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ORIGINAL PAPER

Rapid assessment of linear transport infrastructure in relation to the impact on landscape continuity for large ranging mammals

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Abstract Many Eastern European countries still host landscapes with high value due to their habitat quality and size. Some of these countries are new member states of the European Union, and EU-accession is accompanied by huge investments in the development of traffic infrastructure. Environmental assessments mandatory for road constructions in the EU do not necessarily require explicit measures for the mitigation of fragmentation, and technical constructions associated with road building are frequently assumed to provide sufficient possibilities for wildlife crossings. We evaluated those technical structures at two motorway sections separating relevant subpopulations of the brown bear (*Ursus arctos*) in Bulgaria. Our assessment revealed that the permeability of the two motorways has been considerably overestimated. A total of just 13 out of the 77 potential crossing possibilities of the two roads together meet the requirements we defined for suitable wildlife crossings. We found that the potential for improvement of the crossing functionality of already existing technical facilities along the motorways is very limited. Given

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the dependence on a small number of habitat paths connecting suitable crossings with habitat on both sides of the road, connectivity between subpopulations is vulnerable to fragmentation impacts.

Keywords Fragmentation · Road ecology · Bulgaria · Transport infrastructure · GIS · Brown bear

Introduction

Bulgaria hosts a considerable amount of valuable non-fragmented habitat. The country covers an area of 110,640 km^2 with a current road density of 0.293 km/km^2 which is relatively small by European standards. Improvement of the national transport infrastructure is an important concern in Bulgaria today (Ministry of Transport of the Republic of Bulgaria 2006). As clearly demonstrated by the situation in many European countries, increasing development of transport infrastructure is accompanied by a considerable danger of habitat destruction and fragmentation (De Vries and Damarad 2002; Bennet and Wit 2001; Iuell 2003; Jaeger et al. 2011). Transport infrastructure affects wildlife populations in diverse ways (Forman and Alexander 1998). Roads can take up considerable land area, noise can disturb animal behavior (O'Brien 2006), and road kills may contribute to significant mortality rates within populations (Seiler and Helldin 2006). Nevertheless, the formation of barriers is probably the most significant impact of high volume traffic and transport routes on wildlife (Chruszcz et al. 2003). This is particularly true given that fencing of express roads and motorways is necessary in order to protect humans and wildlife from car accidents (Clevenger et al. 2001; Kusak et al. 2009). Large carnivore species are shown to be particularly susceptible to habitat fragmentation caused by transport infrastructure development (Trombulak and Frissell 2000). Given its demand for large areas as well as its habitat requirements involving a variety of habitat types, the brown bear in Europe is particularly vulnerable to fragmentation effects and can serve as indicator for landscape continuity (Swenson et al. 2000; Crooks 2002).

Bulgaria hosts one of the largest brown bear populations in the Balkan region. The population is estimated at between 600 and 800 individuals living in diverse subpopulations. The Central Balkan regions and the Rila–Pirin–Rhodope Mountains hold important subpopulations of the species. Currently, the gene flow between the two Bulgarian subpopulations and also with occurrences of the species within the western border region to Serbia is assumed to be under threat (Zlatanova 2010). The degree of isolation of the subpopulations will probably be intensified by motorways planned and already built, respectively, as part of the development of national transport infrastructure (Fig. 1).

Ideally, infrastructure planning should incorporate recognition of the value of non-fragmented habitats as an important and restricted resource, which would require sound environmental impact assessments prior to infrastructure development. In reality, the approval processes provide ample scope for interpretation about the methodological standards of impact assessments, and technical facilities that are built in the course of the road construction, e.g. viaducts, tunnels or bridges, are frequently assumed to provide sufficient crossing possibilities for wildlife. Thus, conservationists are frequently confronted with situations in which traffic lines have already been constructed and are considered to be permeable even though ecological factors have not been adequately accounted for. Once an environmental impact assessment process has been conducted and following the completion of road construction, it is difficult to accomplish supplementary

