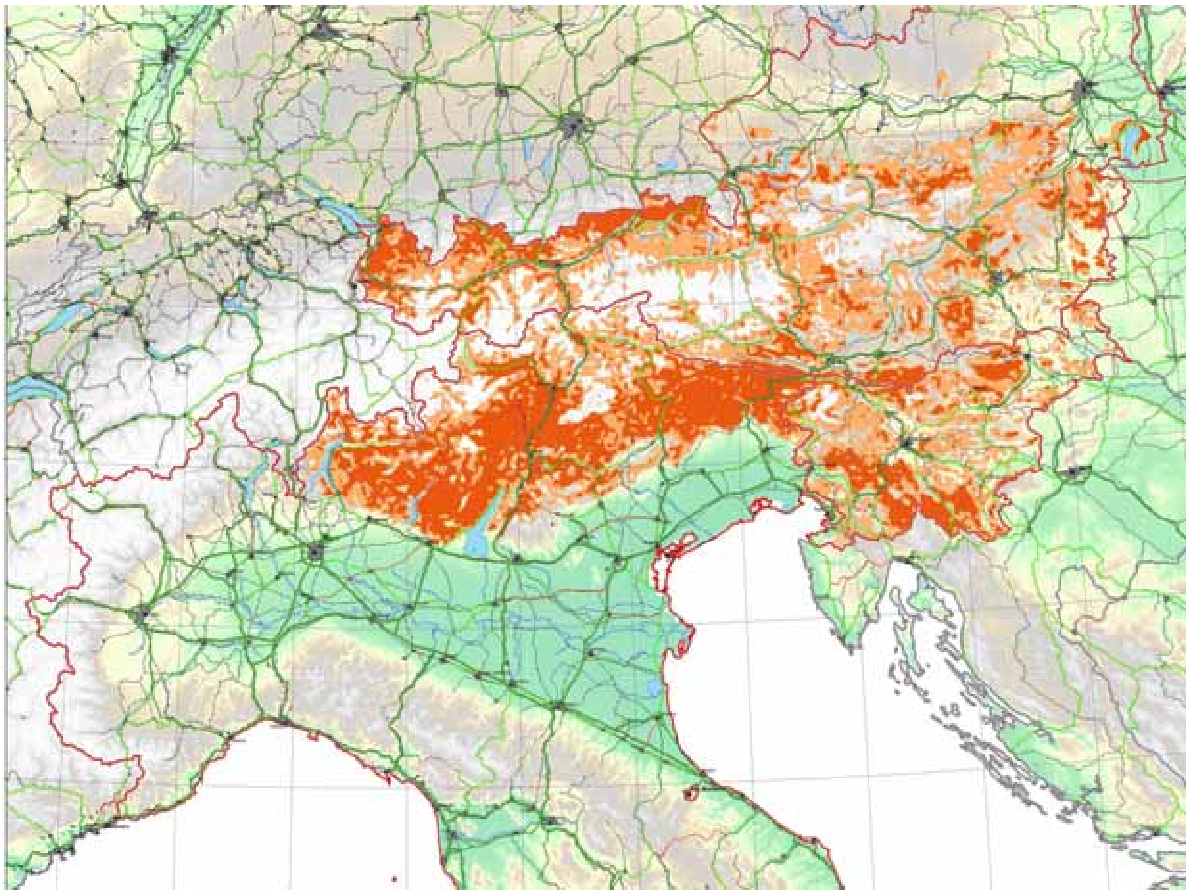
LIFE-Nature Co-op Project
"Principles for the establishment of an
Alpine brown bear metapopulation"

Action A.2

Analysis of possibilities of establishing a brown bear metapopulation



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Analysis of possibilities of establishing a brown bear metapopulation

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CONTENTS

1. PREFACE

The present document was compiled thanks to EU contribution in the framework of a LIFE Co-op project aimed at assessing the possibilities of a steady establishment of bears on Central-eastern Alps ("*Principles for the establishment of an Alpine brown bear metapopulation*").

This report represents the realization of Action A2 (*"Analysis of possibilities of establishing a brown bear metapopulation"*) of the project, which is carried through by Adamello Brenta Natural Park and, as partners, by Slovenian Republic Forest Service, WWF Austria and University of Udine (Veterinary Faculty, Animal Production Sciences).

