Strasbourg, 13 September 2002 **T-PVS/Inf (2002) 27**
[Inf27e_2002.doc]

CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE
AND NATURAL HABITATS

Standing Committee

22nd meeting
Strasbourg, 2-5 December 2002

The development of an ecological network in the Carpathian Ecoregion: identification of special areas for conservation of large carnivores

Report for the Council of Europe
Directorate of Culture and Cultural and Natural Heritage

By

Valeria Salvatori

IEA ISTITUTO ECOLOGIA APPLICATA

Document prepared by
the Directorate of Culture and Cultural and Natural Heritage

TABLE OF CONTENTS

Introduction

Within the Habitat Directive of the European Union, the Council of Europe, Natural Heritage Division, is promoting the identification of Ecological Networks (EN) at pan-European level. Although most of the countries taking part to the Union have undertaken the process of identifying Special Areas of Conservation (SAC) for the protection of habitats and species covered by the Habitat Directive, some of the countries in the accession process have only recently started to identify such areas.

This report focuses on a geographical area that includes four countries in Central Europe. It only represents the first stage of a process aiming at identifying SACs that could be part of an ecological network, and it is based on information about the presence of three species of large carnivores: the brown bear (*Ursus arctos*), the Eurasian lynx (*Lynx lynx*) and the grey wolf (*Canis lupus*). The consideration of three species only represents a limitation for a comprehensive ecological analysis required for identifying potential SACs. Such analysis should be based on an exhaustive database on biodiversity, including different taxa of animals and plants, and will be the focus of the second stage of the EN identification process.

The analyses performed and described in the present report are part of a three-year project funded by the World Wide Fund for Nature International (source: WWF-Netherlands) and developed under the umbrella of the Large Carnivore Initiative for Europe (LCIE). The project aimed at modelling conservation areas for large carnivores in the Carpathian Mountains (hereafter CALCC). It was technically coordinated by the Istituto di Ecologia Applicata (IEA) of Rome, and operationally developed by the author in collaboration with a number of experts from the interested countries, and the University of Southampton, UK.

The Carpathian Ecoregion was originally selected because of its peculiar ecological importance for the European population of large carnivores. Within a pan-European approach, the Carpathian Mountains spread across seven countries: Austria, Czech Republic, Poland, Slovakia, Hungary, Romania and Ukraine (Witkowski, 1999). Some of these are involved in the accession process for being part of the European Union and are therefore required to comply with the standards set by the Habitat Directive. In this perspective, the identification of SACs and the subsequent establishment of an EN are essential.

The methodology used follows a procedure successfully developed and applied by IEA (1999) for modelling areas for conservation of large carnivores on the Alps. The analytical approach uses multivariate statistical methods for spatially identify areas that are associated with various degrees of environmental suitability. Such suitability classes are established according to the environmental characteristics of areas where the presence of each species considered was recorded. The primary outputs of the main project are maps of probability of presence of bears, lynx and wolves. These can be considered a proxy for environmental suitability for the conservation of the three carnivores in the Carpathians. The analyses have been performed at two different spatial resolutions, using cells of 1km x 1km and 250m x 250m size. The project is still ongoing and final reports will be produced within the year 2002. The Council of Europe is significantly contributing to the project by giving the opportunity to pool the results coming from the three separate species into a single output, thus creating the ground for a synergetic conservation approach that maximizes the information and focuses the attention of wildlife managers to those areas that are most significant for the three species at once.

The following sections will describe (i) the Carpathian Ecoregion, (ii) the methodology used, (iii) the results achieved, and (iv) a final discussion of the results.

The Carpathian Ecoregion

The Carpathians are the second largest chain of mountains in Central Europe after the Alps and certainly the ~~most important one~~largest in central-eastern Europe. They spread from the Danube river tract of Slovakia, north west of the capital city Bratislava, to the Iron Gate on the Romanian Danube ~~in~~at ~~its~~ their south-eastern end ~~part in Romanian territory~~ (Voloscuk 1999), covering a territory of approximately 200,000 km^2 when including the Transylvania plain of Romania (Fig. 1).

