<sup>2</sup> of the Nigerian continental shelf. This is to safeguard nursery grounds from indiscriminate fishing and protect artisanal fishers who operate within the zone.



- A minimum codend mesh size of 44 mm (stretched) for any shrimp trawl net, in order to promote the sustainability of inshore trawl fisheries.
- Prohibition of the use of the same vessel licensed to trawl for fish from trawling for shrimp, in order to limit shrimp trawling effort.
- Prohibition of discarding edible and marketable sea products and transshipment at sea of bycatch. The immediate purpose of this is to encourage vessels to bring all catches back to the home port to increase the supply of fish to the domestic market. This should also indirectly discourage non-compliance with the mesh size regulation, which leads to catching small-sized or juvenile fish.
- A regulation concerning minimum fish sizes for sale, to discourage the catching of undersized fish and ensure the use of legal mesh size in the codend.
- Prohibition of single and pair trawling by motorized vessels of less than 20 GT and in waters shallower than 18 m, to protect juvenile fish and biodiversity in fishing grounds, which are also nursery grounds in some areas.
- The requirement for using a TED on shrimp trawls (from September 1996).

Amire (2003) discusses two additional issues important in the management of Nigeria's shrimp fisheries.

- *Removal of subsidies.* In an effort to stimulate the development of the fisheries subsector, the Nigerian Government adopted various subsidy arrangements of up to 50 percent on all canoes, fishing equipment and spare parts that it supplied to members of registered fishers' cooperative societies up to 1984. This subsidy was subsequently withdrawn when the government was satisfied with the level of capacity development in the subsector. Fishers now procure or are supplied with fishing items, whenever available, at current market rates.
- *Consultative arrangements.* There is an elaborate consultative mechanism between the government and representatives of owners of fishing vessels licensed to operate Nigerian-flagged vessels within or outside Nigerian waters. All trawler owners are required to be members of NITOA, which plays a vital communications part between members and the government on all issues that affect members. The Association is usually consulted on all relative matters and its suggestions are usually given serious consideration before decisions are taken.

## ENFORCEMENT

In 1991, the Government of Nigeria established the national fisheries resources Monitoring, Control and Surveillance Unit (MCSU) in the Federal Department of Fisheries in order to achieve fisheries management objectives. Its mandate is to ensure that adequate data on effort and capacity used in harvesting the country's fisheries resources are collected and collated for sustainable management. Other mandated functions of the unit include search and rescue operations for distressed fishing vessels, in collaboration with the Nigerian navy, sea patrols and surveillance to ensure compliance with fishing regulations, and monitoring of resources to enable it to advise the government on the state of resources (Amire, 2003).

The activities of the MCSU include all industrial fishing and shrimping vessels that berth or fish in any part of the country. In order to discharge their duties effectively, some officers of the unit have been deployed to the fishing companies on a permanent basis. Observers on board are also used to the extent that funds permit.

Unauthorized fishing (without a licence) attracts a US\$250 000 fine, a five-year imprisonment term or both. All other offences now attract a US\$5 000–20 000 fine, instead of the derisory US\$400 of previous years.

Perceived difficulties in enforcing shrimp fishery management measures include the lack of an operational fisheries patrol and weaknesses in prosecuting violations of fisheries legislation.

## RESEARCH

Fisheries research and training are the responsibilities of fisheries research institutes and their affiliated colleges. Development departments, such as the Federal Department of Fisheries, also contribute to human resources development through short-term training programmes and the sponsorship of trainees in colleges. NIOMR is the Federal Government agency established to conduct research on the resources and physical characteristics of Nigerian territorial waters and the EEZ. Its activities include fisheries and other aquatic resources surveys, marine geology and geophysical surveys, physical and chemical oceanography, fishery technology research, brackish water aquaculture research, extension research and liaison services. NIOMR is based in Lagos, with a substation at Aluu, Port Harcourt.

NIOMR's contributions to shrimp fishery research and management include:

- an exhaustive mesh selectivity experiment as the basis for the mesh requirements in the 1971 Sea Fisheries Decree;
- reappraisal of the 1971–72 management provisions as the basis for 1992 regulations;
- exploratory shrimping surveys (when vessels were functional);
- determination of the optimum number of inshore shrimp vessels;
- the 1991–96 inventory of small-scale coastal fisheries potential;
- establishment of a catalogue of small-scale fishing gear in Nigeria.

Major external research projects related to shrimp fishing in Nigeria have included:

- the Guinea Trawling Survey, executed in the early 1960s, which covered the entire Gulf of Guinea region;
- a month-long regionwide (Ghana to Cameroon) trawl survey undertaken in February and March 1999, using a 25-m Nigerian shrimp trawler – 44 percent of the trawling was conducted in Nigerian waters;
- a survey by the research vessel Dr Fridtjof Nansen in the eastern Gulf of Guinea (Nigeria, Cameroon, Sao Tome and Principe) in June and July 2004;
- the GEF/UNEP/FAO shrimp fisheries project, “Reduction of the Impact of Tropical Shrimp Trawling Fisheries on Living Marine Resources, through the Adoption of Environmentally Friendly Techniques and Practices”, has carried out research on Nigerian shrimp fisheries, including resource monitoring, socio-economic investigations relating to trawl bycatch, and development of appropriate bycatch reduction technology.

## DATA REPORTING

Catch data on shrimp fisheries are collected at landing sites along the coast of Nigeria. They are then collated in the state field offices and sent to Abuja for final collation and publication.

The only on-board data available to date are those collected under the GEF/UNEP/FAO shrimp fisheries project.

Regarding data quality, Chemonics (2002) reported that reliable production data on shrimp fisheries in Nigeria are scarce. However, there have been some recent improvements.

- New data formats have been designed and subsequently reviewed by the National Steering Committee of the GEF/UNEP/FAO shrimp fisheries project. They are being used to collect data from 224 industrial trawlers.
- A five-day training workshop was organized for 49 data collectors and fisheries assistants. This involved species identification, sampling methods, sorting/measurement and recording of data.

### **IMPACTS OF SHRIMP FARMING**

Shrimp farming has not started on any appreciable/commercial scale in Nigeria; its effects on shrimp fishing in the country are therefore negligible.

### **MAJOR ISSUES**

The major issues related to shrimp fishing in Nigeria are:

- the interaction between large- and small-scale shrimp fishing, including the encroachment of industrial shrimp trawlers upon areas reserved for small-scale fishing, and competition for the same fishery resources;
- the major importance of shrimp as a basis for both employment and exports;
- overcapacity in the trawl fleets;
- lack of reliable catch and effort data;
- the current low profitability of commercial shrimp fishing caused by piracy, falling catch rates and shrimp prices, and increasing fuel costs; and
- limitations to enforce management measures while at sea.



# Shrimp fishing in Norway

*Based on the work of Øystein Hermansen*

## AN OVERVIEW

Norway is a major shrimp producer. Between 60 000 and 70 000 tonnes of shrimp are caught annually and the country is the 14th largest producer of shrimp in the world. Shrimp fishing in Norway is, however, not nearly as important as fishing for other species such as herring, blue whiting, cod and saithe. Shrimp represented about 4 percent of the value of all Norwegian fishery products exports in 2003.

The main shrimp stocks exploited by Norwegian fishers are those in the Barents Sea, Skagerrak and the North Sea. In addition, many Norwegian fjords have small local stocks. For regulatory purposes, the shrimp resources are treated as three separate stocks: north of 62°N, Skagerrak and the North Sea. In addition, Norwegian vessels are allocated quotas around Greenland and the Flemish Cap.

The poor profitability of many types of shrimp vessels in Norway is a major problem. This has probably arisen from a combination of factors, including excess capacity, increasing fuel costs and falling market prices for shrimp.

Much of the management of Norwegian shrimp fishing, both domestically and internationally, is driven by the need to avoid both overfishing and the bycatch of cod and other important species.

## DEVELOPMENT AND STRUCTURE

Modern Norwegian shrimp trawling began in the 1890s, when the renowned fisheries researcher Johan Hjort collaborated with Danish researchers and introduced trawl technology for shrimp fishing. The fishery started as a coastal fishery in the southern part of Norway and, by the 1930s, had spread all along the Norwegian coast.

The catch was predominantly boiled on board and hand-peeled on shore. Much of the production in the northern part was exported, while the local market for fresh shrimp in the southern part was larger and more developed.

In 1970, the Norwegians started exploiting the shrimp stock in the Barents Sea and around Spitsbergen, using large ocean-going trawlers. The quantities caught from this



TABLE 67  
Number of licences for shrimp trawlers

	1990	1995	2000	2004
Offshore trawlers	147	119	108	90
Coastal south 62° N			173	174
Coastal north 62° N*			104	78

\* A licence is not required for vessels under 50 GRT; the number given is the number of vessels that have delivered fresh shrimp.

Source: Norwegian fishers sales organization.

stock quickly surpassed the coastal fisheries and grew to a maximum of 128 000 tonnes in 1984.

Norwegian vessels have also exploited stocks in the northwest Atlantic, off Canada and Greenland. The fishery off Canada started in 1993.

The Norwegian shrimp fishery is in general a single-species fishery for northern shrimp. Operations are carried out by two distinctly separate fleets: one fishing inshore,

employing small trawlers (wood/steel) of 10–20 m in length, and the other fishing offshore with large steel trawlers of 20–70 m in length. Most of these vessels use high-opening bottom trawls, rigged as single or twin.

Even though the fishery is single-species, about half of the offshore trawlers also have licences for catching groundfish, but these are carried out as separate fisheries with different trawls and locations.

The coastal vessels fish in the fjords along the Norwegian coast and in Skagerrak, and deliver their catch fresh. The large trawlers fish at several locations: around Spitsbergen, in the Barents Sea, east of Greenland, the Flemish Cap and Jan Mayen. This catch is delivered frozen.

Access to the shrimp fisheries is regulated through a licensing regime. This applies both to offshore trawlers and coastal vessels fishing south of 62°N. North of this boundary, access is open for coastal vessels. While most of the fisheries operate within the EEZs of various countries, the fishery in the west of the Atlantic also operates in international waters. This fishery is managed through the Northwest Atlantic Fisheries Organization (NAFO). Within zone 3M (Flemish Cap), the fishery is managed through an effort allocation scheme, in which Norway had 1985 fishing days in 2006 and participated with 32 vessels.

Over the last decade, the numbers of both coastal and offshore trawlers have declined. The number of licences issued in the offshore fleet and in the fishery south of 62°N are shown in Table 67. In 1998, access to the latter fishery was closed (and licences became mandatory), hence there is no licence information for 1990 and 1995. The number of coastal vessels that delivered fresh shrimp north of 62°N is also shown, giving an indication of activity in the fishery. Statistics from 1990 and 1995 are unreliable for this group.

Through the Participants' Act, only persons with Norwegian citizenship are allowed to own fishing vessels; the shrimp fleet is therefore domestically owned. To a large extent it is owned by the vessel operators themselves, or by close family. There are a few companies, particularly in the western part of Norway, operating more than one large offshore trawler.

### TARGET SPECIES, CATCH AND EFFORT

Norwegian shrimp trawling targets a single species, the northern shrimp (*Pandalus borealis*), which is also known as the pink shrimp and the deep-water red shrimp. It is widely distributed in the boreal waters of the North Atlantic, North Pacific and Arctic Oceans. In the North Atlantic, the southern boundary of the stock to the west is the Gulf of Maine, while the North Sea forms the southern limit of the stock in the eastern Atlantic (Graham, 2005).

Cold-water shrimp landings come mainly from four North Atlantic countries: Canada, Greenland, Iceland and Norway itself. In 2004, global landings were estimated at 450 000 tonnes, of which about 175 000 tonnes were landed by Canada (IntraFish, 2005).

TABLE 68  
Norwegian catches of shrimp by area, 1995–2004

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
North Sea	5 181	5 143	5 460	6 519	3 987	3 556	2 959	3 709	3 736	4 638
Skagerrak	2 879	2 772	3 112	3 092	2 761	2 562	3 952	3 612	3 979	4 360
Barents Sea	19 337	25 445	29 079	44 792	52 612	55 333	43 021	48 799	34 652	36 188
Other areas	11 853	8 118	4 305	2 643	4 177	5 053	15 279	13 019	23 662	14 041
Total	39 250	41 478	41 956	57 046	63 537	66 504	65 211	69 139	66 029	59 227

Source: ICES, 2005.

TABLE 69  
LPUE and effort for Norwegian vessels in Skagerrak and the North Sea, 1996–2004

	1996	1997	1998	1999	2000	2001	2002	2003	2004
LPUE	37	42	44	32	31	32	39	47	57
Effort	214	212	219	219	195	217	186	166	159

Source: ICES, 2005.

Note: units: effort – 1 000 trawl hours; LPUE – kg/hr.

TABLE 70  
Effort and CPUE for Norwegian vessels in the Barents Sea, 1996–2004

	1996	1997	1998	1999	2000	2001	2002	2003	2004
CPUE	179	180	238	229	204	226	216	200	191
Effort	84.9	124.9	153.8	197.2	237.4	182.5	223.6	151.4	165.4

Source: ICES, 2005.

Note: units: effort – 1 000 trawl hours; CPUE – kg/hr.

There are several individual stocks of northern shrimp. The main stocks exploited by fishers from Norway are those in the Barents Sea, and the one in Skagerrak and the North Sea. In addition, many Norwegian fjords have small local stocks. Catches of shrimp by area, from 1995 to 2004, is shown in Table 68.

Table 69 shows the history of landings per unit effort (LPUE) and estimated effort measured in 1 000 trawl hours for the shrimp fishery in Skagerrak and the North Sea, from 1996 to 2004.

The development in CPUE and estimated effort measured in 1 000 trawl hours for the fishery in the Barents Sea, from 1996 to 2004, are shown in Table 70. The first double trawls entered service in 1996, and their use has spread rapidly to most vessels.

## ECONOMIC CONTRIBUTION

The Norwegian Directorate of Fisheries conducts a survey each year of profitability and employment in the various vessel groups. This survey only encompasses the vessels that are considered to be operating all year. Table 71 summarizes employment on these vessels, calculating the share from shrimp fishing on the basis of its proportion of catch value.

TABLE 71  
Employment on various types of Norwegian vessels

Vessel group	Number of people employed	Shrimp catch (tonnes)	Shrimp share (value) (%)	Number of people employed by the shrimp industry
Factory trawlers	714	7 138	10.7	76
Large cod trawlers	835	14 912	20.6	172
Medium cod trawlers	473	13 236	28.8	136
Shrimp trawl 8–11 m	38	23	71.9	27
Shrimp trawl 11–28 m	288	5 914	78.1	225
Shrimp trawl >28 m	234	17 459	100	234
Total		58 682		870

Source: Directorate of Fisheries, 2004.

To the 870 jobs attributed to shrimp fishing, the following must be added.

- Only 8–28 m shrimp trawlers participate in the catch in Skagerrak/North Sea. A share of 5 937 out of 7 715 tonnes is covered in the Directorate's survey. It is assumed that the remaining 1 778 tonnes have the same employment effects, providing jobs in the fishery for a further 64 people.
- In the Barents Sea, a catch share of 31 953 out of 34 652 tonnes is covered in the survey. Assuming the remaining 2 699 tonnes all come from large cod trawlers, this provides jobs for a further 31 people.
- For catch in other areas, a share of 21 191 tonnes is covered in the survey. Assuming the remaining 2 471 tonnes are caught by shrimp trawlers of more than 28 m in length, employment is provided for an additional 33 people.
- Total employment on board Norwegian shrimp fisheries is therefore estimated at 998 people.

Regarding domestic nutrition, because a high proportion of Norway's shrimp catch is exported, the nutritional contribution from shrimp fisheries is not large. Hempel (2001) states that the per capita consumption of shrimp was 1.7 kg in 2000. This is a small proportion of the Norwegian annual per capita consumption of all fish and fish products, which is 54.7 kg according to FAO (2005d).

The contribution of fishing to Norway's GDP in 2003 can be determined by using the profitability survey conducted by the Directorate of Fisheries, in which value added to the various Norwegian shrimp fisheries is estimated. For large offshore trawlers, it is estimated that value added is Nkr5 700/tonne.<sup>35</sup> For smaller coastal trawlers, value added is estimated at 8 480 Nkr/tonne. These fleets obtain significantly different prices for their catch, with Nkr27/kg for the small trawlers compared with 21.4 for the large trawlers. The small trawler value added per tonne estimate is multiplied by the Skagerrak and North Sea shrimp catch. The large trawler estimate is multiplied by the shrimp catches in the Barents Sea and other areas. This yields a total value added and contribution to GDP of Nkr397 million. Of a total Norwegian GDP of Nkr1 561 billion, this is a mere 0.25 percent. There is an additional contribution to GDP from the shrimp processing industry.

### TRADE ASPECTS

Shrimp is exported from Norway in varying degrees of processing. The value and quantity of Norwegian exports in 2004 are shown in Table 72.

The Skagerrak/North Sea fishery produces two main categories of products: boiled or fresh large shrimp (35 percent total catch) and the smaller factory-processed shrimp (65 percent). About 60 percent of the large fresh shrimp is for the domestic Norwegian market, with the remainder exported to Sweden.

Shrimp represented about 4 percent of the value of all Norwegian fishery products exports in 2003 (Stella Polaris, 2005). The country's main markets, in decreasing order of importance, are Sweden, the United Kingdom, Denmark, Finland, Iceland and Japan. Hempel (2001) reports that Norway also imports shrimp, both cold-water shrimp and tropical species. In 2000, 28 021 tonnes were imported.

IntraFish (2005) reports a soft market for cold-water shrimp from Norway and the other main producers (Canada, Greenland and Iceland). There is increasing competition

TABLE 72  
Export of shrimp from Norway by product, 2004

Product	Value (million Nkr*)	Quantity (tonnes)
Peeled, frozen	588.5	15 547.3
Raw, frozen	106.9	8 131.7
Boiled, fresh, shell on	62.4	1 455.9
Peeled in brine	45.0	728.0
Boiled, frozen, shell on	42.7	1 509.0
Raw, fresh	18.1	1 337.5
Dried or salted	7.6	139.5
Other	5.4	186.9
Total	876.6	29 035.8

\* Average exchange rate of US\$1 = Nkr6.793 (2004).

Source: Norwegian Seafood Export Council, 2005.

<sup>35</sup> The average exchange rate was US\$1 = Nkr7.079 in 2003.



from tropical species, which are generally larger. A major shrimp processor in recent years closed nine cold-water shrimp processing plants, including three in Norway. Hempel (2001) stated that there were ten shrimp peeling plants in Norway in 2000, but only two remain in operation.

### BYCATCH ISSUES

Norwegian shrimp fisheries target only shrimp, but in the shrimping process other species groups are taken. The catch composition in the North Sea and Skagerrak shrimp fisheries in 2003 is given in Table 73.

Norway has a discard ban for all commercially important species. The ban requires that when these species are captured as bycatch and as juveniles of the target species, the catch has to be taken ashore and deducted from the TAC of the species concerned. According to Kelleher (2005), this discard policy, exercised through international fishing agreements, is one of the factors responsible for relatively low discard rates in the major fisheries of the North Atlantic.

The discard ban does not mean that Norwegian fisheries, including shrimp fisheries, do not discard unwanted fish but rather stipulates that important species are not to be discarded. In recent years, the North Sea and Skagerrak shrimp fisheries landed about 6 000 tonnes of shrimp and discarded 6 300 tonnes of various species for a discard rate of 51.2 percent (Kelleher, 2005).

Norway uses various means to reduce bycatch in shrimp fisheries. Graham (2005) summarizes the situation.

*In the Barents Sea and Svalbard area, Norwegian rules are that the fisheries be regulated by fishing licences and by smallest allowable shrimp size (maximum 10 percent of catch weight may be less than 15 mm carapace length). Fishing grounds are closed if bycatch limits given as number of individuals in 10 kg of shrimp are exceeded. In 2004 and 2005, the values of allowed bycatch are set at eight for the sum of cod and haddock, ten for redfish and three for Greenland halibut per catch of 10 kg shrimp. Sorting grids in shrimp trawls first became mandatory operating within the Norwegian 12-mile zone in February 1990. In October 1991, this directive was extended to apply to shrimp trawls used in all of the Norwegian EEZ. In 1993, the Joint Norwegian Russian Fisheries Commission agreed that the sorting grid was to be mandatory for all vessels conducting shrimp fishery in the Barents Sea and the Svalbard area. The maximum bar spacing permitted is 19 mm in all areas.*

The various countries and international regimes involved with North Atlantic shrimp have different measures for reducing bycatch. Table 74 compares these requirements.

Cod bycatch is a major issue. Although it is only about 1 percent of total shrimp landings, the cod stock is at low levels in some areas. ICES, the organization that coordinates and promotes marine research in the North Atlantic, recommends a zero

TABLE 73  
Bycatch in the North Sea and Skagerrak shrimp fisheries, 2003

Species	North Sea		Skagerrak	
	(Tonnes)	(% of total catch)	(Tonnes)	(% of total catch)
Norway lobster	15	0.3	28	0.7
<i>Pandalus</i> shrimp	3 927	85.6	3 700	86.3
Anglerfish	135	2.9	26	0.6
Whiting	11	0.2	14	0.3
Hake	13	0.3	6	0.1
Ling	34	0.7	28	0.7
Saithe	164	3.6	58	1.4
Witch flounder	5	0.1	34	0.8
Cod	125	2.7	184	4.3
Other	158	3.4	208	4.9

Source: ICES, 2005.

## BOX 35

**The Nordmøre grid**

The Nordmøre grid is the most widespread gear-related technical measure used in the North Atlantic Shrimp Fishery to reduce bycatch. The concept came from a shrimp fisherman, Paul Brattøy, who lived in the Nordmøre area of Norway, hence the name. He developed the grid, which had comparatively large bar spacing initially used to exclude the bycatch jellyfish often found on shrimp grounds.

In 1989, after a few months of testing and modification, the Nordmøre grid was introduced to the shrimp fishery. Fishing grounds that were closed because of the high bycatch of juvenile cod and haddock were opened for shrimp trawling when a grid was installed in the trawl. Fishers were at first reluctant to use the device, but when a few skilled shrimpers proved that they both managed to handle the grid and access shrimp grounds giving very good catches, the grid was a success. Soon a large proportion of the coastal fleet used the grid voluntarily.

Following the success of this device, a series of formal experiments with a grid system having narrower bar spacing (19 mm) were undertaken in Norway. The research demonstrated considerable reductions in the bycatches of cod, haddock, redfish, Greenland halibut and polar cod with minimum loss of shrimp (around –5 percent). In 1991, Canadian researchers tested grid technology on the Gulf of St Lawrence Fishery. A number of vessels were fitted with 19 mm Nordmøre grids with retaining bags fitted to the escape outlet. The catch retained was used to estimate the quantity of bycatch escaping from the trawl as well as monitor potential shrimp loss. On average, the reduction of bycatch was 97 percent with only a 2 percent loss of shrimp. Other experiments in the eastern Scotian Shelf showed bycatch reductions of 97, 100, 95 and 100 percent for plaice, cod, redfish and haddock, respectively.

*Source:* Graham, 2005; Isaksen, 1997.

TABLE 74  
Overview of technical measures to reduce bycatch

Country/region	Minimum mesh size (mm)	Nordmøre grid	Bar spacing (mm)	Bycatch limit
NAFO	40	Y	22	Y
EU	40	N	n.a.	Y
Greenland	44	Y*	26	Y
Faeroe Islands		n.a. – international fleet		
Canada	40	Y	28	Y
Norway	35–40	Y	19	Y
Iceland	36	Y	22	Y
United States of America	n.a.	Y	25	n.a.

\* The inshore sector has dispensation for a grid.

catch of cod in Skagerrak and the North Sea. At present, the Norwegian quota in these areas is about 4 000 tonnes. Norway enforces an active closure scheme to protect juvenile cod in the Barents Sea (Kelleher, 2005). In this scheme, the closed areas change in relation to the distribution of the undesirable bycatch of juveniles. Closures are determined according to the percentage of juveniles in the catch, based on combined information from research cruises, observer reports and monitoring of chartered commercial trawlers.

Poseidon (2003) examines the legislation in Norway and lists 21 decrees, regulations and directives dealing with bycatch.

TABLE 75  
Average profitability of individual shrimp vessels, 2003<sup>a</sup>

	Factory trawler	Large trawler	Medium trawler	Shrimp trawler 8–11 m	Shrimp trawler 12–28 m	Shrimp trawler > 28 m
Revenues	36 772	20 232	18 362	663	1 828	32 508
Running costs	37 992	20 741	17 969	669	1 782	34 590
Operating profit	-1 220	-509	393	-6	45	-2 082
Financial income <sup>b</sup>	864	201	118	5	25	822
Financial costs <sup>c</sup>	4 254	3 023	2 750	36	112	4 894
Net income	-3 390	-3 331	-2 632	-37	-41	-6 154
Operating profit/ revenues	-3.3 %	-2.5 %	2.1 %	-0.9 %	2.5 %	-6.4 %
Revenues/assets	0.51	0.36	0.42	0.94	0.69	0.34
Return on assets	-1.7 %	-0.9 %	0.9 %	-0.9 %	1.7 %	-2.2 %
Length (m)	61.2	49.3	40.3	10.5	16.7	60.6
G(R)T	1963	925	716	13	172	2 216

Source: Directorate of Fisheries, 2004.

Note: units: Nkr1 000.

<sup>a</sup> The average exchange rate was US\$1 = Nkr7.079 in 2003.

<sup>b</sup> Financial income is interest earned on bank deposits.

<sup>c</sup> Financial costs are primarily interest on loans.

## PROFITABILITY

There is good-quality information on shrimp vessel profitability in the annual surveys conducted by the Directorate of Fisheries. Vessel owners are required to supply data for the studies, which are scrutinized and adjusted manually by Directorate officers.

Regarding these surveys, the following should be noted.

- Because many vessels do not fish exclusively for shrimp, there is some difficulty in separating the shrimp fishing profit from that of other species.
- Some inaccuracies can occur by allocating costs without detailed knowledge of the production process.

Table 75 gives the average 2003 profitability of individual vessels in the various Norwegian fleets that catch shrimp. Large trawlers are on average 50 m in length, while medium trawlers average 40 m. The catches by factory trawlers, large trawlers and medium trawlers are 10–20 percent shrimp. Catches by the three classes of shrimp trawler shown in Table 75 are almost exclusively shrimp. It can be seen that none of the fleets show a positive net income. Some observers feel that this suggests that resource rent is dissipated by excess capacity or overfishing of stocks. It should be noted that fuel prices in 2004 and 2005 were almost double those of 2003 and that prices for cold-water shrimp have been slack.

## ENERGY INPUT ASPECTS

Shrimp trawling consumes a relatively large amount of fuel per kg of catch compared with most other Norwegian fisheries. Fuel use per kg of shrimp is shown in Table 76, assuming a price per litre of fuel in 2003 of Nkr1.7/litre. The average length of the shrimp trawl is 16.7 m and serves as a proxy for coastal trawlers, while other trawls are 60.6 m long and illustrate ocean-going vessels.

Applying these figures to the shrimp catches in Skagerrak/North Sea and the Barents Sea gives a rough estimate of total fuel consumption for the shrimp catches of 125 million litres.

Increased fuel taxes are possible in the future because of CO<sub>2</sub> and SO<sub>2</sub> emissions.

## BIOLOGICAL ASPECTS

Shrimp stocks in Skagerrak/North Sea were assessed by ICES through a cohort analysis from 1987 to 2000, but the approach was abandoned as a result of methodological

TABLE 76  
Fuel data by fleet, 2003

	Shrimp trawl 12–28 m	Shrimp trawl >28 m
Fuel costs (Nkr)	211 850	8 051 533
Fuel price (Nkr/litre)	1.7	1.7
Fuel consumption per kg/shrimp	1.9	1.9

TABLE 77  
Shrimp biomass indices in the Barents Sea

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Russian index	441	765	576	966	800	468	980		
Norwegian index	276	300	341	316	247	184	196	212	151

Source: ICES, 2005.

problems. A new assessment approach was introduced, applying a stock production model, including predator relationships. This model was used for making assessments from 2001 to 2003. A break in time-series data and criticism of the stock production model resulted in a lack of updated assessments for 2004. However, changes in LPUE and results from Norwegian trawl surveys indicate a stable stock. Models predict the stock size to be above the MSY level and ICES has concluded that a TAC of 15 000 tonnes is unlikely to have an impact on stock status.

The stock in the Barents Sea is assessed through the Russian CPUE index and the Norwegian survey index (Table 77). Stocks peaked in 1998 and then declined until 2002 when they stabilized and showed signs of moderate increase. From 2003 to 2004, the Norwegian index decreased sharply to the lowest level observed since 1987. Russian data are not available for 2003 and 2004. There is fairly good correlation between the Russian and Norwegian indices but a large difference was recorded in 2002.

Norway and many other countries aim to bring the management of their fisheries resources to a level where the stocks are not viewed in isolation but as part of the ecosystem. From an ecosystem approach, the step towards bioeconomics is likely, where costs and earnings of fisheries are also taken into account.

Biological studies have shown that, in the Barents Sea, northern shrimp change sex from male to female at the age of four to seven years. Northern shrimp is an opportunistic omnivore and, in turn, is prey for demersal fish. Cod is the most significant predator of shrimp; when capelin is abundant, it is the primary food for cod but, when less available, cod turns to amphipods, krill and shrimp. From 1992 to 1998, total consumption of shrimp by cod was estimated to be between 317 and 532 000 tonnes, which is ten times the annual shrimp catch by fishing vessels (Reithe and Aschan, 2004). With a weak capelin stock, this predator-prey relationship gives an inverse relationship between the cod and shrimp stocks. Single-species management is thus unlikely to result in economic profit maximization.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

Only a few studies of the interaction effects between shrimp trawls and bottom fauna in Norwegian waters have been published. The review of study methodology and physical and biological impacts by Løkkeborg (2005) is a good source of information on this topic.

The physical impacts of otter trawling on the sandy/gravel bottom of the Barents Sea are generally furrows (20 cm wide and 10 cm deep) and berms (10 cm high) created by the doors. In addition, rockhopper gear creates smaller depressions (Humborstad *et al.*, 2004). These marks are relatively quickly cancelled out by natural forces.

Short-term biological effects have been studied in the Barents Sea by Kutti *et al.* (2005). Experimental trawling did not seem to have a great effect on the benthic

assemblage. This is probably related to the general environment with its strong currents and large temperature fluctuations. A study of relevance to trawling was conducted in the cold Norwegian waters of the Bering Sea (McConnaughey, 2000). This study concluded that biomass, niche breadth and diversity were reduced among sponges and anemones when heavily trawled. For the more motile groups and infaunal bivalves, results were mixed.

