THE SPECTACLED BEAR'S IMPACT ON LIVESTOCK AND CROPS AND USE OF REMNANT FOREST FRUIT TREES IN A HUMAN-ALTERED LANDSCAPE IN ECUADOR

By

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ABSTRACT

Human alteration of spectacled bear (*Tremarctos ornatus*) habitat has led to mutual conflict between bears and humans. There have been very few studies of spectacled bear conflict to date, but a better understanding of the conflict is urgently needed due to the negative impacts on people and severe consequences for bears. Extensive land use systems for agriculture and livestock reduce important food sources for spectacled bears. Bears have been found foraging in forest fruit trees that still remain in fields and pastures after forest has been cleared. Conversion of natural habitat for agriculture also provides new potential food sources in the form of crops and livestock. Spectacled bears raid cornfields and attack livestock, which have negative economic impacts for rural farmers. As a result of this conflict, farmers often turn to an indiscriminate hunting of spectacled bears in an effort to safeguard their livestock. This thesis examines the spectacled bear's use of remnant forest fruit trees in fields and pastures and its impact on livestock and crops in rural agricultural communities around the Antisana Ecological Reserve in northeastern Ecuador.

Chapter 1 looks at the spectacled bear's use of remnant forest fruit trees outside contiguous forest on eight selected farms. Tree characteristics are compared between climbed trees and a subset of unclimbed trees for three species that are known to be a part of the spectacled bear's diet. The probability of a tree being climbed is hypothesized to be influenced positively by canopy area and negatively by distance to forest. Results show that canopy area and the interaction term between canopy area and distance to forest are significant model variables, when all three species are analyzed together. Distance to forest significantly contributes to the model and explains the difference for *Nectandra*

membranacea, a member of the Lauraceae family. *N. membranacea* is preferred by the spectacled bear in fields and pastures in the study area. The tree's lipid-rich fruits, limited upper distribution in Ecuador, and the reduction of this fruit source due to deforestation in the study area are possible explanations for the preference and use of *N. membranacea* in fields and pastures.

Chapter 2 examines the spectacled bear's impact on the livestock and crops in the communities around the Antisana Ecological Reserve and includes an economic assessment of this damage. Prior to April 2000, bear attacks on cattle were unknown in this area of Ecuador. In the period from April 2000 to April 2001, 31 cows were reported to have been killed or wounded by bears. The chapter also explores the negative consequences of the conflict, specifically in terms of illegal hunting of spectacled bears. Data are collected on farms affected and unaffected by livestock depredation. Crop raiding by the spectacled bear is quantified on eight farms. Analysis of the economic impact of crop raiding and livestock depredation shows a much greater economic loss for livestock attacks (an average of $0.67 for crop damage per farm compared to $755.56 for livestock damage per farm for the period of the recent livestock attacks). As a result of the conflict, there are reports of 11 bears killed in the study area in a period of 13 months. Comparison of farm-level characteristics of affected and unaffected farms reveals a significant difference in cattle location (adjacent or not adjacent to forest edge) and cattle carcass removal practices. The presence of livestock carcasses may draw bears to pastures where they first consume livestock as carrion and subsequently change their behavior to active depredation. Changes in farm management practices to reduce future conflict with spectacled bears, such as the restriction of cattle access to the forest edge and the removal or interment of carcasses, are discussed.

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CHAPTER 1:

THE SPECTACLED BEAR'S (*TREMARCTOS ORNATUS*) USE OF REMNANT FOREST FRUIT TREES IN A HUMAN-ALTERED LANDSCAPE AROUND ANTISANA ECOLOGICAL RESERVE, ECUADOR

ABSTRACT

Seasonal fruits are an important dietary component for many species of bear, including the endangered spectacled bear (*Tremarctos ornatus*). Forest clearing for agriculture and livestock is replacing some of the best fruit sources for the spectacled bear and may force bears to forage in cornfields and in pastures where they feed in remnant forest fruit trees and where they may prey on livestock. We investigated the spectacled bear's use of remnant forest fruit trees on eight farms located around the Antisana Ecological Reserve in northeastern Ecuador. Three tree species (*Nectandra membranacea* [Lauraceae], *Cecropia andina* [Cecropiaceae], and *Hyeronima macrocarpa* [Euphorbiaceae]) were identified as having been climbed by spectacled bears in cornfields and/or pastures. Eight farms were surveyed for climbed and unclimbed trees of these three species. Data on DBH, canopy area, tree height, slope, altitude, and GPS location were recorded for all climbed trees and a subset of unclimbed trees. Transects were completed in forests above four of the eight farms. The same suite of data was collected for the three tree species located in forest transects. Logistic regression was used to assess the probability of a climbed tree in fields and/or pastures, given the explanatory variables of canopy area, distance to forest, and their interaction term. Results showed that canopy area ($P = 0.019$) and the interaction term between canopy area and distance to forest ($P = 0.0828$) were significant model variables, when analyzing all three species together. When *N. membranacea* was considered alone, distance to forest ($P =$

0.0005) was the only variable that significantly contributed to the model. For *C. andina* alone, canopy area was the only significant model variable ($P = 0.0920$). There were no significant variables for *H. macrocarpa*. Comparing forest and field trees with a Mann-Whitney test did not reveal a significant difference in canopy area to basal area ratio for *N. membranacea* or *H. macrocarpa*. There was a significant difference in the ratio of canopy area to basal area for *C. andina*, but the mean ratio for forest trees was larger than the mean ratio for field trees, contrary to what was expected. Preference for *N. membranacea* in cornfields and/or pastures was revealed by a Fisher's Exact test. The overlap between high human activity, recently deforested areas for agriculture and livestock, and the limited upper distribution of this lipid-rich fruit may account for the preference and use of *N. membranacea* in the study area and highlights a potential conservation concern for the spectacled bear.

INTRODUCTION

We investigated the spectacled bear's (*Tremarctos ornatus*) use of remnant forest fruit trees on farms located around the Antisana Ecological Reserve in northeastern Ecuador. Spectacled bears are known to consume the fruits of over 30 species of trees (Peyton 1980), most of which are available seasonally and occur in a narrow band of cloud forest around 2000 m altitude (Peyton 1988). Listed as vulnerable to extinction (IUCN 1996), the major threats to the spectacled bear in the five Andean countries it inhabits are perceived as hunting, illegal trade in bear parts, and the accelerated pace of habitat conversion to agriculture (Peyton 1999). Agriculture and livestock, in particular, are replacing some of the best fruit sources for the spectacled bear (Peyton 1988). Bears increasingly forage in cornfields and in pastures where they feed in remnant fruit trees and where they may prey on livestock (this study; Peyton 1987b, 1988).

Although spectacled bears are omnivores whose diet includes bromeliads, orchids, palms, bamboo, insects, rodents, birds, livestock, and carrion (Peyton 1999), seasonal fruits are an important dietary component as for many bear species. North American grizzly and black bear populations rely on summer and fall fruit to provide energy reserves in preparation for reproduction and winter hibernation (Welch *et al.* 1997 and references therein). Recent studies on the sloth bear (Joshi *et al.* 1997) and the sun bear (McConkey and Galetti 1999) also reveal a seasonal increase in fruit consumption. The spectacled bear is not an exception. As one of the most arboreal and herbivorous species of bear, spectacled bears require access to fruit trees for several reasons. In periods of fruit ripening, presumed mating pairs have been spotted together. Females may not gain enough weight to sustain the high energy

demands of pregnancy and lactation without a reliable source of fruit. Additionally, wild births are timed so that cubs are old enough to feed on ripe fruit (Peyton 1988, 1999).

Optimal foraging theory suggests that individuals should choose the most profitable foods or fruits thus maximizing the long-term net rate of energy gain. Studies of dietary selectivity of non-human primates and avian frugivores have often examined the question as an optimal foraging problem. Studies increasingly emphasize that food/fruit selection is a complex process based on an array of interacting morphological and spatial features of food/fruit and also on the morphology and physiological needs and capabilities of each species (Moermond *et al.* 1987, Lepczyk *et al.* 2000). Avian fruit preferences have been related to caloric content (Sorensen 1984, Johnson *et al.* 1985, McPherson 1987), concentration of major nutrients (Denslow 1987, Levey 1987, Jung 1992), fruit size (Paszkowski 1982), accessibility (Denslow and Moermond 1982, Moermond and Denslow 1983, Moermond and Denslow 1985), digestibility (Levey and Karasov 1989, Martínez del Rio and Karasov 1990), and abundance/crop size (Snow 1971, Howe and Estabrook 1977, Murray 1987, Sallabanks 1992). Non-human primate food selectivity has been related positively to chemical variables such as protein, and negatively to chemical variables such as fiber and tannin content of seeds and leaves, and to spatial distribution variables such as patch size (Leighton 1992 and references therein). Leighton's research on orangutans in Borneo suggested caution in interpreting univariate analyses of non-human primate food selectivity, and emphasized the importance of multivariate analysis and the incorporation of spatial variables that may affect fruit selectivity.

The consumption of fatty foods by polar bears and the preference for high-lipid fruits among frugivorous birds provide further evidence that animals may seek to maximize the

long-term net rate of energy gain by consuming these high-energy foods. Compared to carbohydrates or proteins, lipids yield approximately twice the amount of energy on catabolism (Paine 1971), thus providing twice the energy per ingested food mass (Stiles 1993). A study of digestive and metabolic efficiencies of bears suggested that bears could maximize energy intake by choosing diets with the greatest fat content (Pritchard and Robbins 1990). Indeed, polar bears have been observed eating the fat of seals (Stirling and McEwan 1975).

In the tropical Andes, spectacled bears may choose high-lipid fruits to maximize energy intake. Even though studies are lacking on this topic for spectacled bears, there are studies of tropical bird fruit selection that reveal a reliance on high-lipid fruits. These studies also contain analyses of the nutritional value of fruits, including the values of fruits within the families and genera eaten by the spectacled bear. For example, the Lauraceae family of plants is known to have mostly high-lipid species, and analysis of many *Ocotea* and *Nectandra* species, as exemplified by avocado, have yielded high-lipid contents (Stiles 1993). A dependence on lipid-rich fruits of the Lauraceae is demonstrated in a study of quetzals in Costa Rica (Wheelright 1983). While quetzals may ingest over 41 species of fruit on an annual basis, including low-lipid species, they depend on the lipid-rich fruits of 18 species of Lauraceae. Furthermore, the fruiting phenologies of these species appear to signal the timing and direction of quetzal seasonal movements.

Thus, when we observed that spectacled bears foraged in remnant fruit trees, we hypothesized that high-lipid fruit and crop size could explain fruit selection. We present data on the use of remnant forest fruit trees outside of contiguous forested areas on eight farms around Antisana Ecological Reserve, Ecuador. First, we determine if the spectacled bear

showed a preference for a particular tree species. The importance of laurel trees (Lauraceae) trees is highlighted here. We then compare the characteristics of climbed trees with unclimbed trees. Using canopy area as an estimator of crop size, we hypothesized that trees with a larger canopy area would be more likely to be climbed. Additionally, Peyton (1987b) found that spectacled bears stay closer to hiding cover in areas with human activity than in areas without human presence; so, we hypothesized that distance from the forest edge to a fruit tree would negatively influence the probability that a tree would be climbed. Lastly, we take data on trees collected from transects in the forest and compare characteristics of field trees with forest trees. A mechanistic approach to the study, which allows for an examination of possible causal factors, also allows us to explain the results in light of current conservation problems, concerning the spectacled bear and important seasonal fruit resources.

STUDY AREA

The study was conducted from June 24, 2000 to August 11, 2000 and from February 1, 2001 to April 25, 2001 in two agricultural communities that are located outside the Antisana Ecological Reserve on the northeastern slopes of the Andes in Ecuador, Napo Province (0.63S 77.92W). The two study areas were in the communities of Santa Lucia de Bermejo and Las Palmas, which are located from 2000 – 2300 m altitude. The communities are found between the small towns of Baeza and Cosanga, which are points that can be accessed from the main highway that links the capital city of Quito to the city of Tena in the southeastern part of the country (Figure 1.1). The region of Baeza-Cosanga forms part of the Rio Cosanga Watershed. This mountainous region has a total area of 22,290 hectares and ranges in altitude from 1000 - 3600 m. Eighty-seven percent of the watershed is composed of disturbed vegetation, including 30% of the total area as pasture. Natural vegetation occupies 13% of the total area. Cloud forest occurs at an altitudinal range of approximately 2000 – 2900 m (Proyecto PLAN-Ecuador 2000). The average annual precipitation is 3,028 mm. The average temperature is 5 degrees Celsius, with strong daily and hourly fluctuations.

FIGURE 1.1. Map of the eastern portion of Ecuador, showing the three protected areas surrounding Baeza. Cosanga is located approximately 15 km south of Baeza.

The human population in the study area consists mainly of new colonists who settled in the area in the 1970s after the construction of the modern highway. The majority of families depend on livestock as their most important economic activity (Proyecto PLAN-Ecuador 1998). Forest continues to be cleared to establish more pastures for livestock and agricultural production. Although most deforestation took place in the 1970s, when families first established livestock activities in the zone, some families continue to cut small areas of forest on a yearly basis. Currently, the properties in the two communities average 57 ha in

size (28 – 85 ha) and contain an average of 30.72 ha (6.75 – 61 ha) in pastures/fields and an average of 26 ha (8 – 39.5 ha) still in unconverted forest, most of which is secondary forest. When forest is cleared, selected trees are left standing to create shade for livestock, construct fences in the future, and prevent erosion. Commercially valuable trees, like *Nectandra membranacea*, are left to harvest and sell in the future. On particularly steep inclines, small patches of vegetation may be left uncut. Spectacled bears forage in remnant trees in this matrix of cornfields, pastures, and small patches of vegetation (Plate 1.1).

PLATE 1.1. Remnant trees in a field in Las Palmas, Ecuador.

METHODS

Eight properties were selected in the two communities: four in Santa Lucia de Bermejo and four in Las Palmas. The properties were selected based on the presence of cornfields and then were selected randomly from within that group. This was done to facilitate the collection of data on crop raiding by the spectacled bear, which was a study being conducted concurrently.

During preliminary field work in August 2000, three species of trees were identified as having been climbed by the spectacled bear in cornfields and/or pastures and were identified locally or in other studies as being a part of the spectacled bear's diet: *Nectandra membranacea* (Lauraceae), locally called Chisinco; *Cecropia andina* (Cecropiaceae), locally called Guarumo; and *Hyeronima macrocarpa* (Euphorbiaceae), locally called Motilón. Samples were collected and identified at the National Herbarium in Ecuador.