The role of the Carpathian arc as corridor in the south-north direction during the Pleistocene glaciations gives it a unique character and it can be considered a large biome in the middle of Europe. The unbroken forest tracts, preserved especially in the eastern and southern Carpathians, have maintained, in some areas, the character of a natural Carpathian Primeval forest. Relatively low human population densities, difficult access to many mountain ranges and a considerable number of large forests have allowed a rich and diverse fauna to exist in the Carpathians, where abundant populations of large carnivores can be found in the wild.

Although the mountain complex is divided among 7 countries, the CALCC project only consider focuses only on countries that contain at least around 10% of the Carpathians within their territory, considering that smaller areas at the boundary of the mountains are not vital for the conservation of the Carpathian large carnivores population. The analyses are thus limited to Poland, Slovakia, Ukraine and Romania, which all together contain almost 90% of the Carpathian chain.

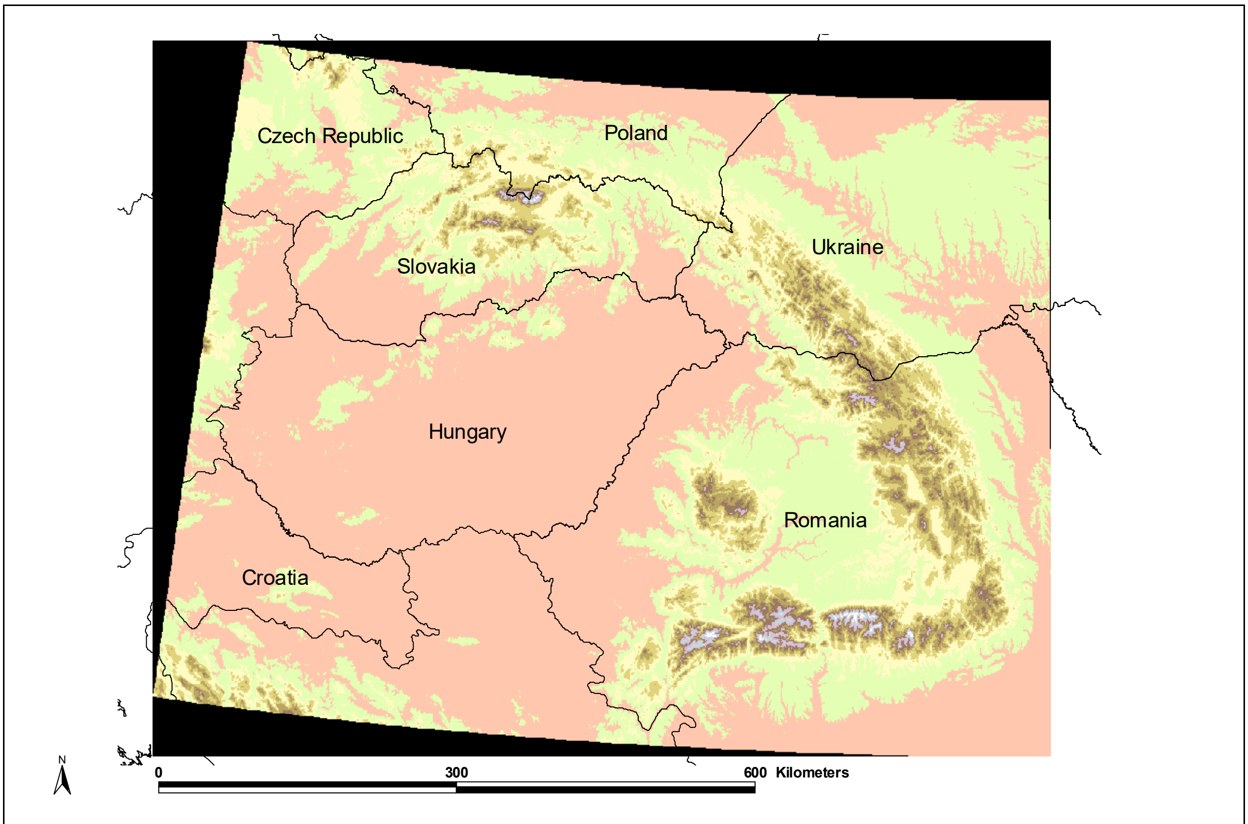

Figure 1 – The Carpathian Mountains represented by the Digital Elevation Model available from the United States Geological Service.

