# BROWN BEAR HABITAT QUALITY IN GORSKI KOTAR, CROATIA

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*Abstract:* The brown bear (*Ursus arctos*) population in Croatia is a possible source of bears for reintroducing and augmenting disappearing European brown bear populations in western Europe. For successful reintroduction, knowledge about bear habitat quality of both source and target areas is necessary. We developed a habitat suitability index (HSI) model to assess European brown bear habitat quality in Gorski kotar, Croatia. Important habitat variables included seasonal foods, cover, roads, and fragmentation. Food sources were available year-round, whereas foraging and denning cover were more limited. Human influence was manifested through a relatively high density of roads (1.91 km/km$^2$), which included forest roads. Habitat fragmentation did not occur within the study area, but a highway under construction was a possible threat. The overall HSI value of 0.42 for the entire area indicated that brown bear habitat in Gorski kotar is average. Brown bear habitat could be improved with changes in management practices such as closing forest roads, seasonally avoiding logging in denning areas, and reducing reforestation of beech–fir (*Fagus* sp.–*Abies* sp.) areas to spruce (*Picea abies*).

*Ursus* **10:281–291**

**Key words:** Croatia, European brown bear, habitat quality, habitat suitability index, *Ursus arctos*.

One of the largest remaining brown bear populations in Europe occurs in the Dinara, Šara, and Pindus mountains (approximately 60,000 km$^2$) spanning Slovenia, Croatia, Bosnia and Herzegovina, Monte Negro, Macedonia (Huber and Frkovic 1993), Albania, and Greece (Servheen 1990). Within the Croatian portion of this range, about 400 bears inhabit approximately 9,800 km$^2$ (Huber and Frkovic 1993), and this number has been stable since the early 1980s (Frkovic et al. 1987).

Mitochondrial DNA testing has demonstrated that brown bears in the Dinara Mountains have greater genetic similarities to the small, isolated populations in the Alps, Apennines, and Pyrenees than to other European populations (Taberlet and Bouvet 1994, Randi et al. 1994). Consequently, they may be the best source to reintroduce or to augment existing bear populations in western Europe. Projects to reintroduce bears from the Dinara Mountains to other countries are in progress, with 3 (2 F, 1 M) bears already translocated to the Austrian Alps and another 3 (2 F, 1 M) to the French Pyrenees.

Maintenance of suitable bear habitat is central to the continued presence of the species in Europe (Servheen 1990). Knowledge of brown bear habitat relationships is needed to enhance management of existing European brown bear populations and to improve chances for successful reintroduction efforts. We developed a habitat suitability index (HSI) model for brown bears in southern Europe following the U.S. Fish and Wildlife Service's (1981) habitat evaluation procedures. We then used the HSI model to evaluate brown bear habitat in the Gorski kotar region of Croatia; we recommend management changes based on that analysis.

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## BROWN BEAR HABITAT SUITABILITY INDEX MODEL

### Habitat Use Requirements

Food habits and habitat use of brown bears in Croatia were analyzed by Cicnjak (1991). In spring and early summer, bears were found at lower elevations where food was available. Main food sources included broad-leaved garlic (*Allium ursinum*), lords and ladies (*Arum maculatum*), and carrion and corn at permanent feeding sites. Bears also visited meadows where they consumed grasses (*Gramineae* spp.), clovers (*Trifolium* spp.), and sorrels (*Rumex* spp.). During the summer wild angelica (*Angelica silvestris*) and stinking aposeris (*Aposeris foetida*) were the main plant foods eaten, although bears occasionally fed in oat fields (Huber and Moric 1989). By late summer, fruits ripened in meadows, abandoned orchards, along fields and roads, and in the forest; the most important bear foods were raspberry (*Rubus idaeus*), bramble (*R. fruticosus*), common buckthorn (*Rhamnus cathartica*), and blueberry (*Vaccinium myrtillus*). During fall, bears spent the most time in forested areas where beech nuts were abundant. Similar patterns were found in Cantabrian Mountains, Spain (Clevenger et al. 1992*a*,*b*). Beech trees start producing nuts at 40–50 years. Maximum crop production ($\bar{x}$ = 1.38 kg/tree) can be expected every 7th to 12th year; in other years production is 0.11 kg/tree. The cycle of beech productivity is different in different parts of the forest (Regent 1980). Depredation on domestic animals in Croatia was lower than in other European countries because of the availability of natural and supplemental food (Cicnjak 1991). While feeding on natural food, the average distance of bears to settlements and roads was not statistically different from randomly distributed points (Cicnjak 1991). Brown bear distribution and abundance has not been associated with water availability in Croatia (Cicnjak 1991).

European brown bears do not rely on protective cover to access food; they have developed crepuscular and nocturnal activity patterns when protection cover is poor (Roth and Huber 1986). The closest distance to which man can cautiously approach a European brown bear is about 30 m (pers. observ.). Bears that are approached closely may abandon some feeding places, but this may not be of great importance in habitat with good food sources elsewhere. Protective cover may be more important for selection of suitable daybeds or dens. Resting sites (day beds) had the shortest horizontal visibility ($\bar{x}$ = 8.4 m, range = 3–46 m), followed by denning sites ($\bar{x}$ = 12 m, range = 1–18 m) and feeding sites ($\bar{x}$ = 36, range = 6–186 m) (Cicnjak 1991).

Bears in Croatia den in forested areas at elevations from 450 m to 1370 m ($\bar{x}$ = 863 m, $N$ = 28). The average distance from dens to the nearest road was 486 m (range = 39–1500 m) and from dens to the nearest settlement was 1435 m (range = 200–4000 m) (Huber and Roth 1995). Feeding on energetically rich beech nuts, which were the most important food source for bears in Croatia in autumn (Cicnjak 1991), could be of great importance for successful wintering and giving birth (Schooley et al. 1994).

