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Selective habitat use by brown bear (*Ursus arctos* L.) in northern Pindos, Greece

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The brown bear (*Ursus arctos* L.) is a key species indicating the conservation status of natural and seminatural mountainous ecosystems. Brown bear populations in Greece are confined to the mountain ranges of Pindos and Rodopi. Systematic data on brown bear spatial behavior based on telemetry data were lacking in Greece until 1997. This paper presents the results on brown bear habitat use patterns monitored on an annual basis in the area of Grammos and NW Voio mountains located in Northern Pindos range. A sample of six radiocollared brown bears (n = 6, 5 males - 1 female) was monitored from 1997 to 2002 using ground telemetry. Generated data (n = 3,052 bearings and n = 739 radiolocations) were combined to an analysis of vegetation characteristics identified through a classification of eight habitat types according to vegetation structure and dominant formations. Bear home range size varied individually from 102 km^2 to 507 km^2. Seasonal variability of home range size was also evident with fall presenting the highest values ranging from 87 km^2 to 314 km^2. Bears showed clear preference for mixed agro-forestry systems as well as for agricultural lands especially in the end of summer and beginning of fall (χ^2, $p = 0.05$). Forests with mixed broadleaved species including chestnuts (*Castanea sativa*) and hazelnuts (*Corylus avellana*) were also used more than expected (χ^2, $p = 0.05$). Brown bear habitat choice and preferences can be used as a decision making tool to delineate important areas and to take appropriate management and conservation measures for the targeted species and the related forest ecosystems.

Key words: brown bear, *Ursus arctos*, telemetry, habitats, N. Pindos.

INTRODUCTION

The brown bear (*Ursus arctos,* L.) distributional range in Greece comprises two distinct nuclei located in Pindos mountain range (NW Greece) and Rodhopi mountain complex (NE Greece). The total area of continuous bear range comprises 8,600 km^2 (Mertzanis, 1992; 1994). The Pindos population comprises two sub-populations: one close to the Albanian border (including Grammos, Voio, Mali-Madi and Triklari Mts.) and one larger in the southern parts of Pindos range, distributed mainly in the Grevena, Ioannina and Trikala districts (Mertzanis, 2002). During the last years, brown bear populations in Pindos exhibit a clear trend of an expanding distribution towards the eastern and southern parts of the species former range (Mertzanis, 2002; 2005; Bousbouras, 2005). The minimum brown bear sub-population size in the study area has been estimated between 34 and 41 individuals (Mertzanis, 2002; Defigou, 2003). However, the brown bear status in Greece remains critical and faces major threats from human caused mortality, habitat fragmentation, habitat loss and habitat degradation (Mertzanis, 1999;

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2002).

Management decisions with reasonable expectancy of success require a constantly updated knowledge of the ecological needs of the brown bear that would allow the appropriate adjustments in specific management situations (Servheen, 1994). Appropriate management of threatened brown bear populations requires, also, adequate information levels on the biological needs and ecological requirements of the species (Servheen, 1994). To this extent, biological information on brown bear spatial behavior (home range and habitat use) is of high value for proper habitat management (Mano, 1994; Wooding & Hardisky, 1994).

Brown bear habitats coincide to a large extent with high productivity forests that are being managed for timber production during the last decades. Habitat conservation for the specific brown bear populations must take into account timber production and other related management components.

In this context, we studied bear spatial behavior using ground telemetry. This approach was combined to an analysis of vegetation and habitat types. The aim of the present study was to investigate on brown bear habitat use and selection patterns on a annual basis and to use this information in order to contribute in improving forest management decisions in the study area. The long term objective is to achieve a satisfactory conservation status of the species habitat through more appropriate forest management practices.

MATERIALS AND METHODS

Study area

The study area (Fig. 1) is located in the mountains of Grammos and NW Voio, part of Northern Pindos mountain range, and is delineated southwards by Sarantaporos river, eastwards by Aliakmon river and northwards by the borderline with Albania. The study area covers approximately 850 km^2 at altitudes that range between 600 to 2520 m above sea level. The largest part of the area is located in the watersheds of Sarantaporos and Aliakmon river valleys.