A longer-term study was carried out in a small fjord system in Sweden (Hansson *et al.*, 2000; Lindegarth *et al.*, 2000). Results from this study could not attribute any decrease in biomass to trawling, but did note that the number of echinoderms was reduced. This is different from other studies that had shown them to be resilient to trawling disturbance. The authors conclude that the disturbance caused by trawling is relatively subtle compared with the impact from natural factors.

There is an ongoing study of the effects of trawling disturbances in the North Sea on benthic communities, the EU-funded “Managing Fisheries to Conserve Groundfish and Benthic Invertebrate Species Diversity (MAFCONS)”. As part of this study, Robinson (2003) observes that there is unequivocal evidence that the type of benthic substrate will affect the level of mortality of invertebrates in the towpath of the gear. This is partly because the level of penetration of ground gear will be affected by the type of substrate and also because there is a direct relationship between substrate type and the community composition of benthic invertebrates present in the area.

Communities in stable sediments subject to low-frequency natural physical disturbance have been shown to be less resilient to bottom trawling than communities subject to the same fishing regime in mobile sediment types.

### IMPACTS ON SMALL-SCALE FISHERIES

The Norwegian Coastal Trawl Shrimp Fishery can be considered a small-scale fishery. The impact from the offshore shrimp fisheries on coastal trawlers is considered to be slight since they fish in different areas.

Any interaction between the large- and smaller-scale shrimp fisheries is likely to occur in the marketplace. The volume of shrimp landed from the offshore fleet probably has some negative impact on the price obtained for industry-grade shrimp from the coastal fleet. The dominant effect on these prices, however, is more likely to be a result of world market supply and demand.

The Coastal Trawl Shrimp Fishery could conceivably generate conflicts with local non-shrimp fisheries. However, the lack of information suggests that problems between the coastal shrimp fleet and other fleets are few or non-existent.

### MANAGEMENT

With regard to the general management of fisheries in Norway, the Norwegian Government produced a White Paper in March 2002 stating the need for the principle of sustainable development to be integrated into management plans. More specific targets set by the White Paper include further development of the fishing industry and the implementation of an ecosystem-based management and precautionary approach. The paper also acknowledges the need to strike a balance between commercial interests, e.g. fisheries, aquaculture and the petroleum industry, and the need to protect the marine environment and biological diversity. Other future governmental plans are to reduce the fleet capacity to a level that will allow efficient harvesting of the marine resources in a sustainable way (FAO, 2005d).

As regards shrimp fisheries management, an important aspect is that Norwegian shrimp fisheries operate both in international waters in the northwest Atlantic and within the Norwegian EEZ. Accordingly, there are, two legislative management

regimes to consider: the national system and the NAFO regime.<sup>36</sup> For Norwegian shrimp fishing, the most important areas are 3M (regulated through an effort allocation scheme) and 3L (regulated by TAC), while there are a further two regimes regulating output within the NAFO area.

A licensing regime regulates access for shrimp fisheries in both the Barents Sea and Skagerrak/North Sea.

In Skagerrak/North Sea, management regulations are:

- a minimum mesh size of 35 mm;
- prohibition of fishing in water shallower than 60 m;
- a maximum of 50 percent bycatch of other species is allowed;
- the number of undersized cod and haddock cannot exceed a total of eight per 10 kg of shrimp;
- a maximum of 10 percent of undersized shrimp (<15 mm carapace length) is allowed;
- TAC is established;
- quota regulations in which fishing is divided into three periods with: (i) quotas per vessel in each period; (ii) trip quotas per vessel; and (iii) mandatory rest days between trips.

In the Barents Sea, management regulations consist of:

- a maximum of 10 percent undersized shrimp (less than 15 mm carapace length) is allowed;
- the mandatory use of sorting grids, with a maximum bar spacing of 19 mm;
- closure of an area if the bycatch in that area (in number of fish) exceeds a set limit per 10 kg of shrimp. In 2004, this number was eight for the sum of cod and haddock juveniles, ten for redfish and three for Greenland halibut.

In the Svalbard area, a 1920 treaty stipulates that Norway has full sovereignty over the islands. As a result of the somewhat special legal status, Norway has not created a full EEZ around the islands, but a fish protection zone. Norwegian fisheries regulations are in force within this zone but other countries are allowed to fish there, based on historical catch. In addition to the technical regulations in force for the shrimp fishery in the Barents Sea, each country is allocated a maximum number of vessels that can participate and a maximum number of fishing days.

The following is a chronology of regulations relevant to shrimp fishing in the Barents Sea, showing the evolution of management legislation in Norwegian shrimp fisheries.

- January 1973: minimum mesh size of 35 mm introduced.
- April 1973: vessels greater than 50 GRT require a licence.
- June 1978: no additional licences for vessels with freezers installed; not more than one licence per person; change of vessels not allowed (at the discretion of the authorities); prohibition on installation or expansion of freezing on board (at the discretion of the authorities); and licences not used for a period of two consecutive years can be withdrawn.
- March 1979: all vessels over 65 feet (19.8 m) or over 50 GRT require licences.
- June 1979: quotas are established for fresh and frozen shrimp; fishing can be stopped when the quota is reached.
- January 1980: no permission for replacement vessels will be given if fishing capacity expands.
- May 1980: the authorities can suspend fishing if undersized shrimp, cod or haddock are caught – fishing was suspended for 14 days during the summer.

<sup>36</sup> NAFO is an intergovernmental fisheries science and management body. It was founded in 1979 as a successor to the International Commission of the Northwest Atlantic Fisheries. NAFO's overall objective is to contribute, through consultation and cooperation, to the optimum utilization, rational management and conservation of the fishery resources of the convention area.

- March 1981: suspension for 14 days of fishing during the summer; vessels without freezing licences can apply to freeze if they deliver for processing on shore.
- 1982: vessels without freezing licences can apply to freeze if they deliver for production on shore.
- 1983: vessels that had applied for freezing in 1981 and 1982 can also freeze in 1983.
- 1984: vessels with permission for freezing in 1981–83 can also freeze in 1984.
- June 1984: Licences are granted to particular vessels/owners; hold capacity is determined for each vessel and larger catches are not allowed; the purchase of vessels and “transfer” of hold capacity are allowed with a maximum 20 percent increase, but the “giving” vessel has to be withdrawn from the fishery. In the case of vessel licence renewal, hold capacity can be increased by a maximum of 20 percent. A licence can be withdrawn if not active for more than two months during a two-year period.
- March 1992: mandatory use of sorting grids.
- November 2000: maximum hold capacity that can be utilized is 400 m<sup>3</sup>. If the hold capacity is transferred from another vessel, the maximum allowed is 600 m<sup>3</sup> and the giving vessel must be withdrawn from the fishery. A maximum of 70 percent of the hold capacity can be transferred.

## ENFORCEMENT

Management measures are enforced mainly through two organizations. First, all fish and shellfish must be sold through Norwegian fishers’ sales organizations, which enables the recording of landed quantities for each vessel and notification when a quota is reached. This organization is also involved in coordinating requirements for limiting the number of vessels that can fish and for mandatory resting days between fishing trips. Second, the Norwegian Coast Guard performs controls at sea, ensuring that vessels respect closed areas and maximum bycatch levels.

The effectiveness of the above measures is thought to be good, although there is probably some high grading done in the Skagerrak/North Sea fishery.

The cost of the Norwegian management and enforcement regimes is hard to quantify, as the organizations involved have a number of tasks that are not only related to resource management/enforcement. It is even harder to allocate management costs to the level of species and fisheries. Because of these difficulties, the 2004 annual estimate of total management costs by the Ministry of Fisheries is available only to the level given in Table 78.

The amounts given for the budget items in Table 78 do not reflect the full costs, but rather those related to the catching sector. With regard to dividing expenses to the catching sector, the following should be noted.

TABLE 78  
Costs of Norwegian fisheries management, 2000–03 in US\$

	2000	2001	2002	2003
Ministry of Fisheries	28 188	26 052	29 818	30 140
Membership in international organizations	5 420	6 100	6 060	6 750
Institute of Marine Research	116 355	132 527	145 873	166 500
Operations of research vessels	88 577	94 212	174 802	94 900
New research vessel	0	0	284 545	0
Directorate of Fisheries	115 514	115 963	129 436	126 978
Coast Guard	344 455	364 667	386 548	389 448
Total	698 509	739 521	1 157 082	814 716

Source: 2004 annual estimate of the Ministry of Fisheries.

Note: The average exchange rate was US\$1 = Nkr7.079 in 2003.

- Ministry of Fisheries: an estimated 40 percent of the total costs of the Ministry are related to the catching sector.
- Membership in international organizations: this includes organizations relevant to the sector.
- Institute of Marine Research: an estimated 75 percent of total costs are related to the sector.
- Operations of research vessels: 100 percent of total net costs were expected to relate to the sector.
- New research vessel: the catching sector benefits in general from all activities of the research vessels; hence 100 percent of the transfer is reported.
- Directorate of Fisheries: the figures represent 50 percent of total costs minus user payments. Of the total user payments of Nkr69 million in 2002 and Nkr52 million in 2003, about Nkr30 million are related to the catching sector in both 2002 and 2003.
- The Coast Guard: most activities of the Coast Guard are for the benefit of the capture fisheries; hence 60 percent of total costs are reported here.

## RESEARCH

Norwegian research on shrimp is almost exclusively related to stock assessment, which is carried out by the Institute of Marine Research. Until 2005, a dedicated shrimp-swept area survey was carried out in the North Sea, Skagerrak and the Barents Sea. From 2005, the Barents Sea study has been replaced by a joint ecosystem study, thereby breaking the time-series and making stock assessment more difficult. Data for an age-structured model has also been collected and processed. The continuation of this work is dependent on budget and costs are not easily quantified; however, a leading shrimp researcher estimated the cost for 2004 at about Nkr8 million.

ICES (2005) has made a number of recommendations for future research on shrimp stocks.

- It strongly recommends that the Russian and Norwegian shrimp surveys be reinstated.
- If these shrimp surveys cannot be reinstated, then the existing ecosystem survey should be calibrated by conducting a directed survey for shrimp in spring in a limited area in two consecutive years.
- Scientists should further investigate procedures for estimating the shrimp consumed by cod and give reliable estimates of biomass consumed.
- Licensing of vessels participating in the shrimp fishery must include an obligation for all countries active in the fishery to report length of and sex distributions from commercial catches.
- The authorities should enforce the submission of accurately completed logbooks; it is especially important that the use of single, double or triple trawls be recorded.
- Work on developing and evaluating assessment methods should be continued.
- Catch and effort statistics should be submitted to ICES by all countries active in the shrimp fishery in the Barents Sea and the Svalbard area by 1 September.

## DATA REPORTING

As mentioned above, all shrimp is sold through fishers' sales organizations. Catch information is obtained from the sales documents written between buyer and vessel. In the Barents Sea fishery, where there is no quota, there are probably only small problems with high grading and reporting less catch. In the Skagerrak/North Sea fishery, these issues may be more common.

The fishers' organizations report the sales documents to the Directorate of Fisheries, which compiles Norwegian catch statistics. Effort estimates are obtained from the vessel's logbooks.



Overall, statistics from the shrimp fisheries are of good quality.

### **IMPACTS OF SHRIMP FARMING**

No shrimp farming takes place in Norway. Overseas shrimp farming may affect Norwegian shrimp fishing to the extent that the current falling prices for tropical shrimp could negatively impact world market prices for some cold-water shrimp products.

### **MAJOR ISSUES**

The major issues related to Norwegian shrimp fishing are:

- the current low profitability of most shrimp fishing operations;
- competition with other countries, especially Canada, in the northern shrimp market;
- competition with warm-water farmed shrimp;
- the need to avoid cod and other important species as bycatch in the shrimp fisheries; and
- the mitigation of environmental impact.



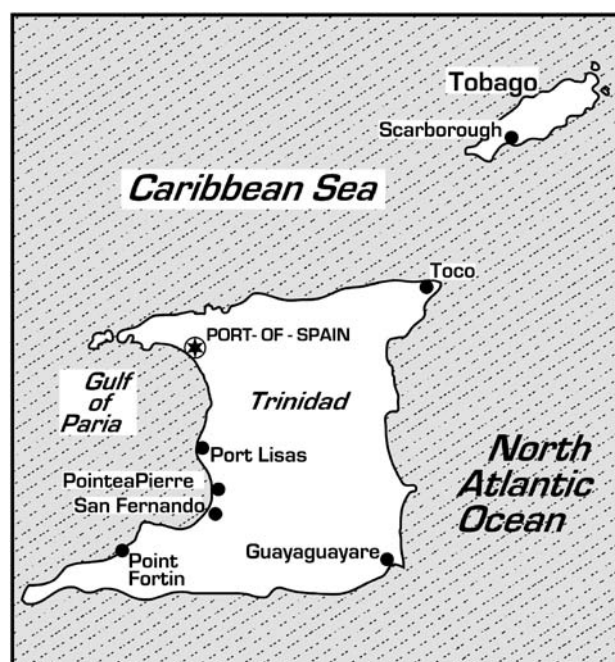
# Shrimp fishing in Trinidad and Tobago

Based on the work of Suzuette Soomai

## AN OVERVIEW

Shrimp fishing is carried out in Trinidad and Tobago by 102 artisanal trawlers, ten semi-industrial trawlers and 20–25 industrial trawlers. Annual shrimp catches from 1999 to 2004 averaged about 825 tonnes. In 2004, an estimated 785 tonnes of shrimp were landed, valued at US\$2.72 million, and 703 tonnes of groundfish bycatch, valued at US\$0.65 million. Currently, 96 percent of exports go to the states of the Caribbean Community (CARICOM).

There is a high incidental fish catch associated with shrimp trawling. This is one of the most important sources of conflict between the trawl fishery and other fisheries in the country. Other areas of concern are the full or overexploited condition of shrimp stocks as well as that of bycatch, the high levels of bycatch/discards and the degree of overcapitalization in the trawl fishery.



## DEVELOPMENT AND STRUCTURE

According to Kuruvilla *et al.* (2000), the trawl fishery developed in the early 1960s as an artisanal fishery targeting mainly the southern white shrimp, *Litopenaeus schmitti*.<sup>37</sup> The number of artisanal vessels increased from 66 in 1966 to 166 in 1969. The boats were generally 7–9 m in length, powered by two outboard engines, and set and retrieved one trawl net manually. These vessels operated out of sites on the west coast of Trinidad and fished mainly off the southwest coast of Trinidad and in the inshore waters of the Orinoco Delta on the coast of the Bolivarian Republic of Venezuela.<sup>38</sup> They returned to their bases daily to sell the catch.

In 1972, fishing permits were issued for a period of one year to 72 nationals of Trinidad and Tobago to trawl for shrimp in the Orinoco Delta region. In 1977, the first official bilateral fishing agreement was signed between Trinidad and Tobago and Venezuela permitting 60 artisanal trawlers access to inshore fishing areas of the Delta.

<sup>37</sup> The FAO name for this species is southern white shrimp *Penaeus schmitti*. In the Americas, many taxonomic authorities divide the shrimp genus *Penaeus* into two genera: *Litopenaeus* and *Farfantepenaeus*.

<sup>38</sup> The Bolivarian Republic of Venezuela, the official name of the country, is henceforth generally referred to as Venezuela.

The fishing agreement was renegotiated in 1985, permitting 70 artisanal vessels to operate under specified conditions in the Orinoco Delta for a seven-month season.

In 1991, artisanal vessels were categorized into Type I and Type II vessels. There were 113 Type I and 66 Type II vessels. Type I vessels had two outboard engines, each of about 56 HP and generally ranged in length from 6.7 to 9.8 m. They predominantly operated in the Orinoco Delta. Type II vessels ranged between 7.9 and 10.4 m in length and utilized one inboard engine of 48–110 HP. In 1995, access to the Orinoco Delta Shrimp Fishery was terminated and most of the Type I trawl fleet was subsequently refitted for other forms of inshore fishing. In 1998, 13 Type I trawlers were still operational. Both Type I and II vessels manually set and retrieve a single trawl net. They have neither storage facilities nor electronic equipment on board.

Towards the end of the 1960s and into the 1970s, development of the offshore sector was promoted. Gross (1973) states that, in the 1960s, for political and economic reasons, the capital of Trinidad and Tobago (Port of Spain) offered a desirable base from which as many as 115 industrial shrimp fishing vessels fished grounds off the Guianas and northeast Brazil. In 1969, in addition to the artisanal fleet, there were nine Gulf of Mexico-type (outrigger) industrial trawlers fishing locally. These trawlers were between 10.9 and 23.6 m in length, with 365–425 HP inboard diesel engines and a GRT of between 30 and 96 tonnes. They operated with two nets (one on each side) and were fitted out with electronic fishing aids, communication equipment and a fish/ice hold.

The local industrial vessels landed their catch in Trinidad at the state-owned National Fisheries Company (NFC) for processing and export. Between 1972 and 1979, NFC processed and exported shrimp from its fleet of 24 trawlers, in addition to purchasing some shrimp and fish from vessels owned by nationals and from foreign-based trawlers fishing on the continental shelf of northeast South America.

Between 1977 and 1985, NFC availability of shrimp and fish fluctuated and was dependent on the ability of the Trinidad and Tobago Government to obtain access for the industrial fleet to the shrimp grounds off Brazil. After 1985, NFC disposed of its trawlers, most of which were bought by nationals of Trinidad and Tobago and entered the local fishery.

The trawl fleet is now categorized into four types (I to IV) based on vessel length, engine HP and degree of mechanization. Types I and II are described above. Semi-industrial trawlers (Type III) are inboard diesel-powered and set/retrieve one trawl net at the stern; they are fitted out with electronic fishing aids, communication equipment and a fish/ice hold similar to the industrial trawlers (Type IV).

It is estimated that there were 102 artisanal trawlers (47 Type I and 55 Type II), ten semi-industrial trawlers (Type III) and 20–25 industrial trawlers (Type IV). Vessel numbers have remained more or less constant since 1991, except for the artisanal Type I fleet, which has declined significantly because of the termination of access to fish in the Orinoco Delta of Venezuela in 1995. Current numbers in the Type I fleet represent 42 percent of the 1991 fleet.

Regarding the age of the vessels, 78 percent of artisanal vessels are between five and 15 years old, while 22 percent are over 20 years old. Eighty-three percent of semi-industrial vessels are between 15 and 20 years old, while 17 percent are over 20 years old; some vessels as old as 30 years are still operating. Eighty-four percent of industrial vessels are over 20 years old. A large proportion of this fleet consists of vessels that once operated as trawlers out of the state-owned NFC during the 1970s. Other industrial vessels in the industrial fleet were purchased as used vessels from the United States of America or from locations within the Caribbean.

Artisanal vessels are constructed locally whereas semi-industrial and industrial vessels are built outside Trinidad and Tobago and imported into the country as used vessels. Therefore, in the semi-industrial and industrial fleet, the number of years that the vessel has operated in the local fishery is less than the age of the vessel.

TABLE 79  
Landings, effort and revenue for trawl fleets, 1999–2004

Year	Landings (tonnes)		Effort (hours at sea)	Value of catch (US\$ million)	
	Shrimp	Bycatch		Shrimp	Bycatch
1999	731.66	807.17	305 761	3.26	0.69
2000	848.76	854.65	306 591	3.47	0.63
2001	934.91	832.71	349 298	3.95	0.62
2002	940.00	1 004.87	346 420	3.80	0.77
2003	799.26	815.00	284 364	2.97	0.59
2004	685.09	702.82	238 726	2.72	0.65

The average artisanal trawler is owned by one individual and generally operated by a family relation of the owner. The average semi-industrial or industrial trawler is also owned by one individual, with the captain being a trained seaman. Some individuals own more than one vessel. Within each fleet, the average vessel changes ownership several times from when it first enters the local fishery.

Artisanal and semi-industrial vessels operate all year in the Gulf of Paria. The main fishing season for semi-industrial vessels runs from May to August in the Gulf of Paria and from October to March on the south coast.

Artisanal vessels operate at depths of between 1.8 and 18 m within an estimated area of 607 km<sup>2</sup>. Semi-industrial vessels operate at depths of between 9 and 41.4 m within an estimated area of 1 793 km<sup>2</sup>. Industrial vessels operate in the Columbus Channel at depths of 18–41.4 m and cover 1 740 km<sup>2</sup>; in the Gulf of Paria at depths of 9–48.6 m over an area of 1 269 km<sup>2</sup>; and on the north coast at depths of 37.8–57.6 m within a limited area of 184 km<sup>2</sup>. Most vessels operating in the coastal waters of Trinidad and Tobago trawl both day and night.

All trawl fleets operate out of sites located along the Gulf of Paria where there are five major landing sites and eight landing sites of lesser importance.

Trawling is basically a single boat operation. Vessels within a particular fleet may, however, operate simultaneously on a fishing ground when shrimp or fish aggregations occur.

#### TARGET SPECIES, CATCH AND EFFORT

According to Kuruvilla *et al.* (2000), trawlers catch several shrimp species, the most important of which is the southern white shrimp (*Litopenaeus schmitti*).<sup>39</sup> Other important species are *Farfantepenaeus subtilis*, *F. notialis*, *F. brasiliensis* and *Xiphopenaeus kroyeri*.

Catches of groundfish are considered bycatch since the higher-valued shrimp is the target species. Certain species of finfish may, however, be targeted according to market demand or during the wet season when shrimp abundance decreases. Groundfish of commercial importance commonly caught by trawl are the sciaenids (*Cynoscion* spp., *Macrodon ancylodon*, *Micropogonias furnieri*); gerreids (*Diapterus* spp.); lutjanids (*Lutjanus* spp., *Rhomboplites aurorubens*); haemulids (*Haemulon* spp., *Genyatremus luteus*, *Orthopristis* spp.); and ariids (*Bagre* spp., *Arius* spp.).

The shrimp and fish resources in the Gulf of Paria and Columbus Channel are considered to be shared stocks exploited by the fleets of both Trinidad and Tobago, and Venezuela.

Landings, effort and value of catch for trawl fleets in recent years are shown in Table 79.

As regards the geographic distribution of trawling effort, the fishing grounds around Trinidad are located in fishing area 31 of the FAO major fishing area coding system.

<sup>39</sup> The FAO name for this species is southern white shrimp *Penaeus schmitti*.

Trawling was restricted by law in 1998 to the westernmost part of the coast and is also limited in this area by season and is restricted to daytime operations. Major areas of the seafloor of the east coast shelf are not suitable for trawling but are, however, prohibited to trawlers under existing legislation in order to protect other fisheries and to prevent damage to oil installations. All trawl fleets operate in the Gulf of Paria on Trinidad's west coast. In addition, the industrial fleet operates in the Columbus Channel on the south coast of the island. Some industrial vessels trawl off the north coast of Trinidad between November and January.

Under a 1997 fishing cooperation agreement with Venezuela, fishing vessels including trawlers from both Venezuela and Trinidad and Tobago are permitted to fish all year in the Columbus Channel located to the north of Venezuela and south of Trinidad. Access is prohibited only within a band of two nautical miles from the coastline of each country. There have been problems associated with the implementation of this agreement, however, and Trinidad and Tobago trawlers do not fully access Venezuelan territorial waters.

Fishing trips vary according to fleets.

- The average fishing trip for artisanal vessels lasts for eight hours but is recorded as one day. These vessels carry a crew of two for the day operations and three for the night.
- The average semi-industrial vessel carries a crew of three and has a fishing trip of 21 hours, which is also recorded as a one-day trip.
- The average industrial vessel carries a crew of four and has a fishing trip of 15 days, of which two days are used for travelling to and from the fishing grounds.

Shrimp landings and catch rates are generally higher in the first half of the year, which corresponds to the dry season. The highest catch rates have been observed for the artisanal fleet operating in Venezuela (3–9 kg/hr at sea),<sup>40</sup> followed by the industrial fleet (2–7 kg/hr at sea). The shrimp catch rate for the artisanal fleet operating in the southern Gulf of Paria is normally 2–4 kg/hr at sea, while that for the artisanal fleet operating in the northern Gulf of Paria and the semi-industrial fleet is 1–3 kg/hr at sea.

### ECONOMIC CONTRIBUTION

Agriculture's contribution (which includes fishing) to the GDP of Trinidad and Tobago from 1985 to 2002 ranged from 5 percent in 1985 to 1.6 percent in 1999, with a steady decline in the last three years to 1.2 percent in 2002. The contribution of fishing to agricultural GDP averages 10 percent and has therefore contributed about 0.2 percent to national GDP in recent years (Kuruvilla *et al.*, 2002; Kuruvilla and Chan-A-Shing, 2002).

It is estimated, as mentioned earlier, that trawl fisheries are responsible for 20 percent of all fishery landings in Trinidad and Tobago. In 2004, the entire trawl fleet landed an estimated 785 tonnes of shrimp, valued at US\$2.72 million and 703 tonnes of groundfish bycatch, valued at US\$ 0.65 million.

In 1998, a survey of the local hospitality industry estimated an annual consumption of shrimp of 13 000 kg, valued at US\$0.4 million.

There were an estimated 324 fishers directly involved in trawling. Fish landings at sites around the country are generally purchased by wholesale buyers who transport the catch to a processing plant, wholesale fish market, supermarket or to a chain of retail vendors. Some buyers supply hotels and restaurants. There were an estimated 70 buyers in Trinidad and Tobago and their operations generate employment for approximately 210 people.

<sup>40</sup> This high catch rate is for the Trinidad and Tobago vessels operating in the Orinoco Delta. These vessels operate illegally in this area because there is no longer access under the Trinidad and Tobago /Venezuela Fishing Agreement.

In-depth demographic and socio-economic analyses of two communities where trawling is the primary fishing activity (Boodoosingh, 1995; Camps-Campins, 1995; Ramjohn, 1995) revealed that the standard of living was considerably lower for the fishing component of the community than for the non-fishing component. The number of people per household was higher than the national average and education levels were low. Consequently, the ability to seek alternative forms of employment was limited.

A study is currently in progress to establish the social and economic importance of bycatch for the trawl fishing industry and the communities supported by the industry.

### TRADE ASPECTS

Shrimp processing is handled by a variety of privately owned companies and cannot be clearly divided into industrial and artisanal shrimp processing since catches from all classes of trawlers are processed at the plants. Shrimp catches change with the season and processing follows this trend. Only about 16 processors/exporters operate on a full-time basis, handling both shrimp and finfish. There is also ad hoc processing at markets where shrimp is graded according to an existing size and species regime, prior to retailing.

Trawl catches destined for local markets are landed and sold fresh-chilled or frozen. The latter is undertaken by some industrial vessel operators who sell to wholesalers, who may then retail at the landing site and keep the catch on ice for van sales or to be sold to other fish markets, restaurants, supermarkets and private parties. Products sold locally include fresh-chilled, peeled and breaded shrimp.

Exports are mainly in the form of fresh-chilled or frozen shrimp. A small proportion of the exports are a heads-off, peeled and deveined product. The traditional export markets for shrimp used to be the United States, the United Kingdom, Canada and the CARICOM states; however, the relative importance of the latter has become more marked in recent years.

Shrimp exports increased from 288 tonnes, valued at US\$1.0 million in 1992 to 500 tonnes, valued at US\$2.8 million in 1995. This increase was accounted for mainly by demand from the United States, which received 67 percent of exports in 1995.

In 1994, the Fisheries Regulations (Conservation of Marine Turtles) requiring the use of TEDs by the local trawl fleet came into effect, in response to the legislative requirements of the United States. Access to the United States market for shrimp is now dependent on annual recertification by the United States authorities of both the semi-industrial and industrial shrimp trawl fleets. Trinidad and Tobago is currently not certified.

Shrimp exports declined after 1995 to 163 tonnes in 1998, valued at US\$1.6 million, with 96 percent of exports going to CARICOM states. This resulted from several factors, including non-competitive prices in the United States market, exclusion from the EU market and the French departments of Guadeloupe and Martinique, and an increase in local shrimp sales with growth in the national economy.

In 2003, shrimp exports were estimated at 119 tonnes, valued at US\$800 000.

### BYCATCH ISSUES

The incidental fish catch associated with shrimp trawling may be as high as 90 percent for the artisanal trawl fishery; most of these fish are juveniles of other important coastal fisheries. This aspect of trawl fisheries is one of the most important sources of conflict between the trawl fishery and other coastal fisheries in national waters (Kuruvillea *et al.*, 2000).

The high level of bycatch and subsequent discarding are the result of two main factors. First, the shrimp trawl fishery is a tropical, multispecies coastal fishery targeted by relatively unselective gear. Second, the physical structure of the vessels, i.e. limited

hold capacity and the economics of operation, only supports the holding and landing of the shrimp target species and a portion of the bycatch for which there is commercial value. Implementation of management actions to improve selectivity and limit discards has been hampered by the lack of capacity to monitor activities at sea, limited data on catches and on the economics of the fishery, and limited alternative technological options in the harvest sector.

In addition to trawlers, groundfish resources are exploited by an artisanal multigear fleet. This fleet is composed of pirogues similar to the artisanal trawlers, using monofilament and multifilament gillnets and several types of demersal line gear.

Information on shrimp trawl bycatch is given in a number of studies.

- A study of the artisanal trawl fishery conducted from 1986 to 1987 (Maharaj, 1989) identified 70 species of finfish from 40 families in the bycatch, as well as several species of portunid crabs.
- A study of the semi-industrial trawl fishery in 1989 (Amos, 1990) identified 25 species of finfish in the bycatch from 14 families.
- A 1999 study on bycatch of artisanal trawl vessels identified 30 species of finfish from 20 families, as well as several species of portunid crabs.
- A 1991 study of the catch of semi-industrial vessels identified 26 species of finfish from 18 families in the bycatch.

An estimated 90 percent of the bycatch of artisanal vessels is discarded. The total bycatch to shrimp ratio is 12.2:1 and the bycatch landed to shrimp ratio is 1.2:1. Approximately 71 percent of the bycatch of the semi-industrial fleet is discarded. The total bycatch to shrimp ratio for this fleet is estimated at 9.1:1 and the bycatch landed to shrimp ratio is 2.6:1. The most common species in the bycatch landed by the artisanal and semi-industrial fleets belong to the families Carangidae, Gerreidae, Lutjanidae, Portunidae, Sciaenidae and Triglidae.

There is limited information on the non-fish bycatch of the trawl fishery. Populations of portunid crabs, which form a significant component of this category, are thought to have increased as a result of the discards from the trawl fishery, which is likely to be beneficial to scavenger species. This observation is based on both normal fishing practices where much of the crab bycatch is returned to the sea alive and on anecdotal information obtained from interviews with participants in the fishing industry who have described this change in the fauna of the Gulf of Paria.

