

GEOGRAPHIC INFORMATION SYSTEM FOR THE ANALYSIS OF CANTABRIAN BROWN BEAR HABITAT QUALITY

JORGE MARQUÍNEZ, Institute of Natural Resources and Land Management, University of Oviedo, E33071, Spain
PILAR GARCÍA, Institute of Natural Resources and Land Management, University of Oviedo E33071, Spain
JAVIER NAVES, Institute of Natural Resources and Land Management, University of Oviedo E33071, Spain
ARTURO RUANO, Institute of Natural Resources and Land Management, University of Oviedo E33071, Spain

Abstract: A small study area (4,029 ha) was used to build a model of potential brown bear (*Ursus arctos*) habitat quality. In a first step, based on existing data of bear diets and the calculated coverage of food-producing plants, we established a series of food selection indices. Foods with the highest selection indices for bears included the Umbelliferae, apple (*Malus* sp.), bilberry (*Vaccinium myrtillus*), and chestnut (*Castanea sativa*). By combining the food indices with the surface description of each environmental unit, we obtained the trophic values of each habitat. Herbaceous formations, non-oak (*Quercus* sp.) shrub formations and chestnut forests are the most important environmental units in the diet of the bear. The final habitat quality (obtained by calculating mean value between trophic and refuge-cover values) showed that high quality areas were scarce. Processing of GIS data allowed the extrapolation of results to the entire area of study by using trophic resource maps and details of refuge-cover and global habitat quality. This mapping was obtained for each season of the year and annually.

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Key words: brown bear, Cantabrian Mountains, geographic information system, GIS, habitat quality, *Ursus arctos*.

Hierarchical delineation of areas of differing habitat quality is the basis for brown bear habitat management, both from the perspective of conserving areas vital to the species and of planning and managing human activities. The only references found in the European literature that deal in some way with habitat quality are those of Almansan (1979) for Romania, Clevenger et al. (1987) for brown bear habitat in the Cantabrian Mountains (of Spain), and Erome and Michelot (1990), who analyzed the potential of the French Alps to sustain bears, which are now extinct there. In all cases the approach to the problem was qualitative in character and the working scale was regional, covering large areas and general units. At a local and detailed scale in western Europe, evaluation of the quality of bear habitat is based on knowledge of bear use or on aspects of bear biology (e.g., denning, land refuge, seasonal diets, reproduction, etc.). Examples of this are the maps developed by the Office National de la Chasse for the Pyrenees (Camarra 1989) and the refuge area maps prepared by the regional and state administrations in the Cantabrian Mountains (J. Naves and G. Palomero, Institute of Natural Resources and Land Management, University of Oviedo, Madrid, Spain 1989).

In contrast, in the United States and Canada methods have been developed that quantify habitat quality in bear recovery zones. Many of these papers describe grizzly bear habitat on the basis of landforms and plant communities, and describe field work aimed at documenting the distribution, production, and nutritional quality of the food resources consumed by the species. Some of these papers have contributed to the establishment of guidelines for management of bear habitat (Craighead et al. 1982, Contreras and Evans 1986), and some present maps based

on satellite images (Craighead et al. 1982, Banner et al. 1986, Butterfield and Key 1986, Craighead and Craighead 1986). Few studies, however, have incorporated geographical information systems (GIS; Winn and Barber 1986). A general discussion of these studies can be found in Servheen (1987) and Schoen (1990).

This study defined and mapped various categories of brown bear habitat quality in a selected area of the Cantabrian Mountains, using quantitative analysis methods. The GIS includes precise and detailed mapping and graphic displays.

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STUDY AREA

The 4,029 ha study area (Fig. 1), is of special interest because it is the main constriction in the distribution of the western population of brown bear in the Cantabrian Mountains (Campo et al. 1984). This area is characterized by marked relief with elevations of 600–1900 m. The climate largely corresponds to that of the mountain bioclimatic floor. It is classified as hyperhumid with annual precipitation of 140 cm. For biogeographical purposes, the area is included in the Orocantabrian Province of the Eurosiberian Region (Rivas Martinez et al. 1984).

The total human population of the study area is 425 inhabitants, distributed in 9 small nuclei. The principal economic activities are cattle-raising and coal mining, resulting in land usage that has limited woodlands to small areas (30% of total). Administratively, this area belongs to Region of Asturias.

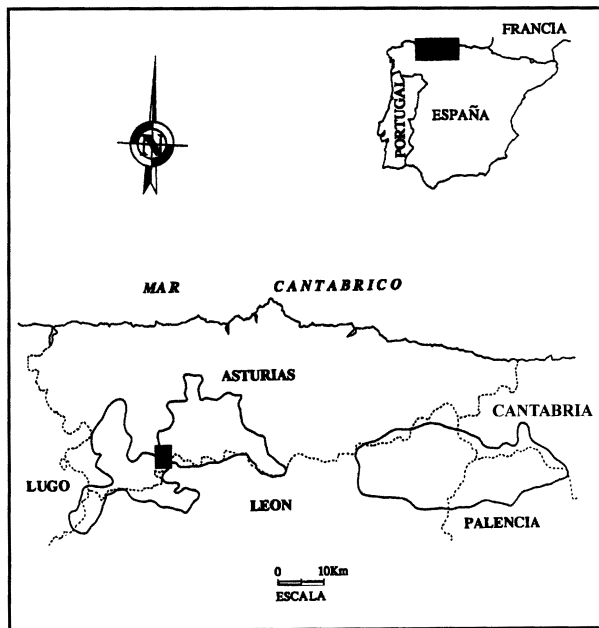


Fig 1. Study area in the western population of brown bears in the Cantabrian Mountains of Spain. Distribution based on Campo et al. (1984).