Approximately 56% of the study area is covered by high forests, 13% by partially forested areas and 21% by grasslands. Forest vegetation is composed of black pine *(Pinus nigra* ssp. *nigra* var. *caramanica)* (27.1%), oak *(Quercus* spp.*)* (42.1%) and beech *(Fagus sylvatica* ssp. *sylvatica)* (26.1%). The remaining area is covered by agricultural land, rocky outcrops

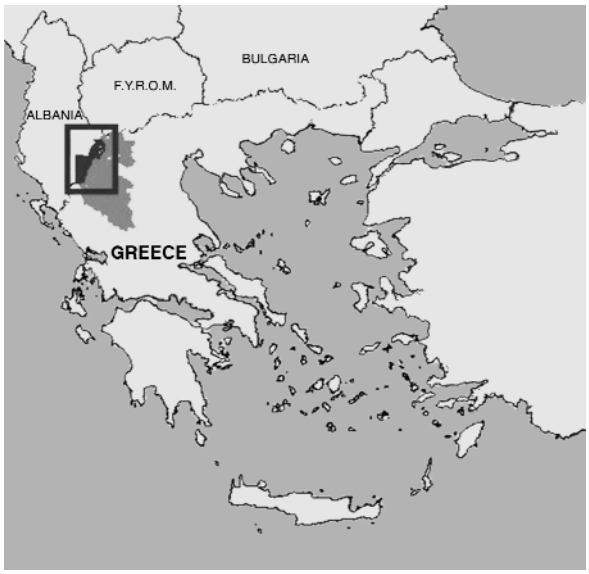

FIG. 1. Study area.

and bare ground. Mean annual temperatures range from -3.1˚C to 27.4˚C. Mean annual precipitation is 814 mm. Nearly all native European mammal species are present in the area, including the wolf (*Canis lupus*), roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*), wild cat (*Felis sylvestris*) and otter (*Lutra lutra*). The study area is remote, characterized by low human density and scattered human settlements. A high density of forest road network (~ 15 m/ha) is related to timber activities, and gives access to a relatively high level of hunting pressure. Hunting is allowed yearly from August to January. The study area comprises one NATURA 2000 (pSCI) site "Koryfes Orous Grammos" (GR 1320002), one Biogenetic reserve ("Flabouro-Barouga" - covering 130 ha) and four (4) wildlife reserves covering a total of 100.5 km^2.

Study animals and data collection methods

Six brown bears (4 adult males, 1 sub-adult male and 1 adult female) were captured with an 'Aldrich Foot Snare' trap type and were sedated with KHCl/xylazine (Rompun) (Table 1). For the heavier bears the initial volume injected with blowpipe was 750 mg /3 ml with and a booster volume of 600 mg/3 ml (with intra-muscular injection). For the smaller bears the initial volume injected with blowpipe was 250 mg /3 ml with and a booster volume of 200 mg/3 ml (with intra-muscular injection). Time to anaesthesia was usually less than 15 minutes. Total immobilization time was approx. 30-45 min. The bears were fitted with conventional radiocollars (MOD-500 NH from

TABLE 1. Brown bear sample main characteristics

Bear specimen id	Sex	Age (years)	Weight (kg)	Capture date	Telemetry monitoring period (months)
A	male	22 (overaged)	130	28-6-1997	11
B	male	1.8 (subadult)	45	28-6-1997	9.5
C	male	4-7 (adult)	120	14-7-2000	10.5
D	male	4-7 (adult)	150	15-7-2000	10.5
E	female	3-4 (adult)	80	9-7-2001	2.5
F	male	5-6 (adult)	150	4-8-2001	7

Telonics, USA) with bi-modal "activity-inactivity" signal. Telemetry data (radiolocations) were collected using a VHF TR-4 receiver (*Telonics*, USA), a directional ("three-element" - "Yagi") type antenna (*Telonics*, USA), a magnetic compass and a portable GPS. For each bearing the "Raised Antenna - Null Signal Average" (RA - NS) technique was used to locate each individual (Springer, 1979; Kenward, 2001). The exact position of each individual was defined by the triangulation method with a minimum of three bearings (Kanellopoulos, 2002; Mertzanis *et al.*, 2005).

Radiolocation frequency was 1/1.1 days in order to ensure statistical independence among location positions. This frequency is considered to be satisfactory and has been used by many researchers in Europe for the study of free ranging bear populations (Roth, 1983; Huber & Roth, 1986; Clevenger *et al.*, 1990; Huber & Roth, 1993; Kaczensky *et al*., 1994; Mertzanis, 1999; Naves *et al*., 2001; Mertzanis, 2005).