Methodology

The methods used follow those applied by Corsi et al. (1999a and b) and IEA (1998). They will be resumed briefly here and with a modest insight in the appendix, but for a detailed description, the readers are encouraged to refer to the cited sources.

Basically, the environmental characteristics found at locations where the bears, lynx and wolves have been recorded are assumed to be the ones that are good enough for granting the specie's presence. The whole area is then compared to such characteristics and scores of suitability are associated to each 250m x 250m cell in the Carpathians according to the similarity to such conditions. The higher the similarity, the higher would be the score of environmental suitability associated to each cell.

The suitability scores have been grouped into 7 classes, class 1 being the most suitable and class 7 the least suitable. Three maps of environmental suitability where produced for the three species and they were pooled together through a principal component analysis (PCA), in order to obtain a map representing the environmental suitability for the three species at once.

The analyses then focused on the comparison between the resulting classes of suitability and the protected areas existing in the Carpathians. Information about protected areas came from the WWF International-coordinated Carpathian Ecoregion Initiative (CEI) and includes a map showing areas with different protection statuses, including the recently established and planned ones. The comparison was based on descriptive statistics that provided the basis for interpretation and guidance for future environmental management strategies.

Results

The four countries considered cover the Carpathian Mountains in different percentages, Romania containing over half of the whole mountain system (Table 1).

Country	**Carpathians portion (%)**	**Area in km^2**
Slovakia	17	35,427
Poland	9	18,994
Ukraine	10	21,570
Romania	52	107,151

Table 1 – Percentage of the Carpathian Mountains in the four countries considered.

Pre-processing

The main challenge of the CALCC project was to collect data of diverse nature from four countries where information published in international publications is very limited. Therefore, a network of local experts and partners had to be established for contributing to the project. Once the geographical data were acquired, they underwent a series of transformation steps in the process of standardising their geographical characteristics (e.g., spatial resolution and coordinate system projection). Then, they had to be appended in order to cover the whole Carpathian Ecoregion, transformed into a continuous raster format and finally processed using a multivariate approach. The variables used where land cover and altitude. For Poland, only land cover was used, as the altitude data were not available. CORINE land cover was used after a reclassification phase that pooled together similar classes.

Processing

The three models resulting from the pre-processing phase were highly correlated between them (correlation coefficients ranging from 0.94 to 0.97). For this reason, the PCA gave highly significant results, the first component accounting for 97% of the total variance. The latter is also very highly correlated with each one of the three suitability indexes. The correlation coefficients were 0.98 for both lynx and bear and 0.99 for wolf.

The environmental suitability index as produced after the PCA was represented graphically (Fig. 2) pooling the three models generated from the pre-processing stage weighed by the first factor score coefficients. They were 0.335, 0.337 and 0.340 for bear, lynx and wolf, respectively.