In particular, the action was realized thanks to the Environment-Health and Security Department of Insubria University (Natural Resources Analysis and Management Unit), which edited all the analysis that brought to the presented Environmental Valuation Model.

The work goal is to identify and apply a modelling procedure to identify suitable areas for bears on the Alpine territories of Austria, Italy and Slovenia.

We must consider that elaborating statistical models of the potential distribution of species is often a difficult task. In fact, in order to obtain a working and reliable model, a good knowledge of habitat preferences of the studied species is essential. The task is even harder if, as in the present work, the Model aims to valuate the possibilities of expansion into areas of potential future occupation. In this case, in fact, also detailed information on the investigated population dynamic is necessary.

For bear, a species capable to modulate either environmental preferences or its population dynamic according to geographic characteristics of the study area, rarely this information is known with the requested precision.

However every modelling process phase has been planned and realized in order to produce easily suitable material as help in supporting decisions in planning conservation of brown bear strategies and interventions.

The Action A.2 expected outcome is the production of a predictive model, in cartographic form (maps), which will allow to identify suitable areas for bear expansion in the near future.

The model outcomes are an important base on which evaluating the possibility of creation of an alpine metapopulation, i.e. a set of cores exchanging periodically individuals who are able to promote a genetic flow.

This situation would be without any doubt an advantage for the conservation of a species like brown bear, considered a priority in the environmental politics of European Union.

This report is addressed to non-technical persons and stakeholders involved in planning and policy-making.

For this reason we tried to summarize the most possible the part of the text over the analysis techniques which brought to the Environmental Evaluation Model (SEPM), giving more room to the description of its outcomes. A choice like this one has been dictated from the wish that the document may be an useful instrument at the sensitization of territory stakeholders towards possible bear arrival in their administrative competence areas.

Model has arrived to assume bear potential “movement path” (corridors) from present occupation area to the ones assumed to be suitable for their presence according to the territory analysis realized.

The present document was compiled on behalf of argumentations shared by all partners of present LIFE Co-op project who have shared all their data and during many workshops discussed in a profitable way the initiative details.

In the same way it was particularly useful the experience developed in the last years from the Natural Resources Analysis and Management Unit of Environment-Health and Security Department of Insubria University about environmental models referred to alpine mammals populations.

2. METODOLOGICAL OVERVIEW

2.1 Study area

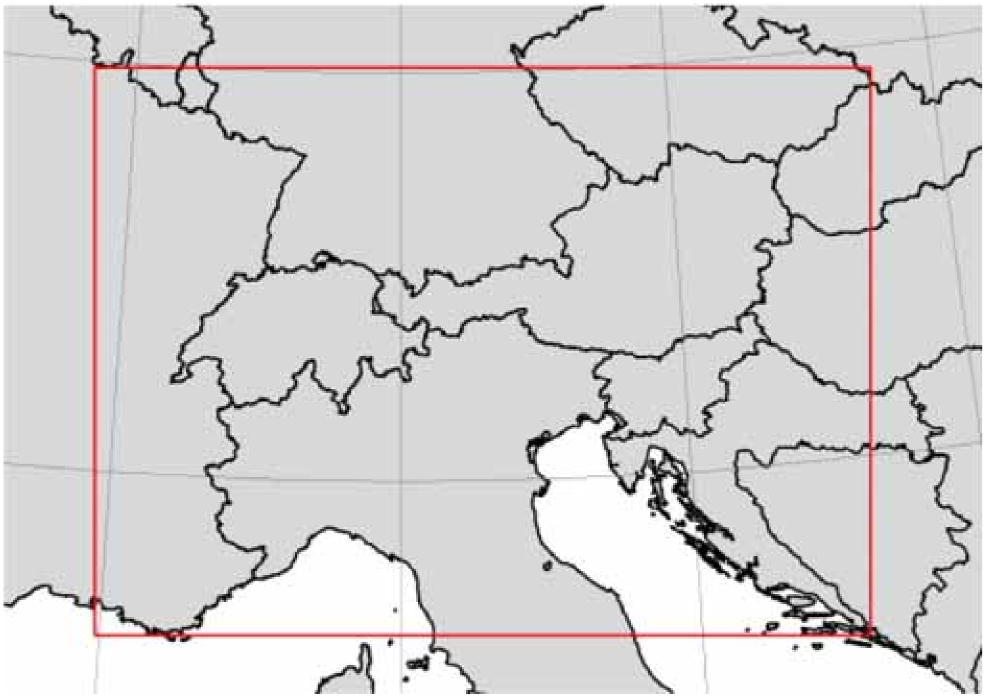

Figure 1: Study area geographic position.