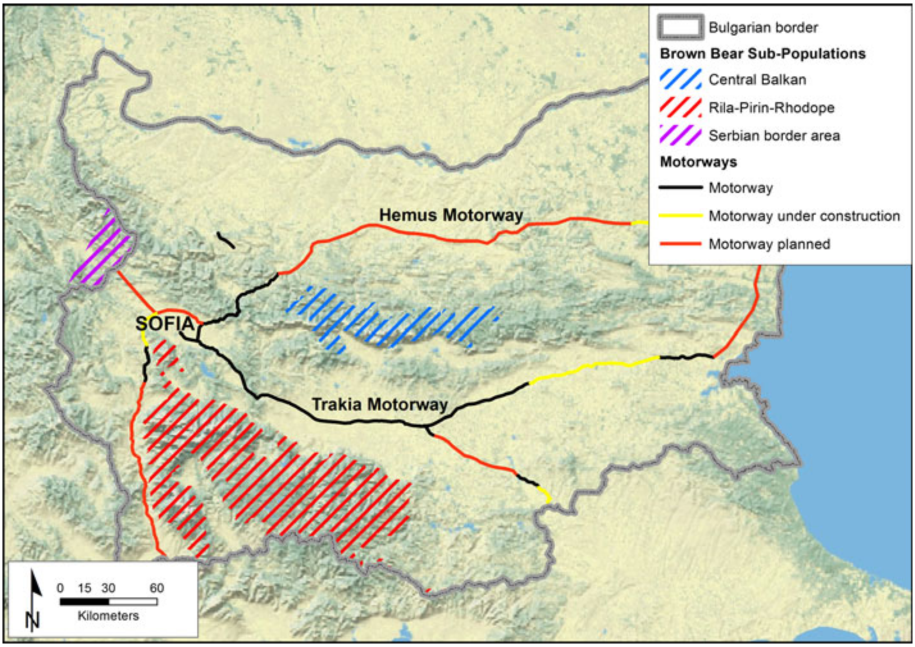

Fig. 1 Situation of motorways in Bulgaria and relevant subpopulations of the brown bear (*Ursus arctos*). Landscape data source: World physical map; US National Park Service

implementation of functional crossing structures. The problem of assertive argumentation is often intensified by data paucity and restricted resources on the conservation side. Effective tools and operational workflows for analyzing the actual permeability of traffic infrastructure are therefore even more essential in order to provide convincing arguments for investments in the mitigation of the impact of already existing transport infrastructure on habitat fragmentation. In this paper, we present a procedure for evaluating technical facilities built in the course of construction at linear transport lines according to their functionality for maintaining landscape continuity for large ranging mammals.

Methods

Our analyses were conducted at two motorway sections assumedly significant in terms of isolation effects between important brown bear subpopulations. The Trakia motorway, currently 280 km long, was built 1975–1982 and is assumed to be a key barrier intersecting the Central Balkans and the Rhila-Rhodopean region. The Hemus highway, presently 140 km in length and built 1984–1999, potentially hinders brown bear dispersal between the Balkans and occurrences of the large predator in the border region to Serbia. The average traffic rate at each of the motorways is 10,000 vehicles per day.

The principal idea behind our evaluation approach is that the ecological functionality of crossing structures mainly depends on three factors: (a) the permeability of the structure on the basis of its technical features, (b) the proximate accessibility of the crossing structure for the animals, and (c) the position of the crossing structure in relation to continuing suitable habitat at the landscape level. The evaluation concerning (a) was conducted directly in the field, whereas work steps for evaluation in relation to (b) and (c) were conducted by means of habitat suitability modeling.

Permeability of crossing structures according to technical characteristics

Potential wildlife crossings were identified by continuously searching the motorways. The permeability of the constructions considered was estimated directly in the field. For each of the structures, GPS coordinates were ascertained as well as the height and width of the passage space, surface conditions of pathways, and the distance from houses to human settlements. The structures were gauged according to an evaluation scheme with 11 categories, where 0 = non-permeable and 10 = no obstacle for ranging animal (Table 1). A value >5 was defined as necessary for crossing structures to be considered sufficiently permeable for bears. The evaluation scheme is based on expert knowledge and on empirical data concerning the use of crossing structures by large carnivores and large and medium sized mammals (Kusak et al. 2009; Clevenger and Waltho 2005, 2000; Hlaváč and Anděl 2002; Huber et al. 2002).

