CRITERIA FOR ASSESSING HABITAT QUALITY OF THE SPECTACLED BEAR IN MACHU PICCHU, PERU

BERNARD PEYTON,[1] 460 NW Elk Ridge, Hamilton, MT 59840

Abstract: Criteria that could be used to determine habitat quality for the spectacled bear (*Tremarctos ornatus*) were defined in the Historical Sanctuary of Machu Picchu and 3 adjacent valleys. Habitat quality was determined by a comparison of vegetative and environmental data between regularly selected sites and sites that contained bear sign. Good grassland habitat was found to have hiding cover within 25 m in subalpine paramo, 35 m in rain paramo, and 40 m in steppe habitat. Desirable criteria for slope were maximum values that ranged between 26.6° and 46.0° for the 3 habitats. Paramo sites used for feeding were found to have at least 3 food species with a combined importance value of 6.0 in subalpine paramo and 9.0 in rain paramo habitat. Similar sites in steppe habitat had at least 2 food species with a combined importance value of 1.4. Four desirable criteria for forested habitats were based on parameters from sites used by traveling or feeding bears. Good quality sites for traveling bears had slopes less than 34.6° and less than 49% vegetation cover between 0.15 and 1 m above the ground. Forested sites that met criteria for good food quality had at least 2 bear foods with a combined importance value of at least 3.8. Better habitat with less human disturbance was found in the Lucumayo and Santa Teresa drainages bordering the Sanctuary than in the Sanctuary.

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Spectacled bear habitat has diminished during the last 30 years in Peru (Brack-Egg 1961, Erickson 1966, Grimwood 1969, Peyton 1980) to the point that national parks are now the best means for protecting this threatened species (Thornback and Jenkins 1982, Peyton 1981). From April to November of 1979 and 1982, I studied spectacled bear habitat in the Historical Sanctuary of Machu Picchu and 3 adjacent valleys. The primary objectives were to establish criteria for assessing habitat quality and to compare the Sanctuary with the adjacent areas to determine the degree to which these areas provided spectacled bears with food, hiding cover, traveling ease, and wilderness.

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STUDY AREA

The study area includes the National Historical Sanctuary of Machu Picchu, 70 km northeast of the town of Cuzco (Department of Cuzco, Province of Urubamba, and District of Machu Picchu), and 3 adjacent valleys to the east, north, and northwest of the Sanctuary (Fig. 1). These 3 valleys were the Santa Teresa Valley (Province of La Convencion, District of Santa Teresa), the Lucumayo or upper Quillabamba Valley (Province of La Convencion, District of Huayopata), and the Piri Valley (Province of Urubamba, District of Ollantaytambo). The study area includes elevations between 2,000 m and the permanent snowline (4,500–4,700 m). Elevations from 950 to 2,000 m were heavily inhabited and cultivated and were not available to bears.

METHODS

Site Location

To determine habitat quality, we recorded data from 143 regularly located sites (regular sites) and 135 sites where we encountered bear sign during field work (bear sites). Sample sites were located by using a stratified sampling method (Ohmann and Ream 1971). A grid of 9 areas, each 47.6 km^2, was superimposed on a planigraphic map of the study area with a scale of 1:50,000. For 72 days we sampled 15 regularly selected sites for each 47.6 km^2 area of the Sanctuary. Sites were sampled for 40 days in 3 47.6 km^2 areas located in 3 adjacent valleys. In each of the 9 areas, we attempted to walk in a straight line from the lowest elevation to the highest elevation below snowline. Trails cut during the field trips allowed access to all forested areas. Regular sites were located with an altimeter along the path of travel at predetermined elevations. The elevational interval that separated regular sites was determined daily by dividing projected elevational progress by the number of sites to be sampled. The interval varied from 100 to 200 m in grasslands and 50–150 m in densely vegetated forests.

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[1]Present address: Museum of Vertebrate Zoology, University of California, 2595 Life Science Building, Berkeley, CA 94720.