The area chosen as modelling arena includes completely the national boundaries of Austria and Slovenia, and encompasses the entire Alpine part of Italy (Figure 1). Its approximate extent is from 4°E to 18°E and from 43°N to 50°N. Due to geographical coverage of available data, all the modelling effort has been concentrated on a smaller area, containing the entire Austrian and Slovenian territory, and only the Alpine and pre-Alpine part of the Italian territory.

2.2 Base dataset

2.2.1 Reference System and Spatial resolution

All data used were kindly supplied by Co-op partners, in their own national coordinate reference systems. Due to the wide geographical extent of the area interested by the modelling process, all data underwent an harmonization phase and were patched in a mosaic and re-projected into a common European coordinate reference system (ETRS-LCC). CORINE land cover data were supplied by the EU and harmonized with the rest of the geographic dataset.

We decided to operate at a minimum spatial resolution of 250 m, that is all the data describing study area as well as model outcomes are referred to a minimum square unit (called *grid cell*) with 250 m side length. Considering the extent of the study area, this is a fine-grained resolution, useful to discriminate at a local scale which areas can be actually used by bears, both in terms of suitable areas and in terms of non-habitat corridor areas.

2.2.2 Bear data

As stated in Section 1, each Co-op partner contributed with its own data to the creation of an uniform bear location dataset, counting 10582 bear locations obtained by radio-tracking on a total of 42 animals. A second dataset related to bear presence has been set up as well, composed by bear sightings locations (bear tracks or other presence signs, bear damage data, etc.). This dataset has not been used in modelling, since all Co-op partners were aware that these data were biased, since sightings and easy recognizable tracks are most often found in open areas, or anyway in areas not properly intensely used by bears.

Space use and home-range analysis conducted on the radio-tracking dataset allowed us to better understand not only home-range size and seasonal variation, but also to estimate some movement parameters needed by the simulator software.

2.2.3 Habitat data

Geographical data used as environmental variables in the Logistic Regression modelling phase (outlined in Section 4.1) can be referred to the following categories:

morphology: mosaic of Digital Elevation Models for Austria, Italy and Slovenia;

land cover: CORINE *Land Cover*;

human pressure: road network (limited to main roads down to provincial level); railways; inhabited areas (derived from CORINE *Land Cover* dataset).

From the geographic data summarized above, 87 derived habitat descriptors have been calculated, and used as input data in the Logistic Regression.

3. MODELLING STRATEGY

The techniques used to obtain predictions on bear habitat suitability and future expansion possibilities are based on standard statistical methods and automated cartography, in an integrated approach where Geographical Information Systems (GIS) and numerical simulation of population dynamics are used together.

Classical population dynamics numerical simulations often ignore the spatial context, giving only results dealing with the variation through time of the number of animals. On the other hand, GIS techniques deal with the spatial meaning and representation of data, often not taking into account the temporal and dynamic aspects. The joint use of both techniques made possible to have an insight of population dynamics in time and space, which constitute a sound basis to define plans and strategies to manage brown bear in Central-eastern Alps. To achieve effective management plans, in fact, the main questions to be addressed are often of the following kind:

- *where* a population will expand?
- *When* a population distribution will reach a given area?
- *How many* individuals will be present at a given time in a given area?

In this particular case, special attention has been addressed at the first two questions, considered of bigger interest to strategic planning and policy making.

4. MODELLING TECNIQUES

The model development strategy has been chosen taking into account two different targets: first, to predict suitable for bear zones inside study area (not considering dynamic aspects such as distribution variations through time or population dynamics); and second, to model bear expansion and movement to and from suitable habitat patches.

Thus the modelling process involved two distinct phases: a static one, dealing with potential species distribution and habitat suitability, and a dynamic one, dealing with bear movement to and from suitable habitat patches and bear population growth.

Several different techniques are available to obtain both static and dynamic models. For static modelling of habitat suitability we used logistic regression (LR), a widely available and used statistical tool. For dynamic population modelling a software program has been expressly written to simulate bear movements and population dynamics.