The three tree species made up approximately 50% of all trees found in fields and pastures on the eight selected properties. Climbed trees were identified as such if bear claw marks extended up into the tree canopy. Age of claw marks was roughly estimated based on general appearance, and trees up to and including an estimated age of five years were included in the data set. Twenty-nine of the 35 climbed trees (83%) were estimated to have been climbed in the previous two years. Dates of forest clearing were gathered from farm owners to verify that climbed trees were indeed located outside the forest boundary at the estimated time of climbing.

A complete survey of the three tree species was conducted on all eight properties. For every tree that had been climbed by the spectacled bear, the location was recorded in UTM coordinates using a hand-held GPS unit. The species of tree, altitude, diameter at

breast height (DBH), height of tree, slope, and canopy area were also recorded. Canopy area was measured using a metric tape measure, recording the horizontal length and width (major and minor axes) of the canopy from below and then calculating area based on the formula for the area of an ellipse: πab, where a is the radius of the major axis and b is the radius of the minor axis. GPS data points on tree locations were imported into an established GIS database of land use/cover. Distance from a tree to a continuous forest edge was calculated in ArcView, using the GIS maps generated by Alianza Jatun Sacha - CDC.

The thematic maps on land use/cover were created by Alianza Jatun Sacha - CDC, Ecuador in 1997 (scale 1:50,000) based on a morphopedalogical map of Napo Province (scale 1:500,000) published by PRONAREG-MAG and on 10 aerial photographs from August 1993 (scale 1:60,000). A multitemporal study was completed by Alianza Jatun Sacha - CDC in November 2001, in which an updated map of vegetation cover was completed based on recent satellite images (Landsat 1999,2000). The study included an analysis of the change in vegetation cover and highlighted the areas in which deforestation has taken place over the course of the last four years (1997-2001). This is a unique study in that it is the first analysis of deforestation available for the study area.

All eight farm properties were also surveyed for unclimbed trees of the three fruit tree species (*N. membranacea, C. andina, and H. macrocarpa*). Each unclimbed tree was marked, assigned a number, and then five were randomly chosen on each property. The same data that were collected for climbed trees were also collected for the subset of unclimbed trees (GPS location, species, altitude, DBH, tree height, slope, and canopy area).

Finally, transects were established 50 m beyond the last area of productive farmland (cornfields or livestock pastures). Two transects were completed in Santa Lucia de Bermejo

and two in Las Palmas. Each transect was 250 m long and 4 m wide. A total area of 4000 m^2 (0.1 ha) was covered. Each of the three species of trees that were recorded in fields and pastures were also recorded along each of the transects. Information on species, DBH, tree height, slope, and canopy area was noted.

Spectacled bears use trees for a variety of purposes, including feeding, vigilance (especially in cornfields when bears raid crops), and intraspecific communication. Care was taken to distinguish between climbed trees for possible fruit consumption and use of trees for other reasons as described below; however, we acknowledge the possibility that all climbed fruit trees included in the data set may not have been climbed for fruit consumption. Trees with claw marks that were not climbed were easy to distinguish because claw marks did not extend into the canopy and were eliminated from the data set. Spectacled bears feeding on fruits in trees often construct tree nests by breaking in branches to reach fruits that are located on branches too small to support a bear's weight (Plate 1.2). After breaking in the branches and eating the fruit, the bear will sit on top of this constructed platform of branches and continue the feeding process.

PLATE 1.2. Spectacled bear tree nest in *N. membranacea,* Las Palmas, Ecuador.

The presence of tree nests was a factor used to determine the difference between trees that were climbed to eat fruit and those that were climbed for other purposes. Goldstein (1991) found that 18 out of 26 tree nests were associated with cattle feeding. In this study, livestock depredation did not take place in any of the pastures or fields on the eight properties surveyed for climbed fruit trees. Furthermore, corn is an attractant for spectacled bears, but the period of fruit abundance does not correspond with the temporal availability of ripe corn. For example, L.G. observed a spectacled bear foraging in *Nectandra membranacea* in a recently planted cornfield in the month of July, a month in which fruit is available but ripe corn clearly is not. Therefore, we interpret the results from a fruit foraging perspective.

Data were analyzed using SAS (1999) statistical software. A Fisher's Exact test, for cross-classified data with a small sample size, was performed to determine if a preference existed for a particular species of fruit tree. The relation between canopy area, distance to forest, their interaction term, and the probability of a climbed tree was analyzed using logistic regression. This is a standard technique for analyzing binary data in which the response variable is a success or failure (Agresti 1996), or in the case of this study, a climbed or unclimbed tree. The model of the form p(climbed tree) = {exp [a + b(canopy area) + c(distance to forest) + d(canopy area x distance to forest)]}/{1 + exp [a + b(canopy area) + c(distance to forest) + d(canopy area x distance to forest)]}, where a, b, c, and d are constants, was fitted to the data. Parameters were estimated by maximum likelihood to determine the variables that significantly improved the fit of the model. A backward elimination procedure was used with the logistic regressions; variables that did not significantly contribute to the model were removed. A Mann-Whitney test was used to compare the canopy area to basal area ratio for the complete group of field trees with the

complete group of forest trees. For both logistic regression and Mann-Whitney analyses, an alpha level of 10% was used to determine significant variables.

RESULTS

CLIMBED FIELD TREES COMPARED TO UNCLIMBED FIELD TREES. -- Within the eight properties surveyed for fruit trees located in fields or pastures, 35 trees were climbed by the spectacled bear (Appendix 1A), 615 trees were marked as unclimbed, of which data for a subset of 40 randomly chosen unclimbed trees were measured (Appendix 1B). It should be noted that data were pooled for the eight properties for all analyses. Only one property showed a pattern different from the rest in that climbed trees were located in or near a patch of vegetation at a relatively large distance from the forest. Climbed trees represented 5.4% of the total number of trees found on the eight properties and were located between the elevations of 2000 and 2294 m. The subset of unclimbed trees was found between the elevations of 2000 and 2288 m. Of the 35 climbed trees, 31 were *Nectandra membranacea* (Lauraceae), 2 were *Cecropia andina* (Cecropiaceae), and 2 were *Hyeronima macrocarpa* (Euphorbiaceae). Of the 40 unclimbed trees, 19 were *N. membranacea*, 16 were *C. andina*, and 5 were *H. macrocarpa*. *N. membranacea* represented 89% of the climbed trees but only 48% of the subset of unclimbed trees. Spectacled bears showed a preference for climbing *N. membranacea* in fields and pastures (Fisher's Exact test, $N = 75$, $P = 0.0002$).

Logistic regression was used to analyze the probability of a tree being climbed given the variables canopy area, distance to forest, and their interaction term. Unclimbed trees ($N = 40$) were assigned a value of zero and climbed trees ($N = 35$) a value of one. Logistic regression P-values represent the contribution of an individual explanatory variable to the model after all other explanatory variables are already in the model (Type III P-values). When analyzing all three tree species together, canopy area ($P = 0.0190$) and the interaction between canopy area and distance to forest ($P = 0.0828$) were both significant. However,

distance to forest did not significantly add to the model ($P = 0.3588$) given the presence of the other two variables. Despite the lack of significance of distance to forest by itself, distance still contributed significantly through the interaction term. There was a negative relationship between the probability of a climbed tree and the interaction term, showing the strong negative influence of distance to forest on the probability of a tree being climbed. For *N. membranacea* alone, distance to forest ($P = 0.0005$) was the only significant explanatory variable, and it negatively influenced the probability of a tree being climbed. When considering *C. andina* alone, canopy area ($P = 0.0920$) was the only significant model variable, with a positive relationship between canopy area and the probability of a tree being climbed. For *H. macrocarpa*, there were no significant explanatory variables; however, the sample size was very small (Table 1.1).

TABLE 1.1. P-values of independent variables that remained in the model after backward elimination in the analysis of the probability of a climbed tree using logistic regression.

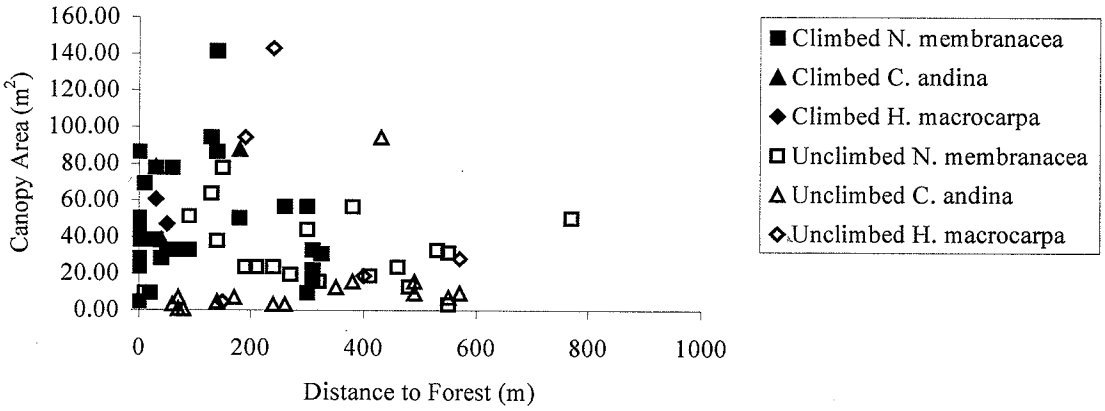
	N	Canopy Area	Distance to Forest	Canopy Area x Distance Interaction
All three species	75	0.0190	0.3588	0.0828
N. membranacea	50	—	0.0005	—
C. andina	18	0.0920	—	—
H. macrocarpa	7	—	—	—

Spectacled bears traveled up to 325 meters from the edge of contiguous forest to access fruit trees. However, two-thirds of the climbed trees were within 100 meters of the boundary between fields/pasture and contiguous forest. Bears did not travel more than 150 meters from the forest edge for any species other than *N. membranacea* (Figure 1.2). The maximum distance to forest for the subset of unclimbed trees was 770 meters.

FOREST TREES COMPARED TO FIELD TREES. -- The forest transects included a total of 22 trees of the three species, only one of which was climbed (*N. membranacea*). In total, there were 5 *N. membranacea*, 4 *C. andina*, and 13 *H. macrocarpa* (Appendix 1C).

A Mann-Whitney test was used to test for a significant difference in canopy area between forest trees and field trees. The ratio of canopy area to basal area was used as the independent variable in this analysis. For two of three tree species, there was no significant difference in the ratio of canopy area to basal area (*N. membranacea* $N = 5$ forest trees, $N =$ 50 field trees, $P = 0.3311$; *H. macrocarpa* $N = 13$ forest trees, $N = 7$ field trees, $P = 0.1486$). In the case of *C. andina*, there was a significant difference between forest and field trees, but forest trees had a larger canopy area to basal area ratio than field trees ($N = 4$ forest trees, $N =$ 18 field trees, $P = 0.0244$).

FIGURE 1.2 Distance to forest and canopy area of three species of climbed and unclimbed field trees.



DISCUSSION

The preference for laurel fruits (Lauraceae spp.), members of the avocado family, is highlighted in this study and the importance of these fruits in the diet of the spectacled bear is confirmed by other researchers (Peyton 1987a, 1987b; Mondolfi 1989). Peyton (1987a) asserts that laurel trees (*Nectandra* spp.) were one of the best food sources around his study area in Machu Picchu, Peru. Although analysis of nutritional content was not done for this study, the fruits in the family Lauraceae, especially in the genera of *Ocotea* and *Nectandra*, are known to be lipid-rich (see citations in introduction); whereas the fruits of Cecropiaceae (Fleming and Williams 1990) and Euphorbiaceae (Snow 1981) are relatively nutrient-poor and are not high in lipids. Since lipid-rich fruits have a higher energy content and offer potentially greater rewards, fruit quality is one likely explanation for the preference for laurel fruits.

Energy-rich fruits can be deficient in macronutrients such as protein (Robbins 1993). Nutritional ecological studies often focus on protein limitations (Thomas 1984, Izhaki 1998, Delorme and Thomas 1999, Rode and Robbins 2000). In a study of grizzly and black bears consuming diets of varying protein content, the researchers found that maintenance energy intake increased greatly with an all-fruit diet (4% protein) (Rode and Robbins 2000). Rode and Robbins (2000) suggest an optimization process in dietary selectivity and a mixed diet that reduces the energy cost of maintenance with a dietary protein content around 12-13%. Protein limitations of a fruit diet may be less important to the tropical spectacled bear due to potential higher protein content of tropical fruits. In a study (White 1989 in Stiles 1993), mean protein content in fruit pulp from Europe (52 species of 35 genera) was $5.5 \pm 0.4\%$, from North America (101 species of 51 genera) was $5.2 \pm 0.4\%$, and from the Neotropics

(122 species of 77 genera) was 8.9 ± 0.6%. Neotropical fruits had a significantly higher protein content for those species evaluated. For example, mean protein for 9 species of *Ocotea* was above the mean at 11.14%; mean value for 4 species of *Nectandr*a was at the mean (8.75%) for Neotropical fruits.

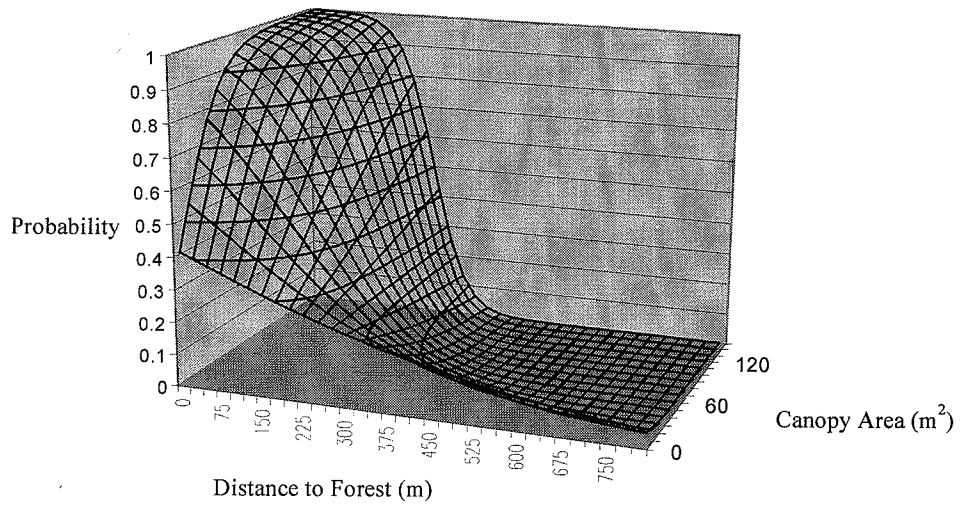
The distribution of *N. membranacea* in Ecuador may also help to explain the spectacled bear's use of this species in the study area. Within the genus *Nectandra*, *N. membranacea* is considered a widespread and frequent species. It can grow from low elevations to around 2400 m altitude and in a variety of habitats (Rohwer 1993). According to the Catalogue of the Vascular Plants of Ecuador (1999), the species has a disjointed elevation distribution in the country; it is found from 0 – 1500 m and from 2000 – 2500 m altitude. The narrow band of the species' distribution in its upper limit supports Peyton's assertion that the fruit trees that make up the bear's diet are found in a narrow band of cloud forest around 2000 m elevation (Peyton 1988). There is broad overlap between the areas of high human activity in the study area (~2000 – 2300 m) and the limited upper distribution of *N. membranacea* (~2000 – 2400 m). Bears in the study area may be attracted to feed outside the boundary of contiguous forest where deforestation, due to agriculture and livestock activities, has reduced the availability of this lipid-rich fruit tree. In contrast with *N. membranacea*'s distribution in Ecuador, *C. andina* is found from 1500 – 3000 m and *H. macrocarpa* is found from 1500 – 3500 m altitude (Jørgensen and León-Yanez 1999).