Data processing

Data processing and plotting was achieved using 'LOCATE II' and GIS (ArcInfo, ArcView) software. Telemetry data were entered into an EXCEL data base and were analyzed by daily groups of bearings. Geographic coordinates of the bearing points were obtained by GPS and were processed through LOCATE II (Pacer Computer Software) for triangulation. Subsequently, the exported coordinates were used in several functions (as well as by the standard ArcView functions). For every triangulation we calculated the "error areas" with the "Maximum Likelihood" estimator that determines bear position to an accuracy of 95% (Nams, 1990). The average error area for the accepted triangulations was fixed to 0.5 Km^2, a small surface, compared to the home range of each individual in the study area, and therefore not affecting the evaluation of habitat use (Nams, 1989).

The selected points were entered into a GIS database using ArcView - ArcGis softwares. Additional databases on vegetation structure, composition and distribution of habitats, as well as on altitudinal zones, nature protection areas, human settlements and infrastructures, were created. Thematic maps were produced and combined subsequently. Bear home range estimation was based on the 'Minimum Convex Polygon' (MCP) method (Mohr, 1947; Hayne, 1949). Bear habitat use within the home range of each individual from the sample was estimated using the "Habitat use - availability" method (Marcum & Loftsgaarden, 1980). The expected use of each habitat type was calculated on the basis of its availability within the home range of each bear from the sample.

In order to compare expected uses with observed habitat use we initially performed χ^2 homogeneity tests. In case of a significant difference between expected and observed values, the "*Bonferroni*" simultaneous confidence intervals were then calculated in order to assess which habitat categories and to what extend they were used more or less than expected, by the bears. Data from the hibernation period (January to middle of March) were excluded from data analysis. Data from bear (E), adult female, were treated separately from the core sample given the shorter monitoring period. This female bear was tracked between 7 July and 14 September 2001.

Habitat classification

An inventory of vegetation types was carried out, based on field survey. Vegetation types were classified into phytosociological units of high taxonomic rank according to Dafis (1973), Horvat *et al.* (1974), Athanasiadis (1986) and Mucina (1997).

Furthermore, a classification of habitat types was made following the criteria and methodology described in European Union Directive 92/43 (O.N.E.U., 1992) and the respective European Union manuals

and handbooks (European Communities, 1991; Devillers & Devillers, 1996; Dafis *et al.*, 1999; 2001).

Several of the above mentioned habitat types were subjected to sylvicultural management according to the vegetation type, structure and productivity. Thus, we grouped them consequently, based on data originating from sylvicultural management plans prepared by the forestry services of Kastoria, Konitsa and Kozani (Gatzoyannis, 1998) and with the use of a digital data base.

Based on the above criteria we assigned habitats into eight categories (Table 2).

F-1: High productive forests with multistorey structure. Pure or mixed forests mainly with *Fagus sylvatica* ssp. *sylvatica*, *Pinus nigra* ssp. *nigra* var. *caramanica* and *Abies borisii-regis*. They are assigned to Fagion sylvaticae (Querco - Fagetea class, Fagetalia sylvaticae order) and Orno - Ericion (Erico - Pinetea class, Erico - Pinetalia order). Habitat types included in this category are "Acidophilus beech forests" (9110), "Hellenic beech forests with *Abies borisii-regis*" (9270) and "Mediterranean pine forests with endemic black pines" (9536).

F-2: Low forests (deriving from coppice stands) with *Fagus sylvatica* ssp. *sylvatica* and *Quercus* spp. (mainly *Quercus cerris* and *Quercus petraea* ssp. *medwediewii*) in conversion and stands of mixed broadleaves. They are assigned to Fagion sylvaticae (Querco - Fagetea class, Fagetalia sylvaticae order), Quercion confertae (Quercetea pubescentis class, Quercetalia pubescentis order) and Ostryo - Carpinion (Quercetea pubescentis class, Quercetalia pubescentis order). Habitat types included in this category are "Acidophilus beech forests" (9110), "Balcanic thermophilous oak woods" (924A) and "Thermophilus hop-hornbeam forests" (925A).

F-3: Coppice oak forests subjected to clear-cut felling management or conversion felling. They are assigned to Quercion confertae (Quercetea pubescentis class, Quercetalia pubescentis order) and Ostryo - Carpinion (Quercetea pubescentis class, Quercetalia pubescentis order). Habitat types included in this category are "Balcanic thermophilous oak woods" (924A) and "*Quercus trojana* woods" (9250).

