Bear Habitat Suitability in Relation to Habitat Types of European Interest in NE Pindos Mountain Range, Greece.

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Abstract. *Northern Pindos mountain range constitutes the largest continuous bear habitat in Greece and the southernmost edge of the Dinara-Pindos bear population. It is mostly covered by high forest vegetation including many important habitat types of European interest. In this study, results from a 2 year bear monitoring period using satellite telemetry, and ground surveys, as well as results from a habitat type inventory, using field surveys and remote sensing, are presented and analysed.*

Ecological Niche Factor Analysis (ENFA) model as performed by the Biomapper package was used to compile and analyze brown bear data sets in relation to key habitat factors.

Bear habitat suitability maps were produced in order to compare bear habitat suitability levels to spatial distribution of EU habitat types.

Keywords. Habitat types, habitat use, Pindos, satellite telemetry, *Ursus arctos*.

1. Introduction.

For a given species and/or population, physical habitat could be essentially defined as the number of environmental components, necessary to satisfy its ecological and biological requirements in a given time and space frame and at any stage of its biological cycle. A habitat is also defined as any part of the biosphere where a particular species can live either temporarily or permanently [8]. We could refine the habitat use concept in relation to a specific bear population/sub-population, given the fact that even though the basic ecological requirements of the species present general common features throughout its distributional range in a given eco-geographic region (i.e. S. Balkans), the realized habitat preferences in a more specific geographical area may differ to a certain extent from those exhibited in another sector of the species regional range. In an environmental management context targeting a geographically defined bear sub-population, we need to take into account the aforementioned assumption in order to adjust and optimize the necessary measures for the conservation of the specific sub-population.

Moreover, definition of the habitat concept has been formulated by the EU terminology [12] for the Habitats Directive (92/43 EEC). Under this legislative tool "habitat of a species" means "*the environment defined by specific abiotic and biotic factors, in which the species lives at any stage of its biological cycle*". However, under the 92/43 Directive the term "habitat" has been also used to include a more broad bio-geo-coenose concept. According to this approach "*natural habitats are terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural*". The identification and categorization of natural habitat types is achieved in most cases by means of phyto-sociological classification criteria of plant communities in high taxonomic ranks.

The establishment of the European ecological network Natura 2000 is based on the designation of sites that are important for the conservation or restoration of rare and/or typical natural habitats (habitat types of Community interest) and habitats of rare and/or endemic species (species of Community interest).

However, the two interpretations of the concept of habitat have direct consequences in the implementation of the concept in the field and

ultimately inenvironmental management. The aim of this study is to implement and compare the two interpretations in a defined area. More specifically, in the Grevena region of NE Pindos we study the fine scale habitat suitability of the brown bear (Ursusarctos), a conservation priority species. In the same area, we define the habitat types in accordance to the EU directive. We compare the two results and highlight how they are interrelated and how this possible combination could enhance conservation proposals.

2. Materials and Methods

2.1. Study area

Our study site Grevena extends over 800 km^2 of a mixed forest and agricultural ecosystem and is located in the north-eastern part of Pindos mountain range (Lygos and Hassia mountain massifs) (Fig. 1). Of this area 75% are forests, 10% meadows (pasture lands), 14% agricultural lands, whereas low population density human settlements occupy 0.3% of the total area. Major forest vegetation types comprise oak (*Quercus* spp.), black pine (*Pinus nigra* ssp. *nigra* var. *caramanica*) and beech (*Fagus sylvatica* ssp. *sylvatica*). A mosaic of dense forests, openings and small-scale cultivations characterizes the area. Altitude ranges between 500 m - 2200 m asl. Mean monthly temperatures range from -3.4° C min to 28.2° C max. Mean annual precipitation is 589 mm. [13]. Part of the study site is included in the Northern Pindos National Park.

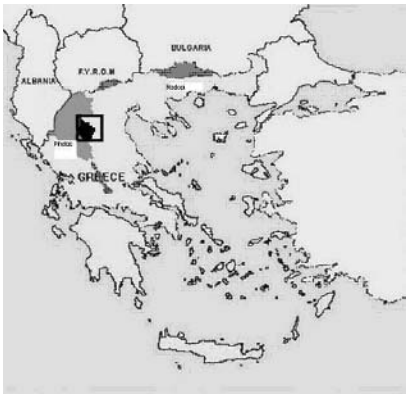

Figure 1. Brown bear range in Greece and study area

2.2 Data collection

We used an 'Aldrich Foot Snare' trap type to catch six adult brown bear specimens (13.6% of the minimum sub-population estimated at 44 individuals through DNA typing [14]. Sex ratio and age classes of the sample were partitioned as follows: 4 young adult males and two adult females. The bears were sedated with Zoletil (50)/Domitor (MT). We fitted the bears with satellite GPS TELEVILT radio-collars with remote download system (RX-900 TELEVILT receiver) and 12 hours VHF beaconing. The collars were set-up to give 15-17 positions daily (the effective positions averaged 6-10 daily). GPS telemetry data coordinates were directly mapped on EGSA 87 probolic system using ArcGis 9.2 software. Duration of bear monitoring period ranged from 1 to 13 months (average 6.8 months). Total monitoring period extended from 2003 to 2005.