The results of this study can be interpreted in terms of optimal foraging theory. Not only do spectacled bears prefer lipid-rich fruits, which provide more energy, but more often climb trees with larger canopy areas. Vertical climbing is energetically expensive (Robbins 1993) and spectacled bears should weigh the costs of climbing against the nutritional benefits

of the fruits, gaining a greater reward from trees with a greater total fruit pulp mass. Although distance to forest was not a significant factor alone, it still contributed significantly through the interaction term between canopy area and distance to forest. Figure 1.3 illustrates this interaction. The probability that a tree with a small canopy area will be climbed decreases steadily as distance increases, whereas the probability that a tree with a large canopy area will be climbed remains high for a longer distance from the forest edge and then drops rapidly. Bears are willing to go farther for trees that offer potentially greater rewards. However, spectacled bears are wary of human presence and there is a real danger of being shot by farmers in some parts of the study area, which likely play a part in bear foraging decisions. Given the risks, there is an apparent limit beyond which a bear will not travel from contiguous forest regardless of the size of fruit tree.

When *N. membranacea* is considered alone, results show that distance is an important factor and not canopy area as to whether or not the tree will be climbed. However, the

FIGURE 1.3. Probability of a climbed tree.
Model p (climbed tree) = -0.32 + 0.05 canopy area - 0.003 distance to forest - 0.0002 canopy area x distance to forest interaction.



available set of *N. membranacea* trees in fields and pastures may have been larger. The *N. membranacea* trees in fields and pastures, on average, had larger canopy areas than *C. andina*, for example (Mann-Whitney test $P = 0.0004$). This is probably explained by the fact that there were very few *N. membranacea* saplings growing in fields and pastures; whereas there were many *C. andina* saplings growing in fields and pastures, as trees in the genus are considered pioneer species. However, spectacled bears climbed *N. membranacea* trees with a wide range of canopy areas (4.71 – 141.37 m^2) but only the largest *C. andina* trees (78.23 and 87.96 m^2), suggesting that the energetic benefits of consuming lipid-rich fruits may outweigh any canopy area effect and, therefore, distance is the primary limiting factor for *N. membranacea.*

These results have been interpreted in terms of static foraging decisions, in which each climbed tree was considered independent, but spectacled bears most likely choose an optimal foraging path instead of optimal points. In a dynamic model, past decisions affect future decisions (Stephens and Krebs 1986). For example, a bear might decide to forage in a fruit tree that is 25 m from the forest edge and then, because it has traveled that far, may decide to forage in another tree that is an additional 10 m away from the first tree selected even if it would not have initially chosen to visit this second tree in absence of the first. The observed spatial clumping of three climbed *N. membranacea* trees at relatively large distances from contiguous forest (>300 m) suggests that this could occur. However, this detail of observation is very likely impossible due to the difficulty in directly observing foraging spectacled bears. Although the senior author (L.G.) observed one spectacled bear foraging in a fruit tree, it was only for a moment before the bear rushed down from the tree and into cover about 15 meters away. It is a rare occurrence to observe a spectacled bear and

the accumulation of a sufficient number of data points to distinguish among several relevant variables influencing food choice is unlikely.

The lack of any statistically significant variable to explain the difference between *N. membranacea* forest trees and field trees reinforces the concern over the effects of deforestation on the availability of this fruit source. Open-grown plants show increases in fruit crop size compared to those growing in closed forest conditions (Levey 1990) and could account for bears foraging in remnant fruit trees in open fields/pastures. If analysis had revealed that the canopy area of field trees was larger than forest trees, one could argue that bears might be more willing to risk leaving the forest to access trees that were larger and had more fruit pulp mass. As this was not the case, it tends to support the idea that deforestation in the study area is reducing the availability of laurel fruits in particular and that spectacled bears are confronted with the risk of leaving contiguous forested areas to access remnant fruit trees in cornfields and pastures.

A mechanistic approach to the question of why the spectacled bear forages in remnant fruit trees not only reveals that laurel fruits are an important food resource, which has already been documented in descriptions of the food habits of the spectacled bear but, more significantly, provides further statistical evidence for this claim and the framework in which the results can be interpreted. It highlights a conservation issue that may directly affect the survival of the species in the study area and provides direction for future research. Further studies should be conducted on the nutritional content, distribution and use of *Nectandra membranacea* in the area as well as the spectacled bear's seasonal foraging and movement patterns.

LITERATURE CITED

Agresti, A. 1996. An Introduction to Categorical Data Analysis. John Wiley & Sons, Inc., New York.

Delorme, M. and D. W. Thomas. 1999. Comparative analysis of the digestive efficiency and nitrogen and energy requirements of the phyllostomid fruit-bat (*Artibeus jamaicensis*) and the pteropodid fruit-bat (*Rousettus aegyptiacus*). Journal of Comparative Physiology 169: 123-132.

Denslow, J. S. 1987. Fruit removal rates from aggregated and isolated bushes of the red elderberry, *Sambucus pubens*. Canadian Journal of Botany 65: 1229-1235.

Denslow, J. S. and T. C. Moermond. 1982. The effects of accessibility on rates of fruit removal from tropical shrubs: An experimental study. Oecologia 54: 170-176.

Fleming, T. H. and C. F. Williams. 1990. Phenology, seed dispersal, and recruitment in *Cecropia peltata* (Moraceae) in Costa Rican tropical dry forest. Journal of Tropical Ecology 6(2): 163-178.

Goldstein, I. 1991. Are spectacled bear's tree nests feeding platforms or resting places? Mammalia 55(3): 433-434.

Howe, H. F. and G. F. Estabrook. 1977. On intraspecific competition for avian dispersers in tropical trees. American Naturalist 111: 817-832.

IUCN. 1996. IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland.

Izhaki, I. 1998. Essential amino acid composition of fleshy fruits versus maintenance requirements of passerine birds. Journal of Chemical Ecology 24: 1333-1345.

Johnson, R. A., M. F. Willson, J. N. Thompson, and R. I. Bertin. 1985. Nutritional values of wild fruits and consumption by migrant frugivorous birds. Ecology 66: 819-827.

Jørgensen, P. M. and S. León-Yanez, Eds. 1999. Catalogue of the Vascular Plants of Ecuador. Missouri Botanical Garden Press, St. Louis, MO.

Joshi, A. R., D. L. Garshelis, and J. L. D. Smith. 1997. Seasonal and habitat-related diets of sloth bears in Nepal. Journal of Mammalogy 78(2): 584-597.

Jung, R. E. 1992. Individual variation in fruit choice by American Robins (*Turdus migratorius*). Auk 109: 98-111.

Leighton, M. 1992. Modeling dietary selectivity by Bornean orangutans: Evidence for integration of multiple criteria in fruit selection. International Journal of Primatology 14(2): 257-314.

Lepczyk, C. A., K. G. Murray, K. Winnett-Murray, P. Bartell, E. Geyer, and T. Work. 2000. Seasonal fruit preferences for lipids and sugars by American Robins. Auk 117(3): 709-717.

Levey, D. J. 1987. Sugar-tasting ability and fruit selection in tropical fruit-eating birds. Auk 104: 173-179.

____. 1990. Habitat-dependent fruiting behaviour of an understorey tree, *Miconia centrodesma*, and tropical treefall gaps as keystone habitats for frugivores. Journal of Tropical Ecology 6(4): 409-420.

Levey, D. J. and W. H. Karasov. 1989. Digestive responses of temperate birds switched to fruit or insect diets. Auk 106: 675-686.

Martínez del Rio, C. and W. H. Karasov. 1990. Digestive strategies in nectar- and fruit-eating birds and the sugar composition of fruit rewards. American Naturalist 136: 618-637.

McConkey, K. and M. Galetti. 1999. Seed dispersal by the sun bear *Helarctos malayanus* in Central Borneo. Journal of Tropical Ecology 15(2): 237-241.

McPherson, J. M. 1987. A field study of winter fruit preferences of Cedar Waxwings. Condor 89: 293-306.

Moermond, T. C. and J. S. Denslow. 1983. Fruit choice in Neotropical birds: Effects of fruit type and accessibility on selectivity. Journal of Animal Ecology 52: 407-420.

____. 1985. Neotropical avian frugivores: Patterns of behavior, morphology, and nutrition, with consequences for fruit selection. Ornithological Monographs 36: 865-897.

Moermond, T. C., J. S. Denslow, D. J. Levey, and E. Santana. 1987. The influence of context on choice behavior: Fruit selection by tropical birds. In M. L. Commons, A. Kacelnik, and S. J. Shettleworth (Eds.). Quantitative Analyses of Behavior, pp. 229-254. Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.

Mondolfi, E. 1989. Notes on the distribution, habitat, food habits, status and conservation of the Spectacled Bear (*Tremarctos ornatus* Cuvier) in Venezuela. Mammalia 53(4): 525-544.

Murray, K. G. 1987. Selection for optimal fruit crop size in bird-dispersed plants. American Naturalist 129: 18-31.

Paine, R. T. 1971. The measurement and applications of the calorie to ecological problems. Annual Review of Ecology and Systematics 2: 145-164.

Paszkowski, C. A. 1982. Vegetation, ground, and frugivorous foraging of the American Robin. Auk 99: 701-709.

Peyton, B. 1980. Bears, *Tremartcos ornatus*, in Peru. Journal of Mammalogy 61(4): 639-652.

_____. 1987a. Criteria for assessing habitat quality of the spectacled bear in Machu Picchu, Peru. Int. Conf. Bear Res. Manage. 7: 135-143.

_____. 1987b. Habitat components of the spectacled bear in Machu Picchu, Peru. Int. Conf. Bear Res. Manage. 7: 127-133.

_____. 1988. The spectacled bear, its ecology and conservation. AAZPA (Am. Assoc. Zool. Parks Aquariums) Regional Conference Proceedings.

_____. 1999. Spectacled Bear Conservation Action Plan. Bears. In C. Servheen, S. Herrero and B. P. (compilers). Status Survey and Conservation Action Plan. IUCN/SSC Bear and Polar Bear Specialist Groups. IUCN, Gland, Switzerland and Cambridge, UK.

Pritchard, G. T. and C. T. Robbins. 1990. Digestive and metabolic efficiencies of grizzly and black bears. Canadian Journal of Zoology 68: 1645-1651.

Proyecto PLAN - Ecuador. 2000. GL-CRSP: Community Planning for Sustainable Livestock-Based Forested Ecosystems in Latin America. Annual Report of Activities - PLAN - Ecuador. Quito, Ecuador.

Robbins, C. T. 1993. Wildlife Feeding and Nutrition. Academic Press, New York.

Rode, K. D. and C. T. Robbins. 2000. Why bears consume mixed diets during fruit abundance. Canadian Journal of Zoology 78: 1640-1645.

Rohwer, J. G. 1993. Lauraceae: Nectandra. New York Botanical Garden, New York.

SAS version eight. 1999. SAS Institute Inc., Cary, NC, USA.

Sallabanks, R. 1992. Fruit fate, frugivory, and fruit characteristics: A study of the hawthorne, *Crataegus monogyna* (Rosaceae). Oecologia 91: 296-304.

Snow, D. W. 1971. Evolutionary aspects of fruit-eating by birds. Ibis 113: 194-202.

_____. 1981. Tropical frugivorous birds and their food plants: A world survey. Biotropica 13: 1-14.

Sorensen, A. E. 1984. Nutrition, energy and passage time: Experiments with fruit preference in European Blackbirds (*Turdus merula*). Journal of Animal Ecology 53: 545-557.

Stephens, D. W. and J. R. Krebs. 1986. Foraging Theory. Princeton University Press, Princeton, NJ.

Stiles, E. W. 1993. The influence of pulp lipids on fruit preference by birds. Vegetatio 107/108: 227-235.

Stirling, I. and E. H. McEwan. 1975. The caloric value of whole ringed seals (*Phoca hispida*) in relation to polar bear (*Ursus maritimus*) ecology and hunting behavior. Canadian Journal of Zoology 53: 1021-1027.

Thomas, D. W. 1984. Fruit intake and energy budgets of frugivorous bats. Physiological Zoology 57: 457-467.

Welch, C. A., J. Keay, K. C. Kendall, and C. T. Robbins. 1997. Constraints on frugivory by bears. Ecology 78(4): 1105-1119.

Wheelright, N. T. 1983. Fruits and ecology of the resplendent quetzal. Auk 100: 286-301.

APPENDIX 1A. Species, distance to forest, DBH, and canopy area of climbed trees in the eight selected properties around Antisana Ecological Reserve, Ecuador.

Tree ID	Species	Distance to Forest	DBH (cm)	Canopy Area (m^2)
1	*N. membranacea*	140	49.5	86.39
2	*N. membranacea*	180	44.5	50.27
3	*N. membranacea*	140	67.0	141.37
4	*N. membranacea*	130	49.0	94.25
5	*N. membranacea*	70	23.8	32.99
6	*H. macrocarpa*	30	48.1	60.62
7	*C. andina*	30	56.2	78.23
8	*C. andina*	180	56.0	87.96
9	*H. macrocarpa*	50	62.4	47.12
10	*N. membranacea*	0	27.0	40.06
11	*N. membranacea*	0	46.0	28.27
12	*N. membranacea*	0	45.0	38.48
13	*N. membranacea*	20	21.0	9.42
14	*N. membranacea*	30	24.0	38.48
15	*N. membranacea*	90	40.0	32.99
16	*N. membranacea*	50	42.3	32.99
17	*N. membranacea*	60	82.5	77.75
18	*N. membranacea*	40	34.5	28.27
19	*N. membranacea*	0	29.5	43.98
20	*N. membranacea*	30	95.8	77.75
21	*N. membranacea*	0	33.5	4.71
22	*N. membranacea*	0	33.5	86.39
23	*N. membranacea*	0	36.9	50.27
24	*N. membranacea*	0	29.4	23.56
25	*N. membranacea*	0	47.0	43.98
26	*N. membranacea*	0	28.0	23.56
27	*N. membranacea*	10	38.8	69.12
28	*N. membranacea*	300	53.0	56.55
29	*N. membranacea*	310	39.6	32.99
30	*N. membranacea*	310	20.6	15.71
31	*N. membranacea*	300	19.7	9.42
32	*N. membranacea*	325	34.2	30.63
33	*N. membranacea*	310	27.3	21.99
34	*N. membranacea*	260	29.4	56.55
35	*N. membranacea*	10	41.3	38.48

APPENDIX 1B. Species, distance to forest, DBH, and canopy area of unclimbed trees in the eight selected properties around Antisana Ecological Reserve, Ecuador.