PF: Partly forested areas covered by woody and shrubby vegetation, mainly *Fagus sylvatica* ssp.

TABLE 2. Habitat type classification and description of the study area

Abbreviation	Habitat type	Syntaxon	EU Habitat Code[1]
F-1	High, multistorey forests	Fagion sylvaticae, Orno - Ericion	9110, 9270, 9536
F-2	Low broadleaved forests	Fagion sylvaticae, Quercion confertae, Ostryo - Carpinion	9110, 924A, 925A
F-3	Coppice oakwood	Quercion confertae, Ostryo - Carpinion	924A, 9250
PF	Partly forested areas	Fagion sylvaticae, Orno - Ericion, Quercion confertae, Ostryo - Carpinion	5130, 5210, 9110, 924A, 9250, 9270, 9536
GR	Grassland	Daphno - Festucetea (Festucetalia)	4060, 4090, 6170, 6230
R	Rock and scree	Drypetea (Drypetalia) spinosae, Asplenietea trichomanes	8140, 8210
MAG	Mixed agroforestry areas		84.4
AG	Farmland		82.3

[1] numbers correspond to habitat codes according to E.U. Directive 92/43 and Corine (EC 1991)

sylvatica, *Quercus* spp. and *Juniperus* spp. on a percentage of 10-40%. All the above mentioned syntaxa and habitat types are included in this category as well as scrub assigned to Fagion sylvaticae (Querco - Fagetea class, Fagetalia sylvaticae order) and Quercion confertae (Quercetea pubescentis class, Quercetalia pubescentis order) and the habitat types "*Juniperus communis* formations on calcareous heaths or grasslands" (5130), "Juniper formations" (5210).

GR: Grasslands of the mountainous and subalpine zone with low woody and herbaceous plants. They are assigned to Daphno - Festucetea class, Daphno - Festucetalia order. Habitat types in this category include the following: "Alpine calcareous grasslands" (6170), "Species rich *Nardus* grasslands" (6230), "Alpine and subalpine heaths" (4060) and "Endemic oro-Mediterranean heaths with gorse" (4090).

R: Rocky outcrops and scree that are either bare or have scarce herbaceous vegetation. They are assigned to Drypetea spinosae class, Drypetalia spinosae order and Asplenietea trichomanes class. This category includes the habitat types "Balkan scree" (8140) and "Vegetated calcareous inland cliffs" (8210).

MAG: Mixed agro-forestry areas that include pastures and residual broadleaved thickets of the submontane zone (84.4 Corine) e.g. *Castanea sativa* thickets.

AG: Farmland that includes orchards, cereals and abandoned farms (82.3 Corine).

RESULTS

The overall telemetry data with 3,052 bearings and 739 radiolocations showed that bear activity period ranged from nine to ten months annually and that during the winter period a clear decline of activity level due to hibernation was recorded. Data on home range surface showed a notable variation between male adult individuals (values ranged from 102 km^2 to 507 km^2) and between seasons: from 48.63 km^2 in summer to 314.23 km^2 in autumn (Table 3). Total home range surface for each of A, B, C and D specimens encompasses a large portion of the study area, while a considerable degree of overlapping is observed between home ranges of the 6 bear specimens of the sample. Highest overlapping rate was observed between home range of adult male bear (F) over summer home range of the adult female (E) (88.8%). High rate of home range overlapping was also observed in the case of the adult male (C) over adult male (D) (70.8%). Home range overlapping rate of the old adult male (A) over sub-adult (B) was (65%) (Fig. 2). Clustering of radiolocations in bear home ranges indicated core areas of selective use. Concentrations of radiolocations for adult male (D) show intensive use of 15% of the total home range extent, whereas radiolocations of adult male (C) show intensive use of 14.8% of total home range. Bear habitat types availability according to vegetation structure, land cover and dominant species with trophic significance for the brown bear and subsequent use patterns by each bear specimen within its home range, are presented in Tables 4 and 5.