METHODS

Many resource management studies in the Cantabrian Mountains have lacked in detailed and precise environmental cartography. It was this lack that led the Institute of Natural Resources and Land Management (INDUROT) in 1988 to begin development of an environmental cartography plan to a scale of 1 = 25,000, financed by the Ministry of Agriculture (ICONA). This project was based on intensive ground surveillance and aerial photographs and used GIS and a group of specialists in various subjects (Marquinez et al. 1991). This system incorporated data on vegetation, bedrock, elevation, slope, aspect, lithology, geomorphology, rocky areas, and human infrastructures, allowing for analysis and subsequent treatment of relevant information to establish habitat quality criteria (Fig. 2).

Based on data on bear feeding and selection of areas for refuge or denning, unions of different vegetation classes and overlap between vegetation and other variables were identified to establish a model with homogeneous environmental units of bear habitat. The total number of environmental units distinguished was reduced to 17 to simplify the subsequent sampling and analysis. In accordance with the surface area occupied by each of the environmental units, a network of 139 sample points, distributed among the different environmental units, was designed based on methodology proposed by Mealey

(1986). We did not sample any units belonging to the category of towns, mines, and spoil heaps (surface area = 12.9 ha) or rocky areas and talus scree (surface area = 12.5 ha).

We sampled an area within a radius of approximately 15 meters at each sample point. Data relevant to food-producing plant cover was measured and calibrated on a scale of 1 to 10 (1 = 0–10%, 2 = 11–20%, 3 = 21–30%, etc.). Visibility within the environmental unit at 1 meter above ground level were also taken in 4 directions at each sample point and indexed as 1 (<10 m visibility), 2 (<100 m visibility) and 3 (>100 m visibility). To detect changes in availability of Umbelliferae, Poaceae, and other herbs, sampling points were visited during different seasons: September 1990 (summer), December and January 1990 and 1991 (fall–winter), and May 1991 (spring).

The food resources considered for each of the seasons and for the annual cycle were obtained from Braña et al. (1989), which considered the Cantabrian Mountains as a whole. Food items we sampled at each of the sample points were selected from this study. Fall and winter diets were combined as the diet of bears were similar during these seasons. It was, however, necessary to correct this data for subsequent analysis. *Rhamnus alpina*, which is of considerable importance to bears, was eliminated because it was non-existent in the zone; we decided to distribute its seasonal frequency among the rest of the foods in proportion to their frequency (Table 1).

We calculated total coverage of each food-producing plant for each environmental unit (A_{jk}) as:

$$A_{jk} = \frac{S_j C_{kj}}{10}$$

where S_j = surface area of the environmental unit j , and C_k = average cover of food plant k in the samples of the environmental unit j . A selection index (I_{ik}) was calculated for each food in each season and was expressed as:

$$I_{ik} = \frac{F_{ik}}{\sum_{j=1}^n A_{jk}}$$

where F_{ik} is the frequency of consumption of food k in season i . The values of this selection index lie between 0 and 1. The trophic value for each of the environmental units for each of the seasons (V_{ij}) is expressed as:

$$V_{ij} = \sum_{k=1}^n \frac{100A_{jk}}{S_j} I_{jk}$$

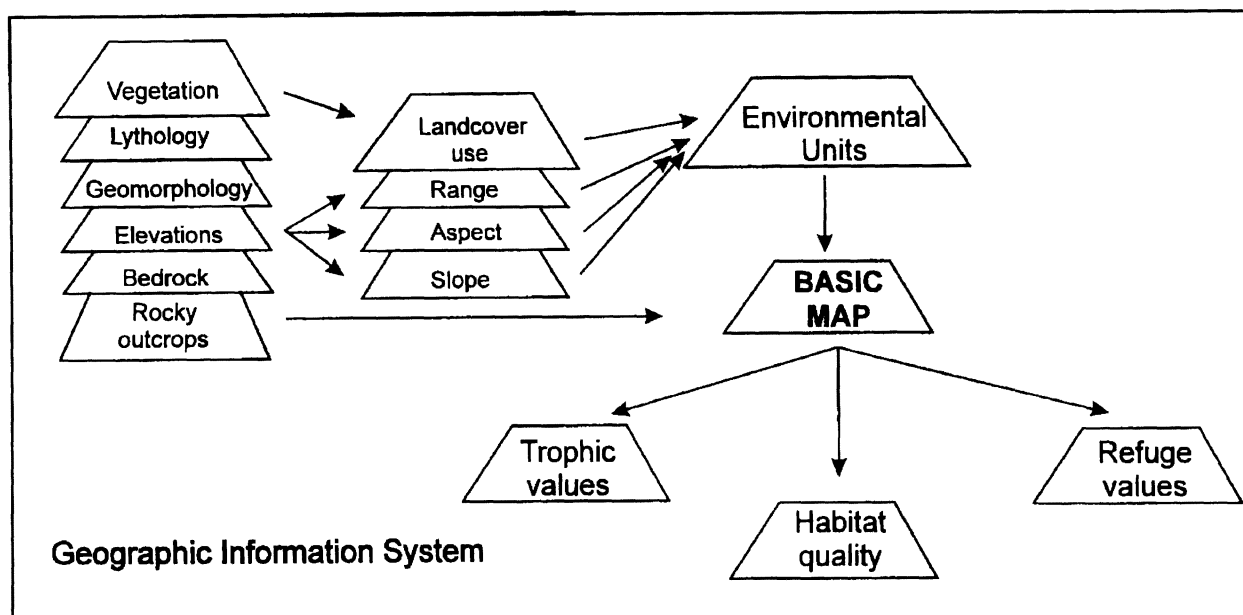


Fig 2. Organization of the geographic information system to evaluate habitat quality for brown bears.

The annual trophic value was obtained by calculating the mean of the seasonal trophic values.

In constructing the refuge-cover values of each environmental unit, we used information provided by Naves and Palomero (1989); the potential selection of sites for beds and dens was determined by the presence of rocky outcrops with dense vegetation cover. An overlay of overlapping environmental units and rocky areas served as the base map (Fig. 2). Information from field work relating to trophic values and visibility were included in map development, thus allowing this data to be applied to the entire study zone.

We used 6 classes of refuge-cover values, varying the amount within a range comparable to annual variation in trophic value. To assign these values to each polygon, the following criteria were applied: first, all polygons with rocky areas were selected on the base map. These provided the best refuge and were divided into 3 classes according to the density of vegetation cover: rocky areas with tree and bush cover, rocky areas with brush cover, and other rocky areas. The rest of the map (non-rocky areas) also was divided into 3 classes: visibility index <1.5, visibility index 1.5–2, and visibility index >2.

We assigned a final value of habitat quality for each season by calculating the mean of the trophic value and refuge-cover value for that time. These values were generated in the GIS and were incorporated into the data base as new items. The GIS allowed graphic representation of generated results.

RESULTS

Trophic Resources

Based on the field data (Table 1) and the total surface area of each environmental unit, we estimated the amount of each food item in the environmental units, and the total area of the trophic resources in the zone under study. The umbellifers, herbaceous, and graminoid plants are the principal resources in spring, with umbellifers being outstanding due to their high selection index (Tables 2 and 3). The food index for bilberry (*Vaccinium myrtillus*) is important in summer, although the greatest selection index corresponds to apples. In fall and winter, acorns and beechnuts made up the bulk of the diet, although apples and chestnuts had the highest selection index.

The trophic values of the environmental units were calculated for each season and for the year (Table 4). In the spring herbaceous formations are first in importance, followed by birch forest <1300 m, hygrophile forest, and beech forest. Shady oak forest and non-oak shrub formations make up a third group. These last two groups of environmental units have a mainly northerly orientation with an abundance of springtime foods, and they incorporate the nut harvest of the previous fall, which can be important during this season.

In summer the trophic value of non-oak shrub formations and moors with abundant heather is evident with bilberry being a determining factor. A similar interpretation may be put on the high trophic value of the second

Table 1. Averages of cover obtained in field sampling in 1990-91 for food-producing plants and visibility index of each environmental unit for the Cantabrian Mountains, Spain. The total surface area of environmental units are included.

Environmental units	Spring			Summer			Fall			All year										Surface area (ha)
	um ¹	po	he	um	po	he	um	po	he	a	b	c	d	e	f	g	h	i	j	
Beech forest	4.00	1.00		4.00	1.00		2.00			0.40	0.80	1.40		1.33	0.66	9.00	2.00	2.00	2.00	88.1
Birch forest										0.40	0.80	1.40					0.80	1.00	1.00	124.9
Sunny oak forest	3.81	1.86		1.14	0.72		1.15	0.71		0.09	0.02	1.04	0.11	0.02	7.36		0.41			365.8
Hygrophile forest	0.83	5.16	1.66	3.00	2.33		3.00	3.00	3.00	0.50	0.20	2.10	0.50	0.10	1.60		2.20			189.0
Chestnut forest	0.50	3.50	1.50	3.25	1.00		1.75	1.00		0.50		3.00			8.75	1.50	1.50			14.7
Shrub without oak	8.00	3.00		8.00	2.00		2.00	2.00		6.00				3.00						62.2
Shrub with oak	3.00	0.50		0.50	0.50		1.00	0.50				1.00	0.25		6.50					86.3
piornal	4.70	0.87		3.65	1.12		2.62	1.33		0.20	0.03	2.01	0.29		0.03	0.25		0.12		406.5
<1300m heath rich																				
in <i>Calluna</i>	4.75	1.75		2.75	1.75		2.75	1.75						3.75						22.5
other heath cushion	3.00	0.75		2.14	0.50		1.00			0.08	0.75			0.42	0.42			0.08		1127.5
heath	5.00	1.00																		
grassland	1.40	7.54	1.06	1.16	6.80	1.00	0.67	5.80	1.80	0.20	0.71	0.21		0.07	0.21		0.50			23.0
shady oak forest	5.50	2.00		7.50	2.00		4.16	1.50		0.85	0.37	1.00	0.75	0.25	4.00		2.75			148.4
piornal																				
>1300 m birch forest	3.30	0.75		8.60	0.80		2.66	0.67		0.40				0.20						507.4
>1300 m	8.00	1.50		4.00	1.00		1.00	1.00		1.43	0.43			1.28	1.28	0.14				263.7