Tree ID	Species	Distance to Forest (m)	DBH (cm)	Canopy Area (m^2)
1	*N. membranacea*	90	53.8	51.40
2	*N. membranacea*	240	29.0	23.56
3	*N. membranacea*	320	16.3	15.71
4	*N. membranacea*	300	49.1	43.98
5	*N. membranacea*	270	45.0	19.63
6	*H. macrocarpa*	570	50.0	28.27
7	*N. membranacea*	150	41.7	77.75
8	*N. membranacea*	410	27.0	18.85
9	*N. membranacea*	550	10.8	3.14
10	*C. andina*	570	32.4	9.42
11	*H. macrocarpa*	150	24.8	4.71
12	*H. macrocarpa*	190	56.7	94.25
13	*H. macrocarpa*	240	52.1	142.94
14	*N. membranacea*	550	53.7	31.42
15	*N. membranacea*	770	60.3	50.27
16	*C. andina*	70	13.6	0.79
17	*C. andina*	380	20.7	15.71
18	*C. andina*	430	33.2	94.25
19	*N. membranacea*	460	42.8	23.56
20	*C. andina*	490	28.6	9.42
21	*C. andina*	70	21.5	7.07
22	*C. andina*	40	38.0	38.48
23	*C. andina*	140	32.0	4.71
24	*N. membranacea*	140	30.8	37.70
25	*N. membranacea*	130	50.3	63.62
26	*C. andina*	60	22.5	3.14
27	*C. andina*	240	30.2	3.14
28	*N. membranacea*	210	37.8	23.56
29	*C. andina*	260	25.0	3.14
30	*C. andina*	80	15.0	0.79
31	*C. andina*	350	23.0	12.57
32	*C. andina*	490	18.5	15.71
33	*N. membranacea*	480	22.0	12.96
34	*N. membranacea*	530	26.9	32.99
35	*C. andina*	550	12.0	7.07
36	*N. membranacea*	10	14.5	9.42
37	*N. membranacea*	380	28.5	56.55
38	*H. macrocarpa*	400	24.8	18.85
39	*N. membranacea*	190	22.3	23.56
40	*C. andina*	170	15.0	7.07

APPENDIX 1C. Species, DBH, and canopy area of trees found on four transects in forest above the fields of four of the selected properties around Antisana Ecological Reserve, Ecuador. The only climbed tree is marked with asterisks.

Tree ID	Species	DBH (cm)	Canopy Area (m^2)	Climbed
1	*H. macrocarpa*	16.2	3.14	
2	*N. membranacea*	24.4	35.34	
3	*C. andina*	25.8	28.27	
4	*N. membranacea*	29.5	9.42	
5	*C. andina*	14.9	9.42	
6	*H. macrocarpa*	60.0	28.27	
7	*H. macrocarpa*	30.4	7.07	
8	*H. macrocarpa*	68.0	43.98	
9	*H. macrocarpa*	21.4	15.71	
10	*N. membranacea*	48.7	23.56	
11	*C. andina*	23.0	28.27	
12	*H. macrocarpa*	36.3	31.42	
13	*H. macrocarpa*	47.5	28.27	
14	*H. macrocarpa*	41.6	14.14	
15	*N. membranacea*	70.4	142.94	***
16	*C. andina*	8.2	7.07	
17	*H. macrocarpa*	57.0	19.63	
18	*H. macrocarpa*	49.0	19.63	
19	*H. macrocarpa*	63.0	12.57	
20	*H. macrocarpa*	42.0	38.48	
21	*H. macrocarpa*	28.0	23.56	
22	*N. membranacea*	23.0	9.42	

CHAPTER 2:
THE IMPACT OF SPECTACLED BEARS ON THE LIVESTOCK AND CROPS AROUND ANTISANA ECOLOGICAL RESERVE, ECUADOR

ABSTRACT

The overlap of spectacled bear (*Tremarctos ornatus*) habitat and extensive grazing and land use systems can lead to conflict between bears, cattle, and agriculture. The consequences of this conflict can be severe for bears as humans subsequently hunt them, often indiscriminately. We investigated the accounts and economic impact of livestock attacks and crop damage attributed to the endangered spectacled bear on farms outside the Antisana Ecological Reserve in northeastern Ecuador. All farms that reported livestock lost to predatory bears were identified and data were recorded on farm characteristics. A sample of unaffected farms was chosen and compared to affected farms, using a chi-squared test for categorical variables and a Kruskal-Wallis test for continuous variables. Crop raiding was monitored on eight farms in two communities. Reports of hunting were compiled from key informants. Crop damage was considered minimal, but 31 livestock attacks were attributed to the spectacled bear in a 13-month period. As a result, 11 bears were reported to have been killed in the study area during the same time period. Chi-squared analysis revealed cattle location (adjacent or not adjacent to forest) as well as cattle carcass removal practices (bury or leave) as significant differences between affected and unaffected farms. The presence of livestock carcasses may draw bears to pastures where they first consume livestock as carrion and subsequently change their behavior to active depredation. Farmers should change certain

farm management practices to ameliorate future conflict such as removal of cattle carcasses from pastures and restriction of cattle access to the forest edge.

INTRODUCTION

Extensive grazing and land use systems in bear habitat can lead to negative interactions between bears, agriculture, and livestock. The conversion of natural forests to agriculture and pasture for livestock in spectacled bear (*Tremarctos ornatus*) habitat has led to increasing conflicts between humans and spectacled bears (Peyton 1999). Individual farmers can suffer considerable losses due to livestock depredation and crop raiding by bears (Davenport 1953, Mysterud 1980, Fritts 1982, Horstman and Gunson 1982, Jorgensen 1983, Goldstein 1991) and attitudes can quickly turn against bears as farmers view them as agricultural pests. The consequences are often severe as programs of lethal control are implemented to eliminate problem bears and as livestock owners engage in illegal hunting, often indiscriminately (Jorgensen 1983, Peek *et al.* 1987, Peyton 1987, Goldstein 1991, Herrera *et al.* 1994, Yerena 1998, Peyton 1999). These consequences for endangered species of bear are of particular concern. For this reason, it is important to understand the spatial pattern and causal explanations for conflict, and to ameliorate future problems.

The consequences of bear-human conflict are critical in the case of the spectacled bear. Categorized as vulnerable to extinction (IUCN 1996), the greatest threats to populations and individuals, in the five Andean countries it inhabits, are perceived as the illegal hunting and sale of bear parts and an accelerated conversion of natural forest for agriculture and livestock activities (Peyton 1999). High hunting pressure may have the greatest short-term effect on spectacled bear populations (Yerena 1998) and are often a result of bear-human conflict that gives local farmers an economic incentive to kill bears (Goldstein 1991, Herrera *et al.* 1994). Local farmers can turn to an indiscriminate killing of bears in an effort to safeguard their livestock.

The purpose of this paper is to quantify the damage and the economic impact of the spectacled bear on the crops and livestock around the Antisana Ecological Reserve, in northeastern Ecuador. We evaluate the attacks attributed to the spectacled bear, and assess the relative impacts of livestock depredation and crop raiding. We then test landscape features and animal husbandry practices against the pattern of livestock losses to bears. In this way, we aim to better predict and ameliorate future depredations. As these are the first reports of active depredation of cattle by the spectacled bear on the eastern slopes around the Antisana Ecological Reserve, a study of the conflict is particularly important to establish a record of these events and to contribute information, based on our analysis, that can positively change farm management practices.

LITERATURE REVIEW

Published studies on bear-human conflicts are relatively few in number and published studies of spectacled bear conflict rarer still. Here we will review relevant literature on human-bear and also draw from general studies of human-carnivore conflict. First, we address the general case of human-bear conflict and the consequences of real and perceived depredation by bears. We then discuss the factors that can be used to test patterns of bear depredation, such as landscape features at the regional level and husbandry practices at the farm level. Our aim is to provide background information on human-bear conflict and lay a foundation for our study of human-spectacled bear conflict in Ecuador.

Bears are adaptable animals that can learn to exploit new anthropogenic foods introduced into bear-occupied areas. Brown bears (*Ursus arctos*) and black bears (*Ursus americanus*) have taken advantage of agricultural crops and livestock as easily as they have become accustomed to feeding in garbage dumps (Jorgensen 1983). Indeed, many species of bears cause conflict when they forage on crops or attack livestock. Brown bears are known to kill cattle and sheep (Murie 1948, Mysterud 1980, Horstman and Gunson 1982, Jorgensen 1983, Cozza *et al.* 1996, Garcia-Gaona 1997). Black bears have also been responsible for the deaths of livestock and agricultural crop damage (Davenport 1953, Jorgensen 1983, Stowell and Willging 1992). Spectacled bears are not an exception; cases of human-bear conflict exist throughout its range (Peyton 1980, Mondolfi 1989, Goldstein 1991, Peyton 1999).

The consequences of real and perceived depredation by bears are severe and often lead to lethal control and illegal hunting. Some of the first articles on bear-livestock conflict discussed selective control as a measure to rid an area of predatory bears (Murie 1948). From the 1970s to mid-1980s, grizzly bear mortality due to lethal control and illegal hunting

was substantial in the United States (Peek *et al.* 1987). In the Greater Yellowstone Ecosystem, for example, deaths related to livestock depredation were a major source of mortality. From 1974-1979, 10 of 37 radio-collared grizzly bears were suspected of predatory behavior (Knight and Judd 1983). There were reports of 20 bears that were killed on sheep allotments and 2 on cattle allotments from 1970-1975. After 1975, when the grizzly bear was listed as a threatened species, there may have been up to 14 grizzlies killed during the first 2 years. This reaction to grizzly bear depredation seems disproportionately severe considering the actual damage. Johnson and Griffel (1982) stated that grizzly bears accounted for the death of only 0.5% of the 15,707 sheep on the grazing allotments on the Targhee National Forest.

Black bears suffer mortality from illegal hunting and lethal control as well. Jorgensen (1983) reported that black bears in Idaho and Wyoming, around the Targhee National Forest, were shot without confirmation that the bear was responsible for depredation events. Herders were reported to check snares left by government trappers, and when a bear was found, killed the bear and reset the snare to kill additional bears. An estimated 10-12 or more bears were killed annually in the study area. In Wisconsin, for example, black bear attacks on livestock do not occur frequently, but chronic livestock depredation or crop raiding can result in the issuance of a kill permit by the Wisconsin Department of Natural Resources (Stowell and Willging 1992).

For spectacled bears, illegal hunting is also significant. Poaching has been identified as potentially having the greatest short-term effect on local bear extirpation because it occurs frequently and is uncontrolled (Yerena 1998). Even though very few cattle are actually killed by spectacled bears, farmers view each bear as a potential or actual predator and try to

eliminate every bear that is encountered (Herrera *et al.* 1994). For example, depredation events in the Venezuelan páramo resulted in the killing of 23 bears (Goldstein 1991). Bears are at risk from individual hunters as well as organized hunting parties after reported cattle depredation events. Poaching of spectacled bears, even though illegal, is justified in the minds of farmers who have suffered economically from livestock depredation and who fear further loss (Goldstein 1991).

In order to explain the location and timing of depredation events, both regional and farm-level variables have been proposed. On a regional level, researchers of bear and other carnivore depredation on livestock have suggested that greater conflicts occur at park boundaries (Jorgensen 1983, Woodroffe and Ginsberg1998, McLellan *et al.* 1999). River valleys may also be a problem area for bears and wolves. These habitats support wintering ungulates and high densities of ungulates year-round in areas where livestock are also concentrated (Fritts *et al.* 1992, Mace *et al.* 1996). Increased incidents of bear-human conflict may also be related to shortages of natural foods (Rogers 1976, Jorgensen 1983, Inglis 1993). In eastern Russia, low precipitation during drought years resulted in poor forage production and increased bear-human conflicts (Gillin *et al.* 1997). Bears in poor physical condition approached human settlements, where they preyed on livestock. The same relationship between natural food production and depredation events may also exist for spectacled bears, although more research is needed. However, Peyton (1988) commented that livestock depredation by spectacled bears occurred in páramo habitat when forest fruit production, an important seasonal food source, was at a low.

Herd management practices are likely the most important farm-level variables explaining the development and perpetuation of depredation problems (Roy and Dorrance

1976, Fritts 1982, Jorgensen 1983, Fritts *et al.* 1992). Improper disposal of carcasses has been identified as an important variable linked to the incidence of livestock depredation. The presence of livestock carcasses can draw predators like wolves to pastures where they consume carrion (Fritts 1982). This can be a first step toward active livestock depredation. Even though wolf depredation events in Minnesota typically occurred in remote farm areas, they also took place within a few meters of farm buildings where livestock carcasses had been disposed (Fritts *et al.* 1992). Unprotected herds may also suffer greater depredation rates. Inadequate monitoring of herds that have access to large wooded areas may make livestock more vulnerable to predators (Fritts 1982, Fritts *et al.* 1992). For spectacled bears, both Goldstein (1991) and Peyton (1988) remarked on the risks of traditional herding practices in páramo habitat. In this type of system, cattle are located in remote areas, visited infrequently, and may suffer high mortality due to predation.

Additional farm-level characteristics that can explain locations of depredation events include large farm and herd sizes and suitable terrain for predators. Wolf-livestock conflict in Minnesota took place in wooded areas and in open pasture near woods but was particularly severe in pastures with a combination of field and forest (Fritts *et al.* 1992). Large farms (Mech *et al.* 2000) and large herd sizes (Dorrance and Roy 1976, Nass *et al.* 1984, Cozza *et al.* 1996, Mech *et al.* 2000) have been associated with farms that are hit disproportionately hard. Interestingly, Jorgensen (1983) mentioned that the overlap of berry patches, an important seasonal bear food, and grazing of sheep may lead to conflict, and herders should avoid these areas when bears are present.