In Croatia, habitat types reflect differences in elevation, geology, and other ecological factors. Seasonal movements of bears reflect changes of food availability in different habitat types. In the contiguous habitat found in Gorski kotar, average home range size of bears for both sexes did not vary between spring, summer, and fall ($\bar{x}$ = 28 km$^2$, range = 1–102 km$^2$, $n$ = 32), although winter range was significantly smaller ($\bar{x}$ = 4 km$^2$, range = 0–18 km$^2$, $n$ = 5) (Huber and Roth 1993).

Forest management in the mountains of Croatia involves building a dense network of forest roads. These roads are not closed, which increases human access. Increased traffic on local and regional roads and railroads can increase traffic mortality of bears. Crossing sites on roads and railroads were recognized as important parts of migrating corridors (Huber et al. 1998). Telemetry studies in Slovenia (Kaczensky et al. 1996) showed that highways are a physical barrier for movements of females, whereas males occasionally cross during the mating season.

## HSI Model Applicability

This model describes habitat suitability in Gorski kotar, Croatia (Fig. 1). It can be applied to similar mountainous areas in Europe, such as the Alps, Pyrenees, Apenines, and Carpathians. It is designed to produce HSI values for year-round habitat needs of the brown bear. We assumed that carrying capacity is restricted by food availability and that a weak compensatory relationship exists for food availability among seasons. To stress importance of fall food, we weighted it by a factor of 2. The model can be applied on areas where beech, mixed beech–fir, and spruce forests prevail. The average home range size for both sexes of bears during foraging season was 28 km$^2$ (range = 1–102 km$^2$) (Huber and Roth 1993). Therefore, the model requires a minimum habitat area of 30 km$^2$.

The model was developed based on our knowledge of bear biology, expert opinion (A. Frkovic, Croatian Forests, Delnice, Croatia, pers. commun., 1993) and a thorough comparison with other models (Aste 1993; Van Manen and Pelton 1993, 1995; Clevenger et al. 1995); however, it has not been tested under field conditions.

## Components

A habitat suitability index (HSI) is a numerical index that represents the ability of a given habitat to support a specific species. An index of 0.0 represents unsuitable habitat, whereas an index of 1.0 represents optimal habitat. For HSI to be between 0.00 and 1.00, an assumed linear relationship between chosen habitat components and carrying capacity must be met (U.S. Fish and Wildlife Service 1981).

We defined food, cover, and human impact as the main bear habitat components (Fig. 2). Van Manen and Pelton (1993) defined ecological, physical, and cultural habitat components for American black bear (*Ursus americanus*). Aste (1993) listed the following bear habitat components for Austria: food type, food availability, availability of remote and safe places, and effect of limiting factors. Clevenger et al. (1992*a*) ranked bear habitat in Cantabrian Mountains (Spain) by quality of forest cover, elevation, distance to nearest village, and distance to nearest paved road. The following sections describe the important habi-