Development of a modeling tool for habitat analyses

We used habitat suitability modeling to evaluate the potential crossings in relation to their direct accessibility for the animals and according to their position in relation to continuing suitable habitat which allow brown bear movements between subpopulations. The basic approach was to derive habitat suitability parameters from areas where bears regularly occur in Bulgaria and to analyze the areas in question according to these parameters by means of GIS-modeling. Signs of brown bears ($n = 412$), e.g. tracks, scat, direct observations etc. sampled by change throughout the areas of bear occurrence in Bulgaria served to indicate bear presence in the model. As a reference measure for optimal habitat conditions for brown bears we used the minimum distance of any bear location to certain spatial habitat units. With this parameter at hand, any given location can be gauged

Table 1 Field evaluation of potential crossing structures

Rating of permeability	Criteria
0	Concrete canals passing under the motorway with diameter ≤1.5 m
1	Concrete canals passing under the motorway with diameter ≥1.5 m in highly urbanized areas
2	Local roads (asphalted or dirt roads) passing under the motor way within sight distance to houses
3	Dirt roads passing under the motor way out of sight distance to human settlements
4	Viaducts, 20–40 m wide, within sight distance to houses
5	Viaducts, 20–40 m wide, out of sight distance to human settlements
6	Viaducts, 41–60 m wide, out of sight distance to human settlements
7	Viaducts more than 80 m wide; overpasses (motor way goes in a tunnel) or green bridges up to 40 m wide
8	Overpasses 40–80 m wide
9	Overpasses 80–1,000 m wide
10	Overpasses >1,000 m wide

according to its distance to optimal habitat conditions (represented by attributes according to spatial ecological data) (Corsi et al. 2000).

Forest cover, the availability of food, and human disturbance are assumed to be the main factors determining habitat suitability for the brown bear in Europe (Swenson et al. 2000). We derived the spatial ecological data underlying the habitat modeling from Corine Landcover 2006 (CLC). We used urban settlements, industrial facilities, and transport infrastructure to represent human disturbance in the spatial data layer. Depending of the status of growth and harvest, respectively, intensive agricultural land can provide food, but also constitute inhospitable areas for the bear. Therefore, we included intensive and extensive agricultural land use, respectively, as separate attributes in the model. Forested and wooded areas as well as extensive agricultural areas provide food and shelter for the bear, and grassland can also be relevant for providing forage for the animals. In total, eight modeling variables were defined (Table 2). Applying the variables, we obtained eight layers representing the minimum distance of any location within the area in question to the spatial units representing the respective habitat attributes. The next step was to combine the layers in order to derive a measure for gauging habitat conditions at any given location. As a metric for this multi-factorial measure we used the "Mahalanobis distance" (Mahalanobis 1936; Jenness 2003).

$$D^2 = (x - m)^T C^{-1} (x - m)$$

where D^2 = Mahalanobis distance, x = vector of data, m = vector of mean values of independent variables, C^{-1} = inverse covariance matrix of independent variables, T = indicates that the vector should be transposed

D^2 is a distance measure in a point cloud, where the distance between each observation and the centroid of that cloud is calculated. The parameter obtained can therefore be regarded as a measure of "landscape similarity" relative to a set of sample sites in a multidimensional space (De Maesschalck et al. 2000). We used eight variables; habitat suitability is thus measured in an "eight-dimensional" point cloud.

Subsequently, the continuous model values were converted into discrete suitability classes (Salvatori 2004). Normal distribution of D^2 values is not to be expected because the bear locations assumedly represent the highest degree of habitat suitability. We therefore replaced the mean with the modal for the portioning procedure. The modal was set to the origin of D^2 value distribution by applying the equation:

$$D^2_{trans} = ABS\left(D^2 - modal_{(D^2)}\right)$$

D^2_{trans} values were then sliced by quartiles where class 1 represents the best suitable habitat whereas class 4 denotes the most inappropriate habitat conditions. Thus, we finally obtained a tool that can be applied for habitat analyses resulting in a habitat suitability map of the area in question.