In addition to identifying causal factors to reduce conflict, it is also important to verify incidents of livestock depredation in order to accurately assess the cause of death, and

in the case of active depredation, the species responsible. The difficulty of verifying depredation is apparent from the literature (Roy and Dorrance 1976). Researchers, park personnel, and state/federal wildlife damage specialists who assess depredation events are faced with a certain challenge. Oftentimes, there is a delay in notification and kills are not evaluated immediately after the suspected attack; therefore, important evidence cannot be collected. Other times, the full assemblage of evidence that one would hope to find, such as tracks, scat, blood as evidence of struggle, and tooth/claw marks on the carcass, is not available. Investigators may have to make judgments based on the available evidence and rely on their experience and intuition (Wade and Bowns 1982).

Verification of active depredation is especially confusing for species that also consume meat as carrion. Bears are frequently and incorrectly blamed for active depredation due to this habit (Murie 1948), and it seems to be the most critical issue when trying to discern if bears, and spectacled bears in particular, have engaged in active depredation. Goldstein (1991) felt that prior comments on spectacled bear depredation (Peyton 1980, Mondolfi 1989, Suarez 1989) did not have enough evidence to differentiate between active depredation and consumption of the carcass as carrion. However, Goldstein's 1991 study on spectacled bear depredation in Venezuela concluded that bears do actively kill based on signs of struggle and the cessation of cattle deaths after the suspected bear had been killed or the cattle had been moved to a different area.

In order to construct a model that would explain the locations of depredation events by the spectacled bear in our study area, we collected and compared farm-level data on the characteristics of affected farms and unaffected farms. Potential significant factors were identified from bear and wolf depredation literature. Thus, we hypothesized that farms

where cattle were pastured next to and had access to forest, larger farms, larger herds of cattle, cattle that were visited less often by farmers, and farmers who did not bury or remove cattle carcasses would account for the location of depredation events.

STUDY AREA

The study was conducted from February 1, 2001 to April 25, 2001 in agricultural communities near the Antisana Ecological Reserve on the northeastern slopes of the Andes in Ecuador, Napo Province (0.63S 77.92W). The average annual precipitation is 3,028 mm. The average temperature is 5 degrees Celsius, with strong daily and hourly fluctuations.

The communities in the study area lie along the main highway that links the capital city of Quito to the city of Tena in the southeastern part of the country (Figure 2.1). The region of Baeza-Cosanga forms part of the Rio Cosanga Watershed. This mountainous region has a total area of 22,290 hectares and ranges in altitude from 1000 - 3600 m. Eighty-seven percent of the watershed is composed of disturbed vegetation, including 30% of the total area as pasture. Natural vegetation occupies 13% of the total area. Cloud forest occurs at an altitudinal range of ~2000 – 2900 m (Proyecto PLAN-Ecuador 2000). Collection of crop raiding data took place in the two communities of Santa Lucia de Bermejo and Las Palmas (~2150 – 2300 m). Livestock depredation took place between the small town of Baeza and the community of Las Palmas (~2000-2500 m).

The Rio Cosanga Watershed is an important area ecologically on the regional, national, and international scale. It is located between the three protected areas of Antisana Ecological Reserve (1200 km^2), Cayambe-Coca Ecological Reserve (4,031 km^2), and Sumaco-Napo-Galeras National Park (2,052 km^2) (Figure 2.1). This area forms the principle source of water for the capital city of Quito (Fundación Antisana 1998). The forests in this area also maintain a very high level of biodiversity of national and international importance and include the endangered spectacled bear (*Tremarctos ornatus*) (Fundación Antisana 1998).

The Antisana watershed has been identified in the Spectacled Bear Conservation Action Plan as one of the five most important watershed areas to be conserved in Ecuador (Peyton 1999). Currently, there are no reliable estimates of spectacled bear populations (Peyton *et al.* 1998); however, the Spectacled Bear Specialist Group is confident that there are more than 20,000 spectacled bears located in the 5 Andean countries it inhabits (Peyton 1999). The number of spectacled bears is based on an estimated quantity of spectacled bear-occupied habitat at North American black bear densities. In the Antisana Ecological Reserve, there are an estimated 600 km^2 of occupied spectacled bear habitat. At a low adult black bear population density (7/100 km^2), there could be approximately 42 adult spectacled bears in the reserve. At a median adult black bear population density (25/100 km^2), there could be approximately 150 adult spectacled bears. These numbers do not include bear habitat that is still available between the reserve boundary and the communities that are located on the eastern side of the reserve. However, these numbers should be taken with caution since it is not definitively known if spectacled bear population densities are similar to North American black bear densities.

FIGURE 2.1. Map of the eastern portion of Ecuador, showing the three protected areas surrounding Baeza. Las Palmas is located approximately 8 km south of Baeza.

The human population in the study area consists mainly of new colonists who settled in the area in the 1970s after the construction of the modern highway. In addition to the construction of the modern highway, the national government played a role in conversion of natural vegetation to field and pasture through land titling schemes and through promotion of agriculture and livestock. Formal property law, as formerly executed by IERAC (Ecuadorian Institute for Agricultural Reform and Colonization), established that idle forests be converted into productive cropland or pasture before recognizing private rights in a colonized parcel

(Southgate and Runge 1990). Additionally, livestock production requires high initial monetary investments, which is difficult for impoverished new colonists to initiate without the support of the state and the opportunity to establish credit with a lending institution. The Banco Nacional de Fomento functioned as the lending agency for people in the Baeza region. Between 1979 and 1998, the Banco Nacional de Fomento issued credit on 447 occasions to a total of 155 people. The majority of the credits (60%) went directly to the establishment of livestock activities, either purchases of cattle or to finance conversion of land to pasture, and signifies the favorable outlook of the State toward cattle in the region (Ospina and Carrillo 1999).

As a result, most families in the local communities depend on livestock as the most important economic activity (Proyecto PLAN-Ecuador 1998). Milk from dairy cattle is collected on a daily basis by NESTLÉ. NESTLÉ established a chilling plant in Baeza during the 1970s and provided a stable source of income for the Cosanga region. During the early 1970s, there were 109 local producers of milk; the number of producers in the region reached its maximum in 1992, with 500. In recent years there has been a decline in the number of producers, but the sale of milk to NESTLÉ continues to be a crucial component of the local economy (Ospina and Carrillo 1999). Many families also cultivate corn for autoconsumption or for small domestic animal feed, but surplus corn is occasionally sold in local markets. An additional source of income, which varies in level of importance depending on the community, is extraction of wood from the forest.

Typically, families open up forest to first cultivate corn, taking advantage of soil nutrients present, and then convert the cornfields to pasture for livestock. This has been a continuous process as families convert more and more of their property from forest to

cornfield to pasture, although the majority of deforestation took place in the 1970s when families first established livestock activities in the zone. When forest is cleared, selected trees are left standing to create shade for livestock, construct fences in the future, and prevent erosion. Commercially valuable trees are left to harvest and sell in the future. On particularly steep inclines, small patches of vegetation may be left uncut. Spectacled bears utilize this matrix of cornfields, pastures, and small patches of vegetation (this study, Chapter 1).

METHODS

LIVESTOCK DEPREDATION. -- The very first reports of active depredation by spectacled bears in the study area surfaced in April 2000, before this investigation began, and continued through the end of April 2001, which marked the end of the study. No institution is responsible for monitoring livestock attacks; therefore, the method of reporting attacks is informal. The incidents of livestock attacks by spectacled bears were gathered from key informants in the community and community park guards who are local residents, hired and trained by Fundación Antisana. All farms that reported livestock lost to the spectacled bear were identified, GPS readings were taken at each farm, and the owners were interviewed. Data collected during interviews included 1) number of cattle present during the time of the attack, 2) cattle location on farm (adjacent or not adjacent to forest edge), 3) the overall farm size (number of hectares in pasture and number of hectares in forest), 4) how often cattle are visited by farmers, and 5) cattle carcass removal practices when death occurs for any reason. Farmers were asked to describe the events leading up to and following the suspected attack. Most attacks took place when an investigator was not present at the study site, but each kill site was visited and detailed notes were taken on the farmer's description of events. Special care was taken to note any description of attack characteristics, such as carcass scarring, as this is one method to distinguish between possible predators and between active depredation and the consumption of carrion. Field verification of depredation incidents was conducted when an investigator was present in the study area and informed at the time of the attack or shortly thereafter (N = 4, 13% of total reported attacks).

The economic impact of suspected livestock depredations by the spectacled bear was ascertained through interviews. All affected farmers were asked for the replacement value of

the cattle lost in depredation events. Values varied according to the age and quality of livestock. Traditional x Holstein cows, for example, were considered an improved race over the traditional breed and were valued more highly due to their capacity to produce greater quantities of milk. The total economic impact of livestock attacks was simply the sum of all replacement values.

We then selected a sample of unaffected farms based on geographic proximity to affected farms. The owners of the unaffected farms were interviewed and the same data that were collected from affected farms were also collected from the sample of unaffected farms. Data included number of cattle present on the farm, cattle location on farm (adjacent or not adjacent to forest edge), the overall farm size (number of hectares in pasture and number of hectares in forest), how often cattle are visited by farmers, and cattle carcass removal practices when death occurs for any reason.

Data analysis was performed using SAS statistical software (SAS 1999). Analyses were completed to test for significant differences between the farms where depredation events occurred and the farms where no depredation events were recorded. Chi-squared tests were used to test the categorical variables of cattle carcass removal practices (bury or leave) and cattle location (adjacent or not adjacent to the forest edge). Kruskal-Wallis tests were performed to test the continuous variables: number of cattle, visits/week, and farm size. For all tests, an alpha level of 10% was used to determine significant variables.

CROP RAIDING. -- Data on crop raiding by spectacled bears were collected to compare the relative economic impact of crop raiding with the economic impact of livestock depredation. At the end of the study, farmers were asked to rank, from 1-4, the species that caused the

most damage to their fields during the corn season. Eight fields were selected based on the availability of ripening corn in those fields during the study. Four were chosen in the community of Santa Lucia de Bermejo and four in the community of Las Palmas. Seven of the eight fields reported prior incidents of bear raiding. The location of each field was recorded using a handheld GPS unit. The area of each field was measured using a hip chain. The average cornfield size was 2 ha (0.62 - 4 ha). The eight cornfields represented approximately 50% of the cornfields in these two communities. The fields were monitored for crop raiding by spectacled bears on a weekly basis from February 2001 to the end of April 2001. The area of corn damaged by the spectacled bear was measured using a hip chain, and the number of ears of corn eaten/damaged was counted. The total area and the number of ears of corn affected were summed at the end of the study.

To evaluate the economic impact of crop raiding, we collected data from farmers on the cost of corn production. To calculate the opportunity cost of corn production lost to crop raiding spectacled bears, we gathered information on the cost of seed and pesticide as well as labor costs. Labor costs were calculated based on the number of individuals participating in the planting of corn, the number of days to plant, and the wage rate. Weeding of cornfields takes place about a month after planting and this cost was also included. All costs for each respondent were calculated per hectare of planted corn and averaged over all respondents. The average cost/ha multiplied by the total area damaged by the spectacled bear was used to calculate the economic impact of crop raiding.

HUNTING OF THE SPECTACLED BEAR. -- Due to the fact that it is illegal to hunt the spectacled bear as established in Resolution 105 of Ecuador's forestry laws and the covert nature of

hunting activities, we were not able to verify successful hunting events. The reports of hunting were compiled from interviews with key informants in the community and community park guards.

INTERVIEWS WITH KEY INFORMANTS AND DISSEMINATION OF PRELIMINARY RESULTS. -- Key informants within the community provided essential information on reports of spectacled bear depredation on livestock as well as reports of hunting. A community park guard, José Romero, served as a field assistant for this study. He was especially key to investigating reports of livestock depredation. Additionally, Armando Ruiz, a biologist at Fundación Antisana, provided information on and assessment of some of the spectacled bear depredation incidents. Preliminary results were discussed with key community informants, park guards, members of Ecuadorian NGOs involved in investigations at the study site, as well as members of the local community and high school and local government administrators.

GIS DATABASE OF SPECTACLED BEAR CONFLICT ZONES. -- GPS data points on the locations of livestock attacks and crop raiding were imported into an established GIS database of land use/cover to identify bear conflict zones. Thematic maps on land use/cover were created by Alianza Jatun Sacha – CDC, Ecuador in 1997 (scale 1:50,000) based on a morphopedalogical map of Napo Province (scale 1:500,000) published by PRONAREG-MAG and on 10 aerial photographs from August 1993 (scale 1:60,000). A multitemporal study was completed by CDC in November 2001, in which an updated map of vegetation cover was completed based on recent satellite images (Landsat 1999,2000). The study included an analysis of the change

in vegetation cover and highlighted the areas in which deforestation has taken place over the course of the last four years (1997-2001). This is a unique study in that it is the very first analysis of deforestation completed for the study area.

RESULTS

CROP RAIDING. -- From February 2001 to the end of April 2001, there were a total of eight incursions by the spectacled bear into only three of the eight cornfields (38%), one cornfield in the community of Bermejo and two in the community of Las Palmas. One hundred thirty-six plants were eaten and/or damaged in a total area of 321.69 m^2, representing 0.2% of the total cornfield area. However, farmers broke cornstalks to remove ears of corn, sometimes on a daily basis for domestic animal feed and for autoconsumption, which made the distinction between wildlife damage and damage caused by farmers more difficult to ascertain. Therefore, a selection bias may exist.

All three affected farms have forest on at least one side of the cornfield; however, only one of the five unaffected cornfields was not located at the forest edge. Even though crop damage by other species was not quantified, when farmers were asked at the end of April which species caused the most damage, without hesitation, all named the oropendula (*Psarocolius angustifrons*). Only two farmers included the spectacled bear in their ranked list (1 to 4, 1 being the worst) of crop damaging wildlife. The farmer of cornfield 8 stated that the spectacled bear was the second worst species, while the farmer of cornfield 2 stated that the spectacled bear was the third worst species. Other species mentioned among the farmers' top four offending species were the red squirrel (*Sciurus granatensis*), green jay (*Cyanocorax ynca*), black agouti (*Dasyprocta fuliginosa*), and various species of rats (Table 2.1).

TABLE 2.1. Ranked list (1-4, 1 being the worst) of crop raiding wildlife.

