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Coexistence Between Humans and Capuchins (*Sapajus libidinosus*): Comparing Observational Data with Farmers' Perceptions of Crop Losses

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Abstract Foraging on anthropogenic food by wildlife is a prevalent form of human–wildlife interaction. Few studies have evaluated the impact of wildlife crop foraging in Neotropical areas where small-scale agriculture is practiced and the habitat has not been heavily altered. Our objectives were 1) to evaluate the perceptions of small-scale farmers living in southern Piauí (Brazil) of the impact of bearded capuchins (*Sapajus libidinosus*) on their crops and 2) quantify crop losses due to the monkeys and other vertebrates. In 2013, we interviewed 78 residents about the impact of capuchins on their crops. Subsequently, we recorded foraging by vertebrate animals in corn fields, and evaluated farmers' crop losses. The farmers showed a positive attitude toward the capuchins and their perceptions of wildlife behavior were generally accurate. The impact of wildlife varied in relation to the field's location, number of foraging individuals, and time spent foraging, as well as plant growth patterns. Vertebrates consumed between 23 and 100 % of the crops. Capuchins consumed the majority of crop losses, though birds consumed up to a third. The presence of a watchman reduced losses from wildlife by 66 %. In conclusion, although capuchins forage flexibly on anthropogenic crops, in a society relying on subsistence agriculture, their impact is perceived to be moderate overall. Peaceful coexistence between humans and monkeys

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favors conservation actions targeted toward protection of the capuchins and their habitat, both of which are seriously threatened by industrial agriculture in this region.

Keywords Anthropogenic food · Cerrado · Conservation · Crop foraging · Ethnoprimatology · Subsistence economy · Wildlife

Introduction

Humans and human activities increasingly occur in ecosystems inhabited by nonhuman primates. This generates a matrix of areas where humans and wildlife share space (Estrada 2006; Hockings *et al.* 2015). Proximity of cultivated areas to forest edges allows wildlife access to anthropogenic resources such as agricultural crops (Hill 2000; Naughton-Treves 1998). The loss in production and subsequent economic impact on farmers can generate conflicts between different human groups, *e.g.*, farmers *vs.* wildlife managers or conservation nongovernmental organizations (Hill 2015; Redpath *et al.* 2013) and/or between humans and the local wildlife (Fungo 2011; Hill and Wallace 2012; Lee and Priston 2005; Strum 2010; Woodroffe *et al.* 2005). To address such conflicts, it is essential to evaluate farmers' perceptions of the animals' behavior, especially in areas where the wildlife consumes economically important resources, such as cash crops (Lee 2010). Understanding people's perception, beliefs, and attitudes toward animals is also necessary to ensure efficient planning of conservation actions and to obtain the community's collaboration in such actions (Madden 2004).

Primates, in general, are behaviorally flexible and opportunistic and many are omnivorous; these traits allow them to exploit novel resources, including crops (Hill 2000). The exploitation of food sources found in plantations, *i.e.*, crop raiding, has been amply documented in several species of primates, including baboons (*Papio* spp. and *Theropithecus* spp.) and chimpanzees (*Pan troglodytes*) in Africa (Henzi *et al.* 2012; Hill 2000; Hockings and McLennan 2012; Katsvanga *et al.* 2006; Tweheyo *et al.* 2005; Warren 2008), and orangutans (*Pongo* sp.) and macaques (*Macaca* spp.) in Sulawesi and Indonesia (Campbell-Smith *et al.* 2010; Marchal and Hill 2009; Priston *et al.* 2012; Riley and Priston 2010).

In Brazil, several studies have documented the consumption of corn (*Zea mays*, also referred to as maize), sugarcane (*Saccharum* spp.), and manioc (*Manihot esculenta*) plantations by tufted capuchins (genus *Sapajus*) (Freitas *et al.* 2008; Galetti and Pedroni 1994; Ludwig *et al.* 2006; Rimoli *et al.* 2008; Siemers 2000). The majority of these studies have yielded information about damage done by capuchins and subsequent conflict with the farmers in areas of industrial agriculture. Among the best documented are the exploitation of plantations of pine (*Pinus* spp.) and eucalyptus (*Eucalyptus* spp). Tufted capuchins may substitute a diet composed of naturally distributed resources for anthropogenic food items, especially in areas where the plantations are extensive (see Liebsch and Mikich 2015; Mikich and Liebsch 2009). In these areas, damage caused from capuchins stripping the bark from trees to consume the phloem is economically significant and many producers see the capuchins as "pests" (Rocha 2000; Vilanova *et al.* 2005). The main factors favoring the exploitation and intake of anthropogenic items by capuchins are the scarcity of natural foods and habitat fragmentation (Freitas *et al.* 2008), proximity of the plantations to the native forest (Liebsch and Mikich 2013), and capuchins' high behavioral flexibility (Fragaszy *et al.* 2004) and propensity to take risks (De Petrillo *et al.* 2015).

Few studies have sought to evaluate the attitudes and perceptions of small-scale farmers that coexist with capuchins in agroecosystems where agriculture is not industrial and the habitat is not completely altered. In small rural properties in central Rio Grande do Sul state in Brazil, where farmers practice subsistence agriculture, farmers frequently observe black-horned capuchins (*Sapajus nigritus*) feeding in corn fields. In such areas, farmers say that the capuchins cause damage, but most of the interviewed farmers cannot estimate the total crop losses. However, most farmers also consider the capuchins an important part of nature and believe it is possible for humans and monkeys to coexist (Rocha *et al.* 2014). In another area of small properties in southern Brazil, farmers report capuchins damaging corn and pine plantations. Despite this, only 6 % of the residents interviewed expressed a negative perception of the capuchins. Residents with negative views of capuchins were mainly pine farmers (Barros 2011). These studies suggest that farmers' attitudes and perceptions of crop losses to capuchins depend on the type of agriculture practiced, with negative perceptions occurring in areas of more industrial agriculture (Rocha 2000), where damage generates loss in an economically important resource.

