Action A.2

Analysis of possibilities of establishing a brown bear metapopulation

Final Report

LIFE CO-OP NATURE PROJECT
"Principles for the establishment of an Alpine brown bear population"
LIFE2003NAT/CP/IT/000003

ACTION A.2 of the project, assigned and financed by European Commission to **Adamello Brenta Natural Park** (beneficiary)**, Slovenia Forest Service – Department for Wildlife Conservation and Hunting** (partner)**, Department of Animal Production Science - University of Udine** (partner), **WWF Austria** (partner).

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Preface

The present document was realized 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 A.2 (*"Analysis of possibilities of establishing a brown bear metapopulation"*) of the project, which has been conducted by Adamello Brenta Natural Park (beneficiary), Slovenia Forest Service – Department for Wildlife Conservation and Hunting (partner), Department of Animal Production Science - University of Udine (partner), WWF Austria (partner). The present action was realized thanks also to the Environment-Health-Security Department of Insubria University (Natural Resources Analysis and Management Unit), which performed all the analysis for the realization of the presented Environmental Valuation Model. The experience developed, in the last years, by this University Research Institute about environmental models referred to alpine mammals populations appeared as a guarantee for project success.

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

Every modelling process phase has been planned and realized in order to produce a tool which can be of help in supporting decisions for planning strategies and interventions for brown bear conservation.

Action A.2 outcome is a predictive model, in cartographic form (maps), which allows to identify suitable areas for bear expansion in the near future.

But first of all, the "pictures" of the bear suitable habitat are intended as a tool to evaluate the possibility of creation of an alpine metapopulation (i.e. a set of bear "core areas" which can periodically exchange individuals one with the other, promoting in this way a genetic flow).

This situation would be undoubtedly essential for the conservation of a species like brown bear, referred to as "priority species" in the environmental politics of European Union (Habitats Directive 92/43 CEE).

For this reason, the present report is not addressed only to technicians but also to stakeholders and to anybody who is involved in planning and policy-making.

We tried to be as concise as possible in the part of the text regarding the analysis techniques which permitted the elaboration of the Environmental Evaluation Model, in order to leave more room to the description of its outcomes. This choice comes from the wish that this document may be a useful instrument for the sensitization of territory stakeholders towards possible bear arrival in their administrative competence areas.

The model has assumed the existence of bear potential "movement paths" (corridors) going from present occupation areas to the areas assumed to be suitable for bear presence according to the territorial analysis realized.

This work was realized thanks to a preliminary sharing of datasets collected in last years by beneficiary and partners of the project.

In order to find the adequate criteria for data harmonization and analysis, two meetings and a forum on-line were necessary.

Notwithstanding these initial agreements, in the last phase of the work some criticisms about methodology and modeling results were brought. In particular, WWF

Austria manifestly and evidently criticized some technical steps that have been used to realize the Environmental Evaluation Model that is here presented.

On the contrary, Slovenian (Slovenia Forest Service) and Italian (Adamello Brenta Natural Park and University of Udine) participants to the project agreed with the most relevant steps of the technical work realized by Insubria University.

In any case, it must be underlined that, thanks to the constructive contribution of WWF Austria, an intense technical debate was carried on: this has permitted to evidence that, at European level, more "schools of thought" about applied research for modelling purposes exist.

In the conviction that also such a debate can be considered a useful output of the present LIFE Co-op project, in Annexes A.2 of the "Technical final report" of the project all the emails useful to better comprehend the technical argumentations that took place among the partners during and after the elaboration of the models are collected.

Unfortunately, as better explained in the conclusions of present document, the Environmental Evaluation Model realized has not been subscribed by WWF Austria, as WWF Austria notices a low correspondence between the model and brown bear distribution in Austria.

On the contrary, the Model seems to be precise enough in describing brown bear environmental suitability for Slovenian territory and for north-eastern Italy.

In order to better understand such a discrepancy, after the elaboration of the first model, other technical possibilities have been considered and consequent maps of environmental suitability have been realized. The outputs of these new analyses, which by the way evidence similar scenarios, are reported in the following section of the present document, realized by Insubria University. In the conclusions of the present document some more details about the results of the technical work realized are given, together with hypotheses about the above mentioned problems encountered.

It is important, moreover, to consider that elaborating statistical models of species potential distribution is often a difficult task, especially when such models are realized on a wide and heterogeneous territorial scale as in the present project.

It cannot be excluded also that the environmental characteristics of the different areas where data were collected have caused different criteria of collection of the data of bear presences on which the model is based.

Besides these territorial problems, we have to consider that, 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 brown bear, a species greatly capable to modulate its environmental preferences according to ecological characteristics of different areas frequented, this information is probably not enough known.

In this context, a lack of knowledge about brown bear population dynamics has especially been evidenced. This also because in bibliography few data, often discordant, are available.

The hope is thus that, in the next future, specific scientific researches will be promoted in order to deepen the knowledge about the ecology of this species, which is definitely scarcely known if compared to other "big" alpine mammals such as ibex, roe-deer, etc.

In summary, concerning the main goal of the present LIFE Co-op project

(“*Principles for the establishment of an Alpine brown bear metapopulation*”), it can be stated that, besides the above mentioned difficulties and technical discussions, the project reached its finality which is to show that the possibility to create a metapopulation of brown bears on the study area exists.

Analysis of possibilities of establishing a brown bear metapopulation

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This report is written by **Insubria University (Varese – Italia)** on the basis of the convention between the beneficiary and the Research Institute stipulated on May 25th, 2005 with a mandate to realize an "Analysis of possibilities of establishing a brown bear metapopulation in the study area of the project".

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1 OVERVIEW

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 estabilishment of bears on Central-oriental Alps: its goal is to identify and apply a modelling procedure to identify areas suitable for bears on the Alpine territories of Austria, Italy and Slovenia.

The outcomes of the model produced will allow to identify areas suitable for bear metapopulation expansion in the near future.

This report is thus addressed to all technicians interested in habitat suitability evaluation and to non-technical persons interested in predicting the development of the Central-oriental Alpine brown bear populations.

The present document was compiled on behalf of argumentations shared by all partners of present LIFE Co-op project —Adamello Brenta Natural Park, Slovenia Forest Service – Department for Wildlife Conservation and Hunting, Department of Animal Production Science - University of Udine, WWF Austria — who have acquired experience in bear conservation and management in the last decade.

2 INTRODUCTION

Modelling potential species distribution is a daunting task: in fact, to implement a working model, a sound knowledge of species population dynamics and habitat preferences is mandatory.

Unfortunately, this is just an ideal situation, beacuse often some vital information is missing or still unknown, even in the case of “well-known” species, such as the brown bear.

On the other hand, if a modelling effort is required, model outputs should be reliable at the decision and policy-making level, given the constraints determined by information and knowledge availability.

The expected result of Action A.2 is the production of a predictive model, in the form of a map, useful both to identify suitable areas for brown bear in the Central-eastern Alps, and to identify where the re-introduced populations will probably expand in the next years.

To achieve this goal, we decided to use Spatially Explicit Population Dynamics Models (SEPMs) (Rushton et al., 1997), a methodology based on an integrated approach between GIS and numerical simulation of population dynamics. The following chapters present the methodology used, dealing with all the necessary steps and data needed to obtain a working model, and discuss the results obtained.

3 METHODS

3.1 Study area

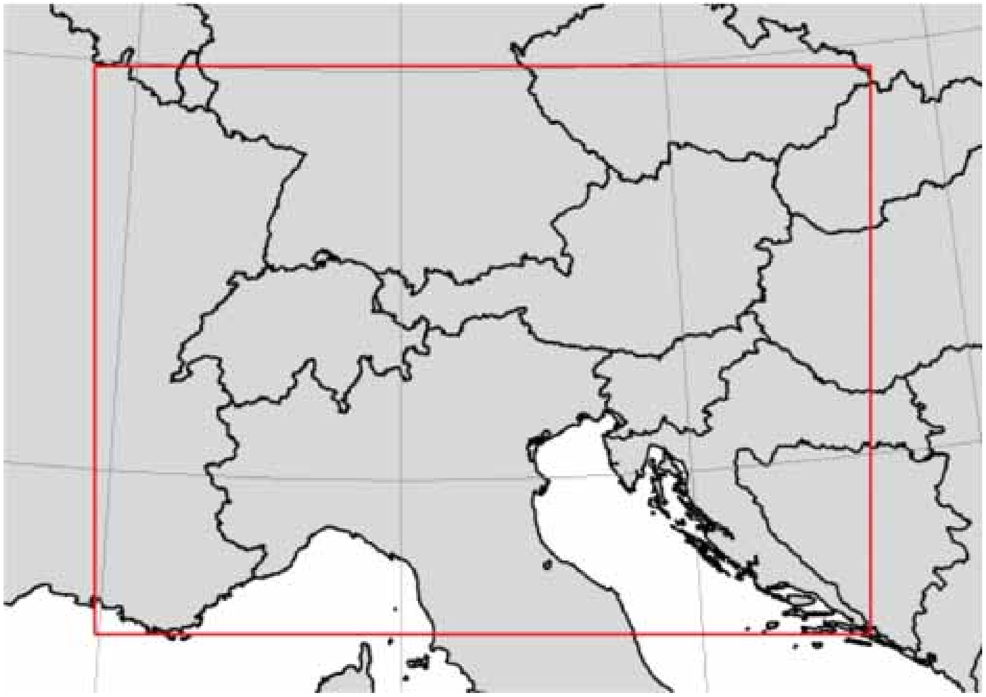

Figure 1 - Study area geographic position.

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.

3.2 Base dataset

3.2.1 Reference system and Spatial resolution

Due to the wide dimensions of the proposed study area, it was almost impossible to fit everything into a single national coordinate system (CRS) without substantial distortions.

Anyway, it was expected that geographical data were supplied by each partner in their own national CRS. To deal with these two constraints, we decided to use a common CRS, choosing among those proposed by the EU, and to reproject all geographic data from their original national CRS into the common CRS. This solution made it possible both to work in a common CRS, and to export data in any projected system (included national CRSs for each Co-op partner) with minimum effort.

Table 1.: ETRS-LCC Coordinate Reference System parameters.

Datum:	GRS80
Projection:	Lambert conformal conic, 2 standard parallels
Lower parallel:	35_N
Upper parallel:	65_N
Origin latitude:	52_N
Origin longitude:	10_E
False northing:	2 800 000 m
False Easting:	4 000 000 m

The selected CRS, chosen among those recommended by the EU, ETRS-LCC (CRS-EU, 2005a), whose specifications are reported in Table 1.

All national geographic data sets and coverages have been prepared by each partner according to its own national CRS, according to the proper specifications listed in CRS-EU (2005b). Six ARC/INFO projection files have been prepared in order to simplify the process of data conversion from and to ETRS-LCC and each one of the national CRS.

3.2.2 Spatial resolution

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 can be accounted as a fine-grained resolution.

Several other models have been produced to predict bear distribution in Europe, but they cover small areas, or use a coarser spatial resolution (Posillico et al., 2004; Jerina et al., 2003; Wiegand et al., 2004). We thought useful to discriminate at a local scale which areas can be potentially used by bears, both in terms of suitable areas and in terms of non-habitat corridor areas, so we set the spatial resolution at a 250 m, the same as CORINE Land Cover (Commission of the European Communities, 1993).

3.2.3 Habitat data

Geographical data used as environmental variables in the Logistic Regression modelling (outlined in Section 3.5.1) can be attributed to the following categories:

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

land cover: CORINE Land Cover (CLC90 dataset, version 12/2000)[1];

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[1] Proper permission to use CLC90 datasets has been granted from the European Environment Agency - Information Centre.

human pressure: road network, limited to main roads down to the provincial i.e. NUTS 3 level (Council of the European Communities, 2003); railways; inhabited areas (derived from CORINE Land Cover dataset).

geographic position: latitude and longitude, taking into account their e_ect up to the third order, that is using squared and cubed values; distance from Slovenian core area.

From the geographic data summarized above, 87 derived habitat descriptors have been calculated, and used as input data in the GLM + LR process. A complete list of variables is reported in Table 2.

Conversion of vector data to raster format

All variables cited in Table 2 as expressed as percentage of presence in a given grid cell — such as aspect or each one of the reclassified CORINE Land Cover classes — have been calculated in ARC/INFO Workstation GRID over two different moving window of about 2 and 10 km^2, to take into account short- and medium-scale habitat perception by the species.

DEM-derived descriptors — such as aspect and percentage of presence for each different aspect class — have been calculated using ArcInfo Workstation Arc and GRID standard procedures (McCoy, 2004).

Reclassification of CORINE Land Cover data

The 50 original CORINE Land Cover classes have been grouped in a superset functional to known brown bear ecology, with the agreement of the partners, in a participative fashion, discussing alternatives on the collaborative World Wide Web portal and perfecting class grouping in technical meetings. CORINE Land Cover reclassification has been done with the aim of reducing the number of variables to be used in the models, grouping them according to the relevance of difference among classes, based on knowledge on brown bear ecology and biology. A comprehensive list of orignial CORINE Land Cover classes and their correspondance with the classes used in this work is reported in Annex A.

Evaluation of habitat fragmentation

As forests are considered the primary habitat for bears (see Kobler and Adamic 2000; Zajec et al. 2005 among others), we hypothesized that shape, extent and distance of forested areas could influence brown bear presence. As a consequence, we grouped together all the three CORINE Land Cover forest classes ("Mixed", "Broad-leaf" and "Coniferous") and calculated five di_ernet landscape metrics for the new general "forest" class. For each clump of continuous forested area, we calculated the following landscape features: size, patch size relative to all available forests, perimeter/area ratio, contiguity index, and shape index. Contiguity is an index of spatial connection based on patch boundary configuration, shape index gives a value to the complexity of patch shape compared to a square and perimeter/area ratio is a measure of patch fragmentation. All the cited landscape metrics have been evaulated according to McGarigal and Marks (1995).

Evaluation of geographic trend and distance from core areas

Spatial correlation is an issue, especially when dealing with wide study areas (Legendre, 1993), as it is in the present case, where the area of interest is characterised by an n extent greter in longitude than latitude, see Figure 1. Therefore, we introduced geographic coordinates (i.e. the "geographic trend") as variables in the model.