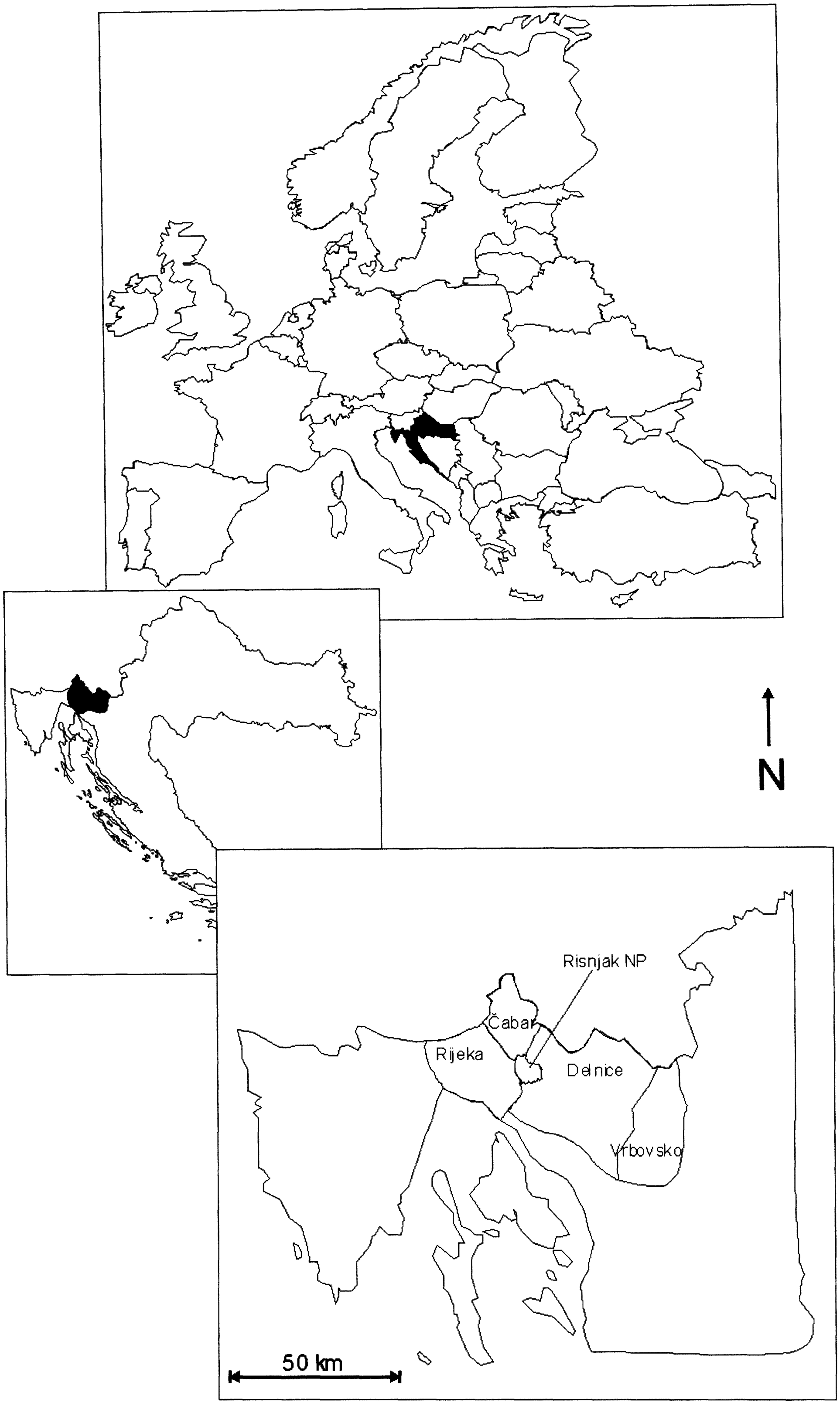



**Fig. 1. Location of Croatia (top), the Gorski kotar study area (middle), and the study area sections (bottom).**

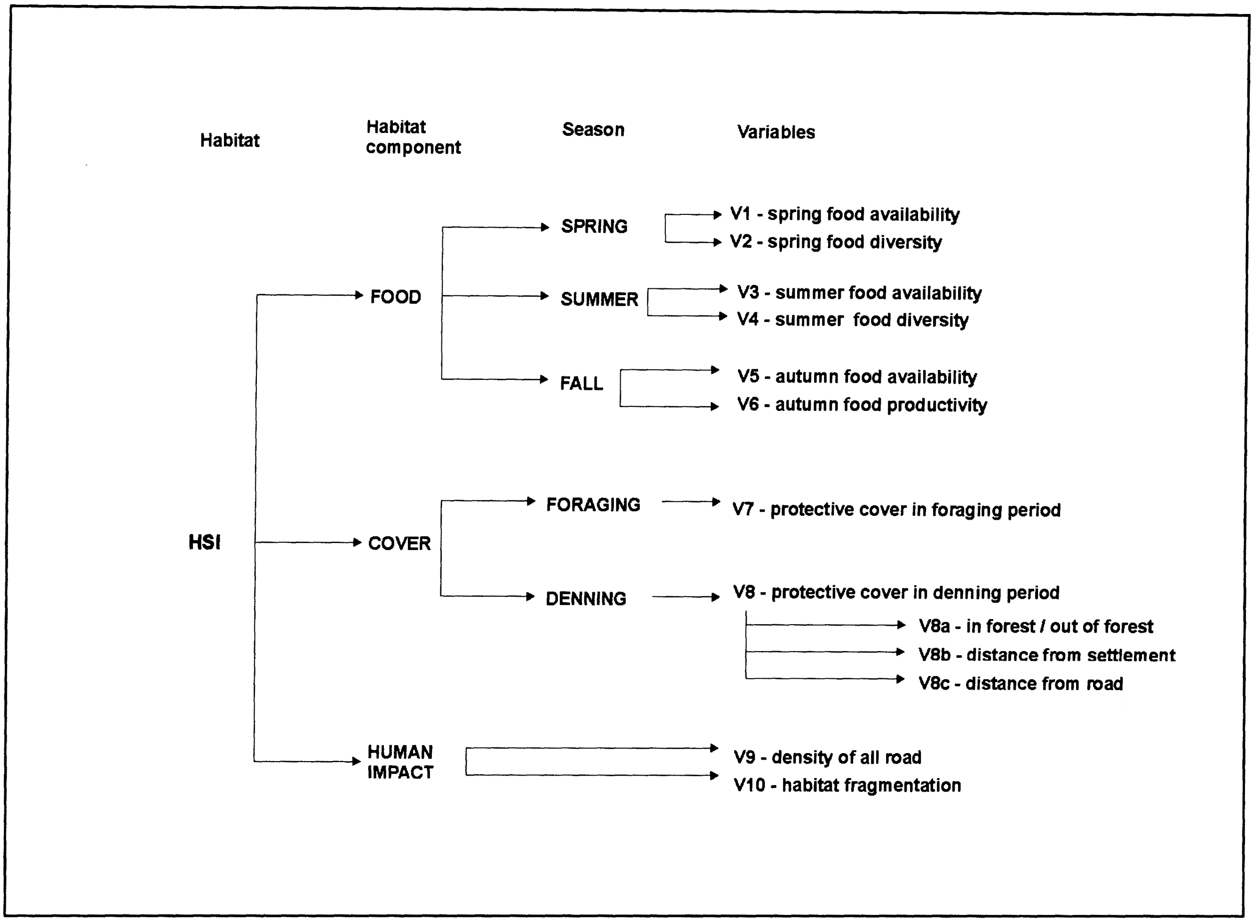



**Fig. 2. Structure of the brown bear habitat suitability index (HSI) model for Gorski kotar, Croatia.**

tat variables used in the model, the suitability level of these variables, and the relationships among variables.

*Food.*—We considered only plants that were present in bear diets with a frequency ≥5% and volume ≥0.5% (Cicnjak 1991). A total cover of 10% for 1 or for several plants was taken as the threshold of optimal index (Fig. 3 A, C). We measured the following 10 variables of suitability indices (SI) and further subdivided variable 8 into 3 subvariables:

V1, spring food availability
V2, spring food diversity
V3, summer food availability
V4, summer food diversity
V5, autumn food availability
V6, autumn food productivity
V7, protective cover in foraging period
V8, protective cover in denning period
 V8a, in/out of forest
 V8b, distance from settlement
 V8c, distance from road
V9, density of all roads
V10, habitat fragmentation

When total cover was <10% (V1 or V3 <10%), calculation for spring and summer was $SI_{V1 \text{ or } V3}$ = 1/10 V1 or V3. When total cover was ≥10% (V1 or V3 ≥ 10%), the value was $SI_{V1 \text{ or } V3}$ = 1.00 (Fig. 3 A, C). Beech cover, because it produced the most important fall food, changed SI linearly from 0% to 100%, (Fig. 3 E). This relationship was chosen because productivity cycles of beech trees vary in time in different areas. Not all beech trees produce maximum crops in the same year (Regent 1980). The same model was used by Aste (1993).

