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Wildlife damage to crops adjacent to a protected area in southeastern Mexico: farmers' perceptions versus actual impact

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Abstract: Human–wildlife conflicts occur when wildlife has an adverse effect on human activities (e.g., predation of livestock, crop raiding). These conflicts are increasing, particularly in areas surrounding natural protected areas, where villagers engage in subsistence agriculture. Crop damage may cause farmers to retaliate and harm wildlife species considered responsible for the damage. Among the factors that determine the intensity of the conflict are the frequency of the damage and the amount of biomass consumed relative to the perceptions, values, and cultural history of the farmers affected. To better understand the conflicts between farmers and wildlife, we compared farmer perceptions of wildlife damage to corn (*Zea mays*) to damage estimates recorded from May to June 2016 in 2 communities located in southern Mexico adjacent to the Natural Protected Area of Agua Blanca. We identified 128 farmers who had reported previous damage and used an administered structured questionnaire to assess their perceptions of the magnitude of the damage. Over 70% of the farmers surveyed considered that wildlife incursions in crops are a problem and 18% of them had implemented hunting and poisoning as a control measure. Farmers attributed their losses mainly to white-nosed coati (*Nasua narica*) and northern raccoon (*Procyon lotor*). However, our field data indicated that birds were causing more damage. On average, each corn crop lost $30.80; this value may be considered low, but the farmers' dependence on the harvest they obtain from their crops causes these losses, added to those they already have due to other causes (i.e., long droughts, insect pests, and fungus), which impact their bottom line. Wildlife crop depredation is not the main cause of economic loss, but its impact negatively influences the perception of some farmers on wildlife. A poor perception in farmers could lead to an increase in the use of lethal methods, which may also affect nontargets.

Key words: Birds, conservation, corn, crop damage, depredation, human–wildlife conflicts, mammals, Mexico, protected areas, *Zea mays*

Human–wildlife conflicts are defined as those occurring when an action by either humans or wildlife has an adverse effect on the other (Messmer 2000, Redpath et al. 2013). Conflicts in which wildlife affects human activities have increased, particularly in agricultural areas around protected natural areas. In these areas, in most cases the type of agriculture practiced is subsistence and relies on crops such as corn (*Zea mays*) and beans (*Phaseolus vulgaris*). As the wildlife species involved in crop damage are generally not charismatic or in danger of extinction, the conflict is rarely investigated in some regions, such as Mexico.

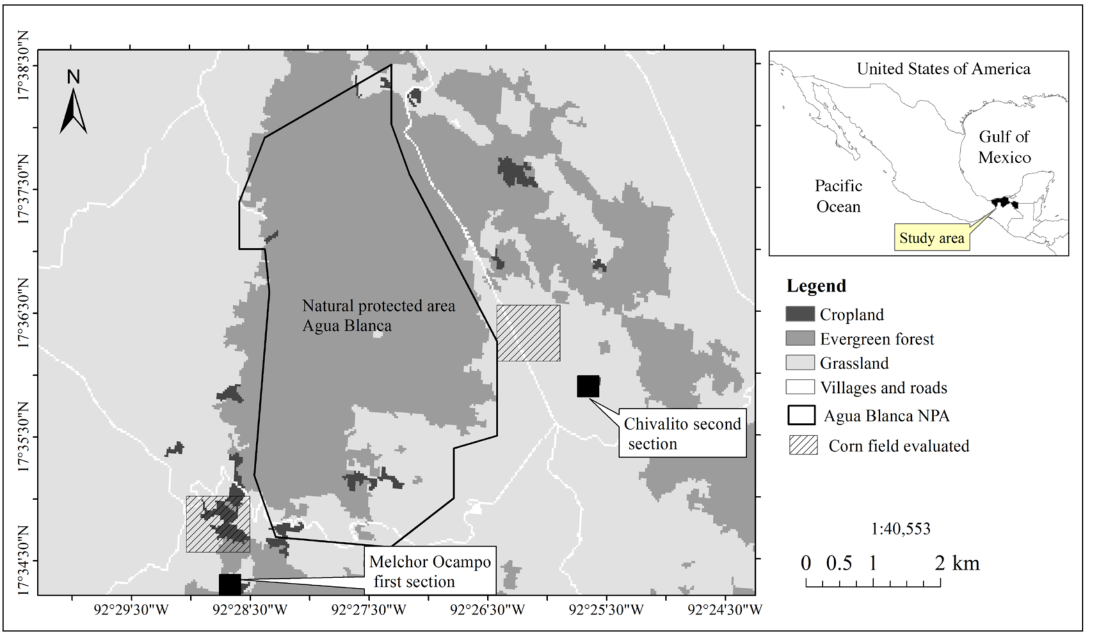

Figure 1. Corn (*Zea mays*) crops evaluated and villages where we investigate wildlife perceptions during the period from January to March 2016 in 2 communities near the National Protected Area Agua Blanca, Tabasco, Mexico.

Previous studies in Mexico reported birds and mammals of medium size as the main crop predators. Among the species that have been reported were the great tailed grackle (*Quiscalus mexicanus*), parrots (*Amazona* spp.), brown jay (*Psilorhinus morio*), pecari (*Dicotyles crassus*), northern raccoon (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus*). The primary crops impacted included rice (*Oryza sativa*), beans, and corn (Villar-Gonzáles 2000, Monge 2007). These conflicts are most noticeable in rural areas of southeastern Mexico, where crops like beans and corn are only grown in 2 seasons of the year and are the main source of support for farmers. For this reason, the crop depredation is not tolerated by farmers, who may hunt wildlife feeding on their crops as a control measure (Hill 2004, Romero-Balderas et al. 2006, Treves 2007, Gallegos et al. 2010).

