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Telemetry as a Tool to Study Spatial Behaviour and Patterns of Brown Bears as Affected by the Newly Constructed Egnatia Highway – N. Pindos - Greece

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1. Introduction

Throughout the world, traffic volumes have increased markedly in the past two decades (United Nations 1992) and the increasing area occupied by recently constructed roads is affecting wildlife populations in the EU from 1990 to 1998 circa 33.000 ha of landscape (10ha daily) have been used and occupied for transportation infrastructure development purposes. The average surface of undisturbed (by transportation infrastructure) continuous landscape ranges from 20 km2 in Belgium to 600 km2 in Finland with an EU average of 130 km2 (EEA, 2001). For many mammal populations, the main demonstrated impact of roads to date has been in terms of increased disturbance or mortality. Avoidance of otherwise suitable habitats in close proximity to roads has been shown to occur for brown bears *(Ursus arctos)* and wolves (*Canis lupus*) in the U.S.A. (McLellan and Shackleton 1988, Mace et al. 1996, Mech et al. 1988). For some mammal species, roads have been shown to act also as a considerable barrier to dispersal (Mader 1984). Roads can therefore have a significant effect in fragmenting wildlife populations and eventually lead them to local extinction (Fahrig and Merriam 1994). Increased awareness of environmental problems caused by infrastructure construction has moved engineers, ecologists and policy makers to develop planning concepts to deal with the impacts on nature and landscape. If avoidance of a certain project is not feasible, mitigation measures can be undertaken as a second planning concept.

In this general context of invasive roading and large scale transportation infrastructure development Greece has not "escaped". The "Egnatia" highway project of modern times was planned to connect the western part of the country with the eastern and serve as a trade route between the EU, through Italy and Greece, and the Orient. With funds allocated by the EU (Cohesion Funds) and the Hellenic Government, the modern Egnatia, only partly follows the route of its predecessor "Via Egnatia" from the Roman times (as of Rome's first

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imperial roads), and is a 670 km long and 24.5m (+/- 5m) wide highway, thus making it one of the largest construction projects in Europe and part of the TENT (Trans-European Network Transportation). This highway actually connects Greece with all neighbouring countries and service 5 ports, 6 airports and 36% of the country's total population.

Throughout its course in northern Greece, the highway crosses also the Pindus mountain range, cutting through natural areas, which are of outstanding importance for biodiversity and several priority species of the Hellenic mammal fauna and avifauna (i.e. bear (*Ursus arctos)*, wolf (*Canis lupus*) etc. see maps 1 & 2) as well as for priority habitat types, according to E.U. Directive 92/43 "(i.e. pinus nigra forests 9530*) but also for being one of the last strongholds of the brown bear (Ursus arctos) in the southern Balkans. (see photos 1,2&3).

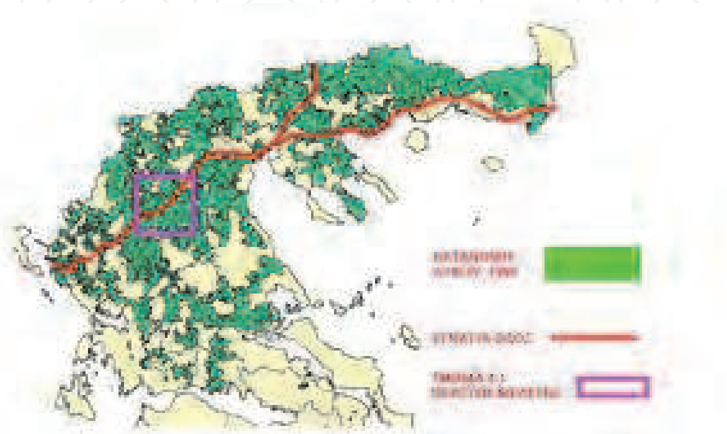
Photo 1., 2. and 3. Construction of the Egnatia highway

With only 290-350 bears remaining in Greece and the expected detrimental impact of the highway on natural habitats, bear population structure and movement patterns of the NE Pindus brown bear sub-population the NGO's were alerted and made several notifications to the competent authorities. In the very beginning hardly any mitigation measures were foreseen along the 37 km most critical highway stretch cutting through core brown bear habitat with a bear indigenous population estimated approximately at 80 ind . It is only after NGO's strong pressure that the revised highway EIA study finally incorporated the construction of a number of additional mitigation measures such as: tunnels, wildlife underpasses, green bridge and viaducts that are expected to prevent serious habitat fragmentation and population disruption of the indigenous large mammal species. Additional mitigation measures included a ban on hunting in a 2+2 km corridor along the highway, the construction of noise barriers, adequate fencing and the appropriate ecological landscaping of areas affected by the construction of the highway.
It is important to note that the above measures were taken only after a Council of the State verdict issued in 1997 and postulating the least environmentally costly alignment of this highway stretch (regarding especially bear populations and habitat), obliging EGNATIA ODOS A.E. (the construction supervisor) to carry out a revised EIA study for this most compromising (for the brown bear) 37km highway stretch and to incorporate additional mitigation measures such as: 13 tunnels (8.85 km), 11 bridges (2.64 km), 1-2 green bridges and 5 – 9 wildlife underpasses, thus mitigating about 31% of the 37km highway stretch. (photo 4.)

Photo 4. Partial view of the mitigated Egnatia Highway

Moreover in compliance to the relevant articles of the relevant EIA study, a special monitoring and research project was set-up and launched in 3 phases and in cooperation between the highway construction supervisor (EGNATIA ODOS A.E.) and specialized NGO's. The aim of this project was to monitor and assess the highway's impact on big mammals and their habitats prior and during highway construction as well as during highway operation. In compliance with the Joint Ministerial Decision for the 37km stretch Panagia - Grevena (4.1) of the Egnatia highway, the two phases (2003-2009) of the project were carried out in cooperation with three NGO's ("Arcturos", "Callisto" & Hellenic Ornithological Society) and two Universities (Aristotle University of Thessaloniki and University of Thessaly, comprising 4 Faculty departments). The two phases of the project were co-financed by the EGNATIA ODOS S.A. and the E.U. (DGREGIO). Implementation of the third phase is still on paper.It is worth mentioning that the implementation of this project was an integrated part of the environmental terms and provisions of the revised EIA study, the ex-ante part being of outstanding importance. The aim of the overall project was to evaluate the status of brown bear and wolf populations in the study area prior to and during the planned construction of the 37 km Egnatia highway stretch. The final objective of the project was a comparative evaluation of the effectiveness of the mitigations measures versus the status and ecological requirements of the targeted species in the study area. The required multilevel approach of this project encompassed several disciplines such as: Genetics, Ecology, Forestry, Wildlife management, provided by the aforementioned parties.

Map 1. Brown bear (Ursus arctos) distribution versus Egnatia highway total alignment (Greece)



Map 2. Wolf (Canis lupus) distribution versus Egnatia highway total alignment (Greece)

To date the two first phases of the project (prior to construction 2002-2005 and during highway construction 2006-2009) have been completed. Due to lack of financial resources on behalf of the state authorities and the construction supervisor (EGNATIA ODOS A.E.) the third phase (monitoring of highway impact during construction) scheduled for 2009 has been delayed. Nevertheless and after three (3) traffic fatalities with two bear victims on the monitored highway stretch and which occurred within the first 4 months of the highway operation (between June and September 2009), further pressure was put from NGO's upon state authorities in order to replace the inappropriate highway fence with a bear proof fence. The fence was replaced in 2009 and 2010 although not keeping full standards recommendations (see photos).

Photo 5. First bear traffic fatality on Egnatia highway

Photo 6. New bear proof fence

Photo 7. Old inappropriate fence destroyed by bears highway crossings

Photo 8. New fence permeability problems due to inadequate standards
(missing of the upper bent part)

The main objectives of the study were to investigate behavioral changes of the brown bears in response to the road as a disturbance factor in terms of :

- Potential changes in habitat use range
- Potential differences in movement distance (mean and max)
- Potential differences in movement patterns
- Habitat suitability conditions and status in relation to bear presence and activity.

2. Study area

The project area extends over almost 1000km^2 of a mixed forest and agricultural ecosystem and is located in the north-western part of Greece, in Pindos mountain range. Of this area 43.23% are forests, 31.11% are meadows (pasture lands), 19.47% agricultural lands, whereas human settlements occupy 3.69% of the total area. Major forest vegetation types comprise oak (*Quercus sp*.), black Pine (*Pinus nigra*) and beech (*Fagus sp*.) (see photos 1 & 2). The area is characterized by a mosaic of dense forests, openings and small scale cultivations. Altitude ranges between 500m –2.200 m. Specific sampling pressure was given to the sector that was more directly influenced by the highway construction works and which covers a surface of 160 sq.km. This surface includes the total length of the highway segment (37 km) in a "buffer zone" of 2+2 km width. The current alignment of the newly constructed Egnatia Motorway (total length 670 km), which is one of the largest transportation infrastructures projects in Europe and part of the TENT, cuts through the study area over a 50km stretch. In the total study area the overall highway mitigation measures comprise: 20 tunnels (16.465 km), 12 bridges (2.84 km), 1 green bridge (50m), 7 wildlife underpasses, and 59 culverts have been placed thus mitigating about 38,6% of the 50 km highway segment. The wider study area extends over 5.229 km^2 and there are 48.293 inhabitants (9.56 id/ km^2).

Photo 9. and 10. Two different aspects of the study area: mixed coniferous and deciduous forests and oak forests with openings and small scale cultivations

3. Materials and methods

3.1 Telemetry protocol

Over a three 3 year bear monitoring period (2007-2009) during the project's second phase, field work has focused on satellite telemetry combined to systematic collection of bear signs of presence and activity. An additional monitoring protocol was developed using thermo-sensitive, IR and conventional pre-programmed video and photo cameras.

In total twenty two (22) adult and sub-adult brown bears have been fitted with GPS/GSM radiocollars: eighteen (15) males and seven (7) females. Bears were trapped from April to mid May and from September to mid-October in 2007 and 2008 within a buffer zone of 10 kilometres along the Egnatia Highway stretch 4.1 (routing from "Grevena to Metsovo"). We captured bears using Aldrich foot snares (Johnson and Pelton 1980) and immobilized bears with a zolazepam-tiletamine /medetomidine combination and reversed with atipamezole (Riegler et al. 2009). Body measurements were recorded and a premolar was extracted to determine bear age (Stoneberg and Jonkel 1966).

Photo 11., 12., 13. and 14. Bears equiped with radio-collars – radio-collars types: Simplex, Tellus GSM

Bears were fitted with Televilt/Followit Simplex, Tellus, Tellus GSM and Tensyx GPS collars with remote drop-offs. GPS collars were fitted with devices such as VHF transmitter, mortality -activity sensors and were programmed to record a location every 60 minutes. During the denning period we programmed each GPS-receiver to obtain a location fix twice a day. For Simplex and Tellus collars data were remotely downloaded from the ground four times monthly using a RX-900 Receiver (Televilt TVP Positioning AB, Lindesberg, Sweden). Tellus/GPS-GSM collars worked via cell phone coverage and data were downloaded through internet every 8 hours via Televilt-Followit server.

3.2 Home range size

We calculated home ranges with Arc View 3.2.a and the Home Range Extension (A. R. Rodgers and A. P. Carr, Ontario Ministry of Natural Resources) using the minimum convex polygon (100%MCP), 95%MCP, Fixed Kernel method and 50% contours of activity for core areas (areas of high intensity of use). The 100% MCP estimates were used to facilitate comparisons between studies and regions. Fixed Kernel Method range analysis was performed because, in addition to estimating range size, it reveals range use patterns, using a smoothing factor determined by least squares cross validation (LSCV) (Seaman and Powell 1996). We ignored autocorrelation within the data because the data continued to exhibit a high degree of dependence even when using extended fix intervals (24 hr; e.g., Reynolds and Laundre´ 1990, Rooney et al. 1998, De Solla et al. 1999). We tested collars GPS accuracy in the field and the mean error was 30m (Giannakopoulos et al. 2010).

Data gathered from the aforementioned methods were mainly used to identify bear presence as well as bear movements patterns and spatial behavior versus the highway alignment and especially in correlation to two main factors:

- the disturbance related to the construction phase
- the location of the different mitigation measures

3.3 Habitat use – movement distances - movement patterns – habitat suitability

More specifically data analyses were used in order to test whether the highway construction phase affected:

(a) the dispersal ability, (b) preferences on habitat use and (c) distributional patterns of the species.

To estimate **potential changes in habitat use range** we estimated home range polygons (95% Kernel core area). Additionally group home range estimates were based on home range size. We also calculated min distance of polygons from road using t-test and ANOVAs. Data were organized and grouped according to the sex of the individuals and the seasons. Adequate data to perform statistical analyses were found for males in spring and summer and for females in summer.

The analysis was repeated for males and females and for data collected at different seasons

To estimate **potential changes in movement distances** we analyzed day and night movement distances but also home ranges of each individual (estimated by using Kernel based methods) to examine whether the distance from the highway is an important indicator of the quality or quantity of brown bears activity levels. Mean and maximum moving distances according to the time of activity and distance from the highway were examined as well as variations in mean direction with respect to the distance from highway (angular analysis of point patterns). We used ANOVAs and the analysis was repeated for males and females and for data collected on daytime or at night.

To estimate **potential changes in movement patterns** angular analysis of point patterns (changes in mean direction with respect to the distance from road) was performed according to the following protocol:

- we used point records to describe movement patterns
- we grouped moment pattern data into 4 categories in relation to distance from the highway (0-2000m, 2000-4000m, 4000-6000m & >6000m)
- we used circular stats (*Rayleigh's Mean Direction test*) to test differences in direction

To **assess habitat suitability** in relation to bear presence and prediction of use of a certain point (or area) of the HR, we used a series of digital sources to derive potential predictor variables (land use, topographical, vegetation). In addition, 17 variables were calculated by using neighbourhood statistics techniques. The significance of distance from highway and of the former predictor variables upon species distribution and habitat use were assessed by using Generalized Linear Models (GLM), Logistic Regression (LR) and Regression and Classification Trees (CART). Relative abundance - (Generalised Linear Models)(Naves et. al., 2003, Wiegandet al., 2004, Nielsen et al., 2006).

For each bear habitat pixel we calculated the following parameters using neighbourhood statistics:

- Average altitude within a 5 pixels radius from the central pixel. This variable allows to characterize the altitude of the central pixel based not only on its proper value but also on the values of the neighboring pixels as for the pixel selection by a bear depends also on its accessibility which is related to the altitudinal variation (ruggedness).
- Average altitude within a 20 pixels radius from the central pixel.
- Altitude coefficient of variance within a radius of 5 pixels from the central pixel. This variable allows the quantification of altitude variance in a wider area.
- Altitudes range within a 5 pixel radius from the central pixel. This variable examines the max and min altitude differences in an area and functions as an indicator of selection or avoidance of movement in the given area.
- Average slope value within a 5 pixels radius from the central pixel.
- Coefficient of variance of the average slope value within a 5 pixels radius from the central pixel.
- Coefficient of variance of the average slope value within a 25 pixels radius from the central pixel.
- Slope range values within a 5 pixels range from the central pixel.
- Slope range values within a 15 pixels range from the central pixel.
- Slope range values within a 25 pixels range from the central pixel.
- Vegetation types variability index within a 5 pixels radius from the central pixel. Vegetation types variability was calculated after Shannon's (H) index as follows:

$$H' = \sum_{i=1}^{S} p_i \cdot \ln p_i$$

Where: *H* the Shannon's index value

- p_i**:** is the relative abundance of each vegetation type, which is calculated from the percentage of occurrence of the characteristics of a given vegetation type compared to overall vegetation characteristics within in the same pixel.
- *S* the number of vegetation types.

- Shannon (vegetation) diversity index within a 10 pixels radius from the central pixel.
- Shannon (vegetation) diversity index within a 5 pixels radius from the central pixel.
- Number of different vegetation types within a 5 pixels radius from the central pixel.
- Number of different vegetation types within a 10 pixels radius from the central pixel.
- (%) of contribution of the dominant vegetation type over the total number of recorded vegetation types within 5 and 10 pixels radius from the central pixel.
- (%) of contribution of 2^{nd} and 3^{rd} rank vegetation type over the total number of recorded vegetation types within 5 and 10 pixels radius from the central pixel.

Bear telemetry data sets were incorporated on these pixel maps. For each map pixel with a bear radiolocation we extracted all relevant information related to topographic and vegetation characteristics, distances from the highway and the values of all neighborhood statistics variables as described above. It is important to note that in a random pixel of the study area there may be more than one radiolocation indicating bear presence. This may be attributed to selection and repetitive use (by one or more bears) of a given pixel due to its specific attributes and characteristics. Therefore it is interesting to investigate the effect of pixels attributes upon the probability of their use by bears (preference/avoidance) but also the frequency of their use. For this we have developed prediction models focusing on various characteristics related to spatial behavior and presence of bears, according to two main approaches:

- To what extent the selected variables allow prediction of abundance of bear presence in given areas. This allows to identify which variables contribute most in the selection of most frequently used/visited habitat units by bears.
- prediction models emphasized only on the presence or absence of bears in each pixel without taking into account the frequency of use (stationary of transitional) of each pixel.

For the first approach we used General Linear Models (GLM) which allow the development of linear relations between the dependent variable and a group of categorized or qualitative factors but also with continuous variables (covariates) through specific operational connection functions (Quinn and Keough, 2002). These models allow a non-normal distribution of the dependent variable. We used Pearson's correlation coefficient to investigate the correlation degree between all variables. In total 15 variables were kept in our analysis. Their utility to predict abundance of bear presence over the study area was examined. Of them, two (vegetation types and aspect) were introduced in the model as "factors" and the rest as "covariates" (continuous numeric variables).

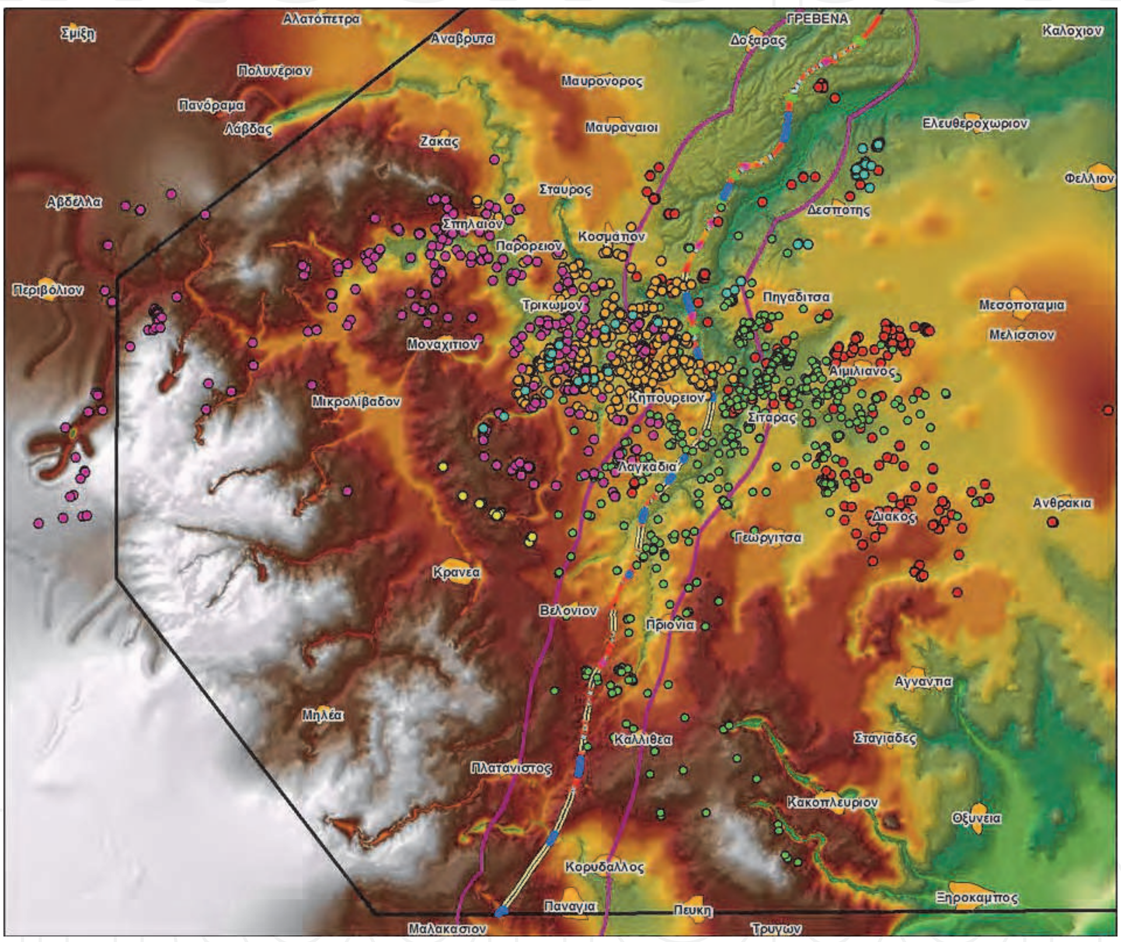
The possibility of implementation of those models and their prediction efficiency in bear presence abundance and habitat pixels use according to the explanatory variables, was evaluated following different statistical tests such as: likelihood-ratio chi-square test, Deviance, Pearson Chi-Square statistics (Quinn and Keough, 2002).

For the second approach we developed a Logistic Regression model (LR) which is only applied in the case of binary data (presence/absence). We used a logic function to interrelate the key variable (presence and bear activity) with the group of descriptive variables. We performed a group of diagnostic tests such as Hosmer-Lemeshow goodness-of-fit statistic, improvement of chi-square test in order to examine the suitability and efficiency of the model as a predictor tool for bear presence or absence in a given pixel of the study area.

Additionally we developed Classification Trees (CT) by using bear presence and absence as the dependent variable and we examined probable classification rules for the explanatory (descriptive variables). Here again we performed a group of diagnostic tests in order to examine the efficiency of the produced rules from the aforementioned analysis. This type of analysis is based on artificial intelligence methods (machine learning techniques principle) (Vayssieres κ.α. 2000, De'ath & Fabricius 2000, Thuiller κ.α. 2003, Mazaris κ.α. 2006).

4. Results

Telemetry data from the twenty two (22) radio-collared bears of the sample have yielded up to **42,849** GPS radiolocations. Part of the sampled radiolocations in relation to the highway alignment and the highway buffer corridor and the study area are shown on map 3.



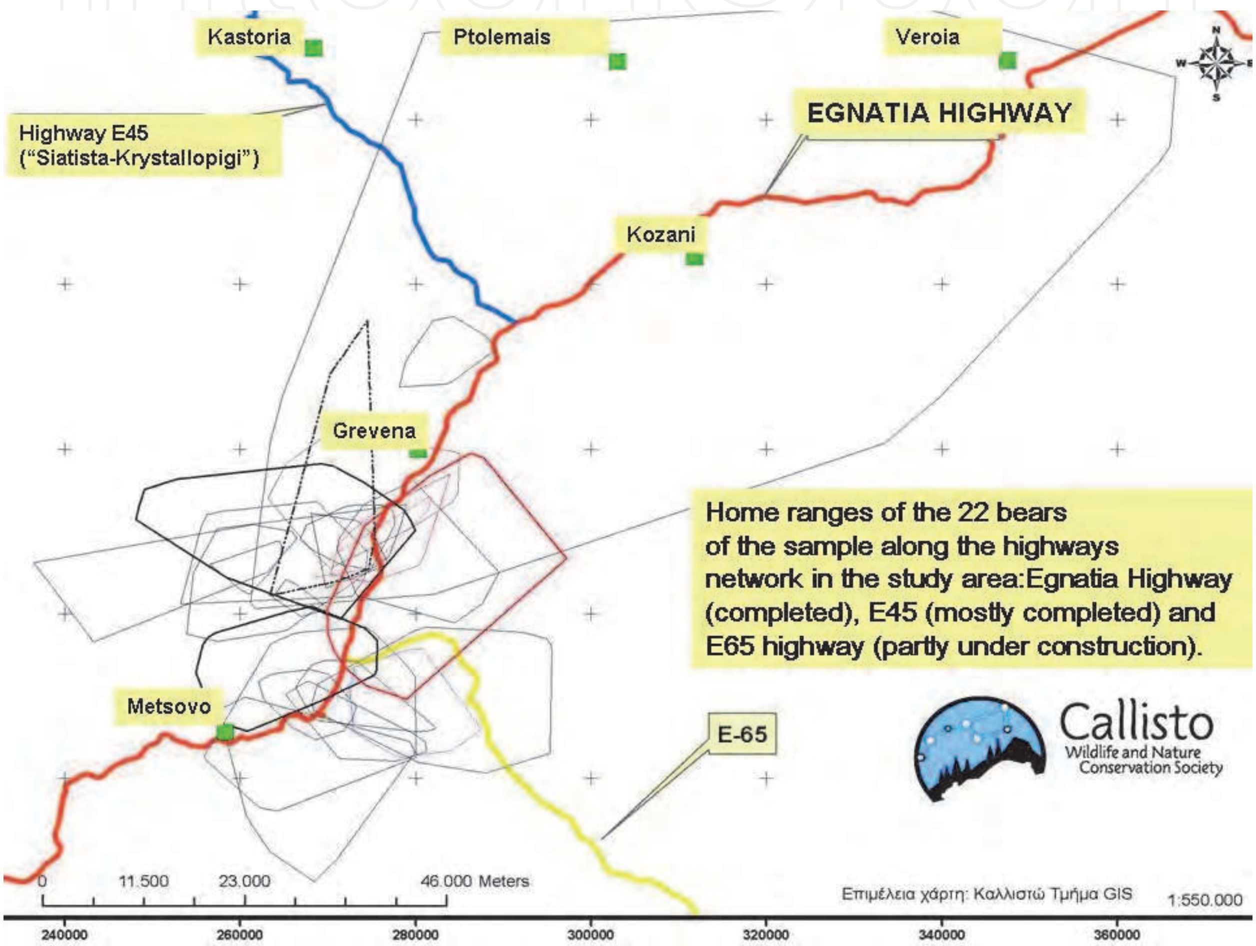
Map 3. Radiolocations of seven (7) different bears from the sample in the study area

4.1 Home range

The annual average MCP100 home range of all bears of the sample was 213,77 ± 35,8 (SE) and ranged from 58,13 – 362,12 Km^2 (Table 1). The mean MCP100 for males (*n*=5) was 271.075 Km^2 ± 26.12 and for females (*n*=3) 118.245 Km^2 ± 48.85. The male annual home-ranges were significantly larger than female using also the other three estimating methods: 95%MCP, Fixed Kernel Method 95% and Core Areas 50% (Mann–Whitney U test: Z=−-2,236, P=0.025).
Home range sizes of males (*n*=5) differ significantly between all seasons (Friedman test, Monte-Carlo simulation for exact P<0.05). Home range sizes of females (*n*=3) did also differ significantly between all seasons only for MCP100 and FKM (Friedman test, Monte-Carlo

simulation for exact P<0.05). Males home range sizes were significantly larger than females with all estimate methods (Kruskal-Wallis test: MCP100: χ^2=11, P=0.012, MCP95: χ^2=10.76, P=0.013, FK95: χ^2=9.6, P=0.022 and CA50: χ^2=9.33, P=0.025).(Giannakopoulos et al.2011). (see also table 1 and 2).

In addition we found that the bears (2 males and 2 females) who kept collars more than one year seemed to maintain the same territories. Moreover the spatial patterns and distribution of home ranges between males and females were delineated in most of the cases by natural barriers and landmarks such as rivers, big streams, county roads and in some cases according with the topographic complexity (Giannakopoulos et al. subm.).



Map 4. Home ranges of 22 bears of the sample versus highways network in the study area

Sex	Age	N	Gps Lo	MCP100	MCP95	FKM	CA50
Males	Adult	5	22083	271±26,1	200±14,5	130±15,1	30±4,2
Females	Adult	3	15502	118±48,8	72±28,2	39±13	7±3,2

Table 1. Annual home range sizes of GPS collared bears (2007-2009) estimated with (MCP100, MCP95, FKM and CA50) in Northeastern Pindos mountains Greece (n=8)

Data from the above table (1) refer only to the bears of the sample (males and females) that have kept their collar for an entire year cycle. A more analytical presentation of data on seasonal home range sizes on the overall sample are presented in table (2).

From map (4) we observe a high level of home range overlap among most bears. Fifty-nine of the 82 possible pairings of bears indicated overlapping areas according to the MCP95 and FK methods. For areas of high intensity of use (CA50) 40.24% pairings of bears indicated overlapping areas (Giannakopoulos et al. subm.).

Bear	Sex	Spring MCP100	Summer MCP100	Autumn MCP100	Winter MCP100
MELIS	MALE	159,641	251,34	178,094	-
AL PATSINO	MALE	34,657	-	-	-
KOYTALAINOS	MALE	153,127	54,46	-	-
TETRADAKTYLOS	MALE	194,729	45,646	-	-
STRATIGOS	MALE	22,054	48,908	-	-
KALLISTO	FEMALE	13,1	-	-	-
KATERINA	FEMALE	7,09*	28,457	54,729	7,459
TOBIAS	MALE	148,126	64,061	119,532	17,46
MONAXH	FEMALE	-	-	26,171	0
ALEKA	FEMALE	1,381*	38,18	204,066	1,744
KAPETANIOS	MALE	190,297	322,4	207,807	22,789
KLEOPATRA	FEMALE	75,004	50,473	30,542	2,035
ARIS	MALE	59,076	39,424	-	-
DIAS	MALE	21,662	46,594	-	-
SOFOKLIS	MALE	196,023	337,71	14,74	-
HLIAS	MALE	170,466	248,97	76,969	7,861
LIGNOS	MALE	195,927	140,053	53,447	28,349
PETHEROS	MALE	174,917	155,129	147,834	54,901
TYXERH	FEMALE	-	54,764	9,197	-
POLIMYLOS	MALE	2.684	731,68	992,101	126,409

Table 2. Seasonal Home ranges (km^2) for Brown bears (n=20) in Northeastern Pindos mountain range in Greece, 2007-2009

4.2 Potential changes in habitat use amplitude and range

Regarding the **potential changes in habitat use amplitude and range (surface units)** in relation to the distance from the highway, the results of our analysis demonstrated that the size of the habitat units (within spring and summer male bears home range) significantly increased with the distance from the highway while their number (of used habitat units) decreased as the distance from highway increased.

The differences between the number of habitat units and their size (surface) used inside the home range in relation to distance from the highway were statistically significant in all cases of males bears in spring and summer (spring: $F=5.419$, $P<0.01$; summer: $F=6.52$, $P<0.01$) and for females in summer ($F=18.735$; $P<0.01$). An example of this differentiation is given on fig.1 in the case of the male bears of the sample.

More specifically in the case of all male individuals of the sample the number of used habitat units (perceived through clustered radiolocations) is significantly higher as their surface size decreases and subsequently their distance from the highway decreases as well (spring: $x^2=96.63$, $P<0.01$; summer: $x^2= 20.204$, $P<0.01$). This means that larger ranges in surface and limited distinct ranges (in clustered radiolocations) were observed as the distance from the highway increases.

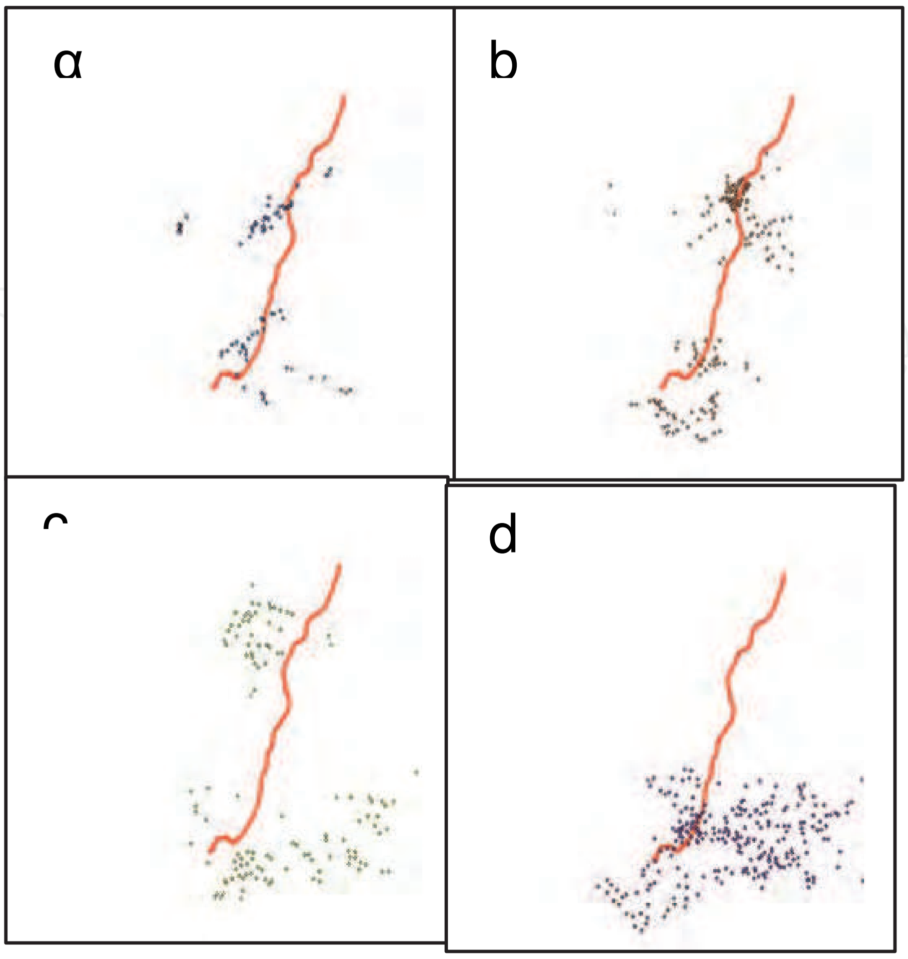


Fig. 1. Distribution of habitat units clusters (from a to d) for male bears in spring. Diagrams from **a** to **d** correspond to different increment units of activity areas (surfaces) within the home range

4.3 Potential differences in movement distance and patterns

Regarding **potential differences in movement distance and patterns:** we found no statistically significant differences in dispersal patterns of bears with respect to the time (hour-daytime/night time) of activity and/or distance from the highway. Analyses showed no statistically significant differences between the maximum and minimum distances travelled by male and female individuals during the day or night (in most of the cases up to P>0.05) in relation to the distance from the highway. Nevertheless significant differences were observed in specific cases when bears movements were studied individually and seasonally but even in these cases there was not enough evidence of a specific pattern regarding spatial behavior of the bears versus the distance of the highway. No significant differences were observed between the average and maximum distances travelled by bears in relation to their distances from the highway under construction. Similarly, we found only limited evidence to support an effect of the highway upon bears movement angles when approaching the highway corridor.

4.4 Habitat suitability

Regarding **habitat suitability** analyses in relation to bear presence and habitat use: *distance from highway* was recognized as one of the statistically significant variables affecting both analyses: the relative *abundance* (GLM) (table 3) and the *bear presence/absence* (LR) (table 4) thus influencing in both scenario cases the selection and the frequency of use of the different sites (habitat units) within the study area and in relation to the presence of the highway under construction. Bears seem to appear more often at distant sites from the highway. For the first analysis: **bear abundance and frequency of habitat pixels use,** of the set of 13 variables selected, seven (7) could be used as reliable prediction tools. Results of this analysis are presented in table (3).

Variables	Wald Chi-Square	P-value	Wald statistic	P-value
Aspect	80,444	0.000	65,844	0.000
Distance from road.	288,652	0.000	1196,691	0.000
Mean altitude within 1.5km radius.	21,683	0.000	15,199	0.000
CV of altitude within 1.5km radius	23,198	0.000	7,810	0.005
CV of mean slope within 1.5km radius	19,902	0.000	16,071	0.000
CV of mean slope within 7.5km radius	104,065	0.000	181,321	0.000
Diversity of vegetation types within 1.5km radius	8,961	0.003	60,570	0.000

Table 3. General Linear Models parameters as predictors of bear abundance in relation to the presence of the highway

For P values < 0.01, the related variables are considered to effectively contribute in the prediction model. We notice that vegetation types, altitude and aspect are recognized as important variables for the prediction of areas (habitat units) with more abundant/frequent bear presence and use. We also notice that the slope variance in neighbouring pixels also plays a role in the spatial distribution of the signs of presence. As stated above distance from the highway is the key variable with high statistical value in the model thus influencing site selection by bears. The negative value of the related coefficient indicates that the number of the most frequent bear occurrences in specific sites increases as the distance from the highway decreases.

Our analysis showed that there are no specific habitat parameters close to the highway corridor that hinder bears movements. Bears utilize the same habitat types within the overall landscape but move in a much more "conservative" pattern (in terms of duration and habitat surface used) when found in proximity of the highway corridor.

The second analysis regarding **presence/ absence** data (by means of LR & CART- *predictive accuracy of models which was high*) demonstrated a series of topographical and vegetation characteristics (habitat features) as important predictors for bear presence or absence. Here again **distance from highway** was recognized, as mentioned above, as one of the critical factors affecting the presence of an animal in a given point (pixel) of its home range. According to table (4) we may notice that a group of variables remains effective in the model for the prediction of bear presence in pixels with specific characteristics. We once again notice the importance of "altitude" and "slope" and their range of variations as prediction indicators. It comes out that the combination of landscape ruggedness with the characteristics of certain vegetation types and the distance from the highway influence selection or avoidance by bears of a given pixel (habitat unit).

Variable	Coefficient	Wald	Level of importance
Average altitude within 5 pixels radius.	-0,004	15,199	0,000
Altitude coefficient variation within 5 pixels radius.	0,067	7,810	0,005
Average slope within 5 pixels radius.	0,039	58,315	0,000
Average slope coefficient variation within 5 pixels radius.	-0,003	16,071	0,000
Average slope coefficient variation within 15 pixels radius.	-0,015	181,321	0,000
Vegetation types variability	-0,098	0,641	0,423
Vegetation Type		23,492	0,001
Type (1)	-1,207	7,244	0,007
Type (2)	-1,112	11,511	0,001
Type (3)	-1,102	11,466	0,001
Type (4)	-1,117	8,990	0,003
Type (5)	-1,186	13,805	0,000
Type (6)	-,957	5,891	0,015
Type (7)	-,585	2,712	0,100
Distance from highway	-0,000114	1196,691	0,000
Aspect		65,844	0,000
Slope	-0,007	10,344	0,001
Number of different vegetation types within a 5 pixel radius	-0,477	60,570	0,000
(%) of contribution of dominant vegetation type within a 5 pixels radius	-0,005	0,682	0,409
(%) of contribution of the 2nd rank vegetation type within a 5 pixels radius	0,001	0,611	0,435
(%) of contribution of the 3rd rank vegetation type within a 5 pixels radius	0,003	1,978	0,160

Table 4. Results from the LR analysis for the prediction model on bear presence/absence.

The negative sign of variable "distance from highway" indicates that presence or absence of bears decreases as distance from the highway increases. In a recent study by Roever et al. (2008) it was found that grizzlies showed a relatively high frequency of occurrence in areas nearby forest roads despite the relatively high mortality probability rate in these areas (also McLellan, 1998, Benn and Herrero, 2002, Johnson κ.α., 2004 και Nielsen κ.α., 2004). But this phenomenon might also be related to other parameters such as:

α) the type of data used in the analysis
β) a possible adaptive "shift" in bears behavior.

In our case we may have two possible explanations:

1. the topography of our study area allows bears to approach and use sectors in the immediate vicinity of the highway under construction in order to move towards other important sectors such as denning areas, high food availability areas etc. We have to bear in mind that this is a fraction of the whole picture, as at a wider scale (including our study areas) there might be bears avoiding completely the highway sector or moving at longer distances.
2. More frequent bear occurrence and use of pixels in the vicinity of the highway maybe related to the fact that bears do valorize small surface habitat units due to the fact that they still remain attractive. It is also likely that bears are waiting for the appropriate moment to cross the highway and therefore are attempting to locate more appropriate crossing points.(Mace κ.α., 1996). The highway as an artificial barrier is a stress factor and is likely to induce a certain modification in bears spatial behavior exposing a limitation of movements combined to an opportunistic mobility related to the most favorable low disturbance conditions.

The **CRT analysis** showed also that the variable "distance from highway" was used to separate two central "branches" of the classification tree in the early analysis stages. Two differentiated branches are defined according to a limit value of 4.996 m of distance from the highway. When this distance is <4.996 m then a combination of topographic characteristics in relation to high slope values and medium altitude values are characterizing the pixels used by bears.

In the second case d > 4.996 m, vegetation types but also certain combinations of topographic characteristics define the habitat use patterns in each pixel. It also came out from this analysis that pixels at a distance > 8.434m have lower use frequencies by the sampled bears.

5. Conclusions-discussion

A general conclusion would be that the presence of the highway under construction and the distance from it in relation to bear presence, abundance and activity is an interrelated and dynamic system in which telemetry is the most appropriate technique to approach and understand it.

The following behavioral patterns in relation to bear activity, movements and habitat use have been identified:

- High in number and small surfaced clusters of bear activity and movements appear when the animals are located at close distance from the highway, whereas less clusters in number and on larger surfaces appear when the animals are located at a longer distance from the highway.
- This differentiation which in the first case appears fragmented in time and space and in the second case continuous and more expanded maybe related to the disturbance factor of the highway under construction upon bears activity and spatial behavior or in a more pronounced habitat fragmentation problem close to the highway due to its degradation because of the construction woks.
- For male individuals which yielded a larger data set, we have observed that the number of activity and habitat use clusters increases with the fragmentation degree of the larger zones of used habitat. Therefore we may conclude that it is not some different habitat features that hinder bear habitat use when close to the highway but more the fact of a quantitative and qualitative reduction and fragmentation of the habitat units in most probably relation to highway construction.

- Distance from the highway does not seem to influence independently bear habitat selection activity and abundance (presence/absence), but co-acts in synergy with other habitat characteristics.
- Findings from all three models agree on the importance of the "distance from the highway" as a critical variable for the prediction of bears spatial behavior in relation to the highway. Therefore the new highway represents a critical parameter that significantly affects distribution, habitat use, movement selection and frequency of occurrences of brown bears.
- The frequent presence of brown bears within the vicinity of the road network highlights the need for direct and effective protection measures in the area. (i.e adequate and appropriate fencing).

Considering previous results we suggest that animal (bear) activity is not reduced but rather qualitatively affected by the existence of the highway.
Overall we suggest that the new highway functions as a critical landscape parameter (barrier) that seems to significantly affect distribution, habitat use, movement patterns and frequency of occurrences of brown bears.
The results of our study will essentially contribute in further adjustment of mitigation measures along the highway as well as in close monitoring of their efficiency during highway operation in the critical areas.

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7. References

Austin, M. P. 2002. Spatial Prediction of Species Distribution: an Interface Between Ecological Theory and Statistical Modelling. Ecological Modelling 157:101-118.

Benn, B., Herrero, S., 2002. Grizzly bear mortality and human access in Banff and Yoho National Parks, 1971–1989. Ursus 13, 213–221.

Bergman, C. M., J. A. Schaefer, and S. N. Luttich. 2000. Caribou Movement as a Correlated Random Walk. Oecologia 123:364-374.

Bontadina, F., H. Schofield, and B. Naef-Daenzer. 2002. Radio-Tracking Reveals That Lesser Horseshoe Bats (Rhinolophus Hipposideros) Forage in Woodland. Journal of Zoology 258:281-290.

Debeljak, M., S. Dzeroski, K. Jerina, A. Kobler, and M. Adamic. 2001. Habitat Suitability Modelling for Red Deer (Cervus Elaphus L.) In South-Central Slovenia With Classification Trees. Ecological Modelling 138:321-330.

Dettki, H., R. Lφfstrand, and L. Edenius. Modeling habitat suitability for moose in coastal northern Sweden: empirical vs. process-oriented approaches. AMBIO 32[8], 549-556. 2003.

Death, G. and Fabricius. K. E., 2000. Classification and Regression Trees: a Powerful Yet Simple Technique for Ecological Data Analysis. Ecology 81:3178-3192.

Franco, A. M. A., J. C. Brito, and J. Almeida. 2000. Modelling Habitat Selection of Common Cranes Grus Grus Wintering in Portugal Using Multiple Logistic Regression. Ibis 142:351-358.

Giannakopoulos Al., Akriotis T., Mertzanis Y.(2011) : Spatio-temporal interactions in relation to social behaviour of Brown bears in Greece (submitted.)

Glenz, C., A. Massolo, D. Kuonen, and R. Schlaepfer. 2001. A Wolf Habitat Suitability Prediction Study in Valais (Switzerland). Landscape and Urban Planning 55:55-65.

Gros, P. M. and M. Rejmanek. 1999. Status and Habitat Preferences of Uganda Cheetahs: an Attempt to Predict Carnivore Occurrence Based on Vegetation Structure. Biodiversity and Conservation 8:1561-1583.

Guisan, A., J. P. Theurillat, and F. Kienast. 1998. Predicting the Potential Distribution of Plant Species in an Alpine Environment. Journal of Vegetation Science 9:65-74.

Guisan, A. and N. E. Zimmermann. 2000. Predictive Habitat Distribution Models in Ecology. Ecological Modelling 135:147-186.

Hastie, L. C., S. L. Cooksley, F. Scougall, M. R. Young, P. J. Boon, and M. J. Gaywood.2003. Characterization of Freshwater Pearl Mussel (Margaritifera Margaritifera) Riverine Habitat Using River Habitat Survey Data. Aquatic Conservation-Marine and Freshwater Ecosystems 13:213-224.

Heithaus, M. R., L. M. Dill, G. J. Marshall, and B. Buhleier. 2002. Habitat Use andForaging Behavior of Tiger Sharks (Galeocerdo Cavier) in a Seagrass Ecosystem. Marine Biology 140:237-248.

Hirzel, A. H. and R. Arlettaz. 2003. Modeling Habitat Suitability for Complex Species Distributions by Environmental-Distance Geometric Mean. Environmental Management 32:614-623.

Hirzel, A. H., J. Hausser, D. Chessel, and N. Perrin. 2002. Ecological-Niche Factor Analysis: How to Compute Habitat- Suitability Maps Without Absence Data? Ecology 83:2027-2036.

Hirzel, A. H., V. Helfer, and F. Metral. 2001. Assessing Habitat-Suitability Models With a Virtual Species. Ecological Modelling 145:111-121.

Huettmann, F. and J. Linke. 2003. An Automated Method to Derive Habitat Preferences of Wildlife in Gis and Telemetry Studies: a Flexible Software Tool and Examples of Its Application. Zeitschrift Fur Jagdwissenschaft 49:219-232.

Jerina, K., M. Debeljak, S. Dzeroski, A. Kobler, and M. Adamic. 2003. Modeling the Brown Bear Population in Slovenia - a Tool in the Conservation Management of a Threatened Species. Ecological Modelling 170:453-469.

Johnson, C. J., K. L. Parker, D. C. Heard, and M. P. Gillingham. 2002. Movement Parameters of Ungulates and Scale-Specific Responses to the Environment. Journal of Animal Ecology 71:225-235.

Johnson, C.J., Boyce, M.S., Schwartz, C.C., Haroldson, M.A., 2004. Modeling survival: application of the multiplicative hazards model to Yellowstone grizzly bear. J. Wildl. Manage. 68, 966–978.

Jones, P. F., R. J. Hudson, and D. R. Farr. 2002. Evaluation of a Winter Habitat Suitability Index Model for Elk in West-Central Alberta. Forest Science 48:417-425.

Kobler, A. and M. Adamic. 2000. Identifying Brown Bear Habitat by a Combined Gisand Machine Learning Method. Ecological Modelling 135:291-300.

Le Pape, O., F. Chauvet, S. Mahevas, P. Lazure, D. Guerault, and Y. Desaunay. 2003. Quantitative Description of Habitat Suitability for the Juvenile Common Sole (Solea Solea, L.) In the Bay of Biscay (France) and the Contribution of Different Habitats to the Adult Population. Journal of Sea Research 50:139-149.

Mace, R.D. Waller, J.S. Manley, T.L. Lyon L.J. and Zuuring, H. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana, Journal of Applied Ecology 33, 1395–1404.

McLellan, B.N., 1998. Maintaining viability of brown bears along the southern fringe of their distribution. Ursus 10, 607–611.

Manderson, J. P., B. A. Phelan, C. Meise, L. L. Stehlik, A. J. Bejda, J. Pessutti, L. Arlen, A. Draxler, and A. W. Stoner. 2002. Spatial Dynamics of Habitat Suitability for the Growth of Newly Settled Winter Flounder Pseudopleuronectes Americanus in an Estuarine Nursery. Marine Ecology-Progress Series 228:227-239.

Massolo, A. and A. Meriggi. 1998. Factors Affecting Habitat Occupancy by Wolves in Northern Apennines (Northern Italy): a Model of Habitat Suitability.Ecography 21:97-107.

Matthiopoulos, J. 2003. Model-Supervised Kernel Smoothing for the Estimation of Spatial Usage. Oikos 102:367-377.

Mazaris, D. A., Matsinos, G. Y., Margaritoulis, D., 2006. Analyzing the profiles of nest site selection of loggerhead sea turtles. A case study of the island of Zakynthos, W-Greece. Journal of Experimental Marine Biology and Ecology 336, 157 – 162

Mauritzen, M., A. E. Derocher, O. Wiig, S. E. Belikov, A. N. Boltunov, E. Hansen, and G. W. Garner. 2002. Using Satellite Telemetry to Define Spatial Population Structure in Polar Bears in the Norwegian and Western Russian Arctic. Journal of Applied Ecology 39:79-90.

Mcgrath, M. T., S. Destefano, R. A. Riggs, L. L. Irwin, and G. J. Roloff. 2003. Spatially Explicit Influences on Northern Goshawk Nesting Habitat in the Interior Pacific Northwest. Wildlife Monographs1-63.

McLoughlin, P. D., H. D. Cluff, R. J. Gau, R. Mulders, R. L. Case, and F. Messier. 2002. Population Delineation of Barren-Ground Grizzly Bears in the Central Canadian Arctic. Wildlife Society Bulletin 30:728-737.

Miller, J. and J. Franklin. 2002. Modeling the Distribution of Four Vegetation Alliances Using Generalized Linear Models and Classification Trees With Spatial Dependence. Ecological Modelling 157:227-247.

Mladenoff, D. J., T. A. Sickley, and A. P. Wydeven. 1999. Predicting Grey Wolf Landscape Recolonization: Logistic Regression Models Vs. New Field Data. Ecological Applications 9:37-44.

Naves, J., Wiegand, T., Revilla, E., and Delibes. M., 2003., Endangered species balancing between natural and human constrains: the case of brown bears (Ursus arctos) in northern Spain Conservation Biology 17:1276-1289.

Nielsen, E.S., Boyce M.S. and Stenhouse, G.B., 2006. A habitat-based framework for grizzly bear conservation in Alberta. Biological Conservation, 130, 217-229

Nielsen, S.E., 2005. Habitat ecology, conservation, and projected population viability of grizzly bears (Ursus arctos L.) in west-central Alberta, Canada. Ph.D. Thesis. Department of Biological Sciences, University of Alberta, Edmonton, Alberta.

Patthey, P. 2003. Habitat and corridor selection of an expanding red deer (Cervus elaphus) population.

Peeters Ethm and J. J. P. Gardeniers. 1998. Logistic Regression as a Tool for Defining Habitat Requirements of Two Common Gammarids. Freshwater Biology 39:605-615.

Quinn, G.P., Keough, M.J., 2002. Experimental Design and Data Analysis for Biologists. Cambridge University Press, Cambridge;

Riegler S., Riegler Ar., Mertzanis Y., Giannakopoulos Al., Tragos Ath: Recovery times s in brown bears in greece using zolazepam-tiletamine/medetomidine/ketamine and Atipamezole, Ursus (in prep.).

Roever, C.L., Boyce, M.S., Stenhouse, G.B. 2008. Grizzly bears and forestry II: Grizzly bear habitat selection and conflicts with road placement. Forest Ecology and Management 256, 1262–1269.

Robertson, M. P., C. I. Peter, M. H. Villet, and B. S. Ripley. 2003. Comparing Models for Predicting Species' Potential Distributions: a Case Study Using Correlative and Mechanistic Predictive Modelling Techniques. Ecological Modelling 164:153-167.

Rondinini, C. and C. P. Doncaster. 2002. Roads as Barriers to Movement for Hedgehogs. Functional Ecology 16:504-509.

Schadt, S., E. Revilla, T. Wiegand, F. Knauer, P. Kaczensky, U. Breitenmoser, L.Bufka, J. Cerveny, P. Koubek, T. Huber, C. Stanisa, and L. Trepl. 2002.Assessing the Suitability of Central European Landscapes for the Reintroduction of Eurasian Lynx. Journal of Applied Ecology 39:189-203.

Schmitt, F. G. and L. Seuront. 2001. Multifractal Random Walk in Copepod Behavior. Physica a-Statistical Mechanics and Its Applications 301:375-396.

Seoane, J., J. Vinuela, R. Diaz-Delgado, and J. Bustamante. 2003. The Effects of Land Use and Climate on Red Kite Distribution in the Iberian Peninsula. Biological Conservation 111:401-414.

Stoner, A. W. and R. H. Titgen. 2003. Biological Structures and Bottom Type Influence Habitat Choices Made by Alaska Flatfishes. Journal of Experimental Marine Biology and Ecology 292:43-59.

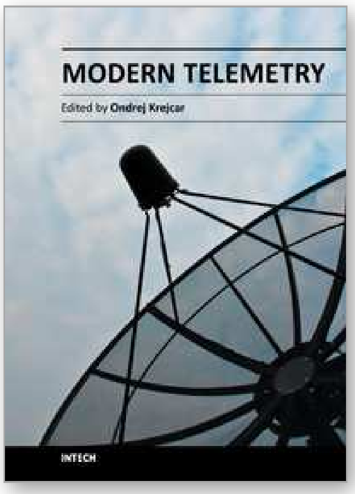
Thuiller, W., Araujo, M. B. and Lavorel. S., 2003. Generalized Models Vs. Classification Tree Analysis: Predicting Spatial Distributions of Plant Species at Different Scales. Journal of Vegetation Science 14:669-680.

Vayssieres, M. P., Plant, R. E. and Allen-Diaz, B. H. 2000. Classification Trees: an Alternative Non-Parametric Approach for Predicting Species Distributions. Journal of Vegetation Science 11:679-694.

Wiegand, T., Knauer, F., Kaczensky, P., and Naves, J., 2004. Expansion of brown bears (Ursus arctos) into the eastern Alps: a spatially explicit population model. Biodiversity and Conservation 13:79-114. 2004.

Yee, T. W. and N. D. Mitchell. 1991. Generalized Additive-Models in Plant Ecology. Journal of Vegetation Science 2:587-602.

Zaniewski, A. E., A. Lehmann, and J. M. C. Overton. 2002. Predicting Species Spatial Distributions Using Presence-Only Data: a Case Study of Native New Zealand Ferns. Ecological Modelling 157:261-280.



Modern Telemetry

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Telemetry is based on knowledge of various disciplines like Electronics, Measurement, Control and Communication along with their combination. This fact leads to a need of studying and understanding of these principles before the usage of Telemetry on selected problem solving. Spending time is however many times returned in form of obtained data or knowledge which telemetry system can provide. Usage of telemetry can be found in many areas from military through biomedical to real medical applications. Modern way to create a wireless sensors remotely connected to central system with artificial intelligence provide many new, sometimes unusual ways to get a knowledge about remote objects behaviour. This book is intended to present some new up to date accesses to telemetry problems solving by use of new sensors conceptions, new wireless transfer or communication techniques, data collection or processing techniques as well as several real use case scenarios describing model examples. Most of book chapters deals with many real cases of telemetry issues which can be used as a cookbooks for your own telemetry related problems.

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