Evaluation of crossing structure surroundings

With the habitat model available, we conducted analyses of the habitat conditions within the surroundings of structure locations in order to assess the proximate accessibility of the prospective crossings. For this purpose, semi-circle buffers of 1-km radii on both sides of the respective highway were analyzed according to the amount of area representing habitat

Table 2 Reclassification of relevant CORINE 2006 classes to habitat attributes and definition of modeling variables

CORINE 2006 classification	Habitat attributes	Modeling variables
1. Continuous urban fabric	Urban	1. Minimum distance to urban areas $\leq$1 km^2
2. Discontinuous urban fabric		2. Minimum distance to urban areas >1 and $\leq$5 km^2
3. Industrial or commercial units		
4. Port areas		3. Minimum distance to urban areas >5 km^2
5. Airports		
6. Mineral extraction sites		
7. Dump sites		
8. Construction sites		
9. Green urban areas		
10. Sport and leisure facilities		
11. Road and rail networks and associated land	Transportation	4. Minimum distance to transportation area
12. Non-irrigated arable land	Intensive agriculture	5. Minimum distance to intensive agriculture
13. Permanently irrigated land		
14. Rice fields		
15. Vine yards	Extensive agriculture	6. Minimum distance to extensive agriculture
16. Fruit trees and berry plantations		
17. Olive groves		
18. Annual crops associated with permanent crops and complex cultivation patterns		
19. Land principally occupied by agriculture with significant areas of natural vegetation		
20. Sclerophyllous vegetation	Forest and other wooded land	7. Minimum distance to forest and other wooded land
21. Transitional woodland-scrub		
22. Agro-forestry areas		
23. Broad-leaved forest		
24. Coniferous forest		
25. Mixed forest		

Table 2 continued

CORINE 2006 classification	Habitat attributes	Modeling variables
26. Natural grassland	Grassland	8. Minimum distance to grassland
27. Moors and heath land		
28. Pastures		
29. Sparsely vegetated areas		
30. Burnt areas		
31. Inland marshes	Waters	Excluded
32. Peat bogs		
33. Salt marshes		
34. Salina		
35. Intertidal flats		
36. Watercourses		
37. Waterbodies		
38. Coastal lagoons		
39. Estuaries		
40. Sea and ocean		

suitability classes 1 and 2 referring to the habitat model described above. Estimation of the accessibility of the crossing structures was subsequently carried out according to the following rules: Accessibility was estimated as suitable if the amount of model habitat class 1 and 2 accounted for ≥70 % of the semi-circle buffers at both sides surrounding the respective crossing structure. If the amount of habitat classes 1 and 2 accounted for at least ≥30 % <70 % in both semi-circle buffers, further field evaluation of the structure's surrounding was recommended. Crossing structures connected to a buffer circle containing <30 % of the relevant habitat classes were considered to be insufficiently accessible.

Evaluation of crossing structure locations in the context of continuing suitable habitat at the landscape level

Starting at the definite locations of each of the crossing structures, we analyzed the area between the motorway and the next brown bear subpopulation to determine the connectivity area. We implemented the outcome of the habitat suitability model described above as a cost grid. This allowed for use of the *mahalanobis distance* as a similarity metric for the process of identifying connectivity area. We defined model habitat quality class 2 as the minimum requirement for the determination of connectivity area. The "Connectivity area Designer Evaluation Tool" provided by Jenness et al. (2008) was then used for the calculation of least-cost-paths through the connectivity area between habitat block polygons. The least-cost-paths result from creating least-cost-polylines by raster analyses to all sides. During this process, central cells are weighted higher than those located closer to the edge (Jenness et al. 2008). The combination of the habitat grid and the least cost-path-calculation allows for the identification of a set of habitat paths through a connectivity area corresponding with the principles defined by our habitat suitability model.

Results

Permeability of potential crossings according to technical features

The field evaluation of the Hemus and Trakia motorways identified 77 constructions to be explored for suitability as crossing structures for large terrestrial mammals. We identified 25 public roads, 23 canal constructions, and 2 railroad tunnels as potential wildlife passages for crossing the motorways. Twenty-two viaducts provide possibilities for wildlife to cross below the motorways. In five cases the motorway passes through a tunnel thus providing overpasses for wildlife (Table 3).