The Natural Protected Area of Agua Blanca (NPAAB) is an important area in the state of Tabasco in Mexico because it is among the last relicts of medium-sized evergreen forests in the country, hosting a high biodiversity (Secretaría de Desarrollo Social y Protección al Medio Ambiente [SEDESPA] 2002). These characteristics have led the NPAAB to be considered an area of high importance for conservation within the initiative of the Mesoamerican Biological Corridor in Mexico (Alvarez-Icaza 2013). However, the designation of Agua Blanca as a protected natural area restricts communities from activities such as subsistence hunting and cultivating crops within the protected area. Nevertheless, in the surrounding areas of the NPAAB, the crops are allowed and their presence have created agricultural landscapes that provide an abundant source of easily accessible food for some wildlife species, which is a problem for affected farmers (Linkie et al. 2006).

Because of the complexity of the conflicts, the management of the problem will require better knowledge of its importance locally, as well as the knowledge of the species involved in the conflict, and the perceptions of those affected (Hill et al. 2002). The goals of our study were to assess farmers' perception of wildlife species involved in crop damage in the NPAAB, quantify corn damage by birds and mammals in the same area, and provide recommendations to better inform future decisions about mitigating human–wildlife conflicts in the area.

Study area

The study was conducted from May to June 2016 in 2 communities located in southern Mexico around the NPAAB (Figure 1). The

Figure 2. Biologist concealed in the tree to observe wildlife that came to feed on the crop.

climate of the area is warm and humid with rainfall occurring all year long. The average annual precipitation in the NPAAB is 210–320 mm with the average annual temperatures between 23 °C and 26 °C (Instituto Nacional de Estadística Geografía e Informática [INEGI] 2001). In both communities, the vegetation is composed of grassland, rain-fed crops, and some fragments of secondary vegetation. The main crops are corn, beans, plantains (*Musa paradisiaca*), orange (*Citrus sinensis*), and rice.

Rain-fed crops are established on high areas adjacent to fragments of natural vegetation with different degrees of disturbance. The average distance of the crops to the NPAAB is 77.2 m (range = 0–409.8 m) and the average cultivation plot is 0.4 ha (range = 0.003–0.4 ha; Can-Hernández 2017). Although many of the plots are adjacent to each other, some of them are isolated and sometimes surrounded by grazing areas.

The communities where the study was conducted are Melchor Ocampo first section and Chivalito second section, both listed as indigenous communities belonging to the Chol ethnic group (INEGI 2015). In both communities, corn crops are sown in 2 periods: December to March and June to September. The wildlife species reported as corn consumers and common in the area are the collared peccary (*Pecari tajacu*), white-nosed coati (*Nasua narica*), northern raccoon, gray squirrel (*Sciurus aureogaster*), white-tailed deer, agouti (*Cuniculus paca*), great-tailed grackle, blackbird (*Dives dives*), white-fronted parrot (*A. albifrons*), brown jay, and montezuma oropendola (*Psarocolius montezuma*; Koller 2012, Hernández 2015).

Methods

Villagers' perceptions of wildlife crop damage

From May to August 2016, we administered a structured questionnaire with open and closed questions to 128 farmers affected by crop damage by wildlife (Appendix A). The selection of farmers was carried out through the principle of the snowball method, for which key stakeholders were first interviewed and provided information on other farmers. A key stakeholder was an individual who possessed information related to the objectives of the study (Sierra 1998). In this case, it was local authorities and farmers previously identified who provided references from other farmers who have suffered losses due to wildlife damage to their crops.

In the questionnaire, information obtained included respondent demographics (i.e., age, main source of income, educational level, name, and crop grown). Farmers were asked which wildlife species feed on crops and which of these were regarded as having the highest impact on crops. We asked about the harvest seasons and stages of development in which crops are affected by wildlife. In addition, we asked about the control methods farmers use to mitigate the damage. The questionnaire also served to identify the willingness of farmers to allow access to their fields for damage estimation. The results of the surveys are described in percentages.

We used the participant observation method (Taylor and Bogdan 1987) to record field observation because some of the activities used by farmers to manage the damage may not be recorded through a survey. To do this, we sometimes went with the farmers to their daily activities at the cornfields, and we observed in detail the crop and its periphery (Figure 2).

Wildlife surveys

From the interviews with the farmers, we selected 24 corn fields in which at least 2 samples of birds and 2 of mammals were carried out during the season when the plants have cobs. The selection of corn fields surveyed was based on 2 criteria: the willingness of the farmer to allow access to their crop, and whether the farmer had crops at the time the study was conducted. To conduct the observations, we