While crop raiding by wildlife has been widely studied, with a number of papers indicating that farmers' perceptions of crop losses are often unreliable (Linkie et al. 2007; Riley 2007; Webber and Hill 2014), few studies have explicitly confirmed this purported unreliability. This study addresses this gap in the literature through a cross-disciplinary approach, *i.e.*, combining interviews with local people with observations of wildlife crop foraging behavior on experimental plots, made with the participation of local farmers. We used an ethnoprimatological approach (Fuentes and Hockings 2010; Sponsel 1997) to evaluate the perceptions of farmers living in a rural area in southern Piauí (Brazil) of the impact of capuchins (*Sapajus libidinosus*) on small corn fields located within the monkeys' home range. We also evaluated the quantity of corn taken by capuchins and other vertebrates. We sought to evaluate the accuracy of residents' perceptions of crop loss from crop foraging by monkeys and other vertebrates. We attempted to identify the factors influencing the consumption of crops by wildlife, particularly by the capuchins, to examine whether crop loss is affected by easy access to the crops. Finally, we quantified corn yield in each corn plot. Our hypothesis is that the traditional practice of subsistence agriculture and many years of coexistence (as in Brazilian Cerrado; see Ratter *et al.* 1997) favor a positive relationship between humans and capuchins. Therefore, unlike farmers relying on commercial plantations (Liebsch and Mikich 2015), we predicted (P1) that residents would perceive that monkeys' consumption had a minimal effect on crop yield. We also predicted that (P2) residents' perceptions of wildlife crop foraging behavior would be accurate. Because cultivated crops can be easily accessed, energy-rich, and highly nutritious resources (Riley *et al.* 2013; Strum 2010), we predicted (P3) that other animals forage on the corn, in addition to the capuchins. In accord with the findings about other primate species feeding on planted crops (Priston *et al.* 2012; Wallace and Hill 2012), we predicted (P4) that the quantity of corn ears taken by the capuchins would depend on the number of individuals entering the cultivated plot, the time spent foraging in plot, and the proximity of trees to the plot. Nevertheless, in line with farmers' perceptions, we predicted (P5) that the loss of corn due to damage from wildlife would be a small proportion of the total yield.

Methods

Study Area

This study was conducted in a rural area of *ca.* 60 km^2 in the municipality of Gilbués, in southern Piauí, Brazil. The climate is characterized by 7 months with occasional rain (October–April), with precipitation between 1500 and 2000 mm, and by no rain during the remaining 5 months (Spagnoletti *et al.* 2012). The vegetation is a mosaic of sandy plains, marshes, cliffs, and plateaus, mostly composed of small (3–5 m tall) xeromorphic and scleromorphic trees (for details, see Visalberghi *et al.* 2007). Anthropogenic areas are part of the capuchin habitat, including cultivated areas, marshes (locally called *brejos*), hills, and woodland savanna where livestock graze, and a few less human-impacted forest areas (Izar *et al.* 2012). The study area includes the home range of two groups of capuchins at Fazenda Boa Vista (Fig. 1) that we have studied since 2005. The combined home range for the two groups has been estimated at 300 ± 50 ha (Izar *et al.* 2012), with a population density estimated at 2.3 individuals/km^2 (Verderane *et al.* 2013). Although there is a long dry season, it is not associated with reduced availability of fruits and seeds, which are available to the capuchins all year (Spagnoletti *et al.* 2012).

In this region, the livelihood of the human residents is based on subsistence agriculture. Often they own a small property (*ca.* 225 ha, Spagnoletti, *unpubl. data.*), raise a few cattle and other livestock and plant rice, manioc, beans, and corn during the wet season. The annual production of these crops is essential to feed domesticated animals and sustain the families throughout the year; it is the sole source of income for >80 % of the residents (Spagnoletti, *unpubl. data.*). The monkeys' diet is composed primarily of fruits and invertebrates (Spagnoletti 2009; Verderane *et al.* 2013). They also eat anthropogenic foods such as corn and the fruit from abandoned mango trees (an introduced species), but these do not constitute the bulk of their diet (Santos 2015; Verderane 2010).

Data Collection

We interviewed 78 residents ($N = 40$ men, $N = 38$ women) in April and May 2013, to assess the community's perceptions of their relationship with the capuchins. Using semistructured interviews (Bernard 1988) based on previous informal conversations (which revealed that monkeys visit the corn fields), we asked the residents about 1) what crops are usually planted; 2) what types of crops the capuchins may visit; 3) how much of the corn crop is consumed by the monkeys (none, little, very much, not known); 4) if the intake of corn by the capuchins is higher or lower than that of other animals; 5) what method the person interviewed uses to prevent crop losses to the capuchins; and 6) whether the method is effective. After these questions, the interviewee was free to describe the behavior of the capuchins when they entered the cultivated fields. Interviews were conducted by N. Spagnoletti in Portuguese, recorded digitally (Coby CXR190) and later transcribed by a local assistant. In addition to the interviews, we obtained *ad libitum* information during occasional talks with the residents, such as the quantity of corn planted by a family per year, and the destination of the harvested corn.