Assessment of the technical environment of the structures revealed that about 30 % of the crossings provide permeability ≥class 5, implying that the respective structures are permeable for brown bear. A closer look at the technical characteristics reveals that sufficient structure permeability is given only where the motorways pass through tunnels and therefore provide overpasses of considerable width or, in the case of viaducts, where they allow large mammals to pass under the motorway (Table 3).

Connectivity function of potential crossing structures

Our three scale analysis allows differentiated and systematic analyses of technical transport infrastructure facilities according to their connectivity function at the landscape level. At

Table 3 Evaluation of different types of crossing structures according to their technical permeability for brown bear

Character of structure	Trakia motorway		Hemus motorway	
	Total no. of structures	No. of structures with permeability rating >5	Total no. of structures	No. of structures with permeability rating >5
Canal	16	0	7	0
Overpass over tunnel	1	1	4	4
Railway tunnel	2	0	0	0
Road asphalt	12	0	5	0
Road soil	5	0	2	0
Road soil plus canal	1	0	0	0
Viaduct	12	9	10	8
Total	49	10	28	12

the Trakia motorway, four constructions that were gauged as permeable for the brown bear according to technical characteristics were revealed as being not directly accessible for the animals because of insufficient habitat conditions within the proximate surrounding of the structure. At one of these structures, connectivity through habitat connectivity areas on a landscape scale is actually given on both sides of the motorway. This finding suggests that this explicit crossing structure might potentially be improved by means of habitat management within the structure's surroundings. At the Hemus motorway, 5 out of 12 technically permeable crossing areas are not directly accessible for bears. Given that they are also not interconnected by suitable habitat paths with bear occurrences, investment in habitat improvement of the surroundings of these facilities does not seem efficient.

The analyses at the landscape level suggest that a total of 26 out of 49 structures at Trakia and 19 out of 28 at Hemus are interconnected with relevant subpopulations on each side of the road. A closer look at the spatial characteristics of these habitat paths exposes aspects crucial for conservation: All paths show considerably narrow bottlenecks of only about 140–300 m in width. The portion of sections less than 2,000 m in width ranges amongst diverse paths from 2 to 20 %.

Overall assessment

In total, our assessment revealed that only 7 out of 28 constructions along the Hemus highway and 6 out of 49 potential crossings at the Trakia highway could actually fulfill the overall requirements with regards to permeability of the structure, proximate accessibility from the surrounding habitat, and the extent to which they are functionally connected by a habitat path with brown bear subpopulations (Fig. 2). Obviously, the majority of the structures evaluated turned out to be non-functional in terms of maintaining interconnection between brown bear subpopulations. Our analyses revealed that potentials for improvement of already existing facilities are very restricted. Further, potentially available connectivity area on both sides of the motorways is currently only linked by a few actually functional crossings. These findings suggest a need for additional mitigation structures at the road sections in question. In turn, the maintenance of the functionality of already suitable structures is essential for connectivity. As demonstrated by our assessments, the majority of suitable habitat paths lead into a few main paths (Fig. 2). Sustainable retention of these areas is therefore significant for the interconnection of brown bear subpopulations.

Discussion

The need for operational procedures

Roads can affect wildlife in numerous ways (Sweanor et al. 2000; Forman 2004). Respective studies address mortality caused by traffic accidents (Seiler and Helldin 2006; Jones 2000), and alteration of habitat conditions and levels of connectivity (Forman et al. 2003). The deleterious effects of roads, particularly those with high traffic volumes are underscored by conservationists and therefore increasingly recognized by administrations. Consequently, environmental assessments are required before cross-regional roads can be constructed in countries of the European Union (Iuell 2003). In order to cope with the different ecological and socio-economic circumstances and legal systems within the diverse European countries, EU nature legislation is restricted to a mandatory frame. Within this framework member states hold jurisdiction for the substance and implementation of conservation law. The mandatory frame of EU legislation offer ample scope for interpretation. Relying exclusively on the legislative tools of EU nature conservation policies, therefore, will not necessarily ensure a retention of undisturbed landscape (Wesolowski 2005) and will perpetuate the danger of underestimating the problem of road impact on animal populations and ecosystems. This is the case with the road infrastructure