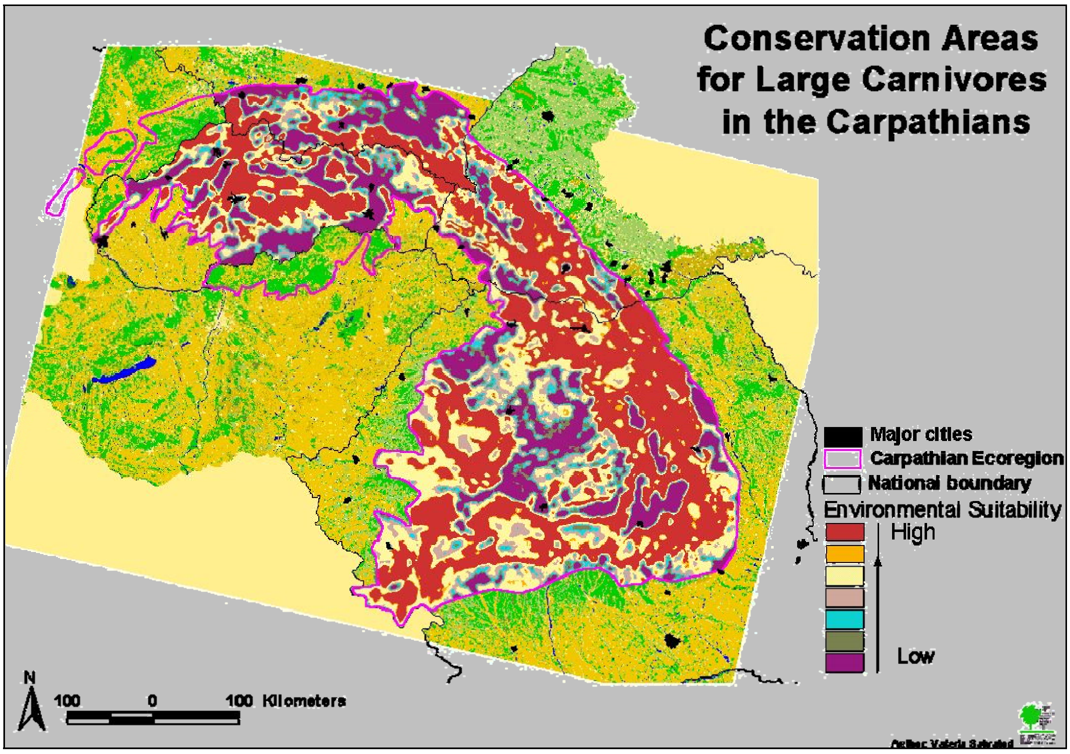

Figure 2 – Graphic representation of the suitability index as calculated after the principal component analysis.

The suitability classes were set according to the values recorded at the locations were the presence of large carnivores were reported. Due to the high correlation between the three original, separated models, the classes reproduced quite neatly the classes set in the three models. The first two classes of the PCA index can be compared with the first class in each of the three models, while the second two are in various measures included in the second and partly the third classes of the original models. The model for the bear shows the highest deviation from the pooled model, as its original standard deviation has the highest value of the three (29, compared with 22.7 for lynx and 20.8 for wolf). Classes four and five fully include the fourth class for the wolf and the lynx, but only partially for the bear, suggesting that this suitability class only takes into account the contribution of the former two. Finally, class 7 partially covers values in classes 5, 6, and 7 of the original models. The variability of the pooled model is significantly lowered by the PCA analysis, thus the overall values of suitability are lower than the original models. For this reason class 7 does not cover all the values of classes 6 and 7 of the original models.

Because of this correspondence between the classes of the joint model and the original ones, for further analyses classes have been reduced to four main ones: 1-2, 3-4, 5-6 and 7. The total area covered by each class is reported in Figure 3.

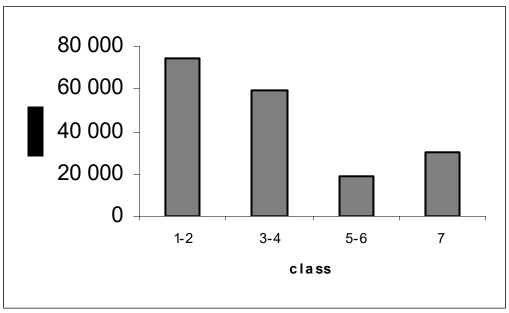

Figure 3 – Area of the Carpathians included in each suitability class for the three carnivores.

When considering the four countries separately, the percentage of the Carpathian territory included in each class, appear to be consistent throughout the ecoregion (Tab. 2).

