Food Habits and Livestock Depredation of Sympatric Jaguars and Pumas in the Iguacu National Park Area, South Brazil

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ABSTRACT

Understanding coexistence between sympatric felines with similar body sizes, such as jaguars Panthera onca and pumas Puma concolor, requires knowledge of the way these predators consume and partition food resources. Yet the importance of livestock predation on jaguar and puma coexistence is poorly known. I investigated food habits and patterns of livestock depredation of jaguar and pumas in the Iguacu National Park (INP) in southern Brazil. From 1997 to 2001, I collected scats opportunistically on trails and roads in INP and visited ranches on the border of INP. I found that jaguars relied mostly on large and medium-sized wild prey species, while pumas concentrated on medium-sized prey species. Livestock was the fifth most frequent prey found in jaguar scats but the most important one in terms of biomass consumed. Jaguar and puma diets differed significantly when all prey items were compared and also when livestock was excluded from the jaguar diet. Jaguar predation on livestock was considerably higher than predation by pumas. However, predation was not substantial relative to availability of livestock, and cattle likely constitute an alternative source of prey for jaguars. Degree of diet overlap between jaguar and puma in INP suggests that coexistence was likely driven by exploitative competition through some degree of food partitioning. My results highlight the importance of more actions toward increasing numbers of large ungulates to preserve the population of jaguars in INP.


Key words: diet; Felidae; food partitioning; large carnivores; Panthera onca; Puma concolor; sympatry.

For sympatric large felids inhabiting tropical forests, the controversy over factors promoting population viability involves ecological and behavioral factors. When prey resources are abundant, ecological factors such as availability of appropriated-sized prey and habitat characteristics are of primary importance (Scognamillo et al. 2003). In contrast, when key resources are in decline, behavioral factors such as the ability to use human-disturbed areas and diet flexibility through the use of small prey may be more important in promoting coexistence (e.g., Bailey 1993, Ramakrishnan et al. 1999) and increasing dietary breadth of predators (Neale & Sacks 2001), thereby leading to likely increases in overlap.

Prey abundance and availability are vital in shaping interactions between similar large felines and can certainly alter patterns of coexistence (Iriarte et al. 1990, Ramakrishnan et al. 1999, Núñez et al. 2000). For large felines with similar body sizes such as jaguars Panthera onca L. and pumas Puma concolor L., coexistence may be the result of exploitive competition through some degree of food partitioning (Johnson et al. 1996) or use of different prey species (Taber et al. 1997, Núñez et al. 2000, Scognamillo et al. 2003). It follows that the larger jaguar should specialize on larger prey species (Gittleman 1985) and likely consumes a larger range of prey types than the smaller puma (e.g., see Rosenzweig 1966, Gittleman 1985). Indeed, some studies have shown that, in general, jaguars take larger wild prey, but have a narrower dietary breadth than pumas (Taber et al. 1997, Núñez et al. 2000, Scognamillo et al. 2003). However, few studies have examined how the availability of alternative sources of prey, such as livestock, might affect the interaction between jaguars and pumas (Polisar et al. 2003, Sconamillo et al. 2003). The last significant population of jaguars in southern Brazil is located inside a protected area, the Iguacu National Park (INP). Jaguars at INP have mainly faced the effects of direct persecution by humans through opportunistic killing and retaliation for livestock predation, since livestock are relatively abundant just outside of the park (Crawshaw 1995, Conforti & Azevedo 2003). Pumas are also present, but livestock predation by this species has been rarely documented in the area (Conforti & Azevedo 2003). In addition, direct competition from poachers eliminating some of the most important prey species of large carnivores has affected the local prey population. For instance, once reported as one of the most important large prey species for jaguars and pumas in INP (Crawshaw 1995), the white-lipped peccary Tayassu pecari has apparently disappeared from INP mostly because of illegal hunting (Conforti & Azevedo 2003). Under these circumstances, predator–livestock conflicts are expected to increase as cats expand their diet to include livestock as an alternative source of food (Schaller & Crawshaw 1980, Schaller 1983, Woodroffe 2001). In the present study, I investigated the food habits and patterns of livestock depredation of jaguars and pumas in INP. I was particularly interested in determining the size and range of prey classes used by the two predators and assessing the effect of livestock on their coexistence in INP.