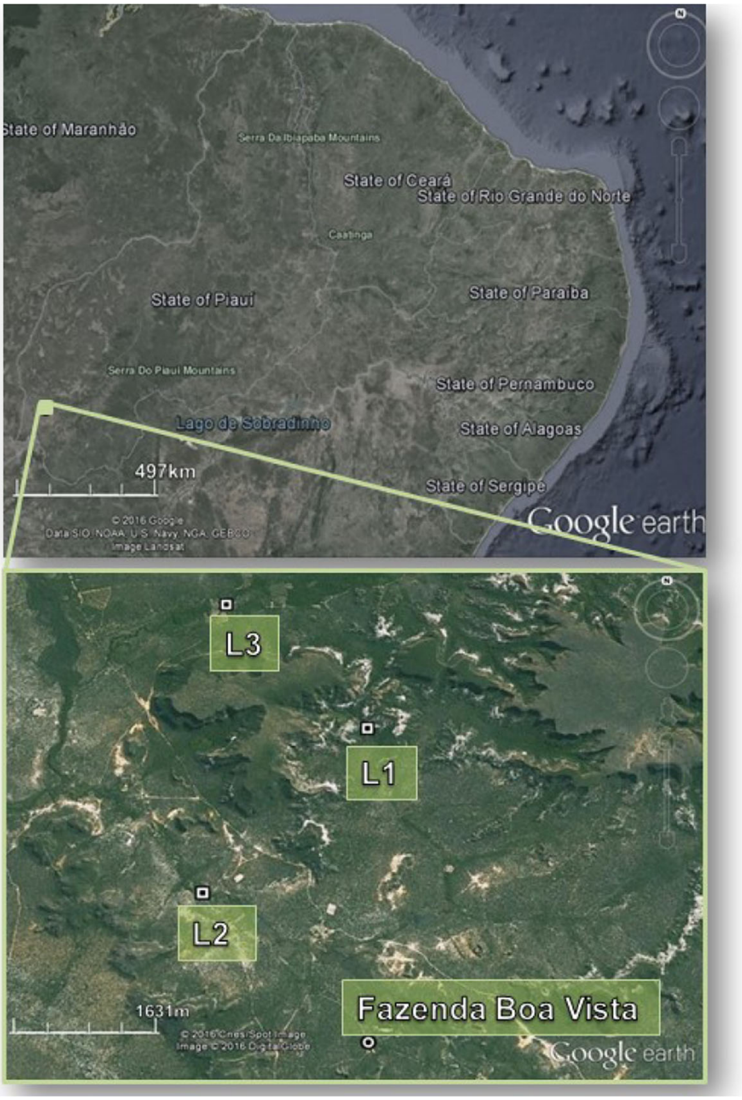

Fig. 1 Location of corn plots L1, L2, L3 and of Fazenda Boa Vista in the municipality of Gilbués (Piauí), Brazil. (Adapted from Google Earth™ 7.1.5, 2015).

Based on farmers' previous answers about crop consumption by undomesticated free-ranging vertebrates (hereafter, wildlife), we aimed to observe this behavior directly. To evaluate the impact of wildlife on the small plantations, three of the interviewed farmers agreed to plant corn in an area measuring *ca*. 50 × 50 m (the minimum area for corn planting, referred to locally as *tarefa*), following the traditional procedures used by the region's farmers. After preparation of the land in January 2014, the corn was planted in three areas (L1, L2, L3) differing in vegetation and belonging to three different farmers (Table I). The soil and the location of the field (close to a cliff or close to a marsh) differed across the plots, as well as the exact dimensions of the plot.

Fields L2 and L3 were each protected with barbed wire and wood fence to prevent access by cattle, horses, donkeys, and pigs belonging to the farmer. L1 was not fenced because it was not visited by domestic animals.

Due to the lack of rain in December and January, the two farmers of L1 and L3 replanted the corn in February 2014. We recorded visits by animals in April and May 2014, when the ears were ripening. The total number of days and observation hours for L1, L2, and L3 were 17 days (corresponding to 170 h), 31 days (232 h), 25 days (184 h), respectively. The number of observation days varied among plots due to the development of the corn plants and the damage they suffered from wildlife. We made systematic observations from Monday to Friday and ended when the ears were all removed or destroyed by vertebrates, or when farmers started harvesting their crop. This method allowed us to estimate crop losses to wildlife until harvest. We built a small hide in each plot that hid the observers from view during data collection. At L1 and L2, we made all observations without interference from the farmer. At L3, the observer watched the field from the hide and recorded behaviors, while the farmer used traditional methods to scare away the animals (presence of watchmen, shooting stones with a slingshot to scare birds, and/or shouting sporadically to scare other animals). At each plot, three trained field assistants (Josemar da Silva Oliveira, Arisomar da Silva Oliveira, and Claudio Fonseca Feitosa), who were assisted by N. Spagnoletti, recorded animal behavior and counted the number of ears of corn damaged by the monkeys or by other vertebrates. The three assistants were natal residents of the area, and thus familiar with the land and the animals. They were able to identify indirect signs of crop damage caused by local wildlife. At L2, we also observed one group of capuchins (N = 13 individuals in April 2014) studied by the Etho*Cebus* project research team since 2006 (Izar *et al.* 2012).