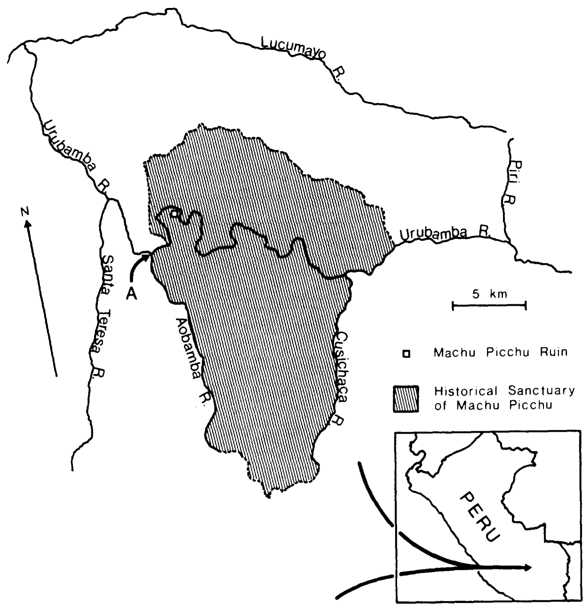

Fig. 1. Location of the Historical Sanctuary of Machu Picchu, Peru and adjacent valleys.

Bear sites contained evidence of bear sign (e.g., scats, tracks, daybeds, feeding sign, climbing sign, tree nests, and marking sign). We found them while locating regular sites and confirmed bear signs by locating supporting evidence such as hair.

Data Collection

Environmental and vegetative data from regular sites were collected at site reference points positioned at the predetermined elevations and 10 m to the side of any trail. Reference points for bear sites were located within 1 m of the evidence of bear sign. A bear sign was considered to be in a different site than a neighboring sign if the 2 signs were separated by at least 100 m. I determined that a bear selected certain site attributes by comparing the vegetation, environmental characteristics, and degree of human use between regular sites and bear sites and compared sites within the same habitat to define criteria for determining habitat quality. The following environmental data were recorded for all sites: location, elevation, aspect, topography, slope, and distance to water. Aspects were recorded according to membership in 1 of 8 groups. Each group consisted of a 45° exposure. Similarly, distance from site reference points to water was recorded as 1 of 4 intervals: < 10 m, 10–50 m, 50–300 m, and > 300 m. Habitat types were determined for sites following the procedures I used in earlier studies (Peyton 1984, 1986). The distance between a bear sign and the point from where it was detected (sighting distance) was recorded on all bear sites.

Vegetation characteristics were measured along transect lines on all regular sites and on 87 bear sites. Vegetation data were not recorded on 48 bear sites due to time limitations. Transects were perpendicular to the fall line of the slope, with its midpoint touching the site reference point. Transect length was 20 m in grasslands, 15 m in high-elevation forests, and 20 m in the more species-rich, lower-elevation forests. We read 3.74 km of transect lines.

The percent cover and relative cover (Barbour et al. 1980) of vegetation was measured using a point intercept method described for grassland use (Lindsey 1955), which I adapted to work in forests and grasslands (Peyton 1984). At 20-cm intervals along the transect, I used a stick to help me envision a vertical projection and recorded, at each 20-cm interval, the number of times that the imagined vertical projections contacted each plant species and the abiotic component of litter. These contacts were further recorded according to their position above the ground in 4 height zones: substrate–15 cm, 15 cm–, 1–5 m, and > 5 m. The percent cover of all living and dead vegetation for a height zone was estimated in the following manner: adding the point interceptions in a height zone, dividing this sum by the number of vertical projections in the transect, and then using the resulting numbers to estimate vegetation density in the 4 height zones. Dividing the number of point interceptions recorded for bear forage plants by the number of point interceptions recorded for all living plants provided an estimate of the relative cover of plant species known to be eaten by spectacled bears (Peyton 1980, 1981, 1984). The relative density of forage plants was estimated (Barbour et al. 1980) using a plot-frame method (Bormann 1953). Twenty quadrats were placed at regular intervals along the transect tape and the number of rooted plants of a species within a 0.5-m^2 rectangular quadrat was recorded. Density measurements for fruit-producing trees with a diameter at breast height (DBH) greater than 10 cm were taken at 4 equidistant intervals along the transect using a point-center distance method (Cottam et al. 1953). All density measurements were standardized to a 10-m^2 area. The relative density of forage species was calculated by dividing the number of each forage species per 10 m^2 by the total number of plant species in the standardized area. The relative cover and relative density measurements for each bear food species in a site were averaged and then multiplied by 100 to calculate the importance values, which were used as the measures of food abundance. At each site, food abundance was estimated for foods that were were eaten throughout the year and for foods that were available only seasonally. The number of bear foods found in the point interception and plot frame count was also recorded for each site. The data on bear foods were recorded to determine if bear sites had a greater number and abundance of foods than regular sites and if the condition that characterized sites in the Sanctuary also characterized those in adjacent areas. Biases introduced by unequal transect lengths were reduced by multiplying all vegetative measurements from 20-m transects by 0.75. Biases inherent in the relationship between the size and distribution of forage species and the means of measuring their abundance were reduced by averaging the relative cover and relative density values of each forage species (see Peyton 1986 for a discussion of the advantages and disadvantages of the methods). The canopy height was taken in forested sites at 4 equidistant points along the transect with a range finder. The average of these measurements was used as an estimate of canopy height.