METHODS

STUDY SITE.—Fieldwork was conducted in Iguacu National Park, southern Brazil (25°05′–41° S, 53°40′–54°38′ W), which covers 1852 km² of subtropical forest along the international boundary between Brazil and Argentina. In Argentina, the protected forest...
at Parque Nacional Iguazu joins INP, and the combined protected area covers about 2400 km² of subtropical forest separated by the Iguazu River. The landscape is comprised mostly of flat terrain, of elevation 100–300 m (Salamuni et al. 1999). Mean monthly temperatures range from 15°C to 26°C, and the climate is predominantly rainy without defined dry seasons, averaging 1712 mm of rainfall per year (Salamuni et al. 1999). The vegetation consists mainly of dense tropical semi-deciduous forest with some former clearings and regenerating forest left over from prior human settlement. Roads and trails are rare inside INP. The principal prey species of jaguars and pumas in INP included white-tipped (T. pecari) and collared (T. tajacu) peccary, red-brocket deer (Mazama americana), rufous-brocket deer (M. rufina), capybara (Hydrochaeris hydrochaeris), paca (Agouti paca), tapeti (Sylvilagus brasiliensis), coati (Nasua nasua), armadillo (Dasypus novemcinctus), opossum (Didelphis sp.), agouti (Dasyprocta azarae), and tegu-lizard (Tupinambis teguixin) (Crawshaw 1995). Prey density estimates for Iguazu are scanty. Estimates were only available for white-tipped peccaries (1.5 animals/km²; Crawshaw 1995) and collared peccaries (0.9 individuals/km²; Crawshaw 1995). Livestock were present in relatively large numbers along the edge of the Park (Azevedo & Conforti 1999).

Along the border of INP, livestock were raised in rudimentary farms, with no clear allotments, few fences, and no direct protection against predators (Azevedo & Conforti 1999). Fences or streams served as barriers separating INP from livestock grazing areas, and these barriers did not constitute obstacles to jaguars and pumas. In 2004, the 14 towns surrounding INP had a total population of 479,000 residents, with an average of 34,000 inhabitants per town. Subsistence economy through crop farming was the main activity in the region, with livestock ranching being a secondary source of food (MMA/IBAMA 2006).

LIVESTOCK HOLDINGS AND RANCH CHARACTERISTICS.—During 1997–2000, a total of 150 ranches from 14 towns on the border of INP were visited; a subsample of 85 ranches was selected for intensive study based on location and proximity to INP border. This selection provided a sample of farms immediately adjacent to INP, each having livestock present. Ranches were visited at least twice a month. During site visits to the ranches, I collected data on the amount and type of livestock, as well as the general measures of protection from predators (e.g., fences, clearings, etc.). Most ranches did not protect livestock in corrals during the night. To document predation events, I recorded cases of livestock attacked by predators. A survey of the species, gender, and age of depredated livestock was conducted. To minimize biased sampling, only livestock mortality events associated with actual carcass recovery were included in the data set (Mondolﬁ & Hoogesteijn 1986). Identification of predation on old carcasses was based on the presence of signs of bites or punctures on ribs, skulls, vertebrae, clavicles or other long bones. Identification of predation on wounded animals was based on bite marks and infected wounds that would be detectable for approximately 1 mo after the attack. In the case of claw marks left on wounded livestock, signs of an attack remained evident up to several years after the attack (Hoogesteijn & Mondolﬁ 1992).