We collected data in two phases. First, we counted the number of corn plants and ears of corn present in each cultivated plot on day 0 (Table I). From day 1 onwards, we counted the number of individuals entering each plot (all-occurrence recording, Martin and Bateson 1993) in the morning (06.30–10.30 h) and in the afternoon (13.30–17.30 h). We defined crop foraging events as the arrival of one or more individuals of the same species, from the time the first individual entered until the time the last

Table I Characteristics of cultivated plot in the municipality of Gilbués (Piauí), Brazil, in 2014, in terms of geographical coordinates (latitude and longitude), locality, vegetation, perimeter, area, number of corn plants, and number of ears of corn present at the beginning of the study (day 0)

Plot	Geographical coordinates	Locality	Vegetation	Perimeter (m)	Area (m^2)	Number of corn plants	Number of corn ears
L1	9°37′51.83″S 45°25′6.21″W	Baixão do Quebra	Sandy plain/talus	177	1655	2034	735
L2	9°38′49.43″S 45°25′59.40″W	Boa Vista	Marsh/sandy plain	197	2169	5455	3370
L3	9°37′2.34″S 45°25′53.13″W	Boi Morto	Marsh/sandy plain	224	3214	826	887

individual left. For each crop foraging event, we recorded: 1) day; 2) plot number (L1, L2, L3); 3) type of data collected (direct observations of animals foraging at the plot, or indirect observations of foraging by animals; that is, the remnants of damaged or removed corn ears); 4) foraging species; 5) the total number of individuals; 6) for species that arrived in groups, we recorded the time of first and last arrival; and 7) number of ears of corn damaged (by birds) or removed (by monkeys). Before the afternoon observation (13:30 h) we checked for indirect crop foraging traces. Because we noted that birds could forage on the same ear for several days, we marked each newly damaged ear with colored flagging, noting the day it was first damaged (see Fig. 3). Because capuchins removed the entire ear(s), after counting their direct or indirect damage to the ears, we removed the entire corn plant to avoid recording the same damaged plant twice. To describe the foraging patterns and compare the behaviors of the wildlife that visited the plots, we recorded the behavior of each individual for all species, using the following categories: collects ear(s) of corn and leaves = the individual collects one or more ears of corn from the plot and leaves; eats at the plot = the individual collects one or more ears of corn and eats at the plot; eats away from the plot = the individual collects one or more ears of corn and eats it away from the plot, but within the observer's view.

For each plot, we estimated corn production as kilograms of whole ears of corn and of corn kernels. We did this by multiplying the number of ears of corn counted at the start of the study (Table I) by the mean weight of whole ears and of corn kernels from a sample of ears collected in each plot ($N = 5–10$) and weighed with a semianalytic scale (Series UX-6200H, capacity of 6200 g and precision of 0.01 g) (Table II).

Finally, we calculated the amount of corn lost from each plot due to crop foraging by wildlife as 1) absolute number of ears of corn consumed, 2) proportion of ears taken = the number of ears taken divided by the number of ears counted on day 0, and 3) proportion of corn taken = the weight of whole ears and of corn kernels consumed by wildlife divided by the estimated yield (in numbers of ears of corn and in kilograms of corn kernels) of the plot.

Table II Mean, minimum, and maximum weight in kilograms of whole ears and corn kernels, and mean, minimum, and maximum estimated yield in kilograms, for whole ears and corn kernels for each corn plot planted in 2014 in the municipality of Gilbués (Piauí), Brazil

Plot	Corn weight (kg) (min and max)		Corn yield (kg) (min and max)	
	Whole ears	Corn kernels	Whole ears	Corn kernels
L1	0.0215 (0.0094–0.0374)	0.0097 (0.0022–0.017)	15.8 (6.9–27.4)	7.1 (1.16–12.4)
L2	0.1298 (0.0473–0.2565)	0.0949 (0.0212–0.1997)	437.6 (159.4–862.7)	319.6 (71.4–673)
L3	0.0829 (0.0442–0.2075)	0.0578 (0.0303–0.1552)	73.5 (39.2–184)	51.3 (26.9–137.7)

We sampled five ears for L1 and ten ears each for L2 and L3.

Data Analyses

We transcribed and analyzed interviews with Atlas.ti v.7 (Muhr 1991) to extract and quantify concepts, phrases, and ideas that emerged from participants' answers to the categories of questions. We present interview data as the percentage of participants that gave a particular response to each survey question. The sample size of responses to individual questions varied because interviewees sometimes gave responses that were not applicable to the question. We included qualitative data obtained *ad libitum* outside semistructured interviews for supplementary purposes.

We coded and analyzed behavioral data *via* IBM SPSS v.20. We used nonparametric statistical tests because some variables (duration of crop foraging event, number of individuals, number of ears of corns taken, amount of crop lost, presence/absence of watchman) did not conform to a normal distribution (Kolmogorov–Smirnov test, $P < 0.05$ for each variable). For analyses, we defined two categories of vertebrates: birds (which included all bird species detected) and the capuchins. Since all individuals are part of the same population, for each category we combined observations recorded at the three cultivation plots. We used Mann–Whitney tests to examine the difference in the quantity and proportion of corn taken by monkeys and the birds. We used the category "vertebrate" as the independent variable and the number of individuals, time spent at the plot, and number of ears of corn taken as dependent variables. We used the same test to compare the number of ears of corn taken or damaged as a function of presence or absence of a watchman. We used a Spearman's correlation to test the relationship between the number of individuals in the plot, time spent at the plot, and number of ears damaged or taken, for each category of foraging behavior. We set significance to $P < 0.05$ and all tests were two-tailed.

Ethical Note

The research complied with protocols approved (CAAE: 14337013.9.0000.5561; no. 333.067) by the Human Research Ethics Committee of the Institute of Psychology of University of São Paulo and adhered to the Brazilian legal requirements and to the American Society of Primatologists' principles for the ethical treatment of primates.