Cornfield ID	1	2	3	4
CF1	oropendula	red squirrel		
CF2	oropendula	red squirrel	spectacled bear	
CF3	oropendula	red squirrel		
CF4	oropendula	red squirrel		
CF5	oropendula	black agouti	rat	red squirrel
CF6	oropendula	red squirrel	green jay	
CF7	oropendula	red squirrel	green jay	
CF8	oropendula	spectacled bear	red squirrel	

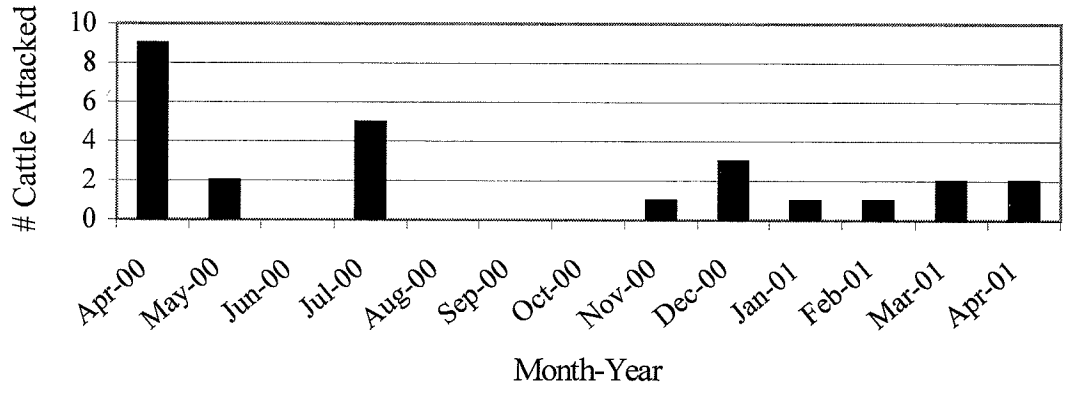
The results of the economic impact of crop raiding by the spectacled bear revealed a total impact of US$5.32, averaging $0.67/farm (Table 2.2). This is a low estimate of crop damage during the season as local farmers advised us of a small amount of additional damage that took place during the month of May. However, even if the impact doubled during May, the damage to corn crops would still be considered a relatively small amount.

TABLE 2.2. Crop damage and economic impact of damage by spectacled bears.

Cornfield ID	Date	# Plants	Area (m^2)	Area (ha)	Cost ($US)
CF1		0	0.00	0.0000	$0.00
CF2	3/15/01	42	52.75	0.0053	$0.49
	3/23/01	15	8.96	0.0009	$0.08
CF3		0	0.00	0.0000	$0.00
CF4		0	0.00	0.0000	$0.00
Total Bermejo		57	61.71	0.0062	$0.57
CF5		0	0.00	0.0000	$0.00
CF6	3/27/01	15	6.00	0.0006	$0.08
CF7		0	0.00	0.0000	$0.00
CF8	2/15/01	12	63.00	0.0063	$1.16
	3/19/01	18	72.42	0.0072	$1.33
	3/20/01	4	15.56	0.0016	$0.29
	3/30/01	10	25.20	0.0025	$0.46
	4/11/01	20	77.80	0.0078	$1.43
Total Las Palmas		79	259.98	0.0260	$4.76
TOTAL		**136**	**321.69**	**0.0322**	**$5.32**

LIVESTOCK DEPREDATION. -- The very first incident of active spectacled bear depredation on livestock ever reported in the zone took place in April 2000. From April 2000 to the end of April 2001 (13 months) there were 31 attacks on cattle attributed to the spectacled bear on 9 farms, representing 6% of the total number of cattle: 26 were fatal, 4 were wounded, and 1 was, without doubt, incorrectly attributed to the spectacled bear (See Appendix 2A for a description of cattle attacks attributed to the spectacled bear). Additional information on 4 of the 26 fatally attacked cattle could not be gathered because the employee who was responsible for the cattle at the time of the attacks no longer worked for the owner and could not be interviewed. Reported livestock depredation events (22 fatal and 4 nonfatal) took place during 8 months of the calendar year, with the most reported in April 2000 (Figure 2.2).

FIGURE 2.2. Reported livestock attacks/month by the spectacled bear from April 2000 to April 2001.



A map of the reported livestock attacks was created based on Alianza Jatun Sacha – CDC's GIS database, showing the GPS locations of the kill sites. All attacks occurred between the elevations of 2000 m and 2500 m. Furthermore, more than three-quarters of the attacks took place less than 10 meters from the forest edge. Although the resolution of the satellite images was not fine enough to detect forest edge within the "mixture of trees and pasture," there are boundaries within the mixture that are discernible in the field. The map shows two clusters of livestock attacks. The larger cluster is located in the area called Oritoyacu, adjacent to a recently deforested area labeled Arrayán. The smaller cluster is located in Las Palmas (Figure 2.3).

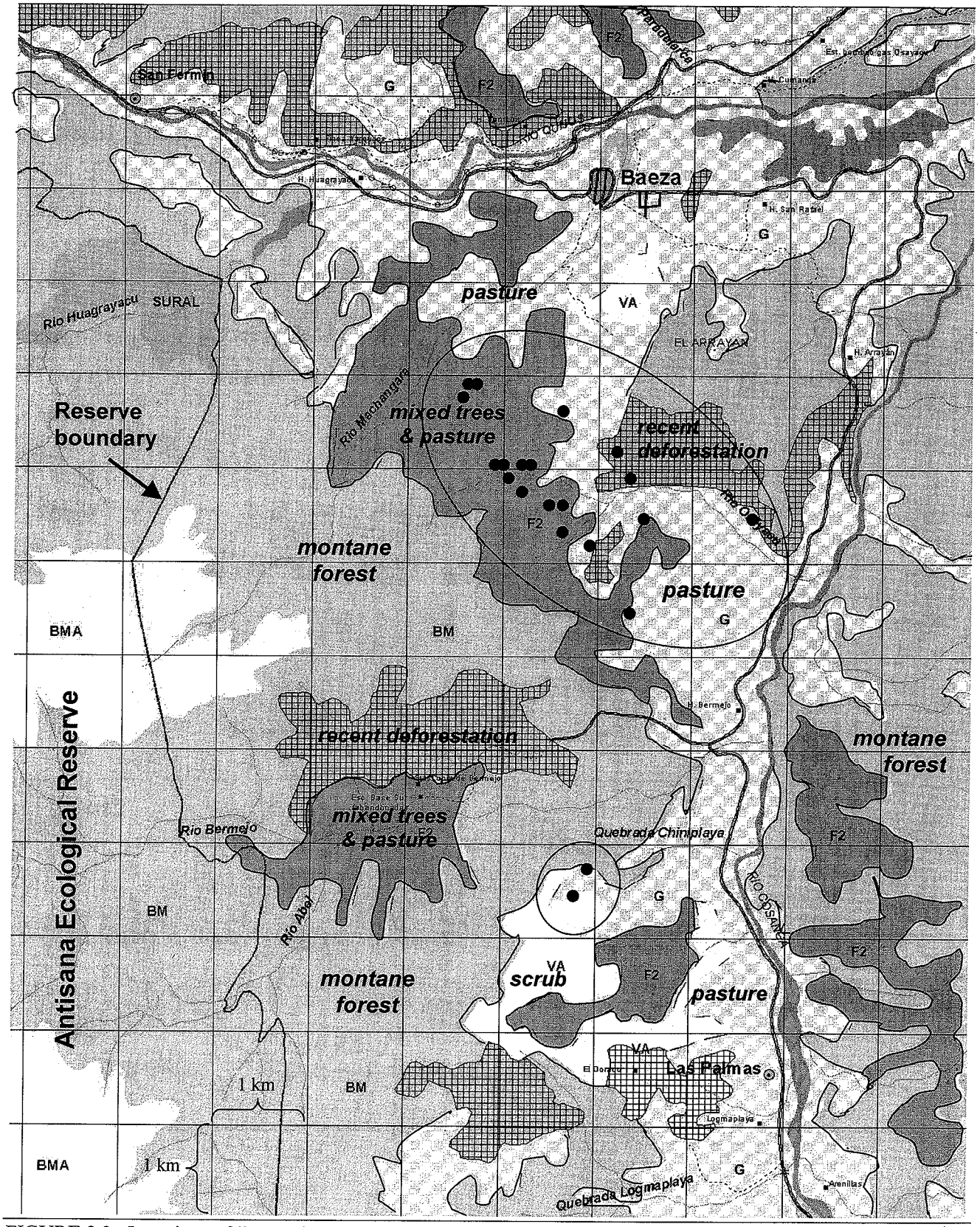


FIGURE 2.3. Locations of livestock attacks by spectacled bears, taking place at forest edges within a matrix of vegetation and pasture, labeled here as "mixed trees and pasture." Note areas of recent deforestation adjacent to livestock attacks, specifically "El Arrayán." Base map created by Alianza Jatun Sacha-CDC, Ecuador.

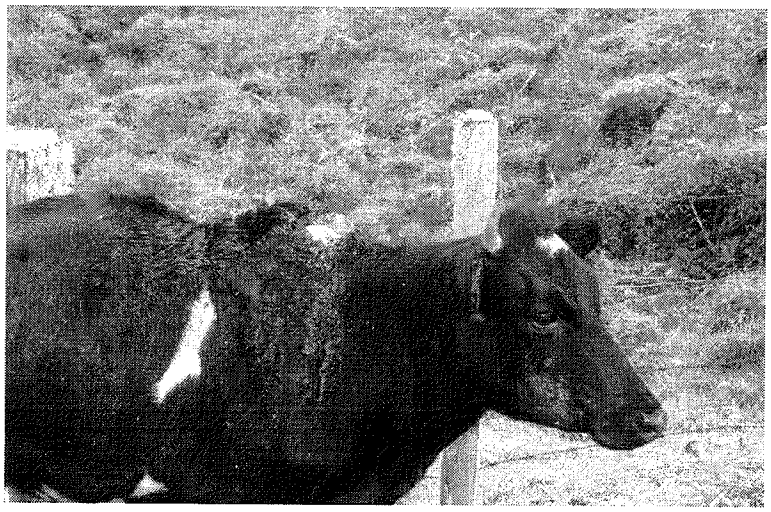
The maximum loss by a single farm was six heads of cattle. Cattle of both sexes were attacked: 3 males and 19 females, of which 7 were reportedly pregnant. They ranged in age from 1 to 7 years (Table 2.3).

TABLE 2.3. Number of cattle, sex, age, and economic impact of fatally attacked livestock by the spectacled bear.

Farm ID	# Cattle	Sex	Age		Cost ($US)
Farm 1	1	F	7.0		$400
Farm 2	1	F	1.5		$200
Farm 3	6	F	3.0		$320
		F	3.0		$320
		F	2.0	pregnant	$240
		F	2.0	pregnant	$240
		F	2.0	pregnant	$240
		F	2.0	pregnant	$240
					$1,600
Farm 4	2	F	1.3		$200
		F	6.0		$400
					$600
Farm 7	6	F	5.0		$400
		F	4.0		$400
		F	3.0	pregnant	$300
		M	2.5		$400
		F	1.0		$200
		M	2.5		$400
					$2,100
Farm 8	1	F	3.0	pregnant	$300
Farm 9	5	M	2.5		$400
		F	2.5	pregnant	$300
		F	2.5		$300
		F	2.5		$300
		F	2.5		$300
					$1,600
TOTAL	**22**				**$6,800**

The quality and quantity of evidence gathered for each report varied according to the presence or absence of an investigator [either the senior author (L.G.) or a biologist from Fundación Antisana] at the study site during or shortly after the time of attack. A complete description of the information gathered for all reported attacks on each farm affected by livestock depredation is in Appendix 2A. Spectacled bear(s) were spotted in the vicinity of cattle carcasses on one farm (11%). Seventy-eight percent of the farms had wounded cattle or fresh carcasses that showed characteristic marks of a bear attack. Carcass scarring and wounds on cattle that survived attacks, in particular, very clearly demonstrated active depredation by spectacled bears in the study area (Plate 2.1).

Plate 2.1. Surviving cow on Farm 5, Oritoyacu, Ecuador, showing characteristic wounds of a bear attack. Photograph by Armando Ruiz, Fundación Antisana.



Thirty-three percent of farms found bear tracks near carcasses. Twenty-two percent found bear scat near carcasses. Eleven percent of farms found bear beds near the carcass. Forty-four percent of farms reported trees climbed by bears in association with cattle attacks (Table 2.4).

TABLE 2.4. Evidence of spectacled bear presence/predation by farm.

	Bear seen	Carcass scars	Tracks	Scat	Bear bed	Tree nest
Farm 1			■	■		■
Farm 2			■	■	■	■
Farm 3	■	■				■
Farm 4		■				
Farm 5		■				
Farm 6		■				
Farm 7		■				
Farm 8		■				■
Farm 9		■	■			

The economic impact of livestock depredation by the spectacled bear is significant when all of the attacks for which we have cost data are taken into account (n=22). The replacement value of livestock varied between US$200 and US$400 each, depending on age, sex, and breed. Adding all the values collected in interviews with farmers, the total economic impact of the spectacled bear on the livestock in the study area was US$6,800. Each farmer lost between US$200 and US$2,100, with an average loss of US$756 (Table 2.3).

To analyze the possible causal factors for depredation events, characteristics of 13 unaffected farms from the communities of Oritoyacu, Santa Lucia de Bermejo, and Las Palmas were compared with the characteristics of the nine affected farms. Five independent variables were tested in chi-squared or Kruskal-Wallis analyses: 1) number of cattle, 2) farm size, 3) cattle location, 4) visits per week by farmers, and 5) carcass removal practices (Appendix 2B). While we cannot be certain of the precision of these data, we have no reason to expect a high or low bias. Cattle carcass removal practices ($P = 0.0353$) and cattle location (adjacent or not adjacent to forest edge) ($P = 0.0658$) were statistically significant variables that explained the difference between the affected and unaffected farms (Table 2.5).

In interviews, farmers explained that they typically butcher cattle for meat if the meat is good and can still be consumed. When the meat cannot be consumed, due to disease or other reasons, some farmers bury the carcass but others choose to leave it in the pasture.

TABLE 2.5. P-values for the independent variables tested in chi-squared or Kruskal-Wallis analyses. Asterisks mark the significant variables.

	Chi-squared		Kruskal-Wallis
Carcass removal practices	0.0301	***	
Cattle location	0.0658	***	
Farm size			0.6158
Number of cattle			0.7634
Visits/week			0.2263

HUNTING OF THE SPECTACLED BEAR. -- Between April 2000 and April 2001, there were reports of 11 bears killed in the study area. Seven were hunted and four were poisoned in a cornfield. Four were killed in Oritoyacu, four were poisoned in Oritoyacu, and three were killed very near Baeza, approximately 500 m from the town. Hunting incidents of the spectacled bear could not be confirmed.