The geographic trend is commonly represented with the three roots of a cubic equation containing both East and North coordinates, i.e. as the roots of $(\mathit{Longitude} + \mathit{Latitude})^3$, in order to test positional effects up to the third order (Rondinini, 2003). We found more convenient to express geographic position in decimal degrees (geographic coordinates) instead of ETRS-LCC metric coordinates to represent the geographic trend, in order to reduce collinearity.

Table 2.: List of all the variables used to describe habitat. The sum is less than 87 because all variables expressed as a percentage have been calculated on two different neighbourhood, but are listed only once. See text for details.

Class	**Parameter**
Morphology	Elevation (m a.s.l)
	Aspect (degrees)
	Percentage of cell with East aspect
	Percentage of cell with North aspect
	Percentage of cell with North-East aspect
	Percentage of cell with North-West aspect
	Percentage of cell with South aspect
	Percentage of cell with South-East aspect
	Percentage of cell with South-West aspect
	Percentage of cell with West aspect
	Percentage of cell with no aspect (flat)
	Solar radiation (MJ cm-2 year-1)
Land cover[2]	Percentage of urban areas [100]
	Percentage of sparsely urbanised [121]
	Percentage of road railways [122]
	Percentage of green urban areas [140
	Percentage of Irrigated land [210]
	Percentage of Arable land [211]
	Percentage of irrigated land [212]
	Percentage of Orchards [220]
	Percentage of Pastures [231]
	Percentage of Agricultural mosaic [240]
	Percentage of Agricultural seminatural [250]
	Percentage of Broad-leaf forest [311]
	Percentage of Coniferous forest [312]
	Percentage of Mixed forest [313]
	Percentage of Grasslands [321]
	Percentage of Heat-lands [322]
	Percentage of Sclerophyllous [323]
	Percentage of Shrub-land [324]
	Percentage of Beaches [331]

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[2] Numbers in square brackets indicates reclassified CORINE Land Cover code.

	Percentage of Rock [332]
	Percentage of Sparsely vegetated [333]
	Percentage of Burnt areas [334]
	Percentage of Glaciers and snow [335]
	Percentage of Marshes [410]
	Percentage of Coastal areas [420]
	Percentage of Inland waters [510]
	Percentage of Sea [530]
Human pressure	Distance from populated places
	Distance from railways
	Distance from any kind of road
	Distance from highways and other high-traffic roads
	Distance from federal and regional roads (medium-traffic roads)
	Distance from local and other low-traffic roads
Landscape metrics	Size of contiguous forested areas (km^2)
	Forest patch shape index
	Forest patch contiguity index: 0 < *index* < 100
	Forest patch ratio: *perimeter/area*
	Forest patch relative size: *clump size/total forested area* × 1000
Geographic trend	Longitude
	Latitude
	(Second and third order effects)
	Distance from Slovenian core area
	Distance from nearest bear core area[3]

3.2.4. Bear data

Each Co-op partner contributed with its own bear location 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.). In a technical meeting, all partners agreed on not to use this data in modelling, since sightings and easy recognizable tracks are most often found in open areas, or anyway in areas not properly definable as "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.

3.3 Software tools

All processes involving GIS data harmonisation and manipulation have been performed in the ESRI ArcGIS ARC/INFO Workstation and ArcMap environments, version 9.0 (McCoy, 2004) and in ESRI ArcView GIS version 3.2 (ESRI, 1996); landscape metrics have been calculated using FRAGSTATS version 3.3 build 4 (McGarigal and Marks, 1995), a dedicated application for for quantifying landscape structures. Further statistical data analysis has been performed using SPSS SYSTAT statistical package, version 7.0 (Wilkinson, 1999). Dynamic model has been produced in the C++ language (Stroustrup,

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[3] Either Slovenian core area or reintroduction areas in Austria and Italy

1997) using the KDevelop Application Programming Environment, version 3.2.2 and the Geographic Data Abstraction Layer software library (GDAL, Warmerdam 2006).

3.4 Modelling strategy

The model development strategy has been chosen taking into account two different targets: first, to predict zones inside study area suitable for bear (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. Actually, the modelling process involved two distinct modelling phases: a static one, dealing with potential species distribution and habitat suitability, and a dynamic one, dealing with bear movement inside study area.

At present several different techniques are available to obtain both static and dynamic models. We chose to model habitat suitability (i.e. static modelling) using logistic regression (LR) (Hosmer and Lemeshow, 2000; Guisan and Zimmermann, 2000) coupled with General Linear Model (GLM, McCullagh and Nelder 1990) for variables pre-selection. The coupled use of GLM and LR (GLM + LR) is a widely available and used technique (Pearce and Ferrier, 2000), even if some other authors warn about using authomated methods (included GLM) for variable selection (Hastie et al., 2001).

Dealing with dynamic modelling, we chose instead to develop a specific software to model bear movements, based on potential habitat maps, to gain insight on future bear expansion.

In this case, the technique adopted is a derivation of the commonly used cellular automata (CA) modelling paradigm (Berec, 2002), in particular the application of CA to the simulation of single individuals, called Individual Based Model (IBM).

Both techniques were applied in a spatially-explicit fashion (Dunning et al., 1995), producing a Spatially Explicit Population dynamics Model (SEPM, Rushton et al., 1997) coupling standard statistical modelling techniques with the use of Geographical Information Systems.

The SEPM application realized here di_ers from Rushton et al. (1997) in the fact that single individuals had been modeled and as a consequence, movement has been modeled in more detail.

3.4.1 Spatially explicit bear expansion modelling

In developing a dedicated SEPM we mainly concentrated on movement simulation, since the main objective was to identify potential corridors and not to predict future population growth. Thus, major attention has been given to the movement patterns simulation engine and population dynamics has not been modeled with high detail. The simulatir accepts input data via a configuration file, that can be edited in order to change different parameters, according to season and possibile bear "strategy". The term strategy is used to refer to a complex of behavioural patterns, seasonally variable: for example, "mover" and "settler" bear can be modeled specifying different movement parameters.

The movement engine is derived from the work presented in Gardner and Gustafson (2004), and it is based on two random number generators (RNG for short, Press et al. 1991), derived from the widely used Mersenne Twister algorithm (Matsumoto and Nishimura, 1998;Wagner, 2003): a random deviate generator based on the Lévy probabilty distribution (Viswanathan et al., 1996) was use to generate net displacements (i.e. distances moved) and a second RNG was used to generate "normally" distributed directions, based on the Von Mises circular probability distribution (Devroye, 2001; Wood, 1994).

All the movement parameters fed into the RNG have been estimated from the radio tracking dataset. Movement length and direction are calculated each time, depending on the current position of each simulated animal in a probability landscape (i.e. a map constructed from Logistic Regression model application in GIS). The movement simulator makes animal move generally in the direction of "best" habitat, that is, "climbs" a locally estimated habitat suitability gradient.

In more detail, for each simulated month (Figure 2) a first normal deviate is generated (with mean and standard deviation based on current animal strategy) and such a number of random L`evy flight steps is generated and added to a points shapefile specified in the configuration file. The same points are then both concatenated in a second (line) shapefile and also used to calculate an MCP home range (with all the points, i.e. a 100% MCP), placed in a third (polygon) shapefile. All shapefiles names and placement in the filesystem can be specified in the simulator configuration file.

The iterative process used to generate Lévy flight-distributed points, paths and to evaluate MCPs can be described as follows:

1. a Lévy deviate is generated and will be used as net displacement (i.e. distance) from the current point, using l0 and μ parameters dependant on the current animals strategy;

2. a normal deviate is generated based on mean and standard deviation dependant on the current animal strategy paremeters (specified in the configuration file), and used as average habitat perception radius;

3. the "suitability landscape" map, i.e. a static model unclassified (raw) map is sampled in a circular neighbourhood as wide as the habitat perception radius parameter generated in the previous step;

4. on the above sample, the gradient is calculated using standard aspect calculation procedures;

5. a Von Mises deviate is generated with the above calculated gradient as mean direction vector and a fixed dispersion parameter k depending on the current animal strategy;

6. the above calculated direction and the net displacement allow to calculate the new point position, relative to the current point position;

7. if the segment connecting the new point with the current point intersects an entity in the barriers line shapefile (as specified in the configuration file) the new point is invalidated and the procedure restarts from the beginning;

8. if the new point is valid, the new point is stored in the points shapefile along with attribute data such as simulation time stamping (year and month cycle numbers) and simulated animal ID and becomes current point

9. the procedure is repeated until the needed number of points has been generated, then the points are used to generate both path and MCP geometries;

10. if more than half of the "probability landscape" cells inside MCP home range fall in the "suitable habitat" class according to ROC AUC (see Section 3.5.3) the homerange is kept as good, otherwise (module change homerange in Figure 2), a further series of Lévy flight points is generated starting from current home range center, consequently moving the animal upwards the habitat suitability gradient (module move, Figure 2), and the entire procedure is repeated.

3.4.2 Corridors identification

The content of the paths shapefile, at the end of a simulation run, is then used to evaluate potential corridors location, calculating the density of lines (paths) passing for each 250 m grid cell over the whole study area. Potential corridors are finally evaulat1ed by visual inspection of the path density map, positively identifying as corridors all cells with high relative path density and suitability below the treshold defined as HR > 99.7% (Section 3.5.3).

A further advantage coming from the use of Geographical Information Systems consisted in the fact that all simulator outputs (bear locations, paths and home ranges) are in the form of a map (as ESRI shapefiles), and thus readily readable and interpretable, also by non–technical persons.

A flow chart of the simulator SEPM is reported in Figure 2.

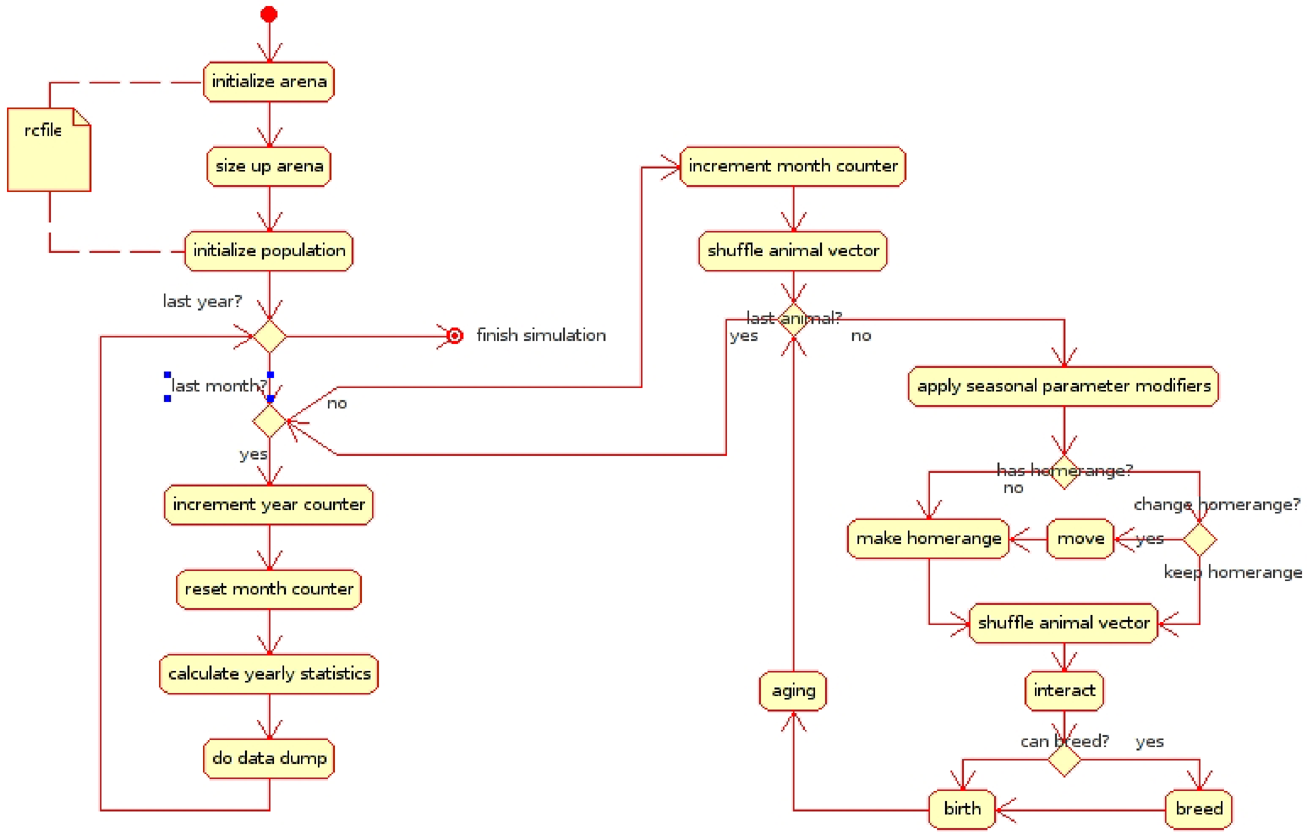

Figure 2 - Flow chart of simulator program.

Some simulator parameters have been taken from the existing literature, while others — in particular those related to movement capacity (i.e. species vagility) — have been estimated from field data. Since a simulation program need "exact" numerical parameters as inputs and often these information are not known with the precision needed, in some cases we resorted to estimates based on the available knowledge (literature and personal estimates of the Co-op participants, developed during technical meetings).

As shown in Figure 3.2, the population dynamics part of the simulator software only dealt with interaction, birth and death according to the following rule set:

lifespan: absolute maximum lifespan has been fixed to 30 years, after that age an animal is removed from the model; this is handled by the aging module shown in Figure 2, which also increments each simulated animal's age, and checks for mortality (see below);

weaning age: both males and females are independent (and are actually handled as individuals by the simulator) after the second year of life (average 1.4–2.4 years, Swenson et al. 2000);

breeding: a simulated bear can mate if older than 4 and 2 year for males and females respectively, no upper breeding age limit has been set; breeding can occur only in months from May to July (months 5–7 in simulator time), and exclusively if two bears of opposite sexes have overlapping home ranges (i.e. with non-empty intersection); a pregnant female cannot breed, and a female with cubs of age < 1 year cannot breed as well;

death: a fixed death rate has been set to 15% (for adult bears Wiegand et al. 2004 indicate a range between 8 and 18%);

birth: a female gives birth always to two cubs per litter, births occur only at the beginning of each simulated year (months 1–2, Swenson et al. 2000).

