Research Article

Attitudes and knowledge of shade-coffee farmers towards vertebrates and their ecological functions

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Abstract

The purpose of this study was to assess farmers' attitudes, as well as perceptions and knowledge that shape those attitudes, toward the ecological role of vertebrates inhabiting shaded-coffee farms. We also aimed to determine whether differences existed among two groups of farmers: one that had attended environmental education workshops, and one that had not. We conducted 36 oral interviews of farmers in the region of Cuetzalan, Mexico. All farmers were members of an important regional cooperative, Tosepan Titataniske. In general, farmers' attitudes towards birds were positive. Snakes were perceived as useful but dangerous animals. Attitudes towards non-flying mammals were mostly indifferent. Bats were poorly understood and badly perceived. Seed dispersal was perceived as an important ecological function performed by animals. Pollination was also perceived as important, but to a lesser degree. Knowledge about ecological functions was high for seed dispersal, and low for pollination. We found a positive correlation between attendance of educational workshops and the presence of "environmentally-friendly" attitudes, perceptions, and knowledge. However, a cause-effect relationship could not be clearly established. We suggest that environmental education programs include the objective of increasing the knowledge of people about the ecological functions played by different groups of animals that live in agroecosystems. Particular efforts should be directed toward improving the way in which certain non-charismatic groups of animals, such as bats, are perceived.

Key Words: Agroecosystem, animal conservation, ecosystem services, environmental education, perceptions.

Resumen

El propósito de este estudio fue evaluar las actitudes de agricultores, así como las percepciones y los conocimientos que moldean dichas actitudes, hacia el papel ecológico que juegan los vertebrados en los cafetales de sombra. Asimismo se quiso determinar si existían diferencias entre dos grupos de agricultores: uno que había asistido a talleres de educación ambiental, y otro que no. Realizamos 36 entrevistas orales a agricultores en la región de Cuetzalan, México. Los agricultores eran miembros de una cooperativa regional: Tosepan Titataniske. Las actitudes hacia las aves fueron muy positivas. Las serpientes fueron percibidas como animales útiles, pero peligrosos. Las actitudes hacia los mamíferos no voladores fueron mayormente indiferentes. Los murciélagos fueron poco conocidos y mal percibidos. La dispersión de semillas fue percibida como una función importante realizada por los animales. La polinización también fue percibida como importante, pero en menor escala. El conocimiento sobre las funciones ecológicas fue alto para la dispersión de semillas y bajo para la polinización. Encontramos una correlación positiva entre la asistencia a los talleres educativos y la presencia de actitudes, percepciones y conocimientos "ambientalmente amigables". Sin embargo, no se pudo establecer claramente una relación de causa-efecto. Sugerimos que los programas de educación ambiental incluyan como uno de sus objetivos, aumentar el conocimiento de las personas sobre las funciones ecológicas de los animales que viven en los agroecosistemas. En particular, debe hacerse un esfuerzo por mejorar la forma en que son percibidos grupos de animales no-carismáticos, como los murciélagos.

Palabras Clave: Agroecosistema, conservación de animales, educación ambiental, percepciones, servicios ecosistémicos.

Received: 28 January 2009; Accepted: 15 May,2009, Published: 10 August, 2009

Cite this paper as: López-del-Toro, P., Andresen, E., Barraza, L. and Estrada, A. 2009. Attitudes and knowledge of shade-coffee farmers towards vertebrates and their ecological functions. *Tropical Conservation Science* Vol.2 (3):299-318. Available online: www.tropicalconservationscience.org

Introduction

The conservation of biodiversity is essential for the proper functioning of ecosystems and for the maintenance of the environmental services they provide [1]. However, the high rates of deforestation and habitat destruction that currently exist frequently cause the local extinction of plant and animal species [2]. Much of this habitat destruction is caused by the often unavoidable expansion of the agricultural frontier. Such changes in land use in the name of human welfare and the associated losses in biodiversity represent a social and ecological challenge [3-5].

In recent years, a new paradigm for approaching the development-biodiversity conflict has arisen, which proposes a change in the way conservationists and managers view the agricultural matrix. According to this paradigm, an effective strategy for the conservation of biodiversity in tropical areas cannot solely depend on forest remnants, but must also include the agricultural matrix, with specific efforts to increase its ecological value when necessary [3,4,6]. A type of agricultural matrix, recognized worldwide as one that maintains high levels of biodiversity and ecosystem function in the tropics, is shade-grown crops, such as shade coffee and shade cocoa plantations [6-8]. In these agroecosystems, the goal of obtaining economic benefits for improving the quality of life of rural people also provides a very high potential for ecosystem conservation. Thus, the inclusion of local farmers as key players in conservation efforts becomes a crucial element [9].

The implementation of conservation strategies needs to take into account not only the ecological aspects but also the social ones, which include reconciling the local population with their surrounding nature, when necessary [10]. The attitudes that people have towards their surrounding natural environment can often favor and be conducive to biodiversity conservation [11]. At other times, however, such human attitudes can be antagonistic with respect to conservation goals and may result in the loss of biodiversity [12, 13]. People's attitudes are shaped by many factors, including demographic factors (e.g., age, gender, nationality, education), internal factors (e.g., beliefs, perceptions, individual values), and external factors (e.g., institutional, economic, tradition, culture) [14]. For example, it is recognized that a high degree of knowledge and understanding about the environment can lead to positive attitudes toward it [15]. Thus, having a good understanding of people's attitudes toward the different components of their environment, and of the factors that shape such attitudes, becomes a necessary step in integrative context-specific conservation programs in human-dominated landscapes [16-18].

Farmers cultivating crops in shade-plantations are generally characterized by pro-environmental behavior, showing a high interest in sustainability and a rational use of resources [19], compared to farmers in other types of agricultural practices (e.g., cattle ranching, intensive monoculture systems). However, it is likely that most of the interest of shade-plantation farmers is focused on the productive biota rather than the resource

biota [20]. The productive biota includes those biodiversity components that are chosen and exploited directly by farmers. On the other hand, the resource biota includes all organisms that contribute to the productivity of an agroecosystem through the ecological functions they perform. In shade-plantations in the tropics, many plant species are in the productive biota, while many animals are in the resource biota. Since the productive biota is used by farmers, representing a direct value to them, motivation for the implementation of management strategies that will conserve this biota is high.