The boundaries of the areas occupied by humans and their agricultural activities (e.g., villages, potato and corn fields, pastures occupied by livestock) were drawn on a planigraphic map of the study area (scale 1:50,000). These demographic locations were based on visual observations I made of the study area. The extent of human use in the study area was estimated by laying a grid over this map and counting whole and part squares within areas I determined to be occupied by humans. I converted the estimate of the human use area to a proportion by dividing the number of squares within the human use areas by the total number of squares occupied by the study area. I chose a grid size that represented 6.25 ha on the ground, the smallest area in which I could determine human use given the scale of existent maps.

The locations of spectacled bear sign and the boundaries of undisturbed areas were also plotted on the map. Spectacled bears were assumed to occupy undisturbed areas that contained habitat the species was known to inhabit elsewhere in the study area. The proportion of the study area occupied by spectacled bears was estimated in the same manner described for estimating that proportion of the study area occupied by humans.

In all sites, the type of human use was recorded, and the degree of human use was subjectively rated on a scale from 0 (no human use) to 3 (high human use). To estimate the vegetative and topographic cover available for hiding spectacled bears, a rectangular cloth model was placed with a long edge touching the site reference point. The model was 100 by 125 cm and was divided into 20 equal squares. The distance to the cloth model was measured from a point where 90% of the model was obscured by topography or vegetation. This measurement was taken to the nearest decimeter from 4 directions: uphill and downhill from the model along the slope line and to the right and left of the model on a line perpendicular to the slope line. The average of the 4 measurements was used as an index of hiding cover (Thomas et al. 1976, Mollohan 1985).

Habitat Quality

Criteria for determining habitat quality were defined for vegetative and environmental attributes that differed significantly between bear sites and regular sites. Criteria selected from attributes that contributed most to habitat quality were based on correlations between attributes. Sites were judged to be excellent if they met all requirements, fair if they met 1 requirement, and poor if they met no requirements. Minimum values were computed for attributes whose quality was positively related to an increase in that attribute. This value was defined as 1 standard deviation (SD) below the mean of an attribute in this group. Conversely, maximum values were defined as 1 SD above the mean of an attribute whose quality was negatively related to an increase in that attribute. A site was considered to be of good quality if 2 of the vegetation or environmental attributes had values that met minimum and maximum requirements. This system of defining habitat quality did not take into account preferences of bears based on individual learning or their physiological condition, sex, or age.

RESULTS AND DISCUSSION

Environmental Attributes of Bear Sites

Bear sign was found at 135 sites between the elevations of 2,020 and 4,170 m. These sites were located within 6 of the 9 habitat types of the study area (subalpine paramo, rain paramo, high steppe, very humid forest above 2,700 m, and humid and very humid forests below 2,700 m). Bear sign was not found in the tundra, low steppe, or dry forest habitat types, even though the latter 2 habitats were known to support bears elsewhere in Peru (Peyton 1980, 1981).

Although regular sites were sampled evenly among the 8 aspect groups (X^2 test, df = 7, P = 0.496), the distribution of aspects for bear sites was significantly different than that of regular sites (X^2 test, df = 7, P = 0.0003; Fig. 2). The cells that contributed most to the X^2 statistic reflect the fact that 40.7% of the bear sign was found on north- and west-facing slopes in the northwest quarter of the Sanctuary and the Lucumayo drainage, the 2 wettest areas of the study area. No difference was noted in the distance to water from the reference points of bear sites and regular sites (X^2 test, df = 3, P = 0.497).

Likewise, the bear site and regular site topography differed (X^2 test, df = 7, P < 0.001), with ridgelines and upper slopes used in greater proportion than their availability and lower slopes and streambeds used less than their availability (Fig. 3). In grassland habitat, bear sites comprised 54% of the sites sampled on upper slopes and ridges. The widespread presence of agriculture on valley bottoms, lower slopes, and midslopes might explain why only 12% of the grassland bear sites were encountered on these topographical features.