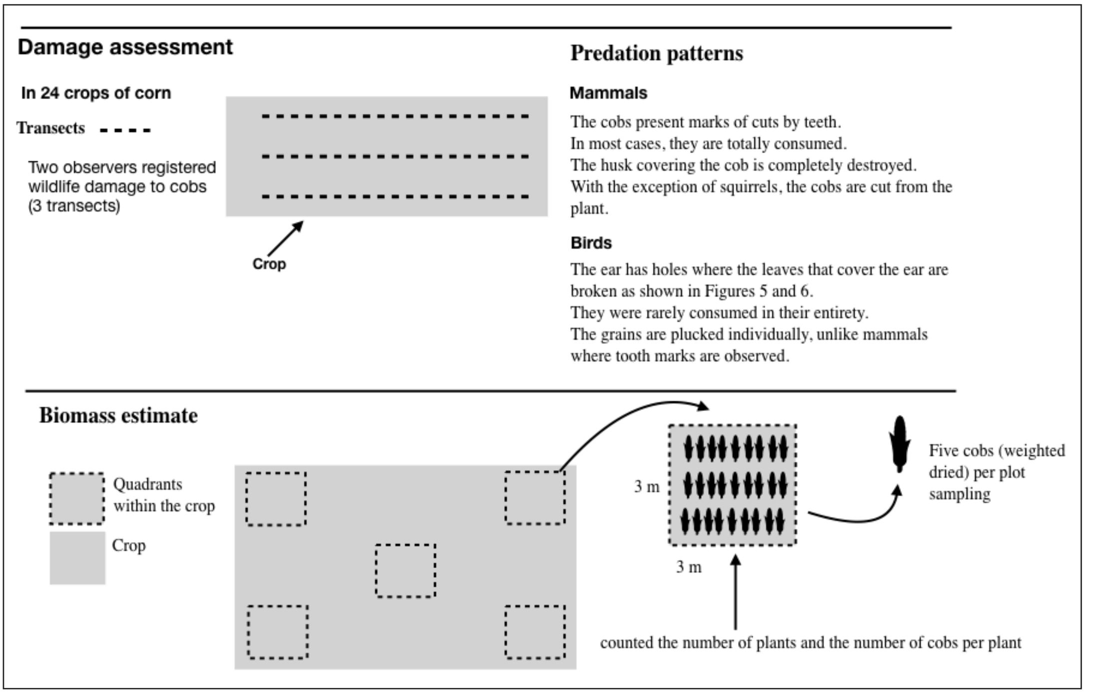

Figure 3. Scheme of the methodology used to assess damage caused by wildlife during the period from January to March 2016 in 2 communities near the National Protected Area Agua Blanca, Tabasco, Mexico.

received support from 3 biology students who had experience in bird and mammal identification. In addition, all received training prior to the start of the sampling to standardize data collection.

We used these observations to identify which species came to feed on corn and how often they did it. For mammal observations, we established 3 transects of variable width and length in each field; the length of each transect varied according to the size of the field. In each field, 2 transects were established on the sides of the crop and 1 transect inside it. In each sampling, mammalian traces were searched to determine which species visit the crops to feed on them. Each trace was associated with the presence of damaged corn cobs. The Aranda (2000) guide was used to identify the tracks of mammals that visited the crops.

The bird samplings were made from 0600–0800 hours. The bird observation was made from far away points (range = 20–25 m) from the crop, allowing the observer to have a complete view of the crop and where the birds would not notice the observer (Figure 2). The observations were made at 10-minute intervals, with rest periods of 5 minutes between 1 observation interval and another. We used 10 x 50-mm binoculars to conduct our observations. For identification at the species level, we used the Van Perlo (2006) bird guide. In each observation, the species and number of individuals coming to feed on corn were recorded.

Damage assessment

Field work was conducted from January to March 2016 to assess damage to corn crop in 14 and 10 fields belonging to the Melchor Ocampo community first section and to the Chivalito community second section, respectively. Each corn field was visited 3 times during the development stage known as cobs of corn. Damage was only assessed at this stage of corn growth because it is the only time that farmers reported damage by birds and mammals in surveys.

To estimate the damages caused by birds and mammals, in each corn field we placed 3 transects of variable wide and length: 2 transects at the edges and 1 transect at the center of the field. Its length was a function of each corn field length. Most fields had 4 definable edges; for these fields, we surveyed the 2 edges that ran parallel to the entire field row planting

Figure 4. Corn (*Zea mays*) cob eaten by squirrel (*Sciurus aureogaster*). The base of the cob shows the bites.

Figure 6. Corn (*Zea mays*) cob eaten by white-tailed deer (*Odocoileus virginianus*). Identification was based on the pattern of consumption and the presence of footprints around the plant.

Figure 5. Corn (*Zea mays*) cob consumed by a coati (*Nasua narica*). Its identification was based on the pattern of consumption and the presence of footprints around the plant.

Figure 7. Corn (*Zea mays*) on the cob depredated by birds.

orientation. For crops with irregularly shaped fields (>4 edges), we surveyed the 2 major edges that ran parallel to the entire crop planting orientation (Figure 3).

Transects were surveyed by 2 observers who documented all cobs or plants that exhibited any sign of wildlife-caused damage. We recorded wildlife species responsible for damage of each cob or plant. To distinguish between birds and mammals, we used consumption patterns (Figures 4, 5, 6, and 7) and other information such as feathers, tracks, hair, or excrement, and any traces that would allow identifying the species causing the damage. The plants or cobs that were knocked down by the wind, cobs with the presence of fungi, or those with incomplete development were recorded as losses not attributed to wildlife, and this sampling was carried out after sampling of birds. From the number of damaged cobs per transect, the number of damaged fruits was estimated for each corn field evaluated (Romero-Balderas et al. 2006).

To evaluate the yield of each corn crop in terms of biomass produced, 5 quadrants of 9 m^2 were established in each corn crop, 1 quadrant in each corner of the crop and 1 quadrant in the center (Figure 3). We counted the number of plants and the number of cobs per plant. From this, the average number of cobs per plant and the number of plants per quadrant were estimated, which allowed us to estimate the total number of cobs per corn crop (Romero-Balderas et al. 2006). In addition, 3 cobs were collected by quadrants (n = 5) during the pre-

Figure 8. A scarecrow placed on a watchtower is used by the farmers to scare mammals in the crop at night and to scare off birds.