DATA ANALYSIS.—I determined predator diet from scat content analysis. Scat collection occurred opportunistically on trails and roads in INP Park and its border (1997–2001). I identiﬁed predator species by their association with tracks close to the site of scat collection; scats deposited in sites where tracks were not found were excluded from the analysis (Emmons 1987, Núñez et al. 2000, Scognamiglio et al. 2003). I further calculated error rates for identiﬁcation of predator species based on the comparison between the presence of tracks associated with scats and predator hairs present in scats. I dried scats at 72°C for 24 h, separated contents under running water and collected fragments in a 600 µm sieve. I identiﬁed food contents to genus and species using hair, skull fragments, teeth, scales, and via comparison with reference material from INP. Note that among prey species identiﬁed as consumed by jaguars and pumas, I combined two species of deer (M. americana and M. rufina) averaging species weight as a single prey item.

To quantify and compare diet between species, I determined the frequency of occurrence of food items by calculating the percent of scats containing each food item (Kitchen et al. 1999, Sovada et al. 2001). Chi-square with Fisher’s exact tests served to compare frequency of occurrence of food items between predator species. When multiple items were recovered from a single scat, I calculated the relative frequency of each food item as the number of times a speciﬁc item was found as a percentage of all items identiﬁed (Ackerman et al. 1984, Hidalgo-Mihart et al. 2001, Neale & Sacks 2001). To evaluate the inﬂuence of sample size on the results of scat analysis, I chose four scats randomly, analyzed food contents, and then included five additional scats. I continued this procedure until all scats were included in the analysis. I then assessed the cumulative frequency of occurrence of the most common prey items (relative frequency of occurrence ≥ 5%) to infer the effect of sample size on the ﬁnal dietary results (Biswas & Sankar 2002).

Although frequency of occurrence has been widely used to quantify carnivore diet, this measure can inadequately overestimate the presence of small prey (Ackerman et al. 1984) and underestimate the presence of large mammalian prey (Weaver 1993). To account for variation in prey sizes and minimize sampling bias, I also estimated relative biomass consumed by converting estimates of relative biomass and relative number of prey consumed through the use of a correction algorithm: $Y = 1.98 + 0.035 X$ given by Ackerman et al. (1984) for puma, where $Y$ is the weight of prey consumed per scat and $X$ is the live weight of the prey. To analyze temporal patterns of jaguar or puma diet change and compare results to previous work in the same area (see Crawshaw 1995), I calculated the mean weight of vertebrate prey (MWVP) in jaguar and puma diets as described in Iriarte et al. (1990). Prey live weight estimates were based on published references (Ackerman et al. 1984; Robinson & Redford 1986; Emmons 1987, 1990; Crawshaw 1995). To classify prey biomass consumed by each predator species, I divided prey in three size categories according to their mean adult mass (e.g., see Iriarte et al. 1990). The three major groups were: small prey ≤ 1 kg; medium = 1–15 kg; and large ≥ 15 kg.

I calculated measures of niche breadth (Levins 1968) using the relative frequency of occurrence of food items (where $B = \frac{1}{\sum p^2}$, where $B =$ Levin’s measure of niche breadth; $p_j =$ fraction of items in...
the diet that are of food category j, and standardized dietary breadth on a scale from 0 to 1.0 using Hulbert’s measure (1978): $B_A = (B - 1)/(n - 1)$, where $B_A$ = Levin’s standardized niche breadth; $B$ = Levin’s measure of niche breadth; $n$ = Number of possible resource states (see Krebs 1999). This approach enabled me to assess the extent to which carnivore-specific food selection patterns focused on particular food categories. I used the Renkonnen index

$$P_{jk} = \left[ \frac{\sum_{i=1}^{n} \min(p_{ij}, p_{ik})}{n^2} \right],$$

where $P$ = percentage overlap between sample $j$ and $k$; $p_{ij}$ = proportion of resource $i$ is of the total resources utilized by species $j$; $p_{ik}$ = proportion of resource $i$ is of the total resources utilized by species $k$; $n$ = total number of resources used to examine overlap in resource use between the two predator species (see Krebs 1999).