Almost all the scope of the altitudinal range available in the study area was used by all five male

TABLE 3. Overview of telemetry results

Bear specimen id	Total number of Radiolocations	Home range (MCP) (km^2)	Seasonal home range (MCP) (km^2)		
			Summer	Autumn	Spring
A	92	483	66.86	285.07	181.07
B	71	206	97.88	165.66	–
C	185	507	78.73	314.23	245.00
D	151	312	48.63	195.37	104.53
E	60	13*	13.00	–	–
F	180	102	55.6	87.02	32.89

(*) Only for summer 2001

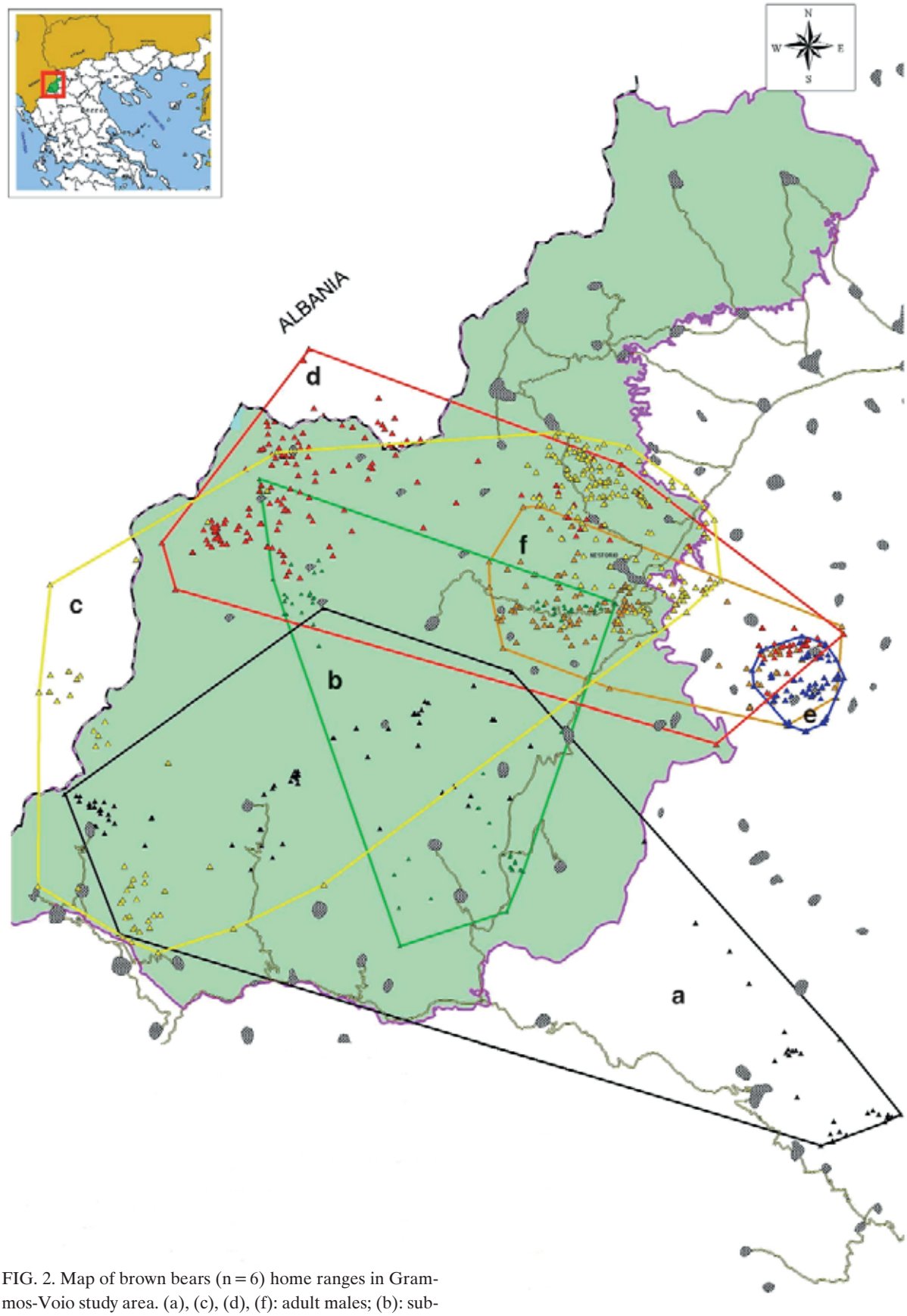

FIG. 2. Map of brown bears (n = 6) home ranges in Grammos-Voio study area. (a), (c), (d), (f): adult males; (b): subadult male; (e): adult female (summer home range).