Unlike with plants, the use of animals as part of the productive biota (i.e., extraction) is in many cases not compatible with conservation purposes. However, while farmers usually have a good knowledge of the identity of animal species inhabiting their plantations [21, 22], they may have limited understanding of the indirect benefits that animals provide as part of the resource biota. Such indirect benefits include ecological processes such as pollination, biological control, and seed dispersal, which emerge from biotic interactions. Biotic interactions and the associated processes are of particular relevance for the long-term maintenance of tropical-forest ecosystems [23], be they natural, or anthropogenic, such as shade-plantations. As a consequence of this limited understanding of the functional roles of animals in their plantation, motivation for the conservation of fauna may be weak or non-existent. It might be envisioned then, that, if farmers had a good understanding of the ecological functions that fauna plays in agroecosystems, the motivation for their conservation might increase considerably.

Our main objective was to identify and understand some of the attitudes, perceptions, and knowledge that shade-coffee farmers have regarding the resident vertebrate fauna and their associated ecological functions. Additionally, we wanted to evaluate whether two groups of farmers—those who had been participating in an environmental education program and those who had not—differed in their attitudes, perceptions, or knowledge regarding vertebrates and their importance for the agroecosystem. It is expected that the information obtained in this study may facilitate the implementation of context-specific conservation strategies, and the development of environmental education programs according to local knowledge and needs.

Methods

Study site and system

The study was conducted in the municipality of Cuetzalan (20 ° 06 'N and 97 ° 35' W) which has an area of 135.22 km^2 and is located in the northeastern part of the state of Puebla, Mexico (Fig. 1). Altitudes in this region range from 320 to 1,500 m. Annual temperature and precipitation average 20.5 º C and 4,521 mm, respectively, and no pronounced rainfall seasonality exists. The regional forest types of pine-oak forest, cloud forest, and tropical rainforest occur along an elevational gradient. However, most of the original vegetation, and in particular the cloud forest, has been replaced by agriculture and pastures. Land dedicated to agriculture (including coffee) and pastures encompass today 63% and 19% respectively of the municipality's total non-urban area, while natural forests encompass 18% of the area [25]. Despite the severe history of land-use change in the region, the vertebrate fauna still shows high levels of diversity: 54 species of reptiles and amphibians, 115 species of birds, at least 19 species of medium-large non-flying mammals (excluding small mammals such small rodents, small marsupials, and shrews; see Appendix 1) and more than 30 species of bats [24]. Regarding the herpetofauna of interest to this study, of the 23 snake species present in the study area, only 6 are poisonous (*Geophis semidoliatus*, *Lampropeltis triangulum smithi*, *Sibon sartorii*, *Micrurus diastema*, *Atropoides nummifer*, *Bothrops asper*) [26].

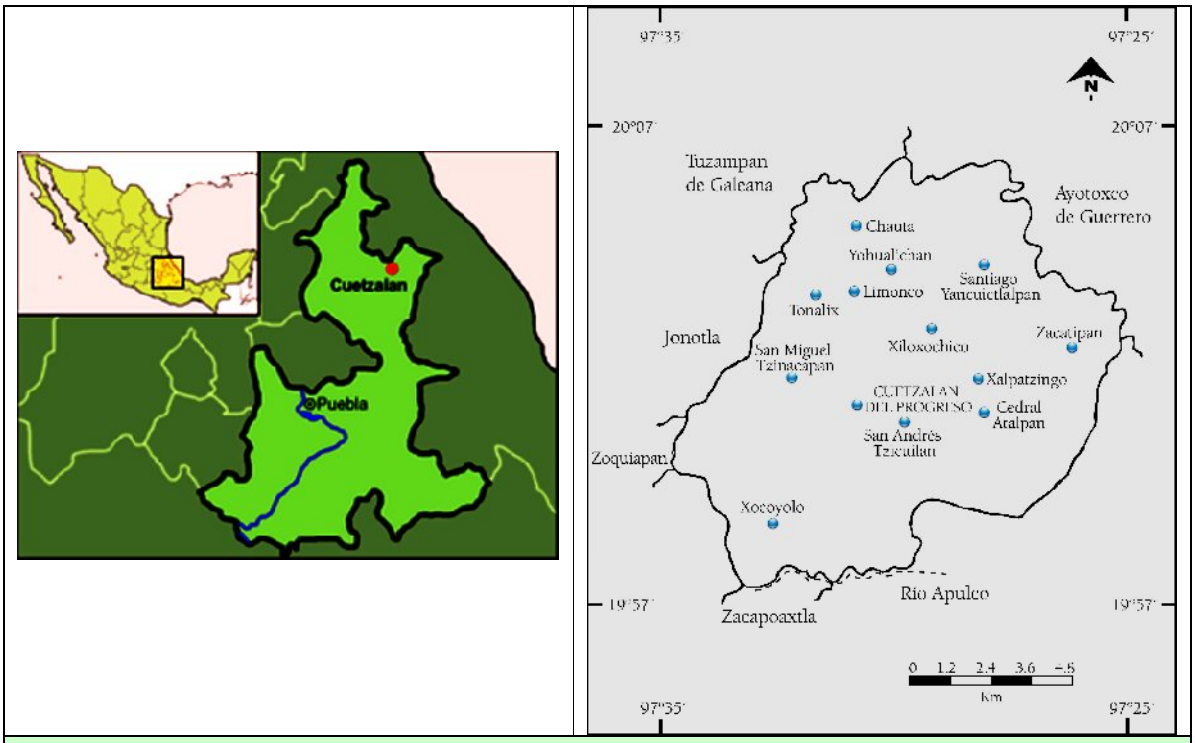

Fig. 1. The map to the left shows the location of Cuetzalan del Progreso (red dot) in the state of Puebla (light green), with the inset showing the location at the country level. The map to the right shows the specific location, with respect to the main urban center (Cuetzalan del Progreso) of the 12 communities included in this study.

The municipality of Cuetzalan includes 160 human communities, totaling 45,781 inhabitants [25]. The great majority (80%) of the population is composed of indigenous people, most of whom belong to the Nahua ethnic group (Fig. 2). Almost 70% of the population of Cuetzalan is dedicated to agriculture and cattle ranching, while approximately 20% is active in tourism-related activities. In terms of agriculture, approximately 26% (3,500 ha) of the territorial area of the municipality is dedicated to coffee production, with a large proportion of it being shade-coffee [25, 27].