The interaction routine (interact in Figure 2) is based on a simple "mate or flee" design, that is if two animals have overlapping home ranges, one of the two animals will become a "mover" in the next simulation cycle. The identification of the "mover" animal between the interacting pair is subject to the following rule set:

- a female with cubs will never become a "mover";

- the younger younger animal will be tagged as "mover" if its age falls below minimum breeding age (that is from 2 to 4 years for males, always for females);

- in any other case each animal has a 50% probability of becoming a mover: uniform random deviates in the interval (0,1) are generated and if value falls below 0.5 the animal tagged as a "mover". In the case that both animals score over or below 0.5 (that is none or both should become "movers") the procedure is repeated drawing random numers again;

- if interacting bears are of opposite sex and breeding rules (see above) are satisfied, breeding occurs in addiction to the "mover tagging" process described above.

3.5 Potential distribution analysis

3.5.1 Logistic Regression

Logistic Regression is widely regognized as an appropriate tool for habitat selection studies (Manly et al., 1992) and it has been used to assess potential species distribution for many species (see for example Posillico et al. 2004; Schadt et al. 2002 for large carnivores) and for conservation planning (Glenz et al., 2001; Sà-Sousa, 2000).

As recently outlined by Keating and Cherry (2004), interpretation of Logistic Regression results is dependant on sampling design. In an ideal case of random sampling, i.e. when species presence and absence can be detected without bias, Logistic Regression output can be interpreted as true probability of use. Unfortunately, this sampling design cannot be used in the case of a reintroduced species, such as the brown bear, because it is not possible to tell whether absence from some habitats is the result of a negative selection rather than a consequence of previous local extinctions. I has to be stated anyway that Keating and Cherry advices should be not held as definitive, since based on theoretical examples.

Other sampling designs imply more caution in interpreting logistic regression results unless some assumptions on species distribution can be made. If the probability of use is small for all habitat classes, at least on average, use-availability and case-control designs (sensu Keating and Cherry 2004) are approximately equivalent, because the sample of available sites will consist in almost unused sites.

In the present study, the above mentioned hypothesis of small probability of use for all habitats can be held as true, since we are dealing with a large carnivore, with individuals having usually non-overlapping home ranges (Dahle and Swenson, 2003a,b) and with populations at low densities, at least in Italy and Austria where few individuals have been released.

For all this reasons we believe the "rare use" assumption is sound and we can approximate an use-availability sampling design to a case-control design. Finally,a superimposition on model output, represented in cartographic form, of the second data set (see Section 3.2) of about 20000 presence points, allowed us to consider that our study satisfies all the conditions needed to trust logistic regression results, at least as indicator maps (Isaaks and Srivastava, 1989). Indicator maps are a particular case of cartographic representation, where a numerical model continuous output is reclassified in a few (generally no more than 2–4) discrete classes, gaining in map readability since the main interest is in difference among broad classes and not in small differences among values belonging to the same class (Slocum, 1999).

In case of wildlife studies, and especially in those performed with radio tracking techniques, species absence cannot be detected without bias, or even can not be quantified at all, and it is often necessary to introduce into the model randomly generated absence points. We added to the 10582 radio-located presence data set a similarly sized sample of pseudo-absence points, drawn at random in the whole study area embracing an use-availability experimental design sensu Keating and Cherry (2004). According to Manly et al. (1992), the sampling design we used can be defined as Design II, case 1, which means that habitat selecion has been evaluated on a population basis, from data derived by radio-tagged animals and randomly sampling "unused" or "absence" points are inside the whole study area.

We preferred this approach instead of another possible analytical design, defined on Manly et al. (1992) as Design III, case 1, where sampling of presence points is made from animals with radio-tag as well, whereas "unused" points are derived randomly sampling inside home range, according to the postulate (as stated in White and Garrott 1990) that home range represents in some way a prior selection of habitat, and by the assumption that modelling focuses on animals at the individual level and resource availability is measured at the population level. Moreover, the fact that home range has been estimated as an utilization distribution (UD) probability function using the kernel method (Silverman, 1986; Hooge et al., 1999), any point inside 95% UD could reasonably be held as "presence" point, thus disqualifying the alternative technique mentioned above.

According to what suggested in Keating and Cherry (2004), we did not use probabilities as predicted by the model as "true" habitat selection probability estimates (Resource Selection

Probability Function, RSPF, (Manly et al., 1992), but merely as Resource Selection Function (RSF), which is proportional to RSPF by a factor k. This is sufficent enough to build an indicator map Isaaks and Srivastava (1989), since in this mapping techniques true value are not of chief importance, given that values are partitioned in classes according to their frequency distribution. As stated in Keating and Cherry (2004), if RSPF

= k RSF, then the shape of the frequency distribution will be identical both for RSPF and RSF, given k as a mere scaling factor, and the cut-off points will be similarly placed, yielding identical maps.

Anyway, to make quantitative comparisons of habitats we relied on odd ratios, that are not affected by the model constant k (Hosmer and Lemeshow, 2000).

3.5.2 Modelling scenarios and model evaluation criteria

To dela with the uncertainty caused by randomly-generated "absence" points, as suggested in technical meetings by some Co-op partners, several scenarios has been set up, generating "absence" points in four different fashions:

Scenario 1a, 1b: 10500 random (bivariate uniform) points, generated across the whole study area. The difference between Scenario 1a and 1b is in the fact that in Scenario 1a geographic trend has been explicited using longitude and latitude, whereas in Scenario 1b (and in all the following scenarios) distance from core areas and from Slovenia were used.

Scenario 2: 10500 random (bivariate uniform) points generated in the region identified by the topological union of all bears home ranges (95% UD kernel), plus a buffer zone as wide as the average daily travel distance, evaluated from the radio locations dataset, that is 2.5 km;

Scenario 3: 10500 random (bivariate uniform) points generated in the region identified by the topological union of all bears home ranges (95% UD kernel), plus a buffer zone as wide as the maximum daily travel distance, evaluated from the radio locations dataset, that is 45 km;

Scenario 4: 10500 random (bivariate uniform) points generated in the region immediately out of the the topological union of all bears home ranges (95% UD kernel) but not exceeding the maximum daily travel distance, evaluated from the radio locations dataset, that is 45 km (same as Scenario 3, but with sampling only in the buffer zone).

Each one of the random points datasets had been joined with radio tracking locations dataset described in Section 3.2.4, and from each one of the resulting base datasets 10 subsets of 4000 randomly selected points were created, under the following conditions: about 2000 "unused/absence" points, plus about 2000 presence points, drawn equally (1/3 each) from Austria, Slovenia and Italy datasets. In practice, about 670 points have been drawn from each subset of radio locations and then merged.

The procedure outlined above created for each scenario 10 different data subsets, used for the Logistic Regression analysis procedure described in Section 3.4. For each set of 10 models, all models has been ranked using Bayes' Information Criterion (Schwarz, 1978), and the best scoring one has been selected.

On the "best predictor" model in each subset, a further evaluation of predictive power has been carried out applying the standard practice of Receiver Operating Curve Area Under the Curve analysis (ROC AUC, Hosmer and Lemeshow 2000), used also to identify cut-off points to produce the indicator discussed in Section 3.5.3. Usually, the classification performance of a Logistic Regression model is evaluated in terms of the rankings reported in Table 3.

Table 3: Predictive power rankings according to ROC AUC analysis.

Predictive power classification	
0.0<AUC<0.5	Unusable: model is not different from a random classifier.
0.5<AUC<0.6	Faulty: misclassification rate too high.
0.6<AUC<0.7	Poor classifying performance.
0.7<AUC<0.8	Fair classifying performance. Model can be used but classifications must not be trusted as always correct.
0.8<AUC<0.9	Good classifying performance. Model prediction can be trusted.
0.9<AUC<1.0	Excellent classifying performance. Model prediction can be trusted.

In applying back into the GIS the logistic equations as estimated by the Logistic Regression analisys, geographic trend terms have been left out, as well as the distance from the area identified by type 1a and 1b core areas in Slovenia, and the distance from the nearest core area (as above for Slovenia, topological union of all 95% UD kernels for Austria and Italy).

3.5.3 Graphic presentation of model output

Model output, as feed back in to the GIS consists usually in a map containing a continuous range of values ranging from 0.0 to 1.0, as a continuous surface. This result, also if treated with the necessary precautions discussed in Section 3.5.1 is better understandable if reclassified into discrete classes. At this purpose the standard practice of Receiver Operating Curve analysis helped in identify the correct “cut-off” values, balancing the constraint between maximum predictive power and minimum rate of false positives, guaranteeing that a predetermined level of confidence is maintained (Hosmer and Lemeshow, 2000). ROC curve analysis allowed to split the continuous output in three classes, at the fixed tresholds of 80% and 99.7% hit ratio (HR), represented in cartographic form as potentially suitable habitat (HR > 99.7%), potential corridor areas (80% < HR < 99.7%) and unsuitable areas (HR < 80%), applying the concept of indicator map as explained in Isaaks and Srivastava (1989).

3.6 Individual-based model

3.6.1 Parameter estimation

As previously stated in section 3.4 the movement engine of the simulator software is based on the Lévy probability distribution for distance and Von Mises distribution for direction.

The two main parameters governing movement pattern generation are a minimum distance between subsequent steps l0 and a fractal dimension μ. Those parameters, as well other measures such as average home range size and overlap (Preatoni et al., 2005) have been estimated from the radio tracking dataset with standard home range analysis techniques (Hooge et al., 1999), to obtain realistic parameters to feed into the simulator.

3.6.2 Analysis of paths and movement patterns

The simplest approach to describe movement of individuals as trajectories in two-dimensional space is to model trajectories as Brownian motion using, for example, the classical bidimensional random walk approach. However, this model does not give an accurate representation of most animal movement, especially for vertebrates. An alternative, more viable description of animal trajectories is based on the assumption of independent probability distributions for displacement lengths and turning angles (Austin et al., 2004): the so-called "Lévy flight" is a special class of random walk models whose step lengths are not constant as in classical random walk, but are chosen from an inverse power law probability distribution expressed as:

$$P(l) = l_0^{-\mu} \tag{3.1}$$

where P(l) is the probability of a displacement of length l, l0 is the minimum displacement length and μ is a fractal dimension parameter, that for the Lévy probability distribution can assume values in the domain $1 < \mu < 3$. If $\mu > 3$, the Lévy distribution converge to a Gauss (normal) distribution; for $\mu = 3$ it approximates a random Brownian motion and for $\mu < 1$ it does not correspond to any standard distribution (Viswanathan et al., 1996).

Lévy flights are characterised by many short moves and a few large displacements, a pattern that maximises the number of places visited with few repetitions. Evidences that Lévy flight is a suitable model to describe animal trajectories in space have been found for many species, among which albatross (*Diomedea exulans*, Viswanathan et al. 1996), reindeer (*Rangifer tarandus*, Mårrel et al. 2002), grey seal (*Halichoerus grypus*, Austin et al. 2004) and jackals (*Canis aureus*, Atkinson et al. 2002). Moreover, due to its fractal component a Lévy flight is scale-independent and thus more useful to simulate point patterns as those obtained by radio-tagged animals (Marzluff and Millspaugh, 2001).

Movement patterns for each individual, as well as all home range calculations and analyses were estimated using the Animal Movement Extension (Hooge et al., 1999) in ArcView (ESRI, 1996). For each bear, distances between successive radio-locations have been calculated and used to estimate l0 (Equation 3.1). To obtain estimated for μ, a 20-bin histogram has been calculated for each animal obtaining distances frequency distribution and Lévy parameter μ has been estimated from a linear regression on a log-log plot of frequency vs. move length as illustrated by Austin et al. (2004).

4 RESULTS

4.1 Static modelling

All variables usde in the modelling process are listed in the following tables using the acronyms listed in Table 4.

Table 4: List of the predictor variables acronyms used.