There may also be incidents of turtle capture by the fishery but, according to Kuruvilla and Chan-A-Shing (2002), records do not indicate a high incidence of turtle capture in the areas where trawling is permitted.

The imposition of TED requirements on the semi-industrial and industrial trawl fleets was not well accepted by the industry. The requirement to use these devices is particularly unpopular with the semi-industrial fleet for which the United States export market is of less importance compared with other CARICOM markets. The fleets also claim that the device traps large debris in the net, causing damage to the net or significant loss of catch since shrimp is diverted away from the codend (Kuruvilla and Chan-A-Shing, 2002).

### PROFITABILITY

From surveys conducted in 1997 and 2000, the net profit (gross cash flow less depreciation and imputed interest costs) for an average semi-industrial trawler was estimated at US\$8 899, with the average artisanal and industrial vessels experiencing net losses of US\$389 and US\$996, respectively. The return on investments (net profit before tax as a percentage of the invested capital), indicating the profitability of trawling in relation to alternative investments, was estimated at -4 percent, 15 percent and -1 percent for an artisanal, semi-industrial and industrial trawler, respectively (Kuruvilla *et al.*, 2002).



Most vessel owners do not keep good financial records and hence do not account for depreciation in their operations. It is also possible that some costs may have been overestimated or revenues underestimated.

In examining the profitability of the shrimp trawl fleets, the following should be noted:

- Boat owners perform most of the labour themselves and further reduce costs by purchasing used engines and parts in order to make a profit or break even.
- The taxes paid by an average trawler owner in each vessel category are fairly negligible.

Kuruvillea *et al.* (2002) adjust the profit and loss account for an average vessel in each trawl fleet to examine the impact of subsidies on economic performance.

- *Scenario A*: without the subsidy on fuel and oil, and without the value-added tax (VAT) waiver on marine supplies. This cost, estimated at US\$708 for an artisanal trawler, would increase vessel running costs. Most of the semi-industrial and industrial trawlers would not be affected by the removal of these two subsidies since most of them are VAT-registered and hence claim VAT back on all inputs to the business.
- *Scenario B*: without two of the main services offered to the industry by the Fisheries Division (landing site facilities and fisheries management). The cost for the use of landing site facilities is estimated at US\$484/boat/year; the fisheries management cost is estimated at US\$1 081/year for an artisanal vessel and US\$13 887/year for semi-industrial and industrial vessels. The estimated fisheries management cost of US\$2.5 million was allocated to the artisanal, semi-industrial and industrial fleets based on the ratio of the annual revenue of the particular fleet to the total annual revenue of all fleets. These costs would increase the fixed costs of the vessels.
- *Scenario C*: the impact of including a licence fee for access to the fisheries resources. It was determined that the licence fees collected from each of the artisanal, semi-industrial and industrial fleets should earn 3 percent of the annual ex-vessel value of the catch from the respective fleet. The licence fee was estimated to be US\$277/year for an artisanal vessel and US\$3 435/year for the semi-industrial and industrial vessels. The implementation of a licence fee would increase the fixed costs.

Considering the above scenarios, in the case of an artisanal trawler, the return on investment declines from -4 percent in the current scenario with subsidies to -8 percent in Scenario A, -23 percent in Scenario B and -25 percent in Scenario C. For a semi-industrial trawler, the return on investments decreases from 15 percent in the current scenario to -9 percent in Scenario B and -15 percent in Scenario C. In the case of an industrial trawler, the return on investments declines from -1 percent in the current scenario to -13 percent under Scenario B and -16 percent under Scenario C.

The increase in fuel cost over the years has caused an increase in operation costs for all trawler types and has consequently reduced profits (see following section).

### ENERGY INPUT ASPECTS

Under the Agricultural Incentive Programme, a subsidy on fuel for use in fishing vessels is available to boat owners whose fishing vessel and engine are registered with the Fisheries Division. The subsidy is provided on petrol, diesel and oil under a quota system based on the size of the engine. These subsidies are small in relation to the cost of fuel. In 2000, government subsidies were: US\$0.02/litre for petrol at a price of US\$0.40 (TT\$2.52)/litre; US\$0.02/litre for diesel at a price of US\$0.21 (TT\$1.32)/litre; and US\$0.12/litre for oil at a price of US\$2.26/litre. Prices in 2006 for petrol and diesel were US\$0.44 and US\$0.24/litre, respectively.<sup>41</sup>

<sup>41</sup> The average exchange rate used was US\$1 = TT\$6.30 (April 2006).

The average trawler owner attempts to compensate for the loss in profits caused by increased fuel costs by increasing the sales price for the catch. This usually works when catches are low, demand is high and consumers pay the increased prices. Trawler owners are also attempting to reduce fuel usage by modifying some fishing practices, such as not trawling against the tidal current.

### BIOLOGICAL ASPECTS

Brown shrimp (*Farfantepenaeus subtilis*) is one of the dominant species exploited by the trawl fleets of Trinidad and Tobago and Venezuela in the Orinoco-Gulf of Paria region. Joint biological analyses were conducted from 1973 to 1996 and from 1973 to 2001.

- Results of the study using data for *F. subtilis* for 1973–96 indicate an MSY of approximately 1 300 tonnes with a fishing effort of 13 000 days at sea for both fleets combined. The study also showed that the fishing effort should be maintained sufficiently below these days at sea for several years to allow stocks to rebuild (Alió *et al.*, 1999a).
- The second study, using data for 1973–2001, indicates that the *F. subtilis* resource is severely overfished and that overfishing has been taking place since the 1970s. Current fishing mortality was estimated to be more than three times greater than the fishing mortality at MSY and the current biomass is less than one-quarter (23 percent) of the biomass at MSY, with MSY being 1 000–1 200 tonnes. The study recommended that measures be introduced to reduce fishing mortality and that Trinidad and Tobago and Venezuela develop a common strategy for effort control (Die *et al.*, 2004).

An assessment using data for 1990–91 for white shrimp (*Litopenaeus schmitti*) and brown shrimp (*F. subtilis*) exploited by the Trinidad artisanal fleet in the Orinoco Delta, showed these resources to be fully fished to overfished. No increase in fishing effort was recommended (Lum Young, Ferreira and Maharaj, 1992).

Bioeconomic analyses of the shared Trinidad and Tobago/Venezuelan shrimp fishery from 1995 to 1998 indicate that at levels of effort during that period (8 175 days at sea for the Trinidad and Tobago fleet and 9 348 for that of Venezuela), there was a 39 percent probability of the biomass of *F. subtilis* falling below sustainable levels. The studies suggested that the shrimp resources were overexploited and a reduction to 80 percent of current levels of effort would reduce this probability to 15 percent and improve profits for the fishery by 12 percent (Seijo *et al.*, 2000; Ferreira and Soomai, 2001).

Assessments were conducted for southern pink shrimp (*Farfantepenaeus notialis*) and Atlantic seabob (*Xiphopenaeus kroyeri*) in the Trinidad and Tobago trawl fishery from 1992 to 2002 (Ferreira and Medley, 2005). Overall, results suggest full exploitation to overexploitation of the two shrimp stocks. Other findings included the following.

- Biomass per recruit models developed for *F. notialis* females suggest that the stock is fully exploited and that the catch is predominantly very young, small shrimp. At the current level of effort, the biomass of *F. notialis* remaining in the sea is estimated to be 39 percent of the unexploited biomass of the species, which is just about at the limit reference point of 40 percent.
- Biomass per recruit models developed for *X. kroyeri* females suggest that the stock is overexploited. At the current level of effort, the biomass of *X. kroyeri* is 22 percent of the unexploited biomass of the species, i.e. below the limit reference point. The effort exerted on this species would have to be reduced to less than 60 percent of the current level, in order to bring the biomass up to an acceptable level (i.e. 40 percent of the unexploited biomass).
- Based on a yield per recruit model for the two species combined (*F. notialis* and *X. kroyeri*), the 2002 fishing effort of the trawl fleets targeted at these species is

estimated at about 71 percent of the effort required to obtain the maximum yield from the fishery.

- Following on from the above, the management recommendation is to control fishing effort on these stocks by limiting the numbers of trawlers, with a view to a reduction in fleet size. This will require the implementation of a licensing system for trawlers and updating of fisheries legislation to facilitate a limited entry fishery (see section *Management* below.)

The biological status of some important elements of the shrimp trawl bycatch is described as follows.

- Biological assessments of *Micropogonias furnieri* (croaker) and *Cynoscion jamaicensis* (Jamaica weakfish) in the groundfish fishery in the Gulf of Paria and the Columbus Channel of Trinidad and Tobago were conducted from 1989 to 1997 (Soomai *et al.*, 1999). These assessments used data from trawl fleets and the artisanal gillnet and line methods catching groundfish in a depletion model. The results showed that fishing mortality values were well above the optimum biological condition of the species and that the resources are not generating optimum yield and are most likely experiencing potential spawning decreases. Results clearly indicate an extremely intensive exploitation of these resources.
- In 1999, a joint analysis by Trinidad and Tobago and Venezuela on *M. furnieri* in the Gulf of Paria and the Columbus Channel was conducted, using data from 1987 to 1998 (Alió *et al.*, 1999b) from all trawl fleets, as well as the artisanal gillnet and line fleets of Trinidad and Tobago, in a surplus production model. Results show that the current level of effort exceeds the levels at which yields of both species are maximized. MSY for croaker is 1 500 tonnes and was generally exceeded from 1987 to 1994 and in 1998, with landings ranging from 1 800 to 2 800 tonnes per year. These analyses used limited information from Trinidad and Tobago's industrial trawl fleet, as well as information on the size structure of the species caught by its gillnet and line fleets.
- A bioeconomic assessment of *M. furnieri* was conducted for the artisanal groundfish fishery of Trinidad and Tobago, using data for 1989–97 in a biodynamic economic model (Soomai and Seijo, 2000). Results show that a major decline in yield, net revenues and biomass of both species was expected if open access is continued. The net present value and the biomass of *M. furnieri* were examined under alternative management strategies, including combinations of limiting or banning certain artisanal gears. The recommended management option was to limit effort of all fleets to maintain the resource and the profits for the fishery at sustainable levels.

These results on shrimp trawl bycatch were considered preliminary because of limitations of the data and models, which are expected to be addressed in future research and assessments of the fishery. However, a precautionary approach should be applied to the management of the trawl fishery, based on the best scientific evidence available.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

To date, there have been no specific studies to determine the impact of trawling on the benthos in national waters. Some information suggests that the trawl grounds are swept twice a year by the fleets, although this is probably an underestimate for the inshore areas to which the artisanal vessels are restricted.

### IMPACTS ON SMALL-SCALE FISHERIES

No specific studies of the impacts of shrimp fishing on small-scale fisheries have been conducted to date. It is well known, however, that the bycatch of the trawl fishery is also caught in the artisanal gillnet and line fleets. Assessments of a few commercially

important fish species (see *Biological aspects* section above) have been conducted and can give some feedback on impacts on small-scale fisheries.

Results of a 1994 local knowledge survey (Ramjohn, 1995) showed that non-trawl fishers perceived that trawling is the greatest threat to fishing in the Gulf of Paria. All respondents (trawl and non-trawl) noted a decline in individual catches and most thought that damage to the seafloor and destruction of juvenile fish by trawling were responsible. Trawl respondents replied that the major cause was pollution; however, 39 percent of all respondents felt that trawling was responsible, while artisanal trawlers held industrial trawlers responsible and industrial trawlers claimed that the inshore activities of artisanal trawlers were responsible.

In 1999, in the preparatory phase of a project to reduce the environmental impact of shrimp trawling (Project EP/GLO/201/GEF), a survey of trawl fishers was conducted to examine perceptions on issues related to shrimp exploitation and the impacts of trawling on resources and the environment (Kuruvilla, 2001). In 2000, a national workshop was held with the fishing industry (FAO and Fisheries Division, 2001) to discuss the results of shrimp and groundfish assessments. The general perception was that pollution of the inshore area through industrial and agricultural runoff contributed to the significant decrease in fish populations. Participants were also of the view that trawling for shrimp in inshore areas, which is prohibited under national legislation, is responsible for a further decrease in resources through the removal of large numbers of juvenile fish as bycatch, and for physical damage to fishing grounds. Fishers stated that there is an urgent need for the government to enforce the regulations governing area/zone restrictions, particularly with regard to artisanal vessels.

## MANAGEMENT

The legislative basis for the management of domestic fishing in Trinidad and Tobago is Fisheries Act 1916 and its subsequent amendments, the Fisheries (Amendment) Act 1966 and the Fisheries (Amendment) Act 1975. The Act applies to all rivers and tidal waters in Trinidad and Tobago and to the 12-nautical-mile territorial sea; it does not apply to the EEZ.

The Act is limited in scope and merely empowers the Minister in charge of fisheries to make regulations controlling mesh size, form and dimensions of nets and appliances for fishing, and the manner of their use. It sets minimum sizes for species that may be fished or sold, declaring prohibited areas for fishing and prohibited fishing for specified species, either absolutely or by season or area. Furthermore, the Act prohibits the sale of fish or any species of fish, again either absolutely, or by season or area. Sanctions of US\$323 or six months' imprisonment are imposed for most infractions.

Policy directions for the trawl fishery are influenced by the recognition that it cannot be managed only for the benefit of the shrimp resources harvested, but also for reducing its impact on other inshore species taken as bycatch. The high proportion of finfish bycatch and its negative impact on the coastal ecosystem, as well as on the resources harvested by other fisheries, also influence policy decisions on the fishery.

Management of the shrimp and groundfish fisheries needs to take into consideration many factors, including:

- the fully exploited or overexploited condition of targeted stocks as well as that of bycatch;
- high levels of bycatch/discards comprising juveniles of commercially important species targeted by other gears;
- the degree of overcapitalization in the trawl fishery;
- the socio-economic importance of artisanal fisheries to the stability of rural coastal communities;
- interaction between fleets exploiting the same resources, often leading to conflict;

- the need for cooperation in the management of the shrimp and groundfish resources exploited by the fishing fleets of both Trinidad and Tobago, and Venezuela; and
- the implications of semi-industrial and industrial trawlers using or not using TEDs.

Current management measures focus on fishing areas and fishing gear. Under Section 4 of the Fisheries Act, Fisheries (Control of Demersal [Bottom] Trawling Activities) Regulations 1996, and Fisheries (Control of Demersal [Bottom] Trawling Activities) (Amendment) Regulations 2001 specify restrictions on the areas of operation of the different trawler fleets and give gear specifications.

- Trawling is prohibited on the east coast of Trinidad and within 12 nautical miles of the coast of Tobago. This is a result of the topography, although there are some trawlable areas in the shallow waters in the southeast. Trawling is permitted on the north coast of Trinidad outside two nautical miles in the area west of Sauté Dead from 15 November to 15 January, but not at night, so as to reduce the impact on other established fisheries. It is permitted on the south coast of Trinidad outside two nautical miles. Trawling is subject to a zoning regime in the Gulf of Paria: (i) artisanal trawlers are permitted to operate outside one nautical mile from the coast; (ii) semi-industrial trawlers are permitted in depths of six fathoms (1 fathom = 6 ft/1.83 m) or more; and (iii) industrial trawlers are permitted in depths of ten fathoms or more.
- The stretched mesh size of the codend of the trawl net must be no smaller than approximately 7.5 cm (3 in) when trawling for fish and approximately 3.5 cm (1.38 in) for shrimp.

The Fisheries Act of 1916 does not provide a legal basis for controlling access by nationals of Trinidad and Tobago to fisheries resources under the national jurisdiction. Efforts to limit fishing effort in the trawl fishery have subsequently been carried out through a 1988 Cabinet decision to restrict entry of new vessels, both artisanal and industrial. This measure is effective to a greater extent for the semi-industrial and industrial fleet where permission for the importation of any new fishing vessel must be obtained from the Minister in charge of fisheries.

Under Fisheries (Conservation of Marine Turtles) Regulations 1994, the semi-industrial and industrial fleets are required to use TEDs on their nets. These regulations fall under Section 4 of the Fisheries Act and were drafted in accordance with trade requirements for the export of shrimp to the United States and the stipulations under Section 609 of United States Public Law. Regulations have also been drafted that address the type, specifications and proper installation of TEDs.

The Fishing Industry (Assistance) Act of 1955 makes provisions for the granting of financial assistance to the fishing industry by such means as fuel rebates, tax waivers and subsidies on fishing equipment.

Existing legislation is inadequate as a legal basis for a modern national fisheries management system. A Fisheries Management Bill prepared in 1995, which will be known on finalization as the Marine Fisheries Management Act, will repeal the Fisheries Act of 1916. The Marine Fisheries Management Act will provide for the preparation of fishery management plans and, accordingly, will control and limit access to fish resources through the establishment of a licensing system for both local and foreign fishing vessels.

A draft management plan for the trawl fishery proposes that trawler owners be required to hold entitlements to the fishery, which should be transferable, provided that the replacement vessel does not have a greater HP or fishing power, and provided that replacement of the vessel is in keeping with the level of fishing effort approved in the plan.

The current thinking of the Fisheries Division is that there is limited opportunity for reducing fishing effort in overexploited areas by expansion of fishing into new

areas. The artisanal Type II fleet is limited in its operations to the shallow inshore waters of the Gulf of Paria. There are no real opportunities for this fleet to expand its area of operation or to establish alternative trawling areas in waters under national jurisdiction. The situation for the semi-industrial fleet is similar in that, although mechanized, vessels are limited through operating depth and storage capacity to operations in the Gulf of Paria. The industrial fleet, although capable of a greater range in area of operation, is limited by topography and the current legislative regime, which does not favour expansion in trawling activity in national waters. There have not been any government initiatives to seek access for demersal trawlers to alternative domestic fishing grounds and it is unlikely that any request to do so would be treated favourably.

Alternative opportunities for the trawl fleets are available only through the refitting of vessels for other forms of fishing, although it is only the industrial fleet that has the capability of exploiting offshore resources. The results of preliminary assessments of inshore fisheries resources suggest that most of these resources are either fully exploited or overexploited. This supports the contention that the Fisheries Division be provided with the means to control fishing effort.

### ENFORCEMENT

Under the Ministry of National Security, the Trinidad and Tobago Coast Guard is responsible for maritime surveillance, monitoring and enforcement of fisheries regulations as well as rules under fisheries agreements. It is a major participant in marine delimitation negotiations and carries out inspections of fishing vessels for compliance with fisheries regulations.

In 1999, the Fisheries Division, in collaboration with the Coast Guard, implemented an enhanced programme of dockside and at-sea inspections of semi-industrial and industrial trawlers to ensure compliance with Fisheries (Conservation of Marine Turtles) Regulations 1994, regarding the use of TEDs in their nets. The Fisheries Division is also currently involved in establishing a Fisheries Monitoring Surveillance and Enforcement Unit (FMSEU), which was commissioned in June 2004 after obtaining Cabinet approval. FMSEU will undertake, *inter alia*, visits to fish landing sites and at-sea surveys to ensure compliance with fisheries regulations and to enforce them where necessary. It will conduct inspections of processing plants and spot checking of shipments bound for export at the various ports in Trinidad and Tobago, to prevent mislabelling of goods.

With regard to the costs of fisheries management and associated enforcement, there are no precise calculations; nevertheless, the following estimations from 2000 are available.

- It was estimated that 50 percent of the Fisheries Division's recurrent budget (personnel, goods and services) was allotted to administrative activities related to fisheries management services, which includes data collection, research and monitoring and control activities. This cost was approximately US\$387 000.
- It was estimated that 10 percent of the recurrent general administration budget of US\$6.5 million for the Ministry of Agriculture, Land and Marine Resources was allocated to the administration of fisheries affairs, based on the contribution of fisheries to agricultural GDP.
- It was estimated that fisheries-related services provided by the Coast Guard were valued at 10 percent of total costs, which included operating costs, recurrent expenditures (personnel), depreciation costs on fleets of vessels and aircraft, and depreciation costs on land-based infrastructure. This cost was approximately US\$371 000.

## RESEARCH

The Fisheries Division of the Ministry of Agriculture, Land and Marine Resources is responsible for the assessment, management and conservation of the marine fisheries resources of Trinidad and Tobago, and for the provision of extension and specialized information services on marine fisheries. These responsibilities include the implementation of ongoing fisheries monitoring programmes such as catch and effort, economic and biological data collection on the major commercial fish species for use in stock assessments, and the development of fisheries management plans.

Regarding research on shrimp fisheries, a biological sampling programme for shrimp has been in place since the early 1990s. Length frequencies have been collected from the artisanal, semi-industrial and industrial trawl fleets, and computerized in Excel. From the 1990s to the 2006, within the framework of the Western Central Atlantic Fishery Commission (WECAFC) ad hoc Working Group on the Shrimp and Groundfish Resources of the Brazil-Guianas Continental Shelf, a series of subregional workshops was conducted, involving Brazil, French Guiana, Guyana, Suriname, the Bolivarian Republic of Venezuela and Trinidad and Tobago to assess shared stocks of shrimp and groundfish.

Between 1994 and 1998, Trinidad and Tobago participated in the Shrimp and Groundfish Subproject under the CARICOM Fisheries Resource Assessment and Management Programme (CFRAMP). CFRAMP collaborated with the FAO/WECAFC ad hoc working group in conducting shrimp and groundfish assessments. The Programme has now been replaced by the Caribbean Regional Fisheries Mechanism (CRFM), which has formed similar working groups to ensure continuity in the assessment work initiated under CFRAMP and FAO/WECAFC. CRFM coordinated its first scientific workshop in June 2004.

Trinidad and Tobago is participating in a GEF-funded global project coordinated by FAO, Project EP/GLO/201/GEF, "Reduction of the Environmental Impact from Tropical Shrimp Trawling through the Introduction of By-catch Technologies and Change of Management". The project seeks to reduce the negative environmental aspects of bottom trawling by removing barriers to the introduction of environmentally friendly gear and fishing practices. One of the specific objectives of the project is the reduction of discards of fish captured by shrimp trawlers. This involves gear research and subsequent modifications to reduce bycatch.

The current Trinidad and Tobago/Venezuelan Fishing Agreement outlines a Protocol on Fisheries Research, which is a collaborative approach to research on shared fisheries resources. To date, this Protocol has not been fully activated.

The average annual budget for research in the Fisheries Division is estimated at US\$170 000. The budget supports the ongoing catch and effort, biological sampling programmes, participation in regional scientific working groups and counterpart funding for the GEF trawl project. It is estimated that 35 percent of the annual research budget is focused on the demersal trawl fishery (shrimp and groundfish resources), and another 35 percent on pelagic fisheries. The remaining 30 percent covers information services shared equally between demersal and pelagic fisheries.

## DATA REPORTING

Fisheries catch and effort statistics have been collected in Trinidad and Tobago since 1954, mainly through two wholesale fish markets. In 1959, a formal onshore collection programme was launched at specific beaches and focused on artisanal fisheries. By the end of 1999, there were full-time enumerators at 17 landing sites, five of which are the main trawl landing sites. This data collection system has remained basically intact over the years in terms of the nature of the data recorded and the process by which it is recorded (Ferreira, 2000).

In 1991, a logbook system was introduced for the semi-industrial and industrial shrimp trawlers. Captains were expected to record catch data for each of the shrimp and fish components of the catch, including discards. By May 1992, however, owners stopped submitting logbook returns because of a number of commercial developments in the industry. There are plans to reimplement the logbook system for these fleets. Estimates of landings for the trawl fleets are being determined in the interim from data collected by the biological sampling team.

Catch and effort data collectors employed by the Fisheries Division live close to the beaches and record data on the beach, either from fishers directly or from the vendors who meet them on the beach to purchase catches from fishing vessels landing daily. The main document used for collection purposes is the Return of Fish Landed form. Data are collected for each vessel on vessel registration number, times of departure and return, number of crew, gear type used, weights of "species" landed (grouped by local names), ex-vessel price per "species" and area fished.

The catch and effort data collection system provides reasonably good coverage of vessels, since data collectors have been traditionally employed at the major landing sites throughout the years and each enumerated site is assumed to be representative of artisanal fishing activity within a zone. Data are recorded for at least 20 days selected at random in a month. When the collection system was first established in 1959, there was only an artisanal inshore fishery; the system began to cover the industrial fleet in 1995.

There are plans to implement an observer/at-sea sampling programme to obtain information on discards and verify logbook returns. In the interim, an at-sea sampling programme covering all fleets was initiated in 1999.

In the late 1990s, the Fisheries Division established a monitoring system for fish imports and exports, primarily to be able to provide actual and reliable export data. The system requires the return of export licences of the previous shipment, certified by customs, from all exporters. This involves detailed information on all shipped fish and fishery products prior to approval being granted for additional licences. The system is used to verify data from the Central Statistical Office.

The current catch and effort system has been developed in the Windows version of the Oracle Relational Database Management System (RDBMS). The Fisheries Division maintains a server on which the Oracle RDBMS resides, and the catch and effort application is a multi-user operating system. The system provides for secure, efficient and effective storage of landings data that can be readily retrieved. The combined strengths of both the operating system and RDBMS allow for extensive data collection.

A frame survey to determine numbers of fishing vessels, fishers and changes in operations is conducted at least every five years. However, with regard to trawling, current numbers of operating vessels are usually known, since the catch and effort data collection system has almost total coverage of trawl landing sites. A formal system to yield accurate data on the number and type of operations of the marketing and distribution subsector has yet to be instituted.

The nominal landings and effort statistics collected on major (enumerated) beaches are used to generate data for secondary (non-enumerated) beaches, where it is assumed that similar fishing takes place, at the same intensity. The nominal catch landings and fishing effort data are raised by two factors. A "first raising factor" adjusts the nominal statistics to account for the non-enumerated fishing days at each enumerated beach, i.e., fishing days on which the field data collector did not collect information. A "second raising factor" adjusts the first raised statistics to account for non-enumerated vessels, i.e., vessels that fished but for which no data were recorded.

Landings from trawling have been computerized since 1991. Trawling raised landings reports are produced for each enumerated beach by gear (trawler type) and fishing area. Total trawl landings and effort are estimated by fleet type and fishing area.



### **IMPACTS OF SHRIMP FARMING**

Domestic shrimp farming has no effect on shrimp fishing because for the moment there is no shrimp aquaculture in Trinidad and Tobago.

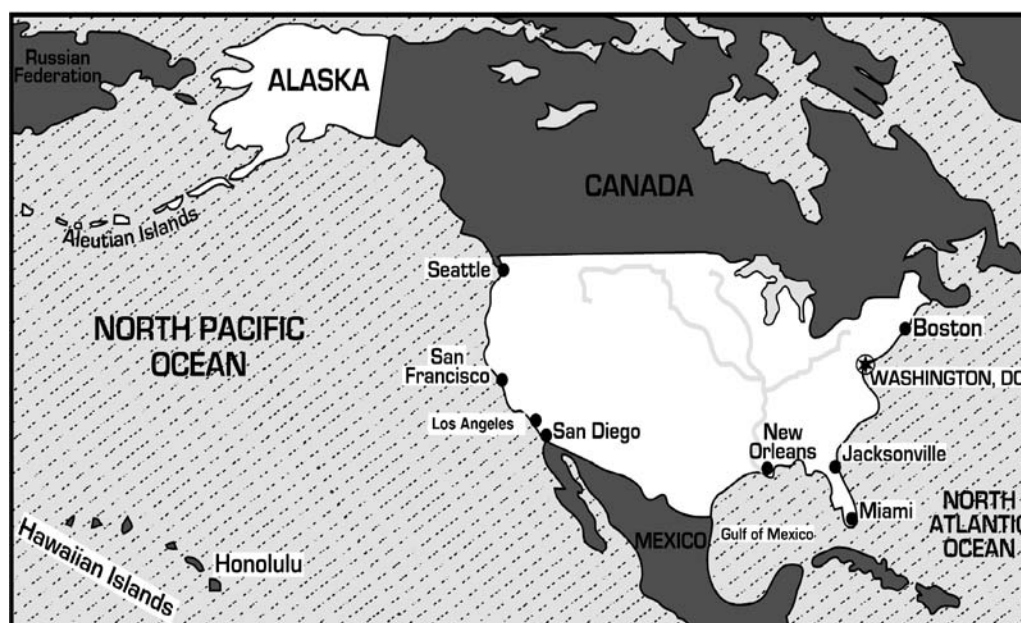
### **MAJOR ISSUES**

The important issues related to shrimp fishing in Trinidad and Tobago are:

- the need to reduce shrimp fishing effort, but a lack of political will and legal tools to do so;
- the present low or negative profitability of shrimp fishing;
- the fact that while fishing effort is growing, the geographic area open for trawling is extremely limited;
- the ban on exporting to the United States; and
- the negative impacts of industrial trawling on small-scale fishing.



# Shrimp fishing in the United States of America



## AN OVERVIEW

Two main types of shrimp fisheries operate in the United States of America: those that target warm-water shrimp off the southeast Atlantic coast and the Gulf of Mexico, and those that target fisheries for cold-water shrimp in the northeast and northwest of the country. In terms of value, shrimp is the second most important fishery after crab.

In recent years, combined landings for domestic shrimp fisheries have been about 144 000 tonnes annually, with the warm-water fisheries responsible for over 90 percent in 2004 (Table 80). The United States domestic production is dwarfed by shrimp imports of 500 000 tonnes per year, over 80 percent of which is from aquaculture.

The domestic shrimp market has greatly expanded over the past few years. Shrimp is the most important seafood item for United States consumers – currently at 1.9 kg<sup>42</sup> edible weight per year. The United States market is now the largest in the world for shrimp, followed by the EU.

Despite record demand for shrimp in the United States, real and nominal prices have declined, primarily as a result of cheaper imported shrimp. This downward pressure on dockside prices, together with the increasing operational costs of domestic shrimp vessels, has resulted in severe financial difficulties in many United States shrimp fisheries.

TABLE 80  
Recent commercial shrimp landings (tonnes)

	2003	2004	Average (1999–2003)
New England	1 121	1 304	1 388
South Atlantic	10 780	11 457	12 146
Gulf of Mexico	115 566	116 519	111 438
Pacific coast	15 538	10 552	18 886
Other	1	0	3
Total	143 007	139 833	144 185

Source: NMFS database.

<sup>42</sup> Seafood weights in the United States are often expressed in pounds (1 pound = 0.453 kg).