Figure 9. A dog (*Canis familiaris*) moored in the crop as a strategy to deter coatis (*Nasua narica*) and peccaries (*Tayassu pecari*).

bending phase. The Romero-Balderas et al. (2006) procedure was used to estimate corn biomass per cornfield and then extrapolated to biomass per hectare. To estimate the variability in the weight of the cobs, we calculated the average weight of the cobs per quadrant and their standard deviation for each corn field. The average weight of cobs per corn crop ranged from 57.0–173.3 g, with a standard deviation ranging from 17.9–63.6 g. These values suggested that there was little variability in the weight of cobs within each corn crop and that the total number of cobs used to estimate biomass per corn crops (15 cobs) was adequate.

From the average number of fruits damaged by wildlife and the average weight of corn fruits, biomass consumed by wildlife was quantified and extrapolated to biomass consumed per hectare. The biomass consumed by wildlife was quantified through the number and average weight of corn fruits. These results were extrapolated to the biomass consumed per hectare. Biomass damaged by wildlife was multiplied by the sale price at the local level, which was $ 0.30 per kg of corn, according to the exchange rate of peso to U.S. dollars, from the BBVA Bancomer Bank (August 07, 2017). We used the non-parametric Kruskal-Wallis test (Zar 2010) to compare the economic cost of the different causes of losses (mammals, birds, and other causes) of farmers in the communities studied. The Wilcoxon rank test was also used to compare the economic losses between communities. Both tests were carried out in the R 3.4.0 program (R Core Team 2017).

Results

Villagers' perceptions of wildlife damage to crops

In our study, 70.4% of farmers considered wildlife that feed on crops to be a problem. Only 21% of farmers surveyed did not consider wildlife a problem, while 8.6% of the farmers did not answer the question. Most farmers (69.3%) said that the reason they tolerated losses was because the source of the problem was the lack of other food sources for the animals. In relation to how farmers perceived corn consuming wildlife, 30.7% classified these species as "pest," while 69.3% mentioned that crop consumption was due to the fact that wildlife did not have other food sources and it is natural. Some farmers tried to explain the problem as "the animals are also of God and therefore also have a right to exist, so we do not kill them and tolerate the damage they cause us."

Bird control methods used by farmers included the placement of scarecrows and cassette tapes (Figure 8). In some cases, they used illegal methods such as baiting and poisoning birds with banana (*Musa* spp.) bunches injected with agrochemicals like Furadan 5G (Carbofuradan) and SIROCO 20 EC (Cypermethrin). For mammals, farmers applied soap to the rocks inside or at the edges of the crop. They believed that this method was effective to chase away the coati and the white-tailed deer. Six plots were observed in which farmers tied their dogs up in the cultivation plots, as they believe that the smell and barking of dogs scare off species like the peccary (Figure 9). All of the farmers surveyed monitor their crops at least twice a day (morning and

Table 1. Damage control measures used by farmers in 2 communities adjacent the Agua Blanca State Park, Macuspana, Tabasco, Mexico. The number of farmers exceeds the sample size because the same farmer may use 1 or more control methods.

Damage control measures	Number of farmers	Percentage of farmers	Group in which it is used
Nothing	33	18.33	
Tie dogs in the crop	6	3.33	Mammals
Hunting	17	9.44	Mammals
Vigilance	58	32.22	Mammals and birds
Scarecrow	31	17.22	Birds
Poisoning	15	8.33	Birds
Firework	5	2.78	Birds and mammals
Cassette tapes	6	3.33	Birds
Soap	9	5	Mammals

afternoon), and a smaller percentage reported watching them at night, usually carrying firearms for illegally hunting mammals feeding on their corn. The interviewees mentioned that in this practice, they reduce losses and provide an extra source of food from the meat of animals killed (Table 1).

Farmers reported that 5 species of birds and mammals fed on their corn. For birds, Passeriform species were the most mentioned (brown jay, great-tailed grackle, and the montezuma oropendula), while for mammals, carnivorous species were the most mentioned (white-nosed coati and northern raccoon). However, when farmers were asked which 3 wildlife species cause the most damage to corn, they mentioned 2 mammals, whited-nosed coati and northern raccoon and one bird, brown jay (Figure 10).

Wildlife surveys

With a sampling effort of 72 hours of bird watching and a total area of 2.4 ha in which the search for track was made along the transects established in the plots of corn, 5 mammal species and 5 bird species were observed feeding on corn in the plots. During the sampling, we counted a total of 2,350 cobs damaged by wildlife. At the group level, 891 of them were assigned to birds and 94 to mammals. At the species level, 1,365 damages were identified. Of the 2,350 cobs damaged by wildlife, 429 were damaged by mammals and 1,921 were damaged by birds.

For 985 cobs, it was only possible to identify the damage at the group level (891 to birds and 94 to mammals). Two procyonid species (white-nosed coati and northern raccoon) visited the corn crops to feed on corn. However, in some cases it was not possible to identify damage at the species level. Procyonids consumed 14.7% of the total of damaged cobs and resulted in the mammal species with the highest consumption. Birds were the group with the highest impact on crop damage (81%) during the sampling period. However, it was only possible in 7.8% of the cases to identify the species with great-tailed grackle and brown jay, the main species responsible for the damage (Figure 11).

Production of corn yield

The corn crops sampled have an average area of 0.22 ha (range = 0.033–0.6 ha). The total corn production estimated by hectares for these fields during the study period was 26,979 kg, with an average production per corn field of 1,124.1 kg/ha (range = 133.7–2,514 kg/ha). In economic terms, the average production of the corn crops for the evaluated period is equivalent to $ 8,807.10 with a production range of $43.60–$820.70 (Table 2).