Acronym	**Description**
A EE 1KM	Percentage of east aspect (1 km window)
A EE 9KM	Percentage of east aspect (9 km window)
A NE 1KM	Percentage of north-east aspect (1 km window)
A NE 9KM	Percentage of north-east aspect (9 km window)
A NN 1KM	Percentage of north aspect (9 km window)
A NW 1KM	Percentage of north-west aspect (1 km window)
A NW 9KM	Percentage of north-west aspect (9 km window)
A SE 1KM	Percentage of south-east aspect (1 km window)
A SE 9KM	Percentage of south-east aspect (9 km window)
A SS 1KM	Percentage of south aspect (1 km window)
A SS 9KM	Percentage of south aspect (9 km window)
A SW 1KM	Percentage of south-west aspect (1 km window)
A SW 9KM	Percentage of south-west aspect (9 km window)
A WW 1KM	Percentage of west aspect (1 km window)
A WW 9KM	Percentage of west aspect (9 km window)
COR3 100	Land use: percentage of urban areas [100] 1.7 km^2 window
COR3 121	Land use: percentage of sparsely urbanised [121] 1.7 km^2 window
COR3 122	Land use: percentage of road railways [122] 1.7 km^2 window
COR3 140	Land use: percentage of gren urban areas [140] 1.7 km^2 window
COR3 210	Land use: percentage of irrigated land [210] 1.7 km^2 window
COR3 211	Land use: percentage of arable land [211] 1.7 km^2 window
COR3 212	Land use: percentage of irrigated land [212] 1.7 km^2 window
COR3 220	Land use: percentage of orchards [220] 1.7 km^2 window
COR3 231	Land use: percentage of pastures [231] 1.7 km^2 window
COR3 240	Land use: percentage of agricultural mosaic [240] 1.7 km^2 window
COR3 250	Land use: percentage of agricultural seminatural [250] 1.7 km^2 window
COR3 311	Land use: percentage of broadleaf forest [311] 1.7 km^2 window
COR3 312	Land use: percentage of coniferous forest [312] 1.7 km^2 window
COR3 313	Land use: percentage of mixed forest [313] 1.7 km^2 window
COR3 321	Land use: percentage of grasslands [321] 1.7 km^2 window
COR3 322	Land use: percentage of heatlands [322] 1.7 km^2 window
COR3 323	Land use: percentage of sclerophyllous [323] 1.7 km^2 window
COR3 324	Land use: percentage of shrubland [324] 1.7 km^2 window
COR3 331	Land use: percentage of beaches or riparian areas [331] 1.7 km^2 window
COR3 332	Land use: percentage of bare rock [332] 1.7 km^2 window
COR3 333	Land use: percentage of sparsely vegetated [333] 1.7 km^2 window
COR3 334	Land use: percentage of burnt areas [334] 1.7 km^2 window
COR3 335	Land use: percentage of glaciers and snow [335] 1.7 km^2 window
COR3 410	Land use: percentage of marshes [410] 1.7 km^2 window
COR3 420	Land use: percentage of coastal areas [420] 1.7 km^2 window
COR3 510	Land use: percentage of inland waters [510] 1.7 km^2 window
COR3 530	Land use: percentage of sea [530] 1.7 km^2 window

COR7 100	Land use: percentage of urban areas [100] 9.6 km^2 window
COR7 121	Land use: percentage of sparsely urbanised [121] 9.6 km^2 window
COR7 122	Land use: percentage of road railways [122] 9.6 km^2 window
COR7 140	Land use: percentage of gren urban areas [140] 9.6 km^2 window
COR7 210	Land use: percentage of irrigated land [210] 9.6 km^2 window
COR7 211	Land use: percentage of arable land [211] 9.6 km^2 window
COR7 212	Land use: percentage of irrigated land [212] 9.6 km^2 window
COR7 220	Land use: percentage of orchards [220] 9.6 km^2 window
COR7 231	Land use: percentage of pastures [231] 9.6 km^2 window
COR7 240	Land use: percentage of agricultural mosaic [240] 9.6 km^2 window
COR7 250	Land use: percentage of agricultural seminatural [250] 9.6 km^2 window
COR7 311	Land use: percentage of broadleaf forest [311] 9.6 km^2 window
COR7 312	Land use: percentage of coniferous forest [312] 9.6 km^2 window
COR7 313	Land use: percentage of mixed forest [313] 9.6 km^2 window
COR7 321	Land use: percentage of grasslands [321] 9.6 km^2 window
COR7 322	Land use: percentage of heatlands [322] 9.6 km^2 window
COR7 323	Land use: percentage of sclerophyllous [323] 9.6 km^2 window
COR7 324	Land use: percentage of shrubland [324] 9.6 km^2 window
COR7 331	Land use: percentage of beaches or riparian areas [331] 9.6 km^2 window
COR7 332	Land use: percentage of bare rock [332] 9.6 km^2 window
COR7 333	Land use: percentage of sparsely vegetated [333] 9.6 km^2 window
COR7 334	Land use: percentage of burnt areas [334] 9.6 km^2 window
COR7 335	Land use: percentage of glaciers and snow [335] 9.6 km^2 window
COR7 410	Land use: percentage of marshes [410] 9.6 km^2 window
COR7 420	Land use: percentage of coastal areas [420] 9.6 km^2 window
COR7 510	Land use: percentage of inland waters [510] 9.6 km^2 window
COR7 530	Land use: percentage of sea [530] 9.6 km^2 window
D CORE	Distance from nearest core area (m)
D PP	Distance from populated places (m)
D RAIL	Distance from railways (passenger and cargo)
D RALL	Distance from all types of roads
D RHWY	Distance from highways and other 4-lane high-traffic roads
D RLOW	Distance from local and other roads
D RMED	Distance from federal and regional medium-traffic roads
D SLO	Distance from Slovenian core area (m)
DEM	Elevation above sea level (m)
F CONT	Forest patch contiguity index (FRAGSTATS) $0 < i < 100$
F CSIZE	Area of contiguous forested area. Values are area of the whole clump (km^2)
F PARA	Forest patch ratio *perimeter/area* (FRAGSTATS)
F PREL	Forest patch relative size *clumpsize/total forestedarea* × 1000
F SHAPE	Forest patch shape index (FRAGSTATS) $0 < i < 100$
LAT	Latitude from Greenwich (decimal degrees)
LON	Longitude from Greenwich (decimal degrees)
SUN	Solar radiation (MJ cm^{-2} year-1)

4.1.1 Scenario 1

Scenario 1a

Best predictor model within this Scenario scored satisfactorily, with an overall ROC AUC classification accuracy of 94.1%. Logistic Regression equation coefficients are listed in Table 5. Model 2-Log-likelihood is 1573.0 ($^{2}_{24df}$ p-value < 0.00001). Odds ratios are reported in Table 6. Figure 3 shows model results in map format.

Table 5.: Parameter estimates for Scenario 1a. Parameter: acronym of each predictor variable (see Table 4); *Estimate*: parameter coefficient; *S.E.*: standard error of estimate; *t-ratio*: standardized coefficent; *p-value*: significance value.

Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
constant	-102.58375	14.31657	-7.16539	0.00001
COR7 100	0.12081	0.02730	4.42531	0.00001
COR7 220	0.14154	0.03753	3.77173	0.00016
COR7 231	0.04406	0.02391	1.84294	0.06534
COR7 240	0.07208	0.02431	2.96464	0.00303
COR7 250	0.01736	0.02800	0.61995	0.53529
COR7 311	0.10118	0.02194	4.61145	0.00001
COR7 312	0.11396	0.02161	5.27380	0.00001
COR7 313	0.13791	0.02187	6.30681	0.00001
COR7 321	0.08606	0.02285	3.76598	0.00017
COR7 322	0.08712	0.02717	3.20709	0.00134
COR7 324	0.14965	0.02454	6.09914	0.00001
COR7 332	0.09327	0.02388	3.90514	0.00009
COR7 333	0.04014	0.02616	1.53460	0.12488
D PPEERS	-0.00008	0.00007	-1.13089	0.25810
D RAILSEER	0.00005	0.00002	2.27411	0.02296
D RALLEERS	0.00004	0.00007	0.57660	0.56421
D RHWEERS	-0.00004	0.00001	-4.48208	0.00001
D RSPEERS	0.00006	0.00001	7.66379	0.00001
F SHAPE	0.00781	0.00359	2.17365	0.02973
XCOORD	-27.86845	17.27816	-1.61293	0.10676
XY	1.65013	0.70892	2.32767	0.01993
X3	0.06407	0.00944	6.78852	0.00001
X2Y	-0.04794	0.00708	-6.77176	0.00001
XY2	-0.01097	0.00823	-1.33310	0.18250

Table 6: Odds ratios for Scenario 1a. *Parameter*: acronym of each predictor variable (see Table 4).

		95% Bounds	
Parameter	**Odds ratio**	**Upper**	**Lower**
COR7 100	1.12842	1.19044	1.06962
COR7 220	1.15205	1.23998	1.07036
COR7 231	1.04504	1.09517	0.99721
COR7 240	1.07474	1.12719	1.02473
COR7 250	1.01751	1.07492	0.96317
COR7 311	1.10648	1.15510	1.05990
COR7 312	1.12070	1.16918	1.07423
COR7 313	1.14787	1.19813	1.09971
COR7 321	1.08987	1.13979	1.04213
COR7 322	1.09103	1.15069	1.03446
COR7 324	1.16143	1.21864	1.10690
COR7 332	1.09775	1.15036	1.04755
COR7 333	1.04096	1.09572	0.98894
D PPEERS	0.99992	1.00006	0.99978

D RAILSEER	1.00005	1.00009	1.00001
D RALLEERS	1.00004	1.00019	0.99990
D RHWEERS	0.99996	0.99997	0.99994
D RSPEERS	1.00006	1.00008	1.00004
F SHAPE	1.00784	1.01497	1.00077
XCOORD	0.00000	401.86769	0.00000
XY	5.20767	20.89664	1.29781
X3	1.06616	1.08607	1.04662
X2Y	0.95320	0.96651	0.94006
XY2	0.98909	1.00517	0.97326

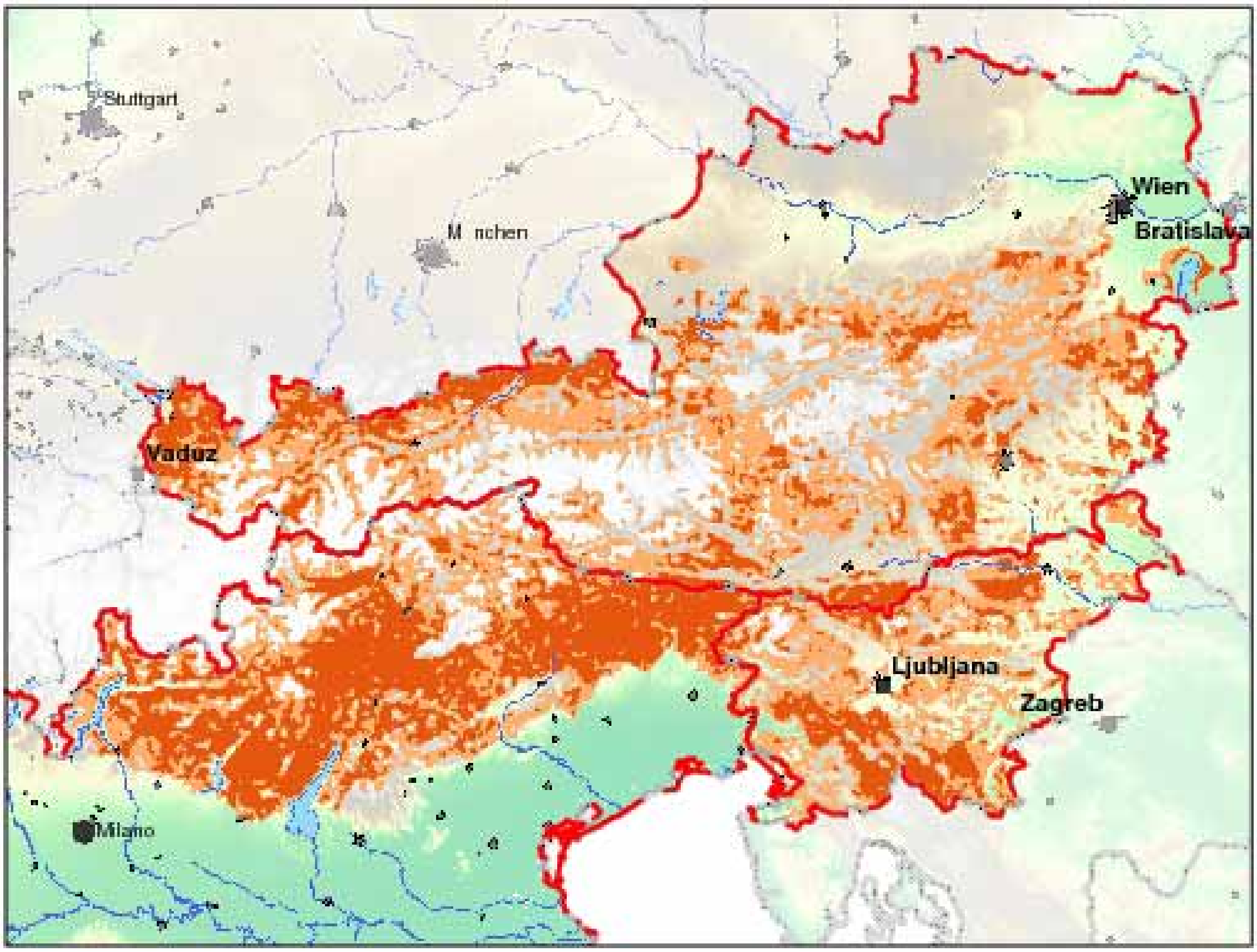

Figure 3 - Map representation of Scenario 1a potential distribution results. Lighter color indicates potential corridor areas.

Scenario 1b

Best predictor model within this Scenario scored satisfactorily, with an overall ROC AUC classification accuracy of 93.7%. Logistic Regression equation coefficients are listed in Table 7. Model 2-Log-likelihood is 4370.6 ($^{2}_{24df}$ p-value < 0.00001). Odds ratios are reported in Table 8. Figure 4 shows model results in map format.

Table 7: Parameter estimates for Scenario 1b. *Parameter*: acronym of each predictor

variable (see Table 4); *Estimate*: parameter coefficient; *S.E.*: standard error of estimate; *t-ratio*: standardized coefficent; *p-value*: significance value.

Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
constant	-2.691	0.771	-3.491	0.001
A NE 9KM	0.032	0.014	2.294	0.022
A NN 9KM	-0.031	0.013	-2.438	0.015
A NW 1KM	-0.014	0.008	-1.749	0.080
A NW 9KM	0.018	0.015	1.175	0.240
A SE 9KM	0.036	0.010	3.513	0.001
A SS 1KM	0.003	0.008	0.436	0.663
A SS 9KM	-0.004	0.016	-0.251	0.802
COR7 100	0.025	0.025	1.025	0.305
COR7 231	-0.013	0.012	-1.128	0.259
COR7 311	0.030	0.009	3.282	0.001
COR7 312	0.040	0.007	5.575	0.001
COR7 313	0.042	0.007	5.820	0.001
COR7 324	0.008	0.016	0.502	0.616
COR7 332	0.018	0.013	1.418	0.156
COR7 333	0.025	0.018	1.418	0.156
COR7 335	-0.069	0.056	-1.228	0.220
COR7 510	0.014	0.051	0.285	0.776
D CORE	-0.313	0.025	-12.680	0.001
D RAIL	0.010	0.020	0.511	0.609
D RHWY	-0.011	0.010	-1.023	0.306
D RLOW	0.064	0.008	7.907	0.001
D SLO	-0.001	0.002	-0.357	0.721
F CSIZE	0.000	0.000	0.780	0.435
F PREL	-0.003	0.005	-0.670	0.503

Table 8: Odds ratios for Scenario 1b. *Parameter*: acronym of each predictor variable (see Table 4).