Both techniques were applied in a spatially explicit fashion coupling standard statistical modelling techniques with the use of GIS.

4.1 Logistic regression

Logistic regression is a multivariate statistical technique which can be used to predict the probability of presence of a species (called the response variable or dependent variable) depending on the values assumed by several environmental variables or independent variables which in turn describe some peculiar aspects of the study area.

A logistic model is calculated starting from a set of GIS themes, each one quantifying a precise study area trait such as elevation, aspect, land cover, distance from roads, etc. The number of themes used can vary, and often more themes than needed are used during the model building process, trying to select the subset of environmental which better predicts species presence. Once a model has been fitted, the model equation is applied to the original GIS themes in order to produce a new theme which can be read as a species probability of presence map.

An useful by-product of a logistic model consists of the list of significant environmental variables, along with their so called *odds ratio coefficient*, which explain the importance of each environmental characteristic in determining species presence.

Environmental variables significance in predicting species probability of presence is assessed against known species presence and absence data, represented by point locations: in this case, the main concern is how to select ”absence” points, since the only known fact, when dealing with species distribution, is species presence.

In our case, presence point locations have been obtained considering ’true’ bear point locations obtained in three independent radio-tracking studies (one for each Coop partner Country, for a grand total of more than 10000 point locations).

”Absence” points are far difficult to obtain, since true species absence in certain zones of its distribution is difficult to assess. In the present case a random sample of point locations has been generated over the entire study area, and the logistic model we obtained compared habitat actually used by the brown bear (and thus actively selected by bears) with randomly chosen sites.

Several preliminary logistic models have been fitted, treating separately data from each Co-op partner and also pooling together all bear observations: each single model performance has been carefully scored using routine statistics such as the Akaike and Bayes Information Criteria (AIC, BIC), often applied to choose the ”best” model, both in term of significance and number of parameters, looking for a trade-off between statistical significance and parsimony.

4.2 Cellular Automata

In the last few years computing power increase has made possible to effectively write and use computer programs able to simulate single individuals’ behaviour, both in wide geographical areas and with high number of simulated animals.

In this study, a dedicated simulator has been written, modelling bear movement patterns on a habitat suitability basis, and also taking into account a simplified version of the population dynamics phenomena.

Basically, the simulator software tries to reproduce bear movements over the study area, simulating movement constrained by habitat quality, represented by the ”probability landscape” obtained from Logistic Regression modelling. Animals move and interact on a monthly basis, taking into account not only seasonal patterns, but also the possibility for an animal to act according to different ”strategies”. From original radio-tracking data analysis we observed in fact two different movement tendencies, not dependant on sex, age or geography, and tried to transfer into the simulator software both ”settler” and ”mover” behaviour.

The simulator output will help to identify not suitable areas prone to be used by the expanding population as corridors connecting good habitat patches, and also to obtain some information on the temporal dynamics of bear future expansion in Central-eastern Alps.

5. RESULTS

Modelling process results are synthesized in the potential distribution map (see enclosed map), where both suitable for bear areas and potential corridor areas are evidenced. The best obtained model depends on 24 environmental variables listed in the following table:

Variable	***Odds Ratio***
Percentage of urban areas[1] (COR7 100)	1.12842
Percentage of orchards (COR7 220)	1.15205
Percentage of pastures (COR7 231)	1.04504
Percentage of agricultural mosaic (COR7 240)	1.07474
Percentage of agricultural semi-natural areas (COR7 250)	1.01751
Percentage of broadleaf forest (COR7 311)	1.10648
Percentage of coniferous forest (COR7 312)	1.12070
Percentage of mixed forest (COR7 313)	1.14787
Percentage of grasslands (COR7 321)	1.08987
Percentage of heath lands (COR7 322)	1.09103
Percentage of shrub lands (COR7 324)	1.16143
Percentage of rock (COR7 332)	1.09775
Percentage of sparsely vegetated areas (COR7 333)	1.04096
Distance from populated places (m, D PPEERS)	0.99992
Distance from railroads (m, D RAILSEER)	1.00005
Distance from roads (any kind) (m, D RALLEERS)	1.00004
Distance from high traffic roads (m, D RHWEERS)	0.99996
Distance from local roads (m, D RSPEERS)	1.00006
Forest patch shape index (F SHAPE)	1.00784
Longitude (XCOORD)	0.00001
Longitude *x* Latitude (XY)	5.20767
Longitude, second & third order effects:	
Longitude (X3)	1.06616
Longitude and latitude (X2Y)	0.95320
Longitude and latitude (XY2)	0.98909