Economic quantification of the damage caused by wildlife

In terms of total production, the damage caused by wildlife ($740.70; range = 0.4–157.7) on average is equivalent to 9.4% of the total production of the 24 corn crops, with a range of losses per corn crop from 0.7–37.3%. According to Kruskal Wallis statistical analysis (Figure 12), factors such as the wind, which knocks down plants with underdeveloped fruits, and the presence of fungi in the fruits caused greater economic losses compared to those caused by birds and mammals ($K_{2, 24}$ = 19.4, P = 0.006). The total losses caused by factors other than wildlife amount to $753.40, with average losses per corn field of $31.40 (range = 1.1–136.8). These losses are followed by those caused by birds ($650), with average losses per corn crop of $27.10 (range = 0.7–132.1; Figure 12). The least damage

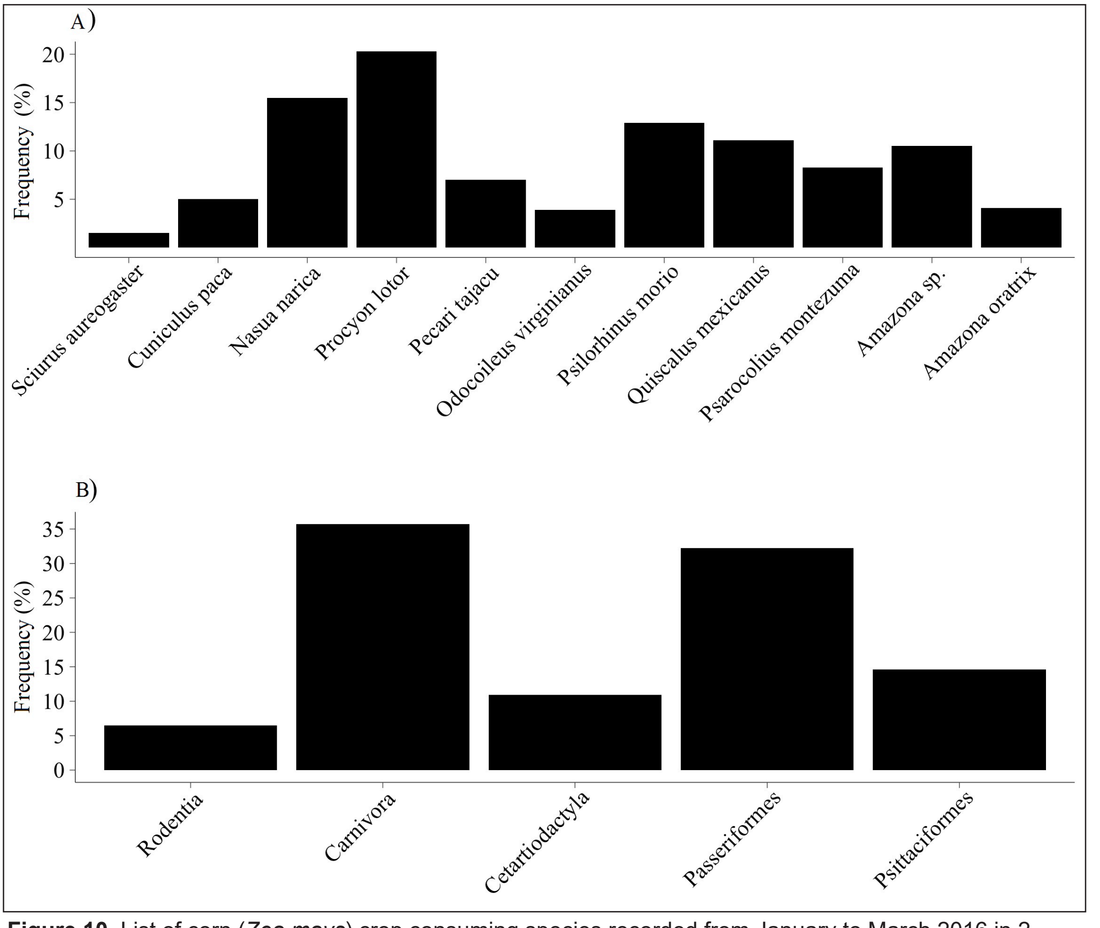

Figure 10. List of corn (*Zea mays*) crop consuming species recorded from January to March 2016 in 2 communities near the Natural Protected Area of Agua Blanca, Tabasco, Mexico: (A) frequency of corn consuming species according to farmers' perceptions, and (B) classification at order level of the most harmful species for corn as mentioned by farmers.