		95% Bounds	
Parameter	**Odds ratio**	**Upper**	**Lower**
A NE 9KM	1.033	1.062	1.005
A NN 9KM	0.969	0.994	0.945
A NW 1KM	0.986	1.002	0.972
A NW 9KM	1.018	1.049	0.988
A SE 9KM	1.036	1.057	1.016
A SS 1KM	1.003	1.018	0.988
A SS 9KM	0.996	1.028	0.964
COR7 100	1.025	1.076	0.977
COR7 231	0.987	1.010	0.965
COR7 311	1.030	1.048	1.012
COR7 312	1.041	1.056	1.026
COR7 313	1.043	1.058	1.028
COR7 324	1.008	1.041	0.977
COR7 332	1.018	1.044	0.993
COR7 333	1.025	1.062	0.990
COR7 335	0.933	1.042	0.835
COR7 510	1.015	1.120	0.919
D CORE	0.731	0.767	0.697
D RAIL	1.010	1.051	0.971

D RHWY	0.989	1.010	0.969
D RLOW	1.066	1.083	1.049
D SLO	0.999	1.003	0.996
F CSIZE	1.000	1.000	1.000
F PREL	0.997	1.007	0.986

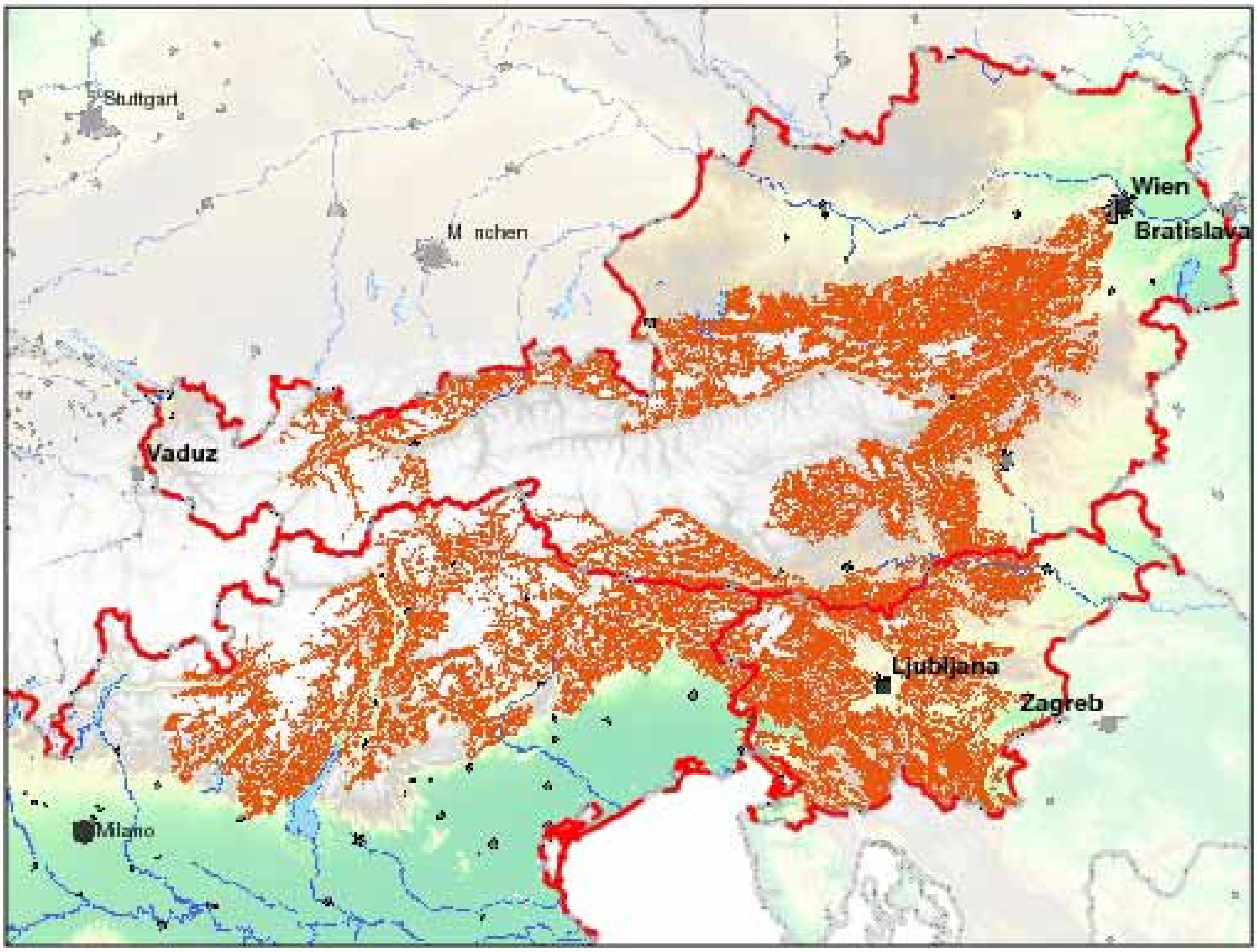

Figure 4 - Map representation of Scenario 1b potential distribution results. Lighter color indicates potential corridor areas.

4.1.2 Scenario 2

Models within this Scenario scored unsatisfactorily: best ROC AUC classification accuracy is 61.8%. Logistic Regression equation coefficients are listed in Table 9. Model 2-Loglikelihood is 4370.6 ($^{2}_{24df}$ p-value < 0.00001). Odds ratios are reported in Table 10. Figure 5 shows model results in map format. For display purposes, an arbitrary cutoff value of 0.5 (i.e. 50%) has been applied to the map: the ROC AUC calculated cutoff should have been 0.99, which is far too high for a realistic model.

Table 9: Parameter estimates for Scenario 2. *Parameter*: acronym of each predictor variable (see Table 4); *Estimate*: parameter coeffcient; *S.E.*: standard error of estimate; *t-ratio*: standardized coeffcent; *p-value*: significance value.

Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
constant	-3.744	0.381	-9.819	0.001
A NN 9KM	-0.029	0.006	-4.666	0.001
A NW 9KM	0.011	0.004	2.589	0.010
A SE 9KM	0.033	0.005	7.342	0.001
A SW 1KM	-0.010	0.003	-3.609	0.001
A WW 1KM	-0.006	0.003	-1.954	0.051
A WW 9KM	0.013	0.006	2.079	0.038
COR7 220	-0.033	0.008	-4.309	0.001
COR7 231	-0.041	0.008	-5.426	0.001
COR7 250	-0.040	0.010	-3.916	0.001
COR7 311	0.029	0.004	6.550	0.001
COR7 312	0.034	0.004	8.270	0.001
COR7 313	0.039	0.004	9.507	0.001
COR7 321	0.033	0.006	5.208	0.001
COR7 324	0.049	0.007	6.847	0.001
COR7 332	0.018	0.006	2.970	0.003
DEM	-0.001	0.000	-5.084	0.001
D PP	0.132	0.042	3.182	0.001
D RALL	-0.116	0.042	-2.750	0.006
D RHWY	-0.050	0.005	-9.883	0.001
D RLOW	0.058	0.004	13.904	0.001
F CONT	0.008	0.004	1.914	0.056
F CSIZE	0.000	0.000	1.585	0.113
F PARA	0.024	0.012	1.916	0.055
F SHAPE	-0.014	0.005	-2.589	0.010

Table 10.: Odds ratios for Scenario 2. Parameter: acronym of each predictor variable (see Table 4).

		95% Bounds	
Parameter	**Odds ratio**	**Upper**	**Lower**
A NN 9KM	0.971	0.983	0.959
A NW 9KM	1.011	1.020	1.003
A SE 9KM	1.034	1.043	1.025
A SW 1KM	0.990	0.995	0.985
A WW 1KM	0.994	1.000	0.987
A WW 9KM	1.013	1.026	1.001
COR7 220	0.968	0.982	0.953
COR7 231	0.960	0.974	0.946
COR7 250	0.961	0.980	0.942
COR7 311	1.029	1.038	1.020
COR7 312	1.034	1.042	1.026
COR7 313	1.040	1.049	1.032
COR7 321	1.034	1.047	1.021
COR7 324	1.050	1.065	1.035
COR7 332	1.018	1.030	1.006
DEM	0.999	1.000	0.999

D PP	1.142	1.238	1.052
D RALL	0.890	0.967	0.820
D RHWY	0.951	0.961	0.942
D RLOW	1.059	1.068	1.051
F CONT	1.008	1.017	1.000
F CSIZE	1.000	1.000	1.000
F PARA	1.024	1.049	0.999
F SHAPE	0.987	0.997	0.976

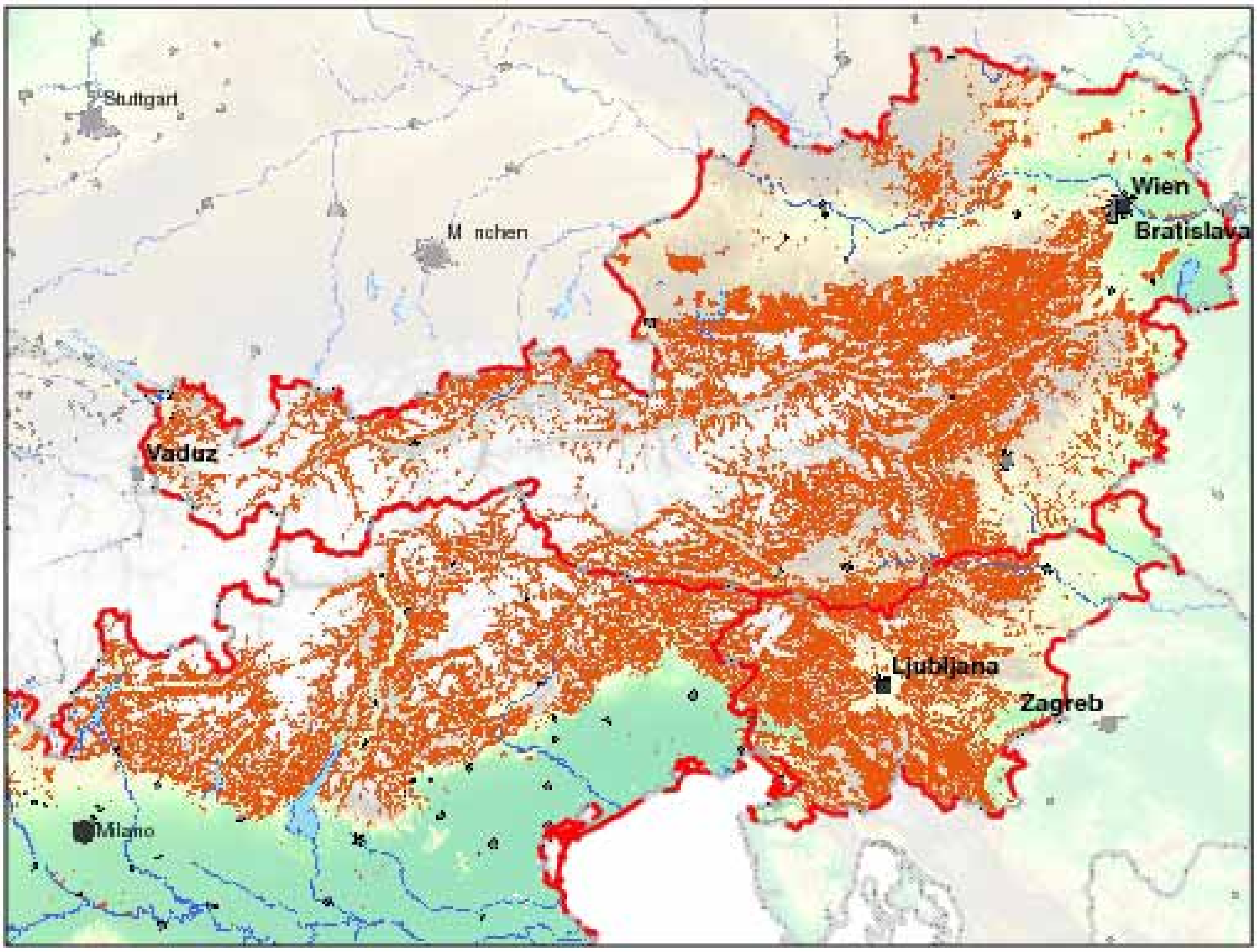

Figure 5 - Map representation of Scenario 2 potential distribution results. Lighter color indicates potential corridor areas. For visualization purposes only an arbitrary cutoff value of 50% has been used, instead of the calculated value of 99%. Applying the prescribed cutoff the map would be left almost empty.

4.1.3 Scenario 3

Best predictor model within this Scenario scored satisfactorily, with an overall ROC AUC classification accuracy of 96.4%. Logistic Regression equation coefficients are listed in Table 11. Model 2-Log-likelihood is 3489.0 ($^{2}_{24df}$ p-value < 0.00001). Odds ratios are reported in Table 12. Figure 6 shows model results in map format.

Table 11: Parameter estimates for Scenario 3. *Parameter*: acronym of each predictor variable (see Table 4); *Estimate*: parameter coefficient; *S.E.*: standard error of estimate; *t-ratio*: standardized coefficent; *p-value*: significance value.

Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
constant	-1.790	0.689	-2.597	0.009
A NE 9KM	0.011	0.007	1.608	0.108
A NN 1KM	0.015	0.006	2.571	0.010
A NN 9KM	-0.034	0.011	-3.122	0.002
A SE 9KM	0.032	0.007	4.815	0.000
A SS 9KM	-0.009	0.008	-1.083	0.279
A XX 9KM	-0.031	0.027	-1.132	0.258
COR7 100	0.026	0.022	1.192	0.233
COR7 121	-0.150	0.092	-1.627	0.104
COR7 211	-0.485	0.261	-1.855	0.064
COR7 231	-0.054	0.010	-5.564	0.000
COR7 250	-0.065	0.014	-4.713	0.000
COR7 312	0.010	0.003	3.098	0.002
COR7 313	0.018	0.003	5.306	0.000
COR7 324	0.020	0.010	1.977	0.048
COR7 333	-0.036	0.012	-2.870	0.004
COR7 335	-0.017	0.021	-0.794	0.427
D CORE	-0.301	0.019	-16.033	0.000
D RAIL	0.028	0.012	2.314	0.021
D RHWY	-0.033	0.007	-5.032	0.000
D RLOW	0.045	0.005	8.380	0.000
D SLO	-0.003	0.001	-2.767	0.006
F CONT	0.024	0.004	6.111	0.000
F SHAPE	-0.018	0.005	-3.484	0.000
SUN	1.334	0.663	2.013	0.044

Table 12: Odds ratios for Scenario 3. Parameter: acronym of each predictor variable (see Table 4).