A very important organization in this region is a cooperative called Tosepan Titataniske (hereafter called the Tosepan). It was created in 1977 and is currently formed by approximately 5,800 farmers, belonging to 60 communities of the Cuetzalan municipality. The main economic activity of the Tosepan is the production of shade-coffee, which has been commercialized since 1978. Traditional polyculture is the most common (70%) type of shade-coffee system used by Tosepan farmers [28]. In this system, coffee is introduced under the cover of the original forest (Fig. 2), but farmers actively manage both introduced and native plant species, creating a species-rich "coffee garden" that has a complex vegetation structure [7]. Under the system of traditional polyculture, coffee farmers use and appreciate an extremely high number of the plant species growing in their coffee plantations (up to several dozen). Furthermore, in 2001 the Tosepan began a process aimed at converting all coffee production, as well as other products obtained in the shade-coffee farms (macadamia nuts, allspice, fruits, honey, etc.), into organic production. Thus, it can be expected that in the system of traditional polyculture, and particularly under the standards of organic production, farmers might also be

appreciative of the ecological processes that aid in the natural regeneration of much of the plant diversity present in the coffee farms, more specifically the processes of seed dispersal and pollination.

The Tosepan also undertakes a variety of social programs with the general goal of improving the livelihood of its members [29]. One such program was the Environmental Education Program (EEP), which was implemented with the help of external funding between 2004 and 2006. The EEP included educational workshops for both coffee farmers and school children [30]. Workshops for farmers were held at the end of monthly meetings organized by the Tosepan in coffee-growing communities that are part of the cooperative. Workshops were conducted only in those communities that requested the implementation of the EEP, and attendance of individual farmers was voluntary. Workshops consisted of discussion sessions, approximately 30 minutes long, during which one context-specific environmental issue was addressed. The topic to be discussed during any given session was chosen from a workbook that was specifically created for the EEP [31]. The following wildlife-related topics are included in the workbook and were probably addressed during some workshop discussions: (a) The term biodiversity includes not only plants; (b) Animals that live in the coffee plantation; (c) Roles that insects, mammals, birds, amphibians, and reptiles play in the coffee farm; (d) Actions that harm the coffee farm, including bird hunting and the interruption of animal life cycles. In general, greater emphasis was placed on environmental and plant-related issues than on wildlife. However, due to the inclusion of topics mentioned above, and due to the workshop's general focus on conservation, we predicted an increase in environmental awareness, including wildlife, in farmers attending the workshops.

Fig. 2. The picture to the left shows two of the shade-coffee farmers interviewed in this study, while the picture to the right shows an example of a shade-coffee plantation.

Data collection

We interviewed a total of 36 farmers, all members of the Tosepan, living in 12 of the 60 different communities that are members of the cooperative (Fig. 1). All farmers interviewed were organic-coffee producers, and have lived in the region all their lives. Organic-coffee farmers who are members of the Tosepan have an average of 4.8 years of school education, and cultivate an average area of 2.2 ha with coffee, earning about $53 USD per week [27].

All interviews were carried out in June-July 2006, with 50% of the farmers having attended the EEP workshops (hereafter called EE-farmers). Interviewed EE-farmers had been participating in monthly workshops since 2004, and continued to do so at the time the interviews were conducted. Since attendance was voluntary, not all EE-farmers attended the same number of workshops before being interviewed. We chose farmers within the same

age range (25 to 55 years) in both groups, to avoid having an additional source of variation. Mean age was 44 years for EE-farmers, and 45 years for non EEP-workshop attendees (hereafter called NEE-farmers). Workshop attendance was voluntary, and thus the possibility exists that those farmers who decided to attend the workshops differed inherently in some way from farmers who decided not to attend. Hence, we are unable to determine unequivocally whether the EEP was responsible for differences among farmer groups, and thus our purpose was merely to establish if farmer groups were different in terms of their attitudes. Moreover, the possibility of pre-existing differences among farmer groups does not undermine the major goal of the study, which is to describe farmers' attitudes, perceptions, and knowledge regarding vertebrates and their associated ecological functions.

We chose to interview only male farmers for two reasons: (1) because coffee-growing is a male-dominated activity in this region, and (2) to avoid having another factor (in this case gender) affecting the responses. To gain a detailed understanding of the attitudes, perceptions, and knowledge of farmers we chose to use a method of qualitative research. Consequently, sample size (36) was restricted due to the in-depth nature of the interview applied to each farmer. Each interview was conducted in an oral (both Spanish and Nahua languages were used) and personal way, and lasted 1 to 2 hours. A pilot interview was conducted to make sure that all questions were clearly understood. Interviews consisted of 29 questions, some of which had sub-questions (Appendix 1). Though classification of animals and plants can vary according to culture and language, it became certain during the interviews that all farmers were referring to the same animal groups in their responses as were the interviewers in their questions, namely "birds", "bats," and snakes" (Fig. 3). In the case of non-flying mammals, the photos of individual species were used to ensure the correct identification of species.

Fig. 3. Examples of four groups of vertebrates (bats, birds, snakes, and non-flying mammals), present in the region of Cuetzalan, and that constituted the focus of the interviews. From left to right, photos correspond to the following species: lesser long-nosed bat (*Leptonycteris curasoae*), red-lored amazon (*Amazona autumnalis*), fer-de-lance snake (*Bothrops asper*), raccoon (*Procyon lotor*). Credit for first two photos http://www.batcon.org/, www.animalpicturesarchive.com/ ; credit for third and fourth photo: www.naturephoto-cz.com/, http://www.freedigitalphotos.net/

Data analyses

In this study we did not use all questions from the original interview for the quantitative analyses. We removed those questions that turned out to be uninformative (e.g., questions 1, 5, 8, Appendix 1), unrelated to wildlife and/or their ecological functions (e.g., questions 25 – 28), or too complex (question 29). Based on the rest of the questions, we prepared, *a posteriori*, a list of 22 questions (Appendix 2) to be used in the quantitative analyses of the data. For each of these questions, the response of every farmer could be classified into two broad categories (yes vs. no; Appendix 2). Four questions were about the different uses farmers attribute to vertebrates, while the other 18 questions focused on attitudes, perceptions, or knowledge regarding a particular group of vertebrates (birds, snakes, non-flying mammals, bats) or a particular ecological function

(seed dispersal, pollination, biological control). Only the latter 18 questions had answers that could be more easily classified into "high vs. low" in the case of knowledge, or "positive vs. negative" in the case of attitudes and perceptions. In the context of our study, answers reflecting higher knowledge or more positive attitude or perception were considered "environmentally-friendly" answers.