Results

Residents' Habits and Perceptions of Crop Losses

When asked what crops are usually planted, corn (*Zea mays*) was the most cited among 78 interviewees, followed by rice (*Oryza* sp.), beans (*Phaseolus* sp.), manioc (*Manihot esculenta*) and a few fruiting plants (Table III). When asked what type of crops could be foraged by capuchins, the interviewees stated that the monkeys foraged on more than one type of crop, especially corn, and to a lesser extent rice, beans, manioc, and the fruiting plants (Table III). When asked what types of crops the capuchins may visit, 87 % of those interviewed ($N = 68$) mentioned monkeys visiting corn fields, while the remaining 13 % ($N = 10$) did not answer, because they did not themselves own corn

Table III Main type of crop planted in the municipality of Gilbués by the farmers interviewed in 2013 (N= 78) and their perception of the main crop visited by capuchins

	Crops planted (%)	Crops perceived as targeted by capuchins (%)
Zea mays	86 (N= 67)	79 (N= 62)
Oryza sp.	35 (N= 27)	26 (N= 20)
Phaseolus sp.	23 (N= 18)	13 (N= 10)
Mandioca esculenta	17 (N= 13)	9 (N= 7)
Fruiting plants	14 (N= 11)	14 (N= 11)

Fruiting plants include banana (*Musa* sp.), watermelon (*Citrullus lanatus*), mango (*Mangifera indica*), pineapple (*Ananas comosus*), and papaya (*Carica papaya*)

fields. Among those who answered, 34 % (N= 23) stated that the proportion of the corn crop lost to the monkeys was high, 28 % (N= 19) said the proportion was low, 22 % (N= 15) said there was no damage, and the remaining 16 % (N= 11) said they could not estimate. Two interviewees said the monkeys could consume one to four sacks of corn (60 kg each) from each field. In addition to the monkeys, other species were also mentioned as foraging on crops, especially birds (79 %, N= 119 answers) and other mammals (21 %, N= 31 answers). When asked whether the loss caused by capuchins is higher or lower than that of birds, 38 % (N= 30) responded that the monkeys consume more corn than do the birds, 36 % (N= 28) said the birds consume more corn than do the monkeys, 9 % (N= 7) said the capuchins and birds consume equal quantities, and 17 % (N= 13) did not know. On this topic, 15 % of interviewees (N= 12) explained that the loss from the monkeys' foraging is higher because they pull off the whole ear, while the birds peck at only some parts of the ear. However, two respondents said that the birds caused more loss because when they pecked at the ears, they left holes that filled with rainwater and rotted the whole ear. Two of the respondents also said that the damage is different, because the monkeys eat the corn and the birds eat the rice. Two respondents stated that the damage depended on the size of the animal group, and specified that since birds came in larger groups and foraged for longer periods than monkeys, the former caused higher losses than the latter. Among those who did not own a corn field, three people said that neither the capuchins nor other animals caused losses.

In addition, 54 % of those interviewed (N= 42) described the behavior of the capuchins when removing the ears of corn from the plant. Among them, 25 described how the monkeys tied the ears before carrying them off: 7 (28 %) said that the capuchins tie one ear to another, 5 (20 %) said that they tie the ears to their tails, 7 (28 %) said the monkeys tie the ears to the husks, and 6 (24 %) said that capuchins tie the corn ears, but did not specify how.

When asked what methods they used to avoid raids by the monkeys, among the 72 % (N= 56) of interviewees who responded, 80 % of the citations (N= 97) were of active vigilance, such as employing dogs, fire, screams, slingshots, rifle noises, general noises, and throwing rocks, while 3 % (N= 4) mentioned a passive deterrence method, such as using a cloth scarecrow, and only 1 % (N= 1) of the citations were of methods harmful to the monkeys (poisoning). However, 12 % (N= 15) referred to alternate and nonviolent solutions such as “planting near the house,” “planting larger crops,” “sharing the crops with the monkeys,” “harvest sooner,” “not planting corn,” and “taming the monkeys.”

When asked about the efficacy of the methods used to avoid raids by monkeys, among 38 respondents, 58 % ($N = 22$) said they worked, 8 % ($N = 3$) did not know, 5 % ($N = 2$) thought the methods did not work, and the remaining 29 % ($N = 11$) argued that the methods worked to scare away the monkeys but were not totally efficient, working only in some situations and that the return rate of the monkeys was high.

According to one farmer, the main use of the corn crop in the region is food production for domestic animals. The farmers usually plant plots of two *tarefas* (about 1 ha), that is, twice as large as the plots planted in this study. This size is considered sufficient to yield 11–12 sacks of corn (60 kg each), totaling *ca*. 660–720 kg, enough to raise 20 chickens and 2 pigs in a year (using about one sack per month).

Observations of the Animals that Fed at the Plots of Corn

We recorded 164 crop foraging events in the corn plots; 94 % ($N = 154$) were observed directly and 6 % ($N = 10$) were inferred from indirect evidence (crop damage). Of the 154 direct observations, 59 % ($N = 91$) were by birds (*Brotogeris chiriri*, *Gnorimopsar chopi*, *Melanerpes candidus*, and *Arautinga aurea*) and the remaining 41 % ($N = 63$) were by capuchins (Table IV). The number of birds at the plots was significantly higher than the number of monkeys, and the birds spent more time foraging at the plot than did the monkeys (respectively: Mann–Whitney U: $N_{(\text{birds})} = 91$ $N_{(\text{monkeys})} = 63$, $U = 4830.5$, $P < 0.0001$; $N_{(\text{birds})} = 88$ $N_{(\text{monkeys})} = 52$, $U = 4225$, $P < 0.0001$).