When a single significant bear plant was found in spring or summer, the area was assigned an $SI_{V2 \text{ or } V4}$ = 0.50. If ≥2 plants were found, we assigned $SI_{V2 \text{ or } V4}$ = 1.00 (Fig. 3 B, D). When <40% of beech trees produced nuts (V6 <40%) SI was calculated as $SI_{V6}$ = (1/40)V6. For V6 >40%, $SI_{V6}$ = 1.00 (Fig. 3 F).

*Cover.*—We evaluated hiding cover separately for the foraging and denning period. If <25% of the sites in a

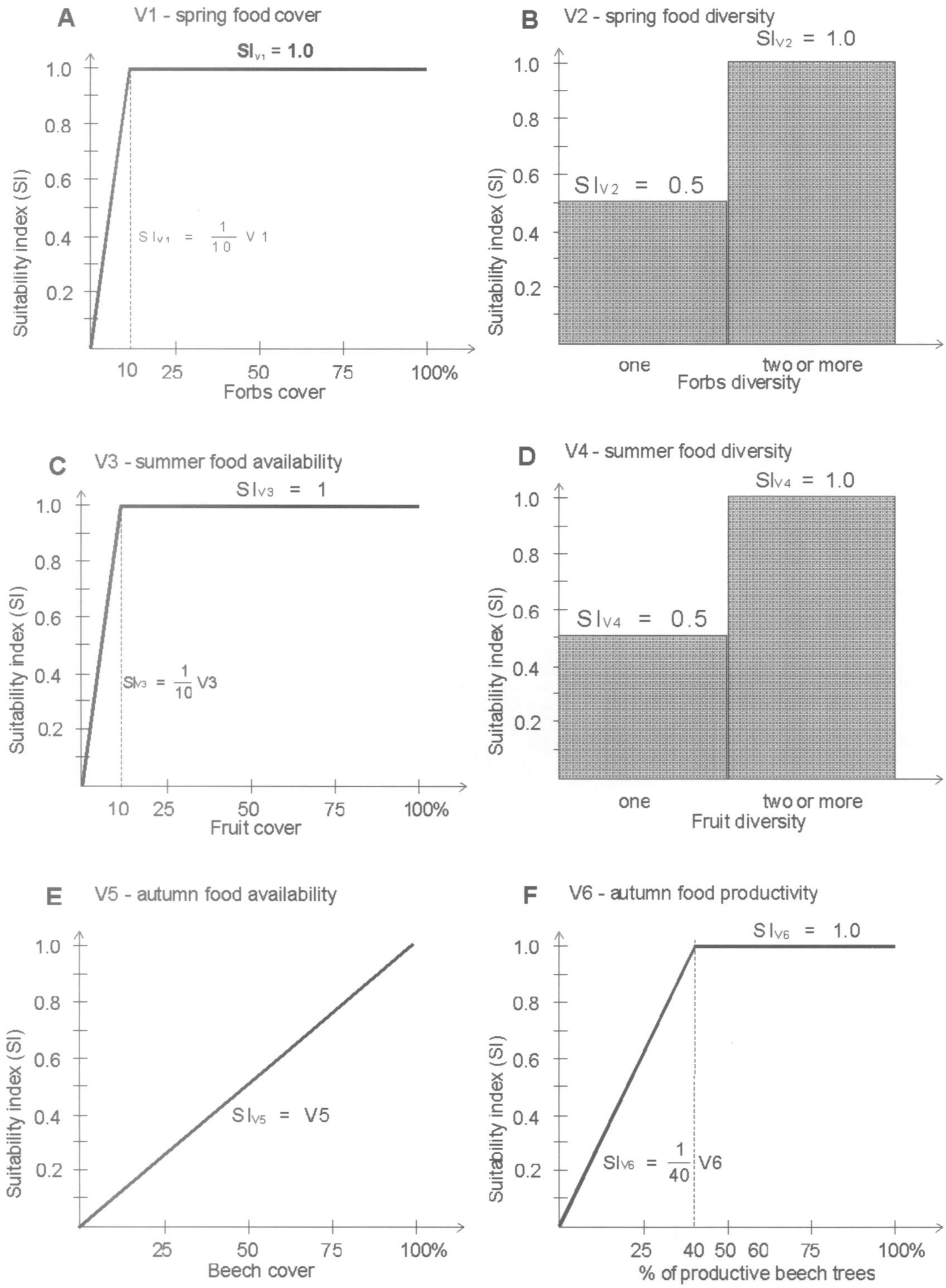



**Fig. 3. Relationships of suitability indices (SI) and 13 habitat variables used in the brown bear HSI model. (A) Spring food availability. (B) Spring food diversity. (C) Summer food availability. (D) Summer food diversity. (E) Autumn food availability. (F) Autumn food productivity. (G) Protective cover in foraging period. (H) Sites for denning. (I) Distance of denning areas from road. (J) Distance of denning areas from settlement. (K) Protective cover in denning period. (L) Density of all roads. (M) Habitat fragmentation.**