To assess differences between the responses of EE- and NEE-farmers, we applied a Fisher Exact test to each of the questions. Two-tailed tests were used for the first four questions regarding the use of vertebrates (non-directional alternative hypotheses: responses of farmers are different for the two groups), while one-tailed tests were used for the remaining 18 questions (directional alternative hypotheses: responses are more "environmentally-friendly" for EE-farmers vs. NEE-farmers). For these tests, due to the small sample size, and the variable nature of social data, we decided to reach conclusions regarding statistical significance using a significance level of 0.1, in order to lessen the probability of Type II error. However, for each test we present the associated exact probability (Appendix 2) so that the reader may focus on the trends observed and decide what he/she considers to be of practical significance, and not only of statistical significance.

To obtain an overall assessment of whether EE-farmers had, in general, more "environmentally-friendly" responses than NEE-farmers, we performed a Wilcoxon Signed Ranks Test. For this test, each of the 18 questions (see above) was treated as an independent paired sample. The response variable consisted of the percentages of farmers, in each of the two groups, giving an "environmentally-friendly" answer.

We also performed an ordination of the 36 farmers using as response variable the presence/absence of an "environmentally-friendly" answer for the 18 questions mentioned above. The ordination was performed with the program PC-ORD using non-metric multidimensional scaling (NMS), which is an ordination technique appropriate for data that are non-normal or are measured in an arbitrary or otherwise questionable scale [32]. For the initial starting configuration of the preliminary NMS the scores of a detrended correspondence analysis were used. A Monte Carlo test with 20 runs was used to choose the appropriate dimensionality. A final NMS was performed for three dimensions, with 200 iterations, the Sorensen distance measure, and using the scores of the preliminary NMS as the starting configuration. Final stress and final instability are reported. The former is a measure of departure from monotonicity in the relationship between the distance in the original n-dimensional space and the distance in the reduced (in this case 3-dimensional) ordination space, while the latter is a measure of variation in stress over preceding iterations [32]. We also calculated the coefficient of determination between ordination distances and distances in the original n-dimensional space, using again the Sorensen distance measure. Finally, to test whether differences existed between the two *a priori* defined groups of farmers (18 EE-farmers and 18 NEE-farmers), based on the presence/absence of a positive answer to each of the 18 questions, we used a multi-response permutation procedure (MRPP), with the Sorensen distance measure [32].

Results

Attitudes, knowledge and perceptions towards groups of vertebrates

Regarding the direct use of vertebrates, farmers were asked whether they used these animals for medicinal purposes, as food, as pets, or in other ways. A large proportion of farmers indicated using wild animals as food (86%) and for medicinal purposes (60%). The animals most commonly consumed were opossums, armadillos, birds, squirrels, and rabbits, but coatis, raccoon, iguanas and frogs were also mentioned. Regarding medicinal use, the skunk, porcupine, and vulture were mentioned as animals commonly used to treat cough, opossum and coyote to treat rheumatism, and finally turtle, iguana and hummingbird feathers for other respiratory diseases. Few farmers (14%) mentioned having kept squirrels, armadillos, rabbits and/or birds as pets. No farmer indicated using animals in other ways.

For each of the first three categories of use, more EE-farmers reported using vertebrates than NEE-farmers (Appendix 2), although differences were only statistically significant for the medicinal use, with 83% of EE-farmers using vertebrates for this purpose, against 33% of the NEE-farmers ($p = 0.0059$).

Regarding groups of vertebrates, attitudes and perceptions were, in general, friendly towards birds, indifferent towards non-flying mammals, mixed towards snakes, and unfriendly towards bats. Similarly, the level of knowledge was high for birds, intermediate for non-flying mammals, and lower for snakes and bats. Nevertheless, almost all farmers (89%) said that, in general, it is important to have many wild animals living in their coffee farms. Almost all farmers think that birds are good for their coffee plantations, and the great majority (in both groups of farmers) could give some explanation as to why birds can be important (mostly mentioning seed dispersal, and, to a lesser degree, biological control of pests). Additionally, most farmers also perceive birds as aesthetically pleasing, as they mentioned that these animals are beautiful and that they enjoy seeing them in their plantation and hearing them sing.

Concerning snakes, the majority of farmers showed a low knowledge in believing that most or all snakes are poisonous (72%). Similarly, only 31% of farmers mentioned rodents when asked what snakes feed on. Farmers clearly perceived snakes as being dangerous animals (76% and 28%, respectively, reported killing them when found in the house and in the plantation), but also reported them as being potentially beneficial for their coffee plantations. In regard to the latter perception, there were significant differences between EE- and NEE-farmers, with 61% vs. 33% considering snakes as being good for the plantations ($p < 0.091$). In terms of knowledge, 28% EE-farmers mentioned that snakes can play an important role in controlling pest populations vs. only 6% of NEE-farmers ($p < 0.089$).

In relation to non-flying mammals, very few farmers mentioned that they are beneficial for the environment (Appendix 2). Yet, only one farmer mentioned that they are bad for the environment. For this group of animals most farmers in both groups (86%) showed indifference, stating that they are neither good nor bad. When asked about particular species, the mammals that people liked best included squirrels (*Sciurus* sp.), rabbits (*Sylvilagus* sp.), armadillos (*Dasypus novemcinctus*), and opossums (*Didelphis* sp.), mostly due to their use of these species as food. The species of mammals that farmers did not like very much included raccoons (*Procyon lotor*), coatis (*Nasua narica*), weasels (*Mustela frenata*), and ocelots (*Felis wiedii*), due to the damage the first two can cause to crops, and the last two to livestock. Finally, pocket gophers (*Geomys* sp.) were perceived as pests (5% of farmers reported killing them) while coyotes (*Canis latrans*) were perceived as dangerous animals.

As for the bats, most farmers (61%) either did not know what these animals feed on, or said that bats only feed on blood. When asked whether bats were important for the environment, 36% of all farmers said yes (44% of EE-farmers and 28% of NEE-farmers, $p > 0.1$), 28% said no, and 36% said that bats were neither good nor bad. When asked whether they considered it bad that bats lived in their farms, most EE-farmers (78%) said no, while most NEE-farmers (56%) said yes ($p = 0.043$). Most farmers who considered it bad to have bats living in their farms specified that bats harmed their domestic animals, and 16% of all farmers reported killing bats when found inside their houses.