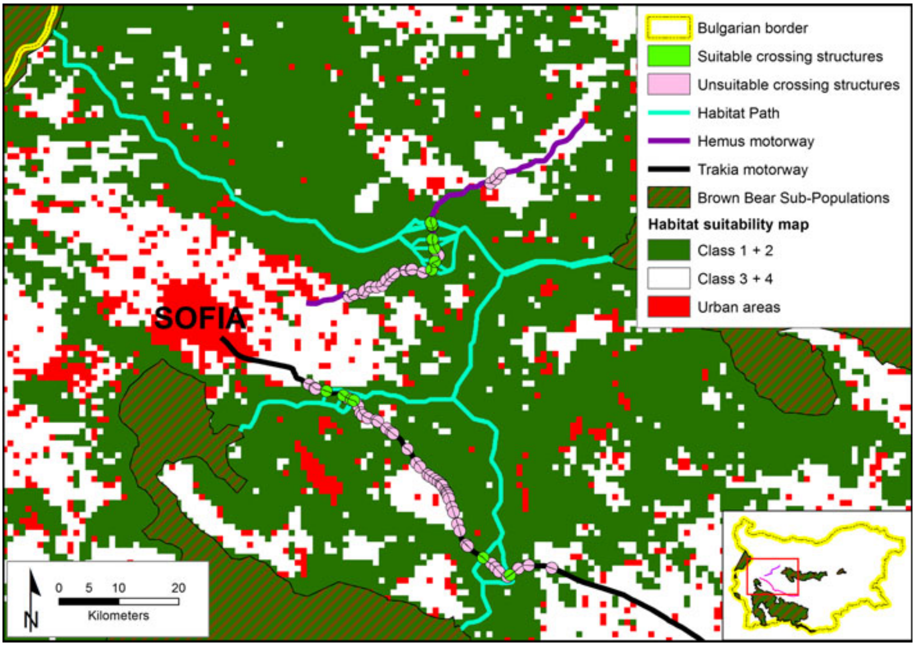

Fig. 2 Fragmentation of the connectivity area between relevant subpopulations of the brown bear (*Ursus arctos*) in Bulgaria caused by two motorways

we evaluated in Bulgaria. The two motorways are routing through areas important for dispersal of brown bears, which entails the danger that subpopulations may become isolated. In fact, our study revealed that the majority of assumed crossing structures actually turned out to be non-functional in terms of mitigating the landscape fragmentation impact of the highways investigated. Against this background, there is a clear need for operational procedures for analyzing infrastructure concerning fragmentation impacts. Developments in Geographical Information Systems (GIS) allow for the processing of huge data sets of the environment and of species distributions and their spatial requirements (Cantú et al. 2004). The technologies provide diverse approaches for landscape analyses, spanning from the identification of wildlife connectivity areas based on land use categories, over elaboration of indices to quantify habitat fragmentation levels and landscape connectivity (Fahrig 2002, 2001; Ryall and Fahrig 2006; Tischendorf and Fahrig 2000; Jaeger 2000), to modeling the effects of habitat fragmentation on species survival rates and ecological mechanisms (Fahrig 2002, 2001; Ryall and Fahrig 2006; Kramer-Schadt et al. 2004; Wiegand et al. 2005) as well as modeling the influence of traffic calming measures on wildlife populations (Langevelde Fv and Jaarsma 2009). Further, algorithms for modeling species dispersion habitat have been developed (Corsi et al. 1999; Kramer-Schadt et al. 2004; Wiegand et al. 2004). That current modeling techniques provide sophisticated analytical tools is undisputed (Carroll et al. 2003; Schumaker et al. 2004; With and King 2001), however, the procedures are regularly data demanding and time consuming. Given that traffic infrastructure development is already in process in Bulgaria, our task was to assess the permeability of the motorways in question under certain time constraints and, furthermore, with sparse data. To produce reliable results—which are nevertheless vital for influencing decision-making processes, our aim was to incorporate available information as efficiently as possible into an analytical workflow. Nevertheless, in the recent study we decided to evaluate technical structures even at highway stretches that are indicated by our modeling trials as not being connected with suitable habitat. Our intention behind this was to provide detailed information about the full range of aspects that are considered to be relevant in the debates between road administration and conservationists. However, if our approach is applied to infrastructure planning or for the analysis of existing linear transport lines in general, the sequence of the different analytical work steps is flexible and can be chosen according to the requirements of the respective task and situation.