TABLE 4. Bear selective habitat use on an annual basis. Habitat classification based on vegetation structure and land cover

Habitat Type	Bear id	χ^2 value	df	*P*	Selective use
High productive forests (F-1)	A	10132	5	0.05	(=)
	B	8551	3	0.05	(-)
	C	> 40137	7	0.05	(-)
	D	9376	6	0.05	(=)
Low forests (F-2)	B	8551	3	0.05	(+)
	C	> 40137	7	0.05	(+)
Coppice oak forests (F-3)	C	> 40137	7	0.05	(+)
	F	> 35612	5	0.05	(+)
Partly forested areas (PF)	A	10132	5	0.05	(=)
	B	8551	3	0.05	(+)
Grasslands (GR)	A	10132	5	0.05	(=)
Mixed agro-forestry areas (MAG)	A	10132	5	0.05	(=)
	B	8551	3	0.05	(+)
	C	> 40137	7	0.05	(+)
	D	9376	6	0.05	(=)
	F	> 35612	5	0.05	(+)
Agricultural lands (AG)	C	> 40137	7	0.05	(+)
	D	9376	6	0.05	(=)
Rocky outcrops	–	–	–	–	–

TABLE 5. Bear selective habitat use on an annual basis. Habitat classification based on dominant and trophically significant plant species

Habitat Type /(dominant species)	Bear id	χ^2 value	df	*P*	Selective use
Black pine forests *(Pinus nigra)*	B	12334	3	0.05	(=)
	C	30481	3	0.05	(–)
	D	18939	4	0.05	(+)
Beech forests *(Fagus sylvatica)*	A	4226	3	0.05	(+)
	C	30481	3	0.05	(–)
	D	18939	4	0.05	(=)
Oak forests *(Quercus* spp.*)*	A	4226	3	0.05	(+)
	B	12334	3	0.05	(=)
	C	30481	3	0.05	(=)
	D	–	–	–	–
	F	12675	3	0.05	(=)
Forests with Mixed broadleaved species (*Castanea sativa, Corylus avellana*)	A	–	–	–	–
	B	12334	3	0.05	(+)
	C	30481	3	0.05	(+)
	D	18939	4	0.05	(+)
	F	12675	3	0.05	(=)

bears of the sample. Significant use of the altitudinal zone between 900 and 1500 m was a common habitat use pattern for all five male bears with concentration of radiolocations in this altitudinal zone ranging from 77% to 90%.

Bear (E), adult female, had the smallest home range area (13 km^2), as the monitoring period covered only the summer period. The area consisted mainly of low productivity forested areas (F-3) (51%) with chestnut (*Castanea sativa*) and oak (*Quercus* spp.) as dominant species forming mixed and pure stands. The summer home range included agro-forestry areas (31%) and cultivated lands (18%) as well. The female individual moved within altitudes between 800 and 1200 m. Summer habitat use was proportionate to the availability of habitat types ($\chi^2 = 2178$, df = 2, $p = 0.05$, Fig. 7).

DISCUSSION

Identifying selective habitat use through a relatively large sample of an endangered brown bear sub-population in Greece may help conservation planning and implementation of specific measures in the study area. Home range size and home range overlapping may be a good indicator tool. Large home ranges have been observed for all four adult males and appear to be a common feature in other brown bear populations of northern Europe which may also be related to the mating season as it was observed in Scandinavia (Dahle & Swenson, 2003). The observed seasonal changes in range size in all five males appears also to be a common characteristic in different brown bear populations in Europe and can be probably related, as observed in Sweden, to a change in limiting resources from receptive females in the mating season to food availability and dispersion in the post-mating season (Dahle & Swenson, 2003).

Range overlap seems to result from the relatively large home ranges of the adult males and appears to be a common feature in other bear populations in Europe and even in the cases of restocked populations like in Adamello-Brenta Alps Italy, suggesting that food abundance in the study area should not be a limiting factor (Preatoni *et al*., 2005)