¹ um = Umbelliferae, po = Poaceae, he = herb, a = *Rosa* sp., b = *Sorbus* sp., c = *Rubus* sp., d = *Prunus* sp., e = *Malus* sp., f = *Vaccinium myrtillus*, g = *Castanea sativa*, h = *Quercus* sp., i = *Fagus sylvatica*, j = *Corylus avellana*.

Table 2. Seasonal variation in brown bear diets in the Cantabrian Mountains, Spain, expressed as percentages of presence over the number of samples analyzed. Elaborated from data in Braña et al. (1989).

Trophic Resource	Spring	Summer	Fall
Umbelliferae	51.11	16.67	4.86
Poaceae	57.78	50.00	31.25
Other herbs	35.56	16.67	7.59
<i>Rosa</i> sp.	–	–	1.38
<i>Sorbus</i> sp.	–	–	4.83
<i>Rubus</i> sp.	–	5.45	8.28
<i>Prunus</i> sp.	–	7.27	2.76
<i>Malus</i> sp.	–	5.45	4.14
<i>Vaccinium myrtillus</i>	–	49.05	11.04
<i>Castanea sativa</i>	–	–	12.42
<i>Quercus</i> sp.	8.86	5.56	47.61
<i>Fagus sylvatica</i>	4.44	1.39	15.18
<i>Corylus avellana</i>	2.22	5.56	6.21

group of environmental units, such as high beech and birch. However, other units with similar values to those (hygrophilic forest and shady oak forest) seem to have high indices because of other fruits consumed in the summer (*Malus* sp., *Prunus* sp., *Rubus* sp., etc.). In fall and winter chestnut forests are the most important environmental unit in providing food for the bear, followed by beech forests, heath rich in *Calluna vulgaris*, shrub formations without oaks, and shady oak forest. Incorporating these results into the GIS allowed us to map trophic values by seasons and annually (Fig. 3).

Refuge-Cover

Table 4 shows that the environmental units offering greatest cover to the brown bear are bush and tree forma-

Table 3. Values of the selection index for trophic resources in each season considered for brown bear habitat in the Cantabrian Mountains of Spain, 1990–91.

Resource trophic	Spring	Summer	Fall
Umbelliferae	0.43	0.25	0.13
Poaceae	0.03	0.03	0.03
Other herbs	0.08	0.05	0.02
<i>Rosa</i> sp.	–	–	0.01
<i>Sorbus</i> sp.	–	–	0.05
<i>Rubus</i> sp.	–	0.02	0.03
<i>Prunus</i> sp.	–	0.14	0.05
<i>Malus</i> sp.	–	0.86	0.87
<i>Vaccinium myrtillus</i>	–	0.37	0.08
<i>Castanea sativa</i>	–	–	0.69
<i>Quercus</i> sp.	0.02	0.01	0.10
<i>Fagus sylvatica</i>	0.05	0.01	0.16
<i>Corylus avellana</i>	0.01	0.03	0.04

tions, in contrast to the greater visibility of bush formations and grasslands. Given the variation in annual trophic values (0.79–23.75), refuge values were assigned within a similar range (1–25), with highest values for rocky areas with dense vegetation cover because of their frequent use by bears for refuge and denning. The final values were: rocky areas with tree and bush cover = 25; rocky areas with brush cover = 15; rocky areas with other cover = 7; environmental units with visibility index <1.5 = 5; environmental units with visibility index 1.6–2 = 3; environmental units with visibility index >2.1 = 1 (Fig. 4).

Habitat Quality

Values for habitat quality were obtained by calculating mean trophic and refuge-cover values. The resulting data have been ordered in 5 classes occupying unequal surface areas (Fig. 5). The 3 classes of lowest quality (<12) covered 89 % of the area (3,583 ha); the remaining 11% were distributed between the classes with high values. High quality areas were scarce (Fig. 5).

DISCUSSION AND IMPLICATIONS FOR BEAR CONSERVATION

The evaluation and quantification of trophic resources and the availability of refuge and cover zones are essential in assessing bear habitat quality in Western Europe. Quantification of these parameters, complemented by detailed and precise cartography and the analytical ability of GIS, provides a powerful tool to evaluate this habitat.