While hunting of spectacled bears certainly existed before the emergence of livestock depredation, there seems to be a renewed interest and intensity in hunting or killing bears. For example, Maria Sol Bejarano (1999) studied attitudes toward spectacled bears in the same study area from 1997-1998 and found that the younger generation had a more positive attitude toward bears, possibly as a consequence of their education level and the influence of the conservation movement that began in the mid-1980s. She noted that the younger generation did not have an interest in hunting (Bejarano 1999). After reports of active livestock depredation surfaced, a group of young men from Baeza began to hunt spectacled bears. Spectacled bears were also at risk from a local hunter whose services were sought by

local farmers after incidents of livestock depredation. Additional risks to bears included farm employees who killed spectacled bears when bears were found on the property, a farm owner who reportedly offered to pay up to $200 for each spectacled bear killed, and farm owners, affected by livestock depredation, who intend to plant corn to attract bears to their fields so they can be killed.

DISCUSSION

We quantified the damage and economic impact of the spectacled bear on the crops and livestock around the Antisana Ecological Reserve and tested landscape features and animal husbandry practices against the pattern of livestock losses. Livestock attacks are almost never directly witnessed and can be incorrectly attributed to spectacled bears; however, predation behavior, including attack characteristics, can be used to distinguish the species of predator responsible and to differentiate between active depredation and carrion feeding. Here, we discuss the predation behavior of spectacled bears in our study area and compare it to published descriptions of spectacled bear, grizzly bear, and black bear predation behavior. After establishing sufficient evidence to confirm active depredation by the spectacled bear in the study area, we discuss the relative impacts of livestock depredation with crop raiding as well as the causal factors of livestock depredation and the resultant consequences for the spectacled bear.

The characteristics of the reported depredation events in the study area correspond with published descriptions of spectacled bear, grizzly bear, and black bear attacks on livestock. Spectacled bear kills are frequently made in the open, and the carcass is pulled to cover where the bear begins to consume the animal (Goldstein 1991). In this study, spectacled bears exhibited this behavior in approximately two-thirds of the suspected fatal attacks. Davenport (1953) reported the same behavior in black bears in Virginia. Spectacled bears have been documented to then drag the carcass to several spots until the animal is completely consumed (Goldstein 1991). The presence of spectacled bear beds, scat, and tree nests are typically found near the sight of the kill and alongside the subsequent spots where

the body is consumed. This behavior was clearly demonstrated by the livestock attack on Farm 2.

Repeat attacks in a location and/or multiple kills are also characteristics of bear depredation. In Norway, Mysterud (1980) reported that brown bears usually kill one to a few sheep at a time, and that occasionally in outlying grazing areas, many are killed. Studies of black bears found repeat attacks at the same location during the same year (Murie 1948, Horstman and Gunson 1982). Spectacled bears can also attack repeatedly and are reportedly capable of killing as many as 14 animals (Goldstein 1991, Herrera *et al.* 1994). Peyton (1980) documented reports of spectacled bears killing an entire herd. During one week at our study site in Ecuador, six out of six heads of cattle were attacked in an isolated pasture. Additionally, Knight and Judd (1983) found that 3 of 10 suspected cattle-killing grizzly bears returned to the same area at approximately the same time each year. Although this is the first year of depredation events in the study area and a pattern cannot be established, it is interesting to note that the one attack on Farm 2 took place almost a year later and approximately 300 m north of the attack on Farm 1.

Spectacled bear researchers have stated that attacks blamed on spectacled bears may actually be a result of depredation by puma (*Felis concolor*) (Peyton 1980, Mondolfi 1989). Puma, which are also found in the study area, are generally believed to have a preference for smaller animals like sheep and reportedly leave very conspicuous wounds on the neck and may also kill by biting the throat (Herrera *et al.* 1994). They frequently cover their kills and leave "scrapes" or "scratches," composed of mounds of soil, grass, or leaves and may leave scrapes around their kills (Wade and Bowns 1982). However, puma can kill larger prey like cattle by leaping on their shoulders or back, and biting the neck. Claw marks on the neck,

back, and shoulders are characteristic of this type of attack. The prey animal's neck may be broken by bites or by the animal falling from the attack. There may also be bites in the throat of this larger prey (Wade and Bowns 1982).

Bears typically kill their prey with bites to the neck and shoulders but may also break the back or neck with blows from the forepaws (Wade and Bowns 1982). Murie (1948) and Davenport (1953) both note bites and blows to the thoracic region. Murie (1948) states that the most characteristic mark on cattle attacked by a grizzly bear is a bite on the dorsal side of the neck. The lumbar region of the back is considered a vulnerable spot to a bear's bite and this type of attack was also noted.

Attack characteristics can be used to differentiate between carrion feeding and active depredation (Jorgensen *et al.* 1978). Goldstein's (1991) best evidence of active depredation by the spectacled bear were signs of struggle and blood at the kill site along with the cessation of depredation events after the suspected predatory bear was killed or the cattle were removed from the area. We believe that active depredation by the spectacled bear in our study site is best shown through accounts of surviving cattle from depredation attempts. The surviving cattle clearly show attempts of active depredation, and the description of wounds match the method of attack typically attributed to bears such as was shown in Plate 2.1. The one carcass examined days after the attack also points to active depredation by the spectacled bear, given the healthy status of the cow several days prior, the short time elapsed between leaving the cattle in the pasture and verification that an animal was dead, and the abundant evidence that the spectacled bear was feeding on the carcass, along with the absence of sign of any other predator.

It is very possible that some of the depredation events attributed to the spectacled bear were actually cases of bears feeding on livestock carcasses, as shown for the one known case on Farm 8 that was wrongly attributed to the spectacled bear. The length of elapsed time between depredation events and field verification and lack of verification are the biggest impediments to assessing whether or not spectacled bears were responsible for all the reported livestock attacks. However, there is sufficient evidence to confirm active depredation by the spectacled bear in the study area. The large number of reported kills within a limited area and time provided both the opportunity and the need for a preliminary analysis of the possible causal factors so that steps can be taken immediately to reduce future conflict.

Results of the chi-squared analysis revealed that cattle carcass removal practices were significantly different between affected and unaffected farms. Bears are known to consume carrion and may have been attracted to pastures to feed on livestock carcasses. This may have been the first step in learning how to kill live prey of the same odor, taste, and appearance as suggested in a wolf study of livestock depredation in Minnesota (Fritts 1982). Additionally, the presence of cattle carcasses in pastures may draw bears to pastures more often, thus increasing the probability of contact between bears and cattle.

Predation may be a learned behavior in some species (Jorgensen 1983). Murie (1948) first suggested that grizzly bears might acquire the cattle-killing habit by example and that some grizzlies continue to learn and carry on the tradition. Horstman and Gunson (1982) suggested that there could be a small number of predatory black bears with either a predisposition or a learned behavior different from the rest. Killing may require experience, and in bears, predation techniques may spread through a population via learning behavior

(Jorgensen 1983). On Farm 3, an adult female and cub were spotted with an adult male and there could have been a transfer of knowledge of predatory behavior between them, especially since the depredations continued even after the male was killed. Additionally, Knight and Judd (1983) reported that all age classes of grizzly bears killed sheep and that a learning process was necessary to be successful. The wounded cattle in our study area demonstrate failed depredation attempts.

Chi-squared analysis also showed that cattle location was a significant difference between affected and unaffected farms. Farmers who pastured cattle adjacent to the forest edge were more greatly affected. Fritts *et al.* (1992) remarked that suitable terrain for predators is a variable that could influence the location of depredation events and that wolf attacks on livestock were particularly severe in pastures with a combination of field and forest. The majority of reported livestock attacks in our study area took place at the forest edge, with areas that present a mosaic of pasture and patches of vegetation as was shown in Figure 2.3.

The claim that habitat reduction is leading to increasing livestock depredation events by the spectacled bear may also be a factor at our study site and warrants further study for several reasons. First, deforestation has taken place in the study area in the past four years. It has reduced the size of a remnant forest patch, labeled Arrayán in Figure 2.3, which is adjacent to the majority of livestock attacks. Second, spectacled bears have raided corn crops and have been killed on the opposite side of this forest remnant, so it is clear that bears are crossing through pasture areas and entering this patch of forest. Third, deforestation, to create more pasture for livestock, may increase the distance bears must travel to access the

resources in this patch and thus increase the probability of contact between livestock and bears in the intermediate pasture.

It remains to be seen if accounts of livestock attacks by bears in the area will continue, as the year 2000 marked the first reports of active livestock depredation by spectacled bears in the study area. Literature on spectacled bear-human conflict typically emphasized crop raiding (Peyton 1999). According to the local population, crop raiding by spectacled bears has occurred for the past 30 years. In the past, people planted more than 10 hectares of corn each. Now the average cornfield size is two hectares and some are deciding not to plant corn at all. The results of this study indicate that the impact of livestock depredation is far greater than the impact of crop raiding. Our results on crop raiding concur with a 1994 study on spectacled bear crop raiding in the community of Bermejo that concluded that the impact of crop raiding by spectacled bears is minimal (Reltig 1994). Farmers complain about both crop raiding and livestock attacks, but the consequences of the conflict for bears are particularly severe for livestock attacks.

Illegal hunting of spectacled bears is uncontrolled in the study area. If all 11 accounts of hunting are true, anywhere from 6% to 22% of the Antisana spectacled bear population could have been eliminated. It is unclear if commercial hunting is also an important factor in the study area. Bejarano (1999) found that 77% of people surveyed said that either the sale of meat from wild animals does not occur or they do not know if it occurs. Hunting of bears in many other regions of the world with bear-livestock conflict is also a reality (see citations in literature review section).

In addition to illegal hunting of spectacled bears in forested habitat, hunters may also take advantage of cornfields as an attractant for spectacled bears. For example, local people

in northern Peru advised a hunter whenever a spectacled bear was in a cornfield, and, in this way, the hunter reportedly killed 11 bears (Peyton 1980). Farmers in Peru have also placed parathion in baits to poison bears in their cornfields. In Ecuador, some of the owners whose livestock were depredated intend to plant corn to attract spectacled bears in order to shoot them. Already, four bears were reportedly poisoned in the cornfield of an owner whose livestock was affected by the spectacled bear.

MANAGEMENT RECOMMENDATIONS

FARM MANAGERS. -- Farmers should implement changes to reduce potential conflict with spectacled bears. One economically feasible management recommendation is for farmers to bury the carcasses of their dead livestock and not to leave them in pastures. Hopefully, this will prevent livestock attacks on additional farms. Farmers can also become involved in better land use management practices. By focusing on improving degraded pastures and more sustainable grazing practices such as pasture rotation, farmers may be able to use restored pastures closer to their houses, thus further from the forest edge, and graze their cattle in pasture for a longer amount of time with higher production, thereby controlling the cycle of continuous deforestation. The current extensive cattle management practices are putting pressure on the forest and should be reduced wherever possible. Farmers should also consider discontinuing the use of pastures adjacent to bear habitat, as cattle are vulnerable in these locations. Additionally, farmers could restrict access of their cattle to forest edges, perhaps by erecting electric fences on the farms that have been most affected by spectacled bear depredation. Electric fences are relatively inexpensive and have been shown to be effective in protecting livestock from large carnivores (Sillero-Zubiri and Laurenson 2001). We do not recommend that farmers cut remaining fruit trees in their pastures. This could have a negative effect on environmental conditions, such as soil erosion, and there is insufficient data to suggest that the removal of fruit trees could reduce livestock attacks by spectacled bears.

PARK MANAGERS. -- Park managers should monitor livestock depredation events. It is very important that data continue to be collected on suspected livestock depredation. One of the

community park guards could be trained and put in charge of collecting these data. Farmers could be made aware of the need to verify depredation events and urged to contact the community park guard so that an assessment may be conducted immediately.

Direct compensation for livestock depredation by spectacled bears could be considered as a means to decrease tension between local residents and bears. Compensation programs exist in many states in the U.S. and elsewhere in the world but currently do not exist in Ecuador. As one example, Wisconsin's Wildlife Damage Abatement and Claims Program (WDACP) emphasizes damage prevention and provides compensation for crop damage by deer, black bear, goose, and turkey and livestock depredation by black bears and wolves (Stowell and Willging 1992). Current abatement techniques for bear damage are carried out by the Wisconsin Department of Natural Resources (WDNR) and include electric fencing, scare devices, repellents, and trapping and translocating problem bears (Stowell and Willging 1992).

A compensation program, such as Wisconsin's, may be difficult to implement in Ecuador for several reasons. First, annual costs to run a damage abatement and claims program are high ($250,000 in Wisconsin) and may not be economically feasible for the country of Ecuador. It is also unknown if and to what extent livestock depredation by spectacled bears exists in other regions of the country, so estimating costs on a country-wide level would be impossible. Second, in the study area, specifically, the mountainous and rugged physical environment could make timely identification and investigation of claims difficult to accomplish. Third, compensation alone does not address the underlying problem and allows the conflict to continue (Sillero-Zubiri and Laurenson 2001). For these reasons,

efforts should be focused on understanding the factors that influence depredation events so that management recommendations can be made to decrease livestock attacks.

Finally, illegal hunting and illegal deforestation need to be addressed. Currently there is no enforcement of Ecuador's prohibition of spectacled bear hunting and no monitoring of deforestation in the communities around the reserve. As both illegal hunting and deforestation are two of the greatest perceived threats to the survival of the spectacled bear, more active management needs to be taken in these areas.

RESEARCHERS. -- Researchers should continue to investigate spectacled bear-human conflict in the study area. If accurate records of livestock depredation events are kept, researchers can compile, review, and analyze the data. In this way, an increasing database of farm-level characteristics of affected and unaffected farms can be established and analyzed again in the future, with a larger sample size. Research on the availability of seasonal foods, especially fruit trees in the family Lauraceae, should also be investigated and incorporated into spatial models of depredation locations. A possible link between fruit trees and depredation events could be established in two complementary studies. First, the distribution, fruiting phenology, and use of Lauraceae species should be studied in areas surrounding farms and extending up toward the reserve to confirm the upper limit and seasonal availability of these species in the study area. Seasonal variation in fruit crop production as well as areas of deforestation that have reduced the availability of these fruit resources could be linked to depredation events as suggested in human-bear conflict literature. In support of such a study, Alianza Jatun Sacha – CDC's analysis of vegetation change, which was the first of its kind in the study area, could be repeated in another four years to give two consecutive series of

deforestation data. Second, a survey of species in the Lauraceae family could be conducted on the farms since pastures are often a mosaic of grasses, remnant trees, and small patches of vegetation. The presence of fruit trees in pastures could serve to attract bears to the area and could be linked to depredation events. The attraction of the bears to these trees in pastures may also be an indication of the critical nature of this food resource for the bears, since less of these resources may be in the forest as a result of forest clearing; thus, it may signal the need for conservation of such food resources as an essential component of conservation of spectacled bears.