Evaluation of crossing structure features

Fencing of motorways and express roads is recommended in order to reduce wildlife mortality and prevent traffic accidents (Seiler and Helldin 2006; Seiler 2005; Huber et al. 1998; Kusak et al. 2000). On the other hand, fenced highways are virtually impermeable for most large mammals (Epps et al. 2005; Kaczensky et al. 2003). Therefore, we concentrated our analyses exclusively on structures that may allow animals to pass under or over the highway. The criteria for gauging if a construction is permeable for bears on the basis of its technical characteristics were derived predominantly from the findings of an evaluation conducted in Croatia of different crossing structures regarding their utilization by large carnivores and large and midsized mammals. Kusak et al. (2009) conclusively demonstrated that brown bear, wolf (*Canis lupus*), and eurasian lynx (*Lynx lynx*) predominantly selected broad tunnels as overpasses and viaducts to underpass motorways and avoided smaller underpasses and bridges. Further, the authors revealed that those crossings preferred by large carnivores were also suitable to a great extent for ungulates species such as red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) (Kusak et al. 2009). Even though bears can cope with human presence to a certain extent, and e.g. houses within a certain distance will not necessarily prevent the animals from using a passage, we required a definite distance from human settlements in order to rate a structure as suitable. Human-bear encounters can cause severe conservation problems detrimental mostly for the animals (Swenson et al. 1994, 2000; Weaver et al. 1996). Against this background, it is important to identify potential crossings preferably unproblematic in terms of human-wildlife conflicts.

Model development and application

Given a latent impact of the motorways on the Bulgarian brown bear metapopulation, assessing possible crossing structures according to their functionality as linking components of suitable habitat on both sides of the roads was also an objective of our work. The edging areas of motorways are usually subjected to specific management measures that can create inhospitable habitat for animals along the roads (Carroll et al. 2002). In this context, it is reasonable to evaluate the proximate accessibility of the diverse crossing structures and to explore the cross-regional habitat network functionality of potential wildlife crossings with two separate work steps. However, for both the work steps, habitat suitability modeling is the basic approach. The motorways evaluated in our study cross connectivity areas between subpopulations. These areas are presently only occasionally frequented by bears, and animal records in sufficient number are for this reason not expected per se. Therefore, the habitat suitability model required for that task has to be developed based on presence data from areas where bears occur in Bulgaria. In so doing, we assumed that the model variables derived from current bear occurrences would be adequate to represent habitat features relevant for the accessibility of a crossing structure and for the identification of connectivity areas. Nevertheless, such an approach requires a sound interpretation against the background of the methodological aspects. It is important e.g. to ensure that the slicing of continuous suitability values into habitat classes does not result in an absolute quantification of the habitat situation. The area in question is allocated to habitat suitability classes as the proportion of each of the classes is preset by the modeler. Since the amount of CLC classes representing suitable bear habitat is considerably high in Bulgaria (according to CLC, e.g. forests and semi-natural areas make up about 93 % of the Bulgarian surface) we assumed that quartile proportions for the classification would be adequate. This assumption is supported by the total number of bear locations we actually identified in the model habitat class 1 (82 %) and class 2 (14 %). In areas with higher anthropogenic impact, for example those prevailing in western European countries, the classes accounting for suitable habitat should probably be adjusted more conservatively.

Distortion due to individual variances, different scales of the variables or inter-correlation of variances can also be problematic when assigning point data with landscape attributes (De Maesschalck et al. 2000). Problems may occur especially when species point data are linked with a range of different landscape attributes. Careful selection of an adequate similarity measure can mitigate this problem. We chose the *mahalanobis distance* metric because consideration of co-variance-matrices in the calculation process makes this similarity measure resistant to dimensional imbalances and autocorrelation of the different landscape attributes. We emphasize this aspect because conservationists and landscape planners rely more and more on *GIS*-tools provided for diverse analytical tasks. For example, the application of a specific similarity metric different from the presetting of a provided *GIS*-tool can be ensured by implementing individually developed cost-grids.