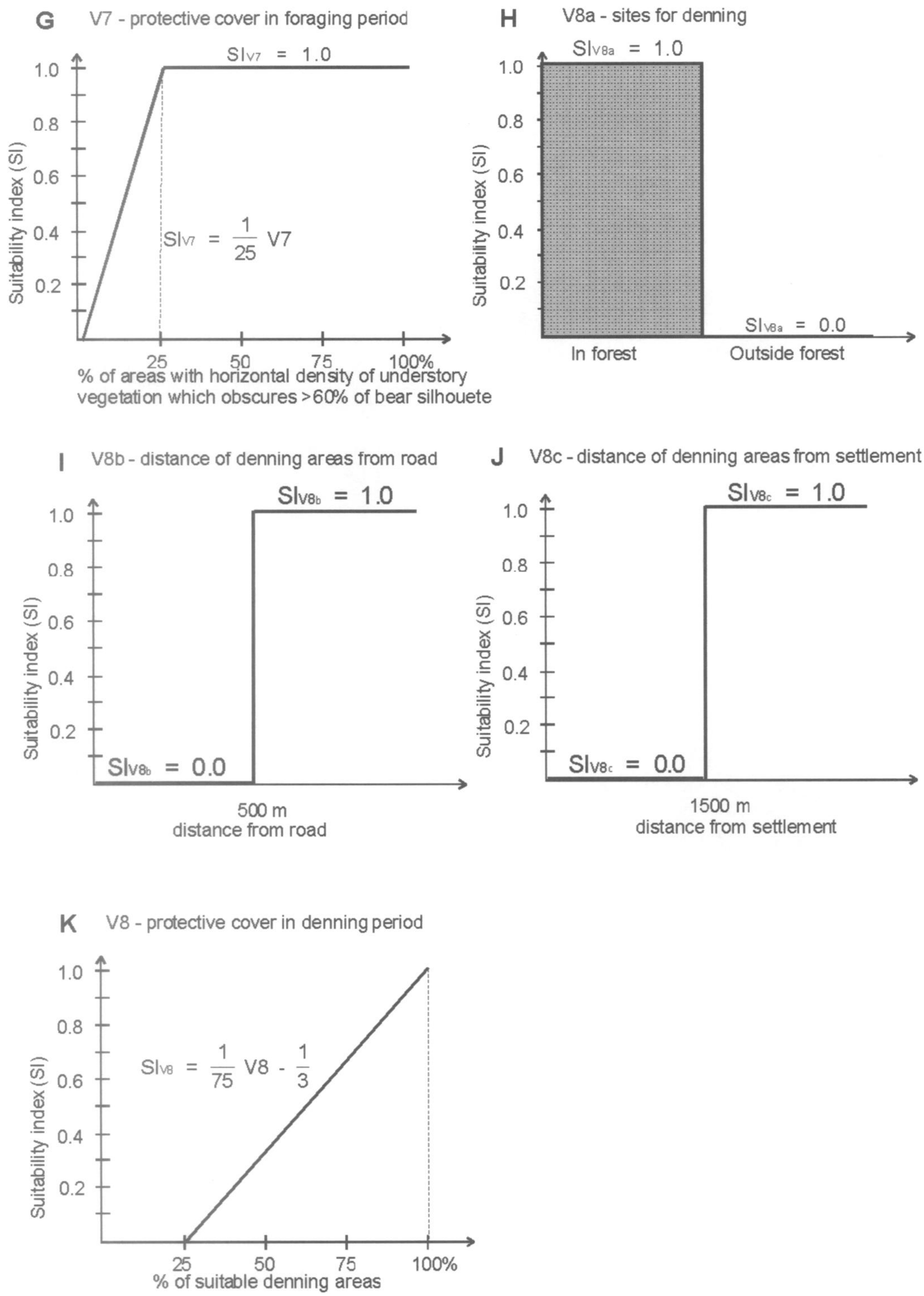
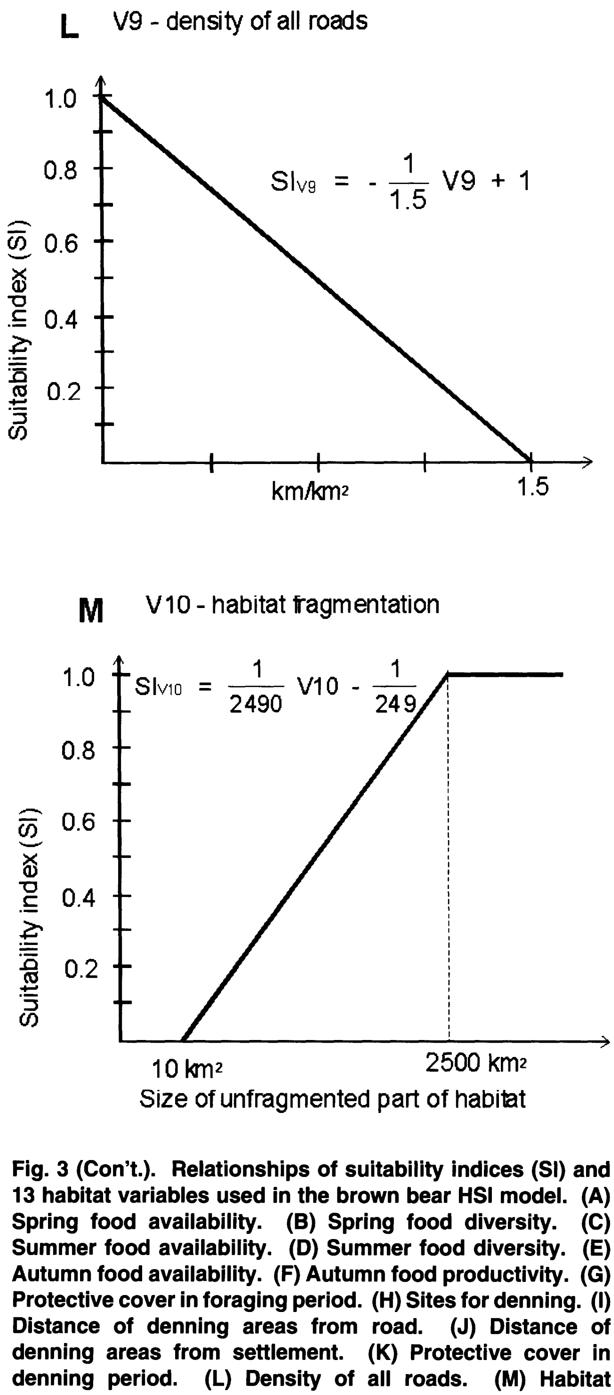