Attitudes, knowledge and perceptions towards ecological functions

As for the ecological functions in which vertebrates participate, all farmers perceived seed dispersal as being important (100% in both groups; Appendix 2). Regarding the knowledge that farmers have on seed dispersal, most farmers were able to explain, to some degree, why seed dispersal is important (75%). Farmers explained that seed dispersal allowed for plants to grow in their plantation without them having to plant them. They also mentioned that thanks to seed dispersal, new plant species often grow in their coffee farms, ones they did not have before.

Pollination was also perceived as being important by the majority of EE-farmers (89%), but not so by NEE-farmers (39%, p = 0.002). Knowledge about the process of pollination was somewhat lower than for seed dispersal in the case of EE-farmers (61% of farmers giving some explanation), but only very few NEE-farmers (12%) could somehow explain why pollination was important (p = 0.002 for EE vs. NEE comparison).

Regarding biological control, we did not include in the interview a direct question of whether farmers considered this ecological function to be important, as we did in the case of seed dispersal and pollination. We assumed that most farmers would indeed consider biological control of pests as something very important, particularly considering the fact that being organic farmers they cannot use pesticides. Rather, we were more interested in assessing whether they identified any of the focal vertebrate groups as playing an important role in biological control. Thus, we recorded the number of farmers who, at some point throughout the interview, mentioned biological control when being questioned about particular groups of vertebrates. Biological control was often mentioned in the context of questions related to an animal group or species, as was also the case for seed dispersal. On the contrary, pollination was never mentioned by farmers out of the context of the direct question on pollination. Thus we consider that farmers perceive biological control as being more important than pollination. Regarding the two groups of farmers, significantly more EE-farmers mentioned biological control at some point during the interview, than NEE-farmers (67 vs. 36%, p = 0.047).

For all three ecological functions the vertebrates most often mentioned as being involved in them were birds, while the least mentioned were bats. All farmers were able to mention at least one seed-dispersing vertebrate species. Almost all farmers (97%) mentioned birds as seed dispersers. Only 25% of farmers indicated non-flying mammals as seed dispersers, and most of these made reference to squirrels, which might actually be acting predominantly as seed predators. Only one farmer mentioned coatis and raccoons as seed dispersers. Similarly, only one farmer mentioned that bats could disperse seeds. On the other hand, of farmers who were able to mention vertebrate species responsible for pollination (only 53%), all mentioned birds (mostly hummingbirds), and only one farmer mentioned bats. Finally, of the 18 farmers (50% of all farmers) that mentioned biological control at some point during the interview, 28% made reference to birds, 17% to snakes and 6% to bats.

Differences among EE- and NEE-farmers

The overall assessment of a difference between EE- and NEE-farmers was done with a Wilcoxon Signed Ranks Test, in which the response variable consisted of the percentages of farmers, in each of the two groups, giving an "environmentally-friendly" answer to each question (n = 18). For a two-tailed test, highly significant differences were detected among groups (Z = -3.416, p = 0.001), since for 17 of the 18 questions a higher percentage of EE-farmers gave an "environmentally-friendly" answer, compared to a lower percentage of NEE-farmers giving this same answer (Appendix 2). For the remaining question (Is seed dispersal important?), 100% of farmers in each group gave the same response.

The significant difference between EE- and NEE-farmers was corroborated with the ordination of the 36 farmers (based on the results of a non-metric multidimensional scaling procedure), in which the two groups of farmers clearly segregated in the three-dimensional space (Fig. 4; Monte Carlo test for three-dimensional solution p = 0.048, final stress = 15-34, final instability = 0.00029, coefficient of determination between ordination distances and distances in the original n-dimensional space, r^2 = 0.862). Finally, the results of the MRPP, based on the presence/absence of an "environmentally-friendly" answer for each of the 18 questions, and each of the 36 farmers, indicated that the two *a priori* defined groups of farmers, can indeed be distinguished statistically based on their responses (T = -4.23, observed delta = 0.346, p = 0.001).