Available *GIS*-tools can nevertheless considerably reduce working efforts and improve the planning process. The corridor designer evaluation package (Jenness et al. 2008) e.g.

provides convenient statistics of corridor parameters such as corridor width and length etc. However, users should take into consideration the algorithms and computing processes preset in the tools provided. We found that calculation of so-called corridors with the Calculate-Patch-Distance function (Jenness et al. 2008) is affected by the spatial extent of the data sets included in the analyses. Thus, the fuzziness of the calculation process correlates with the extension of the area in question. We addressed this problem through the identification of suitable connectivity area based on our habitat model. In the following step, we used a further function (Calculate-Bottle-Neck; Jenness et al. 2008) exclusively for identification of least-cost-paths through the already identified connectivity area in order to indicate the most probable dispersal routes.

The general lack of absence data can also turn out to be a further critical aspect in the context of the habitat suitability modeling, especially where sample sizes are relatively small as is the case with our research. Comprising habitat attributes to ecological predictors is sometimes suggested as an approach for overcoming the problem of sparse data in modeling (Rondinini and Boitani 2006). In fact, habitat models recently developed for the bear in Bulgaria used the slope of the terrain as a predictor for suitable bear habitat because telemetry data suggest that the animals prefer steeper environments over flat areas (Zlatanova 2010). However, it should be taken into account that animal presence or absence is not exclusively linked with the prevailing habitat conditions but also depends on factors such as e.g. disturbance or persecution by humans. In fact, this is the case in Bulgaria, where persecution has obviously forced the bear to prefer steeper areas that are less frequented by humans (Zlatanova 2010). Although our model is based on small sample sizes of bear indications, we refrained from using predictors in our landscape analyses. The involvement of “slope” as a predictor in the model would indicate the current distribution of brown bear rather than the amount of suitable habitat principally available and thus entail a danger of neglecting areas important for conservation.

Aside from the problem of relative sparseness of distributional data concerning the focal species, restricted availability of adequate habitat information can also diminish the rigor of the analyses. Restrictions can result from an insufficient spatial resolution of the data as well as from the problem that the data usually cannot reflect short-term alterations in habitat conditions induced by anthropogenic land use management. For example, in agricultural areas conditions for animals can vary significantly according to the situation of crop harvest given that reaped fields constitute large areas without hiding possibilities. The aspect of short-term or seasonal alteration of the habitat conditions due to agricultural treatment is seldom reflected in the context of modeling population distributions and may explain some discrepancies between model output and actual distributions of species which are present in several research works (Zimmermann 2004; Kramer-Schadt et al. 2005).

Conclusions

Conservation issues will more readily achieve recognition within planning processes if the contributions entail concrete and comprehensive concepts for problem solution and implementation (Alpert et al. 2003). Scarce data, time pressure, and chronic deficit of resources force conservationists into a defensive role while arguing for a sound balance of infrastructure development and habitat preservation. This is also the case in Bulgaria where expansion of transport lines perils habitat connectivity and thus populations of large ranging mammals like the brown bear. The need for increasing our knowledge of large mammals’ habitat use, especially within human modified landscapes, is undisputed.

Likewise, a deeper insight into the methodological potentials and shortcomings of using surrogate species in conservation planning is increasingly required (Rodrigues and Brooks 2007; Linnell et al. 2000). However, the investments of time and financial resources necessary for intensive research are very high and an improvement of respective knowledge cannot therefore be expected in the short run for most Eastern European countries. In this context, efficient and reproducible procedures for rapid assessments of transport infrastructure are urgently required in order to prevent the irreparable loss of connectivity. With the present work, we draw attention to a range of critical aspects that must be taken into account by conservation practitioners when attempting to analyze the impact of transport infrastructure on habitat. Though acknowledging the limitations inherent in the procedures we applied, we nevertheless believe that our approach is efficient for rapid assessments of motorway permeability. We present an analytical workflow allowing for a differentiated assessment of potential crossing structures at linear transport infrastructure elements. This assessment can be conducted using affordable data and manageable methodology. The approach should thus enable conservationists to constructively contribute to nationwide infrastructure planning and therefore strengthen their influence in the relevant decision-making processes.

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