Class	**RO**	**UA**	**PL**	**SK**
1-2	44%	48%	29%	33%
3-4	35%	31%	23%	31%
5-6	9%	9%	16%	12%
7	12%	12%	32%	24%

Table 2 – Percentage of Carpathian territory associated with different suitability classes within each country considered.

When plotting the same values in a diagram, a slight trend appears whereby Romania and Ukraine could form a cluster and Poland and Slovakia could belong to a separate one (Fig. 4). The differences are particularly evident for the first two classes.

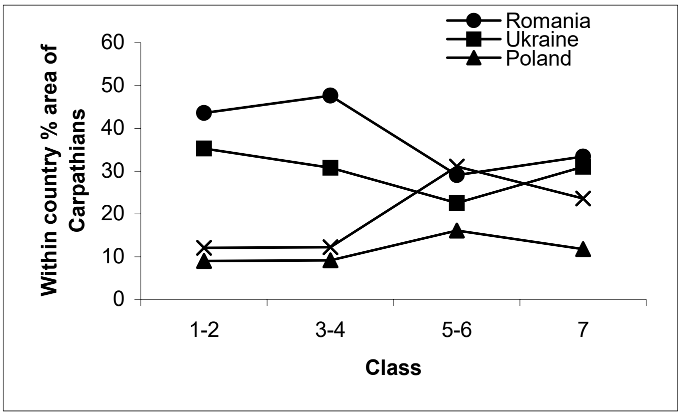

Figure 4 – Graphical representation of the percentage of Carpathians territory associated with different class of suitability within the four countries considered.

A comparison between the results obtained and the map of the protected areas (Fig. 5) shows that 12.2 % of the whole Carpathians, covering an area of 22,420 km^2, is under some kind of legal protection. More than half (59%) of such protected territory belongs to the first suitability class.

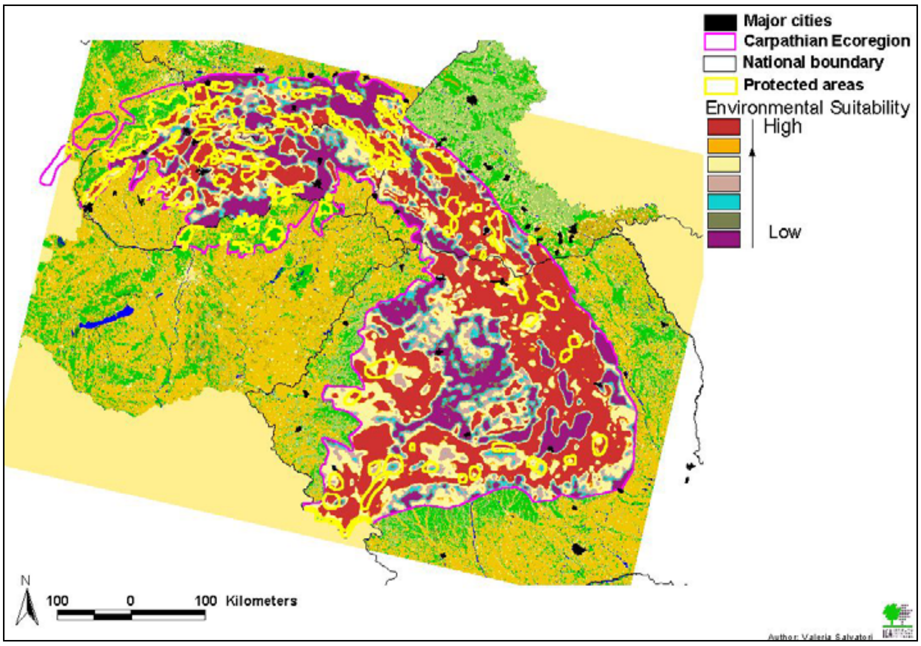

Figure 5 – The overlay of protected areas on the joint environmental suitability index.

Looking at the single countries, an interesting inversion of trend whereby Poland and Slovakia have the highest percentage of Carpathian territory covered by protected areas appears (Tab. 3).