**Fig. 3 (Con't.). Relationships of suitability indices (SI) and 13 habitat variables used in the brown bear HSI model. (A) Spring food availability. (B) Spring food diversity. (C) Summer food availability. (D) Summer food diversity. (E) Autumn food availability. (F) Autumn food productivity. (G) Protective cover in foraging period. (H) Sites for denning. (I) Distance of denning areas from road. (J) Distance of denning areas from settlement. (K) Protective cover in denning period. (L) Density of all roads. (M) Habitat fragmentation.**

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foraging area had adequate cover (V7 < 25%), then $SI_{V7} = (1/25)V7$. When ≥25% of the sites had adequate cover, $SI_{V7}$ was assigned the value of 1.00 (Fig. 3 G).

Suitable denning areas in forests had $SI_{V8a} = 1.00$; denning areas outside forests had $SI_{V8a} = 0.0$ (Fig. 3 H). Denning areas >500 m from roads ($V_{8b}$ > 500 m) were assigned a value of 1.00 for $SI_{V8b}$, whereas closer distances (less suitable) were assigned $SI_{V8b} = 0.0$ (Fig. 3 I). Denning areas <1500 m from human settlements also were considered unsuitable for denning ($SI_{V8c} = 0.0$), but areas >1500 m were considered suitable bear denning habitat ($SI_{V8c} = 1.00$) (Fig. 3 J). Areas suitable for denning (V8) were determined by the factor with the lowest value, because we assumed that factors would be limiting (V8 = min [V8a, V8b, V8c]). It was possible for only part of a section to be suitable for denning if it was in the forest and >500 or >1500 m away from the road or settlement, respectively. The habitat section being analyzed should have >25% suitable denning sites for $SI_{V8}$ to be >0.0 ($SI_{V8} = (1/75)V8 - (1/3)$). The same model was used by Aste (1993) for calculating availability of remote areas.

*Human Impact.*—We evaluated human impact by summing total length (V9, km/km$^2$) of all roads, including forest roads that are open and accessible to the public, and by searching for possible habitat fragmentation. We assumed that habitat quality decreased as the density of roads increased; areas with > 1.5 km/km$^2$ roads received $SI_{V9} = 0.0$ (Fig. 3 L). We used the same model developed by Aste (1993).

Part of the habitat was considered isolated if it was surrounded by 500 m of unforested area. We did not consider habitat as isolated, even if it contained railroads or roads, if there were places for crossing (tunnel, viaduct, "green bridge"). Areas <10 km$^2$ (V10 <10km$^2$) received an $SI_{V10}$ of 0.0, whereas $SI_{V10}$ for areas of 10 to 2,500 km$^2$ were calculated from $SI_{V10} = (1/2490)V10 - (1/249)$ (Fig. 3M). The same model was used by Aste (1993).

## Equations

Suitability indexes of all habitat components were combined according to importance, value, and compensatory or limiting nature. To emphasize the importance of fall food, we squared average of $SI_{V5}$ and $SI_{V6}$. Also, for overall HSI, $SI_{FOOD}$ was multiplied by 2 because of its greater importance compared to other habitat components. To calculate an overall SI, we took the average SI for all sections. The following equations were used to calculate HSI:

$$SI_{FOOD} = (((SI_{V1} + SI_{V2})/2)*((SI_{V3} + SI_{V4})/2)*(((SI_{V5} + SI_{V6})/2)^2))^{1/4} \quad (1)$$

$$SI_{COVER} = (SI_{V7} + SI_{V8})/2 \quad (2)$$

$$SI_{HUMAN\ IMPACT} = (SI_{V9} + SI_{V10})/2 \quad (3)$$

$$HSI = (2SI_{FOOD} + SI_{COVER} + SI_{HUMAN\ IMPACT})/4 \quad (4)$$

All statistical analyses were performed using SAS software (SAS Inst., Inc. 1989)

## Application of the Model

This model can be applied to areas with plant communities defined by Braun–Blanquet's method. Other areas would require field sampling to determine presence and amount of bear food plants.

## Sources of Other Models

Existing models for evaluating bear habitat suitability (Aste 1993, Van Manen and Pelton 1994, Clevenger et al. 1995) were not found to be appropriate for European southeastern mixed deciduous–conifer forests, but were used as a starting point for construction of the model.

## Application of the HSI in Gorski Kotar

Gorski kotar (1,796 km$^2$) is situated in Croatia in the narrowest part of the Dinarids (Fig. 1). It comprises the northwest end of the Dinara Mountains, which divide Mediterranean from the continental part of Croatia and the Adriatic Sea from the Black Sea drainage.

The mountains consist mainly of carbonate rocks with older silicates that are not water permeable (Horvat 1962). The highest mountains are Bjelolasica (1,533 m) and Risnjak (1,528 m). Gorski kotar has a moderately cold climate (yearly average temperature about 8C) with a relatively large amount of precipitation (up to 377 cm/year) and high snow cover, which averages 139 days/year (Penzar 1959). The cover types used by brown bears in Croatia are defined by several plant communities. Forests cover 66% (1,191 km$^2$) of the total area, of which 91% is managed. Vegetation shows clear altitudinal differentiation, and Horvat (1962) described 3 main vegetation belts. Deviations from the main zonality are varied by different exposure, slope, wind, and other ecological factors. Elevations from 0 m to 850 m by the Adriatic Sea are covered with sub-Mediterranean thermophil forests belonging to *Ostryo–Carpinion orientalis* group. Deciduous and mixed forests of *Fagion illyricum* group cover the largest part of Gorski kotar stretching from 900 m (600 m on continental side) to 1400 m above sea level. Dwarf mountain pine (*Pinetum mugi croaticum*) is found above 1400 m (Horvat 1962).