I examined patterns of livestock predation by regressing number of predation events against livestock numbers per farm. I performed a Chi-square goodness-of-fit tests to investigate whether the recorded frequency of predation on different livestock species deviated significantly from the expected. Expected numbers of livestock were based on the availability of domestic prey species within visited ranches. I calculated predation detection rates by comparing the total number of confirmed predation incidents to the total number of visits to all ranches during the period of study.

RESULTS

DIETARY ANALYSIS.—I identified a total of 75 different prey items (mean per scat: 1.43 ± 0.70 SD, $N = 51$) from 12 taxa for jaguar and a total of 62 different prey items (mean per scat: 1.15 ± 0.36, $N = 54$) from 13 taxa for puma. Error rates for identification of predator species were 12 percent for jaguar (6 samples) and 20 percent for puma (11 samples). These samples were previously identified based on close association with one predator species tracks but later found to contain hairs of the other predator species. Thirty-two jaguar scats (63%) had a single prey item, while 19 scats (27%) had two or more prey items. Forty-six puma scats (85%) had a single prey item, while only eight scats (15%) had two or more prey items. After successive draws of five scats from the total sample size, I found that the proportion of different prey species in scats tends to stabilize once a sample of 50 scats were analyzed in both predator species (Fig. 1). The only exceptions pertained to the relative contribution of tegu-lizard in jaguar diets and small rodents in puma diets. I therefore considered my sample size sufficient for the dietary analysis described herein, but suggest an increase in sample sizes to better understand how consumption of these two prey items would affect diets of jaguars and pumas in INP.

The most important wild prey species for jaguars in order of relative biomass consumed were collared-peccary, coati, and deer; combined these species comprised 66.7 percent of the biomass consumed. Overall, jaguar relied mostly on large prey species (Table 1) which comprised 41.2 percent of prey items and 50.0 percent of the biomass consumed when livestock was not included. Medium-sized prey species comprised 54.4 percent of prey items and 49.5 percent of the biomass consumed. The remaining 4.4 percent of prey items and 0.5 percent of the biomass consumed were comprised of small prey species. Pumas relied mostly on medium prey species, which comprised 58.0 percent of prey items and 55.4 percent of the biomass consumed. Large prey species comprised 32.2 percent of prey items and 44.0 percent of the biomass consumed, while small prey comprised 9.7 percent of prey items and only 0.8 percent of the biomass consumed. The most important wild prey species for pumas were deer, agouti, and paca, contributing 55.2 percent of the biomass consumed (Table 2). When livestock was included in the analysis, large prey species comprised 46.6 percent of prey items and 63.1 percent of the biomass consumed by jaguars. Livestock was the fifth most frequent prey found in jaguar scats but the most important one in terms of biomass among all prey species, comprising 26.2 percent of all biomass consumed. No livestock was found in puma scats.

FIGURE 1. Effect of sample size on the frequency of occurrence of most important prey species (frequency of occurrence ≥ 5%) in jaguar (a) and puma (b) scats in INP between 1997 and 2001.
### TABLE 1. Relative biomass of prey consumed by jaguars based on 51 scats collected at Iguacu National Park, Brazil, 1997–2001.

<table>
<thead>
<tr>
<th>Prey species</th>
<th>Frequency of occurrence (%) with livestock</th>
<th>Frequency of occurrence (%) without livestock</th>
<th>Prey weight (kg)</th>
<th>Correction factor</th>
<th>Relative biomass consumed (%) with livestock</th>
<th>Relative biomass consumed (%) without livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tayassu tajacu</em></td>
<td>35.3</td>
<td>24.0</td>
<td>26.5</td>
<td>25.0</td>
<td>2.9</td>
<td>23.7</td>
</tr>
<tr>
<td><em>Mazama sp.</em></td>
<td>17.6</td>
<td>12.0</td>
<td>13.2</td>
<td>22.5</td>
<td>2.8</td>
<td>11.5</td>
</tr>
<tr>
<td><em>Hydrochaeris hydrochaeris</em></td>
<td>2.0</td>
<td>1.3</td>
<td>1.5</td>
<td>45.0</td>
<td>3.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Livestock</td>
<td>13.7</td>
<td>9.3</td>
<td>0.0</td>
<td>175.0</td>
<td>8.1</td>
<td>26.2</td>
</tr>
</tbody>
</table>

### TABLE 2. Relative biomass of prey consumed by pumas based on 54 scats collected at Iguacu National Park, Brazil, 1997–2001.