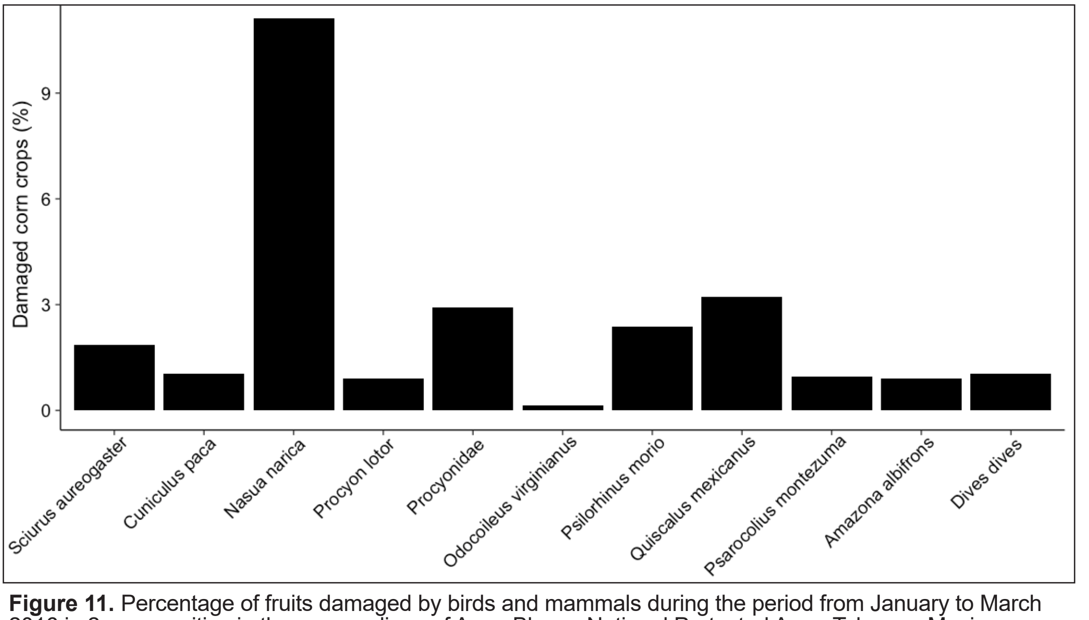

Figure 11. Percentage of fruits damaged by birds and mammals during the period from January to March 2016 in 2 communities in the surroundings of Agua Blanca National Protected Area, Tabasco, Mexico.

Table 2. Production of corn (*Zea mays*) per corn field and economic losses ($/ha) caused by birds, mammals, and other causes in the cornfields evaluated in the period from January to March 2016, in two communities adjacent the Natural Protected Area of Agua Blanca, Tabasco, Mexico. Surf = surface of corn field; Bio = biomass produced by corn field; Prod = value of the total biomass produced by each corn field.

Field	Surf. (ha)	Bio. (kg/ha)	Prod. ($/ha)	Wildlife ($/ha)	Birds ($/ha)	Mammals ($/ha)	Others ($/ha)
1	0.3	498.0	162.90	4.70	4.70	0	5.70
2	0.08	1,046.9	341.80	127.60	86.30	41.30	136.80
3	0.57	924.6	301.80	93.70	93.70	0	79.80
4	0.15	1,734.0	566.00	114.30	105.50	8.70	32.60
5	0.18	2,514.0	820.70	47.40	47.40	0	101.00
6	0.43	1,377.9	449.80	157.70	132.10	25.60	15.20
7	0.03	1,427.2	465.90	27.70	20.20	7.50	51.10
8	0.32	1,337.9	436.70	21.20	14.80	6.40	61.90
9	0.16	591.5	193.10	7.30	7.00	0.20	21.80
10	0.17	893.8	291.80	13.00	13.00	0	3.50
11	0.13	470.9	153.70	6.30	6.20	0	23.50
12	0.19	2,079.9	679.00	0	0	0	3.40
13	0.24	1,111.4	362.80	40.90	40.90	0.10	51.60
14	0.16	133.7	43.60	0	0	0	0
15	0.06	2,028.2	662.10	34.80	34.80	0	92.90
16	0.37	1,265.2	413.00	0.40	0	0.40	26.00
17	0.11	161.1	52.60	5.30	5.30	0	5.30
18	0.003	632.0	206.30	5.30	5.30	0	1.10
19	0.15	1,333.8	435.40	9.80	9.50	0.30	15.80
20	0.37	337.9	110.30	0	0	0	5.00
21	0.17	231.8	75.70	0.70	0.70	0	13.40
22	0.15	2,171.8	709.00	5.20	5.20	0	4.60
23	0.31	2,192.3	715.60	15.10	15.10	0	0
24	0.49	482.3	157.40	2.30	2.20	0.10	1.40

to corn was caused by mammals, with average losses per corn crop of $3.80 (range = 0–90.7).

At the community level, differences were found in the amount of damage caused by wildlife (W = 93, P = 0.006). In the Chivalito second section community, the average loss per corn crop was $63.32, in contrast to Melchor Ocampo first section, where the average loss was $7.70. In both communities, birds were the group that caused the most damage. The average loss per corn crop was $55 in the Chivalito second section and $7.10 in the Melchor Ocampo first section. For mammals, the average economic loss was $8.30 in the Chivalito second section and $0.50 in the Melchor Ocampo first section.

Discussion

The farmers we surveyed perceived that white-nosed coati and northern raccoon were the species with the highest impact on corn. However, field data indicated that the greatest losses were caused by birds. This discrepancy may be due to the fact that when white-nosed coati or raccoon enter into the corn field, they destroy many plants and leave remains of cobs of corn scattered throughout the field. This generates a visual impact, which possibly biases

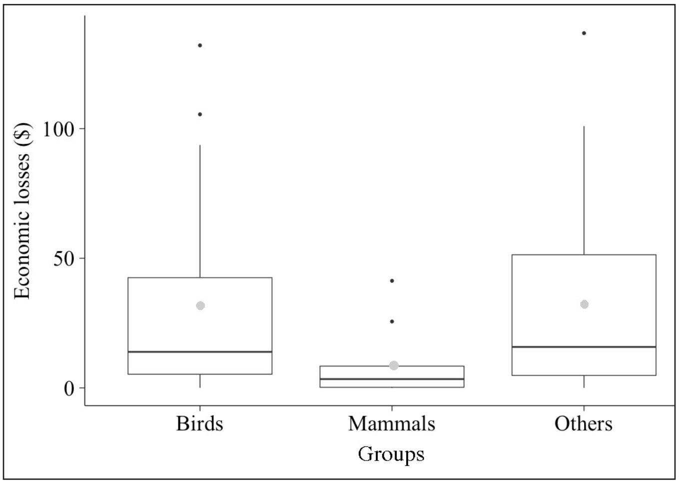

Figure 12. Economic losses caused by birds, mammals, and other causes during the period from January to March 2016 in 2 communities near the National Protected Area Agua Blanca, Tabasco, Mexico. The dot in gray indicates the average.