Gorski kotar is divided into 4 political units: Cabar, Delnice, Vrbovsko, and Rijeka (Fig. 1). These are also forest management units and our study area sections. The area is inhabited by 236,000 people in 308 settlements, but the majority (74%) live in 3 towns on the Adriatic coast (i.e., in the 10% of land area that is marginal bear habitat). The rest of the area (90%) is mountainous and is inhabited by 24 humans/km$^2$. A majority of local people work in forestry (9.5%) and related industries (48%). Only 1.4% work in agriculture on 331 km$^2$ of pastures, meadows, fields, gardens, and orchards that comprise 18% of total study area (Drzavni zavod za statistiku 1993).

We calculated availability of plant food using phytocenological data (Horvat 1938; Trinajstic 1972, 1995; Pavletic et al. 1982; Vukelic 1985) for specific plant communities for each season except winter. The location and size of each phytocenosis came from Delnice Forest Management (1994), the agency that manages the forest in the study area. The percent of beech trees producing nuts was calculated using information that classified crop producers (K. Poštenjak, Dipling. Jastrebarslo, Croatia, pers. commun., 1994) and that provided the number of trees/hectare in each perimeter class for each plant community (Cestar et al. 1986). We estimated the density of understory vegetation on random 450-m$^2$ plots ($n$ = 20 for each plant community) by measuring the percentage of an average bear silhouette (95 x 130 cm) covered at a 15 m distance from east, west, north, and south. This method combined those of Cicnjak (1991) and Van Manen and Pelton (1995). The mean of these 4 measurements was used as percent cover for each site. For each plant community we determined how many random points had cover values >60%. Areas suitable for denning and fragmentation were determined by using 1:25,000 colored topographic maps. For total lengths of main, regional, and local roads, we used data from the State Department of Statistics (Drzavni zavod za statistiku 1993). For forest roads lengths, we used data from Delnice Forest Management (1994).

## RESULTS AND DISCUSSION

Plants belonging to genera *Allium*, *Arum*, and *Rumex* represented spring food availability and provided an overall 4.94% cover. Averaging the $SI_{V1}$ values for each section yielded an overall $SI_{V1}$ = 0.48. (Table 1). The minimum % cover of spring food (1.38) was recorded for habitat facing the Adriatic Sea (Rijeka), whereas the maximum of 8.77% cover was found at lower elevations on the continental side (Vrbovsko). In all sections, only 1 plant species (lords and ladies) was present with 10% coverage, which resulted in $SI_{V2}$ = 0.50 (Table 1) for the entire study area for spring food diversity.

Summer food covered >10% of each habitat section ($\bar{x}$ = 25.21%) giving an overall $SI_{V3}$ = 1.00 (Table 1). The lowest abundance of food was again found near the seacoast compared to higher continental areas. In all habitat sections, we found >1 (max = 10) summer food plants, resulting in $SI_{V4}$ = 1.00 for summer food diversity (Table 1).

Beech, the only important producer of fall food in the study area, covered 55.92% of forested area, resulting in

**Table 1. Suitability indices (SI) of brown bear habitat variables for Gorski kotar, Croatia, 1995.**

| | Suitability indices (SI) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Section | $SI_{V1}$ [a] | $SI_{V2}$ [b] | $SI_{V3}$ [c] | $SI_{V4}$ [d] | $SI_{V5}$ [e] | $SI_{V6}$ [f] | $SI_{V7}$ [g] | $SI_{V8}$ [h] | $SI_{V9}$ [i] | $SI_{V10}$ [j] |
| Delnice | 0.47 | 0.50 | 1.00 | 1.00 | 0.45 | 0.27 | 0.19 | 0.00 | 0.00 | 0.28 |
| Èabar | 0.44 | 0.50 | 1.00 | 1.00 | 0.64 | 0.27 | 0.06 | 0.00 | 0.00 | 0.11 |
| Rijeka | 0.12 | 0.50 | 1.00 | 1.00 | 0.57 | 0.31 | 0.20 | 0.16 | 0.00 | 0.21 |
| Vrbovsko | 0.88 | 0.50 | 1.00 | 1.00 | 0.59 | 0.25 | 0.10 | 0.00 | 0.00 | 0.11 |
| Overall | 0.48 | 0.50 | 1.00 | 1.00 | 0.56 | 0.28 | 0.14 | 0.04 | 0.00 | 1.00 |

[a] spring food availability.
[b] spring food diversity.
[c] summer food availability.
[d] summer food diversity.
[e] autumn food availability.
[f] autumn food productivity.
[g] protective cover in foraging period.
[h] protective cover in denning period.
[i] density of all roads.
[j] habitat fragmentation.

a fall food availability of $SI_{V5} = 0.56$ (Table 1). An average 11.04% of all beech trees were capable of producing nuts, for a suitability index for fall food productivity of $SI_{V6} = 0.28$ (Table 1). Private forests (20% of all forests), which are situated mostly around villages, lack mature beech trees and conifers. There were no significant differences among study area sections in food availability in different seasons ($P > 0.05$).

Bear movements are related to food availability (Craighead et al. 1982, Cicnjak 1991, Hamer et al. 1991). Home range sizes of brown bears in Croatia do not differ among seasons except winter (Huber and Roth 1993). This may be explained by year-round balanced food availability in our study area. Spring food had the lowest abundance in Rijeka section, near the Adriatic Sea, whereas lower continental areas provided the best spring habitat. Fall food availability was good throughout the entire study area because beech trees covered about 50% of all forested surfaces. The limiting factor seemed to be beech productivity. Management practices have resulted in 11.04% of beech trees at productive ages, decreasing the suitability of bear habitat. Clearcuts, which are sometimes made as circular openings or clearcuts of entire mountain slopes, may provide good summer foods during early succession stages. Replanting such areas with spruce, which suppresses most understory vegetation, will not promote good bear habitat for the future. Permanent bear feeding sites, which offered carrion and slaughterhouse refuse, are visited mostly in spring (A. Frkovic, Croatian Forests, Delnice, Croatia, pers. commun., 1993), but there is no data on quantities of food eaten by bears.