Tracks and marked trees on ridgelines comprised 78% of the bear sign encountered in forests above 2,700 m and 23% of the sign found below 2,700 m, indicating the importance of ridgelines for traveling bears. Ridgelines may have been selected because vegetation interfered less with movements, and the moderate slopes allowed the animals to conserve energy. The slope was less on ridgelines ($\bar{x}$ = 22.8°) than on adjacent hillsides ($\bar{x}$ = 39.5°) and ravines ($\bar{x}$ = 31.2, LSD range test, df = 2, 44; P = 0.01). Slopes were less in bear sites ($\bar{x}$ = 24.7°) than in regular sites ($\bar{x}$ = 30.2°, Mann Whitney U test, P < 0.01).

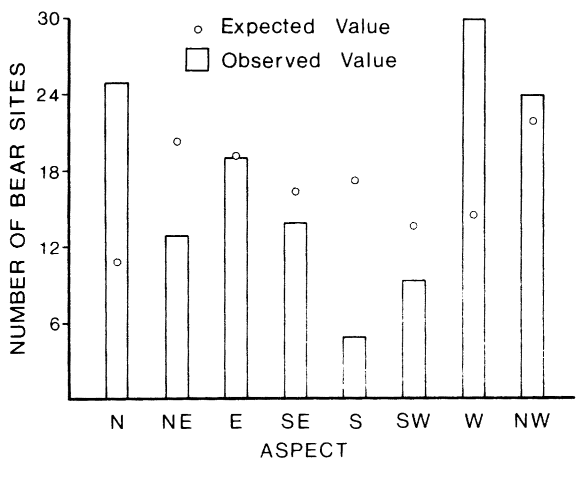

Fig. 2. The number and observed number of bear sites located in 8 aspect zones in the study area.

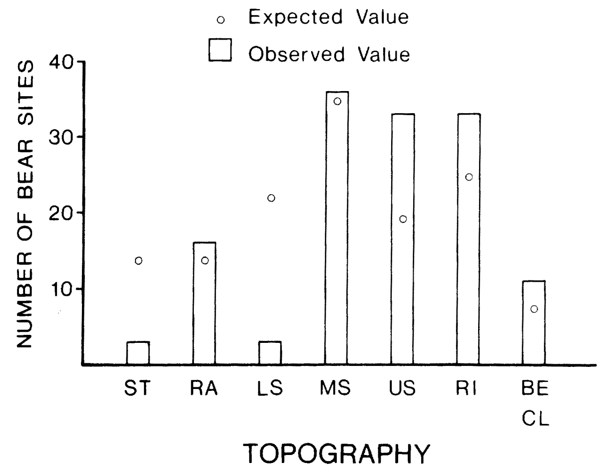

Fig. 3. The expected and observed number of bear sites grouped according to their topography. Topographical features are streams (ST), ravines (RA), lower slopes (LS), midslopes (MS), upper slopes (US), ridges (RI), bench areas (BE), and cliffs (CL).

In forested habitat below 2,700 m, a combination of factors was necessary to explain why bear sign was concentrated on midslopes (42.3% of the sign found in these forests), ravines (20.5%), and ridgelines (23.0%) and nearly absent from lower slopes (2.6%) and streambeds (3.8%). Spectacled bears may have selected midslopes and ravines for the higher nutritional value of foods found there. These areas contained 65.8% of the feeding sites in forests below 2,700 m and had a greater abundance of bear foods than lower slopes (LSD range test, df = 5, 80; P < 0.05; Fig. 4). Food abundance in bench areas and along streams was variable, probably an artifact of my small sample size (21 sites). Consequently, no significant differences in food abundance were found between these sites and the sites that represented other topographical features. Of the feeding sign found on ridgelines, 72% contained 1 eaten plant in a well-traveled trail without additional feeding sign nearby (within 100 m). This suggested that ridgelines in forests below 2,700 m were selected as travel routes, and feeding here was done casually by traveling bears (see Zager 1980 for a discussion of ridgeline use by grizzly bears, *Ursus arctos*). Bear trails used for trav-

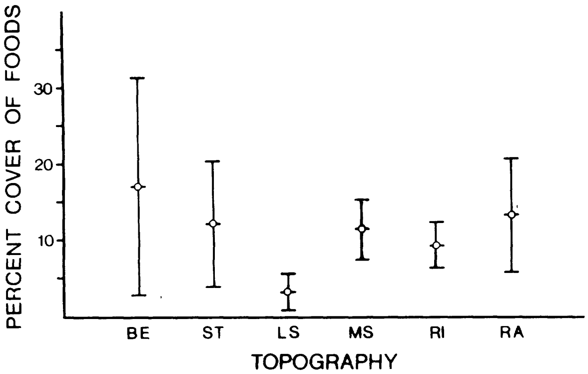

Fig. 4. Percent cover of bear foods in forested sites grouped according to 6 topographical features (95% confidence interval). (See key in Fig. 3.)

eling were relatively straight compared to the ambling configuration of bear trails in feeding sites.