Habitat use of the studied brown bear sample was not proportional in all cases to the availability of the different habitat types in the study area, but appeared to be selective (Figs 3-8). Mixed agro-forestry habitats (MAG) were the habitat type mostly used by the sampled bears. This type was used by all five male bears, of which three individuals showed a clear preference and two used it at the expected rate. The preference for this habitat was more pronounced during the end of summer and the beginning of autumn (Kanellopoulos, 2002). This can be attributed to the fact that many plant species occurring in this habitat type constitute important food sources for the brown bear and provide fruits at this period of the year. Such species, are wild apples, (*Malus* spp., mainly *Malus domestica*), wild pears (*Pyrus* spp., mainly *Pyrus amygdaliformis* and *Pyrus pyraster*), berries (*Rubus* spp., mainly *Rubus hirtus*, *Rubus canescens*, *Rubus idaeus*, *Sorbus* spp., mainly *Sorbus torminalis*, *Sorbus domestica* and more infrequently *Sorbus aucuparia*), wild roses (*Rosa* spp., mainly *Rosa canina*, *Rosa agrestis, Rosa pulverulenta* and *Rosa heckeliana*), plums (*Prunus* spp., mainly *Prunus domestica*), chestnuts (*Castanea sativa*) and hazelnuts (*Corylus avellana*). In relation to previous bear diet analysis studies, our results further support the hypothesis that brown bears show a clear preference for habitats with large openings where the aforementioned plant species find suitable growing conditions reaching high availability levels.

Other habitat types that were used to an extent higher than expected were low forests (F-2), coppice oakwoods (F-3), and to a lesser degree partly forested areas (PF) and agricultural areas (AG). We believe that this preference must be also attributed to the sufficiency of food sources associated to the above vegetation structures for the brown bear, as it was also indicated by previous bear diet food analyses (Mertzanis, 1992; 1994; Mertzanis *et al*., 1996; Bousbouras, 1999).

However, this preference is seasonally expressed during late summer – autumn and in spring (Kanellopoulos, 2002). From their structural aspect, habitat types such as multistorey high productive forests (F-1), low productive broadleaved forests (F-2) and coppice oakwoods (F-3), were used by brown bears in summer and in late autumn just before the hibernation period (Kanellopoulos, 2002). Apart from food availability (beech mast and acorns), we believe that these habitat types are also used because, owing to their multistorey and/or dense structure, they provide adequate cover and refuge conditions for the brown bear including suitable locations for dening sites. Concerning selective use of habitat types classified according to dominant and trophically significant species, we observe that forests with mixed broadleaved species such as chestnuts (*Castanea sativa*) and

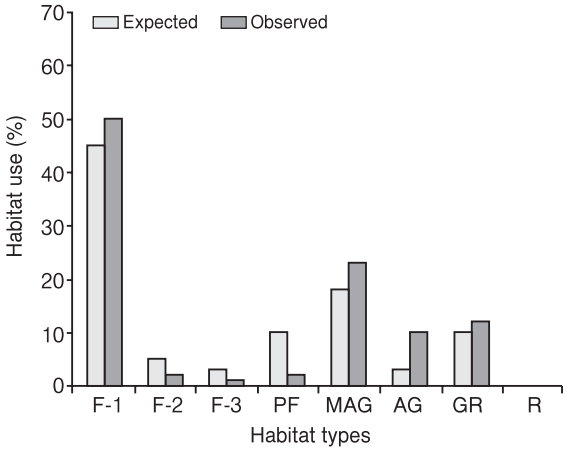

FIG. 3. Habitat use by brown bear individual A.

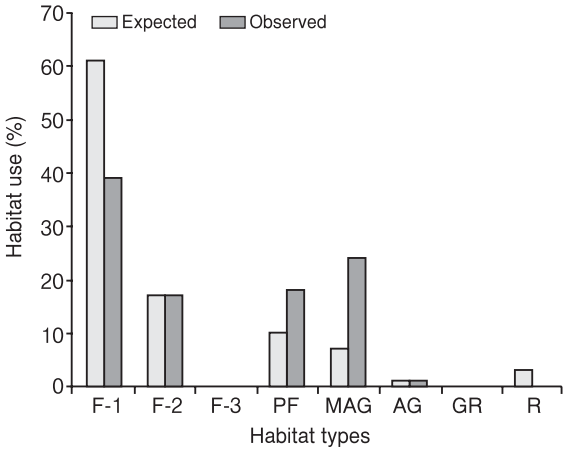

FIG. 4. Habitat use by brown bear individual B.