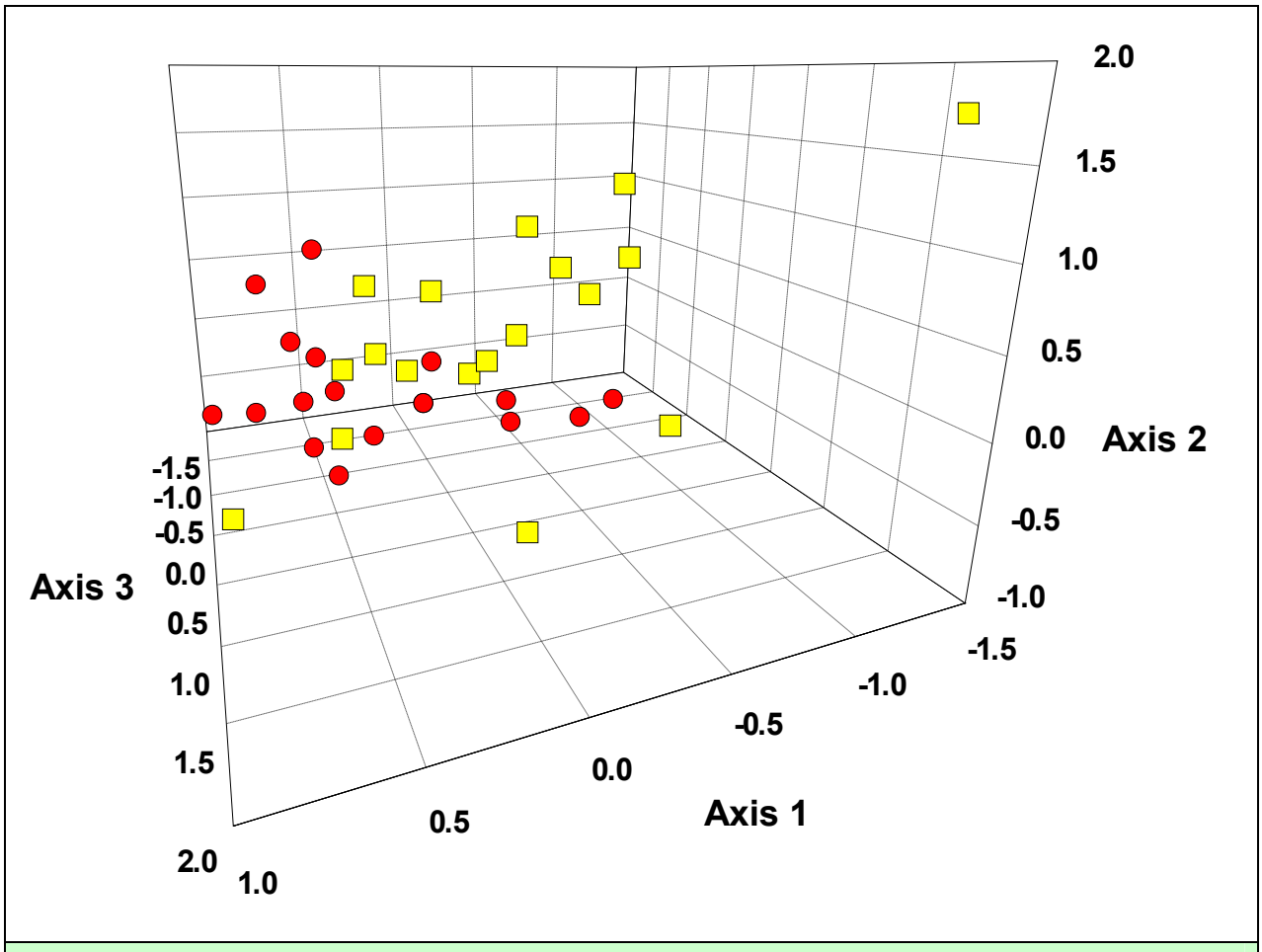

Fig. 4. Three-dimensional ordination of 36 farmers based on a nonmetric multidimensional scaling procedure. EE-farmers are represented by red circles and NEE-farmers by yellow squares. The ordination was done with a data matrix consisting of the presence/absence of a positive answer for each of 18 questions (see text for more details).

Discussion

Attitudes, knowledge and perceptions towards groups of vertebrates

Regarding the direct use of vertebrates, a large proportion of farmers use the local fauna for medicinal purposes and as food. The direct use of animals suggests that there might be little awareness regarding the negative consequences that this extraction could have for animal populations (unless extraction occurs as a means of biological control of certain animal populations). These results are consistent with studies conducted in the United States [33], Latin America [34], and Africa [35, 36], in which the most common attitude of people towards animals is the utilitarian one, with little consideration of the consequences. In South Africa, for example, it was found that species of reptiles more intensively used by traditional healers were also the species that had decimated populations [36]. In our study region several mammal species have already become locally extinct, including jaguar (*Felis onca*), cougar (*Felis concolor*) spider monkey (*Ateles geoffroyi*), white-tailed deer (*Odocoileus virginianus*), and peccary (*Tayassu pecari*) [24, 37]. Other species seem to be on their way to local

extinction as they were reported by the farmers as being very rare nowadays (compared to the past). Such species include coati (*Nasua narica*), anteater (*Tamandua tetradactila*), margay (*Felis wiedii*), otter (*Lutra annectens*), kinkajou (*Potos flavus*), cacomixtle (*Bassariscus astutus*), and paca (*Agouti paca*).

In terms of non-utilitarian attitudes and perceptions, these were very positive towards birds. All farmers like having birds in their shade-coffee plantations, both for their functional value (mostly seed dispersal was mentioned) and for their aesthetic value (visual and auditory). Birds constitute a "charismatic" group of animals in the study region, which is further evidenced by the fact that they are liked even though some bird species may cause damage to certain crops (e.g., maize). These results are consistent with those reported by Kaltenborn et al. [38] for Tanzania, where rural people also showed a higher preference for birds, when compared to other vertebrate groups. In general, people's preference towards charismatic animal groups is well documented [39-41].

In the case of snakes, although they were generally perceived as useful for crops, most of them were believed to be poisonous and consequently dangerous, when indeed only few poisonous snakes exist in the region. These mixed attitudes towards snakes were reflected by the fact that 76% of farmers kill snakes found in their homes, but only 28% kill snakes found in the field. These results resemble those obtained by Smart et al. [36] in South Africa, where snakes are most likely to be killed when found near the villagers' homes. Nevertheless, some farmers in Cuetzalan claimed not to use or kill snakes because of the traditional belief that killing snakes may cause damage to crops. This highlights the importance of the cultural context, as indicated by Cormier [22] in her study about primates in South America, in which she found that hunting and consumption of these species by humans are largely governed by cultural beliefs of the region.

For non-flying mammals, attitudes were in general indifferent. However, when we asked about particular species, perceptions were positive towards species used as food and negative towards species that cause some level of damage. Among the latter were rodents that cause damage to crops (mostly pocket gopher), similar to what was also found in a study of coffee farmers in Chiapas [42]. Negative attitudes were also revealed towards carnivores (mostly coyotes) that cause losses of farm animals, which again coincides with results found elsewhere [38]. Similarly, in countries like Indonesia [43] and India [44] it has been found that direct costs associated with wildlife have a negative impact on local perceptions, while the benefits (e.g., tourism, food) have positive effects. Also, other studies have shown that economic losses related to wildlife reduce tolerance and support for conservation [12, 21], particularly among rural communities, which are the ones that suffer such losses directly [35].

The vertebrates least understood and worst perceived were the bats. Negative perceptions towards bats are possibly linked to the damage that these animals may represent to livestock, in the case of vampire bats. However, the damage or benefit obtained from a group of animals is not the only factor shaping a farmer's attitude. For example, farmers mentioned repeatedly that some bird species can cause damage to their crops, and yet their attitudes towards birds in general were overwhelmingly positive. In this regard, Kaltenborn et al. [38] found that, when animals that cause certain damage are species that are "liked" (charismatic species), or when the damage is small or moderate, the attitudes of people are more positive. Thus, in the case of bats, and to some extent also in the case of snakes and mammalian carnivores, many of the negative perceptions and attitudes can probably be attributed to a mixture of lack of knowledge, and the prevalence of culturally-inherited beliefs. This result stresses the need for generating more positive attitudes toward little-understood and feared species, such as bats, carnivores, and snakes. The first step in achieving this is to provide context-specific information about the large number of benefits associated with these animals, compared to the little damage they can cause [45].