		95% Bounds	
Parameter	**Odds ratio**	**Upper**	**Lower**
A NE 9KM	1.011	1.025	0.998
A NN 1KM	1.015	1.026	1.003
A NN 9KM	0.967	0.988	0.946
A SE 9KM	1.033	1.046	1.019
A SS 9KM	0.991	1.007	0.976
A XX 9KM	0.970	1.023	0.920
COR7 100	1.027	1.072	0.983
COR7 121	0.861	1.031	0.719
COR7 211	0.616	1.028	0.369
COR7 231	0.947	0.966	0.930
COR7 250	0.937	0.962	0.912
COR7 312	1.010	1.016	1.004
COR7 313	1.019	1.025	1.012
COR7 324	1.021	1.042	1.000
COR7 333	0.965	0.989	0.942
COR7 335	0.983	1.025	0.943
D CORE	0.740	0.768	0.713

D RAIL	1.028	1.052	1.004
D RHWY	0.967	0.980	0.955
D RLOW	1.046	1.057	1.035
D SLO	0.997	0.999	0.996
F CONT	1.025	1.033	1.017
F SHAPE	0.982	0.992	0.972
SUN	3.796	13.910	1.036

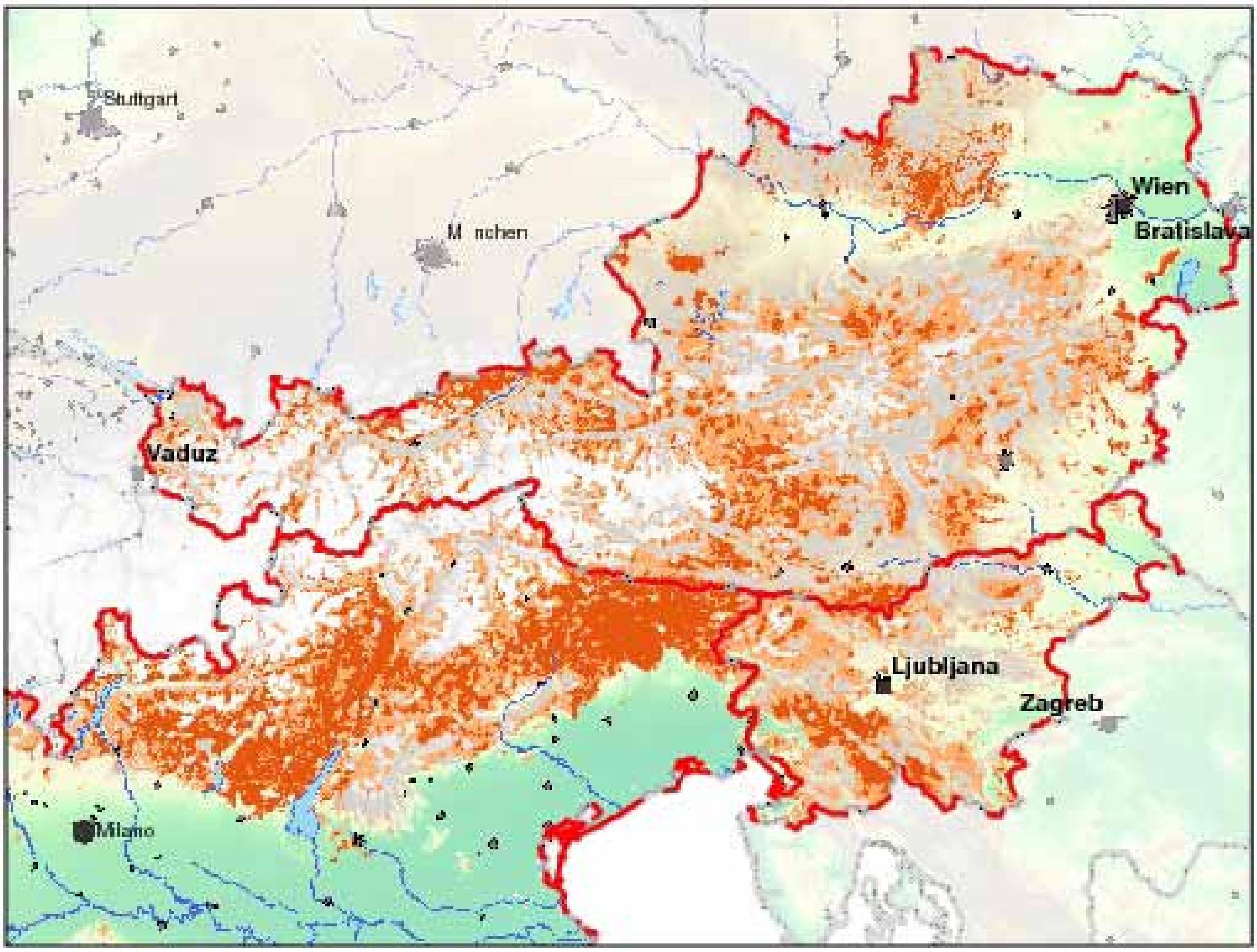

Figure 6 - Map representation of Scenario 3 potential distribution results. Lighter color indicates potential corridor areas. Even if predictive power scores good (96.4% ROC AUC, i.e. excellent), when transformed in an indicator map with a ROC AUC analysis evaluated cutoff point of 55%) tends to identify as potential some areas north and east Linz that seem too much disjoint from the main potential distribution.

4.1.4 Scenario 4

Best predictor model within this Scenario scored satisfactorily, with an overall ROC AUC classification accuracy of 99.1%. Logistic Regression equation coefficients are listed in Table 13. Model 2-Log-likelihood is 4140.6 ($^{2}_{24df}$ p-value < 0.00001). Odds ratios are reported in Table 14. Figure 7 shows model results in map format, with an arbitrary cutoff value of 50%: as for Scenario 3, the calculated ROC AUC cuto_ value should be

0.99, that is all predicted values less than 0.99 should be considered as unsitable areas, which is unrealistic.

Table 13: Parameter estimates for Scenario 4. *Parameter*: acronym of each predictor variable (see Table 4); *Estimate*: parameter coefficient; *S.E.*: standard error of estimate; *t-ratio*: standardized coefficent; *p-value*: significance value.

Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
constant	0.962	0.557	1.728	0.084
A NN 1KM	0.008	0.007	1.159	0.246
A NN 9KM	-0.030	0.015	-1.983	0.047
A SE 1KM	0.005	0.007	0.673	0.501
A SE 9KM	0.024	0.014	1.756	0.079
A SS 9KM	-0.006	0.010	-0.596	0.551
A WW 9KM	-0.006	0.010	-0.596	0.551
A XX 9KM	-0.039	0.029	-1.339	0.180
COR7 100	0.018	0.030	0.612	0.541
COR7 121	-0.144	0.268	-0.537	0.591
COR7 211	-0.396	0.234	-1.693	0.090
COR7 220	0.017	0.020	0.850	0.395
COR7 231	-0.034	0.011	-3.171	0.002
COR7 240	-0.025	0.011	-2.353	0.019
COR7 250	-0.071	0.015	-4.681	0.001
COR7 312	0.010	0.004	2.328	0.020
COR7 313	0.021	0.005	4.395	0.001
COR7 324	-0.001	0.013	-0.094	0.925
COR7 333	-0.062	0.016	-3.862	0.001
COR7 335	-0.054	0.043	-1.261	0.207
COR7 510	-0.038	0.038	-0.999	0.318
D CORE	-0.449	0.026	-17.012	0.001
D RAIL	0.025	0.016	1.613	0.107
D RHWY	-0.031	0.008	-3.638	0.001
D RLOW	0.052	0.007	7.411	0.001
D SLO	-0.006	0.001	-4.335	0.001
F CONT	0.019	0.005	3.962	0.001
F SHAPE	-0.015	0.006	-2.523	0.012

Table 14: Odds ratios for Scenario 4. Parameter: acronym of each predictor variable (see Table 4).

		95% Bounds	
Parameter	**Odds ratio**	**Upper**	**Lower**
A NN 1KM	1.008	1.023	0.994
A NN 9KM	0.971	1.000	0.942
A SE 1KM	1.005	1.019	0.991
A SE 9KM	1.025	1.053	0.997
A SS 9KM	0.994	1.014	0.974
A WW 9KM	0.994	1.014	0.974
A XX 9KM	0.962	1.018	0.909
COR7 100	1.018	1.080	0.961
COR7 121	0.866	1.464	0.512
COR7 211	0.673	1.064	0.425

COR7 220	1.017	1.057	0.978
COR7 231	0.966	0.987	0.946
COR7 240	0.975	0.996	0.955
COR7 250	0.931	0.959	0.904
COR7 312	1.010	1.019	1.002
COR7 313	1.021	1.031	1.012
COR7 324	0.999	1.024	0.974
COR7 333	0.940	0.970	0.911
COR7 335	0.947	1.030	0.871
COR7 510	0.963	1.037	0.893
D CORE	0.639	0.672	0.606
D RAIL	1.026	1.058	0.995
D RHWY	0.970	0.986	0.954
D RLOW	1.053	1.068	1.039
D SLO	0.994	0.997	0.992
F CONT	1.019	1.029	1.010
F SHAPE	0.985	0.997	0.973

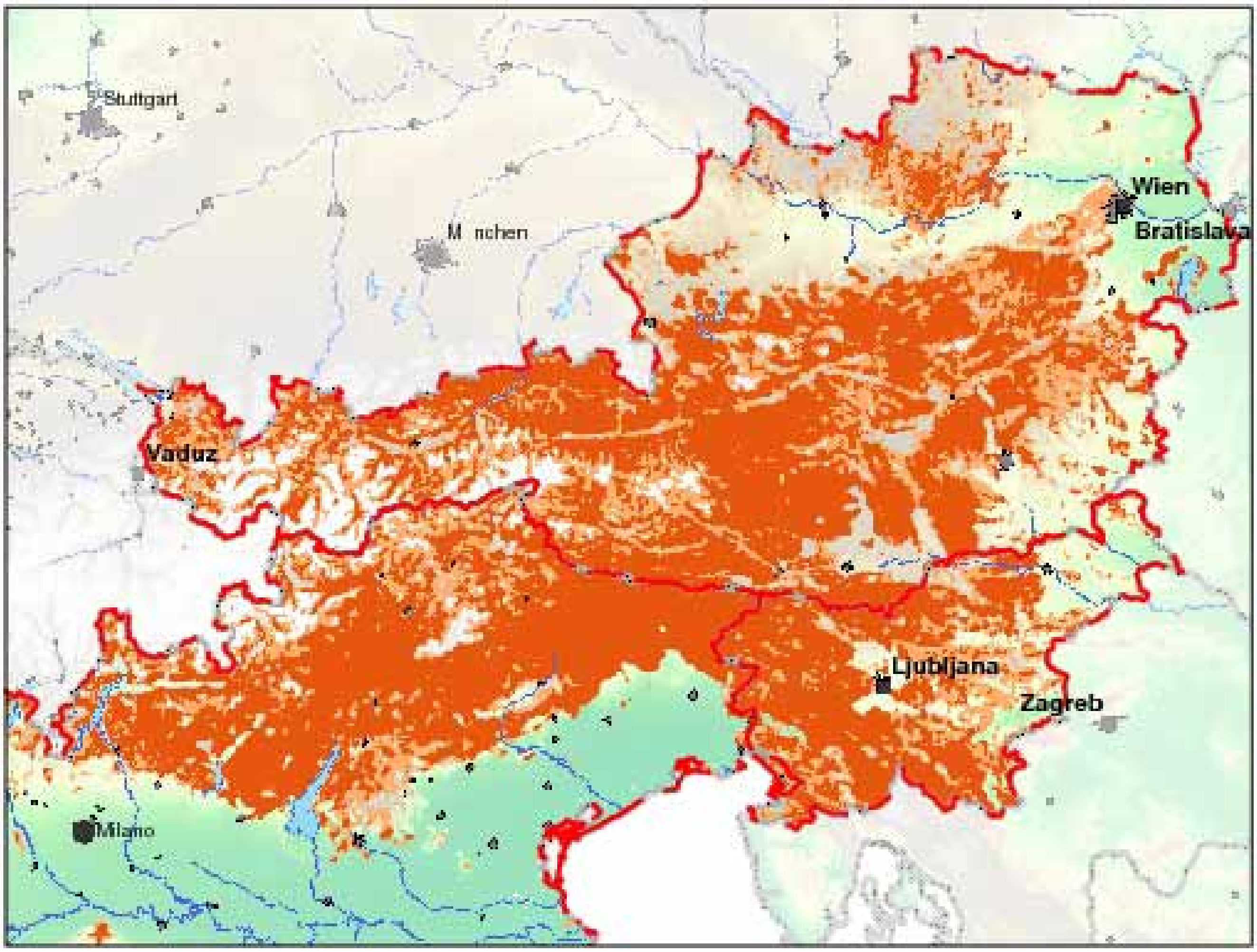

Figure 7 - Map representation of Scenario 4 potential distribution results. Lighter color indicates potential corridor areas. For visualization purposes only an arbitrary cutoff value of 50% has been used, instead of the calculated value of 99%. Applying the pre prescribed cutoff the map would be left almost empty.

4.1.5 Discussion

The results obtained resemble very closely other maps, presented in previously published similar works dealing with brown bear suitable habitat modelling in the Eastern Alps (Zajec et al., 2005; Jerina et al., 2003; Corsi et al., 2002; Kobler and Adamic, 2000), at least if read on the wide scale. In the cited work by Corsi et al., Austrian territory was judged as an area "...which could become an important source for viable populations of large carnivores in the region". Anyway, the same authors recommended to interpret this result with some care due to the low quality of data availavle for Austria, recommending as safer to "to conduct a more detailed analysis of the ecological conditions within the country to increase the reliability of the model". In the present case the outcome is presumably biased on the opposite side, probably by land cover data or by the concentration of bear radio tracking data in a narrow area.

