BROWN BEAR IN GREECE: DISTRIBUTION, PRESENT STATUS—ECOLOGY OF A NORTHERN PINDUS SUBPOPULATION

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Abstract: Brown bear distribution range in Greece comprises 2 distinct nuclei of unequal size, covering a total of about 11,000 km^2, and seems to have stabilized for the last 20 years after dramatic regression in the 19th century. Extra-limital sporadic occurrence of bears southwards of the western population nucleus down to the 39th parallel, as well as unexplored sectors of potential bear occurrence in the northern parts of the country, may add new data to the species chorology in Greece. There is a risk of further internal fragmentation of the western distribution nucleus. Human-caused mortality appears to be the main factor of populations' negative trends. Brown bear food habits were determined by investigations in a 900 km^2 bear area located in the northern Pindus range and scat analysis (N = 343). Only plant material was found in 77% of the samples, whereas 17% contained both plant and animal material, and 6% only animal material (mostly insects-ants). Omnivory and opportunistic strategy appeared as the main characteristics of bears' feeding behavior. Brown bear annual activity cycle was determined by data on signs of presence and activity (N = 664). It appears in relation to trophic optimas and mesoclimatic conditions of the habitat. There is evidence of winter inactivity. Brown bear habitat preferences determined by Marcum & Loftsgaarden's method (N = 289 bear locations) show seasonal influence of types of vegetation communities on habitat use. Bear-human interactions level seems critical: poaching and logging are the main causes of habitat deterioration and population decrease.

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Elements on the historical distribution of the brown bear in Greece are mainly based on historical reports, notes, and available texts.

According to this information, brown bear range in Greece appears to have suffered dramatic regression through the centuries, as in other parts of Europe where the species was or is still in conflict with human expansion. In the late 1960s (1969), brown bear were legally regarded as a protected species in Greece. It is actually considered as an endangered-vulnerable species (Greek Red Data Book-University of Athens 1992). A review of the late 20th century brown bear distribution patterns and population status in Greece gives various estimates for the first 2 decades (Couturier 1954, Hainard 1961, Curry-Lindahl 1972).

Apart from previous authors' fragmentary information, lack of systematic data on the distribution and ecology of the brown bear in Greece before the early 1980s resulted in an urgent need for systematic status and ecology studies.

More up-to-date information (Matsakis et al. 1981, Mertzanis 1989) gives a brown bear distribution pattern of 2 distinct population nuclei located respectively in the Pindus range (northwestern Greece) and the Rhodopes mountain complex (northeastern Greece), and considers the southwestern nucleus as the southernmost range of the species in Europe. These papers also contain some preliminary information on bears' food habits.

In 1985 I started 3½ years of research work, in the framework of a doctoral thesis (Mertzanis 1992), in which were incorporated data and results of the preliminary stage of an EEC-funded survey project, conducted in 1988 by the Royal Institute of Natural Sciences of Belgium in collaboration with the Greek Ministry of Agriculture and the Hellenic Society for the Protection of Nature (Greek Ministry of Agriculture Report 1988).

Results and figures presented in this paper come essentially from the latter sources.

We thank the Greek Ministry of Agriculture, the Hellenic Society for the Protection of Nature, and the Royal Institute of Natural Sciences of Belgium for their collaboration in the data availability. We also thank the Veterinary School of Toulouse-France, the National Institute of Research in Agronomy of Toulouse, France, and the University of Agronomy-Laboratory of Pedology, Athens, Greece for their collaboration and sound technical assistance.

STUDY AREA

The study area for distribution estimate included all northern parts of the Pindus and Peristeri ranges as well as the Rhodopi mountain complex. Divided into 4 main apparent physiographic/phytogeographic units, this area comprises (Fig. 1):

Unit I: The Peristeri range with alpine meadows, large beech (*Fagion sylvaticae*) forests between 1,200 and 2,100 m, and oak forests on lower altitudes, all covering mostly granitic soils (Quezel 1967, Debazac and Mavromatis 1971).

Unit II: Large parts of northern Pindus range, including the valleys of Aliakmon, Sarantaporos, and Aoos rivers with alpine meadows, large black pine forests (*Pinus nigra* ssp. *Pallasiana*) as well as mixed forests with black pine (*Pinus nigra*), fir (*Abies borisii regis*), beech (*Fagus sylvatica*), and white pine (*Pinus heldreichiii*) covering mostly limestone and ophiolithic soils. At lower altitudes the vegetation