Country	**% of Carpathian territory occupied by protected areas**
Romania	6
Ukraine	12
Poland	28
Slovakia	23

Table 3 – Percentage of protected territory in each Carpathian country.

The percentages of protected areas that extend in the different environmental suitability classes appear to be consistent within the four countries (Fig. 6).

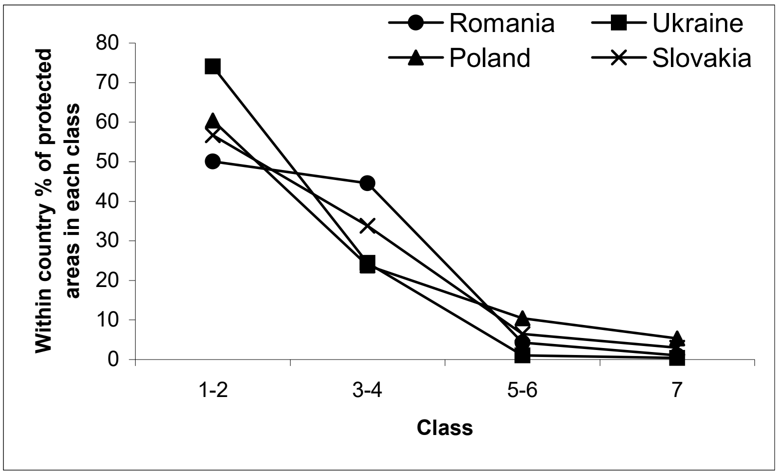

Figure 5 – Percentage of protected areas belonging to the four suitability classes within each country considered.

Discussion

The interpretation of the results presented in this report is highly linked with the acceptance of the limitations of the modelling approach. It is crucial that the reader bears in mind that models are in general a simplified representation of reality that attempts to generalise natural processes using data from localised space and time. When interpreting the output of a model, it is important to remember why the model was built and what source data were used.

In the present case, the original aim of the model was to find a common ground that summarised three single situations at once, compromising accordingly with some kind of objective rule.

Looking at the source data, i.e. the three models of suitability index for each of the three carnivores, there are a number of issues to be considered. For an extensive discussion, the reader is addressed to refer to published material by the CALCC project (in prep.). First of all the lack of extensive information on the study area must be considered. A great deal of local knowledge is present, but very often it is hardly accessible, when it is published it is often in local languages and most of the time of anectodical nature. This is to be put in a context whereby financial means are limited and contacts with the western European countries are very recent for some of the countries considered (e.g., Ukraine). The historical and social backgrounds of the Carpathian countries have a significant role to play in nature conservation, and any inference made from recent analyses must take into account the profound changes the countries have undergone in the last decades and are still undergoing. One advantage of such recent changes is that the legal and social situations in the different countries appear to be consistent or coexisting with some kind of time-shift between each other.

In such a context, the original models were developed with the main aim of creating the base from where to start a series of detailed studies and analyses at both regional and local level. The most successful result was the creation of the "big picture". A picture that presented the Carpathian Mountains as a unit, disintegrating the national boundaries and stimulating the interested countries towards a concerted management for the conservation of one of the most important area of wilderness in central Europe.

The technical limitations of the modelling approach used for producing the three input indexes are not to be discussed here, and the interested reader is encouraged to contact the author for any discussion on the subject.

When looking at the joint model for environmental suitability, it is clear that at a first visual interpretation, the areas associated with high suitability index are by far the larger ones. This suggests that either the three species are highly tolerant or that the ecoregion has wide areas of good environmental quality in terms of granting the presence of the three carnivores. A comparison between the model output and the land cover of the area suggests that the surfaces associated with the first suitability class (1-2) are mostly forested areas, with very low human presence. These are not to be considered as undisturbed areas, as a long tradition of forest management exists in the countries considered, and planned commercial wood cropping is in place since decades. Hunting traditions are also well rooted in the local communities and the three carnivores are not always protected in the four countries considered (Salvatori et al. 2002).