Food Plant Abundance.—In all habitats except the steppe habitat, abundance of bear forage plants was greater on bear sites ($\bar{x}$ cover = 7.9%) than on the regular sites ($\bar{x}$ cover = 3.3%, Mann Whitney U test, $P < 0.0001$). This was true for seasonally available foods and foods that were consumed by bears throughout the year (Table 1).

Forage plants were less abundant on regular sites in forested habitats within the Sanctuary ($\bar{x}$ cover = 1.4%) than on comparable habitats outside the Sanctuary ($\bar{x}$ cover = 6.8%, Mann Whitney U test, $P = 0.01$). The seasonally available fruits from the laurel forests (*Nectandra* spp.) in Santa Teresa contributed most to this difference. No differences in food abundance were detected among regular sites for grasslands inside the Park and those outside the Park (Table 2).

For all habitat types, bear foods were twice as numerous on bear sites ($\bar{x}$ = 2.2) than regular sites ($\bar{x}$ = 1.1, Mann Whitney U test, $P < 0.0001$; Table 2). Bear foods were more numerous on sites in the Sanctuary and in the Lucumayo Valley ($\bar{x}$ = 2.5 for both areas) than on sites in the Santa Teresa Valley ($\bar{x}$ = 1.2, Mann Whitney U test, $P < 0.0001$). No significant difference in the number of foods was found between regular sites in the Sanctuary ($\bar{x}$ = 1.1) and outside the Sanctuary ($\bar{x}$ = 1.2, Mann Whitney U test, $P = 0.55$).

Vegetation Cover.—In the high steppe and subalpine paramo, bear sites had higher vegetation cover than regular sites for the height zone between 15 cm and 1 m (Table 3). Nearly all of the regular sites in these grasslands (88.2%) experienced cattle and horse grazing, and fires that removed the vegetation in this height zone, whereas only 9% of the bear sites included signs of human use. Ravines ($\bar{x}$ percent cover = 9.0) and flat ground on hillsides ($\bar{x}$ percent cover = 2.3) showed significantly less vegetation between 15 cm and 1 m than all other topographical features ($\bar{x}$ percent cover = 30.2–38.4, LSD range test, df = 6, 87; $P < 0.05$). These areas experienced the heaviest grazing. No significant differences were found for vegetation density between bear sites and regular sites in the rain paramo, which was not heavily used by livestock.

All forested bear sites showed lower vegetative cover between 15 cm and 1 m than regular sites (Table 4). Bear selection of areas with less dense understory appeared to be related to human presence and traveling ease. Lower slopes which had denser vegetation between 15 cm and 1 m above the substrate ($\bar{x}$ cover = 65.7%) than all other topographical features ($\bar{x}$

Table 1. Abundance of bear forage plants on bear sites and regular sites in grassland and forest habitats.

Food type	Habitat type	Abundance of bear forage plants[a]		*P* value[b]
		Bear sites	Regular sites	
Seasonal				
	Grassland[c]	6.4 (6.1, 33)[d]	5.0 (8.4, 76)	0.0106
	Forest[e]	12.1 (13.9, 54)	3.5 (7.3, 67)	0.0002
Year-round				
	Grassland	5.1 (5.9, 33)	1.9 (6.0, 76)	<0.0001
	Forest	6.5 (9.8, 54)	2.7 (8.7, 67)	0.0002

[a] Abundance measurements are combined importance values of bear forage plants on a site: importance value for species A = ([relative cover + relative density of sp. A/2] × 100).
[b] Mann U Whitney 2-tailed test.
[c] Grassland habitat types include tundra, subalpine paramo, rain paramo, high steppe, and low steppe.
[d] ( ) standard deviation, sample size.
[e] Forest habitat types include humid and very humid high mountain forest, and humid and very humid low mountain forest.

Table 2. Abundance of bear forage plants on bear sites and regular sites in the Historical Sanctuary of Machu Picchu and outside the Sanctuary in adjacent valleys of the Lucumayo and Santa Teresa rivers.