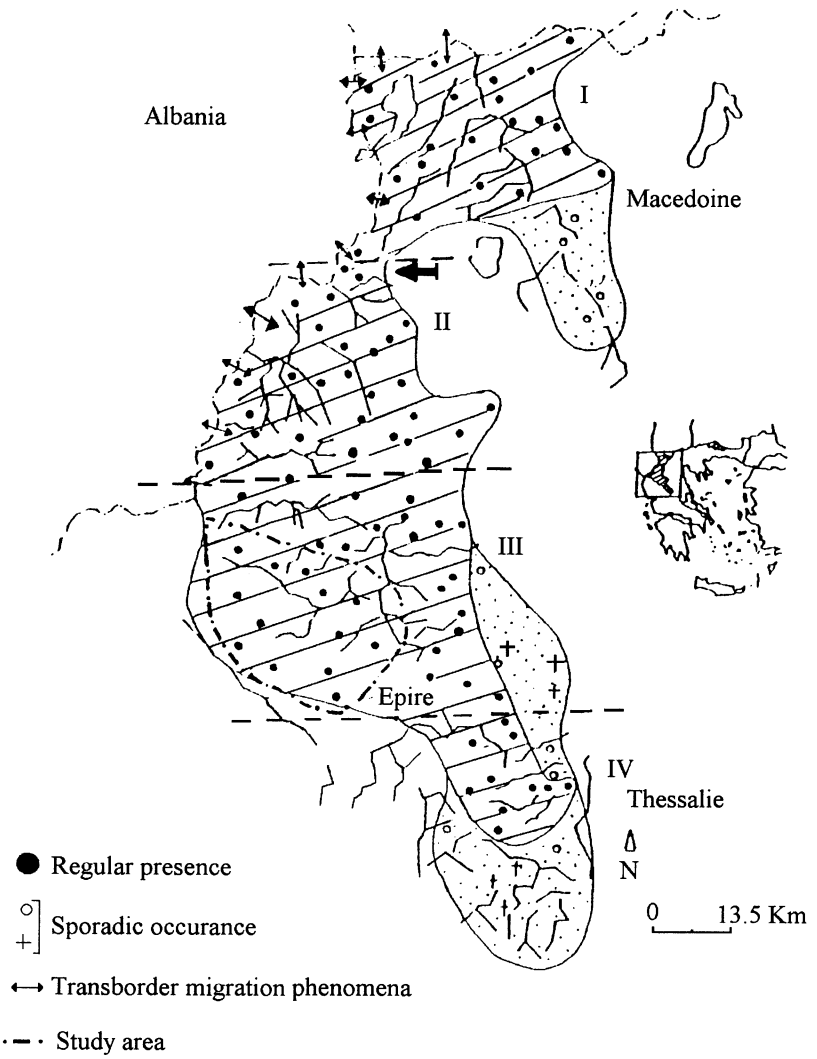

Fig. 1. Brown bear distribution range in Greece—western population nucleus.

zones of Quercion-frainetto and Ostryo-Carpinion are widely present.

Unit III: The river Acheloos high valleys with mainly large fir (*Abies borisii regis*) forests covering limestone soils and oak forests on lower altitudes.

Unit IV: Rhodopi mountain complex: a vast granitic mountain complex covered with large forests of spruce (*Picea excelsa*), forest pine (*Pinus sylvestris*), beech (*Fagus orlentalis, Fagus mosaecus*), and oak (*Quercus frainetto, Quercus macedonica*).

The study area for the ecological analysis extends over a 900 km^2 zone in northwestern Pindus with elevations ranging between 550 and 2,637 m. About 40% of the area presents a denivelation of 500 m per km^2, and 7% of it is above 1,900 m of altitude. Climate of the area is temperate with cold winters. Annual precipitation ranges from 1,270 to 1,450 mm and vegetation zones comprise: oak forests with (*Quercus frainetto, Quercus pubescens, Quercus cerris, Ostrya carpinifolia, Carpinus orientalis*) pure and mixed coniferous and deciduous forests with: black pine (*Pinus nigra*), beech (*Fagus sylvatica*), fir (*Abies borisii regis*), and white pine (*Pinus heldreichii*) followed at the higher elevations by alpine meadows.

The composition (percentage of occurrence) of the main types of forest vegetation is:

Oak forests	27%
Pine forests	27%
Beech forests	10%
Fir forests	5%

Table 1. Percent composition of the 11 vegetation communities in the study area and bear use.

Vegetation communities	Observed use (n = 289)	Expected use (n = 840)
1. Oak forests	0.23 (66)	0.22 (185)
2. Other deciduous forest types	0.03 (10)	0.03 (21)
3. Orchards and cultivated land	0.12 (35)	0.04 (35)
4. Black pine forests	0.18 (52)	0.22 (184)
5. Fir forests	0.01 (4)	0.01 (4)
6. Beech Forests	0.09 (25)	0.04 (32)
7. White pine forests	0.01 (4)	0.02 (15)
8. Mixed Forests	0.06 (18)	0.09 (77)
9. Mixed forests and ecotones	0.10 (30)	0.03 (25)
10. Ecotones	0.08 (24)	0.14 (117)
11. Subalpine and alpine pastures	0 07 (21)	0.19 (145)

Chi-square test demonstrated that there was a highly significant difference between the expected utilization of the vegetation communities and the observed frequency of use in the study area (Chi-sq. test, df = 10; $P < 0.001$).

Consequently, Bonferroni simultaneous confidence intervals were used to determine which categories of habitat types were utilized more or less than expected within an annual cycle.

White pine forests	6%
Mixed forests	11%
Alpine meadows	14%

METHODS

Distribution and Population Status

Estimate of brown bear historical distribution in Greece was based on data from relevant literature. Recent data, based on signs of bear activity, bear sightings, or illegal killing, were gathered through 2 investigation campaigns carried out in 1986 and 1988 by means of questionnaires sent to local populations or filled during interviews. Answered questionnaires were divided into 3 evaluation categories according to quality and reliability of information provided:

- direct information: checked by interview and/or field inspection.
- second-hand information: checked only by interview often coming from several different sources.
- uncertain: reliability of these reports remains doubtful.

The "probable minimum population size" estimate was mainly based on direct information concerning sightings of females with cubs-of-the-year (Servheen 1989) only during 1988. They were often backed by second-hand information of the same year. Cases of bear sightings located in 2 neighboring areas or regions were only counted once. An approach of population trends is attempted through harvest data as well as cases of illegal killing.

Ecology

Food habits.—Collections of scats in the field (N = 343) were used to determine the quantitative importance of food items used by brown bears. Part of the sample (n = 95) was analyzed in the laboratory, whereas the other part (n = 248) was macroscopically analysed in the field. Generally, scat contents were more easily identifiable when fresh in the field. In the second case identification of plant remains was easier when compared with nearby specimens. In several cases materials analyzed in the field were taken to the laboratory for further study. All scats were individually identified according to location, altitude, vegetative surroundings, and age. Analysis of bear scats in the laboratory followed the techniques of Tisch (1961), Russell (1971), Sumner and Craighead (1973), and Faliu et al. (1980). Basic steps involved:

- rehydration of fecal material
- separation of material into homogeneous groups by use of screens (4.0, 2.0, 1.0, 0.5 mm mesh)
- identification of contents
- recording of identified materials.

Identification of species, through macroscopic and microscopic examination, was usually successful, presenting some difficulties for grass. Animal materials were mainly identified through micro-techniques of hair examination using reference collections as well as through examination of bone remains. The occurrence of each identified food item was recorded as each scat was analysed. Visual estimates of occurrence were recorded under 5 categories.

0: trace-5%
1: 5-25%
2: 25-50%
3: 50-75%
4: 75-100%

Underevaluation of the use of some foods had to be taken into account because of differential digestibility of some food items, Mealey (1980). Percent frequency of occurrence and percent of diet for each food item were calculated.

Annual Activity and Habitat Use.—The 3½-year field investigation was based on the indirect method of systematic recording of all observations of bear signs of presence and activity in the study area (N = 664).

Table 2. Utilization of the different vegetation communities by the brown bear within the study area.

Vegetation communities	Bonferroni confidence intervals	Choice of bears
1. Oak forests	-0.06; +0.06	Proportional use
2. Other deciduous forests	-0.04; +0.021	Proportional use
3. Orchards - Cultivated lands	-0.133; -0.26	Preference
4. Black pine forests	-0.03; 0.11	Proportional use
5. Fir forests	-0.03; +0.01	Proportional use
6. Beech Forests	-0.095; -0.002	Preference
7. White pine forests	-0.017; +0.025	Proportional use
8. Mixed forests	-0.016; +0.074	Proportional use
9. Mixed forests and ecotones	-0.123; -0.025	Preference
10. Ecotones	+0.005; +0.11	Avoidance
11. Subalpine and alpine pastures	+0.05; +0.15	Avoidance

As we may see from the above, bears in our study area demonstrate a strong preference for forested habitats with a significant sub-use of open lands. Some forest or vegetation types such as: beech forests, mixed forests with ecotones, and orchards with cultivated lands appear to be utilized in greater proportion than their availability. This could be attributed to their seasonally high value as food resources.

More specifically, significant preference for phytocenotic combinations comprising mixed forests with ecotones (*Abieto-Fagetum, Fageto-Abietum, Pineto-Fagetum, Abieto-Pinetum*) is probably related to the optimum ecological diversity of this type of forest ecosystem, satisfying ecological requirements of the bears such as available food and good shelter.

Because of field ruggedness and heterogeneity, 86 "piecewise" (nonlinear) type transects (Anderson et al. 1980) were chosen for field sampling, covering all major ecological units of the study area. Their length (max length = 20 km; min length = 2 km; average length = 7.7 km) and density were adjusted to the ecological diversity of the investigated sectors. The 3 major categories of sampling transects and their cumulated length were:

- ancient or still in use paths and trails: 235.5 km
- forest roads (of various use levels): 242.3 km
- other transects independent of human use: 195.2 km

Total length: 673.0 km

With a totally walked distance of 2,350 km, interannual and interseasonal comparison of walked distances shows satisfactory sampling pressure and distribution in time (year, season, and month) (F1 = 0.93; F2 = 0.82; $\alpha = 0.05$). Data were cumulated and partitioned by time of season.

Habitat preferences and habitat-use patterns were estimated according to the "Habitat use-availability" model (Marcum and Loftsgaarden 1980). Habitat types were determined and classified according to spatial distribution and availability of vegetation communities in the study area. Bonferroni's intervals were calculated to estimate significance of bear habitat preferences by time of year (annual cycle) and seasons.

RESULTS

Distribution and Population Status

Historic sources as well as 105 localities with names containing the "bear" radical distributed all over the country, inform us about a possible brown bear distribution range in Greece, in ancient times, extending over almost the entire continental part of the country (Xenophon, Pausanias). Bear presence in the mountainous parts of Greece including the peninsula of Peloponnisos seems to have been continuous in time until the 15th-16th centuries (Pizzicoli, Candiloros, Guillet, Dedreux in Simopoulos 1984). In the 18th century, there is evidence of the beginning of a dramatic population decline (Mertzios in Papavassiliou 1963) due essentially to massive bear extermination for the skin, coupled with habitat alteration. More recent oral information confirms the species' extinction in the 1940s from the southernmost and easternmost branches of the Pindus range (Mt. Parnassos, 2,457 m, and Mt. Olympos, 2,918 m). One may assume that the main orographic units of Greece (Pindus range and Rhodope mountains), because of their inaccessibility and remoteness, have been the refuges and dispersal centers of the species in Greece throughout historic times.

Present Status

During the 1986 investigation campaign, 160

questionnaires were sent, to all villages located within the presumed bear range. One hundred and two were answered, confirmed, and mapped. That gives a distribution pattern of the brown bear for the western population nucleus, covering the 3 physiographic/phytogeographic units previously described (Fig. 1.) According to this information, we notice the following points:

- a concentration of bear occurrence around the major mountain units of the northern Pindus range.
- a geographic continuity with adjacent (neighboring) populations (Albanian, Yugoslavian) characterized by migration phenomena along the border line.
- a severe fragmentation tendency of the distribution area nearby the town of Kastoria (see arrow on Fig. 1). This could be explained by the ongoing extension of agricultural lands upon forests (in "discussion" topic).
- a sporadic bear presence in the extreme eastern and southern parts of the range, characterized in the same sectors by a retreat of the species range.

A total of 1,126 reports were registered during the 1988 campaign. Of these, 1,013 (90%) were accepted as referring to the period between 1983 and 1988, and 113 (10%) were rejected. Of the 1,013 accepted reports, 506 (50%) contain direct and second-hand information referring only to the year 1988. In total 479 persons were interviewed and distributed as follows:

shepherds	26%
foresters and forest wardens	24%
hunters	15%
timbers	10%
farmers	8%
beekeepers	4%
hikers	3%
other	10%

Five categories of signs of bear activity and occurrence were taken into account, as follows:

- direct sightings of females with cubs
- tracks, scats, and other signs of activity
- damage to livestock
- cases of illegal killing
- confirmed cases of illegal killing

Their distribution pattern (Fig. 2), extending over 8,000 km^2, appears generally the same as reported in 1986 for the western population nucleus. They also provide new data on species distribution for the eastern nucleus (Rhodope mountains), extending over a surface of about 2,500 km^2.

More specifically: Concerning the western distribution nucleus (Pindus range):

- sporadic occurrence of bears in the far eastern sectors (area of Mt. Askion) was confirmed as well as locally extra-limital bear presence in the far western ones (area of Pogoni) (in 1990).
- from spring 1987 to autumn 1989 several cases of extra-limital sporadic occurrence of bears in the extreme southern sectors (area of Karpenission), were reported and confirmed in the field (location of damage on beehives). In this zone, apparently isolated from the rest of the core bear range, probably 1 male, 1 subadult, and 1 female with a cub were recognized. This is the first evidence of bear occurrence in this area for the last 40 years.
- there are still some unexplored sectors of potential bear occurrence in the extreme north that need confirmation (area of Mt. Voras).
- the risk of internal fragmentation at the same latitude still persists.

Concerning the eastern distribution nucleus (Rhodope mountains):

- sporadic occurrence of bears in the extreme western sectors (area of Serres - Lailias) as well as probabilities of bear occurrence in adjacent sectors (Mt. Belles) makes the delineation of the bear range there more fluctuating.
- migration phenomena across the Greek-Bulgarian border have also been confirmed.

Population Size

Estimation of minimum population size is based on records of observations of females with cubs of the year, within the same year (Servheen 1989).

A minimum size of the total bear population in Greece, in 1988, was roughly estimated between 120 and 140 individuals. Systematic data on illegal killing-poaching covering a 5-year period (from 1985 to 1990) shows an average annual loss of 14 animals (about 12% of the total population) (Fig. 3). Besides, according to same data on a longer period (1962 to 1978), "harvest" levels reflecting population levels (Elgmork 1988) appear to be decreasing (Fig. 4).

Since the official protection status of the species remains hardly effective, there are serious reasons to believe that human-caused mortality is still one of the main factors of bear populations negative trends in Greece. We may also notice that high levels of human caused mortality are particularly concentrated during the wild boar hunting period (Fig. 5).

Food Habits

The global (annual) diet is dominated by food items of plant origin (87%) followed by animal material

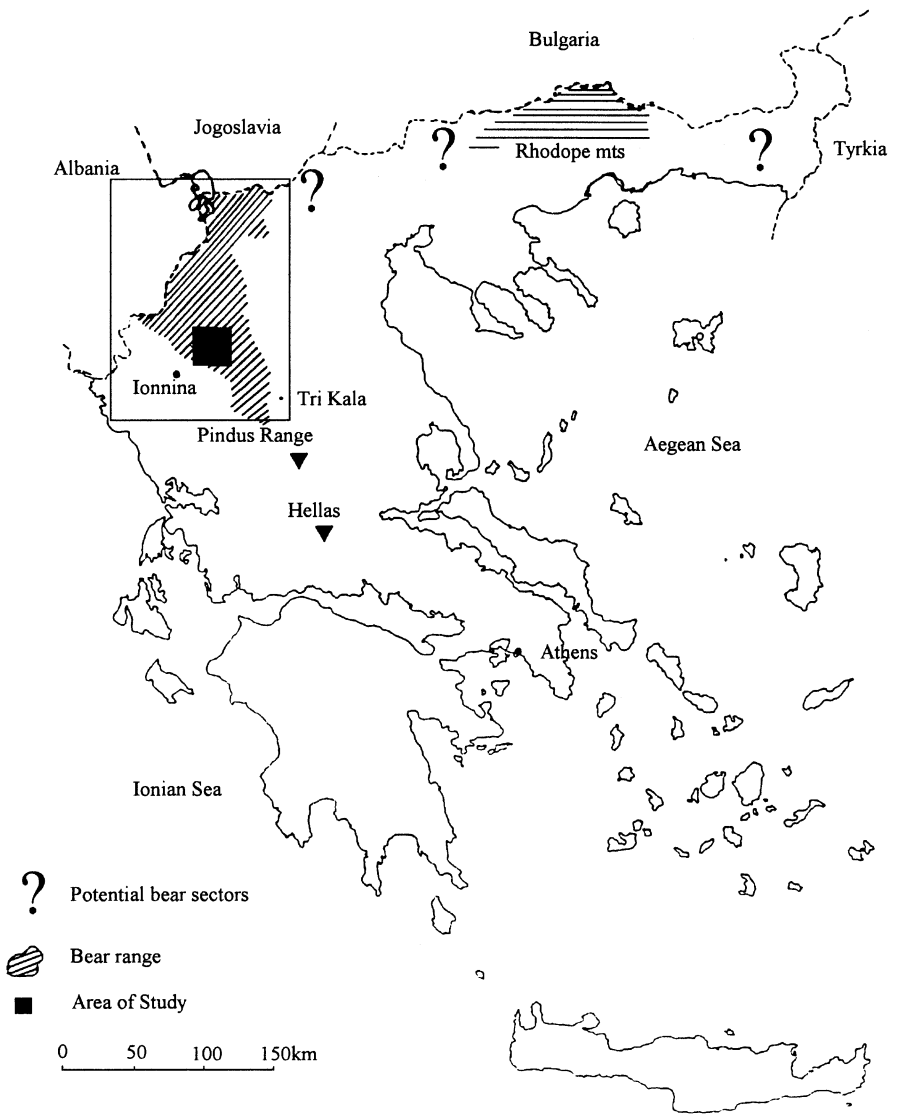

Fig. 2. Brown bear range in Greece according to 1988-89 data.

(13%) mostly composed by insects (ants: 10%). Grass (herbaceous plants), fleshy and dry fruits composed the major proportion of the vegetable part in the bear diet. In total, 54 species were identified, meeting nutritional needs in proteins and glucids respectively (Mealey 1980) (Fig. 6). We noticed that the general feeding cycle appeared to follow plant phenology. We also noticed that there seems to be a close relationship between rhythm of consumption (massive) of several food items and their seasonal availability (short in time) and therefore optimal nutritional value, within their annual phenology stages (cycle) (Fig. 7). Herbaceous plants constituted the principal spring food (60% of occurrence in the spring sample) whereas fleshy fruits constituted the major part in summer (30% of the summer diet, $n = 73$) showing a maximum in autumn (61% of the autumn diet, $n = 209$). We noticed a differential (off season) use of certain vegetable food resources such as acorns (70% of occurrence in the winter sample), beech nuts (45%), and apples and pears (15%). When these were consumed in winter, they seemed to have a compensating role to the feeding stress characterizing this period of the year. Animal material consisted primarily of ants (maximum consumption in summer, 43% of occurrence in the summer sample—10% of the total diet). Percentage of other mammal preys is apparently low (2% of the total diet) (taking into account high animal protein

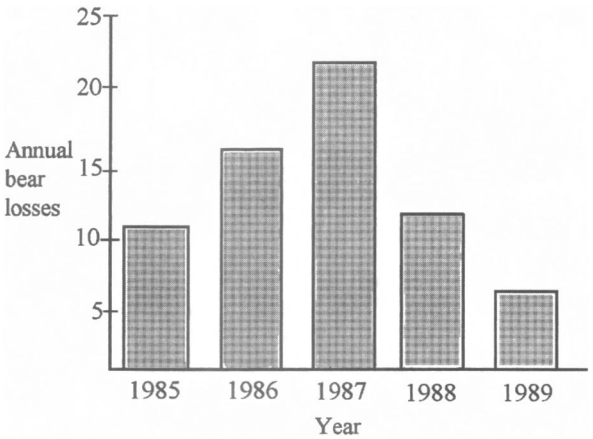

Fig. 3. Confirmed cases of annual bear losses (human-caused mortality) from 1985 to 1989.

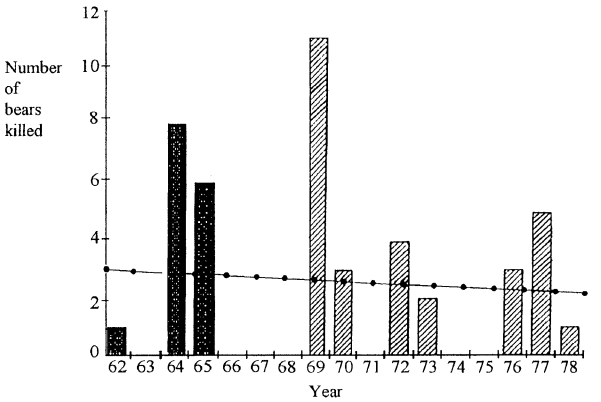

Fig. 4. Brown bear human-caused mortality and tendency of population levels (according to hunting data from 1962 to 1978).

digestibility, Herrero 1978, Mealey 1980). Micrographic study of hair samples showed dominance of domestic ungulates (especially cattle, with the highest number of attacks concentrated in autumn) (Fig. 8.) Remains of sheep, goats, domestic dog, and meles meles were also identified. Remains of tortoise were identified in 1.5% of the total sample.