<table>
<thead>
<tr>
<th>Prey species</th>
<th>Frequency of occurrence (%) with livestock</th>
<th>Frequency of occurrence (%) without livestock</th>
<th>Prey weight (kg)</th>
<th>Correction factor</th>
<th>Relative biomass consumed (%) with livestock</th>
<th>Relative biomass consumed (%) without livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tayassu tajacu</em></td>
<td>7.4</td>
<td>6.4</td>
<td>25.0</td>
<td>2.9</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td><em>Mazama sp.</em></td>
<td>18.5</td>
<td>16.1</td>
<td>22.5</td>
<td>2.8</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td><em>Hydrochaeris hydrochaeris</em></td>
<td>9.3</td>
<td>8.1</td>
<td>45.0</td>
<td>3.6</td>
<td>12.9</td>
<td></td>
</tr>
<tr>
<td><em>Caiman latirostris</em></td>
<td>1.8</td>
<td>1.6</td>
<td>60.0</td>
<td>4.1</td>
<td>2.9</td>
<td></td>
</tr>
</tbody>
</table>

Jaguar standardized niche breadth was 0.41 with seven prey items identified as frequently consumed (relative frequency of consumption ≥ 5%). The MWVP for jaguars was 9.19 kg. When livestock was excluded from the analysis, MWVP was reduced to 8.89 kg and width of niche breadth was 0.35. Standardized niche breadth for puma was broader than for the jaguar, 0.47. The number of prey items frequently consumed by pumas (eight) was slightly higher than by jaguars. However, the MWVP consumed was lower than for jaguar (8.64 kg), even when only wild prey species were included.
Jaguar and puma diets differed significantly when compared including all prey items ($\chi^2 = 35.0$, df = 15, $P = 0.002$) and also when livestock was excluded from the jaguar diet ($\chi^2 = 28.7$, df = 14, $P = 0.011$). Among wild prey consumed by both predators, the main difference was the higher consumption of collared peccaries by jaguars ($\chi^2 = 8.9$, df = 1, $P = 0.003$). No remains of white-lipped peccaries were found in any predator scats during the whole course of this study. We found high dietary overlap between jaguar and puma. The Renkonnen index for overlap in diet including livestock was 55.9 percent, indicating substantial overlap between predators.

**LIVESTOCK DEPREDATION.**—The total area occupied by sampled ranches was 155.2 km$^2$ (mean: 1.8 ± 3.0; range: 0.03–15.7 km$^2$). The majority of ranches (61.2%) comprised < 1 km$^2$. All ranches had cattle, whereas fewer had horses (24.7%), pigs (23.5%) sheep (16.5%), and goats (3.5%). When grouped into categories, the majority of the ranches (52.9%) had ≤ 50 head. The mean number of livestock animals per ranch was 217.9 ± 396.6 and ranged between three and 2000 head. I visited ranches an average of 2.6 ± 2.1 times per month during the study. My detection rate for the period of study was of one predation incident confirmed to 149 possibilities of finding an event of predation through visits to ranches. Of 85 ranches visited during 1997–2000, I recorded livestock attacks in all 4 yr on only 20 ranches (23.5%). I recorded 60 animals attacked during the study, which comprised 0.3 percent of the total livestock holdings on the sampled ranches. Of the 60 incidents, 81.6 percent ($N = 49$) resulted in livestock mortality whereas the remains were wounded.