## DEVELOPMENT AND STRUCTURE

### Warm-water commercial shrimp fishing

Commercial shrimping began in about 1817 on the Atlantic coast of the southern United States, using cast nets and haul seines. In the early part of the twentieth century, the Mississippi haul seine fishery used 12-m sailing schooners to transport fishers 32–128 km to the fishing grounds to catch shrimp for canneries. In Florida, between 1912 and 1915, the large mesh otter trawl used to capture finfish was modified for shrimp fishing. By 1930, these new trawls produced about 90 percent of the shrimp catch, which was mostly canned or air-dried. Over the following decades, trawling and the use of larger vessels allowed fishing in deeper waters further from the shore where bigger catches could be made. By about 1950, most of the potential fishing grounds in waters adjacent to the southeastern states had been discovered. The United States shrimp fleet then expanded its operations to the east coast of Mexico and the western Caribbean Sea. From the early 1960s to the early 1970s, 632–860 United States vessels fished off Mexico. In 1976, a treaty between the United States and Mexico resulted in United States shrimping in Mexican waters being phased out by the end of 1979. From 1959 to 1979, up to 207 United States shrimp vessels fished off the northeastern coast of South America (Iversen, Allen and Higman, 1993).

Poseidon (2003) discusses recent changes in shrimp fishing gear in the Gulf of Mexico. From the mid-1970s through the early 1990s, the trawls used by the offshore shrimp industry changed significantly. Initially, the fleet used high-opening single balloon trawls that fished high in the water column. By the early 1980s, they were replaced by twin trawls with a low vertical opening, which fished lower in the water column, making it possible for the vessel to increase the swept area with the same or less energy. By the early 1990s, these were largely replaced by quad trawls, i.e. two trawls are towed on each side, with the trawls connected by a sledge, and otter boards are only placed at the outside wings. Again, this increased the fished area of the bottom with equal or less energy by reducing the height that the nets fished in the water column.

Cascorbi (2004b), citing several primary sources, states that otter trawls take 91 percent of the shrimp catch in the Gulf of Mexico and South Atlantic (GSA) region, skimmer trawls take 7 percent and various kinds of cast nets or stationary butterfly nets take the remaining 2 percent.

The shrimp harvesting industry in the GSA region represents one of the most economically important components of all the domestic commercial seafood harvesting sectors in the United States. In 2004, commercial shrimp landings from the GSA region were estimated at 127 000 tonnes, with a dockside value of US\$409 million. This represents about 91 percent of the volume of all United States domestic commercial landings of shrimp for the year. Currently, there are more than 16 000 licensed vessels in the Gulf of Mexico and over 2 200 in the South Atlantic. There are numerous differences in shrimp fishing between the various parts of the region. For example, Louisiana's catch is dominated by smaller shrimp, which are targeted by the many smaller, inshore shrimp vessels that characterize the state's shrimp fleet. In contrast, the Texas shrimp fleet is characterized by larger vessels that fish further offshore for bigger, more valuable shrimp (Ward *et al.*, 2004; NMFS, 2005).

In 2005, hurricanes had a major effect on shrimp fishing in the Gulf of Mexico (Box 36).

### Cold-water commercial shrimp fishing

Commercial fishing for cold-water shrimp began in about 1869 on the Pacific coast of the United States and in 1938 on the Atlantic coast. The original Pacific coast fishing grounds were in San Francisco Bay, later in the Puget Sound area of Washington and, by 1916, shrimp fishing was permanently established in southeastern Alaska. In about 1952, shrimping began in the offshore waters of Washington southwards to California.

## BOX 36

**Effects of the 2005 hurricanes on shrimp fishing**

The impacts of the hurricanes on fishing activity were estimated by comparing fishery landings in September 2005 (after Katrina) with September catches from the same states in 2003 and 2004. In 2003–04 the average September catches of shrimp were valued at US\$44 million. Based on figures obtained for September 2005, there was a 97 percent reduction in shrimp landings. Hurricanes Katrina and Rita devastated the shoreside infrastructure and fishing fleet in a wide swathe from Mississippi Sound through the Louisiana Delta, including parts of Florida Keys, western Louisiana and eastern Texas. There is no conclusive estimate of the number of fishing vessels sunk or driven ashore, but the United States Coast Guard initially estimated the number at between 3 500 and 5 000. This estimate includes nearly 2 400 commercial vessels and 1 200 recreational boats. Shoreside infrastructure was devastated in many areas of Mississippi, eastern Louisiana and Alabama. In contrast, it appears that this did not have a significant impact on populations of shrimp and finfishes in offshore areas of the northern Gulf of Mexico. Preliminary results of the survey show that shrimp and bottom fish abundance was the same or slightly higher than in the autumn of 2004, with shrimp and other valuable species relatively abundant and widely distributed (Hogarth, 2005).

In the late 1950s and early 1960s, Gulf of Mexico-style trawls began appearing on west coast shrimp boats. By 1975, in the Gulf of Alaska alone, 54 000 tonnes of shrimp were produced. The number of trawl vessels in the Pacific coast shrimp fishery reached a record high in 1980 but has since declined. Japan and the former Soviet Union fished shrimp off the Alaska coast in the 1960s and 1970s. Most of the fishing in Washington, Oregon and California now uses otter trawls. In 2003, over 90 percent of all Alaskan shrimp landings were from beam trawls and traps (Iversen, Allen and Higman, 1993; Roberts, 2005).

On the Atlantic coast, commercial shrimp fishing began in about 1938 in the coastal waters of Maine. The presence of large shrimp in lobster traps and cod stomachs is believed to have sparked off the Maine shrimp fishery. Today, some traps are used, but most of the shrimp catch is from otter trawling and many of the vessels are rerigged lobster boats, groundfish draggers and scallop boats. Three-quarters of the shrimp landings in New England have been by Maine vessels, with the remainder by Massachusetts vessels. The number of vessels fishing in New England waters has fluctuated considerably, with 300–400 vessels in some years. Many of the participants are opportunistic, switching to shrimp trawling if price, season and accessibility warrant the effort (Iversen, Allen and Higman, 1993; Roberts, 2005).

In 2004, the Pacific coast cold-water shrimp fisheries were responsible for 7.5 percent of United States domestic commercial shrimp landings, while those of the Atlantic were responsible for just less than 1 percent (NMFS, 2005).

**Other shrimp fishing**

In addition to the warm- and cold-water commercial shrimp fisheries described above, other shrimp fishing activity takes place in the United States (Iversen, Allen and Higman, 1993; Cascorbi, 2004b).

- Substantial amounts of shrimp are caught by recreational fishers. The main gear types are dip nets, cast nets, beach seines, push nets and traps. One estimate indicates that about 8 000 small boats participate in recreational shrimp fishing in the Gulf of Mexico.
- Commercial fishing for shrimp for bait for recreational fishing is important in the southeastern United States. In general, juvenile stages of shrimp are caught in

inshore areas. It has been estimated that about 2 200 tonnes of shrimp are caught in the Gulf for bait.

- There has been a considerable amount of experimental fishing in Hawaii for deep-water shrimp, using traps. Although significant catches have been made, commercial feasibility has not been demonstrated.

### TARGET SPECIES, CATCH AND EFFORT

The major species of shrimp taken in the United States shrimp fisheries are the following.

- *Warm water.* In the GSA region, 97 percent of the commercial production is historically made up of pink shrimp (*Farfantepenaeus duorarum*), white shrimp (*Litopenaeus setiferus*) and brown shrimp (*F. aztecus*). Smaller quantities of other species are landed, including rock shrimp (*Sicyonia brevirostris*), royal red (*Pleoticus robustus*) and seabob (*Xiphopenaeus kroyeri*) (Ward *et al.*, 2004; Iversen *et al.*, 1993).
- *Cold water.* On the United States Pacific coast in the four-year period from 2000 to 2003, pink shrimp (*Pandalus jordani*, also known as ocean shrimp) made up 93 percent of the catch; northern shrimp (*P. eous*, also known as pink shrimp), 4 percent; and other species, 3 percent. Of the pink shrimp catches, 67 percent were made in Oregon, 19 percent in Washington and 7 percent in California. All the northern shrimp catches were from Alaska. The most important “other species” were spot prawns (*P. platyceros*), coonstripe shrimp (*P. hypsinotus*), ridgeback prawns (*Sicyonia ingentis*) and some bait shrimp. On the Atlantic coast, northern shrimp (*P. borealis*) is by far the most important, but small quantities of striped shrimp (*P. montagui*) are incidentally taken (Roberts, 2005).

The above shows that there is some duplication in the common names of shrimp in the United States. Three different species are known as pink shrimp and two species as northern shrimp.

Shrimp catches in the two major shrimp fishing regions of the United States are given in Table 81.

TABLE 81  
Catches in the major United States shrimp fishing regions (tonnes)

	Southeast Atlantic and the Gulf of Mexico			Pacific Coast	
	Brown shrimp	White shrimp	Pink shrimp	Total brown, white, pink	Pink shrimp (ocean shrimp)
1985	71 118.5	44 698.2	12 181.9	127 998.6	12 415.3
1986	76 052.6	54 506.1	9 455.7	140 014.4	26 354.5
1987	68 635.7	43 166.4	8 980.4	120 782.5	31 099.0
1988	63 168.6	36 586.2	7 903.7	107 658.5	32 345.1
1989	73 401.8	31 802.1	7 805.4	113 009.3	35 557.1
1990	80 324.8	36 078.8	6 213.4	122 617.0	24 563.8
1991	69 418.7	40 441.3	6 140.9	116 000.9	19 134.0
1992	52 894.8	40 494.6	5 586.7	98 976.1	35 870.0
1993	53 993.1	33 835.0	7 618.3	95 446.4	22 608.7
1994	50 633.6	37 760.6	7 382.6	95 776.8	15 273.3
1995	58 222.2	44 554.6	10 373.7	113 150.5	11 930.0
1996	56 279.3	29 852.4	14 185.7	100 317.4	14 357.7
1997	49 864.9	33 393.6	9 368.1	92 626.6	17 814.6
1998	59 118.8	44 719.1	12 542.8	116 380.7	4 835.0
1999	62 153.4	46 886.9	6 122.8	115 163.1	12 899.2
2000	74 924.1	55 767.7	5 784.0	136 475.8	14 953.6
2001	68 973.9	40 998.7	7 246.6	117 219.2	17 832.6
2002	58 865.4	43 701.1	8 329.4	110 895.9	25 541.0
2003	65 510.2	47 742.5	6 921.0	120 173.7	14 067.3
2004	56 615.2	57 092.0	7 209.4	120 916.6	9 254.2

Source: NMFS landings database.

In a comprehensive review, Ward *et al.* (2004) conclude that shrimp supplies from United States domestic fishing are relatively fixed in the long term, with annual fluctuations reflecting changes in environmental conditions from one year to the next.

In the GSA region, shrimp fishing effort is a complex subject, mainly as a result of both the large number of management units (federal and individual states) and vessels involved. There are more than 16 000 licensed vessels in the Gulf of Mexico and over 2 200 in the South Atlantic. Funds have been provided by United States Congress to conduct a study to determine the amount of fishing effort in the shrimp fishery (Ward *et al.*, 2004). Cascorbi (2004b), using several primary sources, comments on the shrimp fishing effort situation.

*Estimating total fishing effort in United States shrimp fisheries is difficult. The exact number of vessels taking part in Gulf and Atlantic shrimp fisheries is not known to management authorities: there is currently no federal licensing requirement for the South Atlantic region; state licensing regulations vary; and, because shrimpers follow the shrimp across state water boundaries, many shrimp vessels are licensed in several states. The Gulf of Mexico Fishery Management Council (GMFMC) estimates the Gulf shrimp fleet at between 3 500 and 4 500 vessels and the South Atlantic Fishery Management Council estimates the South Atlantic fleet at 1 400 large vessels and 1 000 small boats.<sup>43</sup> Although federal permits have been required for Gulf shrimpers since December 2003, and about 2 500 Gulf permits have been issued since that time, many vessels move in and out of the shrimp fishery opportunistically, fishing for other species when shrimp prices are down or fuel prices are too high. Because exact vessel numbers are not known, NMFS cannot calculate fishing effort as directly as in other fisheries. Currently, NMFS calculates shrimping effort by interviewing a representative sample of vessel captains to determine the number of hours spent fishing. The GMFMC notes that these NMFS effort estimates “have been controversial and not well understood, because the effort reported does not necessarily reflect the number of active vessels in the fleet”.*

Effort data are more precise at the state level. A review of the shrimp fishing effort in all these areas is beyond the scope of this brief study, but an example from a warm-water shrimp fishery and one from a cold-water shrimp fishery can illustrate some important features.

- In Texas, shrimp fishing effort data are collected using nominal days fished, which are defined as actual hours of trawling per vessel, summed for all vessels that fished and converted to total days fished. These values do not consider changes in fishing power or efficiency over time. Annual fishing effort in the bays<sup>44</sup> has generally increased since 1966. Shrimp trawling for brown and pink shrimp in the bays was the most dramatic, with a tenfold increase from 1966 to the peak effort in 1994. Bay effort since then has declined substantially for all shrimp species, probably partly as a result of the licence buy-back programme and economic conditions in the industry. Annual fishing effort in the Gulf has also generally increased since 1966. Brown and pink shrimp were the dominant species sought, with a 72 percent increase in effort from 1966 to the peak effort in 1987. Gulf effort on brown and pink shrimp has generally declined since then. White shrimp effort has fluctuated widely with a 64 percent increase from 1966 to 2000 (TPWD, 2002).
- In Oregon, shrimp fishing effort data are expressed as “single-rig equivalent hours”. From 1968 to 2003, effort ranged from about 18 000 to 160 000 hours, with a peak in 1980 and again in the late 1980s, followed by a declining trend since then. Fishing effort during 2003 was extremely low, both in terms of hours fished and in the number of vessels making Oregon landings. Only 59 vessels

<sup>43</sup> The numbers of vessels are presumably those that operate in the federal (offshore) fisheries and do not include those operating in exclusively state-managed areas.

<sup>44</sup> Two components of shrimp fishing in Texas are recognized: bay fishing and Gulf fishing.

landed shrimp into Oregon ports during 2003, the lowest number since 1984. The 59 vessels fished 31 883 hours, the lowest number since 1972. A low price structure probably kept many vessels from fishing shrimp and some vessels were unable to secure a market (Hannah and Jones, 2004).

### ECONOMIC CONTRIBUTION

The value of shrimp landings from the major shrimp fishing areas is given in Table 82. It can be deduced that the GSA region is responsible for 96 percent of the value of shrimp landings in the country (2004). Ward *et al.* (2004) comment on the economic impacts of shrimp fishing on this region.

*The shrimp industry contributes to local coastal economies on several levels. Shrimp is offloaded by shore-side handling facilities, which then set in motion a myriad of economic activities associated with processing, packing, wholesale distribution and consumer expenditures. Vessel maintenance, repair, refuelling and other activities also contribute to the overall economic activities associated with the industry. Previous studies have suggested that the commercial shrimp industry plays an important role in the economy of the GSA region. A 1984 study found that the shrimp industry within the GSA region created 73 000 jobs, generated approximately US\$1 billion in income, and created \$1.4 billion in added value for the United States economy. A more recent study in 2003 estimated that the commercial shrimp industry in Florida alone creates US\$130 million in economic impact to the state's economy.*

The consumption of shrimp in the United States has increased remarkably in recent years, as shown in Table 83. Shrimp (1.9 kg per capita in 2004) has overtaken tuna (1.5 kg) as the most important seafood in the country. Over three-quarters of the shrimp consumed in the United States is imported, most of which is from aquaculture.

### TRADE ASPECTS

The United States is a major player in the trade of shrimp products. The country represents the world's largest shrimp market and United States Government shrimp import policies have a significant effect on major shrimp exporting countries throughout the world.

Traditionally, Japan was the largest import market for shrimp. However, because of the country's economic problems in the late 1990s, shrimp imports stagnated together with most other imports, and the United States emerged in 1998 as the largest importer in volume and value. Since then, it has increased its shrimp imports even further. Imports topped 500 000 tonnes in 2003 for the first time and rose even higher in 2004 to 518 000 tonnes. The value of total imports in 2004 fell, however, by 2.1 percent (Lem, 2006).

Table 84 shows United States shrimp imports in recent years.

Shrimp is imported into the United States in various forms. Shrimp imports by product type are shown in Table 85.

With regard to the United States shrimp market and trade in recent years, the country has:

- produced commercially about 145 000 tonnes of shrimp per year, with only about 4 000 tonnes from aquaculture;

TABLE 82  
Value of shrimp landings, 2003 and 2004

	2003	2004
New England	2 238 000	1 341 000
South Atlantic	40 663 000	42 106 000
Gulf of Mexico	362 471 000	367 181 000
Pacific coast	15 324 000	14 976 000
Other	9 000	1 000
Total	420 705 000	425 605 000

Source: NMFS database.

TABLE 83  
Consumption of fish/shellfish in the United States

	Per capita shrimp consumption (kg)	Per capita total fish/shellfish consumption (kg)
1998	1.3	6.8
2002	1.7	7.1
2003	1.8	7.4
2004	1.9	7.5

Source: NMFS Web site: [www.nmfs.noaa.gov](http://www.nmfs.noaa.gov)



TABLE 84  
United States shrimp imports, 2003 and 2004

		2003		2004	
		Tonnes	US\$'000	Tonnes	US\$'000
North America	Mexico	25 494	294 088	28 989	327 338
	Honduras	9 706	57 009	11 002	59 120
	Canada	6 478	40 727	8 176	53 683
	Panama	6 153	50 489	5 813	46 145
	Belize	6 218	40 121	6 436	37 921
	Nicaragua	4 507	24 187	4 546	24 051
	Guatemala	3 081	18 949	3 168	19 472
	Costa Rica	468	4 259	335	3 195
	El Salvador	602	5 229	311	1 962
	Jamaica	36	138	288	1 401
	Other	35	159	28	224
	<b>Total</b>	<b>62 778</b>	<b>535 355</b>	<b>69 092</b>	<b>574 512</b>
South America	Ecuador	34 029	211 258	37 509	212 872
	Venezuela (Bolivarian Rep. of)	9 958	60 864	16 268	85 711
	Brazil	21 783	96 764	9 228	40 724
	Guyana	11 423	37 870	8 453	27 966
	Colombia	2 278	17 004	3 539	21 994
	Peru	1 503	8 766	2 868	16 134
	Suriname	1 849	6 889	3 139	11 715
	Argentina	1 721	13 347	161	1 229
	Chile	173	1 414	132	1 035
	Uruguay	3	11	-	-
	<b>Total</b>	<b>84 720</b>	<b>454 187</b>	<b>81 297</b>	<b>419 380</b>
EU	Denmark	81	561	172	1 005
	Spain	29	230	32	186
	Belgium	7	35	17	85
	Netherlands	11	212	1	17
	Portugal	2	7	3	15
	Other	40	165	3	17
	<b>Total</b>	<b>170</b>	<b>1 210</b>	<b>228</b>	<b>1 325</b>
Other Europe	Iceland	35	209	145	774
	Norway	-	3	5	21
	Ukraine	2	12	2	13
	Russian Federation	-	-	-	3
	<b>Total</b>	<b>37</b>	<b>224</b>	<b>152</b>	<b>811</b>
Asia	Thailand	133 220	997 694	132 141	871 948
	Viet Nam	57 378	595 014	37 099	386 044
	India	45 469	408 907	41 004	359 562
	Indonesia	21 663	168 047	46 966	339 994
	China	81 011	441 905	65 976	337 566
	Bangladesh	8 143	82 836	17 379	172 567
	Malaysia	1 294	9 381	12 693	122 467
	Cambodia	-	4	5 330	37 383
	Philippines	1 227	10 929	1 897	15 666
	Sri Lanka	1 110	10 715	1 121	11 573
	Other	6 097	41 076	5 014	25 948
	<b>Total</b>	<b>356 612</b>	<b>2 766 508</b>	<b>366 620</b>	<b>2 680 718</b>
Other	Oceania	100	1 408	125	1 965
	Africa	77	1 558	103	1 965
<b>Total</b>	<b>All regions</b>	<b>504 494</b>	<b>3 760 450</b>	<b>517 617</b>	<b>3 680 676</b>

Source: www.nmfs.noaa.gov

Note: Weights are based on individual products as received, i.e. raw headless or peeled.

- imported about 500 000 tonnes, with countries in Asia supplying 70 percent in 2004 –over 80 percent of shrimp imports are from aquaculture; and
- exported about 15 000 tonnes, with Canada and Mexico receiving about 75 percent of the total.

Clay (1996) makes some interesting observations about the domestic shrimp market:

TABLE 85  
United States shrimp imports by product type

Type of product	2003		2004	
	Tonnes	US\$'000	Tonnes	US\$'000
Shell on (heads off)	248 951	1 854 812	244 635	1 760 153
Peeled:				
Canned	1 772	7 331	1 398	5 904
Not breaded:				
Raw	150 641	1 140 393	151 950	1 099 933
Other	94 373	705 985	103 068	728 322
Breaded	8 757	51 929	16 566	86 364
Total	504 494	3 760 450	517 617	3 680 676

Source: www.nmfs.noaa.gov

- brand names are not particularly important in the United States market, at least not at the consumer level;
- most shrimp purchasers in the United States are restaurants and institutions;
- local restaurant chains tend to be served by distributors, while national chains have central warehouses from which they supply their units;
- shrimp from various sources (domestic/imported, captured/cultured) tends to be handled in the same way by the same actors (brokers, distributors and processors); and
- New York, Chicago and Los Angeles are the principal centres for trading and holding activity.

Some of the important changes in the United States shrimp trade in recent years include the following.

- The total United States supply of shrimp on the domestic market has increased dramatically over the past 20 years. Domestic production and imports were about 200 000 tonnes in the early 1980s, but increased to over 650 000 tonnes in 2004.
- There has been a large increase in shrimp imports. The United States market share supplied by imports increased from 48 percent in 1978 to 80 percent in 2004. The rise in low-cost imports has led to a fall in shrimp prices on United States markets. Ward *et al.* (2004) indicate that ex-vessel prices declined by 27 percent in the Gulf of Mexico and 24 percent in the South Atlantic Shrimp Fishery between 1997 and 2002, as imports increased by 300 percent.
- Value-added products, particularly peeled products, have represented an increasing share of total shrimp imports. In 1980, for example, peeled shrimp represented 35 percent of imports; by 2004 its share had increased to 49 percent.
- Two decades ago, the major exporters of shrimp to the United States were Latin American countries. In 2004, seven of the ten most important exporting countries were in Asia.

The growth in shrimp imports into the United States is attributed to three factors. First, although economic conditions have declined in the three primary shrimp-importing regions (the United States, Japan and the EU), the relative strength of the United States economy has led to a greater rate of import growth. Second, a changing EU tariff structure has redirected shrimp from Thailand (a major producer) to the United States markets. Third, higher detection levels for the banned substances chloramphenicol and nitrofurans under sanitary and phytosanitary measures have resulted in a redirection of shrimp products from the EU to the United States. However, it is important to recognize that the increased trade flow reflects not only increased production in total, but also the source of the increased output (i.e. farmed versus wild production). The farm-raised product has greater consistent quality than the wild product; it is less seasonal in nature and therefore more reliable than its wild counterpart; species and sizes can be controlled better in the farm-based system than in the wild-based one; and the current trend towards vertical integration in the farming

system lends itself to better adaptation to consumer needs. These factors have led to a surge of shrimp imports into the United States over the last few years (Ward *et al.*, 2004).

The United States Government has made two major unilateral interventions affecting shrimp imports that have had significant consequences for both the United States and other countries. These interventions relate to turtle conservation and allegations of shrimp dumping.

According to the United States Department of State, Section 609 of United States Public Law 101–162 provides that shrimp, or products from shrimp, harvested with commercial fishing technology that may adversely affect certain species of sea turtles protected under United States laws and regulations, may not be imported into the United States unless the President certifies to Congress by 1 May 1991, and annually thereafter. The foundation of the United States programme governing the incidental taking of sea turtles in the course of shrimp harvesting is the requirement that commercial shrimp trawl vessels use sea TEDs, approved in accordance with standards established by the United States National Marine Fisheries Service (NMFS), in areas where, and at times when, there is a likelihood of intercepting sea turtles. The aim and chief component of this conservation programme is to protect sea turtle populations from further decline by reducing their incidental mortality by drowning in commercial shrimp trawl operations. The 13 nations currently meeting this standard are Belize, Colombia, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Pakistan, Panama, Suriname and the Bolivarian Republic of Venezuela. Twenty-four nations and one economy were certified as having fishing environments that do not pose a danger to sea turtles.<sup>45</sup> Of these, eight nations and one economy – the Bahamas, China, the Dominican Republic, Fiji, Hong Kong Special Administrative Region, Jamaica, Oman, Peru and Sri Lanka – harvest shrimp, using manual rather than mechanical means to retrieve nets, or other fishing methods not harmful to sea turtles. Sixteen nations have shrimp fisheries in cold waters only, where the risk of taking sea turtles is negligible: Argentina, Belgium, Canada, Chile, Denmark, Finland, Germany, Iceland, Ireland, the Netherlands, New Zealand, Norway, Russian Federation, Sweden, the United Kingdom and Uruguay (C. Stanger, personal communication, Office of Marine Conservation, United States Department of State, October 2005).

The United States policy on TEDs is not without its critics. Many shrimp fishers outside the United States are confused about the actual requirements, while others complain that they simply cannot afford gear similar to that used by relatively rich United States fishers. At a higher level, the United States Government is sometimes faulted for adopting unilateral measures that aim to compel other governments to alter their national policies to be more in line with United States objectives (Joyner and Tyler, 2000).

The second United States intervention affecting shrimp imports concerns anti-dumping action. While it directly affects only aquaculture shrimp exported to the United States by certain countries, it does have some impact on the global shrimp trade because of the size of the United States shrimp market.

Over time, the rise in imports, and in particular of farmed warm-water shrimp from low-cost producers, has led to a fall in shrimp prices on the United States market, with United States fishers consequently becoming less competitive. As a result, United States shrimpers accuse foreign producers of dumping. On 31 December 2003, the Southern Shrimp Alliance (SSA), a lobbying organization formed by shrimp fishers and processors in eight southern states, filed an anti-dumping petition with the United States Department

<sup>45</sup> With regard to Australia, the present United States position is that because the Australian Government maintains good governance over specific fisheries and keeps shrimp harvested apart from those specific fisheries labelled separately, the United States certifies Australian shrimp on a fishery basis and, in early 2006, five fisheries were certified.

## BOX 37

**An alternative view of shrimp dumping in the United States**

Shrimp farming has proliferated for one simple reason: efficiency. Trawling for shrimp is costly and the harvest often varies considerably from year to year with changes in weather and ecological conditions. Shrimp farms not only produce shrimp at much less cost, but they also provide a steady and reliable volume. Seafood processors value the reliable volume: they buy harvested shrimp and produce finished products for consumers whose desire for shrimp does not fluctuate with weather and ecological conditions. As shrimp farming has expanded, world shrimp production has increased and shrimp prices have fallen. Shrimp prices are now so low that they threaten the market survival of United States shrimp trawlers. The trawlers have therefore turned to the United States Government and its anti-dumping law to protect themselves, not from dumping, but from market competition with their more efficient foreign competitors (Mathews, 2004).

of Commerce against shrimp farms in Brazil, China, Ecuador, India, Thailand and Viet Nam. On 6 July 2004, the Department imposed duties varying up to 113 percent on these countries. Some commentators see it from a different perspective (Box 37).

In the short term, some market specialists feel that this action is resulting in higher shrimp prices for consumers. Internationally, supplies directed away from the United States market are leading to falling prices elsewhere. In the long term, however, the duties will not have much of an effect on the United States market except for that of changing the sourcing mix for imported shrimp, and slowing down the overall growth of the market because of the higher costs imposed (Ianelli, 2004; Lem, 2006).

**BYCATCH ISSUES**

According to NMFS, the bycatch of fishery resources, marine mammals, sea turtles, seabirds and other living marine resources has become a central concern of the commercial and recreational fishing industries, resource managers, conservation organizations, scientists and the public, both nationally and globally. During the past 26 years, the regional fishery management councils and NMFS have responded to this concern by taking a variety of actions to address the issue of bycatch. Actions have included research to develop better methods for monitoring and reducing bycatch, outreach programmes to explain the bycatch problem and search for solutions, and regulatory actions to monitor and decrease bycatch ([www.nmfs.noaa.gov](http://www.nmfs.noaa.gov)).

In 1996, Congress amended the Magnuson-Stevens Fishery Conservation and Management Act. The revision specifically defines the term “bycatch” and stipulates that it must be minimized to the extent practicable. “Bycatch”, as defined by the Act, “means fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. The term does not include fish released alive under a recreational catch and release fishery management program.”

The major bycatch issues in United States shrimp fishing are: estimating bycatch in the various fisheries; impacts on protected species, non-protected species and the environment; and various initiatives to reduce this impact, both domestically and internationally.

In his global review of discards, Kelleher (2005) estimates the quantity of discards for the three most important United States shrimp fisheries.

- The Gulf of Mexico Shrimp Trawl Fishery<sup>46</sup> discards an estimated 480 000 tonnes, with a discard rate of 57 percent.

<sup>46</sup> Kelleher notes that numerous recent changes have occurred that may have reduced bycatch in these fisheries.

- The South Atlantic Shrimp Trawl Fishery discards over 70 000 tonnes, with a discard rate of 83 percent.
- The nearshore shrimp fishery of the three Pacific coast states discards approximately 20 000 tonnes, with a discard rate of 44 percent.

Drawing on a variety of sources, Cascorbi (2004b) summarizes the various estimates of bycatch ratios (finfish/shrimp) in the United States warm-water shrimp fisheries. The report states that the exact ratio of non-shrimp bycatch in GSA shrimp trawl fisheries is difficult to quantify. NMFS data suggest that there was a ratio of 10:1 in the 1970s before measures were put in place to reduce growth overfishing of shrimp. Estimates of the bycatch ratio for Florida shrimp trawls range from 6:1 to 1:1. Studies in the late 1990s, by the Texas Parks and Wildlife Department (TPWD) found ratios in Texas state waters of approximately 4:1. In 2003, an industry representative asserted that the GSA fisheries had reduced the bycatch ratio from 10:1 to 3:1 since the mid-1980s. The best recent, non-industry estimates (NMFS, in the late 1990s) suggest that for every pound of shrimp caught, about 4.5 pounds of bycatch are discarded in the United States South Atlantic and about 5.25 pounds of bycatch are discarded in the Gulf. BRDs are believed to reduce finfish bycatch by as much as 30 percent, meaning that, since 1997 (when BRD requirements were put in place), ratios could have reached 2.8:1 in the United States South Atlantic and 3.5:1 in the Gulf. The effectiveness of BRDs in reducing bycatch is currently under study.