Attitudes, knowledge, and perceptions towards ecological functions

The vast majority of farmers have a general perception that animals are important for the welfare of their plantations. In terms of the farmers' understanding of the ecological functions *per se*, regardless of the group of animals responsible for it, the best understood function was seed dispersal and the least understood was pollination. However, the knowledge on ecological functions was clearly in direct relationship to the level of knowledge for a particular group of animals. Thus, while knowledge of the ecological functions performed by birds was relatively high, the farmers´ understanding of ecological functions performed by other groups was low, in particular for bats. This may in part be due to the fact that birds are not only abundant (unlike many non-flying mammals), but are also visible during the day (unlike bats and most non-flying mammals), making it possible for farmers to encounter them on a daily basis, and observe their behavior. Thus, farmers might commonly observe birds eating fruits, nectar, and insects.

The findings of this study indicate that farmers have a greater knowledge about the identity of vertebrate animals that live in their coffee fields than about the importance of these animals. Jacobson et al. [21] also reported for northern Florida a better knowledge of farmers on the identity of birds present in their agricultural plots (95%) than of the ecological functions performed by these animals (87%). The lack of adequate knowledge regarding the ecological importance of animals can be associated with a difficulty in establishing cause-effect relationships in ecological processes (e.g., increase in pests due to the elimination of biological controllers). Such a situation has been observed in other studies, where farmers are unable to associate plant health problems with their causal agents [42].

Some ecological functions may be more easily recognizable than others (see above). What specific ecological functions or ecosystem services are better recognized and understood is very likely to be site- and context-specific. For example, while in this study farmers had the lowest understanding and perception of the importance for pollination, in another study in Mexico, in the region of Chamela-Cuixmala, Castillo et al. [18] found that pollination was better understood than other ecosystem services provided by nature.

Differences among EE- and NEE-farmers

Overall, EE-farmers were different from NEE-farmers, in that the former group had more "environmentally-friendly" attitudes, perceptions, and knowledge towards vertebrates and their ecological functions, than the latter (excluding questions on the direct use of animals). Interestingly, EE-farmers also made direct use (medicinal) of animals more often than NEE-farmers. The increased use of animals by EE-farmers could somewhat reflect a better knowledge of the local fauna, i.e., because they know the animals well, they also know how to use them. In most cases, however, the unmanaged extraction of wild animals can have a negative impact on the animals' populations, and therefore may be difficult to reconcile with conservation purposes. Thus, we have two seemingly contradicting results, in terms of animal conservation, related to EE-farmers. On the one hand, they extract more wild animals, negatively affecting the populations. On the other hand, they are more likely to appreciate the indirect benefits accrued to them through the ecological functions of the animals, which in turn might facilitate the implementation of strategies that aim to conserve the fauna. It remains to be evaluated, however, if the level of extraction of animals by farmers constitutes a real threat to animal populations in the region, or whether other threats (e.g., habitat loss) are the main causes of concern. Moreover, it could be that the extraction of animals by farmers is the only means of controlling the population size of some species which, in the absence of their natural predators, might reach pest levels.

Why are EE-farmers and NEE-farmers different? One reason for the differences observed could indeed be the attendance of EE-farmers at the EEP workshops. Alternatively, considering that workshop attendance was voluntary, it is plausible that inherent differences among farmers (e.g., pre-existing environmentally-friendly attitudes), was the cause for workshop attendance, rather than the consequence. The difference observed in terms of the direct use of animals (in EE-farmers) is very unlikely to have been a consequence of the

Environmental Education Program, as these activities were certainly not encouraged in the EEP workshops. On the other hand, the increased knowledge regarding the importance of vertebrates for the functioning of the agroecosystem might have been shaped by the participation of farmers in the environmental education workshops. Future studies could aim at disentangling the confounding factors of the effects of EEP and pre-existing differences among farmers. For example, in a longer-term study one could assess the attitudes of particular farmers before and after completing an environmental education program. On the other hand, to determine what other socioeconomic, cultural, demographic, and personal variables determine a farmer's inherent attitudes towards environmental issues, one could perform a large-scale study (in terms of the number of farmers) with a multivariate design, in order to identify the most important determinants.

The results of this study show, nonetheless, a positive correlation between participation in environmental education workshops and the degree of environmental awareness. Other studies have also found a strong positive correlation between education and the presence of positive environmental perceptions and attitudes [46-48]. Similarly, the active participation in social organizations, such as the cooperative Tosepan Titataniske in Cuetzalan, has also been associated with pro-environmental attitudes [21].

Implications for conservation

The way wild animals inhabiting agroecosystems are perceived by the people managing those ecosystems will greatly determine the future conservation of animal populations in anthropogenic landscapes. If animals are merely perceived as neutral or even as harmful inhabitants of shaded-plantations, farmers lack any incentive to take specific actions that might favor the long-term maintenance of these animals' populations. However, if animals are rightfully perceived as an integral part of the agroecosystem, one that is responsible for performing diverse ecological functions that in turn help maintain many of the appreciated characteristics of the system, then animal species may face a brighter future. Special attention needs to be focused on enhancing the way non-charismatic animals are perceived. Bats, in particular, need to gain popularity by being recognized as providers of ecosystem services: control of insect populations, pollination, and seed dispersal. Similarly, ignored species, such as most non-flying mammals, need to win a place in people's minds, or else their populations will dwindle towards local extinction, at the same time they are lost from the cultural memory.

Herein lies the urgency of not only implementing environmental education programs in rural communities that still harbor much of their original local biodiversity, but of significantly increasing the emphasis that is put on providing specific knowledge of the local fauna and its associated ecological functions. In this sense, the results of this study show the importance of, as a first step, assessing the knowledge, perceptions, and attitudes of people towards different groups of animals. Once this information is available, charismatic and non-charismatic species can be identified, so that context-specific education programs can be designed in a more efficient way. Education programs should be based on local interests and include the active participation from all members of the community. Teaching methods should promote observation, experimentation, discussion, and manipulation of concepts in order to favor ecological understanding [49].

Acknowledgements

We would like to thank The Cooperative Tosepan Titataniske and the farmers interviewed for their cooperation, and Patricia Moguel, Mayolo Hernández, Lourdes Garcia, Octavio Zamora and José Jiménez for their contribution and assistance to this work. We gratefully acknowledge the comments of Susan Laurance and four anonymous reviewers on an earlier version of the manuscript. We thank the Consejo Nacional de Ciencia y Tecnología (CONACyT 2005-I002-24848) and the Universidad Nacional Autónoma de México for the funding to carry out this research.