LITERATURE CITED

Bejarano R., M. S. 1999. Protección a la vida silvestre: ¿Los buenos juicios prácticos de los campesinos pueden contar? El caso de la zona entre Baeza y Cosanga, provincia del Napo, Ecuador. Master's thesis for FLACSO-Ecuador. Quito. 98 pp.

Cozza, K., R. Fico, M. L. Battistini, and E. Rogers. 1996. The damage-conservation interface illustrated by predation on domestic livestock in central Italy. Biological Conservation 78(3): 329-336.

Davenport, L. B. 1953. Agricultural depredation by black bears in Virginia. Journal of Wildlife Management 17: 331-340.

Dorrance, M. J. and L. D. Roy. 1976. Predation losses of domestic sheep in Alberta. Journal of Range Management 29: 457-460.

Fritts, S. H. 1982. Wolf depredation on livestock in Minnesota. Dept. Int. Fish & Wildl. Service: 11, Washington, D. C., U. S.

Fritts, S. H., W. J. Paul, L. D. Mech, and D. P. Scott. 1992. Trends and management of wolf livestock conflicts in Minnesota, Fish and Wildlife Service, Washington, D. C.

Fundación Antisana. 1998. Diagnóstico general de la Cuenca del Rio Cosanga. FUNAN, Quito, Ecuador.

Garcia-Gaona, J. G. 1997. Damages attributed to the brown bear in Spain: The case of Asturias. Int. Conf. Bear Res. & Manage. 9(2): 97-105.

Gillin, C. M., I. Chestin, P. Semchenkov, and J. Claar. 1997. Management of bear-human conflicts using Laika dogs. Int. Conf. Bear Res. & Manage. 9(2): 133-137.

Goldstein, I. 1991. Are spectacled bear's tree nests feeding platforms or resting places? Mammalia 55(3): 433-434.

_____. 1991. Spectacled bear predation and feeding behavior on livestock in Venezuela. Studies on Neotropical Fauna and Environment 26(4): 231-235.

Herrera, A., J. Nassar, F. Michelangeli, J. P. Rodriguez, and D. Torres. 1994. The spectacled bear in the Sierra Nevada National Park of Venezuela. Int. Conf. Bear Res. & Manage. 9: 149-156.

Horstman, L. P. and J. R. Gunson. 1982. Black bear predation on livestock in Alberta. Wildlife Society Bulletin 10(1): 34-39.

Inglis, J. E. 1993. An analysis of human-black bear conflicts in Algonquin Provincial Park, Ontario (1973-1990). In: Proceedings 11th Eastern Black Bear Workshop 11: 108-123.

IUCN. 1996. IUCN Red List of Threatened Animals. IUCN. Gland, Switzerland.

Jorgensen, C. J. 1983. Bear-sheep interactions, Targhee National Forest. Int. Conf. Bear Res. & Manage. 5: 191-200.

Jorgensen, C. J., R. H. Connolly, R. J. Hamilton, and O. T. Sanders. 1978. Management of black bear depredation problems. Eastern Black Bear Workshop.

Knight, R. R. and S. L. Judd. 1983. Grizzly bears that kill livestock. Int. Conf. Bear Res. & Manage. 5: 186-190.

Mace, R. D., J. S. Waller, T. L. Manley, L. J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33(6): 1395-1404.

McLellan, B. N., F. W. Hovey, R. D. Mace, J. G. Woods, D. W. Carney, M. L. Gibeau, W. L. Wakkinen, and W. F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63(3): 911-920.

Mech, L. D., E. K. Harper, T. J. Meier, and W. J. Paul. 2000. Assessing factors that may predispose Minnesota farms to wolf depredations on cattle. Wildlife Society Bulletin 28(3): 623-629.

Mondolfi, E. 1989. Notes on the distribution, habitat, food habits, status and conservation of the Spectacled Bear (*Tremarctos ornatus* Cuvier) in Venezuela. Mammalia 53(4): 525-544.

Murie, A. 1948. Cattle on grizzly bear range. Journal of Wildlife Management 12(1): 57-72.

Mysterud, I. 1980. Bear management and sheep husbandry in Norway, with discussion of predatory behavior significant for evaluation of livestock losses. Bears - their biology and management. C. J. Martenki and K. L. McArther, Bear Biology Association. 3.

Nass, R. D., G. Lynch, and J. Theade. 1984. Circumstances associated with predation rates on sheep and goats. Journal of Range Management 37: 423-426.

Ospina, P. and A. Carrillo. 1999. Tendencias de los procesos de colonización en Cosanga (1970-1998). Prepared for Heifer Project International-Ecuador, Quito, Ecuador.

Peek, J. M., M. R. Pelton, H. D. Picton, J. W. Schoen, and P. Zager. 1987. Grizzly bear conservation and management: a review. Wildlife Society Bulletin 15(2): 160-169.

Peyton, B. 1980. Bears, *Tremartcos ornatus*, in Peru. Journal of Mammalogy 61(4): 639-652.

____. 1987. Habitat components of the spectacled bear in Machu Picchu, Peru. Int. Conf. Bear Res. Manage. 7: 127-133.

____. 1999. Spectacled Bear Conservation Action Plan. Bears. In C. Servheen, S. Herrero and B. P. (compilers). Status Survey and Conservation Action Plan. IUCN, Gland, Switzerland and Cambridge, UK.

Peyton, B., E. Yerena, D. I. Rumiz, J. Jorgenson, and J. Orejuela. 1998. Status of wild Andean bears and policies for their management. Ursus: 87-100.

Proyecto PLAN - Ecuador. 1998. GL-CRSP: Community Planning for Sustainable Livestock-Based Forested Ecosystems in Latin America. Annual Report of Activities - PLAN - Ecuador. Quito, Ecuador.

____. 2000. GL-CRSP: Community Planning for Sustainable Livestock-Based Forested Ecosystems in Latin America. Annual Report of Activities - PLAN - Ecuador. Quito, Ecuador.

Reltig, M. F. 1994. Estudio efecto del oso de anteojos sobre los cultivos de maíz en las comunidades de Bermejo, Cuyuja, y Sardinas. Cooperación de Conservación y Desarollo (CCD), Quito, Ecuador.

Rogers, L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. North Am. Wildl. and Nat. Resour. Conf. 41: 431-438.

Roy, L. D. and M. J. Dorrance. 1976. Methods of investigating predation of domestic livestock. A manual for investigating officers. Alberta Agriculture Plant Industry Laboratory, Edmonton, Alberta.

SAS version eight. 1999. SAS Institute Inc., Cary, NC, USA.

Sillero-Zubiri, C. and M. K. Laurenson. 2001. Interactions between carnivores and local communities: conflict or co-existence? In J. L. Gittleman, S. M. Funk, D. Macdonald, and R. K. Wayne (Eds.). Carnivore Conservation, pp. 282-312. Cambridge University Press, Cambridge, England.

Southgate, D. and C. F. Runge. 1990. The institutional origins of deforestation in Latin America. University of Minnesota, St. Paul, Minnesota.

Stowell, L. R. and R. C. Willging. 1992. Bear damage to agriculture in Wisconsin. Proceeding of the Eastern Wildlife Damage Control Conference. 5: 96-104.

Suarez, L. 1989. Seasonal distribution and food habits of the spectacled bear (Tremarctos ornatus) in the highlands of Ecuador. Studies on Neotropical Fauna and Environment 23(3): 133-136.

Wade, D. A. and J. E. Bowns. 1982. Procedures for evaluating predation on livestock and wildlife. Washington, D. C., Texas Agricultural Extension Service, The Texas Agricultural Experiment Station of the Texas A&M University System, U.S. Fish and Wildlife Service.

Woodroffe, R. and J. R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. Science 280(5372): 2126-2128.

Yerena, E. 1998. Protected areas for the Andean bear in South America. Ursus 10: 101-106.

APPENDIX 2A. Description of depredation events by farm. Farms are ordered by location.

FARM 1 – In the community of Las Palmas, one cow was reportedly attacked and eaten in May 2000. During that time period, the farmer checked on the cows every 5 or 6 days. The cow was located in a 4-hectare patch of pasture, surrounded by vegetation and 1.59 km uphill from the farmer's house. When the farmer discovered the dead cow, photographs of the bear tracks, scat, and the cow carcass were taken. A nearby tree (*Hyeronima macrocarpa*, Euphorbiaceae) was climbed and parts of the cow were found in the tree nest.

FARM 2 – Almost one year later (March 2001), a neighboring farm's cow was attacked at a spot 300 m north of the one described above. The employees brought 4 cows to an isolated pasture with the intention of leaving them there for one week to graze and then bringing them back down to lower pastures. Two days later, a neighbor reported seeing three of Farm 2's cows near her own, in a lower pasture. Four days after initially bringing the cows up to the pasture, the employees checked on the cows and discovered one missing. Its carcass was found about 20 m within the forest. At this location, there were two oval impressions at the base of trees, with soft gray scat next to the beds. Adjacent to the beds was a climbed strangler fig tree. On the other side of the fig tree, there was an eaten bromeliad next to part of the cow's vertebrae. The carcass was reportedly partially consumed. Four hours later, the employees returned with a local bear hunter. The carcass had been dragged an additional 100m into the forest. We were notified the following day and went to the location with our field assistant and the employees. At this point, the carcass had been almost totally consumed, beginning below the neck and ending before the hindquarters. The intestines

were found near the area of attack and there was bear scat with contents that appeared to be bamboo (*Chusquea* sp.). There was no evidence of another predator at the site.

FARM 3 – This is the first of six affected farms in the area called Oritoyacu that borders the remnant forest patch of Arrayán. Descriptions of events were taken from the farmer's recollection. My field assistant and I were shown the location of six cow remains (skeletons). One attack occurred in April 2000, four in July 2000, and the last in January 2001. After two attacks, the owner and/or employee saw a spectacled bear in the vicinity of the carcass. After one cow was already dead, a male bear was spotted with a female and cub in the vicinity. The adult male was subsequently killed. The farmer reported a climbed tree near one attack, sign of spectacled bear's claw marks on the cow's shoulder and back for all six attacks, and a cow's carcass at the bottom of a hill in three attacks.

FARM 4 – Two cows were attacked on this farm, in February 2001 and April 2001. The owners found one cow still alive but seriously wounded. The cow's back and shoulder were eaten. The owners killed the cow and were going to inject the cow carcass with the poison, Furadan, but decided to butcher the cow there and take the meat for food. After the cow was butchered, the skin was left at the bottom of a hill very near the site of a previous cow attack on Farm 3. The owners found the next cow in a ravine next to a small area of pasture. They still keep their cows in this location but have placed dogs in the pasture to guard the cattle. The owners also reported that in April 2000, a cow had died from fever and a spectacled bear dragged the body and ate it. They saw bear tracks near the carcass.

FARM 5 – On this farm, two cows were attacked and survived, the first in July 2000 and the second in April 2001. The first wounded cow was assessed by Armando Ruiz, a biologist at Fundación Antisana. Upon hearing the reports of spectacled bear predation on cattle in the study area, his first thought was that a puma was responsible for the attack and that a bear probably ate from the dead carcass, leaving prints, and was wrongly blamed for the attack. When he examined the injured cow, he observed the claw marks and deep bite wounds in the dorsal thoracic/lumbar region and concluded that it was indeed the result of an attack by a spectacled bear.

FARM 6 – One cow was wounded at the forest edge in November 2000 and showed characteristic marks of a bear attack.

FARM 7 – Six heads of cattle have been attacked on this farm; one survived. Two attacks occurred in April 2000, one in May 2000, and three in December 2000. Of the five fatal attacks, one showed claw marks on the back but the rest was not eaten, two were partially eaten, one was found near a stream, one had been placed in an isolated and small pasture and its carcass was found downhill near a stream.

FARM 8 – Five attacks have been reported but the current employee was present only during the last. In March 2001, the cow was attacked and dragged down the hill to an isolated section where its back was fed upon, and a tree was climbed, by the bear. The same employee also reported a missing cow and said that a spectacled bear had attacked it; however, my field assistant and I saw this cow on the property of a neighbor. It had recently

died and had not been attacked by any wild animal. A few weeks later all that was left of the cow was its skeleton. The neighbor reported that a bear had scavenged the carcass.

FARM 9 – This farm was located to the north and west of Oritoyacu. These incidents took place at the highest elevation of all the attacks (2500m). Here, the employee brought six heads of cattle to this pasture in April 2000. When he returned one week later, five were dead and one was badly wounded. The employee said that he saw fresh bear tracks, the backs of all five dead cattle were broken, the back and legs were eaten. The intestines were removed from the body. All five carcasses were dragged down a hill to a stream. The owner does not put livestock in this pasture anymore.

APPENDIX 2B. Data for chi-squared and Kruskal-Wallis tests: comparing farms affected by livestock depredation and farms unaffected by livestock depredation.

Farm ID	# Attacks (killed or wounded)	# Months affected	# Cattle	Farm size	% pasture	Pasture (ha)	Forest (ha)	Carcass removal	Cattle location (adjacent to forest?)	Visits/week
AFFECTED										
Farm 1	1	1	17	30	0.67	20	10	leave	Y	1
Farm 2	1	1	22	30	0.50	15	15	bury	Y	1
Farm 3	6	4	200	258	0.66	170	88	bury	Y	2
Farm 4	2	2	8	47	0.53	25	22	leave	Y	1
Farm 5	2	2	12	37	0.54	20	17	leave	Y	7
Farm 6	1	1	80	70	1.00	70	0	leave	Y	1
Farm 7	6	4	96	133	0.75	100	33	leave	Y	7
Farm 8	5	2	36	80	0.50	40	40	leave	Y	2
Farm 9	6	1	6	60	0.30	18	42	leave	Y	1
Average	3.33	2	53.00	82.78	0.61	53.11	29.67			2.56
UNAFFECTED										
	0	0	60	400	0.50	200	200	bury	Y	7
	0	0	100	150	1.00	150	0	leave	N	1
	0	0	80	150	0.40	60	90	bury	Y	6
	0	0	10	64	0.61	39	25	leave	Y	7
	0	0	50	60	0.67	40	20	bury	Y	3
	0	0	11	56	0.29	16	40	bury	Y	1
	0	0	50	47	0.43	20	27	leave	Y	2
	0	0	9	36	0.19	7	29	bury	Y	1
	0	0	20	35	0.91	32	3	bury	Y	7
	0	0	36	33	1.00	33	0	bury	N	7
	0	0	6	31	0.55	17	14	bury	N	7
	0	0	20	30	0.50	15	15	leave	Y	1
	0	0	8	28	0.71	20	8	bury	N	-
Average	0	0	35.38	86.15	0.60	49.92	36.23			4.17

APPROVED

Major professor: Dr. Timothy Moermond

Title: Professor of Zoology

Date: January 18, 2002

Signature: