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Application of GIS Model for Assessment of the Habitat Quality and Prediction of the Potential Distribution of Carnivorous Species in Local Scale - Lynx (*Lynx lynx* L.) in the Strandzha Mountain as an Example

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Abstract: The carnivores, being elusive species because of their secretive life and large home ranges are very difficult to study. The quality of habitat and the food base have proved to be of greatest importance for their presence and their area of occupancy. The assessment of the available suitable habitats and the prediction of current and potential distribution of these species are vital for their conservation, having in mind the existing conflict with humans. This paper deals with the application of deductive GIS-based model to assess the habitat quality in the Strandzha Mountain for a little known in Bulgaria species as is the lynx. The outcome of a model, based on several overlaid environmental variables are 5 suitability classes, of which class 2 and 3 (high and medium suitability) are covering the highest percentage of the area (34.7% and 34.3% respectively). Altogether the two highest suitability classes - class1 (18.1%) and class 2 form 52.8 % of the whole study area of 1852.7 km^2 which gives a potential good quality habitat for about 20-28 lynxes. This approach for assessing the habitat suitability could be applied for other species with scares knowledge of distribution.

Key words: model, GIS, Strandzha, lynx

Introduction

Quality of the habitat and the food base has proved to be of greatest importance for the animal's presence and their area of occupancy. The assessment of the available suitable habitats and thus – the prediction of current and potential distribution of these species are vital for their conservation, having in mind the existing conflict with humans. One of the most important aspects to understand the distribution of the species and the related habitat quality is the knowledge about the spatial requirements of the animals. Unlike to the plant species, animals have the ability to move actively through space which puts a serious problem to define their real area of occupancy (their actual distribution) within their extent of occurrence (the potential or general distribution) (Salvatori 2004).

The analysis of the spatial aspects in the ecosystems provides possibilities to take in account processes, variables or temporal conditions, which influence the dynamics of the species and their distribution in space and time. This could be done through creation of predictive models which could enhance conservation and management efforts. The modern spatial modelling methods use more precise location

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data gathered by GPS devices and analyzed in GIS computer programs for assessment of the populations sizes and dynamics, distribution and diversity of species, habitat quality assessment, potential and actual human impact and other.

The carnivores, especially the large one, being elusive species, because of their secretive life, high mobility and large, sometimes overlapping home ranges are very difficult to study, therefore their research and conservation could strongly benefit from the modelling processes.

Study area

Strandzha Mountain is situated in the south-eastern part of Bulgaria, between Burgas lowland, the Black Sea and the eastern part of the Thracian Plain. The bigger part of the mountain is situated in Turkey. The total area of Strandzha in Bulgaria is around 10 000 км^2. There are three well defined ridges with highest peak - Papia (502 m).

The forests cover about 70 % of the mountain (Fig.1) and consist of *Quercus polycarpa* (SCHUR.), *Quercus frainetto* (TEN.), *Fagus orientalis* (LIP.), *Quercus cerris* (L.) with shrubs of *Rhododendron ponticum* (L.) and other. The native flora includes many relict and endemic plant species. The vertebrate fauna is one of the richest in Bulgaria with well preserved populations, mainly due to the very low inhabited with people area - barely 10 people/km^2, which is the lowest in the country.

There is one big protected area - „Strandzha Nature Park“ covering 1155.1 km^2 including several strict reserves. Currently the future of the park is uncertain due to increasing interests towards its coastal zones for building tourist complexes.

Our study area was covering 1852.7 km2 on the territory of five State forestries and two game breeding stations.

Materials

As a test object for the modeling approach we chose the lynx (*Lynx lynx* L.1758). This species has the following characteristics – active mainly at dusk and during the night; solitary, with exception for the female with kittens, secretive way of life especially because of the nocturnal activity and silent behaviour (makes meowing sounds only during the breeding season). Lynx prey in Europe mainly consists of small ungulates - roe deer (*Capreolus capreolus* L.), chamois (*Rupicapra rupicapra, L.*), less – bigger ungulates (red deer *Cervus elaphus*, L., fallow deer *Dama dama* L., etc), hare *Lepus europeus* (PALL.), birds - hazel-hen *Bonasa bonasia (*L.), carpecaille *Tetrao urogalus* (L.), rock partridge *Alectoris sp.* (KAUP.), pheasants (*Phasianus colchicus,*(L.) and different rodents (BREITENMOSER *et al.2000).*

Lynx in Bulgaria thought to be extinct in the middle of 20th century (the last official record comes from Rila Mountain in 1941). Currently it is recolonazing back to the country from the Carpathian population through Serbia. Some evidences suggest that part of the autochthonous population may have survived in the forests of Strandzha Mountain (both in Bulgaria and Turkey) due to the so called “border effect” – strict regulation of peoples free movement, large uninhabited areas because of the strict military regime (the Turkish –Bulgarian border was the most strictly guarded of all), and because of all this - well preserved old forests with good prey base and lack of disturbance. The last official records for lynx presence in Bulgaria and in Strandzha Mountain in particular are given by ATANASOV (1968)

Aims of the study

- To create a model for the habitat suitability in Strandzha mountain for possible lynx presence with visualization through digital maps.
- To validate the model with field data
- To create suitable algorithm, which could be used with other species with indistinct presence or distribution (lack of presence/absence data) but have important conservation status to consider.

Methods

As the chosen model species has unclear distribution status in the country with lack of presence/absence data, most of the modelling methods are not applicable here.

For this case, we chose a deductive approach with theoretically formulated variables, chosen on the basis of expert opinion and approximation of data coming from the neighbouring countries. This method is similar to the analyses used for Habitat Suitability Index (HSI), where the chosen ecological variables are the ones determining and limiting the presence of the species. These variables are analyzed altogether through weighted overlay and the outcome is validated through field or other independent set of data. All variables are initially preprocessed and later analyzed with GIS software (ARC GIS Desktop, ver 9, ESRI)

The model was validated through an independent data coming from 4 days combined field work, both for gathering field data (searching for tracks and signs and rough evaluation of the habitat quality) and from questioning local people. The main target groups were border policemen, shepherds, foresters and hunters. We conducted 19 interviews (with totally 26 people) – 4 border policemen, 4 shepherds, 4 hunters, 4 foresters and 3 man cutting wood in the forest. Men were preferred for the interviews as women asked in the areas declared that they are rarely interested in the forest and animals. The questionnaires were conducted in standard form. First, we were showing the locals drawings and photographs of mammals including lynx asking if they had seen some of these animals. If they give a positive answer for the lynx, we were asking further questions about when, where (location) and in what habitat it was seen, and any other information they can provide.

With the questionnaires we were able to cover only half of the whole study area – further study is needed to complete the validation.

Variables used

- Corine land cover, 2000 (EEA,1995) supplemented with additional layer with road network from a Bulgarian database;
- Digital Elevation Model (DEM) with scale 100x100 pixels;
- Numbers of red deer, fallow deer, roe deer, wild boar, hare and pheasants are taken from the spring census in2005, 2006 and 2007 in the follow forestry units: State forestry (SF) Novo Panichevo, SF Zvezdets, SF Tsarevo, SF Kosti, SF Malko Tarnovo, Game Breeding Station (GBS) Ropotamo and GBS Gramatikovo, provided by the National Forestry Board. This data was used as index for presence and diversity of the prey base and density of Cervidae as the most important as food source for the lynx (Herfindal et al 2005; Okarma et al. 1997).

Preprocessing of the initial variables

- Corine land cover for the whole country was reclassified from 37 into 7 classes: Forest (broad leaved coniferous and mixed forests), Grass and shrubs (pastures, natural grassland, moors and heathland, sparsely vegetated areas, burnt areas, transitional woodland/ shrub), Agriculture zones (non-irrigated arable lands, permanently irrigated land, rice fields, vineyards, fruit trees and berry plantations, complex cultivation patterns, land principally occupied by agriculture with significant areas of natural vegetation), water (inland marshes, peatbogs, salt-marshes, salines, water courses, water bodies), urban zones (continious urban fabric, discontinuous urban fabric, industrial or commercial units, port areas, airports, mineral extraction sites, dump sites, construction sites, green urban areas, sport and leisure facilities), roads (road and rail networks and associated land) and bare areas (beaches, dunes, sands and bare rock).

After reclassification Corine land cover was converted into raster with scale 100x100 pixels.

- As the road network is underrepresented and virtually missing in Corine Land Cover, 2000 we had included in the model additional more detailed layer of roads to stand for the road factor. The layer was converted into raster.
- All three layers – the reclassified raster land cover, the road layer and the DEM where clipped to the boundaries of the study area delineated by the outer boundaries of the forestry and game breeding stations.
- The mean for each species of prey base for the 3 years was derived from the numbers for red deer, fallow deer, roe deer, wild boars, hares and pheasants (Table 1). From it the density per forestry or game breeding station was calculated. This data

Table 1. Mean value for each prey base species (red deer, fallow deer, roe deer, wild boar, hare and pheasant) for 2005-2007.

Species	Red deer	Roe deer	Fallow deer	Wild boar	Hare	Pheasant
SF Novo Panichevo	9	20	-	22	4	-
SF Zvezdets	12	166	-	136	149	-
SF Tsarevo	109	347	-	273	307	18
SF Kosti	21	70	-	62	26	-
SF Malko Tarnovo	28	435	-	320	488	18
GBS Ropotamo	448	81	319	356	137	32
GBS Gramatikovo	234	334	23	589	66	67
Total:	861	1453	342	1759	1175	135

serves as a base for creation of prey base index (PBI) as follows (Table 2):

$PBI = SIv_1 . SIv_2$

where SIv_1 is the prey base diversity index, and SIv_2 is the density of *Cervidae* index.

The diversity of prey base index is calculated in the following order: if one prey base species is present in the area – the index is 0.5 (V_1=1, then SIv_1=0.5); if 2 or more are present – the index is 1 (V_1>1, then SIv_1=1). This index is covering the presence of alternative prey. For the whole study area the index is 1.

Density of *Cervidae* index is formulated as:

$$SIv_2 = V_1 = \frac{(\text{Density roe deer})^2 + (\text{Density red deer}) + (\text{Density fallow deer})}{4}$$

We took the density of roe deer as square to take into account the fact that in given a choice, the lynx in Europe would prefer the roe dear as it was stated by the many authors (Breitenmoser et al. 2000; Herfindal et al. 2005; Okarma *et al.* 1997) and proven by telemetric study.

All final indices are applied as a layer in GIS.

Application in GIS

The preprocessed GIS layers (Corine land cover, DEM, and prey base) were analyzed altogether with Weighted overlay function. The land cover, DEM and prey base layer were reclassified during overlay in the following way:

Land cover: class 1 (most suitable) – forests; class 2 – grassland and shrubs; class 3 agricultural area, class 4 water, class 5 – bare areas, class 6 (least suitable) – urban areas

DEM: class 1 – above 500 m., class 2 - below 500 m. According to Atanasov (1968) the lynx in Bulgaria prefers altitude between 500 and 1500 m.

Prey base: class 1 – PBI > 3; class 2 – PBI=2.5-3; class 3 - PBI= 2-2.5, class 4 PBI= 1.5-2; class 5 – 0-1.5. Prey base as most important factor for the lynx distribution was given weight 60 %, land cover – weight 30 % and elevation – weight 10%.

The resulted raster is additionally applied with Roads with Math Minus function to simulate the road effect.

The outcome was then processed with nearest neighbourhood function, mean, circle, size of 18

Table 2. Variables and Indices describing the prey base, applied as a layer.

Variables and Indices	V1	SIv1	V2	SIv_2	PBI
SF Novo Panichevo	> 1	1	3,69	3,69	3,69
SF Zvezdets	> 1	1	1,25	1,25	1,25
SF Tsarevo	> 1	1	1,09	1,09	1,09
SF Kosti	> 1	1	1,59	1,59	1,59
SF Malko Tarnovo	> 1	1	1,17	1,17	1,17
GBS Ropotamo	> 1	1	2,76	2,76	2,76
GBS Gramatikovo	> 1	1	2,15	2,15	2,15
Mean:	> 1	**1**	**1,96**	**1,96**	**1,96**

pixels to simulate the species perception of space.

The concept "species perception of space"

All territorial animals, including lynx generally patrol and actively defend their territories from intruders. For doing this they need to know very well every detail of the area they live in, thus they have "perception of space", in which they live (in the frame of their home range) (Powell 2000).

This spatial behaviour is taken into account when we modelled the suitability of the lynx habitat. By introduction of the mean home range as a correction coefficient, we introduce the animal perception as a scale for mapping. The concept of the species' perception of space was considered important for mapping environmental suitability, because it gave the opportunity to scale the suitability score to point locations resulting to be suitable that were spatially close to unsuitable areas, thus producing a result that was closer to the reality and providing a complete view of the environment, without risking considering spot locations regardless of what surrounded them. (Corsi *et al.* 2002; Salvatori 2004).

Taking into account the species' perception of the space, a circular window of a size equal to the size of the home ranges of the target species was used for smoothing the pixel values of the raster images of the model outcome. In our model the results raster was processed with nearest neighbourhood function, mean, circle, size of 18 pixels corresponding to the size of average home range (93,6 кm^2) interpolated for Bulgaria conditions according to Salvatori, 2004, to acquire the ecological signature by stimulating the species perception of space. The resulted map is reclassified by 1 SD.

Results and Discussion

The final results are shown on Fig. 1 and in Table 3. Suitability class 2 has the biggest percentage of the whole territory – 34.7 % (643.1 km^2). The second largest is class 3 with 34.3 % (635.4 km^2). Third is class 1 with 18.1 % (335.9 km^2). Altogether the highest suitability classes 1 and 2 form 52.8 % (979 km^2). The suitable areas are highly related with the presence of the game breeding stations which artificially keep very high densities of ungulates.

Class 1 consist of 1 large patch and 5 smaller, surrounded and interconnected with class 2 areas which provides a continuous massif of good habitat for the lynx, in north-south direction. Thus the good habitat provided a good connection with Turkey assuring the connectivity for dispersal of individuals from Turkey to Bulgaria and back. Class 2, apart from the patch surrounding class 1, consist of several smaller patches interconnected with class 3 (below optimal habitat), which nevertheless that does not provide good quality for living, still could serve as a corridor for crossing between the patches.

The share of the Strandzha Nature Park in the suitability classes for the lynx is as follows: class 3

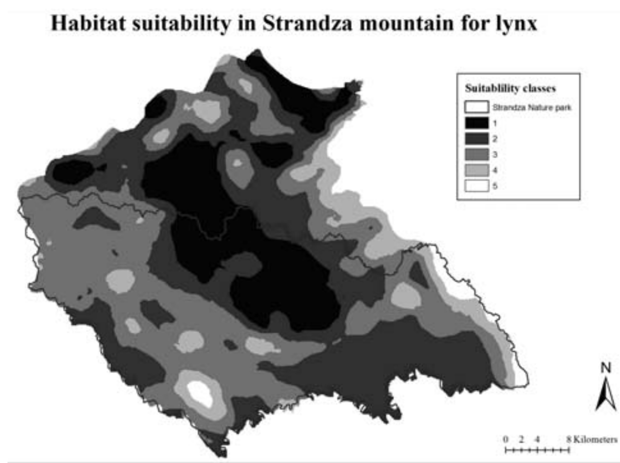

Fig. 1. Map of habitat suitability for lynx in Strandzha Mountain.

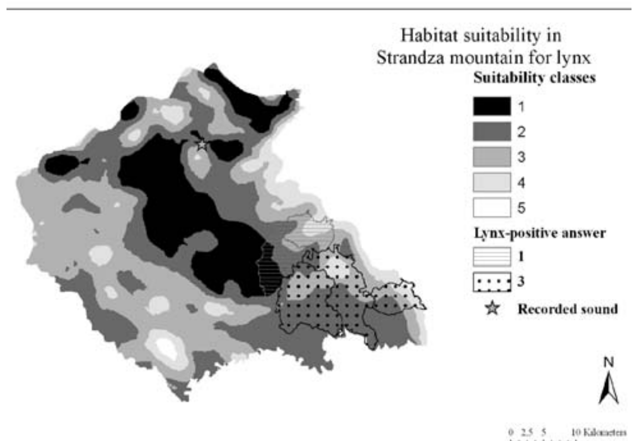

Fig. 2. Map of habitat suitability for lynx in Strandzha Mountain with validation from the questionnaires and other.

Table 3. Suitability classes for the study area and Strandzha Nature Park (area and percentage).

Suitability classes	Study area		Strandzha Nature park	
	Area, км^2.	**%**	**Area, км^2.**	**%**
1	335,9	18,1	169,6	14,7
2	643,1	34,7	405,4	35,1
3	635,4	34,3	465,6	40,3
4	168,4	9,1	88,8	7,7
5	69,9	3,8	25,7	2,2
Total:	1852,7	100,0	1155,1	100

has the biggest share (40.3 %, 465.6 km^2), followed by class 2 (35.1 %, 405.4 km^2). Altogether the highest suitability classes 1 and 2 form 49.6 % (575.1 km^2) of its whole territory and in southern part provides valuable areas for connectivity with Turkish areas.

Validation of the Model

From the 20 questionnaires we got 11 positive answers, 3 per each of the following municipality units: Kosti, Brodilovo and Sinemorets and 1 per Bulgari and Izgrev (Fig. 2). One of the local people from Sinemorets not only confirmed that he had seen the species but also knew its name and habits. He confirmed that he had seen lynx several times, making an assumption that probably its den is close to the village. The most of the positive answers – 3, where given by border policemen, saying that they had seen a lynx while they were patrolling. Two shepherds without dogs were giving positive answers, while two other shepherds with very aggressive dogs were saying that they had rarely seen wild animals. Hunters are always giving negative answers, but we have suspicions that at least one of them had not only seen, but killed a lynx. The interviewed people couldn't give any answer about livestock or other damages as they don't know well the animal and the signs it leaves, but they do report one occasion of a lynx jumped on a man in March, during the breeding season.

Table 4. Suitability classes in validation areas covered as in km^2 and in percentage.

Suitability classes	Area, км^2	% of the total study area
Units with 3 positive answers		
1	0,41	0,2
2	102,34	58,8
3	53,4	30,7
4	16,5	9,5
5	1,34	0,8
Total:	173,99	100
Units with 1 positive answer		
1	19,52	20,9
2	31,47	33,7
3	21,13	22,7
4	21,13	22,7
5	0	0,0
Total:	93,25	100

The three municipality units with 3 positive answers are altogether covering 174 km^2 of which class 1 sustain 0.41 km^2 (0.2% of the whole territory) and class 2 sustain 102.34 km^2 (58.8%). Totally the two highest classes cover 59.1 % of the whole territory of the questionnaires (Table 4).

The two municipalities with 1 positive answer each are altogether covering 93.25 km^2 of which class 1 sustain 19.52 km^2 (20.9 % of the whole territory) and class 2 sustain 31.47 km^2 (33.7 %). Totally the two highest classes cover 54.7 % of the whole territory of the questionnaires.

This high percent of high suitability classes speaks for enough potential habitats with good prey base, available for the lynx to exist in that area.

The findings of the field work validated the quality of habitat and the availability/ density of ungulates, especially in the area managed by the game breeding station. We had found a lot of tracks and signs as also made direct observations on the main prey base animals – roe and red deer and wild boar. On the 5th of March 2006 we were able to hear and record a lynx breeding call near Yasna polyana dam (Fig. 2). The animal was found in class 2 suitability according to the model. Local people in the area confirm that they repeatedly hear lynx calls during the breeding season or see the animal. In addition to this there is a witness report from Andrey Stoyanov, a zoologist from the National Museum of Natural History – Sofia, who claim to have observed with some German colleagues a lynx in the Nature reserve of Ropotamo on 25 May 2005 (Spassov *et al.*,2006). This is about 6-8 km from our point of sound recording.

Possible sources of error

When modeling is used, is very important to account for all possible sources of error which could influence the outcome. Here the possible sources of error are:

- Conversion error while converting from vector to raster. Here it is less than 100 m. which is negligible in this scale
- Improper data from the animal census. This error is difficult to predict as the data is coming from different organizations, where annual census is conducted by people with incomparable expertise. The preliminary analysis of animal census data shows consistency in the numbers but the numbers themselves cannot be trusted, that is why we used the data as coefficient rather than numbers only.
- Possible error on expert level.

Conclusions

According to the model, Strandzha Mountain provides a good habitat for existence of lynx in the area - more than half of the territory of the study area, due to the large continues forests and the presence of game breeding stations which artificially keep high density of ungulates. The model we present here still needs a further development but nevertheless offer a tool for assessing habitat quality for species with uncertain distribution and for identifying areas of importance which needs a special attention and research.

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Приложение на ГИС-базиран модел за оценка на качеството на местообитанието и предвиждане на потенциалното разпространение на хищни видове в локален мащаб - рисът (*Lynx lynx* L.) в Странджа като пример

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(Резюме)

Хищните видове са труден за изучаване обект, поради скрития си начин на живот и големия размер на индивидуалните им територии. Доказано е, че най-голямо значение за тяхното присъствие, имат качеството на местообитанието и хранителната база. Оценката на наличните подходящи местообитания и оттук – предвиждане на настоящето и потенциалното разпространение на тези видове, са от особена важност за тяхното опазване, имайки в предвид съществуващият конфликт с хората. Тази статия третира приложението на дедуктивен ГИС-базиран модел за оценка на качеството на местообитанието в планината Странджа за малко познати видове в България, като риса. Резултат от модела, базиран на наслагването на няколко променливи, като наземно покритие, надморска височина, безпокойство (под формата на полигони на селищата и полилинии на пътищата) и хранителна база, са 5 класа на пригодност, от които клас 2 и 3 (висока и средна пригодност) покриват най-голям процент от изследвания район (34,7% и 34,3% респективно). Заедно двата класа с най-висока пригодност, клас 1 и клас 2 формират 52,8 % от цялата изследвана територия от общо 1852,7 км^2, което осигурява потенциално добро местообитание за около 20-28 риса, имайки предвид териториалната им структура. Този подход за оценка на качеството на местообитанието може да се прилага и за други видове, за които съществуват оскъдни данни за тяхното разпространение.