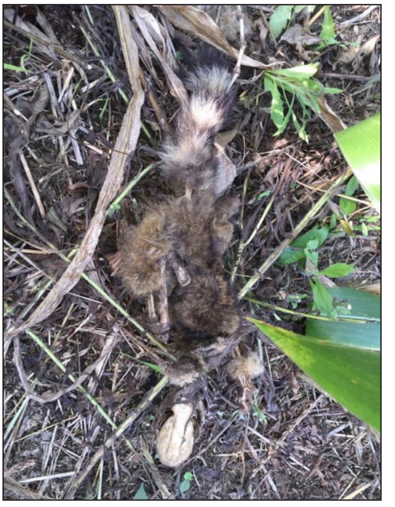

Figure 13. Coati (*Nasua narica*) dead inside a crop in which poison had been placed.

farmers' perceptions (Mishra 1997, Naughton-Treves 2001, Hill 2004, Naughton-Treves and Treves 2005). In comparison, the visual impact of the damage caused by birds is lower despite the greater frequency of visits of bird species. In addition, there are occasions when the cobs are not consumed entirely by the birds so that farmers can still use these crops.

The diminished capacity of farmers to mitigate losses caused by wildlife, along with losses caused by environmental factors, may decrease farmers' tolerance toward wildlife and exacerbate their negative reaction (Dickman 2010). In our study area, this could lead to an increase in the hunting and poisoning already recorded in the area with possible consequences for other species, such as scavengers, which are not responsible for crop damage (Figure 13). The perception and attitude of an individual can change from positive to negative or vice versa, depending on their previous experiences when facing certain events or by rare and extraordinary or extreme events (Naughton-Treves 2001, Manfredo and Dayer 2004). That is why in the study of human–wildlife interactions, the understanding of the individual and collective perceptions, attitudes, and motivations of those affected is a first step toward the resolution of this type of conflict (Gillingham and Lee 2003).

Studies with carnivores show that the perception and tolerance towards these species can be influenced by religious beliefs (Dickman et al. 2013, Inskip et al. 2016). In our study, the religion factor was not investigated; however, comments such as, "they cause harm but are entitled to eat," or "they have no options to feed themselves," or "they are animals of God and are entitled to exist" suggest that moral aspects and religious beliefs of farmers may be having a positive influence on their views of wildlife (Dickman et al. 2013, Inskip et al. 2016).

Controlled hunting and the use of toxicants are practices often carried out by farmers to control the damage wildlife causes to their crops (Messmer and Schroder 1996, Rodríguez-Calderón et al. 2018). In the study area, the use of toxicants to control birds that do not consume corn could impact species such as collared aracari (*Pteroglossus torquatus*) and keel-billed toucan (*Ramphastos sulfuratus*). Other species such as the painted bunting (*Passerina ciris*) could be impacted by feeding on seeds or insects that have been fumigated and even by the direct ingestion of residues of agrochemicals. Species such as the aplomado falcon (*Falco femoralis*), which uses crops and pastures to feed on small rodents, and the lesser yellow-headed vulture (*Cathartes burrovianus*) could also die from indirect poisoning when feeding on the remains of poisoned animals.

All species that could potentially suffer from direct or indirect poisoning in the NPAAB are mentioned in the IUCN red list and in the Official Mexican Standard 059 Secretaría del Medio Ambiente, Recursos Naturales

(SEMARNAT) 2010, which lists the species in danger of extinction for Mexico. In addition, all these species were reported by Koller (2012) to occur in the surrounding area of the NPAAB using crops as transit or feeding areas. Because of this, the use of agrochemicals for the control of invertebrates and to control damage to corn inside and outside the NPAAB should be regulated.

The number of dissuasive methods traditionally used by farmers to repel wildlife is extensive, including predator smells, sounds, scarecrows, lights, and surveillance. The efficiency of some of these methods is considerable. A study carried out on corn, yucca (*Manihot esculenta*), and walusa (*Colocasia esculenta*, *Xanthosoma* sp.) crops demonstrated that dissuasive methods such as smells and sounds can reduce losses by up to 50% (Pérez and Pacheco 2014). Thus, it is important that some of the dissuasive methods that are currently being used by farmers in the study area are evaluated, along with other methods to know how efficient they are in preventing crop damage by wildlife.

Studies conducted on different types of crops have shown, in some cases, that hunting used as a control method can reduce the damage caused by different types of species (Pérez and Pacheco 2014). In the study area, controlled hunting is practiced illegally by some farmers and is practiced on mammal species such as raccoons, coatis, and collared peccary. In Mexico, the control of harmful species can only be carried out under the approval of SEMARNAT and in compliance with the provisions of the General Law of Wildlife (GLW). The possible lack of knowledge of the environmental authority about the problem in the area and the farmers' lack of knowledge of a legal framework that provides management options may reinforce the idea that the environmental authorities do not pay attention to their problems, and this reinforces actions such as hunting and poisoning (Conover and Decker 1991).