Brown bear feeding spectrum showed a significantly higher diet diversity (Student-Newman-Keuls test; $P < 0.05$) in autumn, the period of fruit ripening and therefore of maximum food availability (Fig. 9); its main characteristics being continuity and complementarity within time.

Annual Activity and Habitat Use

The brown bears' greatest activity levels occur within a period of 6 months between May and October (almost 70% of total activity signs) with a first maximum in June (10% of total activity signs) and a second one (more important) in September-October (34% of total activity signs) (Fig. 10) These significantly differ from spring and winter activity levels ($F = 6.09$; $P < 0.0005$).

Annual activity patterns demonstrate 2 peaks (Fig. 10). One occurs in the beginning of summer (June) and appears to be related to the post-denning feeding period as well as to the breeding period (Clevenger et al. 1990). The mid-summer flexion (July) of annual activity could be attributed to 3 main causes:

- significant human presence within bear habitat (logging, grazing, trekking),
- restricted food availability,
- influence of climatic factors (high temperatures) inducing "stational" modes in habitat use patterns (Parde 1984).

The second maximum of activity occurs in fall, suggesting a close relation with the pre-denning feeding period. Bear activity did not cease entirely during winter (10% of total indices). We noted occasional movements of bears as well as feeding activity signs. We suggest 2 main causes of that activity:

- Hunting that could be an important disturbance factor explaining unusual winter mobility.
- Intervals with mild weather conditions (usually February) inducing a "re-activation" of some animals.

Analysis of Habitat Preferences

In the analysis of habitat selection, we investigated the relation between the utilization and availability of habitat types using "vegetation communities" variable.

Different vegetation communities were grouped into 11 types: Oak (*Q. frainetto*, *Q. cerris*, *Q. pubescens*) forest; other deciduous forest types (*Carpinus* sp. *Ostrya* sp.); black pine (*Pinus nigra*) forest; fir (*Abies borisii-regis*) forest; beech (*Fagus sylvatica*) forest; balkan pine (*Pinus heldreichii*) forest; mixed (deciduous and coniferous) forest communities; mixed forests and ecotones; ecotones; orchards and cultivated land; subalpine and alpine pastures.

Habitat availability was determined by mapping the former vegetation communities (vegetation type grid = 1 km^2) and producing 840 coordinates in the study area. Bear locations were also mapped.

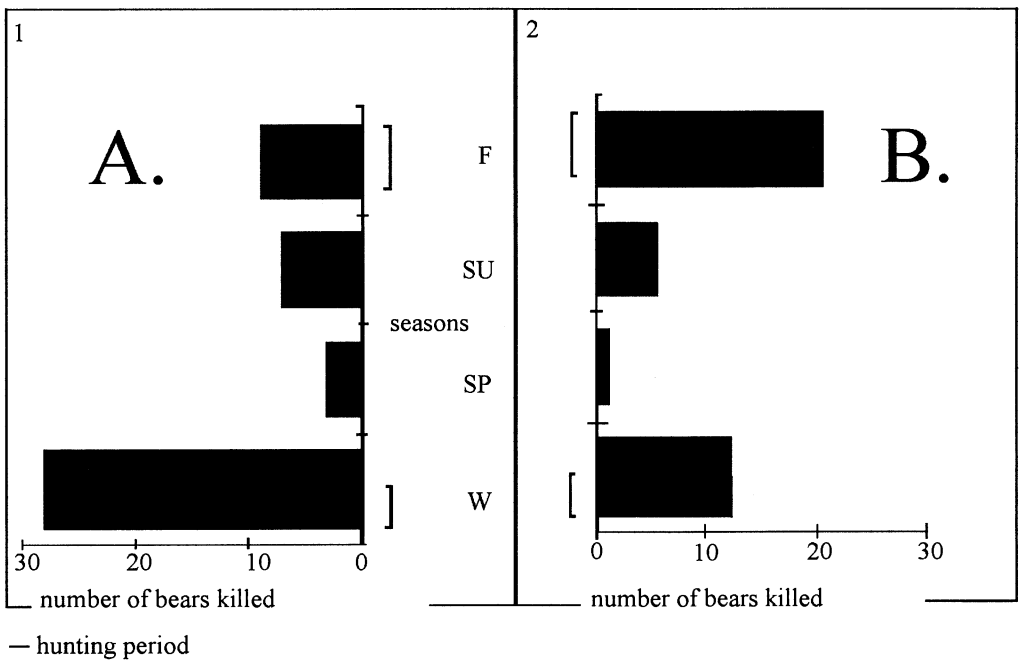

Fig. 5. Seasonal frequency of bear killing. (A) From 1962 to 1978. (B) From 1985 to 1989.