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Appendix 1. Complete in-depth oral interview applied to 36 male shade-coffee farmers in the municipality of Cuetzalan, in the Mexican state of Puebla.

1. What wild animals do you most frequently see in your coffee field?
2. What wild animals do you use for medicinal purposes?
3. What wild animals do you use as food?
4. What wild animals do you use as pets?
5. What wild animals do you kill when encountered, even though you won't use them?
6. Do you use wild animals in any other ways?
7. Do you think it is important to have many different types of animals for the welfare of your coffee field? Why?
8. How often do you see toads and frogs?
9. Are all snakes poisonous?
10. Are snakes in any way beneficial to your coffee field?
11. What do snakes eat?
12. What do you do if you find a snake in your house?
13. What do you do if you find a snake in your field, or on the road?
14. Do you think that birds can be good for your crops? What birds, and how?
15. What do birds eat?
16. Do you think that some birds can be bad for some plants? How?
17. Do you like seeing birds in your coffee field?
18. Do you think there are animals that move pollen from one flower to another? Which animals? Do you think this is important? Why?
19. What do bats eat?
20. Do you think it is bad that bats live near your crops?
21. If you find a bat in your house, what do you do?
22. Do you think that bats are important for the environment?
23. Do you think there are animals that spread out seeds? Which ones? Do you think this is important? Why?
24. What do you think is the main reason for there not being as many animals as there used to be?
25. Do you think that shade coffee is better for the environment than sun coffee? Why?
26. What water-related problems exist, and what can be done to improve the situation?
27. How can soil erosion be controlled and soil fertility improved?
28. What garbage-related problems exist, and what can be done to improve the situation?
29. For each of the following mammals shown in the photographs[1] tell us:
    a) How often do you see it, and since when?
    b) Do you hunt it?
    c) What does it eat?
    d) Is it of any use to you?
    e) Is it beneficial for the coffee field or for the environment, in general?
    f) Is it dangerous for people? Why?
    g) Is it harmful for the crops or the forest? Why?

Appendix 1 continued

[1]Photographs of the following mammal species were shown to farmers, giving their Mexican common names in Spanish and in the native language (Nahuatl):

Scientific name	**English**	**Spanish**	**Nahuatl**
Didelphis marsupialis	Opossum	Tlacuache	Takuatsin
Dasypus novemcinctus	Armadillo	Armadillo	Ayotochin
Tamandua tetradactila	Anteater	Oso hormiguero	Askakuajkej
Lutra annectens	Otter	Nutria	Aiskuinti
Procyon lotor	Raccoon	Mapache	Mapactli
Nasua narica	Coati	Coatí	Peso
Potos flavus	Kinkajou	Marta	Kuoujtancho
Bassariscus astutus	Cacomixtle	Cacomixtle	Tepeitskuinti
Mustela frenata	Weasel	Comadreja	Kosamalot
Mephitis macroaura	Skunk	Zorrillo	Epat
Spilogale angustifrons	Skunk	Zorrillo	Epat
Canis latrans	Coyote	Coyote	Piotekuani
Felis wiedii	Margay	Tigrillo	Xaltigriyoj
Agouti paca	Paca	Tepezcuintle	Tepeitscuintli
Sciurus sp.	Squirrel	Ardilla	Chechelot
Sylvilagus floridanus	Rabbit	Conejo	Tochin
Odocoileus virginianus	White-tailed deer	Venado cola blanca	Masat
Tayassu pecari	Peccary	Pecarí	Kuapitsot
Ateles geoffroyi	Spider monkey	Mono araña	Monojtsin

Appendix 2. List of 22 questions used in the quantitative data analyses. The second column shows one of the two possible answers (yes or no); the answer shown is the one for which the percentage of EE- and NEE-farmers giving that particular answer is shown in the third column. For questions 5 – 22, the answer shown in the second column is considered "environmentally-friendly" (see Methods). The last column shows the exact probability value obtained with the Fisher Exact Test (FE-Test; two-tailed in questions 1 – 4, and one-tailed in questions 5 – 22) to compare statistically the responses of EE- and NEE-farmers.

Question	Answer	EE vs. NEE	FE-Test
1. Does farmer use vertebrates for medicinal uses?	yes	83 vs. 33	p = 0.0059
2. Does farmer use vertebrates as food?	yes	94 vs. 78	p = 0.338
3. Does farmer have wild animals as pets?	yes	17 vs. 11	p = 0.999
4. Does farmer use wild vertebrates in other ways?	no	100 vs. 100	p = 1
5. Is it important to have many wild animals living in the coffee farm?	yes	94 vs. 83	p = 0.301
6. Can birds be good for the coffee farm?	yes	100 vs. 94	p = 0.999
7. Can farmer explain why birds can be good for the farm?	yes	83 vs. 72	p = 0.345
8. Do you think that some birds might be bad for plants?	no	78 vs. 56	p = 0.144
9. Are snakes of any benefit to the coffee farms?	yes	61 vs. 33	p = 0.091
10. Does farmer mention rodents when asked what snakes feed on?	yes	33 vs. 28	p = 0.999
11. Does farmer mention that snakes can play an important role in pest control?	yes	28 vs. 6	p = 0.089
12. Are all snakes poisonous?	no	39 vs. 17	p = 0.132
13. Are non-flying mammals beneficial for the environment?	yes	17 vs. 6	p = 0.301

14. Are bats important for the environment?	yes	44 vs. 28	p = 0.244
15. Is it bad that bats live in the coffee farm?	no	78 vs. 44	p = 0.043
16. Does farmer mention other items, besides blood, when asked what bats feed on?	yes	50 vs. 28	p = 0.153
17. Is it important that animals move pollen?	yes	89 vs. 39	p = 0.002
18. Can farmer explain why it is important that animals move pollen?	yes	61 vs. 12	p = 0.002
19. Does farmer have some knowledge about which animals move pollen?	yes	61 vs. 44	p = 0.253
20. Does farmer mention, at some point in the interview, that vertebrates can play an important role in the biological control of pests.	yes	67 vs. 36	p = 0.047
21. Is the dispersal of seeds important?	yes	100 vs. 100	p = 1
22. Can farmer explain why seed dispersal is important?	yes	83 vs. 67	p = 0.222