Our results are consistent with studies conducted elsewhere that identified birds as the group causing the most losses to farmers (González 2003, Failla et al. 2008, Retamosa et al. 2008, Radtke and Dieter 2011, Monge 2012, Canavelli et al. 2012), although other studies reported that most crop losses were due to mammal species (Romero-Balderas et al. 2006, Retamosa et al. 2008, Gallegos et al. 2010). The group associated with crop damage depends on abundance and diversity of species at the local level and on the characteristic of the landscape in which the corn crops are located (Beasley and Rhodes 2008, Retamosa et al. 2008). Compiling inventory of the species potentially involved in the conflict is essential.

The damage caused by birds in the study area could be associated with the abundance of some species and their wide distribution in the cultivation zones as well as the spatial characteristics of the crops (Retamosa et al. 2008, Canavelli et al. 2012). It has been observed that bird damage is intensified in small area crops, which lack handling technologies and are almost always close to areas of favorable habitat for many species that see crops as an easy source of food (González 2003). Such conditions are present in the NPAAB and its surroundings (Villar-González 2000). Birds most found in the crops were the great-tailed grackle, montezuma oropendula, and blackbird, all tolerant of anthropogenic disturbances and benefiting from crops (Fitzwater 1994, Retamosa et al. 2008).

The average damage per hectare caused by mammals is 5.7%. This is lower than that reported in other places, in which a single species affects 10–80% of the total value of the crop (MacGowan et al. 2006, Retamosa et al. 2008). In both assessed communities, white-nosed coati and gray squirrel were the species that most visited the cornfields to feed on corn. Their presence could be associated with the proximity of the corn fields to vegetation areas where these species are usually abundant (Retamosa et al. 2008) in addition to their omnivorous and opportunistic habits (Aranda 2000). The few records of white-tailed deer during the samplings and their low mentioning in the surveys suggested this species, unlike those found in other studies (Gallegos et al. 2010), does not cause considerable damage to corn in the study area. It is probable that the low presence of deer in cultivation areas is due to local hunting pressure, which reduced the deer density and increased avoidance of areas where hunting occurs (Novack 2003, Gonzáles-Romero 2011).

We found variations in the amount of damage suffered by farmers and in the response that they have to the problem. Farmers perceive substantial losses that in many cases may negatively affect their attitude toward the wildlife. The results of this study are a first step to know the seriousness of the farmers' problem and the threats to wildlife due to methods farmers use to mitigate crop damage. A detailed evaluation of the effectiveness of lethal and nonlethal methods farmers use to reduce human–wildlife conflicts might help to mitigate crop damage and increase local acceptance of these methods. This study shows differences between the real and perceived damages by farmers. The knowledge of the species involved and the magnitude of damage caused by wildlife is the first step to discuss management options and help those affected to understand the magnitude of the problem, ultimately to influence farmers' perceptions and tolerance of wildlife.

Management implications

In Mexico, the literature on conflicts between wild fauna and agriculture is scarce as far as vertebrates are concerned. The results of this study contribute to the knowledge of the subject and expose the threats the conservation of the species that live in protected natural areas adjacent to crops. The NPAAB is located within the area of influence of the international conservation strategy Mesoamerican Biological Corridor section of Mexico, which until now has not considered agriculture wildlife conflicts as part of its conservation strategies. The information generated in this study will allow farmers, wildlife managers, and administrators of protected natural areas to understand the dimension of the conflict and discuss strategies to manage the conflict in accordance with the provisions of the GLW.

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Appendix A. Structured questionnaire administered with open and closed questions to 128 farmers affected by crop damage by wildlife, May to August 2016.

1. What types of crops do you have? a) Corn b) Bean c) Other (specify): ________________

ID:	Name:		Age:
Origin:	Village:		Time living here:
What is your main source of income:		Educational level:	
		Studies completed: Yes __ No__ Specify:	
Name of the interviewer:			

2. In a straight line, at what distance are your crops from the mountain? ______________

3. What are the seasons in which you cultivate? (Months of the year)

Corn Bean Other (specify):

4. Are there any wild animals that feed on their crops? a) Yes b) No

5. If the answer is yes, which animals feed on their crops?

	Bean		Corn		Other (specify)
Mammals	a) Deer b) Raccoon c) Coati		a) Deer b) Raccoon c) Coati		
	Others:		Others:		
d) Birds	Motesuma oropendula	Brown jay	Motesuma oropendula	Brown jay	
	Parrot	Pigeons	Parrot	Pigeons	
	Turkey vulture	Golden-fronted woodpecker	Turkey vulture	Golden-fronted woodpecker	
	Great-tailed grackle	White-fronted Amazon	Great-tailed grackle	White-fronted Amazon	
	Black-bellied whistling duck		Black-bellied whistling duck		
e) Others (specify):					

6. Which of the above-mentioned animals eats the most in your crops? Repeat the list aloud and list them in order from highest to lowest, as directed.

7. What is the development phase of the crop in which wildlife feed on most of their crops? a) seed b) emergent c) gleaning (flowering) d) fruits e) during dubbing

8. Do you like the fauna to feed on your crops?

a) Disagree b) Somewhat in agreement c) Agree

9. What do you do to prevent wild animals from feeding on your crops?

____

10. At times the community has organized itself to seek solutions and prevent wildlife from continuing to feed on their crops. a) Yes b) No

Continued on next page...

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11. Only if the answer to question 10 is Yes, what did they do? ________________________________

12. What do you think about the wildlife that feeds on your crops?
   a) They are good   b) They are a pest   c) They should not exist   d) They do it because they have no option
   e) Other_______________

13. Would you allow the consumption of your crops by wildlife to be assessed? a) Yes b) No

14. In addition to consuming the crops, do wildlife affect you in any other way? a) Yes b) No

15. What kind of problems? Specify: _________________

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