The variables listed have a different influence on model outcome (i.e. on the probability of presence): odds ratio coefficients explain the influence that the variation of a single environmental variable exerts on determining (or not) bear potential presence. Odds ratio value indicates that an increase in distance from high traffic roads and inhabited areas will raise bear probability of presence, as well as an increase in mixed forests, shrub lands, and orchards will raise bear suitability.

[1] calculated on a 10 km square neighbourhood (it is worth for the first 13 environmental variables)

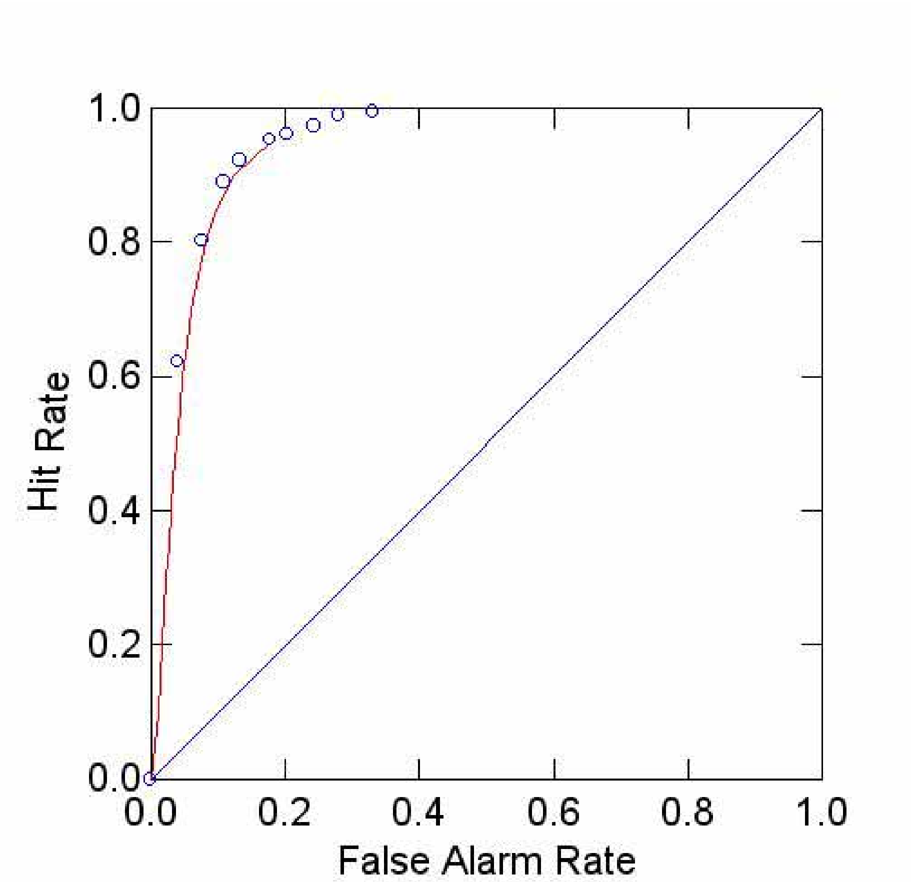

Figure 2: ROC (*Receiver Operating Curve*) for the logistic regression model.

Logistic Regression output consists usually in a map containing a continuous range of probabilities between 0 and 100%. This kind of output is more easily understood if it is classified into just two classes: potential presence and potential absence. The problem is then how to split a continuous range in a meaningful fashion. We used a standard technique, called *Receiver Operating Curve Analysis* (ROC for short, Figure 2), that allows to choose the "cut-point" guaranteeing that a predetermined level of confidence is maintained.

In this study, the best LR model obtained had an overall classification accuracy of 94.1%, and the "cut-point" used to define presence areas has been chosen in order to have a 95% of correct classifications, keeping at the same time the rate of "false positive" (not valid cells classified as valid) as low as possible (17%). This means that for a 250 m square cell classified as potentially suitable for bear you can be confident that there is a 95% probability of having correctly classified that cell, and a 17% probability that cell has been misclassified as suitable when in fact it is not.