Jaguar predation on livestock (95.0%; $N = 57$) was considerably higher than puma predation ($\chi^2 = 48.60$, df = 1, $N = 60$, $P < 0.001$). Pumas were responsible for the killings of only a few medium-sized livestock species, such as sheep (5% of all livestock attacks; $N = 3$) and did not attack cattle. The number of jaguar attacks on livestock was not based on livestock density since the number of livestock losses due to predation did not increase as densities of livestock increased by ranch ($R^2 = 0.114, P = 0.299$). There were significant differences in number of attacks per year during the period of the study ($\chi^2 = 21.5$; df = 3; $N = 60$; $P < 0.01$). The greatest numbers of attacks were recorded in 1998 and 1999 ($N = 29$ and $N = 16$, respectively), which comprised the same period during which livestock was found in jaguar scats.

**DISCUSSION**

**DIETARY BEHAVIOR.**—Although jaguars and pumas consumed similar numbers of prey species, 12 and 13, respectively, I found that jaguars had a narrower dietary breadth than pumas. This result indicates that jaguars were preying more heavily on certain prey species while pumas were taking prey in more similar proportions. Large and medium-sized prey species comprised the bulk of jaguar diet, while medium prey species comprised the majority of prey consumed by pumas. Similar dietary patterns showing narrower dietary breadth and higher use of larger prey species by jaguars were found in other regions of South America where jaguars and pumas are sympatric (Taber et al. 1997, Núñez et al. 2000, Scognamillo et al. 2003). However, my results contrast with dietary behavior of sympatric jaguars and pumas showing similar preferences toward prey species in areas where the prey base is subjected to several levels of hunting pressure (Núñez et al. 2000, Novack et al. 2005).

The MWVP for jaguars at INP was among the lowest reported for most Neotropical sites (Rabinowitz & Nottingham 1986, Hoogesteijn et al. 1993, Taber et al. 1997, Núñez et al. 2000, Scognamillo et al. 2003). The MWVP for jaguars also declined temporarily. From 1990 to 1995, when peccaries were more abundant in INP, MWVP for jaguars was considerably higher, 14.4, even without the inclusion of cattle (Crawshaw 1995). Reduction in the MWVP for jaguar in INP reflects the importance of medium prey items, such as coati, tegu-lizard, and agouti (Novack et al. 2005). Jaguars seemed to adapt their feeding behavior to prey on more likely available prey items, thus supporting the pattern of opportunistic hunting to optimize foraging (Rabinowitz & Nottingham 1986).

Conversely, MWVP for pumas in INP was similar to that reported for other sites where pumas occur in sympathy with jaguars (Novack et al. 2005). Although no comprehensive dietary analysis has been conducted for puma in INP prior to my study, previous data indicated that the MWVP for pumas (10.8 kg) was lower than for jaguars, and peccaries and deer comprised the bulk of biomass consumed (Crawshaw 1995). Therefore, it seems that apparent recent changes in prey availability did not affect puma dietary behavior. During my study, pumas concentrated their feeding on medium prey items and seemed to use large mammals other than peccaries, such as deer and capybara, to complement their diet. The preference for deer has been widely recorded throughout most of the puma’s range (Friarte et al. 1990). However, in regions of sympathy with jaguars, pumas seem to rely more heavily on medium size prey species such as agouti, paca, and coati (Novack et al. 2005), thus alleviating overall levels of competition with jaguars. The similarity in the consumption of medium-sized prey species by jaguar and puma in INP might result from the decline of primary food sources for jaguar, such as peccaries, thus increasing dietary breadth and therefore overlap between these two sympatric predators (Neale & Sacks 2001). The homogeneity of the landscape in INP and the degree of diet overlap suggest that coexistence between these two predators is likely driven by exploitative competition through some degree of food partitioning (Johnson et al. 1996, Scognanillo et al. 2003, Novack et al. 2005).