It is our opinion that these results are not to be intended as prejudicial for Austrian territory: Scenarios 1a and 1b results show for Italy a rather fragmented habitat pattern, even inside the Italian reintroduction area, and a sharp change in suitable habitat presence is noticeable miving westwards, where presumably the high urbanisation of the upper Po plain plays a crucial role. On the premises of the results obtained so far, it is possible to assume Scenario 1a as an "optimistic" one and Scenario 1b as a more conservative.

For these reasons, a final potential distribution map has been generated merging the reclassified maps (see Section 3.5.3) derived from both Scenario 1a and 1b, calculating for each 250 m grid cell the local maximum, that is, assigning the best prediction avilable.

4.2 Movement pattern analysis

4.2.1 Analysis of paths and movement patterns

All bears location have been analysed according to Austin et al. (2004) and for 42 of them a significant (at 95% confidence level) adherence to the Lévy flight model was found (Table 15).

Lévy fractal dimension and minimum displacement, along with average home range size and overlap were used as parameters to configure the SEPM, and simulate movement paths using as a siutability landscape the maps obtained from Logistic Regression analysis in Scenario 1a and 1b (4.1.1).

Table 15.: Fractal dimension μ and regression coefficient R2 adjusted for a subset of 23 (out of 42) bears following Lévy flight model. All R^2 significant at $p < 0.01$.

μ	R_2	Sex	Country	Bear
-1.280±0.153	0.812**	F	Austria	Cilka
-1.659±0.178	0.869**	M	Austria	Djuro
-1.591±0.191	0.907**	F	Slovenia	
-2.557±0.160	0.952**	M	Italy	Masun
-2.623±0.285	0.893**	F	Italy	Kirka
-2.111±0.142	0.932**	F	Italy	Daniza

-2.430±0.133	0.971**	M	Italy	Jose
-1.915±0.136	0.925**	F	Italy	Irma
-2.117±0.094	0.973**	F	Italy	Vida
-2.183±0.231	0.855**	F	Italy	Maja
-2.179±0.274	0.828**	M	Italy	Gasper
-1.287±0.187	0.807**	F	Italy	Brenta
-1.275±0.218	0.735*	F	Slovenia	
-1.175±0.161	0.765*	F	Slovenia	
-1.363±0.192	0.779*	M	Slovenia	
-1.529±0.267	0.761*	M	Slovenia	
-1.599±0.332	0.690*	F	Slovenia	
-1.347±0.335	0.684*	M	Slovenia	
-1.117±0.200	0.684*	F	Slovenia	
-1.579±0.215	0.768*	F	Italy	Jurka
-1.324±0.376	0.533	F	Austria	Mira
-1.179±0.519	0.581	M	Slovenia	
-1.046±0.187	0.670	M	Slovenia	

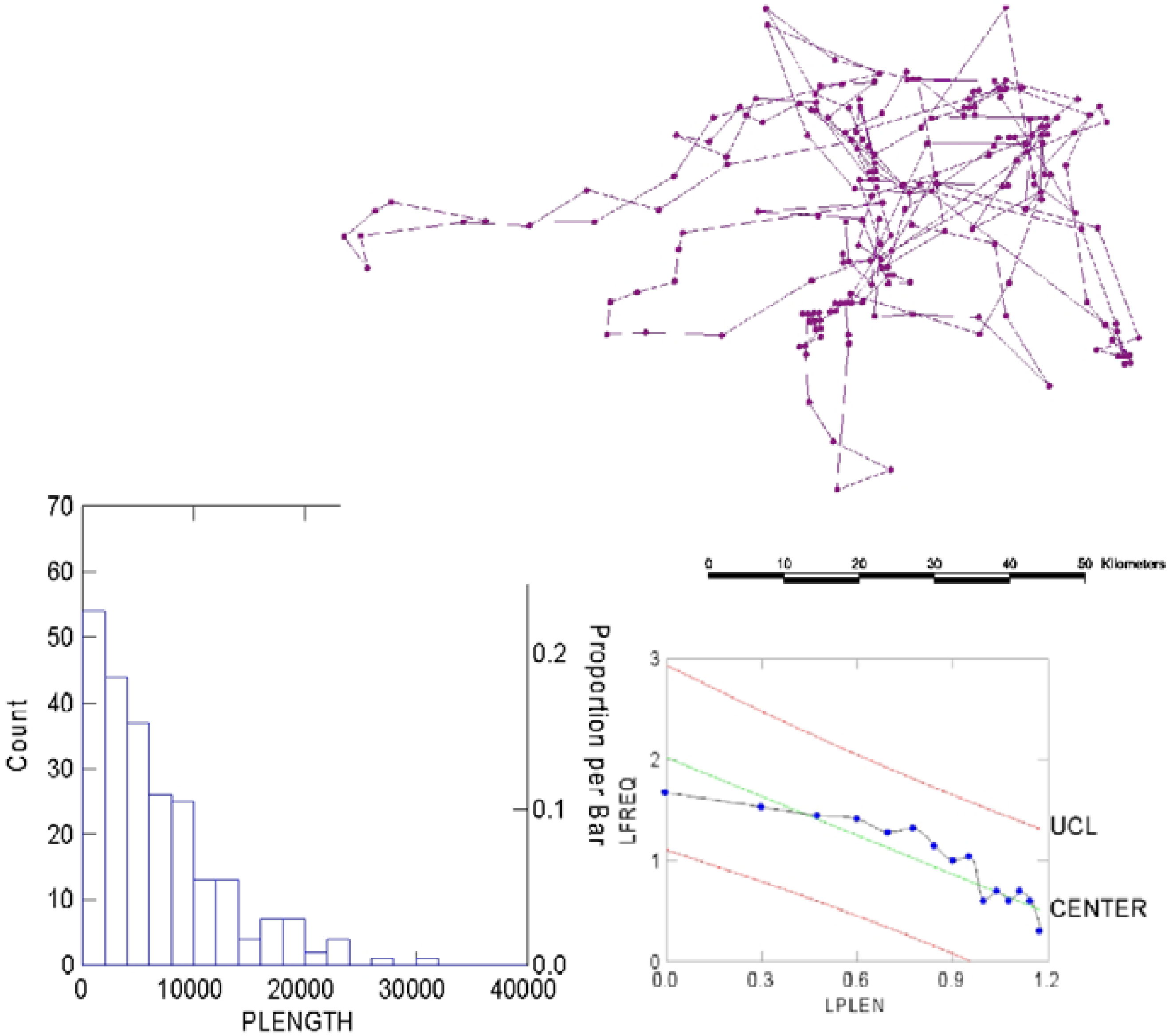

Figure 8 - Average frequency distribution of movement lengths, Double log plot of the same data fitted with a regression line and movement pattern for bear 2, a female released in Austria.

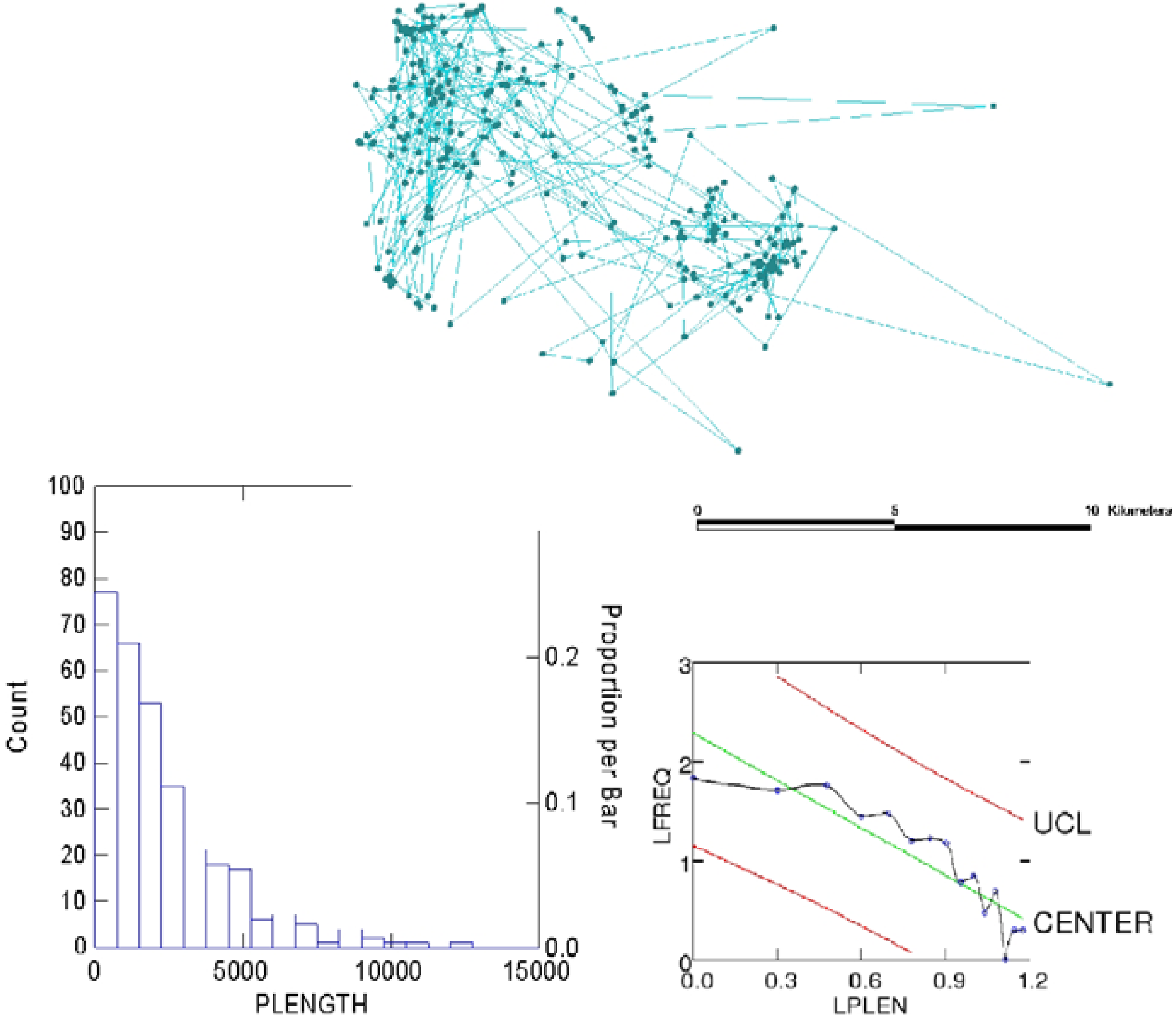

Figure 9 - Average frequency distribution of movement lengths, Double log plot of the same data fitted with a regression line and movement pattern for bear 9, a male, in Slovenia.

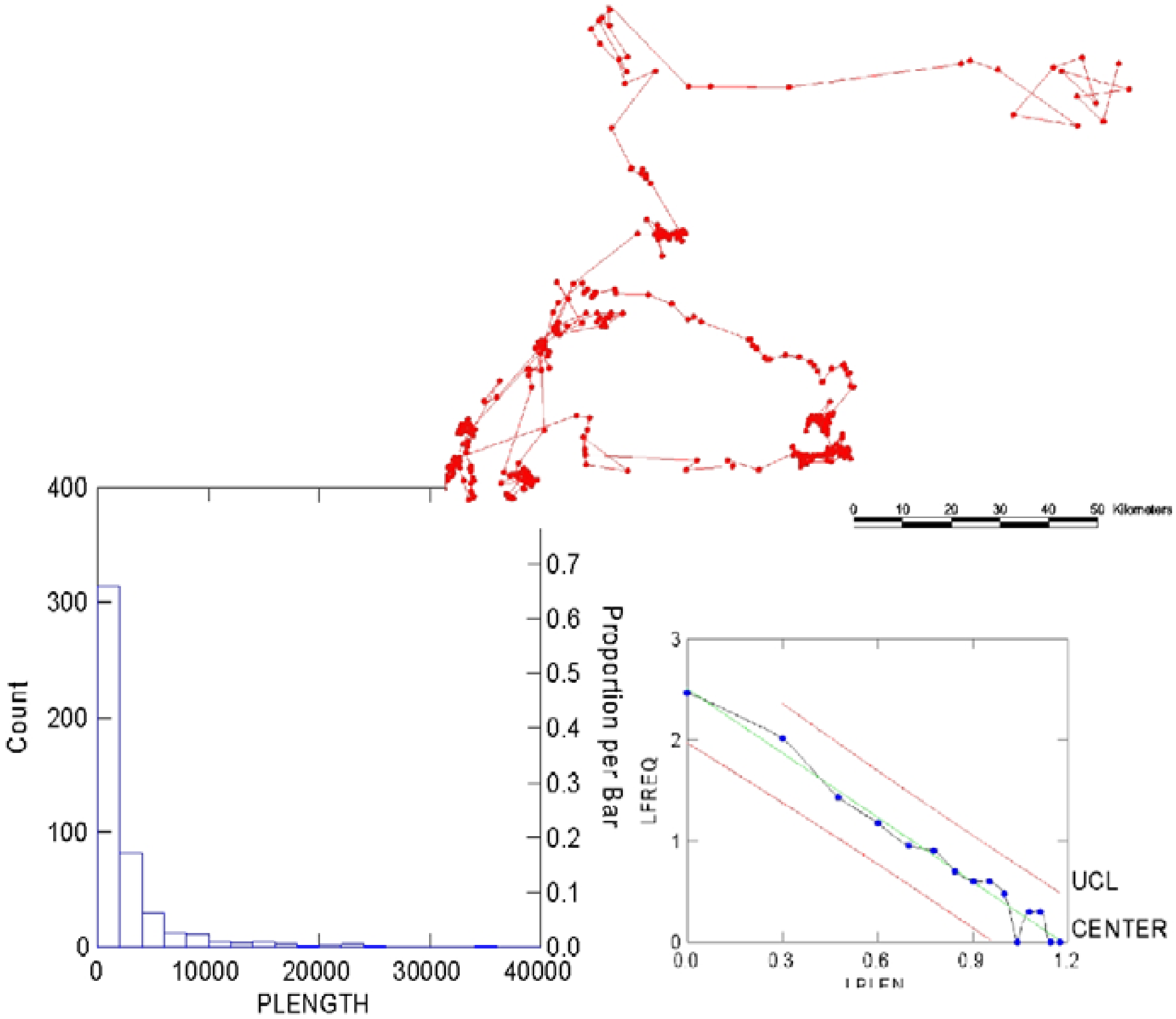

Figure 10 - Average frequency distribution of movement lengths, Double log plot of the same data fitted with a regression line and movement pattern for bear 36, a female released in Italy.