We also conducted systematic ground surveys for collection of bear signs of presence and activity. The total length of sampling transects (1,008 km) followed the dense (1.5 km/km^2) forest road network present in the study area.

As the source data for landscape structure quantification, we used raster maps (resolution 50 x 50 m^2) of the land cover of the study sites. The vegetation cover was mapped by the forestry service (Forest Management Plans of 1994 at a resolution of 1:20.000) and updated based upon orthorectified aerial photographs of the area. For each cell we considered its land use (classified as dense forest, partially forested area, grassland meadows, bare land, cultivated fields, infrastructure and surface water). Woodlands were further classified as oak (*Quercus* spp.), beech (*Fagus sylvatica* ssp. *sylvatica*), black pine (*Pinus nigra* ssp. *nigra* var. *caramanica*), white-barked pine (*Pinus heldreichii*) and mixed broadleaved species.

Our analysis took into consideration not only the contents of each cell in our raster, but also the landscape composition of its spatial neighborhood. We quantified the landscape composition in neighborhoods of different size around each cell and examined how the neighborhood affected the bear's habitat preference. More specifically, we defined the radius of the neighborhoods at 250 m and 450 m. Then, we measured what percentage of the neighborhood area each land use class and each forest type covered. This process was repeated for each cell in our raster.

The land cover maps included information regarding villages and streams. For each cell in our raster, we estimated the distance from the nearest village and stream using the spatial analyst of ArcGIS 9. Topographical information included elevation, slope and aspect, and was obtained from a 100 m Digital Elevation Model (DEM).

2.3 Vegetation and habitat types classification

The inventory of vegetation types was carried out, by the use aerial photographs, forestry service maps and field survey.
Furthermore, a classification of the corresponding habitat types was made following the criteria and methodology described in European Union Directive 92/43 [12] and the respective European Union manuals and handbooks [4], [3], [1] &[2]. The nomenclature of taxa follows [16] (Fig.2).

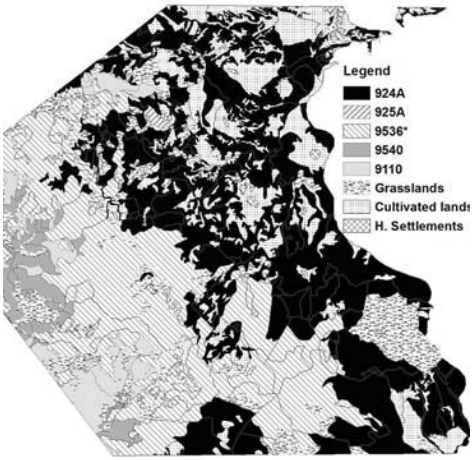

Figure 2. Map of habitat types in the study area

2.4 Statistical analysis

We used location data from bear sign (n=1,410) as well as telemetry data (n=4,564). For each background layer, we estimated the value at the location of the recorded bear presence; we compared the distribution of these values with the distribution of values for this layer in the entire landscape (presence versus availability) [9]. The null hypothesis being that all values of the background layer were equally suitable and its frequency of use depended only on its availability across the landscape. We used the entire extent as background, because bears were observed throughout the area. Ecological Niche Factor Analysis (ENFA) [5] starts off at this point, comparing the distribution of values where the animal is present with the distribution of values in the background. ENFA relies on identifying differences in the two distributions with respect to the mean (marginality) and with respect to the standard deviation (specialization). This idea is applied to all background variables, in our study related to topography, vegetation and land use, as well as the composition of the spatial neighborhood around each cell. The final habitat suitability is estimated with the use of ordination techniques, such as principal component analysis. The analysis estimates an overall marginality index, which expresses the difference between the mean animal preference and the mean condition of the study site. Also the overall specialization index is estimated, which is a measure of the range of environmental conditions the animal tolerates compared to the range of values recorded in the study site. For both indices values close to "0" indicate a species with can equally well utilize the entire area and values close to "1" indicate a highly specialized species that can only use a small part of the available landscape. We performed the analysis using the Biomapper 3.0 software package [6].