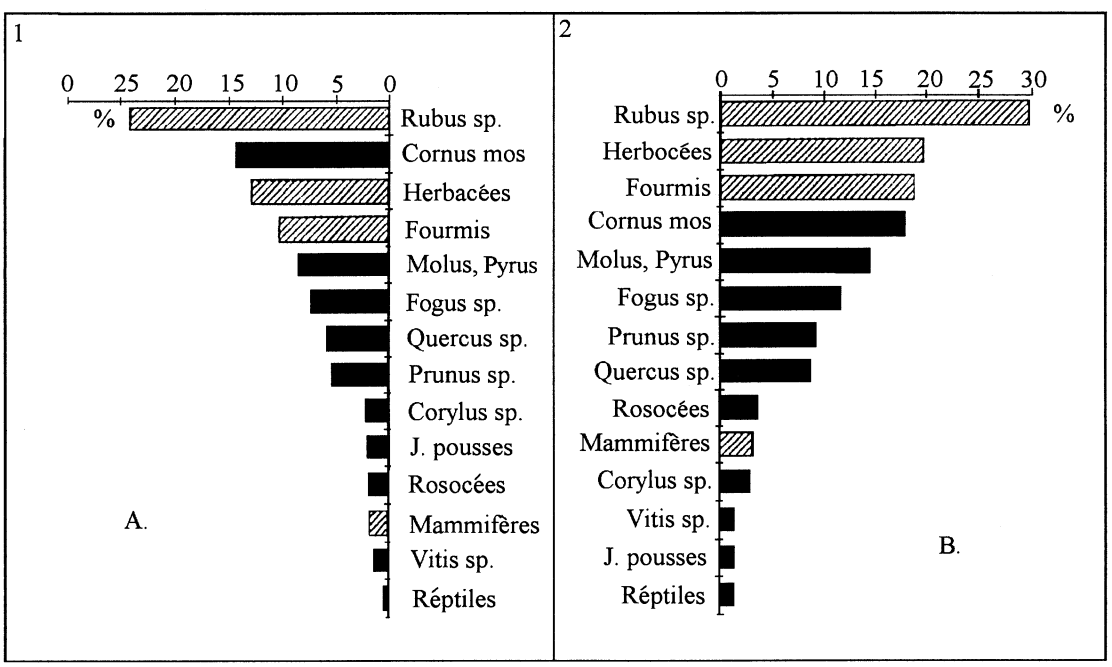

Fig. 6. Absolute and relative occurrence of the main food items in the bear's diet, Pindus, Greece, from 1985 to 1988.

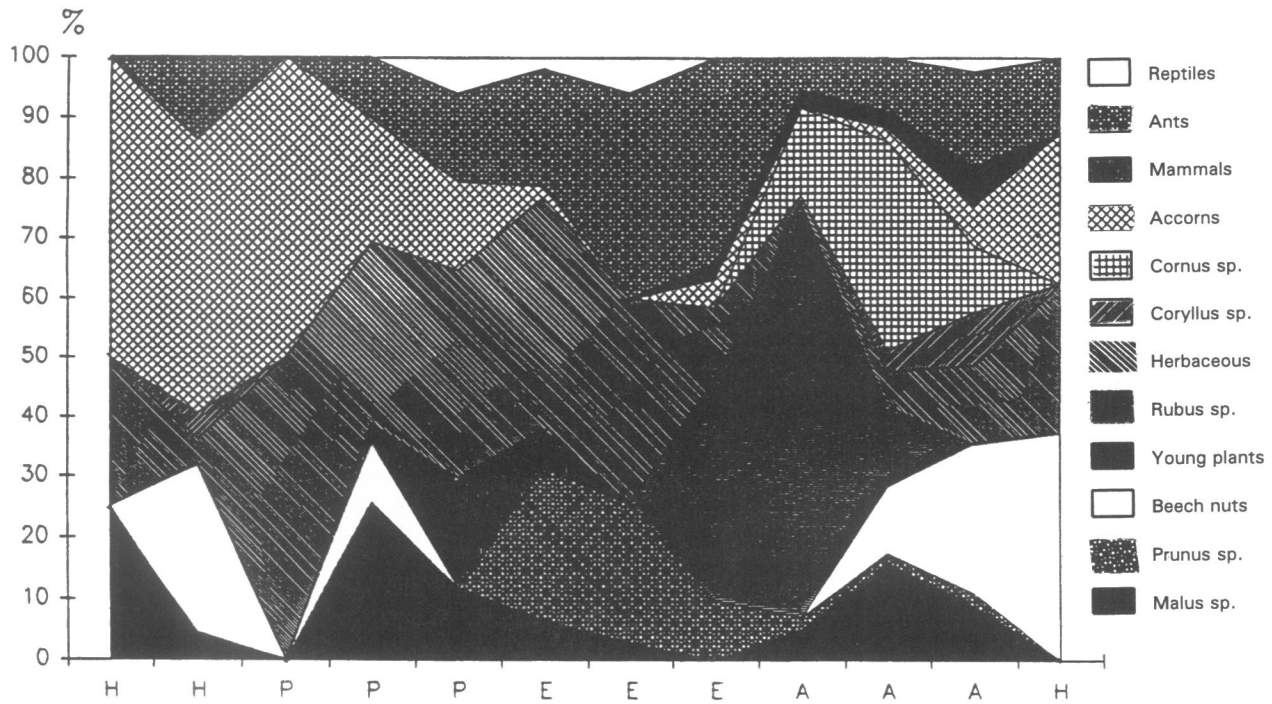

Fig. 7. Annual trophic spectrum of the brown bear in Pindus range, Greece, from 1985 to 1988.

With these locations and those from bear use we tested the "null hypothesis" that bears do not use the habitat types selectively but rather in proportion to their availability or in a random manner. To determine whether there was a significant difference between the expected and observed utilization, a chi-square test was used depending on whether the assumption of normality was met. If a statistically significant difference resulted, Bonferroni simultaneous confidence intervals were used to determine which categories of habitat types were utilized more or less than expected.