The model presented in this paper should be considered only an approximation of potential habitat quality. The proposed map should be evaluated against actual bear activity. Rigorous comparison of models like this with observed habitat use could help to determine the influence of human activity on the area of bear presence and thus provide analytical methods to predict the effect of human activities.

This approach would be comparable to that of cumulative effects models (U.S. Dep. Agric. For. Serv., et al. 1985, 1988). These cumulative effects models, together with GIS, may offer “an opportunity for researchers and managers to evaluate complicated habitat relationships” (Schoen 1990).

The calculation of trophic values will be considerably improved with increased knowledge of the biology of the brown bear and its habitat ecology. The most important need is knowledge of local bear diets to avoid errors from using general diet data obtained for the Cantabrian Mountains as a whole. It is also important to study the produc-

Table 4. Seasonal and annual trophic values of the environmental units for brown bear habitat in the Cantabrian Mountains of Spain, 1990–91.

	Environmental Units ¹														
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
Spring	6.72	7.72	4.05	7.11	4.92	4.89	2.51	2.22	2.88	1.62	2.36	9.39	4.39	1.63	3.77
Summer	8.63	0.98	2.15	5.56	2.61	14.37	1.65	2.45	15.40	2.62	0	6.09	7.96	3.73	6.40
Fall	17.83	2.14	8.33	5.99	63.73	6.81	7.12	2.38	4.41	1.32	0	4.41	9.77	1.43	2.05
Annual	11.06	3.61	4.84	6.22	23.75	8.69	3.76	2.35	7.56	1.86	0.79	6.63	7.37	2.26	4.07

¹ a = beech forest, b = birch forest <1300 m, c = sunny oak forest, d = hygrophye forest, e = chestnut forest, f = shrub without oak, g = shrub with oak, h = piornales <1300 m, i = heath rich in *Calluna vulgaris*, j = other heath, k = cushion heath, l = grassland, m = shady oak forest, n = piornales >1300 m, o = birch forest >1300 m.

tivity of different trophic resources and the carrying capacity of the habitat. Though we do not know relative importance of trophic and refuge values, biological data could provide better information and understanding of these values, thus allowing an appropriately weighted mean to be calculated. The model proposed could also be improved with advances in GIS operations. These advances may include treatment of polygon groups varying in quality, the consideration of border zones, or the inclusion of different units with linear distributions (e.g., hedgerows, riverbanks). Similarly, the introduction of other elements such as roughness of terrain could complete aspects relevant to the refuge value of environmental units. Despite these possible improvements, the usefulness of the method to estimate habitat quality is evident, as it identifies with detail important brown bear habitat and different environmental units. This approach contributed to the delineation of critical zones for the species, on which the approved Recovery Plans of the Cantabrian Brown Bear focus.

LITERATURE CITED

- ALMANSAN, H. 1979. Diagnose écologique des terrains de chasse pour l'Ours brun de Roumanie. Rapport Centre Investigation Cynégétiques. 9pp. (In French.)
- BANNER, A.J., R. POJAR, R. TROWBRIDGE, AND A. HAMILTON. 1986. Grizzly bear habitat in the Kimsquit River Valley, coastal British Columbia: classification, description, and mapping. Pages 36–49 in G. Contreras and K. Evans, eds. Proceedings—Grizzly bear habitat symposium. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT-207.
- BRAÑA, F., J. NAVES, AND G. PALOMERO. 1989. Hábitos alimenticios y configuración de la dieta del oso pardo (*Ursus arctos* L.) en la Cordillera Cantábrica. Acta Biol. Montana, Ser. Doc. Travail 2:27–38. (In Spanish.)
- BUTTERFIELD, B., AND C. KEY. 1986. Mapping grizzly bear habitat in Glacier National Park using a stratified Landsat classification: a pilot study. Pages 58–66 in G. Contreras and K. Evans, eds. Proceedings—Grizzly bear habitat symposium. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT-207.
- CAMARRA, J.J. 1989. Aire de repartition et sites d'activité de l'ours brun dans les Pyrénées Françaises. Off. Nat. de la Chasse, Saint Gaudens, France. 8pp. (In French.)
- CAMPO, J.C., J. MARQUÍNEZ, J. NAVES, AND G. PALOMERO. 1984. Distribución y aspectos poblacionales del oso pardo (*Ursus arctos*) en la Cordillera Cantábrica. Acta Biol. Montana 4:371–381. (In Spanish.)
- CLEVENGER, A.P., F.J. PURROY, AND M. SÁNEZ DE BURUAGA. 1987. Status of the brown bear in the Cantabrian Mountains, Spain. Int. Conf. Bear Res. and Manage. 7:1–8.
- CONTRERAS, G., AND K. EVANS, EDITORS. 1986. Proceedings Grizzly bear habitat symposium. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT-20. 252pp.
- CRAIGHEAD, J., J. SUMMER, AND G. SKAGGA. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. West Wildlands Inst. Univ. Mont. Foundation, Univ. Mont., Missoula. Monogr. No. 1. 279pp.
- CRAIGHEAD, J.F. AND D. CRAIGHEAD. 1986. Using satellites to evaluate ecosystems as grizzly bear habitat. Pages 101–112 in G. Contreras and K. Evans, eds. Proceedings—Grizzly bear habitat symposium. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT-207.
- EROME, G., AND J.L. MICHELOT. 1990. L'ours brun dans les Alpes Françaises. Faisabilité de sa réintroduction. Secrétariat d'Etat à L'Environ. La Maison de Valerie. Artus et Centre Ornitho. Rhone-Alpes, Villeurbanne, France. 409pp. (In French)
- MARQUÍNEZ, J., P. GARCÍA-MANTECA, AND A.M. FELICÍSIMO. 1991. Metodología para una cartografía básica ambiental en zonas no urbanas. Pages 1941–1946 in Second Int. Cong. on Reg. Planning. Servicio de Publicaciones Universidad Politécnica, Valencia, Spain. (In Spanish.)
- MEALEY, S.P. ED. 1986. Method for determining grizzly bear