Site type	Food type	Habitat	Abundance of bear forage plants[a] Inside the Sanctuary	Outside the Sanctuary	P value[b]
Bear sites					
	Seasonal				
		All habitats	6.9 (9.11, 43)[c]	12.8 (13.5, 44)	0.047
		Grassland[d]	6.3 (7.1, 23)	6.6 (3.5, 10)	0.542
		Forest[e]	7.7 (11.2, 20)	14.6 (14.8, 34)	0.070
	Year-round				
		All habitats	8.8 (9.0, 43)	3.2 (7.0, 44)	<0.0001
		Grassland	7.1 (6.1, 23)	0.5 (0.6, 10)	0.0017
		Forest	10.7 (11.4, 20)	4.0 (7.9, 34)	0.0002
Regular sites					
	Seasonal				
		All habitats	3.7 (7.1, 110)	6.4 (10.1, 33)	0.324
		Grassland	5.0 (8.4, 64)	5.4 (8.8, 12)	0.970
		Forest	1.9 (4.1, 46)	6.9 (11.0, 21)	0.078
	Year round				
		All habitats	1.4 (4.5, 110)	5.1 (12.6, 33)	0.612
		Grassland	1.7 (5.5, 64)	2.4 (8.4, 12)	0.447
		Forest	1.0 (2.6, 46)	6.6 (14.5, 21)	0.422

[a] Abundance measurements are combined importance values of bear forage plants on a site: importance value for species A = ([relative cover + relative density of sp. A/2] × 100).
[b] Mann U Whitney 2-tailed test.
[c] ( ) standard deviation, sample size.
[d] Grassland habitat types include tundra, subalpine paramo, rain paramo, high steppe, and low steppe.
[e] Forest habitat types include humid and very humid high mountain forest and humid and very humid low mountain forest.

cover = 34.4%–57.7%, LSD range test, df = 5, 78; $P < 0.01$) were the most accessible and subsequently the preferred sites for lumbering, crop growing, and human foot paths.

Bear Range and Human Use.—Approximately 37% of the spectacled bear range in the study area was included within the Sanctuary boundaries. This range covered about one-third of the Sanctuary (10,800 ha), with 70% located on the north side of the Urubamba River (Fig. 5). Approximately 57% of the Sanctuary (18,500 ha) was used by humans. The areas used by people were subject to frequent fires and agriculture. Six percent of the Sanctuary was tundra or snowbound, areas that experienced little or no human use.

A comparison of the level of human use between regular sites and bear sites revealed that bear sign was generally not found in areas that showed human use (X^2 test, df = 3, $P < 0.001$). Signs of human presence on the paramo were found in 21.0% of the bear sites and 89.5% of the regular sites. Paramo bear sites were in previously burned areas near human foot paths. Bear sign was not found where cattle had entered the forest from the grasslands. In forested habitats, 8.4% of the bear sites and 33.4% of the regular sites contained sign of human use. These bear sites were near cornfields, the only habitat component used by bears that showed high human use.

Bear sign was found in sites where distances to sufficient hiding cover were between 5 and 30 m. Kolmogorov-Smirnof tests revealed no significant differences in distance to hiding cover between bear sites and regular sites in rain paramo and steppe habitats ($\bar{x}$ = 27 m and 28.3 m, respectively). In the subalpine paramo, distances to sufficient hiding cover in bear sites ($\bar{x}$ = 18.3 m) were significantly less than those in regular sites ($\bar{x}$ = 76.7 m, Kolmogorov-Smirnof test, $P < 0.01$). Bear sign in the subalpine paramo was found in ravines or on steep slopes and cliffs that provided hiding cover within 30 m, and they were absent from valley bottoms. Rain paramo areas may provide additional hiding cover in the form of clouds present during storms and between 1000 and 1700 h. Spectacled bears may time their feeding behavior to coincide with periods of cloud cover or darkness in areas with sparse vegetation. Both grizzly bears and

Table 3. Difference in percent vegetation cover between bear sites and regular sites in 3 grassland habitat types.

Habitat type	Vegetation ht. zone	Mean percent vegetation cover		P value	
		Bear sites	Regular sites		
Subalpine paramo	0.0–1 cm	28.9	42.4	<0.05	(41)[a]
	15 cm–1 m	39.7	19.5	<0.01	
Rain paramo	0.0–15 cm	86.1	80.1	>0.25	(18)
	15 cm–1 m	29.6	37.3	>0.25	
High steppe	0.0–15 cm	79.3	26.9	<0.001	(29)
	15 cm–1 m	64.3	34.8	<0.05	

[a] ( ) Unexplained degrees of freedom.

black bears (*U. americanus*) have been reported to use areas with little hiding cover at night (Lloyd and Fleck 1977, Schallenberger and Jonkel 1980).