6. CONCLUSIONS

The applied model outputs how the investigated area offers remarkable development possibilities to the present bear population living in Slovenia, Austria, Trentino and in the three states boundary enclosed territory (Tarvisio – Southern Austria – Northern Slovenia).

Looking at the enclosed map it is evident how, although bear nucleus present at the moment are exiguous (with the exception of Dinaric – Slovenian population which is estimated at the moment in 450-550 individuals) and occupy a limited area, species potential presence suitable areas are widely extended. This makes enables to think that the populations studied have a great future development possibility both in territory that, consequently, in number. Four considered nucleuses are likely to reach independently such dimension that keeps them safe from the extinction in medium and long period.

Besides, the applied model evidences the presence of various areas, not suitable from environmental point of view for the stable presence, but that can be considered suitable for the bears passing. These transition areas can be corridors connecting stable presence areas and allowing the establishment of a metapopulation (intended as a composed from more distinct groups of animal population, geographically separated, but capable of interacting one with the other with reciprocal exchanges of individuals). Through the corridors, in other words, bears will manage to move from one area to the other, moreover allowing individuals (and genes) exchanges among nucleuses otherwise isolated, and therefore making possible the reaching of species typical genetic variability.

In this sense we must also remind the species great movement abilities, allowing to travel dozen of kilometres by a single day and use completely the corridors. In detail, the following two-ways corridors seem to be evident:

Corridor path		Geografic interested area
1	East “Slovenia-Austria”	From Southern Slovenia forests (West core area part - Kočevje Reserve) going to North, passing East of Ljubliana and South-West of Maribor. From here passing North-West Slovenia-Austria boundary you enter in Austrian Steiermark with a curvilinear path West and North of Graz.
2	West “Slovenia-Austria”	From Southern Slovenia forests (West core area part - Jelen-Sneznik Reserve) going to North to Triglav area, as far as ideally connected with the corridor number 3 of the present table.
3	“Slovenia-Austria” boundary	Near and along Slovenia – Austria boundary: northern than Ljubliana, Southern than Klagenfurt, quite as far as two Austrian Länder Carinzia (Kärnten) and of Tirol. This corridor can be intended in continuity with the ones reported with number 1, 2, 4 and 5 of the present table.
4	East-West “Slovenia-Italy”	Huge bear movements potentially suitable area, starting from Southern Slovenia (Western core area part) and developing North-West. Beyond Slovenia-Italia boundary, passing from Friuli and Veneto to get to Trentino.
5	East “Italy-Austria”	On the Italian-Austrian border line (boundary between Friuli-Venezia-Giulia and Veneto regions) going to North with curvilinear path open to West, in the Western part of Austrian Land of Kärnten to Salzburg Land.
6	Centre “Italy-Austria”	From Cadore (BL) towards Bolzano province going up along Isarco Valley. From Vipiteno, towards Brenner pass, in Austria as far as Innsbruck (Tirol).
7	West “Italy-Austria”	In Tirol, along Adige valley, western of Bolzano, along Venosta Valley to Engadina at one side and to Western Austria end at the other.

Corridors listed in the table below must not be intended as the only walkable areas for bears, but more simply as the ones where, according to the identified model, probabilities of their passages are higher. Also for this reason the graphic corridor representation do not report detailed indications and do not supply information about the same corridors width. It is thus evident its only descriptive value.

We must at least consider that the present study, in order to verify the possibilities of establishment of a metapopulation among currently present nucleuses, limited the model application area at Central and Oriental Alps, i.e. at the territory enclosed in the triangle obtained joining existing bear populations. For this reason it is likely that even outside of the studied area there are wide bear suitable territory and, as a consequence, species future development along other portions of the Alps is possible.

Eventual areas in which environmental suitability result not very in harmony with the expectations of people who know the territories can be explained as model errors, owing mainly to the wide territory scale and to the heterogeneity of environmental patches on which it was applied.

Nevertheless it outcomes that current environmental and anthropic attributes of the studied area can be considered suitable at the setting-up of a bear metapopulation. It must be however considered that population dynamic factors, capable to condition this possibility are little predictable in time. In particular, all the factors increasing direct mortality of the animals will have to be carefully examined.