In terms of connectivity among suitable areas, there is a slight difference to be noted between the southeastern and the western part of the mountain range. Southeastern Carpathians appear to have larger areas of suitable environment that are also continuous, while the western Carpathians have a higher degree of fragmentation. A statistical analysis of the degree of fragmentation has not been performed at this stage and it is planned in the future, but even a visual analysis can detect such difference. This trend appears to be consistent with the one highlighted by the description of the % area belonging to the 4 classes in a per country base (see fig. 4) and it is very likely to be linked with the degree of industrial development and the historical events that took place in the last decades. In view of such trend, an effort in connecting protected areas may be put in Slovakia and Poland.

Furthermore, there are some noticeable features that are easily explained with land cover characteristics. The area in Ukraine near the border to Poland is associated with low degrees of suitability (Fig. 2), as well as the large area inside the elbow of the southern portion of the mountain chain. The former can be explained by the presence of a concentrated settlement area. It is a rural valley with small but consistent human settlements with little forest shelter. The latter is the Transylvania Plain, an extensive agricultural area surrounded by the forested mountains of Fagaras in the south and Apuseni in the west.

The overlay of the map of protected areas provides some interesting information for detecting the amount of suitable areas actually under any kind of protection. The overall situation is very encouraging, but it must be noted that most of the protected areas reported for Romania are currently planned and not established. The system of protected areas in Slovakia includes 5 degrees of protection that do not coincide with those suggested by the IUCN. Management practices include various degrees of human actions in all protected areas but National Parks, the only areas where hunting is not permitted. Furthermore, the problems that are usually common in other countries in terms of enforcement of protection laws are further stressed in these countries, where social and political unsettlement does not allocate any significant priority to environmental conservation. The law enforcement in this respect should receive greater attention than it is at the moment, ensuring the minimisation of illegal activities.

The proportion of protected territory belonging to the four suitability classes appears to be consistent throughout the four countries, contributing to the unit vision under which the Carpathian Ecoregion should be seen.

The large carnivore populations in the Carpathians are the largest in Europe and their persistence is highly dependent on the pro-active approach to nature conservation. The high correlations between the three species-specific models give an opportunity for the optimisation of conservation efforts, being the areas suitable for the three single species broadly the same. This, in conjunction with the consistency of forestry and game management practices, should be seen as an opportunity for an integrated management of the Carpathian territory, in full respect of the traditional practices and the need for economical development and stability in view of the inclusion in the European Union.

In conclusion, the model of environmental suitability for bear, lynx and wolf in the Carpathian Ecoregion shows that there is a great deal of space for synergetic action to be taken in order to conserve the forested areas in their healthy state. The present situation offers an opportunity for coordinated actions to be taken in different countries, all sharing significantly similar social end economical backgrounds. Although this analysis can only be applied with regards to three wildlife species, the approach can potentially be valid for the whole range of biodiversity indicators, thus guiding managers towards the selection of SACs that may be part of an Ecological Network in the Carpathians.

Acknowledgments

The author wishes to thank F. Corsi for assistance during analysis and comments on a draft version of this report. Stimulating comments also came from Christoph Promberger and Annette Mertens. Ovidiu Ionescu, Yaroslav Dovhanych, Slavomir Find'o and Henryk Okarma provided information of local large carnivores presence and were engaged in stimulating discussions on the outputs of the processing phase.

References

Corsi F., E. Duprè and L. Boitani (1999a). A large-scale model of wolf distribution in Italy for conservation planning. *Conservation Biology*, **13**: 150-159.

Corsi F., L. Boitani, I. Sinibaldi (1999b). Ecological corridors and species: large carnivores. Final report for the Council of Europe. IEA, Rome, Italy.

IEA (1998) *Large Carnivores Conservation Areas in Europe, discussion paper for the Large Carnivore Initiative for Europe*. WWF International, Gland, Switzerland.

Salvatori V., H. Okarma, O. Ionescu, Y. Dovhanych, S. Find'o & L. Boitani. 2002. Hunting legislation in the Carpathian Mountains: implications for the conservation and management of large carnivores. Wildlife Biology, in press.