In forests above 2,700 m, 93% of the bear sites had sufficient hiding cover within 5–12 m of the site reference point. Although distance to hiding cover in regular sites ($\bar{x}$ = 6.6 m) was less here than in bear sites ($\bar{x}$ = 9.0 m, Kolmogorov-Smirnof test, $P <$ 0.01), the difference was considered insignificant. These results probably reflected the bear's preference for less dense vegetation and moderate slopes that were positively correlated with low hiding cover values ($r = 0.63$). Bear sign was probably not overlooked in forested habitat types because the mean sighting distance to bear sign (2.4–4.3 m) was less than the average hiding cover values for forest habitats. No differences were found for hiding cover distances between bear sites and regular sites in forests below 2,700 m ($\bar{x}$ = 7.9 m and 6.9 m, respectively).

Habitat Quality Criteria.—Table 5 lists the minimum and maximum values of criteria that most differentiated bear sites from regular sites. Aspect was not chosen as a criterion because not enough validity could be gained from the small sample size, particularly without intensive studies using radio-marked bears. Topography was not chosen because its use by bears was associated with food abundance, traveling ease, and possibly human presence. Human presence was not chosen because not enough information was gathered to reveal how humans affect bear usage of areas. The critical factors in grasslands that could be identified without the use of radio-marked bears were hiding cover and food abundance. Criteria for food abundance on grasslands were high in comparison to forests, due to the higher alpha diversity of plant species and greater variability of food abundance values in forests. Vegetation density was not chosen as a criterion for grasslands because it did not appear

Table 4. Difference in percent vegetation cover between bear sites and regular sites in forest habitat types.

Habitat type	Vegetation ht. zone	Mean percent vegetation cover		P value	
		Bear sites	Regular sites		
Humid forest	0.0–15 cm	97.6	108.1	<0.05	(44)[a]
	15 cm–1 m	31.1	51.5	<0.001	
	1 m–5 m	80.3	78.7	>0.25	
	>5 m	76.5	66.5	>0.25	
Very humid forest	0.0–15 cm	89.9	94.7	>0.25	(45)
	15 cm–1 m	33.0	64.8	<0.001	
	1 m–5 m	93.0	107.7	>0.25	
	>5 m	52.6	64.5	>0.25	

[a] ( ) Unexplained degrees of freedom.

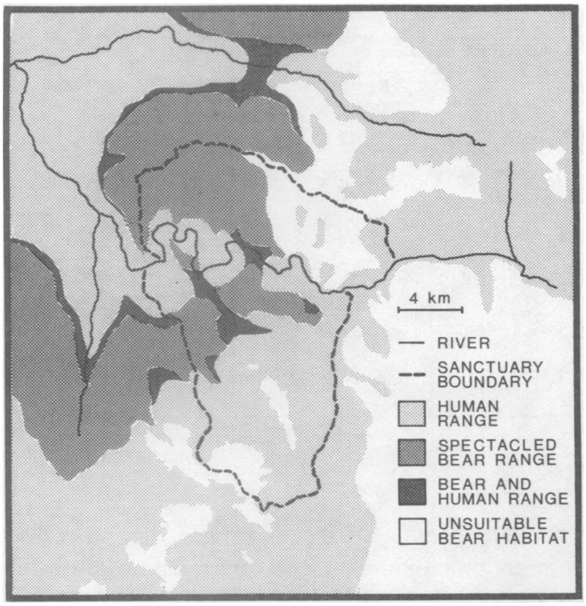

Fig. 5. Areas occupied by humans and by spectacled bears in the Historical Sanctuary of Machu Picchu and adjacent valleys.

to present a barrier to bear movement. Slope was chosen as a criterion because slopes were less inclined on bear sites than on regular sites, and sites with bear trails and no feeding sign were less inclined ($\bar{x}$ slope = 10.8) than sites that showed evidence of feeding ($\bar{x}$ slope = 25.6°, Mann Whitney U test, $P = 0.02$).