3. Results

Bears were present throughout the entire extend of the study area, but they appeared to prefer some parts of the area and avoid others. They avoided areas of high altitude (>1900 m asl), steep slopes (>70% inclination). They preferred areas close to streams and rivers and at an intermediate distance from human settlements. The bear presence in the different land use categories of the area differs slightly from their availability (Table 1). About 61.6% of the area consists of dense forests, and 65% of the bear presences were recorded in this type of structure. Partially forested areas cover 13.8% of the site, and account for 12.9% of the bear presences. Cultivated fields cover 14.3%, and 13.4% of the bear locations were found in this type of land use. Grasslands cover 9.9%, and 8.8% of bear presences were recorded there. Other land use categories are negligible.

Table 1: Landscape availability versus bear use in the study area.

Landscape type	Landscape availability	Bear presence
Dense forests	61.6 %	65.0 %
Partially forested	13.8 %	12.9 %
Grasslands	9.9 %	8.8 %
Agricultural Land	14.3 %	13.4 %
Bare land	0.2 %	0.0 %
Infrastructure	0.3 %	0.0 %

Forests were further analyzed according to their dominant vegetation and the presence of natural habitat types (Table 2). Oak forests (*Quercus* spp.) assigned to Balkanic and supra-Mediterranean oak woods habitat type (coded as 924A) dominated in the study area accounting for 36.3% of the area and for 38.5% of the bear presences. Black pine (*Pinus nigra* ssp. *nigra* var. *caramanica*) assigned to Mediterranean pine forests with endemic black pines habitat type (coded as 9536*) was the second most abundant forest type (29.3% of the site) and accounted for 32.3% of the bear presences. Beech forests (*Fagus sylvatica* ssp. *sylvatica*) assigned to Luzulo-Fagetum beech forests habitat type (coded as 9110) and white-barked pine forests (*Pinus heldreichii*) assigned to Mediterranean pine forests with endemic mesogean pines (coded as 9540) each covered 3.4% of the area and were avoided by bears (2.4% of the presences in beech and only 0.6% in white-barked pines). Finally mixed broadleaved forests assigned to Hop-hornbeam, oriental hornbeam and mixed thermophilous forests habitat type (coded as 925A) were relatively rare (1.5% of the area) and were preferred by the bears (3.7% of the presences).

Table 2: Habitat types availability versus bear use in the study area.

Dominant species / Habitat code	Landscape availability	Bear presence
Oak /*924A*	36.3 %	38.5 %
Black pine /*9536*	29.7 %	32.3 %
Beech /*9110*	3.6 %	2.4 %
White-barked pine /*9540*	3.6 %	0.3 %
Mixed broadleaved /*925A*	1.5 %	3.7 %
Open landscape formations	24.6 %	22.2 %

In order to estimate the importance of the different habitat types in relation to the overall habitat suitability profile of the study area for bears, and for practical reasons, we classified the study area into two main suitability levels according to the habitat suitability gradient produced by ENFA.

In the most suitable habitat configuration the landscape composition was 42.3% oak forest (*Quercus* spp.), 27.6% black pine (*Pinus nigra* ssp. *nigra* var. *caramanica*), 27% open landscape formations whereas all other forest types covered approximately 3%, mixed broadleaved 1.5%, beech (*Fagus sylvatica* ssp. *sylvatica*) 0.7%, and white-barked pine (*Pinus heldreichii*) 0.8%.

In the less suitable habitat configuration, oak (*Quercus* spp.) covered 30.6%, black pine (*Pinus nigra* ssp. *nigra* var. *caramanica*) 31.9%, open landscape formations 22.6%, beech (*Fagus sylvatica* ssp. *sylvatica*) 6.4%, white-barked pine (*Pinus heldreichii*) 6.3% and mixed broadleaved forests 1.5%. Thus, all forest types were present in both levels of bear habitat suitability. However, oak (*Quercus* spp.) forests, open landscape formations and mixed broadleaved had more than 50% of their total surface each characterizing the high suitability habitat configuration.

On the other hand, black pine had 56.9% of its surface characterizing the less suitable level configuration. In the case of beech (*Fagus sylvatica* ssp. *sylvatica*) and white-barked pine (*Pinus heldreichii*) forests more than 90% of their surface (or occupied area) characterized the less suitable habitat level .

Black pine as a priority habitat type is of special interest in this analysis. For this type of forest we observe two contrasting results. The frequency of bear presence in this type is comparatively higher than its availability across the landscape, although only 43.1% of its area is characterized as highly suitable.