Voloscuk, I. 1999. The National Parks and Biosphere Reserves in Carpathians: The Last Nature Paradises. ACANAP Tatranska Lomnica, Slovak Republic. 248 Pp.

Witkowski, Z. 1999. The Carpathian Mountain Range as an ecological system within the Pan-European Ecological Network. - In: P. Nowicki (Ed.) The green backbone of Central and Eastern Europe, ECNC Netherlands, pp. 161-173.

APPENDIX I

Methods used for analysis

Pre-processing – Modelling areas for conservation of each species

The approach defines the ecological conditions in terms of multidimensional space, within which the target species are present. It then extracts the environmental characteristics of the locations where bears, lynx and wolves have been recorded. Averaging the values of environmental variables found at each location would provide with an estimate of the mean environmental characteristics that each species requires for being present. Such average environmental characteristics can be considered the "ecological signature" of each species. Comparisons between the ecological signature and the ecological characteristics of any other location within the study area allow the establishment of some kind of suitability degree based on the difference between them. Thus, the greater the difference between any given location *A* and the ecological signature, the lower the suitability degree assigned to *A*.

Such an approach was applied using the Mahalanobis multivariate distance for each one of the three species. The three resulting maps showed areas of the Carpathians associated with increasing degrees of environmental suitability. The modelling process is continuous probabilistic, thus each suitability class (resulting from a slicing process through setting thresholds) could be read as a probability for the species' potential presence. The outputs of such modelling phase were the starting point for analyses that constituted the work presented in this report. The reader is encouraged to refer to the IEA website (http://www.ieaitaly.org) for a display of the maps for each one of the three species.

Processing – Pooling the outputs for the three species

The processing phase involved three sequential steps and they were the same used by IEA (1999):

1. The three outputs of environmental suitability for bear, lynx and wolf were standardised by subtracting their average value and dividing by their standard deviation. This was necessary because each species has environmental requirements that are particular to its ecological characteristics and do not necessarily coincide with the requirements of the others[1]. In the light of these species-specific differences, it is stressed that any comparison made between the outputs relative to different species has no intellectual meaning, as the values of ecological distance are different (Corsi et al., 1999). This means that a value of 100 for one species does not compare to a value of 100 for another species, as the starting points are different. Standardising the models allows the comparison of the actual variability of the environmental suitability.

2. Once the models were standardised, they were superimposed and a principal component analysis (PCA) was performed in order to minimise the number of variables necessary to build a model that represented the three species at once. The PCA extracts components that account for different percentages of the total variance of the set of variables considered[2]. Each factor extracted is uncorrelated to the others and correlates to the original variables. The advantage of the PCA outputs is that it allows the analyst to use the factor that explains the highest percentage of variance instead of the set of original variables, thus rendering the analytical process less complicated and transferring it from the multivariate to the univariate dominium. One of the constraints of the PCA is that the first factor not always is well correlated with all of the original variables, thus rendering the ecological interpretation of the results very difficult. In the present analysis, the original variables were highly correlated within each other; therefore the first component extracted by the PCA was highly correlated to each one of them.

3. The last step of the analysis deals with the slicing process of the continuous values of suitability by setting thresholds. Seven classes were produced based on the values recorded at the locations of

---

[1] As a reminder, such requirements were estimated by averaging the environmental conditions found in the locations where the species' presence was recorded.

[2] In the present case, the models of environmental suitability for each species represent the variables.

species' presence. The values of suitability were extracted from the model resulting from the combination of the three models. Their mean and standard deviation (SD) were used in the following way:

- Class 1 = 0 up to the mean
- Class 2 = mean
- Class 3 = mean + 1SD
- Class 4 = mean + 2SD
- Class 5 = mean + 3SD
- Class 6 = mean + 4SD
- Class 7 = mean + > 4SD

In this way the thresholds take into account the values of environmental suitability in the areas of observed presence of the three species, taking into account the synergetic nature of the approach.