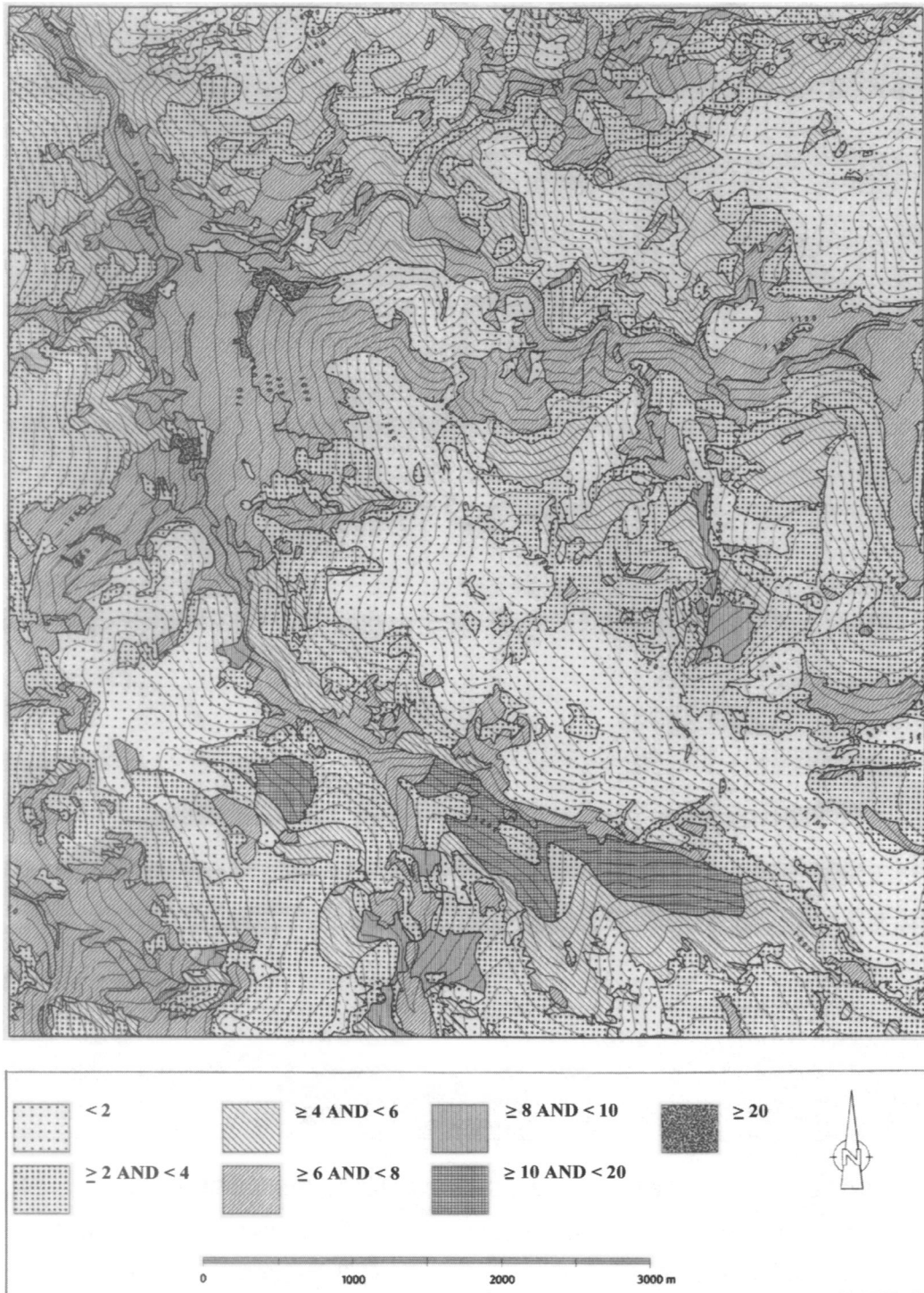


Fig 3. Map showing different trophic values for the whole year for the study area, in accordance with classes established in the Cantabrian Mountains, Spain.

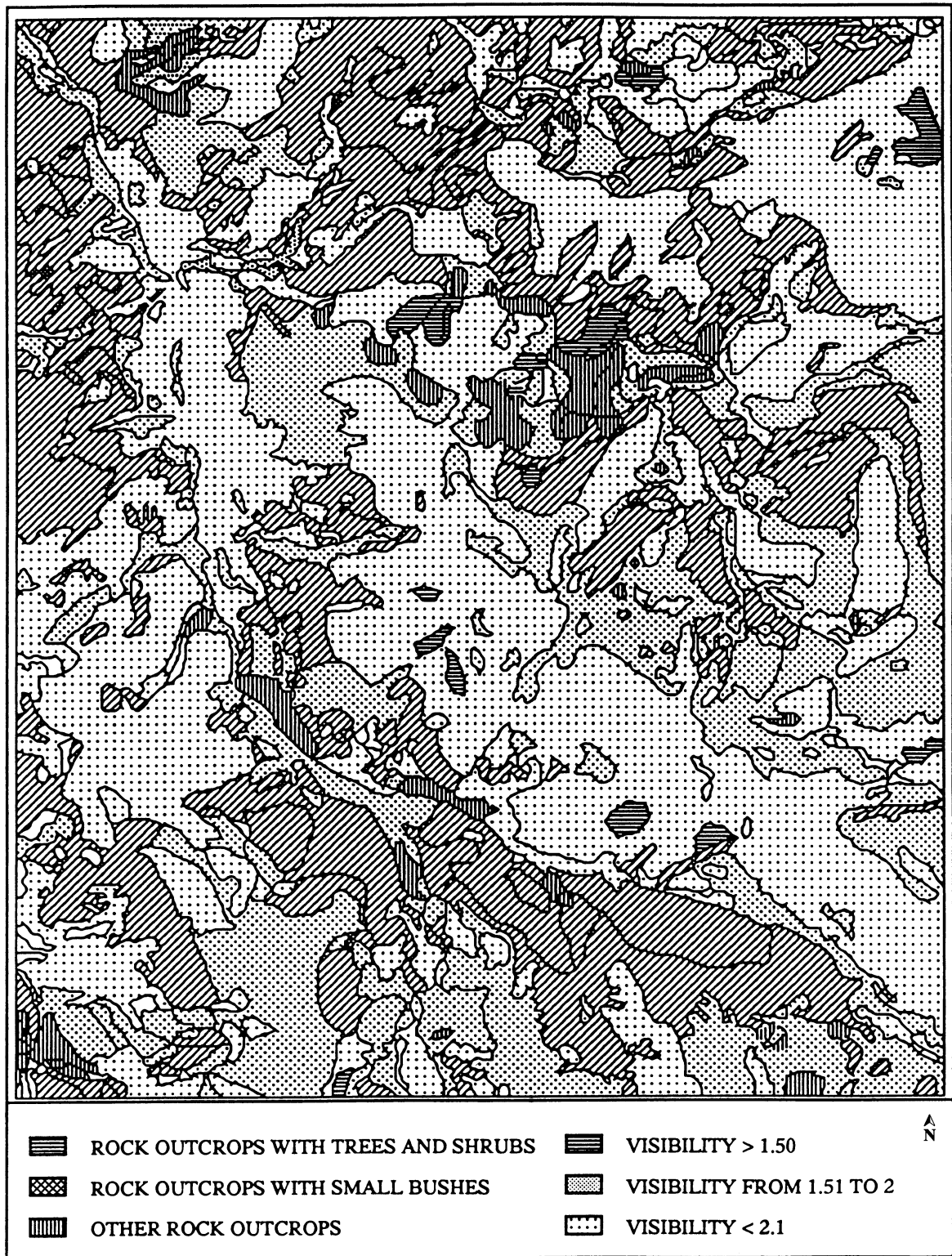


Fig 4. Map of areas with different refuge-cover values in the study area, showing the 6 classes established in the Cantabrian Mountains, Spain.

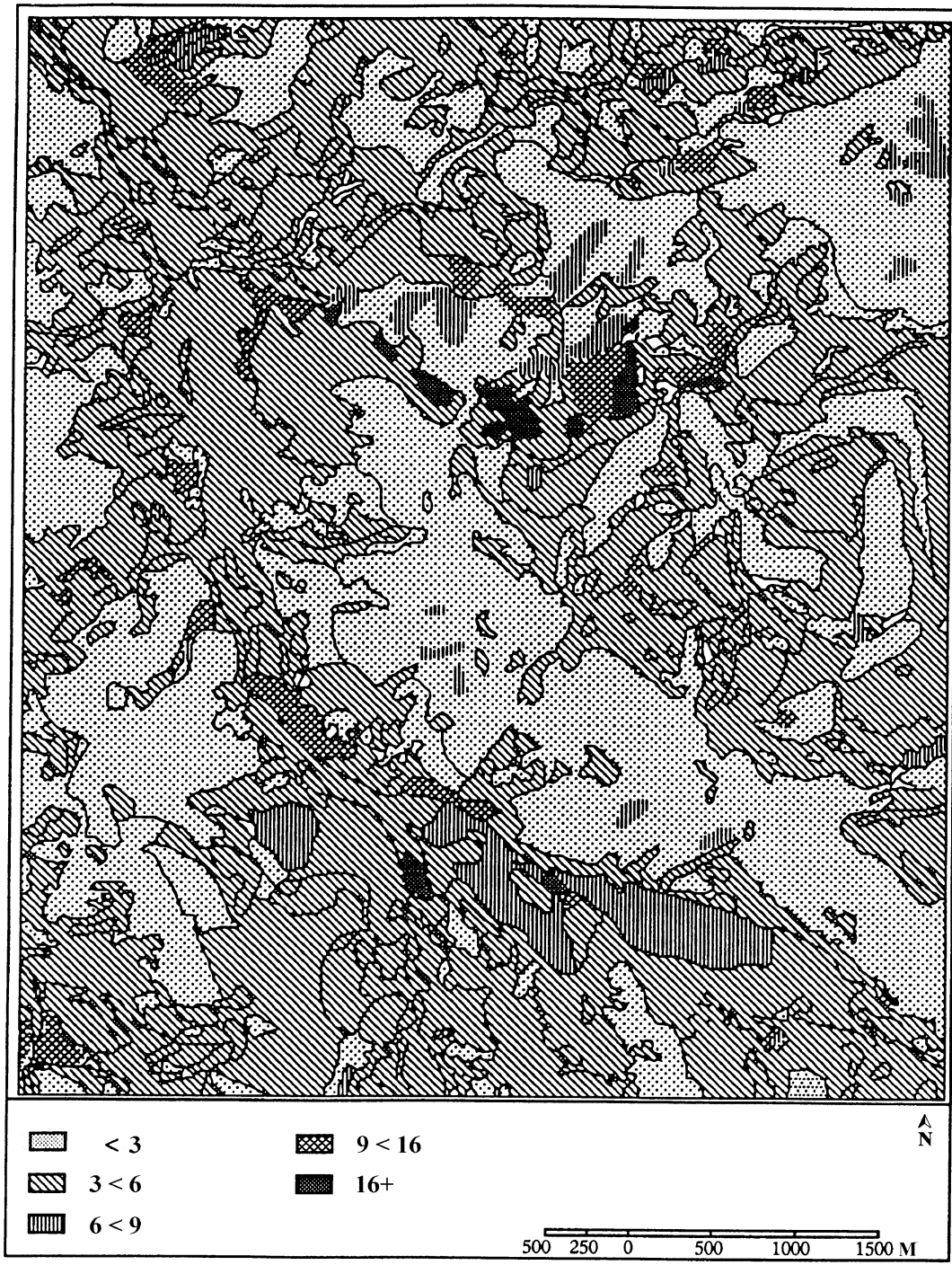


Fig 5. Map of areas with different habitat quality values for the whole year in the study area, showing the 6 classes established in the Cantabrian Mountains, Spain.

- habitat quality and estimating consequences of impacts on grizzly habitat quality. Pages 73–91 in *Interagency Grizzly Bear Guidelines*. U.S. Dep. Agric. For. Serv., U.S. Dep. Int. Nat. Park Serv., Bur. Land Mgmt., Idaho Fish and Game, Montana Dept. Fish, Wildl., and Parks, Washington Game Dept., Wyoming Game and Fish Dept. 99pp.
- NAVES, J., AND G. PALOMERO. 1989. Características ambientales y tipología de las oseras en Asturias. *Acta Biol. Montana, Series Document Travail*. 2:15–22. (In Spanish.)
- RIVAS MARTÍNEZ, S., T.E. DÍAZ, J.A. PRIETO, J. LOIDI, AND A. PENAS. 1984. La vegetación de alta montaña Cantábrica. *Los Picos de Europa Ediciones Leonesas, León, España*. 295pp. (In Spanish.)
- SCHOEN, J. 1990. Bear habitat management: a review and future perspective. *Int. Conf. Bear Res. and Manage.* 8:143–154.
- SERVHEEN, C. 1987. Grizzly bear compendium. U.S. Interagency Grizzly Bear Committee. U.S. Dep. Inter. Fish and Wildl. Serv., Missoula, Montana. 547pp.
- U.S. DEPARTMENT OF AGRICULTURE, NATIONAL PARK SERVICE, INTERAGENCY GRIZZLY BEAR STUDY TEAM, AND IDAHO FISH AND GAME DEPARTMENT. 1985. Cumulative effects model for grizzly bear management in the Yellowstone ecosystem. 38pp.
- U.S. DEPARTMENT OF AGRICULTURE, IDAHO DEPARTMENT OF FISH AND GAME, WASHINGTON DEPARTMENT WILDLIFE, USDI FISH AND WILDLIFE SERVICE, AND MONTANA DEPARTMENT OF FISH WILDLIFE AND PARKS. 1988. Accumulative effects analysis process for the Selkirk/Cabinet Yaak grizzly bear ecosystems. 32pp.
- WINN, D., AND K. BARBER. 1986. Cartographic modeling: a method of cumulative effects appraisal. Pages 247–252 in G. Contreras and K. Evans, eds. *Proceedings—Grizzly bear habitat symposium*. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT-207.