Criteria used to evaluate forested habitats were based on traveling ease (slope and vegetation density) and food quantity (number and abundance of foods). As in grassland habitats, slope in forested bear sites used for traveling was less inclined than in feeding sites (Mann Whitney U test, $P = 0.05$). Although canopy height for forested habitats was higher in bear sites ($\bar{x}$ = 14.2 m) than in regular sites ($\bar{x}$ = 10.8 m, Mann Whitney U test, $P = 0.0045$), it was not chosen as a criterion because 32.7% of the bear sites were situated in a stand of laurel trees (*Nectandra* sp.), one of the best food sources for spectacled bears as well as one of the tallest trees in the study area ($\bar{x}$ height = 18.7 m, $N = 20$). Therefore, canopy height was possibly correlated with the food value of a site. Hiding cover and the degree of human presence were not chosen as criteria because all forested sites had hiding cover values below the critical values established from bear sites in grassland habitats.

Based on the criteria, 96.5% of the bear sites and 33% of the regular sites were considered to be in good habitat. Forty-five percent of the bear sites met all conditions for the habitat types they were in and were rated excellent; no bear sites could be considered to be of poor quality. By contrast, 6.3% of the regular sites could be considered to be in excellent habitat; 11.9% could be considered to be in poor habitat. The relative proportions of good sites was nearly equal for bear sites outside the Sanctuary (93.2%) and inside the Sanctuary (100%). Among the regular sites, the relative proportion of good sites was higher outside the Sanctuary (51.5%) than inside the Sanctuary (27.3%). This result may reflect high human use in the Sanctuary (e.g., disturbance) and greater food abundance on regular sites in adjacent areas (Table 2).

MANAGEMENT IMPLICATIONS

The differences in environmental and vegetative characteristics between bear sites and regular sites

Table 5. Criteria on which to judge habitat quality for spectacled bears in the Historical Sanctuary of Machu Picchu and adjacent valleys. The table shows minimum and maximum values for criteria that were found to be different between bear sites and regular sites.

	Criteria				
	Traveling		Feeding		Security
Habitat	Slope (°)	Vegetation density 0.15-1.0 m above the ground (% cover)	Food number	Food abundance (imp. val.)[a]	Average hiding cover (m)
Forests					
< 2,700 m	≤ 34.6	≤49.0	≥ 2	≥ 3.8	—[b]
> 2,700 m	≤ 34.3	≤ 28.7	≥ 1	≥10.0	+[c]
Subalpine paramo	≤ 38.2	+	≥ 3	≥ 9.4	≤ 25
Rain paramo	≤ 26.5	—	≥ 3	≥ 6.0	≤ 35
Steppe	≤ 48.0	+	≥ 2	≥ 1.5	≤ 40

[a] Abundance measurements are importance values: ([relative cover + relative density/2] × 100).
[b] — indicates no significant difference for the criteria between bear sites and regular sites.
[c] + indicates a significant difference for the criteria but the difference in the absence of further evidence is not considered biologically important.

serve to decrease the area available to bears in the Sanctuary. The Sanctuary contains approximately 8,900 ha of good bear habitat based on an evaluation of observed bear use. This crude estimate was derived by multiplying the proportion of the regular sites in good habitat by 32,592 ha, the area estimate of the Sanctuary from the Ministry of Agriculture in Peru. The scarcity of bear sign in valleys on the north side of the Urubamba River, where regular sites were rated good to excellent, lead me to suspect that the population is below the carrying capacity of its range.

The absence of any credible population estimate for spectacled bears underscores the need for an intensive study using radio-marked animals. A telemetry study would reduce biases of estimates of bear use areas, determine how humans affect bear usage of areas, and more conclusively show what habitat criteria are important to spectacled bears. Encroaching agriculture in grasslands above 3,200 m and forests below 2,700 m in elevation will soon limit the spectacled bear to high mountain forests between these elevational limits. During 4 years of survey work in Ecuador, Peru, and Bolivia, I have not found evidence of a breeding population of bears whose range is limited to only high mountain forests. In a former survey conducted throughout Peru, only 30 of 311 forested areas with bear sign were found in high mountain forests, although I spent as much time in forests above 2,700 m as below (Peyton 1980). Until future studies reveal population parameters and habitat use of radio-marked bears, the Sanctuary boundaries should be increased to include more than 18,000 ha of bear-occupied habitat in the adjacent areas of the Santa Teresa and Lucumayo valleys. These valleys and the Sanctuary form the only known corridor that allow bears to move between the Central and Oriental Andean Ranges. Better food quality with less human disturbance was found in these adjacent valleys than in the Sanctuary, and their inclusion would be beneficial to bears.

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