Despite the length of my study (ca 5 yr), I was able to collect a limited number of scats from jaguar and puma in INP. Difficulties in finding jaguar and puma scats were also apparent in a previous study in the area. During 5 yr of research on the ecology of jaguars in INP, Crawshaw (1995) was able to analyze 73 scats from jaguars and only 28 from pumas. The low number of trails and roads, the denseness of the forest, and the high average temperatures and humidity in INP may have limited my ability to find more samples during the study.
**LIVESTOCK DEPREDATION.**—For some species of large felines, the lack of available habitat and increasing population densities may drive or keep some individuals of a population outside of protected areas (Stander 1990, Saberwal et al. 1994). In INP, however, empty adult home ranges inside the Park were occupied by young male jaguars, indicating vacant territories of available habitat and a likely stable or declining trend in population numbers (Crawshaw 1995). In addition, the lack of suitable habitat and a consistent prey base outside of the Park make habitat available for jaguars only within INP limits. However, my results indicated that, in addition to a significant reduction of consumption of peccaries by jaguar and puma from 1997 to 2001 compared to consumption from 1990 to 1995 (Crawshaw 1995), cattle became important in terms of biomass consumed by jaguars. Therefore, jaguar movement toward the outside of INP and hence predation on livestock seemed to reflect a temporal absence of available food within INP.

Predation on livestock may be substantial when availability or diversity of large wild ungulates is low, which might provoke a shift toward the use of domestic rather than wild ungulates (Meriggi & Lovari 1996, Stahl et al. 2001). Under these circumstances, I would expect livestock predation by jaguars to be established as a common pattern on the borders of INP. I found, however, that livestock depredation was not substantial based on the availability of livestock. Even though ranches had no direct protection against predators, results of this study show low numbers of domestic animals attacked relative to the total livestock holdings in the INP region. Moreover, the impact of jaguars on livestock was not heavier on ranches with higher density of livestock. Most herbivores were not affected by predation and those that were, suffered only sporadic attacks. If only mortality of cattle is considered (0.26%), my results were lower than estimates of annual predation on cattle ranches in the Pantanal region of Brazil (0.84% of the total livestock holdings; Dalponte 2002), in Venezuela (1.3% and 3.5% of the total livestock holdings; Hoogesteijn et al. 1993), and in other tropical areas (Madhusudan 2003, Patterson et al. 2004). The small number of attacks for the extent of the study (1997–2000) limited the analyses of the effect of some variables that might have had influence on livestock predation patterns, such as rainfall regime or calving period (Michalski et al. 2006).

In my study, I found a concentration of predation incidents in 2 yr surveyed (1998 and 1999). In addition, the fact that only jaguars and not pumas were a real threat to livestock likely reflected the lack of enough large wild prey species for jaguars in INP. This predation pattern suggests that, as opportunistic feeders, jaguars may have adapted their land-tenure system and behavior to suit local circumstances, using alternative sources of prey such as domestic stock (Schaller & Crawshaw 1980, Quigley & Crawshaw 1992, Polisar et al. 2003, Patterson et al. 2004). In contrast, it seems that the wild prey base in INP was sufficient for pumas and that this smaller predator had no need to use alternative prey species such as domestic stock.

Most conservation strategies for protection of large carnivores have focused on the establishment of wildlife reserves or sanctuaries to preserve intact habitat and avoid illegal hunting of predator species (Rabinowitz & Nottingham 1986, Quigley & Crawshaw 1992, Woodroffe 2001). At INP, predation incidents on livestock on neighboring ranches have threatened the conservation of jaguars because of retaliation actions from ranchers (Conforti & Azevedo 2003). It appears that habitat protection and control of illegal hunting of predators are not necessarily sufficient conservation actions to ensure persistence of jaguars in INP. Increasing numbers of large wild ungulates and the establishment of management actions to mitigate jaguar–cattle conflicts might be essential to preserve the population of jaguars in INP. Moreover, studies focusing on the spatial distribution and dietary patterns of jaguars and pumas should be conducted concurrently with a monitoring of prey abundance if we want to fully understand the coexistence of predators and predator responses to changes in prey abundance in the protected area of INP.

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**LITERATURE CITED**


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