Only 2.87% of the study area had horizontal protective cover with a density >60%. The average $SI_{V7}$ for all sections resulted in an overall $SI_{V7} = 0.14$ (Table 1). All areas with low horizontal visibility were found in beech forests on rugged terrain with steep slopes and abundant running water. Low visibility was related more to terrain configuration than to vegetation density.

The overall area providing suitable den sites was 19.56%; the average $SI_{V8}$ for all sections was 0.04 (Table 1). The number and size of available sites varied within areas. The Delnice, Cabar, and Vrbovsko sections all had $SI_{V8} = 0.0$ (Table 1). The Rijeka section had an $SI_{V8} = 0.16$ (Table 1); it was the only section with $SI_{V8} > 0.0$. The Rijeka section had 88.76 $km^2$ (37.09%) of suitable denning habitat, which differed significantly ($P = 0.00046$, ANOVA [analysis of variance]) from other sections. Risnjak National Park (16.90 $km^2$) and the section of Rijeka (31.55 $km^2$) that bordered the park were the 2 biggest contiguous denning areas in the northwestern part of study area.

Availability of suitable denning sites was limited mainly by the presence of roads, especially forest roads. The number and size of suitable denning areas can indicate possible habitat fragmentation in the future. Bears in Croatia den in areas that we indicated as unsuitable, but there is a higher possibility of disturbance. Mild winters and early springs with little or no snow cover are regular periods for logging beech trees. At least 3 maternal dens in 1993–94 were disturbed due to logging and hunting. Areas identified as suitable for denning should be excluded from logging during winter until late April if maternal dens need to be protected.

The density of all roads in the study area was 1.91 km/km², resulting in $SI_{V9} = 0.0$ (Table 1). The mean density of all roads in Delnice, Èabar, Rijeka, and Vrbovsko was 2.07, 1.95, 1.74, and 1.89 km/km² respectively, resulting in $SI_{V9} = 0.0$ for all sections (Table 1). This density does not prevent brown bears from inhabiting the area. In the Cantabrian Mountains of Spain, areas inhabited by brown bears have an average roads density of 0.71 km/km² while areas uninhabited by bears have a mean road density of 0.85 km/km² (Clevenger et al. 1995). Road density indicates possible human access into bear habitat which could affect the bears' security (i.e., hunting, forestry operations, traffic caused mortality, tourism, and other activities). By excluding forest roads, the density of main, regional, and local roads dropped to 0.83 km/km². The highest density of non-forest roads was found in Rijeka, (1.31 km/km²), followed by Vrbovsko (0.72 km/km²), Delnice (0.71 km/km²), and Èabar (0.59 km/km²). Closing forest roads would increase $SI_{V9}$ to 0.45, $SI_{HUMAN\ IMPACT}$ to 0.73, and the overall HSI to 0.48. It would also increase the area of suitable denning sites.

Habitat fragmentation did not occur on any section or on the 1,796-km² of study area. The $SI_{V10}$ values for each of the study area sections and for the entire study area were limited only by the sizes of the areas. Gorski kotar is connected with the rest of bear range in Croatia (9,800 km²), which is a part of contiguous brown bear range stretching from Slovenian thorough Croatian, Bosnian, and Monte Negro parts of the Dinara Mountains (Huber and Frkovic 1993). Because this range is part of a much larger area, we assigned $SI_{V10} = 1.00$ (Table 1). The main road stretched through the middle of study area, and the majority of settlements were located along it. The 5-km belt stretching along the main road still had 66% forest vegetation. At least 3 bear crossing sites were identified along the road (Huber et al. 1998). A new highway under construction will connect the Adriatic Sea coast with the continental part of Croatia, through the middle of Gorski kotar. If all proposed measures (D. Huber, Veterinary Faculty, Zagreb, Croatia, unpubl. data.) are implemented, existing bear corridors will not be cut.

The final SI values for the food, cover and human impact habitat components were 0.55, 0.09, and 0.50, respectively, resulting in an overall HSI of 0.42 (Table 2). The HSI evaluation indicated a good food base, especially during summer, below average protective cover , and average impact of humans. The overall HSI indicated average quality of bear habitat in Gorski kotar, Croatia.

Our model assumes that open roads have a big impact on brown bear habitat. As we noted, simply excluding forest roads raises HSI values. Field validation and testing of our model is needed to examine this assumption as it relates to impacts on denning and mortality.

**Table 2. Suitability indices (SI) for habitat components and habitat suitability indices (HSI) for Gorski kotar, Croatia, 1995.**

| Section | $SI_{FOOD}$ | $SI_{COVER}$ | $SI_{HUMAN\ IMPACT}$ | HSI |
|---|---|---|---|---|
| Delnice | 0.50 | 0.10 | 0.14 | 0.31 |
| Èabar | 0.56 | 0.03 | 0.06 | 0.30 |
| Rijeka | 0.49 | 0.18 | 0.11 | 0.32 |
| Vrbovsko | 0.59 | 0.05 | 0.06 | 0.32 |
| Overall | 0.55 | 0.09 | 0.50 | 0.42 |

We conclude that brown bear habitat in Gorski kotar is still in good condition and connected with the remaining bear range on Dinara mountain. Only moderate management changes are necessary to maintain and improve the current state. Proposed short-term measures that would have immediate effects are closing existing forest roads, restricting construction of new roads, and avoiding forest activities in denning areas during denning season. Long-term measures include modifying management to minimize reforestation with spruce in beech–fir areas and ensuring proper garbage management.

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