More importantly, the land cover composition of the neighborhood around each cell influenced the bears' behavior. The percentage of the area covered by open landscape formations (grasslands, cultivated land and fallow land) strongly affected the habitat preference pattern. Bears seem to prefer locations that include such formations in their neighborhood, but avoid sites that either have no open formations or that have predominately open formations in their neighborhoods (>90%). According to this outcome, bears seem to prefer sites near the edge of grasslands and cultivated fields, but avoid

going to the center of large patches of grasslands and cultivated fields.

Ecological Niche Factor Analysis showed that the bears scores 0.37 in the marginality index, and 0.77 in the specialization index. This means that for bears a significant portion of the site is of high suitability but not all. Figure 2 shows the habitat suitability map of the area produced by ENFA. Habitat suitability is represented as a grayscale gradient, with the darker shades representing less suitable habitat.

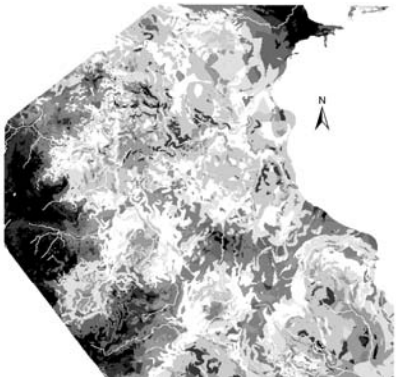

Figure 2. The habitat suitability map produced by the ecological niche factor analysis. Habitat suitability is presented by a grayscale gradient. The brighter the color the more suitable habitat location for the bear

6. Discussion

In our study site, evidence of bear presence was abundant throughout the area. Habitat selection is a scale dependent process and different characteristics of the landscape influence habitat selection at different scales [10]. At the coarse scale, the entire extent of our study site consist of suitable habitat for the brown bear. The present study analyses the fine scale habitat preference of the bears and makes an attempt to relate it to habitat types importance and role.

The frequency of the bear presences display specific patterns of avoidance and preference as also recorded in an adjacent mountain region to the study area [7]. Bears seem to avoid alpine meadows, but prefer black pine, oak and mixed broadleaved forests. However, the deviation between the bear presences and the availability of these landscape types is limited. Also the bears show a strong preference for sites near streams and rivers as also recorded in bear populations of N. America [15]. Furthermore, the bears display an avoidance of human settlements, but a preference for areas at intermediate distances from them, especially areas that serve as food sources (e.g. orchards) [11].

The brown bear is a large mammal species that perceives the surrounding area at a broad scale comparable to the human. Therefore, its habitat preferences do not depend only on the location point but also on the adjacent areas of a habitat unit. This was confirmed by our analysis showing that bears seem to be strongly influenced by the landscape composition of the spatial neighborhood around the location point. Bears seem to prefer areas in the edge of the habitat types, especially in the interface between forest and open landscape formations (i.e. grasslands and agricultural land). Bears seem to avoid locations that are in the core area of the different habitat types in the area. This apparent preference might be explained as a combination between safety, in terms of coverage provided by the neighboring forest vegetation, and feeding opportunities related to the grasslands and fallow lands.

The results show also that bear preference for black pine formations is characteristic. This can be attributed to the seasonal (spring, fall) trophic value related to the presence of the understory species that occur in the shrub and herb layer (berries and graminoids) of this habitat type [7]. It is important to underline that that black pine formations constitute an important habitat component for bears at a regional scale in the southern part of the Balkan eco-region. At the same time black pine forests is a priority habitat type. These facts enhance the criteria for the implementation of specific management and conservation measures targeting both a priority species and a priority habitat type.

Nevertheless, the results of the present study lead us to the assumption that the habitat selection of brown bears is not strongly associated with the concept of habitat as a specific plant community, but takes into consideration wider aspects of the physical environment (such as the landscape composition and fragmentation of the adjacent areas and the intensity of the human presence). Therefore even though the principle of preserving specific habitat types may offer many advantages for several species, in the case of a flag wide ranged species such as the brown bear it has to be

preceded by a landscape spatial analysis in order to define specific correlations between habitat availability and habitat use.

8. Acknowledgements

We would like to acknowledge the financial support of the Hellenic Ministry of Environment, Physical Planning and Public Works, the EU (DGRegio) and EGNATIA ODOS SA, in the framework of the "Monitoring project on impact evaluation of Egnatia highway construction (stretch 4.1) on large mammals in the area of Grevena (2002-2005)" in which the present study was realized. We also acknowledge the contribution of the field team composed by: Y. Iliopoulos, I. Isaak, Al. Karamanlidis, K. Selinidis, S. Riegler, A. Riegler, Ath. Tragos for data collection.

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