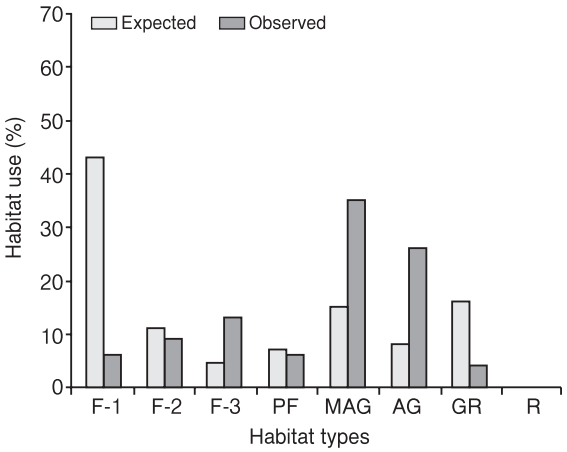

FIG. 5. Habitat use by brown bear individual C.

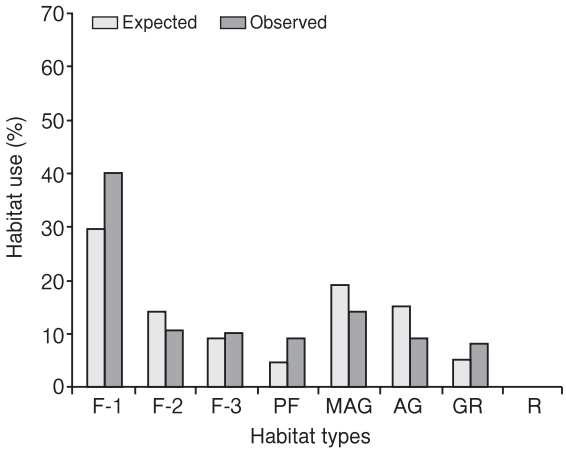

FIG. 6. Habitat use by brown bear individual D.

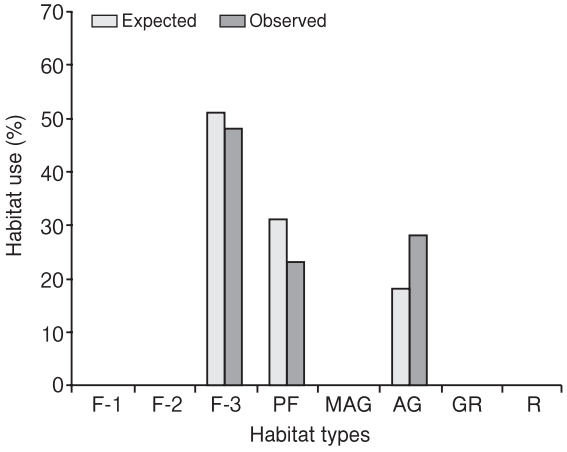

FIG. 7. Habitat use by brown bear individual E.

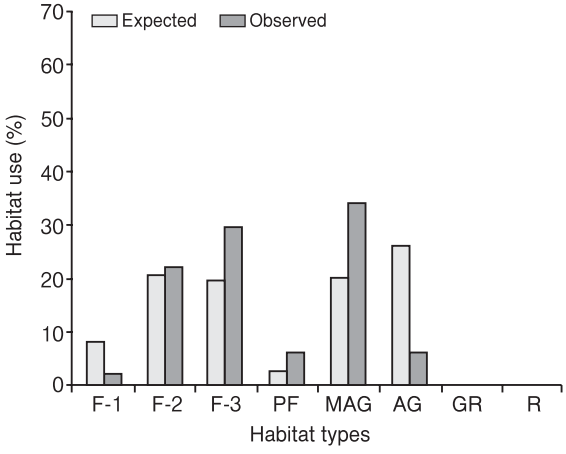

FIG. 8. Habitat use by brown bear individual F.

hazelnuts (*Corylus avellana*) are used more than expected.

From the point of view of conservation implications, the need for a biologically based regulation to assess and limit the impact of natural resource exploitation must be considered as a priority, as it has been the case for the brown bear populations in central Italy (Possilico *et al*., 2004). When it comes to the study area, resource exploitation is mainly related to the current forest exploitation regime enforced in Greece, which should more effectively incorporate criteria and standards based on sustainability and on the principle of "multiple use forests". To this extent, the need of radical reforms of the timber harvesting system becomes a necessity at a national level in order to preserve structurally and spatially important formations with high trophic value for the bears. This is the case of coppice oak forests that should be managed under a different regime than clear cutting. Finally, it is worth mentioning that the aforementioned results have essentially contributed in establishing a zoning proposal in the study area which was one of the main outcomes of an Environmental Study carried out according to environmental law 1650/86 and submitted to the national competent authorities in 1999. The final purpose of this study is to officially assign to the whole study area a specific conservation status.

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