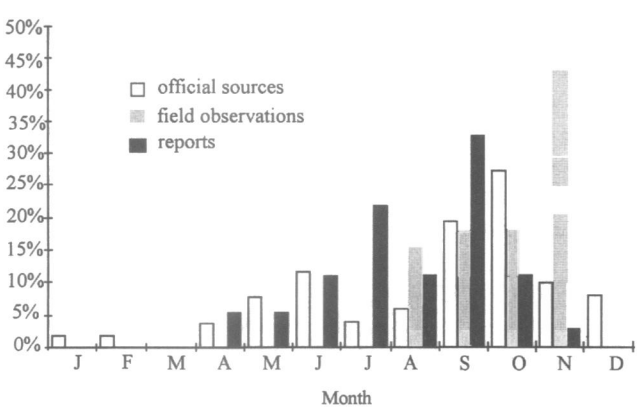

Fig. 8. Annual frequency of bear attacks on domestic cattle, Pindus, Greece.

In fact, in 86% of the cases where this vegetation type occurs in our study area, understory vegetation with fruit trees and berries is well developed. Besides, forest cover rate in 52% of sites of bear locations is above 75%.

Global sub-use of ecotonic formations is probably related to the significant avoidance of subalpine and alpine meadows and subsequently of the upper limit of the forested zones (interface between forest and open lands).

It is worth noting that use of black pine forests, proportional to their availability, which is considerable within the study area, may be as well related to the occurring understory shrub vegetation composed essentially of berries, which as we have seen play a very important role in the bear's diet.

CONCLUSION—DISCUSSION

Despite a tendency of stabilization of the brown bear range in Greece, with some isolated cases of extra-limital occurrence, imminent risks of further internal fragmentation should not be underestimated. Therefore, there is urgent need for a systematic monitoring of the potential and effective causes of aggravation of the

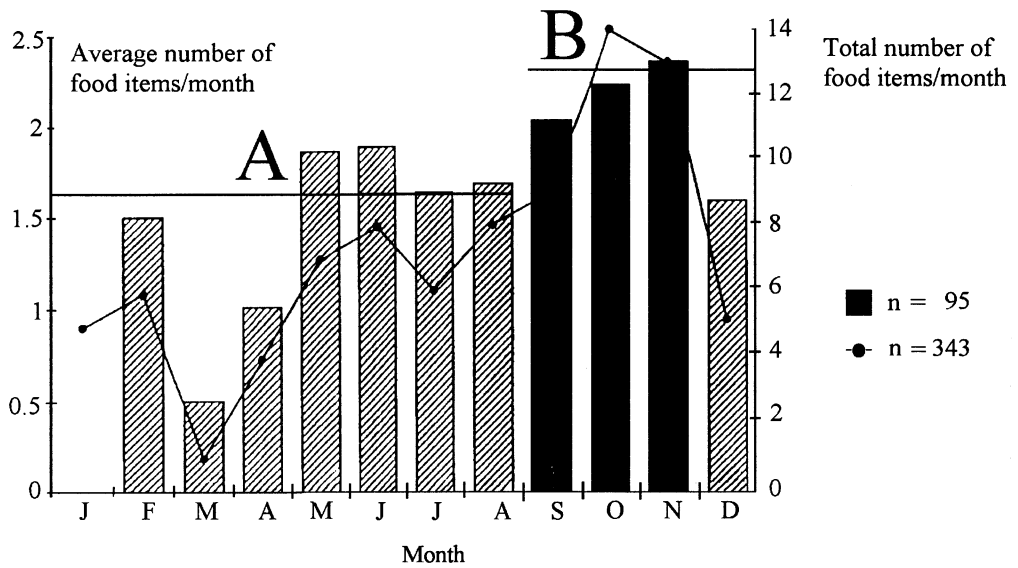

Fig. 9. Annual variation of food items diversity in bear's diet. (A) Winter, spring, summer average. (B) Fall average.

phenomenon at "sensitive" areas.

First systematic data on bear population status show a close relation between human-caused mortality (poaching) and negative population trends. A thorough quantification of the phenomenon should be enhanced by systematic population censuses and combined with hunter's information campaigns. Effectiveness of the existing wardening network should also be reviewed.

Results on food habits and requirements, as well as on rhythms of annual activity and modes of habitat use, provide information for the identification of critical bear food resources, habitat types, and timing of utilization. They should be seriously taken into account when scheduling human activities involving especially logging, hunting, recreation, projects of natural resources exploitation, etc.

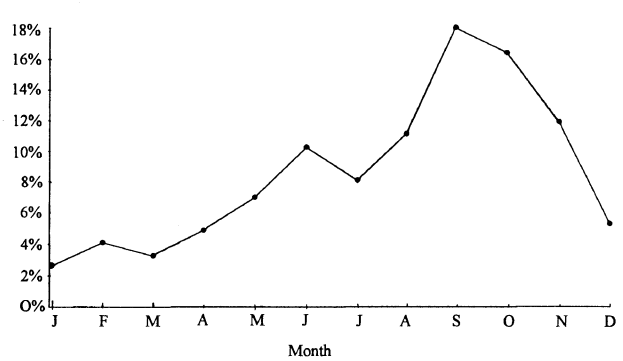

Fig. 10. Brown bear annual activity patterns, Pindus, Greece.

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