Table IV Number and duration (s) of direct observation of crop foraging events, number of individuals per foraging event, and number of ears of corn taken or damaged in the corn plots planted in 2014 in the municipality of Gilbués (Piauí), Brazil

Species	No. of crop foraging events	Duration of crop foraging events (s)		No. of individuals		No. of ears of corn taken/damaged	
		Median	Range	Median	Range	Median	Range
Bearded capuchin (*Sapajus libidinosus*)	63	84.5[a]	18–808	1	1–10	2	0–13
Yellow-chevroned parakeet (*Brotogeris chiriri*)	62	1125	41–4920	10	1–30	0	0–34
Chopi black bird (*Gnorimopsar chopi*)	14	533	119–3309	10	2–40	0	0–12
White woodpecker (*Melanerpes candidus*)	10	1079	234–3218	2	1–4	–[b]	–
Peach-fronted parakeet (*Arautinga aurea*)	5	628	240–900	1	1–1	0	0–1
All bird species	91	985	41–4920	10	1–40	0	0–34

[a] The number of crop foraging events with recorded duration was $N = 52$. [b] When we observed white woodpecker foraging, we were unable to record the number of ears foraged per individual.

For the monkeys, the number of ears of corn taken correlated positively with the number of individuals present at the plot and with the time spent at the plot (respectively: Spearman $r_s = 0.85$, $P < 0.001$, $N = 63$; $r_s = 0.55$, $P < 0.001$, $N = 52$). In the case of birds, the number of ears damaged correlated positively with the number of individuals present at the plot ($r_s = 0.22$, $P = 0.035$, $N = 92$), but not with the time spent at the plot ($r_s = 0.032$, $P = 0.766$, $N = 89$). Regardless of species, the presence of a watchman in L3 affected the total number of ears of corn taken by wildlife (Mann–Whitney $U = 116.5$, $N_{(watch)} = 19$ $N_{(no\ watch)} = 8$, $P = 0.029$). Up to 10 ears of corn were taken in the presence of a watchman (median = 0, IQR = 0; mean ± SD = 0.53 ± 2.06 corn ears) while up to 30 ears of corn were taken in the absence of a watchman (median = 2.5, IQR = 7.25; 3.75 ± 4.36 ears of corn).

The monkeys consumed significantly more ears of corn than did the birds (Mann–Whitney U test: $N_{(birds)} = 91$ $N_{(monkeys)} = 63$, $U = 682.5$, $P < 0.001$; Table IV). At L1, we did not make direct observations of the presence of animals, but we were able to verify the consumption of corn by capuchins through indirect evidence (Fig. 2). Taking into consideration that the cultivated plots were distant from each other (Fig. 1 and Table I), and the fact that we observed monkeys foraging at two different plots on the same day (April 28, 2014), we infer that the experimental plots were visited by at least two groups of capuchins.

Virtually all (97 %) of the direct observations of foraging on ears of corn by capuchins ($N = 61$ events) took place at L2, and 3 % ($N = 2$) occurred at L3, where there was a watchman. None occurred at L1. On three occasions, we observed four

Fig. 2 (*Left*) Indirect evidence of predation on corn ears by capuchins in the corn crops planted in the municipality of Gilbués (Piauí), Brazil. Between May 9 and 12, 2014, the monkeys arrived at plot L1 and consumed 653 ears. (*Right*) An adult female capuchin on a tree branch next to plot L2 eating an ear of corn while holding a second ear with her foot. Photos by N. Spagnoletti

individuals enter and leave plot L3 without taking any corn. Apparently the monkeys were frightened by something and fled. At L2, up to 71 % ($N = 10$) of the individuals foraged together at the plot. We observed four species of birds entering the plots (Table IV); 70 % of observations of birds entering a plot took place at L2. At L2, we also indirectly recorded the consumption of four ears of corn by pigs (*Sus domesticus*), and at L3 we indirectly recorded the consumption of four ears of corn by donkeys (*Equus asinus*).

Among the 154 monkeys we recorded participating in 63 crop foraging events, 73 % ($N = 112$) harvested ears of corn and left the plot to eat them out of the observer's sight, while 19 % ($N = 30$) harvested the ears and ate away from the plot but were still visible to the observer (Table V). Finally, 5 % ($N = 8$) ate in the plot and 3 % ($N = 4$) of individuals entered the plot but soon moved away without harvesting any corn (Table V). At L3, the monkeys visited only on 1 day after 17.30 h, once the watchman had left the plot. On this occasion, the observer recorded two crop foraging events by eight monkeys. In directly observed crop foraging events, the individuals arrived as a group *via* nearby trees, usually using vegetation remaining next to a marsh. From there, the individuals moved along branches and descended to a fence one at a time, sometimes using the same route. Individuals walked along the fence, or quickly descended to the ground and moved in the direction of the corn plants. In all cases, the first ears of corn to be harvested were those closer to the fence or to the tree that the monkey used to come to the ground. A single monkey took from one to three ears of corn (mean = 1.2; $N = 150$) at a time. Once the ear(s) was detached, the monkeys carried it in their hands, the mouth, or under their arms.

Of the 908 birds observed during 91 direct crop foraging events, 81 % ($N = 584$) of the yellow-chevroned parakeets, 93 % ($N = 159$) of the chopi black birds, and 74 % ($N = 14$) of the white woodpeckers ate at the plot (Table VI). In all cases, the barbed wire fence effectively prevented intrusions by cattle and horses, and greatly reduced intrusions by pigs and donkeys.