According to the Gulf of Mexico Fisheries Management Council (GFMC) (2006), the incidental take of juvenile red snapper has been a significant bycatch problem in the Gulf of Mexico Shrimp Fishery, the resolution of which has challenged fishery managers for many years. Despite the use of BRDs in shrimp trawl gear, the fishery appears to be taking juvenile red snapper at a rate that jeopardizes the resource. Recent information suggests that BRDs used by the fleet to minimize bycatch have not been as effective as previously thought, and that a comprehensive effort reduction programme may be needed to achieve the large-scale bycatch reduction required to end overfishing of red snapper by the shrimp fishery.

Roberts (2005) reviews the bycatch situation in North American cold-water shrimp fisheries. The report states that bycatch is a far less serious concern in United States and Canadian cold-water shrimp fisheries than in warm-water ones. A mixture of seasonal regulation and technological fixes has brought bycatch rates down to less than 5 percent of the catch in the Canadian, New England and Oregon pink shrimp fisheries. Since similar regulations are also in place for the other United States and Canadian cold-water shrimp trawl fisheries, bycatch is likely to be equally low in these fisheries. Concerns remain, however, over the bycatch of juvenile groundfish in some fisheries. These concerns are recognized and research is ongoing to try to reduce bycatch even further. No marine mammals, seabirds or sea turtles have been observed caught in cold-water shrimp fisheries in Canada and the United States. Canadian Atlantic, British Columbian and Oregon shrimp trawl fisheries have comprehensive observer programmes in place to monitor bycatch. The New England Fishery, however, has not had an observer programme in place since 1997.

Kelleher (2005) notes that, with regard to bycatch issues in the United States, three features are especially noteworthy:

- the growing impact of the incidental catch of charismatic species in fisheries management and in trade;
- the emerging influence of civil society with regard to bycatch and incidental catch issues; and
- the importance of fisheries management plans in bycatch management.

There have been numerous management interventions to reduce bycatch in the major United States shrimp trawl fisheries. As regards warm-water fisheries, Cascorbi (2004b) states that a 1990 amendment to the Magnuson-Stevens Fishery Conservation

and Management Act authorized a three-year study of bycatch from GSA shrimp trawlers and prohibited federal regulations to reduce shrimp trawl bycatch before January 1994. In October 1992, North Carolina became the first state to require shrimp trawlers to use a finfish excluder device. Since 1997, federal regulations have required the use of BRDs on all shrimp trawls in the central and western Gulf, and an amendment approved by NMFS in 2003 extends the same BRD requirement to the eastern Gulf. Roberts (2005) states that all the major cold-water shrimp trawl fisheries in the United States and Canada have plans in place to reduce bycatch. The northern shrimp fisheries of both countries have mandatory BRD requirements. The Oregon and Washington Pink Shrimp Fisheries have mandatory grate or soft BRD requirements. These, and other measures such as seasonal closures and trawl modifications, have reduced bycatch to less than 5 percent of the total catch, and are therefore deemed effective.

The bycatch of sea turtles in United States shrimp trawl fisheries deserves special mention. Sea turtle conservation became a major issue in the United States in the late 1970s and early 1980s. All five sea turtle species inhabiting state and federal waters are protected under the Endangered Species Act of 1973. Concerns about the continuing declines of sea turtle populations and the potential impact of new gear regulations on commercial shrimp trawlers prompted the United States Congress to add a provision to the Endangered Species Act Amendments of 1988, mandating an independent review of scientific and technical information pertaining to the conservation of sea turtles by the National Academy of Sciences. Congress further mandated a review of the causes and significance of turtle mortality, including that caused by commercial trawling. In 1990, following the reviews, the Committee on Sea Turtle Conservation of the National Research Council (NRC) published a report on the subject. An important finding of the study was that shrimp trawling in the United States results in the deaths of 5 000–50 000 loggerhead turtles and 500–5 000 Kemp's ridley turtles each year. Collectively, all other fishing activity is responsible for an additional 500–5 000 loggerhead deaths and 50–500 Kemp's ridley deaths annually. The incidental capture of sea turtles in shrimp trawls was identified by the committee as the major cause of mortality associated with human activities – killing more sea turtles than all other human activities combined. The study concluded that the best method currently available (short of preventing trawling) is the use of TEDs (NRC, 1990).

Studies by NMFS showed that 97 percent of turtles caught in TED nets can escape. On the other hand, some fishers claim that TEDs reduce the shrimp catch by as much as 30 percent, although federal government tests indicated an average of 10 percent. Some United States fishers were behind the idea of TEDs from the beginning – the earliest TEDs were designed by fishers to keep unwanted catch out of their nets. Many were concerned with “jelly balls” – aggregations of jellyfish – and the fact that the grates released sea turtles was an additional benefit. Nevertheless, other fishers resisted the idea of putting an escape hatch on their nets, and took legal action under the Endangered Species Act to compel NMFS to require TEDs on all United States shrimpers operating in the GSA region. Since 1990, all United States warm-water shrimpers have been required to use TEDs. This federal mandate included all United States shrimp trawlers more than 25 feet (7.6 m) in length working in offshore or onshore waters of the GSA region (Cascorbi, 2004b). Griffin *et al.* (1988) estimated that the requirement for TEDs has cost United States shrimp fishers US\$35 million. In 1992, as a result of lobbying by United States shrimp fishers and environmentalists, the TED provision was extended to foreign fleets. The saga of extending the TED requirement overseas is given in the *Trade aspects* section.

Samonte-Tan (2000) expressed an alternative opinion on the relationship between TEDs and the observed recovery of the Kemp's ridley sea turtle. The report contends that, although TEDs have been certified by NMFS to release 97 percent of turtles entering the trawls, the 97 percent effectiveness of TEDs is based on field certification

tests under controlled conditions and does not accurately reflect actual shrimp trawling operations. In actual applications, the reduction of turtle mortality is less than 97 percent because of: (i) improper installation of TEDs; (ii) inexperience of the crew; and (iii) variation in trawling conditions. For these reasons, the study states that TEDs have a maximum effectiveness of 45 percent. It reviews the recovery of the Kemp's ridley turtle in the Gulf of Mexico and concludes that nest protection, rather than the use of TEDs by shrimp fishing operations, has been and remains the major factor contributing to the recovery of the turtle.

In a recent review of bycatch and its reduction in the United States, Harrington, Myers and Rosenberg (2005) conclude that bycatch management programmes "need to be adaptive and make continuous improvements rather than consist of fixed regulations that are not performance-based. Regulations are needed to provide incentives to reduce bycatch and disincentives to continue fishing practices with high bycatch rates."

### PROFITABILITY

Increased production costs and declining ex-vessel prices have recently resulted in low or negative profitability in most United States shrimp fisheries. Because this phenomenon is best documented in the GSA shrimp fisheries, much of the following discussion centres on that region and is taken largely from Ward *et al.* (2004).

The current economic crisis faced by the domestic shrimp industry is unprecedented in scope, magnitude and duration. Declining real and nominal prices, together with increasing operational costs, have created major difficulties in maintaining financial solvency for commercial shrimp vessels in the GSA region. The two components of this "cost/price squeeze" are given below.

- The costs of operating a commercial shrimp vessel in the GSA region have increased over the last few years. Key causes include higher fuel prices, more costly insurance and costs associated with utilizing TEDs and BRDs. One study found that that, between 1986 and 1997, total expenses for operating a commercial trawler in the Gulf of Mexico ranged from US\$0.83 to US\$1.19 per dollar of gross revenue. Over the period of the study, a cost of US\$0.98 was incurred by the median trawler sampled to generate US\$1.00 of gross revenue. Major costs included crew shares, fuel and repairs to vessels and gear; there is little possibility of passing on these costs in the form of higher dockside prices to the first handler of the shrimp.
- As regards prices for shrimp, the United States supply of shrimp has evolved so much that an increasing share is being derived from foreign sources. These foreign sources are themselves becoming more dependent on cultured shrimp than on trawled shrimp. The technology of culturing shrimp in coastal and inland impoundments has become standardized in many regions of the world. Costs associated with the culture process enable shrimp to be produced and shipped to United States markets at price levels and volumes that have exerted strong downward pressure on domestic dockside prices. Prices declined by 27 percent in the Gulf of Mexico and 24 percent in the South Atlantic shrimp fisheries between 1997 and 2002, as imports increased by 300 percent. It appears that domestic prices at the ex-vessel level decline by about 55 cents for every dollar decline in import price. As a result, gross revenue declined between 2000 and 2002 from US\$654 million to US\$381 million in the Gulf of Mexico and from US\$80 million to US\$54 million in the southern Atlantic states.

Without some form of financial relief, the shrimp fishery could suffer a catastrophic collapse that would severely impact on the economies of the GSA region. Two main mechanisms have been explored for supporting the dockside price of shrimp: import controls and market enhancement. Shrimp import controls and the issues related to their implementation have been described in the *Trade aspects* section. A marketing

programme would encourage consumers to pay a premium price for domestically produced shrimp as opposed to imported shrimp, based on quality, freshness, flavour and texture (Ward *et al.*, 2004).

The shrimp fishing financial crisis in the GSA area is also being experienced in other areas of the country. In Oregon, the average ex-vessel price for pink shrimp in 2004 was US\$0.54/kg, which has not been seen in nominal terms since 1977. The number of vessels to make shrimp landings in Oregon in 2003 (59 boats) was the lowest since 1984 (Hannah and Jones, 2004).

Studies on rent in the United States shrimp fisheries do not feature prominently in the country's literature; however, some studies have been conducted for the Gulf of Mexico Shrimp Fishery. Amendment 9 to the Gulf of Mexico Shrimp Fishery Management Plan estimated the present value of the shrimp fishery at US\$1.9 billion (constant 1977 dollars). If optimal management was adopted for this fishery, its asset value could be increased to slightly over US\$4 billion. The lost rent of US\$2.1 billion is primarily the result of command and control management (TEDs and BRDs) in a relatively unrestricted open access management regime (J. Ward, personal communication, March 2006).

### ENERGY INPUT ASPECTS

Rising fuel costs are a major concern for United States fishers. Because trawling is so fuel-intensive, fuel prices have hit the shrimp industry harder than most other United States fisheries. Increased expenditure on fuel is a major element of the current "price squeeze" described in the section on *Profitability* above. Although fuel prices in the United States are low, compared with those in many developed countries, they generally rose from the mid-1990s to the early 2000s. Especially large fuel price increases occurred in 2004 and 2005. Because shrimp capture fisheries are more fuel-intensive than shrimp aquaculture (Clay, 1996), rising fuel prices will create additional problems for domestic captured shrimp in its competition with imported shrimp, which is mostly from aquaculture.

Some fishers have attempted to mitigate the effects of fuel price increases through the use of stronger/lighter net material and altering fishing practices. This could include fishing closer to a vessel's home port and, in the Gulf, not targeting shrimp that requires greater use of fuel. In some fisheries, fuel consumption has been reduced by otter trawls being double- or even quadruple rigged (dragging multiple small nets rather than a single large one).

On a different level, Ward *et al.* (2004) point out that one of the conclusions of the Houston Shrimp Summit in 2003 was that cost increases related to fuel use may be difficult to control since most businesses that are not bulk purchasers of fuel have no influence on the per unit cost of fuel utilized. Therefore, by reducing fuel costs and most other operating costs, per unit of effort may not be a viable strategy for improving profitability for the industry in the short term; efforts should be made instead to increase prices received for shrimp.

According to a United States shrimp specialist (J. Ward, personal communication, October 2005), the most common strategy currently used by United States shrimp fishers to mitigate a peak in fuel prices is simply to refrain from fishing.

### BIOLOGICAL ASPECTS

There are considerable differences between the biological aspects of warm- and cold-water shrimp.

The characteristics of warm-water shrimp in the United States are summarized by Cascorbi (2004b). Brown, white and pink shrimp is a short-lived and fecund species, completing its life cycle in 18–24 months, and reaching sexual maturity in perhaps 6–12 months. These species are so short-lived that they "provide an annual crop". In



TABLE 86  
Productivity and status of warm-water shrimp resources in the GSA region

Species and area	Recent average yield	Current potential yield	Long-term potential yield (LTPY)	Fishery utilization level	Stock level relative to LTPY
Brown shrimp, Gulf of Mexico	53 080	Unknown	57 653	Full	Near
Brown shrimp, Atlantic	2 645	Unknown	34 472	Full	Near
White shrimp, Gulf of Mexico	28 942	Unknown	29 980	Full	Near
White shrimp, Atlantic	6 045	Unknown	6 305	Full	Near
Pink shrimp, Gulf of Mexico	11 009	Unknown	7 469	Full	Near
Pink shrimp, Atlantic	730	Unknown	955	Full	Near
Royal red shrimp	250	Unknown	Unknown	Unknown	Unknown
Seabob shrimp	3 947	Unknown	Unknown	Unknown	Unknown
Rock shrimp	6 240	Unknown	Unknown	Unknown	Unknown

Source: Nance and Harper, 1999.

the GSA, fishery managers note that the annual abundance of shrimp seems to be most influenced not by fishing effort, but by environmental conditions in the late winter and early spring. Years with warm winters enable greater larval survival and abundant landings the next season; years with winter freezes or severe storms result in lower populations and landings. While most of the shrimp stocks in the GSA region show no clear signs of overfishing, it is believed that most of the populations in the region are currently exploited or near their MSY. Environmental conditions are believed to have a greater effect on shrimp stocks than fishing effort. The high fecundity and migratory behaviour of the penaeid shrimp are conducive to quick recovery from adverse conditions.

The productivity and status of the major warm-water shrimp resources in the GSA region have been summarized by Nance and Harper (1999) and are shown in Table 86.

The characteristics of cold-water shrimp in North America are summarized by Roberts (2005), using several primary references. Pandalid shrimp is fast growing and early maturing, and produces several thousand young. These and other life history characteristics, such as environmental sex determination, make them inherently resistant to fishing pressure. Abundance and biomass in the *Pandalus borealis* Atlantic Canada Northern Shrimp Fishery have been increasing since 1997, and CPUE trends have remained stable or above the long-term average during the same time period. In contrast, New England northern shrimp was overfished for most of the 1990s and overfishing may still be occurring, although recent trends in fishing mortality and biomass indicate an improvement in the health of the stock. Overfishing also appears to be occurring in the Alaskan Spot Prawn (*Pandalus platyceros*) Pot Fishery. The Oregon Pink Shrimp (*Pandalus jordani*) and British Columbian Spot Prawn Fisheries appear to be fully fished; the status of all other cold-water shrimp fisheries is unknown.

### IMPACTS ON THE PHYSICAL ENVIRONMENT

A great deal of documentation exists on the impacts of United States shrimp fishing on the physical environment. Two particularly relevant overall reviews are by Barnette (2001), which focused on the GSA region, and NRC (2002), which had a larger geographic scope.

Barnette (2001) carried out a major review of the fishing gear utilized within the GSA region and its potential impacts on essential fish habitat. As regards otter trawling, the report concluded that this fishing method has the potential to reduce or degrade structural components and habitat complexity by removing or damaging epifauna, smoothing bedforms (which reduces bottom heterogeneity), and removing structure-producing organisms. Trawling may change the distribution and size of sedimentary particles, increase water column turbidity, suppress growth of primary producers and

alter nutrient cycling. The magnitude of trawling disturbance is highly variable. Its ecological effect depends on the site-specific characteristics of the local ecosystem, such as bottom type, water depth, community type and gear type, as well as the intensity and duration of trawling and natural disturbances.

Several studies indicate that trawls have the potential to impact sensitive habitat areas, such as submerged aquatic vegetation, hard bottoms and coral reefs in a serious manner. With regard to hard bottoms and coral reefs, it should be recognized that trawlers do not typically operate in these areas because of the potential damage that their gear may incur. While trawl nets have been documented to impact coral reefs, typically resulting in lost gear, these incidents are usually accidental. Low profile, patchy hard bottom or sponge habitat areas are more likely to be impacted by trawls because of the gear's ability to work over these habitat types without being damaged. While it may be concluded that trawls have a minor overall physical impact when employed on sandy and muddy substrates, the available information does not provide sufficient detail to determine the overall or long-term effect of trawling on regional ecosystems. In general, few studies document recovery rates of habitat; those that do usually only do so after a single treatment, which does not reflect the reality of fishing impacts that are ongoing and cumulative.

NRC was asked by NMFS to study the effects of bottom trawling and dredging on seafloor habitats. In the report (NRC, 2002), it was concluded that: (i) trawling and dredging reduce habitat complexity; (ii) repeated trawling and dredging result in discernible changes in benthic communities; (iii) bottom trawling reduces the productivity of benthic habitats; (iv) the effects of mobile fishing gear are cumulative and are a function of the frequency with which an area is fished; (v) fauna living in low natural disturbance regimes are generally more vulnerable to fishing gear disturbance; (vi) fishing gears can be ranked according to their impacts on benthic organisms; and (vii) benthic fauna can be ranked according to their vulnerability.

Regarding management interventions, the NRC report concluded that the effects of trawling and dredging should be managed according to the specific requirements of the habitat and the fishery through a balanced combination of the following management tools.

- *Fishing effort reductions.* Effort reduction is the cornerstone of managing the effects of fishing including, but not limited to, effects on habitat. Both of the following management tools may also require effort reduction to achieve maximum benefit. The success of fishing effort reduction measures will depend on the resilience and recovery potential of the habitat.
- *Modifications of gear design or gear type.* Gear restrictions or modifications that minimize bottom contact can reduce habitat disturbance. Shifts to different gear types or operational modes can be considered, but the social, economic and ecological consequences of gear reallocation should be recognized and addressed.
- *Establishment of areas closed to fishing.* Closed areas are necessary to protect a range of vulnerable, representative habitats. Closures are particularly useful for protecting biogenic habitats (corals, bryozoans, hydroids, sponges, seagrass beds) that are disturbed by even minimal fishing effort. Because area closures could displace effort to open fishing grounds, effort reductions could be necessary in some cases to reduce habitat effects.

### IMPACTS ON SMALL-SCALE FISHERIES

Commercial shrimp fishing interacts with small-scale fisheries on a variety of levels. These include resource conflicts with recreational fishers and, to a lesser extent, with small-scale commercial fishers. On the positive side, a significant amount of bait used for recreational fishing comes from commercial shrimp fishing.

Recreational fisheries are of great importance in the United States. It has been estimated that the 13 million recreational fishers catch 122 545 tonnes of fish – and have a great amount of political influence (FAO, 2005b). Participation in recreational fishing is much greater in the southeast than in other regions of the United States – over 50 percent of landings along the east coast of Florida are from recreational catches (NMFS, 2003). Some important recreational fish species are also taken by commercial shrimp fishers.

The main negative interactions between commercial shrimp fishing and small-scale fisheries concern the trawl bycatch. TPWD (2002) states that in the offshore waters of the Gulf of Mexico, shrimp trawling has affected important recreational and commercial species such as red snapper (*Lutjanus campechanus*). Combined catches of the recreational and commercial fishery for red snapper began a steady decline in 1983, reaching a low in 1990. Implementation of quotas and size limits in 1991 halted the decline, but stock assessments suggested that recovery was being slowed because age-0 and age-1 red snapper was being caught in shrimp trawls and discarded at a rate greater than the catch rate of the directed fisheries. To reduce red snapper bycatch, NMFS began to require the use of BRDs by the Gulf shrimp fleet in 1998. Cascorbi (2004b) states that the bycatch of juvenile king and Spanish mackerel in the Gulf of Mexico Shrimp Fishery exceeds the number taken in the directed commercial and recreational fisheries combined.

Gear conflicts have arisen between shrimp trawlers and trappers fishing for stone crab and blue crab: trawl nets bring up traps and entangle trap buoy lines. This has led to several management remedies, including seasonal “time-sharing” of fishing grounds off Florida (Cascorbi, 2004b).

Apart from these conflicts, a symbiotic relationship between commercial shrimp fishers and recreational fishers also occurs. Commercial shrimp fishing for recreational fishing bait is important in the southeast of the United States. It has been estimated that about 2 200 tonnes of shrimp are caught in the Gulf for bait. Commercial fishing for bait shrimp is also carried out on the Atlantic and Pacific coasts.

## MANAGEMENT

The country’s premier fisheries law, the Magnuson-Stevens Fishery Conservation and Management Act, created eight Regional Fishery Management Councils that work in partnership with NMFS to manage marine fish stocks. The council membership is a balance of commercial and recreational fishers, marine scientists, and state and federal fisheries managers who pool their knowledge to prepare fishery management plans (FMPs) for marine fish stocks in their respective geographic areas. These plans can limit fishing effort, seasons, fishing gear, the number of fishers allowed to fish for a certain species, and the total amount of fish that can be caught. NMFS receives its ocean stewardship responsibilities under many federal laws in addition to the Magnuson-Stevens Fishery Conservation and Management Act. The most important of these are: the Endangered Species Act, which protects species determined to be threatened or endangered; the Marine Mammal Protection Act, which regulates interactions with marine mammals; the Lacey Act, which prohibits fish or wildlife transactions and activities that violate state, federal and Native American tribal or foreign laws; and the Fish and Wildlife Coordination Act. Many other statutes, international conventions and treaties also guide the fisheries activities of the National Oceanic and Atmospheric Administration (NOAA) ([www.nmfs.noaa.gov](http://www.nmfs.noaa.gov)).

State governments generally manage fishing activity within three nautical miles of the coast, while regional fishery management councils undertake management in waters of the EEZ, from three to 200 nautical miles offshore.

In 1996, in response to findings that had accumulated over two decades, the Magnuson-Stevens Fishery and Management Conservation Act was substantially

revised by the Sustainable Fisheries Act. The amended law required the regional fishery management councils and NMFS to improve the sustainability of fisheries by stopping overfishing, “rebuilding” stocks, reducing bycatch, and identifying and protecting essential fish habitat. As regards bycatch, the revised Act required fisheries to have standardized reporting methodologies and minimize bycatch to the extent practicable.

Ward *et al.* (2004) describe the management of the shrimp fisheries in the GSA region. Each state in the region has jurisdiction over state waters. Management in the federal waters zone is conducted under the auspices of the federal fishery management council structure. Specifically, the shrimp fishery in the Gulf of Mexico region is managed by the Gulf of Mexico Fishery Management Council (GMFMC). The shrimp fishery in the South Atlantic region is managed by the South Atlantic Fishery Management Council. Management is conducted via FMPs for shrimp in each region. Changes in FMP are made via an FMP amendment process. The important events in shrimp fishery management by the two federal fishery management councils are presented below.

The FMP for the Gulf of Mexico Shrimp Fishery was implemented as a federal regulation on 15 May 1981. The major objective was to enhance yield in volume and value. Major amendments to the original FMP were the following.

- *Amendment 1* – Provided authority for adjusting the size of the Tortugas sanctuary or the extent of the Texas closure.
- *Amendment 2* – Updated catch/economic data in the FMP.
- *Amendment 3* – Resolved an ongoing shrimp/stone crab gear conflict on the west-central coast of Florida.
- *Amendment 4* – Simplified the annual review process for the Tortugas Sanctuary and extended the Texas Closure review date. A provision was also approved that allowed for landing of white shrimp in the EEZ in accordance with a state’s size/possession regulations.
- *Amendment 5* – Defined overfishing for Gulf brown, pink and royal red shrimp, and provided for measures to restore overfished stocks if overfishing should occur.
- *Amendment 6* – Eliminated the annual reports and reviews of the Tortugas Shrimp Sanctuary in favour of monitoring and an annual stock assessment.
- *Amendment 7* – Defined overfishing for white shrimp and provided for future updating of overfishing indices for brown, white and pink shrimp as new data become available.
- *Amendment 8* – Addressed various aspects of the management of royal red shrimp.
- *Amendment 9* – Required the use of an NMFS BRD in shrimp trawls in the EEZ.
- *Amendment 10* – Proposed the requirement for installation of an NMFS-certified BRD to reduce the bycatch of finfish. The amendment also proposed utilizing existing trawl surveys to determine annual bycatch estimates.
- *Amendment 11* – Required all commercial shrimp vessels and boats that harvest shrimp in the Gulf of Mexico EEZ to obtain a renewable federal permit. It was also proposed that the use of traps in the royal red fishery be prohibited.
- *Amendment 13* – Required data and information on participation, effort and bycatch in the shrimp fishery.
- *Amendment 14* – Prevent excessive bycatch of juvenile red snapper. (Amendment was under consideration and not yet adopted.)
- A 15th amendment is being proposed to reduce effort and bycatch in shrimp fishing, with the aim of improving socio-economic conditions for fishery participants and fishing communities, further reducing incidental fishing mortality on the red snapper stock, and furthering the ability of the shrimp and red snapper fisheries to achieve optimum yield.

The FMP for the South Atlantic Shrimp Fishery was implemented as a federal regulation in December 1993. The major initial objective was to allow closure of EEZ waters adjacent to each state to protect white shrimp stocks from excessive mortality during periods of severe cold weather. The major amendments to the original FMP were the following.

- *Amendment 1* – Added rock shrimp to the management unit, prohibited rock shrimp trawling in areas of critical *Oculina* coral habitat and requested permits for all captains, vessels and dealers in the fishery.
- *Amendment 2* – Addressed issues related to brown and pink shrimp requirements on the use of BRDs in all trawls used within the EEZ and established a BRD certification process.
- *Amendment 3* – Addressed habitat requirements of the Magnuson-Stevens Fishery and Management Conservation Act with regard to rock shrimp.
- *Amendment 4* – Addressed Sustainable Fisheries Act requirements concerning the rock shrimp fishery, including amending data reporting requirements to comply with the Atlantic Coastal Cooperative Statistics Program, and adding information on fishing communities.
- *Amendment 5* – Proposed several actions pertaining to rock shrimp, including establishing a limited access programme, requiring captains of permitted vessels to have a vessel operator's permit, restricting the minimum mesh size, and requiring permitted vessels to install and use a VMS.
- *Amendment 6* – Proposed to address Sustainable Fisheries Act criteria (MSY, optimum yield, overfishing levels, etc.) and potential modification to the BRD protocol with regard to rock shrimp.

Cascorbi (2004b) summarizes information on shrimp management at the state level (within three nautical miles) in the GSA region. Regulations vary from state to state and area to area, but states are generally protective of the estuarine habitat so important to juvenile shrimp. As one example of a state-mandated programme, the Texas authorities recognized “growth overfishing” among shrimp caught in nearshore waters and undertook extensive modelling to determine the timing of optimal harvest. Noting that shrimp grows so quickly that a delay of even two weeks can mean the difference between growth overfishing and optimal harvest, the state designed a licence buy-back programme to reduce fishing effort, and closed shrimp nursery habitats during critical growth. Louisiana has tackled the same problem with a minimum size limit on white shrimp. In the southeast region, all commercial shrimpers require state licences.

As an example of the management of a cold-water shrimp fishery, the *Pandalus jordani* Pacific Ocean Shrimp Fishery has been under tri-state management since the 1950s. A management plan for shrimp was developed in 1980. Plan objectives include the prevention of biological growth and recruitment overfishing, and the promotion of the economic value of the shrimp resource. Historical management of the fishery has included policy measures to allow age-1 shrimp to escape the catch and to allow berried females to release juvenile shrimp. The trawl fishery is managed using: (i) a minimum mesh size restriction of 39 mm in the trawl nets; (ii) a minimum count per pound restriction of 160 shrimp per pound on landed catch; and (iii) a closed season from November to March.

Largely as a result of the current economic crisis in many United States shrimp fisheries (see section on *Profitability* above), increased attention has been focused on the need for management intervention to address overcapacity in the various shrimp fisheries. FAO (2005b) states that about half the current shrimping effort in the Gulf of Mexico could produce about the same yield. With regard to required management action, it appears that interventions are needed to reduce fishing capacity and prevent its subsequent buildup. Ward *et al.* (2004) summarize the situation in the shrimp fisheries of the GSA region.

*Based on the simulation analysis for the Gulf of Mexico and the South Atlantic shrimp fisheries, it is clear that some type of effort reduction is needed to restore these fisheries to sustainable profitability. Biologically, the shrimp resource is just as productive as ever. Economically, however, shrimp fisheries cannot support as many vessels as they once did because the real price of shrimp has been declining. Simulation analysis demonstrates that to make long-term improvements in the financial condition of the shrimp fishery and develop an economically sustainable fishery, the number of vessels in the fishery must be reduced and barriers to entry must be established.*

A 15th amendment is being proposed to the FMP for the Gulf of Mexico Shrimp Fishery, which features capacity reduction and improvement of socio-economic conditions for fishery participants. Among the options being explored are various schemes to limit the number of participants (GFMC, 2006). Ward *et al.* (2004) conclude that a permit or licence moratorium alone is insufficient to improve the financial viability of the fishery, if the price of shrimp is expected to remain low in the long term. They indicate that regulations are required to produce positive economic profits in the long term. This would entail some type of permit or licence moratorium that also limits capital stuffing and reduces the number of vessels in the fishery.

At the state level, there has been some success in attempts at reducing shrimp fishing capacity. In 1995, the Legislature of Texas enacted an inshore (bay and bait fisheries) shrimp vessel licence limited entry programme designed to reduce the documented fleet overcapitalization. The buy-back programme has purchased and withdrawn commercial inshore shrimp boat licences (422 bay and 393 bait) at a cost of approximately US\$4.3 million. This represents 25 percent of the original 3 231 licences ushered into the fishery in 1995. TPWD (2002) concluded that the licence buy-back programme is showing progress towards reversing the high levels of inshore shrimping effort, but a similar limited entry and licence buy-back programme is needed for the Gulf (offshore) shrimp fleet.

A shrimp specialist at NMFS summarizes the shrimp management situation in the United States.

*Biologically, shrimp needs little management attention since fishing effort has little impact on future recruitment levels in the fishery. However, management regulations have been imposed for a variety of reasons and under a number of different laws, including the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act and the Coastal Zone Management Act. Most problems addressed by shrimp fishery managers derive from the use of an open access management regime that ignores economic efficiency criteria and implicitly stresses economic impacts in the form of state revenues from licence sales, taxes and low paying jobs (J. Ward, personal communication, March 2006).*

## **ENFORCEMENT**

Regarding general fisheries enforcement at the federal level, the United States Department of Commerce, through NMFS agents and the United States Coast Guard (USCG), is responsible for enforcing federal laws and regulations dealing with fisheries. Enforcement is carried out at sea, using USCG vessels and USCG and NMFS personnel, and on shore using NMFS enforcement agents. Agreements with 21 coastal states in the United States and three United States territories make over 2 000 state resource officers available (Everett, 2005).

For the enforcement of federal legislation dealing specifically with shrimp fisheries, a great deal of recent activity deals with ensuring compliance with requirements to use TEDs and BRDs.