Corn production varied by plot (Table II). All of the L1 corn was taken by wildlife, and indirect signs found in the same plot indicated that all the foraging was by capuchins (Fig. 2). Consumption of the ears at L2 and L3 was approximately one quarter of the expected yield (Table VI). At L3, almost all of the ears consumed by monkeys (97 %, $N = 179$) were recorded *via* indirect observations on the first day of counting. Consumption by birds represented 17 % ($N = 296$) of the total corn loss measured in ears ($N = 1762$). At L2, up to a third of the ears were damaged by birds, especially by yellow-chevroned parakeets (Fig. 3). Capuchins were responsible for around 83 % ($N = 1458$) of the total corn loss in this plot. The remaining 0.4 % ($N = 8$) of the consumption was by donkeys and pigs (Table VI).

Discussion

We found ethnoprimatological methods (Sponsel 1997) useful to understand what the farmers plant in our study area, and their perceptions of raids by animals on their crops and the consequent loss of income. As found in other studies (Lee 2010; Lee and Priston 2005; Marchal and Hill 2009; Naughton-Treves 1998), the smallholder farmers we interviewed perceive the greatest loss in the most economically important activity,

Table V Percentage of individuals observed for each species in corn plots L2 and L3 planted in 2014 in the municipality of Gilbués (Piauí), Brazil, and percentage of behaviors scored per individual

	Number of individuals observed	Species	Individual behavior			
			Collects ear of corn and moves away	Feeds on corn in the plot	Feeds on corn outside the plot	Other
L2	63 % (*N* = 549)	Yellow-chevro*N*ed parakeet (*Brotogeris chiriri*)	0	95 % (*N* = 523)	0	5 % (*N* = 26)[a]
	18 % (*N* = 163)	Chopi blackbird (*GNorimopsar chopi*)	0	93 % (*N* = 151)	0	7 % (*N* = 12)
	17 % (*N* = 146)	Capuchi*N* (*Sapajus libidiNosus*)	76 % (*N* = 111)	3 % (*N* = 4)[b]	18 % (*N* = 27)	3 % (*N* = 4)[c]
	2 % (*N* = 19)	White woodpecker (*MelaNerpes caNdidus*)	0	74 % (*N* = 14)	0	26 % (*N* = 5)
Total	877					
L3	92 % (*N* = 169)	Yellow-chevro*N*ed parakeet (*Brotogeris chiriri*)	0	36 % (*N* = 61)	0	64 % (*N* = 108)
	4 % (*N* = 8)	Chopi blackbird (*GNorimopsar chopi*)	0	100 % (*N* = 8)	0	
	4 % (*N* = 8)	Capuchi*N* (*Sapajus libidiNosus*)	12 % (*N* = 1)	50 % (*N* = 4)	38 % (*N* = 3)	0
Total	185					

[a] Includes individuals that entered the plot but left without foraging.

[b] Includes two individuals seen eating on the fence.

[c] Includes two individuals that entered the plot but left without foraging.

Table VI Percentage of corn production consumed in 2014 by vertebrates in the corn plots planted in the municipality of Gilbués (Piauí), Brazil, in terms of number of ears consumed, kilograms of whole ears and corn kernels produced, and number of ears consumed by each species

Plot	Intake from the production by vertebrates			Number of ears consumed by species			
	Number of ears	kg of whole ears	kg of corn kernels	Monkeys	Birds	Pigs	Donkeys
L 1	100 % (N = 735)	15.8	7.1	100 % (N = 735)	0	0	0
L 2	23.5 % (N = 792)	102.8	74.8	67.9 % (N = 538)	31.6 % (N = 250)	0.5 % (N = 4)	0
L 3	26.5 % (N = 235)	19.5	13.6	78.7 % (N = 185)	19.6 % (N = 46)	0	1.7 % (N = 4)
L1+ L2 + L3	(N = 1762)	138.1	95.5	82.8 % (N = 1458)	16.8 % (N = 296)	0.2 % (N = 4)	0.2 % (N = 4)

Fig. 3 (*Left*) Two yellow-chevroned parakeets (*Brotogeris chiriri*) foraging at L2 corn plot planted in 2014 in the municipality of Gilbués (Piauí), Brazil. (*Right*) Damage to the ear by the birds. Note the flagging tape that indicates the first day the ear was damaged. Photos by N. Spagnoletti

that is, the corn crops. This crop is planted by 9 out of 10 farmers to feed their domestic animals. However, unlike what happens in large-scale or commercial plantations (Liebsch and Mikich 2013, 2015), most smallholder farmers in the region perceive that capuchins consume little of their crop. This supports our first prediction (P1), that in a society based on subsistence agriculture, perceptions of capuchins are positive. Farmers' answers about monkeys' behavior and their impact on corn crops revealed that they know capuchins' behavior, supporting the predictions that residents' perceptions of wildlife crop foraging behavior is generally accurate (P2), and that other animals foraged on corn besides the capuchins (P3). In addition to capuchins, residents identify birds (particularly the yellow-chevroned parakeet) as causing damage to corn crops. The interviewees also pointed out that consumption by the capuchins is greater than that by birds due to behavioral and morphological differences between these two types of animals. They note that birds generally eat the corn kernels directly from the ear attached to the plant, while capuchins pull off the whole ear from the plant. Our behavioral observation confirms that birds, especially yellow-chevroned parakeets, visit the plots more often, arriving in larger groups and spending more time at the plot than do the monkeys. Nevertheless, capuchins consume more corn than do birds.

As expected from findings with other primate species that feed on crops (P4), the amount of corn consumed by capuchins depends on the number of individuals foraging at the plot and on the amount of time spent foraging. The intake by birds depends on the number of individuals foraging at the plot, as stated by the residents. The capuchins collectively ate 7–50 kg of corn kernels, *i.e.*, 12–84 % of one sack of corn kernel used monthly by farmers to feed their domestic animals. Although we cannot confirm that this intake is actually economically low, as predicted (P5), local farmers perceive it as moderate, *i.e.*, from low to zero. As for chimpanzees feeding on cashew fruit in Guinea-Bissau (Hockings and Sousa 2012), our study represents an important example of a low-conflict interaction where primates feed on crops without provoking negative perceptions in farmers.

The consumption of corn by wildlife varied across plots. Generally speaking, the crop yield varies with environmental factors such as type of corn, soil erosion, soil productivity, and water (Pimentel *et al.* 1995). In this study, L1 produced only 7 kg of kernels (Table II), likely due to the type of soil and the plot's location away from marshes. In contrast, L2 and L3, both located a few meters from the marsh and the riparian forest, had a much greater yield (see Fig. 1 and Table II). We also found that on days when a watchman was present, there were 66 % fewer vertebrate crop foraging events, confirming that active vigilance is an effective deterrent. As for other primates, the most effective strategy of crop protection should consider the raiding behavior of the local primates and the possibility of combining deterrents, *e.g.*, fence and active guarding (Hill and Wallace 2012). As in most regions of the Northeast of Brazil (Dos Santos Neto and Gomes 2007), active human vigilance is commonly used and does not harm wild animals. In our study most residents stated that, although this method requires time and effort, it is effective because the animals are intimidated by human presence and do not enter the cultivated fields.

Methods that harm the animals were rarely mentioned (only one mention of poisoning). Along with statements about nonviolent alternatives (such as sharing the crop with the monkeys or planting larger plots), our results indicate that the farmers have a nonviolent and positive attitude toward the monkeys, coexisting with them in a tolerant and sustainable manner. Our records show that a small quantity of corn was lost due to foraging by the capuchins, in agreement with most of the residents' perceptions. Thus, in a society relying on subsistence agriculture (which also has a smaller impact on the habitat than industrial agriculture), the impact of wild animals on human activities is small and coexistence is relatively peaceful.

The foraging behavior of the bearded capuchins in our study conforms to the behavior seen in other primate species (Priston *et al*. 2012; Wallace and Hill 2012), including the closely related black-horned capuchins (*Sapajus nigritus*: Barros 2011; Lacerda 2013; Liebsch and Mikich 2013). Capuchins approach the plots from trees at the edges of the native forest, collect the ears of corn, and move back toward the forest, where they husk and consume them (Fig. 2). We therefore conclude that for capuchins, as for other vertebrates (Hill 2000; Linkie *et al.* 2007; Naughton-Treves 1998), the proximity of the planted fields to forest edges leads to high access to cultivated crops. These results, although needing replication, indicate that one solution to monkeys' raids might be to plant the crops away from areas used by the animals. However, as suggested by one of our interviewees and by other authors, the success of this strategy depends on specific cultural, practical and/or economic circumstances (Hockings and McLennan 2012; Lacerda 2013; Priston *et al*. 2012). As the monkeys at our study site do not show much interest in rice, beans, and manioc, we suggest that these crops be planted near forest edges and that the corn be planted further away from the forest edges that border the riparian forest, as these are preferred areas by this population of capuchins (Verderane 2010). Another solution mentioned by eight farmers would be to plant corn near the houses. However, the farmers also stated that repeated planting degrades the soil near the houses and forces residents to plant in areas that are further away and harder to monitor.

Although 25 interviewees said that the monkeys tie a knot on the husk to form a “handle,” put the ears on their back, or tie the ears to their tail to facilitate transport, we never observed these behaviors. These reports suggest that the capuchins catch the attention of the residents owing to their similarity with humans (Sabbatini *et al*. 2006) and are seen as animals that could do things that would be cognitively and/or morphologically impossible for them, such as tying a knot to make a “handle.” This type of perception is very widespread and common in other regions of Brazil as well (Fragaszy *et al.* 2004; Spagnoletti *pers. obs*.). Reports of monkeys foraging on ears of corn are very ancient in the New World. For instance, indigenous people in Venezuela described monkeys stealing corn and carrying one ear in their mouth, one ear in each hand, and one under each arm (Gumilla 1745 *apud* Cavalcante 2014).

Few studies in the Neotropics have evaluated the perceptions of small farmers who coexist in a sustainable low-conflict way with wildlife about the impact of these animals on their crops. The ethnoprimatological approach enabled us to investigate the perceptions of residents, quantify their losses to the crop most economically important to them, and determine the time of greatest consumption by the wildlife. Furthermore, the farmers’ knowledge and our interactions with them made this research possible. Without information they offered, and their collaboration, we would have been unable to plant the corn at the best time of the year and on their property. Similarly, contact with the farmers and sharing the results of this study with them are important to reinforce and promote a positive perception of wildlife. This increases local tolerance of the target species, which is an important component of any conservation strategy (Hill and Webber 2010).

Finally, the fact that the capuchins are not currently considered pests by most of the residents raises the probability that they are open to adopting conservation practices geared toward protecting the capuchins and their habitat, which is highly endangered due to the fast-paced growth of intensive agriculture. As pointed out by other authors (Hill and Webber 2010; McLennan and Hill 2012), long-term human–wildlife sympatry depends on the willingness and capacity of local people to coexist with wild animals. The current peaceful coexistence with, and tolerance of, the capuchins by local residents is potentially liable to change, due to changing economic circumstances. Therefore, we urge implementation of conservation actions before intensive agriculture destroys both the habitat of the monkeys and their peaceful coexistence with farmers.

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