Poseidon (2003) examines enforcement of TED regulations in the Gulf of Mexico. The Eighth District of the USCG monitors compliance with TED construction

requirements in all of their boardings. From 1999 to 2001, TED boardings averaged 1 600 to 1 800 annually, and compliance rates averaged 96 percent.

The NMFS budget for fisheries enforcement in fiscal year 2005 was about US\$70 million. This did not include grants to states and funds of the USCG (Everett, 2005). It is difficult to determine the cost of USCG services related to fisheries enforcement, since the agency is involved in a large range of activities, including sea safety and the prevention of smuggling.

The states have a variety of systems for the enforcement of fisheries regulations, most of which include cooperation with NMFS. For example, in Texas, TPWD has a Law Enforcement Division with a current staff of 68 game wardens assigned to 14 coastal areas. In July 2001, the Law Enforcement Division entered into a Joint Enforcement Agreement (JEA) with NMFS. The JEA was created to enhance enforcement of shrimp, reef fish and highly migratory species regulations in the Gulf of Mexico. The programme increased law enforcement presence in the Gulf and provided Texas game wardens with additional equipment, allowing them to maintain a higher level of patrol in offshore waters. From the inception of the agreement, from July 2001 through March 2002, JEA wardens logged 3 572 patrol hours and 719 boardings and inspections. There were 77 citations issued and 6 206 kg of shrimp confiscated (TPWD, 2002).

## RESEARCH

Most of the work on United States marine fisheries is conducted by or for NMFS. Since 1871, federal fisheries scientists have collected, researched, analysed and published peer-reviewed data on the nation's living marine resources, marine ecosystems and the benefits that they provide. Additional biological, economic and other forms of research are also conducted by universities, and federal and state agencies (FAO, 2005b).

Iversen, Allen and Higman (1993) indicate that, in the United States, biological research on warm-water shrimp began in the 1930s. During the intervening years, extensive basic research has been carried out on the life histories of the white, brown and pink shrimp, and on its relationship to the environment. The United States was considered the epicentre of shrimp fisheries research in the world until the 1960s, when priorities shifted towards research for shrimp farming (S. Garcia, personal communication, October 2005).

Cascorbi (2004b) summarizes warm-water shrimp fisheries research in the United States. An extensive programme to document and quantify bycatch in both Gulf and Atlantic shrimp fisheries (the Southeastern United States Shrimp Trawl Bycatch Program) began in 1992, and produced a comprehensive landmark report in 1998. Since 1991, red snapper bycatch in shrimp trawls has been the focus of a major cooperative research programme organized by fishery stakeholder groups, universities, and state and national management. Bycatch was characterized and various kinds of BRDs developed and tested, often with the cooperation of commercial shrimp fishers. Research generated by this group led to the 1997 decision by GFMC to require BRDs on most shrimp trawls. NMFS has also conducted research into the habitat effects of shrimp trawling in the Gulf and southeast regions. Perhaps the most significant publication to result from research is that of Barnette (2001) – a comprehensive review of the habitat effects of all gear types used in both regions. NMFS conducts stock assessments and evaluates recovery of all five sea turtle species impacted by United States shrimp trawling. A sea turtle management team is based at the Southeast Fisheries Science Center, whose main mandate is to analyse sea turtle bycatch and TED effectiveness in both the Gulf and South Atlantic fisheries. This group and others have developed and tested various kinds of TEDs, often in cooperation with commercial shrimp trawlers.

Roberts (2005) summarizes cold-water shrimp fisheries research in the United States. Assessments of cold-water shrimp stocks generally consist of monitoring population changes, using catch rate series and, in some cases, research surveys. These efforts provide general information on population structure and recruitment, which are used to identify when a change in quota or effort is needed. Biological reference points and formal yield projections are rare. Each state has different levels of research and monitoring. In Oregon (where the largest United States cold-water shrimp fishery is based), fishery-dependent data, particularly logbook data, are the primary sources of information on the distribution and abundance of pink shrimp. Such data have been used to demonstrate that the geographic stock area of pink shrimp expands and contracts roughly proportionally to shrimp recruitment. Research cruises and market sampling provide additional data on distribution, abundance and the likely age structure of the stock. Research cruises are also carried out for other purposes, such as testing the efficacy of different BRDs. The primary objective of the 2004 research cruise was to test the viability of logbook data in providing an accurate picture of the spatial structure of shrimp abundance.

Research on United States shrimp fisheries in the future is likely to focus increasingly on bycatch (reduction and fishery impacts on bycatch species), physical impacts of trawl gear on the environment, and the ecosystem impacts of shrimp fishing.

Science and technology programmes in NMFS totalled US\$249.9 million in 2005 (AAAS, 2005). A breakdown of this research budget by specific fisheries is not available.

#### DATA REPORTING

Southeast collection of landings data and other fisheries-dependent data in the United States is conducted through the Fisheries Information Network, the Atlantic Coastal Cooperative Statistics Program and the Marine Recreational Fisheries Statistics Survey. The Marine Fisheries Commission of the Gulf states currently manages and coordinates the Southeast Fishery Information Network. The purpose of these state-federal cooperative programmes is to collect, manage and disseminate statistical data and information on the commercial and recreational fisheries of the southeast region (NMFS, 2003).

As regards data reporting on shrimp fisheries in the southeast United States, Cascorbi (2004b) reports that there is regular collection and assessment of both fishery-dependent and fishery-independent data. These include logbook reports, some observer coverage and dockside monitoring. NMFS observers on board are employed in the southeast otter trawl shrimp fisheries; the programme is voluntary and NMFS estimates that less than 1 percent of South Atlantic fishing hours is covered by observers.<sup>47</sup> In the Gulf, more than 1 percent of trips are covered by observers. Current stock assessment and other fishery-independent data are robust and reliable and long-term fishery-dependent data are also available.

At the state level, there are a variety of systems for reporting data on shrimp. For example, commercial shrimp resources in Texas are monitored with both fishery-independent and fishery-dependent data. Fishery-independent data include bag seine, bay trawl and Gulf trawl sample data, as well as NMFS trawl data. Fishery-dependent data include NMFS bay and Gulf shrimp landings and catch data, commercial bay and bait landings data, and recreational fishery bait-use data. Furthermore, TPWD has monitored shrimp size and abundance since 1959. Landings of marine species from Texas bays and the Gulf off Texas have been collected from seafood dealers since 1887 (TPWD, 2002).

<sup>47</sup> Subsequent to the Cascorbi report, Amendment 6 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region requires an owner or operator of a trawler that harvests or possesses penaeid shrimp in or from the EEZ off the southern Atlantic states to, *inter alia*, carry an observer on selected trips and to submit catch and effort reports.



Roberts (2005) summarizes data sources and reporting for some of the United States cold-water shrimp fisheries. Data on Alaskan and Oregon trawl fisheries for pink/northern shrimp are collected from several sources, including logbooks, observers and dockside monitoring. In Washington, pink shrimp trawl vessels are not required to carry logbooks nor is there dockside monitoring (except for some enforcement activities). However, there is a logbook programme and dockside monitoring of the Coastal Spot Prawn Fishery. In California, landing statistics and fishers' local knowledge are the primary sources of information on the status of spot prawns, although logbooks are mandatory. Prior to 1994 on the east coast in the Gulf of Maine, effort (numbers of trips by state and month) was estimated from landings data collected from dealers and landings per trip information from dockside interviews of vessel captains. In the spring of 1994, a logbook reporting system replaced the collection of effort information from interviews. At the federal level, Amendment 1 to the west coast's northern shrimp FMP allows for an at-sea observer and logbook programme, as well as dockside monitoring.

There are currently requirements for the use of VMS in some United States shrimp fisheries, such as that for rock shrimp in the South Atlantic. GFMC (2006) discusses the issue of using VMS in the Gulf of Mexico Shrimp Fishery, since it has been shown to be an effective management tool for enforcement in policing closed fishing areas in the EEZ of other regions of the United States. Currently, numerous areas are closed to shrimping in state waters and the EEZ of the Gulf of Mexico. The requirement of VMS for shrimp vessels would provide an important addition to enforcement capabilities for these closed areas. On the other hand, if the shrimp industry is required to pay for and maintain these VMS, this would create an additional financial burden for an industry that is experiencing severely reduced profits, as a result of price reductions from competition with foreign imports and high fuel costs, as well as impacts from recent hurricanes. Finally, VMS or 100 percent coverage using electronic logbooks would be needed to enforce the proposed management system based on quota.

It is interesting to contrast the data reporting situation in the United States shrimp fisheries with that of Canada. In Canada, both the inshore and offshore shrimping industries have observer programmes to document independently what is caught and discarded; all landings are dockside monitored; and all fishers must keep and submit logbooks. The offshore fleet has 100 percent observer coverage; the inshore fleet, a target of 10 percent (Roberts, 2005).

### IMPACTS OF SHRIMP FARMING

Ward *et al.* (2004) state that shrimp is cultured in the United States, although in relatively small quantities. There are shrimp culture facilities primarily in Texas, South Carolina and Florida but also in Alabama and Georgia. These operations produce small amounts of shrimp, mostly as a head-on product for local markets. In 2003, 4 627 tonnes of shrimp were produced by aquaculture in the United States (NMFS, 2005). Considering that capture fisheries were responsible for 143 007 tonnes in that year, aquaculture represented about 3 percent of United States domestic production of shrimp.

Clay (1996) indicates that although United States production of shrimp from aquaculture is not large, the country does have an impact on world shrimp aquaculture and has provided capital, feed, expertise, drugs/medication, training, information and research to shrimp farmers in 50 countries

It is unlikely that the small amount of domestically farmed shrimp has a major influence on the United States market. Yet, shrimp imports into the United States, most of which are from aquaculture, are thought to have a major effect on prices. According to Ward *et al.* (2004), domestic prices declined by about 55 cents for every one dollar

decline in import prices. United States ex-vessel prices declined by 27 percent in the Gulf of Mexico Shrimp Fishery and by 24 percent in the South Atlantic Shrimp Fishery between 1997 and 2002, as imports increased by 300 percent. Imports currently represent over 80 percent of the United States supply of shrimp, with aquaculture making up over 80 percent of shrimp imports.

It appears, therefore, that foreign aquaculture of shrimp has had a large impact on prices in the United States shrimp market and consequently on United States producers. Some view this as efficient overseas production to benefit United States consumers, while others feel that it represents dumping on the United States market to the detriment of domestic shrimp producers. A discussion of this debate and United States Government action is given in the *Trade aspects* section above.

### MAJOR ISSUES

The important issues related to shrimp fishing in the United States are:

- the decrease in recent profitability in the industry because of a profit squeeze;
- environmental concerns: bycatch and physical impacts;
- the use of international trade sanctions on shrimp to achieve United States objectives; and
- interactions between shrimp fisheries and other fisheries.

## References

- AAAS. 2005. *Biological and ecological sciences in the FY 2005 budget*. American Association for the Advancement of Science. (Available at [www.aaas.org/spp/rd/05pch19](http://www.aaas.org/spp/rd/05pch19))
- ABARE. 2005. *Australian fisheries statistics 2004*. Canberra, Australia, Australian Bureau of Agricultural and Resource Economics.
- ABC. 2004. *Australia seeks to join USA shrimp anti-dumping suit*. Australian Broadcasting Corporation. 4 June.
- Abdul-Ghaffar, A.R. & Al-Ghunaim, A.Y.Y. 1994. *Review of Kuwait's shrimp fisheries, their development and present status*. Papers presented at the Technical Consultation on Shrimp Management in the Arabian Gulf. Ministry of Agriculture and Water and the Saudi Fisheries Company.
- ADB/NACA. 1997. *Final report on the regional study and workshop on aquaculture sustainability and the environment*. Bangkok, Thailand, Asian Development Bank and the Network of Aquaculture Centres in Asia and the Pacific.
- AFMA. 2001a. *Northern Prawn Fishery – Northern Prawn Fishery Management Advisory Committee (NORMAC). NORMAC 51 Chair's summary*. Canberra, Australia, Australian Fisheries Management Authority. (Available at [www.afma.gov.au/fisheries/northern\\_trawl/northern\\_prawn/mac/2001/m20010829\\_cs.htm](http://www.afma.gov.au/fisheries/northern_trawl/northern_prawn/mac/2001/m20010829_cs.htm))
- AFMA. 2001b. *Northern Prawn Fishery Five-Year Research Plan 2001–2006*.
- AFMA. 2002. Background paper on bycatch.
- AFMA. 2005a. *Northern Prawn Fishery Management Advisory Committee (NORMAC). MAC chair's summary*. 12 December.
- AFMA. 2005b. *North West Slope Trawl Fishery*. (Available at [www.afma.gov.au/fisheries/northern\\_trawl/nth\\_wst\\_slope](http://www.afma.gov.au/fisheries/northern_trawl/nth_wst_slope))
- Agbayani, R.F., Belleza, E.T. & Agbayani, E.C. 1997. Aquaculture economics in Asia and the Pacific – a regional assessment. In A.T. Charles, R.F. Agbayani, E.C. Agbayani, M. Agüero, E. Belleza, B. González, B. Stomal & J. Weigel. *Aquaculture economics in developing countries: regional assessments and an annotated bibliography*. FAO Fisheries Circular 932. Rome, FAO.
- Aguilar, D. 2002. *INFOPESCA*, 7. August 1994. México DF, México, SEMARNAT/INP. (internal document)
- Aguilar, D. & Grande-Vidal, J. 1996. *Evaluación tecnológica de los dispositivos excluidores de tortugas marinas (diseño rígido) en el Océano Pacífico Mexicano durante el periodo de Febrero 1992–Agosto 1994*. México DF, México, SEMARNAT/INP.
- Ajayi, T.O. 1982. The maximum sustainable yields of the inshore fish and shrimp resources of the Nigerian continental shelf. *J. Fish. Biol.*, 20: 571–577.
- Akande, G. 2002. *Technologies for bycatch handling on board, transfer to shore, processing and marketing*. Lagos, Nigeria, Nigerian Institute for Oceanography and Marine Research. Al-Ayoub, S., Al-Husaini, M., Al-Baz, A., Chen, W., Alsaffar, A.H., Bishop, J.M., Dashti, T., Al-Jazzaf, S., Taqi, A., Al-Saad, F., Almatar, S., Eayrs, S., Bose, S., Day, G. & Murad, H. 2005. *Application of BRDs to Kuwait's shrimp fishery*. Report KISR 7762. Safat, Kuwait, Kuwait Institute for Scientific Research.
- Al-Foudari, H.M. 2005a. *Status of Kuwait's 2003/2004 shrimp fishery*. Technical Report 7503. Safat, Kuwait, Kuwait Institute for Scientific Research.
- Al-Foudari, H.M. 2005b. *Status of Kuwait's 2004/2005 shrimp fishery*. Technical Report 7853. Safat, Kuwait, Kuwait Institute for Scientific Research.
- Alió, J.J., Marcano, L.S. Soomai, S., Phillips, T., Altuve, D., Alvarez, R., Die, D. & Cochrane, K. 1999a. Analysis of industrial trawl and artisanal fisheries of whitemouth

- croaker, *Micropogonias furnieri*, of Venezuela and Trinidad and Tobago in the Gulf of Paria and Orinoco River Delta. In *FAO/Western Central Atlantic Fishery Commission Report of the Third CFRAMP/DANIDA FAO Workshop on the Assessment of Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf, Belém, Brazil, 25 May–9 June*. FAO Fisheries Report 628, pp. 138–148. Rome, FAO.
- Alió, J.J., Die, D., Ferreira, L., Gooriesingh, K., Kuruvilla, S., Maharaj, L., Marcano, L.A., Ramnarine, I. & Richardson-Drakes, A.** 1999b. *Penaeus subtilis* stock within the Orinoco and Gulf of Paria region. In *FAO/Western Central Atlantic Fishery Commission National reports presented and stock assessment reports prepared at the CFRAMP/FAO/DANIDA Stock Assessment Workshop on the Shrimp and Groundfish Resources on the Guiana-Brazil Shelf*. Port of Spain, Trinidad and Tobago, 7–18 April 1997. FAO Fisheries Report 600. Rome, FAO.
- Al-Yamani, F., Khan, N.Y., Bishop, J., Al-Hossaini, M., Subba Rao, D.V., Al-Ghadban, A.N., Salman, M., Abdel Jawad, M., Al-Tabtabaei, M., Behbahani, M. & Morgan, G.R.** 1999. Development study for the optimal utilization of the marine environment. Task 3, Vol. 1–3. *Assessment of the impacts of present and planned utilization of Kuwait's marine environment*. Report KISR 5611. (Final report, FM004C, Task 3.) Safat, Kuwait, Kuwait Institute for Scientific Research.
- Amire, A.V.** 2003. Monitoring, measurement and assessment of fishing capacity: the Nigerian experience. In S. Pascoe & D. Greboval, eds. *Measuring capacity in fisheries*. FAO Fisheries Technical Paper 445. Rome, FAO.
- Amos, M.** 1990. *A study of Type III shrimp trawling in the Gulf of Paria*. Project report. Barbados, Centre for Resource Management and Environment Studies, University of the West Indies, Cave Hill Campus.
- Anon.** 2004a. *Nitrofurans in prawns: a toxicological review and risk assessment*. Technical Report Series 31. Food Standards Australia New Zealand. November.
- Anon.** 2004b. *Seining and netting trawling*. LoveToKnow 1911 Online Encyclopedia. (Available at [www.5.1911encyclopedia.org](http://www.5.1911encyclopedia.org)). [http://encyclopedia.jrank.org/TOO\\_TUM/TRAWLING\\_SEINING\\_AND\\_NETTING.html](http://encyclopedia.jrank.org/TOO_TUM/TRAWLING_SEINING_AND_NETTING.html)
- Anon.** 2005. *Demersal. A Monthly Magazine of Marine and Fisheries Information*, 1 April. Indonesia, Ministry of Marine Affairs and Fisheries.
- APIP.** 2001. *Fisheries and aquaculture development and environment impact review*. Agriculture Productivity Improvement Project. Phnom Penh, Cambodia, Department of Fisheries.
- Arauz, R.** 1998. Implementation of the turtle excluder device (TED) by the shrimp fleet of Pacific Central America. In *Proceedings of the 18th International Symposium on Sea Turtle Conservation*. March.
- ASMFC.** 2006. Species profile: northern shrimp – recent increase in biomass allows section to expand season length. Atlantic States Marine Fisheries Commission. *ASMFC Fisheries Focus*, 15(3). April.
- Auster, P., Malatesta, F.J. & Babb, I.G.** 1994. The impacts of mobile fishing gear on benthic habitat complexity. *Gulf of Maine News*
- Australian Government.** 2006. *Bycatch: national policy*. Chair of Ministerial Council on Forestry, Fisheries and Aquaculture. (Available at <http://www.daff.gov.au/fisheries/environment/bycatch/national-policy>)
- Badrudin, M. & Nurhakim, S.** 2004. *Estimation of the maximum sustainable yield of the shrimp resources in the Arafura Sea using the surplus production model*. Jakarta, Indonesia, Research Institute for Marine Fisheries, Research Centre for Capture Fisheries, Agency for Marine and Fisheries Research.
- Badrudin, M., Sumiono, B. & Murtoyo, T.S.** 2001. Species composition and diversity of tidal trap net catches in the waters of Indragiri Hilir, Riau, Indonesia. *Indonesian Fish. Res. J.*, 7(1): 47–53.
- BAE.** 1985. BAE report on southeastern prawn fishery. Bureau of Agricultural Economics. *Australian Fisheries*, 44(1): 36–7.

- Båge, H. 2003a. *Information study – safety at sea – inventory of past and ongoing activities, based on project documents and other available literature*. Rome, FAO.
- Båge, H. 2003b. *Northern fishing communities development programme (PESNORTE)*. Arild, Sweden, Sigma Fishing Art.
- Bailey, C. 1997. Lessons from Indonesia's 1980 trawler ban. *Marine Policy*, 21(3): 225–235. Amsterdam, the Netherlands, Elsevier Science.
- Bailey, C. & Marahudin, F. 1987. The economics of marine fisheries: costs and earnings. In C. Bailey, A. Dwipongoggo & F. Marahudin. *Indonesian marine capture fisheries*. Studies and Reviews 10. Manila, the Philippines, International Center for Living Aquatic Resources Management.
- Balmori, A. 2003. *Evaluación de dispositivos excluidores de peces en redes de arrastre camarónicas en el Golfo de California, México*. Technical document. México DF, México, INP (Instituto Nacional de la Pesca)/Conservación Internacional.
- Barnette, M.C. 2001. *A review of fishing gear utilized within the southeast region and their potential impact on essential fish habitat*. NOAA Technical Memorandum. Seattle, Washington, DC, United States National Marine Fisheries Service. 62 pp.
- Béné, C. 2005. The good, the bad and the ugly: discourse, policy controversies and the role of science in the politics of shrimp farming development. *Development Policy Rev.*, 23(5): 585–614. September.
- Binet, T. 2007. *Fuelling the threat for sustainable fisheries in Europe*. Brussels, Belgium, WWF European Policy Office.
- Bishop, J.M., Ye, Y., Alsaffar, A.H., Fetta, N., Abdulqader, E., Liu, Q., Al-Mohammadi, J., Al-Qasser, J., Al-Mulla, A.A., Sudiqe, A.R., El-Abdul Had, A.R.M., Al-Jazzaf, S.T., Al-Dhubaib, A.H., Al-Juwaid, K.H., Al-Foudary, H., Almatar, S., El-Ramadan, A.H.M., El-Salah, A.A., El-Rabeigh, A.A., El-Askary, S.A. & Al-Ibrahim, E.H. 2001. *Shrimp stock assessment in the western Arabian Gulf by countries of the Gulf Cooperation Council*. Safat, Kuwait, Kuwait Institute for Scientific Research.
- Boerema, L. 1969. *The shrimp resources in the Gulf between Iran and the Arabian Peninsula*. FAO Fisheries Circular 310. Rome, FAO.
- BoFEP. 2000. Fishing in Fundy – harming seafloor habitats? *FUNDY ISSUES*, 14. Bay of Fundy Ecosystem Partnership. (Available at <http://www.bofep.org/disturbance.htm>)
- Bojórquez, L.F. 1998. Bycatch utilization in Mexico. In *Report and Proceedings of the FAO/DFID Expert Consultation on Bycatch Utilization in Tropical Fisheries*. Beijing, China, 21–28 September. Natural Resources Institute (NRI)/Department for International Development (DFID)/FAO.
- Boodoosingh, M. 1995. *Results of community surveys conducted for two fishing communities in the Gulf of Paria*. FAO/UNDP Integrated Coastal Fisheries Management Project FI: DP/INT/91/007. Port of Spain, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources.
- Boyd, C. & Clay, J. 1998. Shrimp aquaculture and the environment. *Scientific American*, 278(6): 58–65.
- Briggs, M., Funge-Smith, S., Subasinghe, R. & Phillips, M. 2004. *Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific*. RAP Publication. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.
- Broadhurst, M.K. 2000. Modifications to reduce bycatch in prawn trawls: a review and framework for development. Dordrecht, the Netherlands, Kluwer Academic Publishers. *Reviews in Fish Biology and Fisheries*, 10: 27–60.
- Broadhurst, M.K., MacBeth, W. & Wooden, M. 2005. *Reducing the discarding of small prawns in NSW's commercial and recreational prawn fisheries*. Coffs Harbour, Australia, NSW Department of Primary Industries, Fisheries Conservation Technology Unit.
- Brock, J.A. 1997. Special topic review: taura syndrome, a disease important to shrimp farms in the Americas. *World J. Microbiology and Biotechnology*, 13(4): 415–418.

- Brock, J.A., Gose, R.B., Lightner, D.V. & Hasson, K.** 1997. Recent developments and an overview of taura syndrome of farmed shrimp in the Americas. In T.W. Flegel & I.H. MacRae, eds. *Diseases in Asian Aquaculture III*: 275–283. Manila, the Philippines, Fish Health Section, Asian Fisheries Society.
- Brown, J. & Tyedmers, P.** 2004. *Production of fish*. Briefing Paper 2, Conference on Sustainable EU Fisheries. Facing the Environmental Challenges. European Commission (DG Fish). The Esmée Fairbairn Foundation, FISH and English Nature.
- Butcher, J.G.** 1999. *Why do Thai trawlers get into so much trouble?* Symposium on the Indian Ocean Fisheries: Past, Present and Future. School of Asian and International Studies, Griffith University, Fremantle, Western Australia, Western Australian Maritime Museum. November.
- Butcher, J.G.** 2004. The closing of the frontier: a history of the marine fisheries of Southeast Asia c. 1850–2000. Pasir Panjang, Singapore, Institute of Southeast Asian Studies.
- Cambodia Department of Fisheries/National Institute of Statistics.** 2003. *Cambodia post-harvest fisheries overview*. Phnom Pen, Cambodia, Cambodia Department of Fisheries, Department for International Development, and National Institute of Statistics.
- Camps-Campins, K.A.** 1995. *Results of household surveys conducted for two fishing communities in the Gulf of Paria*. FAO/UNDP Integrated Coastal Fisheries Management Project FI:DP/INT/91/007. Port of Spain, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources.
- Caramelo, A., Lamboeuf, M. & Tandstad, M.** 1999. *Improvement of the legal framework for fisheries cooperation, management and development of coastal states of West Africa*. Report of the Workshop on the Assessment and Management of Shrimps and Crabs in Southwest Africa. Luanda, Angola, 8–12 March 1999. Rome, FAO.
- Caribbean Update.** 2002. *US bans shrimp from Haiti, Indonesia*. June. (Available at [www.allbusiness.com/periodicals/article/185878-1.htm](http://www.allbusiness.com/periodicals/article/185878-1.htm))
- Carpenter, K.E. & Niem, V.H.** 1998. *The living marine resources of the western central Pacific*. FAO species identification guide for fishery purposes. Rome, FAO.
- Cartwright, I.** 2003. *The Australian Northern Prawn Fishery*. Thalassa Consulting Pty Ltd. SIFAR/World Bank Study of Good Management Practice in Sustainable Fisheries.
- Cascorbi, A.** 2004a. *Farm-raised shrimp – world overview*. Seafood Watch, Seafood Report. Vol. III. Monterey, California, United States, Monterey Bay Aquarium.
- Cascorbi, A.** 2004b. *Wild-caught warm-water shrimp*. Seafood Watch, Seafood Report. Monterey, California, United States, Monterey Bay Aquarium.
- Chamberlain, G.** 2001. Sustainable shrimp farming: issues and non-issues. In S. Subasinge & T. Singh, *Shrimp 2001 – Proceedings of Shrimp 2001* Chennai, India. Kuala Lumpur, Malaysia, INFOFISH.
- Chan, T.** 1998. Shrimps and prawns. In K.E. Carpenter & V.H. Niem. *The living marine resources of the western central Pacific*. FAO species identification guide for fishery purposes. Rome, FAO.
- Chapa, H.** 1976. *La fauna acompañante del camarón como un índice de monopesca*. Mem. Simp. Biología y Dinámica poblacional del camarón. Guaymas, Sonora, México.
- Chasanah, E.** 2000. Bycatch utilization in Indonesia. In *Expert Consultation on Bycatch Utilization in Tropical Fisheries*. September. Beijing, China.
- Chávez H. & Arvizu-Martinez, J.** 1972. *Estudio de los recursos pesqueros demersales del Golfo de California, 1968–1969. III Fauna de acompañamiento del camarón (peces finos y basura)*. Memorias del IV Congreso Nal. de Oceanografía, México DF, México.
- Chemonics.** 2002. *Subsector assessment of the Nigerian shrimp and prawn industry*. Chemonics International Inc., Agricultural Development Assistance in Nigeria. Washington, DC, United States, United States Agency for International Development.
- Chen A.** 1994. The stow net fishing situation and management in the Zhejiang coastal area. *J. Zhejiang College of Fisheries*, 13(3): 218–221.

- Chen, W.** 1999. Marine resources, their status of exploitation and management in the People's Republic of China. FAO Fisheries Circular 950. Rome, FAO.
- Chong, K., Dwiponggo, A., Ilyas, S. & Martosubroto, P.** 1987. *Some experiences and highlights of the Indonesian trawl ban: bioeconomics and socioeconomics*. In papers presented at the Symposium on the Exploitation and Management of Marine Fishery Resources in Southeast Asia, held in conjunction with the Twenty-Second Session of the Indo-Pacific Fishery Commission, Darwin, Australia, 16–19 February. 552 pp.
- Christensen, S. & Vestergaard, N.** 1993. A bioeconomic analysis of the Greenland shrimp fishery in the Davis Strait. Marine Resource Foundation. *Marine Resource Economics*, 8: 345–365.
- Chu, S., Koy, B., Li, V., Suos, S., Tat, S., Thuch, N., Vann, M. & Nelson, V.** 1999. *Case study: trawling in Kompong Som Bay*. DANIDA Coastal Zone Management Project. Cambodia, Ministry of Environment,
- Clay, J.** 1996. *Market potentials for redressing the environmental impact of wild captured and pond produced shrimp*. Washington, DC, United States, World Wide Fund for Nature.
- Clay, J.** 2004. *World agriculture and the environment – a commodity-by-commodity guide to impacts and practices*. Washington, DC, United States, Island Press.
- Coates, D.** 2002. *Inland capture fishery statistics of Southeast Asia: current status and information needs*. RAP Publication. Bangkok, Thailand, FAO Asia-Pacific Fishery Commission. 114 pp.
- Cochrane, K.L., Augustyn, C.J. & Cockcroft, A.C.** 2004. An ecosystem approach to fisheries in the Southern Benguela context. *Afr. J. Mar. Sci.*, 26: 9–35.
- Comisión de Pesca de la Cámara de Diputados.** 2001. Consulta Nacional del Sector Pesquero. Enero–Abril 2001. Informe. México DF, México, Cámara de Diputados LVIII Legislatura.
- CONAPESCA.** 1993–2002. *Anuarios Estadísticos de Pesca*. México DF, México, Comisión Nacional de Acuicultura y Pesca.
- Corripio, C.E.** 1979. *Aspectos biotecnológicos de la FAC en la región noreste del Golfo de México*. Mem. De Reunión sobre Aprovechamiento de la FAC. Guaymas, Sonora, México.
- CSIRO.** 1998. *Environmental effects of prawn trawling*. Commonwealth Scientific and Industrial Research Organization. Information sheets. (Available at [www.marine.csiro.au](http://www.marine.csiro.au))
- Dada, B.F.** 2004. Contribution of fisheries to employment, national economy and food security in Nigeria. A paper delivered by the Honourable Minister of State for Agriculture and Rural Development at the 2003 FISON Public Lecture, Lagos. *Fish Network – a quarterly publication of the Fisheries Society of Nigeria (FISON)*, 11(1): 1–2, 5–7, 14. 19 pp.
- Department of Fisheries.** 2002. Application to Environment Australia for the Exmouth Gulf Prawn Fishery against the Guidelines for the Ecologically Sustainable Management of Fisheries for Continued Listing on Section 303DB of the Environmental Protection and Biodiversity Conservation Act 1999. Western Australia.
- Department of Fisheries.** 2005. *National report on seagrasses of Cambodia*. Phnom Penh, Cambodia, United Nations Environment Programme.
- Department of the Environment, Water, Heritage and the Arts.** 2003. *Assessment of the ecological sustainability of management arrangements for the Northern Prawn Fishery*. Canberra, Australia, Australian Government.
- Department of the Environment, Water, Heritage and the Arts.** 2004a. *Assessment of the New South Wales Estuary Prawn Trawl Fishery*. Canberra, Australia, Australian Government. (Available at [www.deh.gov.au/coasts/fisheries/nsw/prawntrawl](http://www.deh.gov.au/coasts/fisheries/nsw/prawntrawl))
- Department of the Environment, Water, Heritage and the Arts.** 2004b. *Assessment of the South Australian Spencer Gulf Prawn Fishery, Gulf St Vincent Prawn Fishery and West Coast Prawn Fishery*. Canberra, Australia, Australian Government.

- DFO.** 2007. *Northern Shrimp Fishery (shrimp fishing areas 0–7)*. Canada, Department of Fisheries and Oceans. (Available at [www.dfo-mpo.gc.ca/decisions/fm-2007-gp/nshrimp-crevetten07\\_e.htm](http://www.dfo-mpo.gc.ca/decisions/fm-2007-gp/nshrimp-crevetten07_e.htm))
- Díaz de León, A.** 2004. *Country review: Mexico*. Rome, FAO Policy and Planning Division, Fisheries Department.
- Die, D., Alió, J.J., Marcano, L.A., Ferriera, L. & Soomai, S.** 2004. *Assessment of demersal stocks shared by Trinidad and Tobago and Venezuela*. FAO FishCode Review 3. Rome, FAO.
- Dintheer, C., Andriambalotiana, N.H. & Razafindrakoto, H.L.** 1998. Etat d'exploitation des stocks de crevettes péniéides côtières à Madagascar: diagnostics et perspectives pour l'aménagement de la pêche. In *Acte de l'Atelier 17–19 Juin sur l'aménagement de la pêche crevettière, Antananarivo, Madagascar*.
- Directorate of Fisheries.** 2004. *Profitability survey of fishing vessels 2003*. Bergen, Sweden.
- DKP.** 2004. *Indikator kinerja sektor kaulautan dan perikanan*. (Performance indicators in marine affairs and fisheries.) Departemen Kelautan dan Perikanan. *Social Ekonomi Tenaga Kerja*, Vol. 3. Sector Kaulautan.
- DKP.** 2005a. *Dalam angka 2005*. Jakarta, Indonesia.
- DKP.** 2005b. Pelaksanaan pembangunan Kelautan dan perikanan. Jakarta, Indonesia.
- Down to Earth.** 2002. EU rejects Indonesian shrimp imports. *Down to Earth*, 52. February. (Available at [www.dte.gn.apc.org/52brf.htm](http://www.dte.gn.apc.org/52brf.htm))
- DPI.** 2005. *The Estuary Prawn Trawl Fishery*. New South Wales Department of Primary Industries. (Available at [www.fisheries.nsw.gov.au](http://www.fisheries.nsw.gov.au))
- Dunaeva, A. & Mathews, D.** 2007. *How the shrimp tariff backfired*. Auburn, Alabama, United States, Ludwig von Mises Institute. (Available at [www.mises.org/story/2644](http://www.mises.org/story/2644))
- Eayrs, S.** 2005 (revised 2007). *A guide to bycatch reduction in tropical shrimp-trawl fisheries*. Rome, FAO.
- Eayrs, S., Buxton, C. & McDonald, B.** 1997. *A guide to bycatch reduction in Australian prawn trawl fisheries*. Launceston, Tasmania, Australian Maritime College.
- Economist (The).** 2006. *Anti-dumping – shrimp cocktail*, pp. 31–32. 5 August.
- EJF.** 2002. *Consumer guide to prawns*. London, United Kingdom, Environmental Justice Foundation.
- EJF.** 2003a. *Smash & grab: conflict, corruption and human rights abuses in the shrimp farming industry*. London, United Kingdom, Environmental Justice Foundation.
- EJF.** 2003b. *Squandering the seas: how shrimp trawling is threatening ecological integrity and food security around the world*. London, United Kingdom, Environmental Justice Foundation.
- Endroyono, P.** 2000. *Executive summary – Symposium on the Present Status of Trawl in Indonesia Waters – “Discover the Eco-friendly Trawl in Indonesia”*. Jakarta, Indonesia, Ministry of Marine Affairs and Fisheries.
- Enticknap, B.** 2002. *Trawling the north Pacific – understanding the effects of bottom trawl fisheries on Alaska's living seafloor*. Anchorage, Alaska, United States, Alaska Marine Conservation Council.
- Environment Australia.** 2002. *Assessment of the Western Australia Shark Bay Prawn Trawl Fishery*. Canberra, Australian Government.
- Eurofish.** 2007. *FISH INFOnetwork market report on shrimp*. April 2007 (available at [www.eurofish.dk/indexSub.php?id=3433](http://www.eurofish.dk/indexSub.php?id=3433)).
- Everett, J.** 2005. *Country review: USA Pacific Coast Review*. Rome, FAO.
- FAO.** 1997. *FAO Technical Guidelines for Responsible Fisheries – Fisheries Management*, 4. Rome.
- FAO.** 1998. *FAO Technical Guidelines for Responsible Fisheries – Fishing Operations – Vessel Monitoring Systems*, 1, Suppl. 1. Rome.
- FAO.** 1999. Report of the Workshop of National Coordinators of the UNEP/GEF/FAO Project on Reducing the Impact of Tropical Shrimp Trawling Fisheries on Living Marine



- Resources Through the Adoption of Environmentally Friendly Techniques and Practices. Rome, Italy, 17-19 March 1999. FAO Fisheries Report 605. 46 pp.
- FAO. 2000a. *Report of the four GEF/UNEP/FAO Regional Workshops on Reducing the Impact of Tropical Shrimp Trawl Fisheries*. Lagos, Nigeria, 15–17 December 1999; Puntareñas, Costa Rica, 15–17 January 2000; Teheran, Islamic Republic of Iran, 28 February–1 March 2000; Denpasar, Bali, Indonesia, 6–8 March 2000. FAO Fisheries Report 627. Rome.
- FAO. 2000b. *Indonesia: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2000c. *Nigeria: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2000d. *The State of World Fisheries and Aquaculture 2000*. Rome.
- FAO. 2001. *Tropical shrimp fisheries and their impact on living resources*. FAO Fisheries Circular 974, FIIT/C974. Rome.
- FAO. 2003a. *Australia: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2003b. *Fisheries management. 2. The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries, 4 (Suppl. 2).
- FAO. 2003c. *Kuwait: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2003d. *Mexico: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2003e. *Pakistan: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2004. *The state of world fisheries and aquaculture 2004*. Rome.
- FAO. 2005a. *Cambodia: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2005b. *United States of America: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org); [www.fao.org/fi/fcp/en/USA/profile.htm](http://www.fao.org/fi/fcp/en/USA/profile.htm))
- FAO. 2005c. *Guidelines for the ecolabelling of fish and fishery products from marine capture fisheries*. Rome.
- FAO. 2005d. *Norway: fishery country profile*. Rome. (Available at [www.fao.org](http://www.fao.org))
- FAO. 2005e. *Putting into practice the ecosystem approach to fisheries*. Rome.
- FAO. 2005f. *World fisheries and aquaculture atlas*. Third edition. Rome.
- FAO. 2006a. *Capture production 1950–2004*. FISHSTAT Plus – Universal software for fishery statistical time series. Rome. (Available at [www.fao.org/fi/statist/FISOFT/FISHPLUS.asp](http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp); or CD-ROM)
- FAO. 2006b. *Commodity trade and production 1976–2004*. FISHSTAT Plus – Universal software for fishery statistical time series. Rome. (Available at [www.fao.org/fi/statist/FISOFT/FISHPLUS.asp](http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp); or CD-ROM)
- FAO. 2006c. *State of world aquaculture 2006*. FAO Fisheries Technical Paper 500. Rome.
- FAO. 2007. *Capture production 1950–2005*. FISHSTAT Plus – Universal software for fishery statistical time series. Rome. (Available at [www.fao.org/fi/statist/FISOFT/FISHPLUS.asp](http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp); or CD-ROM)
- FAO & Fisheries Division, Ministry of Agriculture, Land and Marine Resources. 2001. Report of the National Workshop on Shrimp and Groundfish Fisheries of the Brazil-Guianas Shelf. Rudrinath Capildeo Learning Resource Center, Couva, Trinidad and Tobago, 2–3 May 2000. Rome.
- FAO, NACA, UNEP, WB & WWF. 2006. *International principles for responsible shrimp farming*. FAO, Network of Aquaculture Centres in Asia-Pacific, United Nations Environment Programme, World Bank and World Wide Fund for Nature.
- FDA. 2007. *Questions and answers on FDA's import alert on farm-raised seafood from China*. Washington, DC, United States, US Food and Drug Administration, Center for Food Safety and Applied Nutrition.
- Federal Register, United States Environmental Protection Agency. 2004. *Sea turtle conservation; shrimp trawling requirements*, 69(230). (Available at [www.epa.gov/fedrgstr/EPA-IMPACT/2004/December](http://www.epa.gov/fedrgstr/EPA-IMPACT/2004/December))
- Fernández, J.I., Schultz, L., Wakida, A.T., Medellín, M., Sandoval, M.E., Nuñez, G., Uribe, J.A., Castro, R.G., González, A., González, M.E., Santos, J., Marcet, G., Aguilar, F., Delgado, B. & Chale, G. 2000. Camarón del Golfo de México y Mar Caribe.

- In *Sustentabilidad y Pesca Responsable en México; Evaluación y Manejo, 1999–2000*. México DF, México, Instituto Nacional de la Pesca.
- Ferreira, L.** 2000. *Country report: Trinidad*. Prepared for the CFRAMP Fisheries Management Data System Terminal Workshop, The Way Forward – A Review and Planning Session, 25–28 November, Saint Lucia, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources.
- Ferreira, L. & Medley, P.** 2005. The southern pink shrimp (*Farfantepenaeus notialis*) and Atlantic seabob (*Xiphopenaeus kroyeri*) fisheries of the Trinidad and Tobago trawl fishery. CRFM Report of the First Annual CRFM Scientific Meeting. *CRFM Fishery Report*, 11: 63–88. Belize, Secretariat of the Caribbean Regional Fisheries Mechanism.
- Ferreira, L. & Soomai, S.** 2001. *Trinidad and Tobago, shrimp and groundfish fisheries*. 1994 Draft Policy Directions for Marine Fisheries of Trinidad and Tobago in the 1990s. Policy Mission Report of FAO Project TCP/TRI/2352(A). Port of Spain, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources and Rome, FAO. 123 pp.
- Fletcher, W.J.** 2005. The application of qualitative risk assessment methodology to prioritize issues for fisheries management. *ICES J. Marine Science*, 62: 1576–1587.
- Flewelling, P. & Hosch, G.** 2004a. *Country review: Cambodia*. Rome, FAO, Policy and Planning Division, Fisheries Department.
- Flewelling, P. & Hosch, G.** 2004b. *Country review: Indonesia*. Rome, FAO, Policy and Planning Division, Fisheries Department.
- Fogarty, M.J.** 2002. An introduction to the concept and application of marine protected areas. In *Fisheries, oceanography and society: marine protected areas*. Massachusetts, United States, Ocean Life Institute, Woods Hole Oceanographic Institute.
- Funge-Smith, S., Lindebo, E. & Staples, D.** 2005. *Asian fisheries today: the production and use of low value “trash fish” from marine fisheries in the Asia-Pacific region*. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.
- Galeano, D., Langenkamp, D., Shafron, W. & Levantis, C.** 2004. *Australian fisheries surveys report 2003: economic performance of selected fisheries in 2000–01 and 2001–02*. Canberra, Australia, Australian Bureau of Agricultural and Resource Economics (ABARE).
- Galeano, D., Vieira, S., Shafron, W. & Newton, P.** 2006. *Australian Fisheries Surveys Report 2005*. ABARE Report Prepared for the Fisheries Resources Research Fund, Canberra, August.
- Gandini P.A., Frere E., Pettovello A.D. & Cedrola P.V.** 1999. Interaction between Magellanic Penguins and shrimp fisheries in Patagonia, Argentina. *The Condor* 101:783–789.
- Garcia, S.** 1989. The management of coastal penaeid shrimp fisheries. In J.F. Caddy, ed. *Marine invertebrate fisheries: their assessment and management*. New York, United States, J. Wiley & Sons.
- Garcia, S.M., Zerbi, A., Aliaume, C., Do Chi, T. & Lasserre, G.** 2003. *The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook*. FAO Fisheries Technical Paper 443. Rome, FAO.
- GFMC.** 2006. *Scoping document for amendment 15 to the shrimp FMP*. Gulf of Mexico Fisheries Management Council. (Available at [www.gulfcouncil.org/downloads](http://www.gulfcouncil.org/downloads))
- Gillett, R.** 1996. *Marine fisheries resources and management in Indonesia, with emphasis on the Exclusive Economic Zone*. Workshop Presentation Paper 1. FAO Project “Strengthening Marine Fisheries Development in Indonesia”. 34 pp.
- Gillett, R.** 2001. *Fisheries management aspects of revising fisheries legislation in Indonesia*. FAO/Indonesia Marine Fisheries Legislation Project, TCP/INS/8922. Rome, FAO. 39 pp.
- Gillett, R.** 2004. *The marine fisheries of Cambodia*. FAO FishCode Review 4. Rome, FAO. ISSN 1728-4392. 58 pp.

- Gillett, R. & Preston, G. 1997. *The sustainable contribution of fisheries to food security in the Oceania subregion of the Asia-Pacific region: review of food security issues and challenges in the Asia and Pacific Region*. UNDP TSS1 Project Ras/95/01T. Gillett, Preston and Associates. 50 pp.
- GLOBEFISH. 2003. *Commodity update – shrimp*. FAO, Rome.
- Gómez, V. 2001. *México y sus recursos pesqueros ante el tratado de libre comercio*. (Available at [http://www.economia.gob.mx/pics/p/p1763/pesca\\_final.pdf](http://www.economia.gob.mx/pics/p/p1763/pesca_final.pdf))
- Graham, N. 2005. *An overview of bycatch reduction legislation in the Pandalus borealis (Northern Shrimp) Fisheries of the North Atlantic and its effectiveness*. Fisheries Technology Committee, Report 2005. Copenhagen, Denmark, International Council for the Exploration of the Sea.
- Graham, N., Polet, H. & Revill, A. 2005. *The brown shrimp (Crangon crangon) fisheries of the North Sea: a review of discards and by-catch, technical measures and their efficacy*. Report of the ICES/FAO Working Group on Fishing Technology and Fish Behaviour, 18–22 April, Rome.
- Grande-Vidal, J.M. 1987. *Experimentación tecnológica de los dispositivos excluidores de tortugas marinas en México*. Internal technical report. SEPESCA/INP.
- Grande-Vidal, J.M. 1996. *Optimización de redes camarónicas con bolsos de malla cuadrada y excluidores de tortugas*. Research report. SEMARNAP/INP.
- Grande-Vidal, J.M. 2003. *Evaluación de la productividad excedente de camarón del Golfo de México en el periodo 1970–1999*. Informe de Investigación CRIP Veracruz. Internal document. INP/CONAPESCA
- Grande-Vidal, J.M. 2004. A model for estimating surplus productivity from annual catches. *ICCAT Science Paper*, 56(2): 642–659.
- Grande-Vidal, J.M. 2006. La explotación pesquera en México (1929–2003). In *Pesca, acuicultura e investigación en México*. México DF, México, Comisión de Pesca de la Cámara de Diputados y Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria (CEDRSSA).
- Grande-Vidal, J.M. & Díaz, L. 1981. *Situación actual y perspectivas de utilización de la fauna de acompañamiento del camarón en México*, 1(2): 43–55. México DF, México, Ciencia Pesquera. Inst. Nal. Pesca. Depto de Pesca.
- Gray, J.S. 2000. The measurement of marine species diversity, with an application to the benthic fauna of the Norwegian continental shelf. *J. Experimental Marine Biology and Ecology*, 250(1): 23–49.
- Gray, J.S., Dayton, P.K., Thrush, S.F. & Kaiser, M.J. 2006. On effects of trawling, benthos and sampling design. *Marine Pollution Bulletin*, 52: 840–843.
- Greenpeace. 2004. *Skimp on shrimp*. (Available at [www.Greenpeace.org/international/press/reports/skimp-on-the-shrimp](http://www.Greenpeace.org/international/press/reports/skimp-on-the-shrimp))
- Griffin, W., Clark, J., Clark, J. & Richardson, J. 1988. *Economic impact of TED on the shrimp industry in the Gulf of Mexico*. United States National Marine Fisheries Service.
- Gross, G.B. 1973. Shrimp industry of Central America, Caribbean Sea and northern South America. Foreign Fisheries Leaflet 73–1. *Marine Fisheries Rev.*, 35(34): 36–55. Washington, DC, United States National Marine Fisheries Service, United States Department of Commerce.
- GSMFC. *Species summaries*. Gulf States Marine Fisheries Commission. (Available at [www.gsmfc.org](http://www.gsmfc.org))
- Gulland, J.A. 1984. Report of the Workshop on the Scientific Basis for the Management of Penaeid Shrimp. In J.A. Gulland & B.J. Rothschild. *Penaeid shrimps – their biology and management*. Farnham, United Kingdom, Fishing News Books Limited.
- Gulland, J.A. & Rothschild, B.J. *Penaeid shrimps – their biology and management*. Farnham, United Kingdom, Fishing News Books Limited.
- Hall, S. 1999. *The effects of fishing on marine ecosystems and communities*. Oxford, United Kingdom, Blackwell Science.

- Hannah, R. & Jones, S.** 2004. *Annual Pink Shrimp Review*. Newport, Oregon, United States, Marine Resources Program, Oregon Department of Fish and Wildlife.
- Hansson, M., Lindegarth, M., Valentinsson, D. & Ulmestrand, M.** 2000. Effects of shrimp-trawling on abundance of benthic macrofauna in Gullmarsfjorden, Sweden. *Marine Ecology Progress Series*, 198: 191–201.
- Harrington, J., Myers, R. & Rosenberg, A.** 2005. Wasted fishery resources: discarded by-catch in the USA. *Fish and Fisheries*, 6: 350–361.
- Hempel, E.** 2001. The Norwegian shrimp industry. *INFOFISH production and marketing of shrimp*. Proceedings of Shrimp 2001, Kuala Lumpur, Malaysia.
- Hill, B.J. & Wassenberg, T.J.** 1990. Fate of discards from prawn trawlers in Torres Strait. *Aust. J. Mar. Freshw. Res.*, 41: 53–64.
- Hillestad, H., Richardson, J., McVea, C. & Watson, J.** 1981. Worldwide incidental capture of sea turtles. In K. Bjorndal, ed. *Biology and conservation of sea turtles*. Washington, DC, United States, Smithsonian Institution Press.
- Hogan, D.** 2004. *Management experiences in implementing sea turtle avoidance and mitigation measures in commercial fisheries*. Paper presented at the Expert Consultation on Interactions between Sea Turtles and Fisheries within an Ecosystem Context, Rome, 9–12 March. FAO Fisheries Report 738, Suppl. Rome, FAO.
- Hogarth, W.** 2005. Testimony of Dr William Hogarth, Assistant Administrator, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce, on the effects of hurricanes Katrina and Rita on the fishing industry and fishing communities in the Gulf of Mexico, before the Subcommittee on Fisheries and Oceans, Committee on Resources, United States House of Representatives. 15 December. (Available at [www.legislative.noaa.gov/Testimony/hogarth121505.pdf](http://www.legislative.noaa.gov/Testimony/hogarth121505.pdf))
- Holthuis, L.** 1980. *Shrimps and prawns of the world – an annotated catalogue of species of interest to fisheries*. FAO Fisheries Synopsis 125(1). Rome, FAO.
- Humborstad, O., Nøttestad, L., Løkkeborg, S. & Rapp, H.T.** 2004. RoxAnn bottom classification system, sidescan sonar and video sledge: spatial resolution and their use in assessing trawling impacts. *ICES J. Marine Science*, 61: 53–63.
- Ianelli, J.** 2004. *US shrimp tariffs: an economic and environmental analysis*. New Orleans, United States, Loyola University.
- ICES.** 2005. *Report of the Pandalus Assessment Working Group*. Copenhagen, Denmark, International Council for the Exploration of the Sea.
- ICES/FAO.** 2005. *Indonesia. Review of bycatch in world shrimp trawl fisheries*. Report of the ICES/FAO Working Group on Fishing Technology and Fish Behaviour, 18–22 April. Rome.
- ICLARM.** 1999. *Management of fisheries, coastal resources and the coastal environment in Cambodia: institutional, legal and policy perspectives*. Cambodia Working Group, Policy Legal Inst. Stud. Working Paper 3, Policy Research and Impact Assessment Program. Manila, the Philippines, International Center for Living Aquatic Resources Management.
- IMR.** 2007. Protocol of the Annual Meeting between Russian and Norwegian Scientists Murmansk, Russian Federation, 19–23 March. Institute of Marine Research. (Available at [www.assessment.imr.no/Request/HTMLinks](http://www.assessment.imr.no/Request/HTMLinks))
- INFOFISH.** 2004. *Lower duty on seafood products to the Japanese market*. 15 October.
- INP.** 2000. *Pesquerias del Pacifico*. Benito Juarez, México. Instituto Nacional de la Pesca.
- IntraFish.** 2005. Big chill in cold-water shrimp market. *IntraFish Magazine*, 3(12). December.
- IntraFish.** 2007. *US shrimp marketing group asks industry for financial help*. (Available at <http://www.intrafish.no/global/>)
- Isaksen, B.** 1997. The Norwegian approach to reduce bycatch and avoid discards. In *Papers presented at the Technical Consultation on Reduction of Wastage in Fisheries*, Tokyo, Japan, 28 October–1 November 1996. FAO Fisheries Report 547, Suppl. Rome, FAO.

- Iversen, E., Allen, D. & Higman, J. 1993. *Shrimp capture and culture fisheries of the United States*. Oxford, United Kingdom, Fishing News Books, Blackwell Science.
- Janetkitkosol, W., Somchanakij, H., Eiamsa-ard, M. & Supongpan, M. 2003. Strategic review of the fishery situation in Thailand. In G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen & D. Pauly, eds. *Assessment, management and future directions for coastal fisheries in Asian countries*, pp. 915–956. WorldFish Center Conference Proceedings 67. 1120 pp.
- Johnson, K.A. 2002. *A review of national and international literature on the effects of fishing on benthic habitats*. Silver Spring, Maryland, United States National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce.
- Josupeit, H. 2004. *Shrimp market access, tariffs and regulations*. World Shrimp Markets 2004. 26–27 October. Madrid, Spain. Rome, FAO/GLOBEFISH.
- Joyner, C. & Tyler, Z. 2000. Marine conservation versus international free trade: reconciling dolphins with tuna and sea turtles with shrimp. *Ocean Development and International Law*, 31: 127–150.
- JSA. 1997. *An evaluation of potential virus impacts on cultured shrimp and wild shrimp populations in the Gulf of Mexico and Southeastern US Atlantic coastal waters*. Silver Spring, Maryland, United States National Marine Fisheries Service, National Oceanic and Atmospheric Administration, National Program Office. Joint Subcommittee on Aquaculture. 65 pp.
- Kelleher, K. 2002. *The costs of monitoring, control and surveillance of fisheries in developing countries*. FAO Fisheries Circular 976. Rome, FAO.
- Kelleher, K. 2005. *Discards in the world's marine fisheries – an update*. FAO Fisheries Technical Paper 470. Rome, FAO.
- Kenchington, T.J. 1995. A summary of the published evidence relating to habitat modification by fish draggers. In *Canadian Maritimes Fishing: Let's Fix It, An Action Plan*, pp. 109–116. Shelburne, Nova Scotia, Canada, Southwest Nova Scotia Fixed Gear Association.
- Kennelly, S.J. & Broadhurst, M.K. 2002. By-catch begone: changes in the philosophy of fishing technology. *Fish and Fisheries*, 3(4): 340–355.
- Kesteven, G. 1973. *Manual of fisheries science. Part 1: an introduction to fisheries science*. FAO Fisheries Technical Paper 118. Rome, FAO.
- King, M.G. 2007. *Fisheries biology, assessment, and management*. Second edition. Blackwell Publishing. Oxford, England. 381 p.
- Koeller, P., Savard, L., Parsons, D. & Fu, C. 2000. A precautionary approach to assessment and management of shrimp stocks in the Northwest Atlantic. *J. Northwest Atlantic Fisheries Sci.*, 27: 235–246.
- Kompas, T. & Gooday, P. 2006. *Excess capacity and structural adjustment in the Australian Northern Prawn Fishery*. Canberra, Australia, Australian Bureau of Agriculture and Resource Economics (ABARE) Report to the Department of Agriculture, Fisheries and Forestry.
- Kongprom, A., Khaemakorn, P., Eiamsa-ard, M. & Supongpan, M. 2003. Status of demersal fishery resources in the Gulf of Thailand. In G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen & D. Pauly, eds. *Assessment, management and future directions for coastal fisheries in Asian countries*, pp. 137–152. WorldFish Center Conference Proceedings 67. 1120 pp.
- Krampe, P. 2006. *Rising fuel prices and its impact on the tuna industry*. Paper presented at the INFOFISH World Tuna Trade Conference, 25–27 May, Bangkok, Thailand.
- Kristjonsson, H. 1968. *Techniques of finding and catching shrimp in commercial fishing*. FAO Fisheries Report 57, p. 125–192.
- Kura, Y., Revenga, C., Hoshino, E. & Mock, G. 2004. *Fishing for answers – making sense of the global fish crisis*. Washington, DC, United States, World Resources Institute.

- Kuruvilla, S.** 2001. National Report of Trinidad and Tobago. In *Shrimp fisheries in Asia: Bangladesh, Indonesia and the Philippines; in the Near East: Bahrain and Iran; in Africa: Cameroon, Nigeria and the United Republic of Tanzania; in Latin America: Colombia, Costa Rica, Cuba, Trinidad and Tobago, and Venezuela*. FAO Fisheries Circular 974. FIIT/C974. Rome, FAO.
- Kuruvilla, S. & Chan-A-Shing, C.** 2002. *Globalization, international trade and marine fisheries: case study of the trawl fishery of Trinidad and Tobago*. Port of Spain, Trinidad and Tobago.
- Kuruvilla, S., Chan-A-Shing, C., Ferreira, L., Martin, L., Soomai, S., Lalla, H. & Jacque, A.** 2002. *Study on subsidies in the fisheries sector of Trinidad and Tobago*. Port of Spain, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources. 110 pp.
- Kuruvilla, S., Ferreira, L., Soomai, S. & Jacque, A.** 2000. *Economic performance and technological features of marine capture fisheries: the trawl fishery of Trinidad and Tobago*. Port of Spain, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources. Regional Workshop on the Effects of Globalization and Deregulation on Fisheries in the Caribbean. Castries, Saint Lucia, 4 December. 49 pp.
- Kutti, T., Høisæter, T., Rapp, H.T., Humborstad, O.-B., Løkkeborg, S. & Nøttestad, L.** 2005. Immediate effects of experimental otter trawling on a sub-arctic benthic assemblage inside Bear Island Fishery Protection Zone in the Barents Sea. *American Fishery Society Symposium*, 41: 519–528.
- Lamberts, D.** 2001. *Tonle Sap fisheries: a case study on floodplain gillnet fisheries*. RAP Publication. Bangkok, Thailand, Asia-Pacific Fishery Commission and FAO Regional Office for Asia and the Pacific.
- Leadbitter, D. & Oloruntuyi, O.** 2002. *Shrimp fisheries and certification – the role of the Marine Stewardship Council*. London, United Kingdom, Marine Stewardship Council.
- Lem, A.** 2006. An overview of global shrimp markets and trade. In P.S. Leung & C. Engle, eds. *Shrimp culture: economics, market and trade*. Blackwell Publishing. 335 pp.
- Lightner, D.V.** 1996. *A handbook of shrimp pathology and diagnostic procedures for diseases of cultured penaeid shrimp*. Baton Rouge, Louisiana, USA, World Aquaculture Society.
- Lightner, D.V.** 2002. *Introduction of non-indigenous shrimp viruses and their potential impact on farmed and native wild shrimp populations*. International Symposium on Aquatic Animal Health (ISAAH).
- Lindeboom, H.J. & de Groot, S.J.** 1998. *Impact II. The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems*. Den Burg, Texel, the Netherlands. Netherlands Institute for Sea Research (NIOZ) Rapport 1998–1/RIVO-DLO Report COO3/98. 404 pp.
- Lindgarth, M., Valentinsson, D., Hansson, M. & Ulmestrand, M.** 2000. Effects of trawling disturbances on temporal and spatial structure of benthic soft-sediment assemblages in Gullmarsfjorden, Sweden. *ICES J. Marine Science*, 57(5): 1369–1376.
- Liu-Xiong, X.** 1995. *Shrimp fishing with stow nets in China*. FAO Workshop on Research in Selectivity of Fishing Gear and Methods in the Southeast Asian Countries, Malaysia, 28–30 June.
- Løkkeborg, S.** 2005. *Impacts of trawling and scallop dredging on benthic habitats and communities*. FAO Fisheries Technical Paper 472. Rome, FAO.
- Longhurst, A.R.** 1965. Shrimp potential of the eastern Gulf of Guinea. *Commercial Fisheries Rev.*, 27(11): 9–12.
- Lum Young, P., Ferreira, L. & Maharaj, L.** 1992. *Preliminary stock assessment for the shallow water shrimp trawl fishery in the “Special Fishing Area” adjacent to the mouth of the Orinoco River (Venezuela)*. Technical report of the Project for the Establishment of Data Collection Systems and Assessment of the Fisheries Resources. FAO/UNDP: TRI/91/001/TR9. Port of Spain, Trinidad and Tobago, Ministry of Agriculture, Land and Marine Resources.

- Magallón-Barajas, F.J.** 1987. The Pacific shrimp fishery of Mexico. *CalCOFI Rep.*, 28: 43–52.
- Maharaj, V.** 1989. *The bycatch in the artisanal shrimp trawl fishery, Gulf of Paria, Trinidad*. United States, University of Rhode Island. (M.Sc. thesis)
- Maharaj, L., Ferreira, L. & Lum Young, P.** 1993. *Description of the shrimp trawl fishery of Trinidad*. Technical report of the Project for the Establishment of Data Collection Systems and Assessment of the Fisheries Resources. FAO/UNDP: TRI/91/001/TR9. Port of Spain, Trinidad and Tobago, Ministry of Agriculture, Land and Marine Resources.
- Mail and Guardian.** 2005. *Oil is about everything*. Mail and Guardian online. (Available at [www.mg.co.za/](http://www.mg.co.za/))
- Management Information Systems (MIS).** 1991. FISMIS commercial landings module: user documentation. Port of Spain, Trinidad and Tobago. 57 pp.
- Mathews, D.** 2004. *The fallacies of shrimp protectionism*. Auburn, Alabama, United States, Ludwig von Mises Institute. (Available at <http://mises.org/story/1551>)
- McConnaughey, R.A., Mier, K.L. & Dew, C.B.** 2000. An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea. *ICES J. Marine Science*, 57: 1377–1388.
- Melvin, E.** 2007. *By-catch mitigation. Tales of success and failure across ecosystems, technologies and cultures*. Plenary lecture. ICES Annual Science Conference, Helsinki, Finland, September 2007.
- Metschies, P.** 2007. *International fuel prices 2005*. Eschborn, Germany, German Federal Ministry for Economic Cooperation and Development BMZ.
- MMAF.** 2005. *Executive summary – Symposium of Present Status of Trawl in Indonesia Waters. “Discover the Eco-Friendly Trawl in Indonesia”*. Jakarta, Indonesia, Ministry of Marine Affairs and Fisheries.
- Monintja, D., Sondita, F., Purbayanto, A., Kaswadji, R., Bidawi, M., Hasyim, K. & Budiman, S.** 2005. Lingkungan wilayah laut arafura – Marine environment of Arafura. Java, Indonesia, Bogor University. (Powerpoint presentation)
- Morgan, G.** 2004a. *Country review: Australia (Pacific coast)*. Rome, FAO Policy and Planning Division, Fisheries Department.
- Morgan, G.** 2004b. *Country review: Kuwait*. Rome, FAO Policy and Planning Division, Fisheries Department.
- MSC.** 2007. *Certified fisheries*. Marine Stewardship Council. (Available at [www.msc.org](http://www.msc.org))
- Naamin, N. & Martosubroto, P.** 1980. Effect of gear changes in the Cilacap shrimp fishery. In *Report of the workshop on the biology and resources of the penaeid shrimps in the South China Sea area*. Manila, the Philippines, South China Sea Fisheries Development and Coordinating Programme.
- Nageon de Lestang, J.** 2007. *Study on safety at sea for small scale fisheries. 1. South West Indian Ocean*. FAO Fisheries Circular No. 1024/1. Rome, FAO. 56 pp.
- Nance, J. & Harper, D.** 1999. Southeast and Caribbean invertebrate fisheries. In *Our living oceans*. Silver Spring, Maryland, Southeast Fisheries Science Center, United States National Marine Fisheries Service.
- National Committee.** 2001. Reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices in the Arafura Sea, Indonesia. National Committee for Reducing the Impact of Tropical Shrimp Trawling Fisheries in the Arafura Sea, Directorate General of Fisheries Department of Ocean Exploration and Fisheries, Jakarta, Indonesia. In *Tropical shrimp fisheries and their impact on living resources*. FAO Fisheries Circular 974. Rome, FAO.
- Nautilus Consultants and International Institute for Environment and Development (IIED).** 2003. *Investment mechanisms for socially and environmentally responsible shrimp culture synthesis report*. United Kingdom, Peebles and London.

- Naylor, R.J., Goldberg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M. 2001. Effects of aquaculture on world fish supplies. *Issues in Ecology*, 8. Winter.
- Nedelec, C. & Prado, J. 1990. *Definitions and classification of fishing gear categories*. FAO Fisheries Technical Paper 222 (Rev. 1). Rome, FAO. 92 pp.
- NITOA. 1998. NITOA and the Nigerian fishing industry. The trawlers. *Bulletin of the Nigerian Trawlers' Owners Association (NITOA)*, 1(1), February. 12 pp.
- NMFS. 2003. *Southeast region current bycatch priorities and implementation plan FY04 and FY05*. United States National Marine Fisheries Service, Southeast Fisheries Science Center.
- NMFS. 2005. *Fisheries of the United States 2004*. United States National Marine Fisheries Service, Fisheries Statistics Division. (Available at [www.st.nmfs.gov/st1](http://www.st.nmfs.gov/st1))
- NORMAC. 2002. *Northern prawn fishery action plan 2002*. Australian Government, Australian Fisheries Management Authority. Northern Prawn Fishery Management Advisory Committee.
- Norwegian Seafood Export Council. 2005. (Available at [www.seafood.no](http://www.seafood.no))
- NRC. 1990. *Decline of the sea turtles: causes and prevention*. National Research Council Committee on Sea Turtle Conservation. Washington, DC, United States, National Academy Press. 259 pp.
- NRC. 2002. *Effects of trawling and dredging on seafloor habitat*. Washington, DC, United States, Ocean Studies Board, National Research Council, National Academy Press.
- NSW Fisheries. 2003. *Fishery management strategy for the Estuary Prawn Trawl Fishery*. Australia, Cronulla, Cronulla Fisheries Centre.
- O'Brien, J. 2003. *The National Marine Fisheries Management and Development Policy and Action Plan*. Cambodia, Department of Fisheries, Ministry of Agriculture, Forestry and Fisheries.
- Observatoire Économique. 2004. *Analyse dynamique et macroéconomique sur l'exercice 2003 de la sous filière pêche industrielle*. Rapport N°11, Tome 1. Antananarivo, Madagascar.
- Observatoire Économique. 2005. *Analyse dynamique et macroéconomique sur l'exercice 2004 de la sous filière pêche artisanale*. Rapport N°11, Tome 2. Antananarivo, Madagascar.
- Ocean Garden. 2005. *Ocean Garden hails shrimp pact*. Press release, 5 August.
- Oceanic Development. 2005. *Étude de faisabilité de l'évaluation des ressources halieutiques marines à Madagascar. Description des principales pêcheries malgaches*. May.
- Ogbonna, J. 2001. Reducing the impact of tropical shrimp trawling fisheries on the living marine resources through the adoption of environmentally friendly techniques and practices in Nigeria. In *Tropical shrimp fisheries and their impact on living resources*. FAO Fisheries Circular 974. Rome, FAO.
- OIE. (no date). Office International des Epizooties. (Available at [www.oie.int](http://www.oie.int))
- O'Sullivan, G. 2005. *Market outlook: Europe*. In *Global Shrimp Outlook: 2005*. Madrid, Spain; Rome, FAO/GLOBEFISH.
- Overstreet, R.M., Lightner, D.V., Hasson, K., McIlwain, S. & Lotz, J.M. 1997. Susceptibility to taura syndrome virus of some Penaeid shrimp species native to the Gulf of Mexico and the Southeastern United States. *J. Invertebrate Pathology*, 69: 165–176.
- Palmer, G. & Miller, S. 2005. *Prawn fishing in Spencer Gulf and West Coast*. Port Lincoln, Australia, Spencer Gulf and West Coast Prawn Fishermen's Association.
- Pandav, B. & Choudhury, B.C. 1999. Can the olive ridley turtles in Orissa, India be saved – a review of the scientific facts available. *NOAA Technical Memorandum NMFSSSEFSC* 443: 71–73.
- Parsons, D., Colbourne, E., Lilly, G. & Kulka, D. 1998. Northern Shrimp (*Pandalus borealis*) on Flemish Cap (NAFO Division 3M) – oceanography, fishery and biology. *J. Northw. Atl. Fish. Sci.*, 24: 1–26.
- Pauly, D. 1993. From growth to Malthusian overfishing: stages of fisheries resources misuse. South Pacific Commission. *Traditional Marine Resource Management and Knowledge Information Bulletin*, 3: 7–14.



- PCI. 2001. *Study on fisheries development policy formulation. Vol. II. Review and analysis of policies and performances and recommendations*. Pacific Consultants International. Jakarta Fishing Port/Market Development Project. Tokyo, Japan.
- Perdrau, M. & Garvey, J. 2005. *Northern Prawn Fishery data summary 2004*. Canberra, Australia, Logbook Program, Australian Fisheries Management Authority.
- PICES. 2001. *Commercially important crabs, shrimps and lobsters of the North Pacific Ocean*. North Pacific Marine Science Organization.
- Poffenberger, J. 1984. An economic perspective of problems in the management of penaeid shrimp fisheries. In J. Gulland & B. Rothschild. 1984. *Penaeid shrimps – their biology and management*. Summary of Workshop on the Scientific Basis for the Management of Penaeid Shrimp. Surrey, United Kingdom, Fishing News Books Limited.
- Poiner, I., Blaber, S., Brewer, D., Burridge, C., Caesar, D., Connell, M., Dennis, D., Dews, G., Ellis, N., Farmer, M., Glaister, J., Gribble, N., Hill, B., O'Connor, R., Pitcher, R., Salini, J., Taranto, T., Thomas, M., Toscas, P., Wang, Y., Veronise, S. & Wassenberg, T. 1997. *Final report on effects of prawn trawling in the far northern section of the Great Barrier Reef Marine Park*. Draft final report to the Great Barrier Reef Marine Park Authority and Fisheries Research and Development Corporation on 1991–1996 (years 1–5) research. CSIRO Division of Fisheries and Queensland Department of Primary Industries and Fisheries.
- Poiner, I., Glaister, J., Pitcher, R., Burridge, C., Wassenberg, T., Gribble, N., Hill, B., Blaber, S., Milton, D., Brewer, D. & Ellis, N. 1998. *Environmental effects of prawn trawling in the far northern section of the Great Barrier Reef Marine Park 1991–1996*. Final report to the Great Barrier Reef Marine Park Authority and the Fisheries Research and Development Corporation. Hobart, Tasmania, CSIRO Division of Marine Research.
- Poiner, I. & Harris, A. 1996. Incidental capture, direct mortality and delayed mortality of sea turtles in Australia's Northern Prawn Fishery. *Marine Biology*, 125: 813–825.
- Poseidon Aquatic Resource Management. 2003. *Fisheries discards. An assessment of impacts and a review of current legislation and reduction programmes*. Final report. Rome, FAO.
- Prado, J. & J. Valdemarsen. 2005. Fishing gear. In *World Fisheries and Aquaculture Atlas* (CD-ROM). Rome, FAO Fisheries and Aquaculture Department.
- Primavera, J.H. 1995. Mangroves and brackishwater pond culture in the Philippines. *Hydrobiologia*, 295: 303–309.
- Primavera, J.H. 1998. Mangroves as nurseries: shrimp populations in mangrove and non-mangrove habitats. *Estuarine, Coastal and Shelf Science*, 46, 457–464.
- Priyono, B. & Sumiono, B. 1997. The marine fisheries of Indonesia, with emphasis on the coastal demersal stocks of the Sunda shelf. In G. Silvestre & D. Pauly, eds. *Status and management of tropical coastal fisheries in Asia*, pp. 38–46. ICLARM Conference Proceedings 53. 208 pp.
- Public Citizen. 2004. *Chemical cocktail: the health impacts of eating farm-raised shrimp*. (Available at [www.citizen.org/cmep/foodsafety/shrimp/articles.cfm?ID=12706](http://www.citizen.org/cmep/foodsafety/shrimp/articles.cfm?ID=12706))
- Purbayanto, A. 2005. Mengungkap potensi dan permasalahan bycatch di Laut Arafura. *Samudra* magazine. July.
- Purwanto. 2003. Status and management of the Java Sea fisheries. In G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen & D. Pauly, eds. *Assessment, management and future directions for coastal fisheries in Asian countries*, pp. 793–832. WorldFish Center Conference Proceedings 67. 1120 pp.
- Purwanto. 2005. *Business assessment of demersal fishing in Arafura*. Jakarta, Indonesia, Ministry of Marine Affairs and Fisheries.
- QFFI. 2005. Are Chinese exporters using third parties to evade anti-dumping duties on shrimp? *Quick Frozen Foods International*, July. Fort Lee, New Jersey, United States, EW Williams Publications Company.

- Ramjohn, D.** 1995. *Results of fisheries local knowledge survey in the Gulf of Paria*. FAO/UNDP Project FI:DP/INT/91/007 "Integrated Coastal Fisheries Management". Port of Spain, Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Marine Resources.
- Reithe, S. & Aschan, M.** 2004. Bioeconomic analysis of bycatch of juvenile fish in the shrimp fisheries – an evaluation of management procedures in the Barents Sea. *Environmental and Resource Economics*, 28: 55–72.
- Research Centre for Fisheries.** 2001. *Fish stock assessment on Indonesian marine waters*. Jakarta, Indonesia, Research and Development Centre for Oceanography.
- Reuters.** 2007. *Why oil prices are at a record high*. 1 August. (Available at [www.reuters.com/article/hotStocksNews/idUSL0135968820070801](http://www.reuters.com/article/hotStocksNews/idUSL0135968820070801))
- Revell, A.S., Pascoe, S., Radcliffe, C., Riemann, S., Redant, F., Polet, H., Damm, U., Neudecker, T., Kristensen, P.S. & Jensen, D.** 1999. *The economic consequences of discarding in the Crangon fisheries*. European Commission study.
- Roberts, S.** 2005. *Wild-caught coldwater shrimp*. United States, Monterey, California, Seafood Watch, Seafood Report, Monterey Bay Aquarium.
- Robins, C.M., Goodspeed, A.M., Poiner, I. & Harch, B.D.** 2002. *Monitoring the catch of turtles in the Northern Prawn Fishery*. Final report 1998/2002. Canberra, Australia, Fisheries Research Development Corporation.
- Robins, J.B., Campbell, M.J. & McGilvray, J.G.** 1999. Reducing prawn-trawl bycatch in Australia: an overview and an example from Queensland. *Marine Fisheries Review*, 61(3).
- Robinson, L., ed.** 2003. *The ecological disturbance of fishing in demersal fish and benthic invertebrate communities*. MAFCONS Report 2003:003. Aberdeen, United Kingdom, Fisheries Research Services Marine Laboratory. 40 pp.
- Rosales, J.F.** 1967. *Fauna que acompaña al camarón comercial de altamar en la costa de Sinaloa, México*. México, Universidad Autónoma de Nuevo León. (thesis)
- Safina, C.** 1998. Scorched-earth fishing. *Issues in Science and Technology*. (Available at [www.issues.org](http://www.issues.org))
- SAGARPA.** 2004a. *Anuario estadístico de pesca 2003*. México, Secretaría de Agricultura, Granadería, Desarrollo Rural, Pesca y Alimentación. Comisión Nacional de Acuacultura y Pesca.
- SAGARPA.** 2004b. *Carta nacional pequera*. México, Secretaría de Agricultura, Granadería, Desarrollo Rural, Pesca y Alimentación. Comisión Nacional de Acuacultura y Pesca.
- SAGARPA.** 2004c. *Plan de manejo para la pesquería de camarón en el litoral del Océano Pacífico Mexicano*. México, Secretaría de Agricultura, Granadería, Desarrollo Rural, Pesca y Alimentación. Comisión Nacional de Acuacultura y Pesca.
- SAGARPA/INP.** 2001. *Sustentabilidad y pesca responsable en México – evaluación y manejo*. México, Secretaría de Agricultura, Granadería, Desarrollo Rural Pesca y Alimentación. Comisión Nacional de Acuacultura y Pesca.
- Sainsbury, K.J., Campbell, R.A., Lindholm, R. & Whitelaw, A.W.** 1997. Experimental management of an Australian multi-species fishery: examining the possibility of trawl-induced habitat modification. In E.K. Pikitch, D.D. Huppert & M.P. Sissenwine, eds. *Global trends: fisheries management*, pp. 107–112. Symposium 20. Bethesda, Maryland, United States, American Fisheries Society.
- Sainsbury, K.J., Punt, A.E. & Smith, A.D.M.** 2000. Design of operational management strategies for achieving fishery ecosystem objectives. *ICES J. Marine Science*, 57: 731–741.
- Samonte-Tan, L.** 2000. Economic status and policies affecting the shrimp industry in the Gulf of Mexico. Office of Graduate Studies, Texas A&M University, United States. (Ph. D. thesis)
- Sanders, M., Jayawardena, A. & Ediriweera, S.** 2000. *Preliminary assessment for the shrimp fisheries of the Negombo Lagoon (Sri Lanka)*. Fisheries Circular 958. Rome, FAO.
- Seafood Business.** 2004. New marketing campaign promotes quality and variety of Mexican shrimp. *Seafood Business* magazine, 1 April.

- Seefoó Ramos, A., Sarmiento Náfate, S. & Balmori Ramírez, A. 2004. Bycatch reduction technologies in shrimp trawling in Latin American fisheries. Mexico, Salina Cruz, Instituto Nacional de la Pesca.
- Seijo, J.C., Ferreira, L., Alió, J. & Marcato, L. 2000. Bioeconomics of shrimp fisheries of the Brazil-Guianas Shelf: dealing with seasonality, risk and uncertainty. In *FAO/Western Central Atlantic Fishery Commission Report of the Third Workshop on the Assessment of Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf, Belém, Brazil, 25 May–9 June 1999*. FAO Fisheries Report 628. Rome, FAO.
- Sharp, G. 2000. *Historical fishing events/development in the Pacific, Atlantic and Indian Ocean since 1864, up through the 21st century*. (Available at [sharpgary.org/FisheriesTimeline2.html](http://sharpgary.org/FisheriesTimeline2.html))
- Sheppard, C. 2006. Trawling the seabed. *Marine Pollution Bull.*, 52: 831–835.
- Shrimp News International. 2004. *World shrimp farming 2004*. (Available at [www.shrimpnews.com/WSF2004.html](http://www.shrimpnews.com/WSF2004.html))
- Siddeek, M.S.M., Abdul-Ghaffar, A.R. & El-Musa, M. 1988. *Shrimp Fisheries Management Project, Phase IV*. Safat, Kuwait, Kuwait Institute for Scientific Research. 65 pp.
- Siddeek, M.S.M., Bishop, J.M., El-Musa, M., Abdul-Ghaffar, A.R. & Abdulla, M.S. 1994. Possible reasons for increased landings of Kuwait's green tiger shrimp (*Penaeus semisulcatus*) in the late 1980s. In L.M. Chou, A.D. Munro, T.J. Lam, T.W. Chen, L.K.K. Cheong, J.K. Ding, K.K. Hooi, H.W. Khoo, V.P.E. Phang., K.F. Shim & C.H. Tan, eds. *The Third Asian Fisheries Forum*, pp. 224–227. Manila, the Philippines, Asian Fisheries Society.
- Siddeek, M.S.M., El-Musa, M. & Abdul-Ghaffar, A.R. 1989. *Shrimp Fisheries Management Project, Phase V*. (Final report, MB-70). Safat, Kuwait, Kuwait Institute for Scientific Research. 104 pp.
- Silvestre, G.T., Garces, L., Stobutzki, I., Ahmed, M., Valmonte-Santos, R.A., Luna, C., Lachica-Aliño, L., Munro, P., Christensen, V. & Pauly, D., eds. 2003. *Assessment, management and future directions for coastal fisheries in Asian countries*. WorldFish Center Conference Proceedings 67. 1120 pp.
- Silvestre, G.T. & Pauly, D. 1997. Management of tropical coastal fisheries in Asia: an overview of key challenges and opportunities. In G.T. Silvestre and D. Pauly, eds. *Status and management of tropical coastal fisheries in Asia*, pp. 8–25. ICLARM Conference Proceedings 53. 208 pp.
- Smith, A. 2007. *A study into the effect of energy costs in fisheries*. FAO Fisheries Circular 1022. Rome, FAO.
- Sok, V. 2005. *Fish markets in Phnom Penh, Siem Reap and Sihanoukville*, Phnom Penh, Cambodia, Department of Fisheries.
- Soomai, S. 2005. *Case study on the status of coastal zone and fisheries resources management and the incorporation of demographic and socio-economic considerations/indicators: Trinidad and Tobago*. Prepared for the CARICOM Regional Fisheries Mechanism (CRFM).
- Soomai, S., Ehrhardt, N., Cochrane, K. & Phillip, T. 1999. Stock assessment of two sciaenid fisheries in the west coast of Trinidad and Tobago. FAO/Western Central Atlantic Fishery Commission Report of the Third Workshop on the Assessment of Shrimp and Groundfish Fisheries on the Brazil-Guianas Shelf, Belém, Brazil, 25 May–9 June 1999. FAO Fisheries Report 628. Rome, FAO.
- Soomai, S. & Seijo, J.C. 2000. *Case study for a technologically interdependent groundfish fishery: the artisanal multi-species, multi-fleet groundfish fishery of Trinidad*. Fourth FAO/WECAFC Stock Assessment and Management Workshop on the Shrimp and Groundfish Resources of the Guianas-Brazil Shelf, Cumaná, Venezuela, 2–13 October.
- Soumy, M. 2004. *Country review: Madagascar*. Rome, FAO. Policy and Planning Division, Fisheries Department.
- Sour, K. 2005. *The socio-economic status of coastal fishing communities including health and HIV/AIDS*. Prepared for the GCP/RAS/199/SWE Strengthening Capacity in Fisheries Information gathering for Management.

- Sparre, P.J. & Willmann, R.** 1992. *Software for bio-economic analysis of fisheries. BEAM 4. Analytical bio-economic simulation of space-structured multi-species and multi-fleet fisheries. Vol. 2. User's manual.* FAO Computerized Information Series (Fisheries), 3: 46. Rome, FAO.
- Srinath, K., Sridar, M., Kartha, P.N.R. & Mohanan, A.N.** 2000. Group farming for sustainable aquaculture. *Ocean and Coastal Management*, 43(7): 557–571.
- Staples, D., Satia, B. & Gardiner, P.** 2004. *A research agenda for small-scale fisheries.* RAP Publication. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.
- Stella Polaris.** 2005. *Cold-water prawn markets. Global shrimp outlook 2005.* St Louis, United States, Global Aquaculture Alliance.
- Sterling, D.** 2005. *Progress report for an investigation of two methods to reduce the benthic impact of prawn trawling.* Sterling Trawl Gear Services for the University of Queensland and the Queensland Department of Primary Industries and Fisheries.
- Suboko, B.** 2001. Shrimp export processing sector in Indonesia. In S. Subasinghe & T. Singh, eds. *Production and marketing of shrimp: trends and outlook*, pp. 32–34. Malaysia, Kuala Lumpur, INFOFISH.
- Sugiyama, S., Staples, D. & Funge-Smith, S.** 2004. *Status and potential of fisheries and aquaculture in Asia and the Pacific.* RAP Publication. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.
- Sumaila, U., Teh, L., Watson, R., Tyedmers, P. & Pauly, D.** 2006. Fuel subsidies to global fisheries: magnitude and impacts on resource sustainability. Chapter 2. In U. Sumaila & D. Pauly. *Catching more bait: a bottom-up re-estimation of global fisheries subsidies.* Vancouver, Canada, University of British Columbia Fisheries Centre, Aquatic Ecosystems Research Laboratory (AERL).
- Sun, T. & Yin, Y.** (no date). *Selective fishing in China's prawn fisheries.* INFOFISH.
- Suuronen, P.** 2005. *Mortality of fish escaping trawl gears.* FAO Fisheries Technical Paper 478. Rome, FAO.
- Talib, A. & Alias, M.** 1997. Status of fisheries in Malaysia – an overview. In G. Silvestre & D. Pauly, eds. *Status and management of tropical coastal fisheries in Asia*, pp. 47–61. ICLARM Conference Proceedings 53. Manila, the Philippines, International Center for Living Aquatic Resource Management. 208 pp.
- Tan, C.K., Gillett, R., Sciortino, J. & Shawyer, M.** 1996. *Strengthening marine fisheries development in Indonesia.* Final report. FAO Project TCP/INS/4553. Rome, FAO. 82 pp.
- Tobor, J.** 1990. *The fishing industry in Nigeria: status and potential for self-sufficiency in fish production.* Technical Paper 54. Nigeria, Lagos, Nigerian Institute for Oceanography and Marine Research.
- Touch, S. & Todd, B.H.** 2002. *The inland and marine fisheries trade of Cambodia.* Oxfam America.
- TPWD.** 2002. *The Texas shrimp fishery.* Report to the Governor and the 77th Legislature of Texas. United States, Austin, Texas, Texas Parks and Wildlife Department.
- Try, I.** 2003. *Fish stocks and habitats of regional, global and transboundary significance in the South China Sea, Cambodia. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand.* Thailand, Bangkok, UNEP and Washington, DC, United States. GEF.
- Tyedmers, P.** 2004. Fisheries and energy use. In C. Cleveland, ed. *Encyclopedia of Energy*, 2: 683–693. Amsterdam, the Netherlands, Elsevier.
- Tyedmers, P., Watson, R. & Pauly, D.** 2005. Fuelling global fishing fleets. *Ambio*, 34(8): 635–638.
- Van Zalinge, N.P., Kaliluddin, M. & Khan, W.** 1987. *Pakistan's shrimp fishery.* Project PAK/77/033: Marine Fisheries Development. Rome, FAO.
- Vendeville, P.** 1990. *Tropical shrimp fisheries: types of fishing gear used and their selectivity.* FAO Fisheries Technical Paper 261 (Rev.1). Rome, FAO.

- Venema, S. 1996. *Report on the Indonesia/FAO/DANIDA Workshop on the Assessment of the Potential of the Marine Fishery Resources in Indonesia*. Report of Activity 15. Rome, FAO.
- Ward, J. 2006. *Dissipation of resource rent in the US Gulf of Mexico Shrimp Fishery*. Washington, DC, United States National Marine Fisheries Service.
- Ward, J., Adams, C., Griffin, W., Woodward, R., Haby, M. & Kirkley, J. 2004. *Shrimp business options. Proposals to develop a sustainable shrimp fishery in the Gulf of Mexico and South Atlantic*. Washington DC, United States National Marine Fisheries Service.
- Ward, T., Tarte, D., Hegerl, E. & Short, K. 2006. *Policy proposals and operational guidance for ecosystem-based management of marine capture fisheries*. Sydney, Australia, Resource Conservation Programme, WWF Australia.
- Watling, L. & Norse, E.A. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. *Conservation Biology*, 12(6): 1180–1197.
- Watson, J.W. & McVea, C., Jr. 1977. Development of a selective shrimp trawl for the southeastern United States penaeid shrimp fisheries. *Mar. Fish. Rev.*, 39: 18–24.
- Watson, J.W., Mitchell, J.F. Jr. & Shah, A.K. 1986. Trawling efficiency device: a new concept for selective shrimp trawling gear. *Mar. Fish. Rev.*, 48: 1–9.
- Weinberger, E. & Chou, C. 2003. Election bait for Koh Kong fisheries. *Phnom Penh Post*, 18 July.
- Westlund, L. 2006. *Mid-term Review of the UNEP/GEF Project Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management*. United Nations Environment Programme, Evaluation and Oversight Unit.
- Williams, L. 2002. *Queensland's fisheries resources – current conditions and recent trends 1988–2000*. Brisbane, Australia, Department of Primary Industries.
- Willmann, R. 2005. *Economic aspects in the relationship between capture fisheries and aquaculture*. Paper presented at the Regional Workshop on Low Value and “Trash Fish” in the Asia-Pacific Region, Hanoi, Viet Nam, 7–9 June.
- Willmann, R. & Garcia, S.M. 1985. *A bio-economic model for the analysis of sequential artisanal and industrial fisheries for tropical shrimp*. FAO Fisheries Technical Paper 270. Rome, FAO.
- Willoughby, N., Monintja, D. & Badrudin, M. 1999. *Do fisheries statistics give the full picture? Indonesia's non-recorded fish problems*. Report of the Regional Workshop on the Precautionary Approach to Fishery Management, 25–28 February 1997, Mendan, Indonesia. Chennai, India, Bay of Bengal Programme.
- Wilson, J. 1999. *Fuel and financial savings for operators of small fishing vessels*. FAO Fisheries Technical Paper 383. Rome, FAO.
- WorldFish. 2005. *Regional synthesis on the analysis of TrawlBase data for low-value trash fish species and their utilization: the status of low-value “trash fish” resources in coastal fisheries of Thailand and Malaysia*. Summary report for the APFIC Regional Workshop on Low Value and “Trash Fish” in the Asia-Pacific Region, Hanoi, Viet Nam, 7–9 June. Prepared by WorldFish Center, Thailand and Department of Fisheries, Malaysia.
- Ye, Y. & Beddington, J.R. 1996. Bioeconomic interactions between the capture fishery and aquaculture. *Marine Resource Economics*, 11(2): 105–123.
- Zacharin, W. 1997. *Management plan for the South Australian Gulf St Vincent Prawn Fishery*. Fisheries Management Series 30. Adelaide, South Australia, Gulf St Vincent Prawn Fishery Management Committee in association with Primary Industries and Resources.
- Zainudin, M. 2005. *Possible interactions of sea turtles with shrimp trawl fisheries in sorong-papua and tuna long-line fisheries in Benoa, Bali*. Denpasar, Indonesia, WWF-Indonesia Marine Program.
- Zainudin, M. & Pet-Soede, L. 2005. *Bycatch in Indonesian fisheries*. Denpasar, Indonesia, WWF-Indonesia Marine Program.



This report summarizes the results of a global study on the development and status of shrimp fisheries, with a focus on direct and indirect social, economic and environmental impacts. The study reviews the current situation, problems and issues, as well as the solutions found and the trade-offs made. Important topics related to shrimp fisheries are examined in ten countries representative of geographic regions, together with their various significant shrimp fishing conditions. The ten countries selected are: Australia, Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria, Norway, Trinidad and Tobago and the United States of America. The results of the country reviews are combined with specialized studies on important topics related to shrimp fisheries to produce the major findings of the overall study. A major conclusion of the study is that there are mechanisms, instruments and models to enable effective mitigation of many of the difficulties associated with shrimp fishing, taking a precautionary and ecosystem approach to fisheries. The inference is that, with an appropriate implementation capacity, shrimp fishing, including shrimp trawling, is indeed manageable. In many countries, however, weak agencies dealing with fisheries, lack of political will and inadequate legal foundations cause failures in the management of shrimp fisheries. The report makes specific recommendations in a few key areas: the management of small-scale shrimp fisheries, capacity reduction and access to the fishery.