4.3 Bear potential expansion map

Simulated individual trajectories on potential habitat maps indicated the most probable routes which could be used by dispersing bears in the near future. In addition to the procedure described in Section 3.4.2, due to the fact that a strict separation between the three current bear core areas has not been evidenced in suitability maps derived from Scenarios 1a and 1b, corridors have been identified as medium- to low-suitability areas crossed by at least 5 simulated path per simulated year, and the average corridor position had been superimposed to potential distribution map (see Section 4.1.5) as shown in Figure 11.

Potential corridors map were then submitted to all partners for discussion and agreement. For clearness and readability, potential corridors have been rapresented as dotted lines, with darker shades in those segments appearing earlier in time in the simulator software output, and, being mistly located nto suitable habitat, have been defined as already active corridor areas. This observation is supported when points from the non-systematic observations dataset (Section 3.2.4) are superimposed to the corridors map (Figure 12).

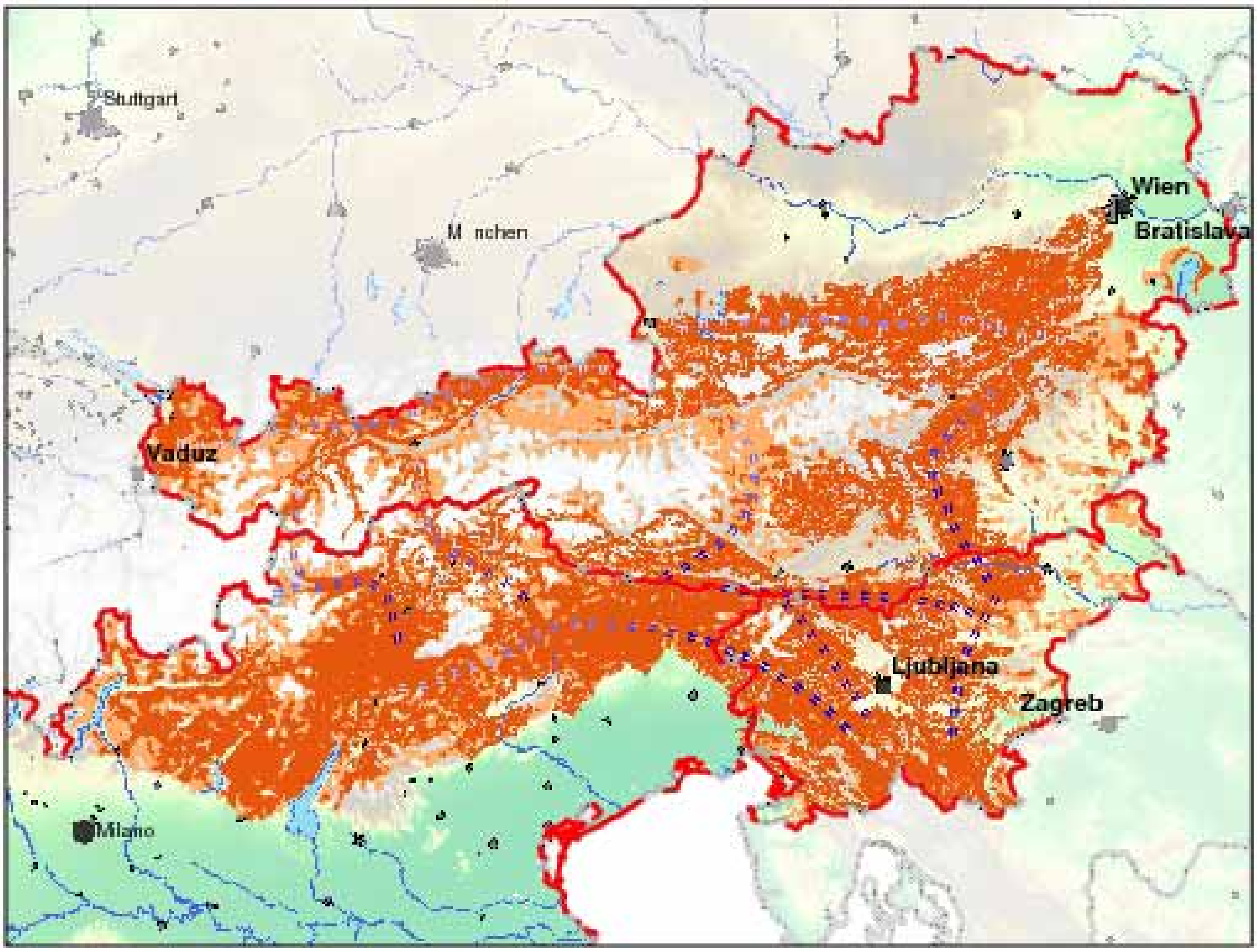

Figure 11 - Potential corridors map showing predicted brown bear corridor areas in Eastern Alps (blue). Darker arrows indicate already active corridors.

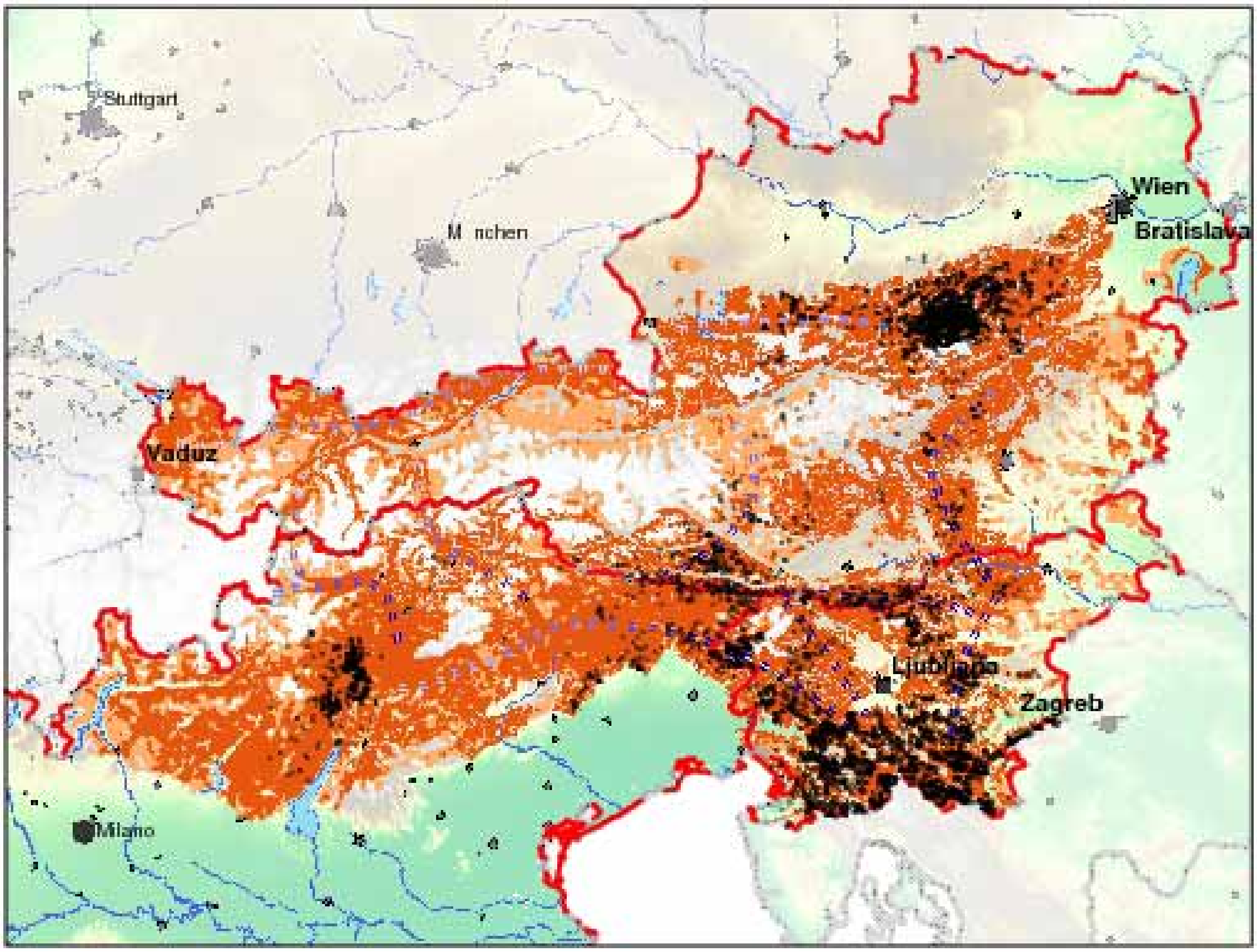

Figure 12 - Bear non-systematic sightings (crosses) superimposed to the potential corridors map.

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Annex A - Corine reclassification summary table

Table A.1.: CLC90 reclassification table

CLC90			**Reclassified**
code	**description**	**code**	**description**
111	Continuous urban fabric	100	Urban areas
112	Discontinuous urban fabric	100	Urban areas
121	Industrial or commercial units	121	Sparsely urbanised
122	Road and rail networks and assoc. land	122	Roads-Railways
123	Port areas	100	Urban areas
124	Airports	100	Urban areas
131	Mineral extraction sites	100	Urban areas
132	Dump sites	100	Urban areas
133	Construction sites	100	Urban areas
141	Green urban areas	140	Green urban areas
142	Sport and leisure facilities	140	Green urban areas
211	Non-irrigated arable land	211	Arable land
212	Permanently irrigated land	210	Irrigated land
213	Rice fields	210	Irrigated land
221	Vineyards	220	Orchards
222	Fruit trees and berry plantations	220	Orchards
223	Olive groves	220	Orchards
231	Pastures	231	Pastures
241	Annual crops associated with permanent crops	240	Agricultural mosaic
242	Complex cultivation patterns	240	Agricultural mosaic
243	Land principally occupied by agriculture, with significant areas of natural vegetation	250	Agricultural seminatural
244	Agro-forestry areas	250	Agricultural seminatural
311	Broad-leaved forest	311	Broadleaf forest
312	Coniferous forest	312	Coniferous forest
313	Mixed forest	313	Mixed forest
321	Natural grasslands	321	Grasslands
322	Moors and heathland	322	Heatlands
323	Sclerophyllous vegetation	323	Sclerophyllous
324	Transitional woodlandshrub	324	Shrubland
331	Beaches, dunes, sands	331	Beaches
332	Bare rocks	332	Rock
333	Sparsely vegetated areas	333	Sparsely vegetated
334	Burnt areas	334	Burnt areas
335	Glaciers and perpetual snow	335	Glaciers and snow
411	Inland marshes	410	Marshes
412	Peat bogs	410	Marshes
421	Salt marshes	420	Coastal areas
422	Salines	420	Coastal areas
423	Intertidal flats	420	Coastal areas
511	Water courses	510	Inland waters
512	Water bodies	510	Inland waters
521	Coastal lagoons	420	Coastal areas
522	Estuaries	420	Coastal areas
523	Sea and ocean	530	Sea

Remarks and conclusions

The outputs for action A.2, realized in the framework of LIFE Co-op project "Principles for the establishment of an Alpine brown bear population", confirm that the area considered by the present study offers significant possibilities for a territorial development of brown bear populations currently present in Slovenia, Austria and northern Italy.

Looking at the maps presented in the previous section of this document, 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, suitable areas for species potential presence are widely extended. Each one of the scenarios elaborated (see scenarios 1a, 1b, 2, 3 and 4) shows a notable deviance between presently occupied and available distributional area for the species. More in detail, wide territories suitable for the species emerge in the midst of the zones currently frequented by bears.

This enables to think that the populations studied have a great future development possibility both in territory and, consequently, in number. The four considered nuclei are likely to reach independently such a dimension that keeps them safe from the extinction in medium and long term period.

Therefore, the picture which comes out from the analysis performed clearly **shows as possible the future achievement of a brown bear metapopulation in Southern Europe**.

Considering that the first goal for action A.2 was to verify such a possibility, we can state that present LIFE Co-op project has obtained a notable result, supporting the idea that brown bear conservation in Southern Europe must be considered in a supranational context.

This situation is, on one side, potentially positive for the future of the species. On the other side, though, it necessarily leads to reflect on what kind of actions can be realized in order to favour the expansion of present brown bear populations.

Despite the individuation of such actions is not among the primary goals of the present report, the following hypotheses can be formulated, in a preliminary way, in order to start working for a future territorial expansion of the bears and thus for the achievement of the metapopulation:

- conservation of all suitable habitats;
- release of bears in north-eastern Italy with the aim of creating a "bridgehead" that can favour contacts among already present populations;
- realization of divulgation/sensitization activities for public opinion of the possible expansion areas.

In order to realize the above mentioned points, the necessity of a connection at governmental level among the three involved nations becomes evident. Through their competent Ministries, the Governments of Italy, Austria and Slovenia could in fact search for the most effective strategy for the conservation of the species.

In this context, the participants to the present project, as well as any other institution involved in bear conservation, will be able to act, on the basis of transboundary agreements, as "local executors" of the programmed activities.

Considering more in detail the work presented in the previous section of this document (edited by Insubria University), the "picture" that appears more close to reality for local bear experts is that outlined in scenarios 1a and 1b.

On the basis of the comments of the wildlife operators that, in the last decades, have been working for the species conservation in the area considered by the present project, scenario 1a is the most reliable for the western and southern part of the study area, while scenario 1b is the most reliable for northern and eastern part.

Other scenarios proposed (2, 3 and 4) do not seem to significantly diverge from those previously mentioned, except for the overall level of environmental suitability (probably related to the reliability threshold of the applied model, as better reported in the previous section of the present document). It seems that, in these latter scenarios, only some limited portions of the study area can be evaluated in a different way from what is foreseen by 1a and 1b predictions.

In this context, it has anyway to be considered the scepticism and critics arising from WWF Austria about the result of the applied model, which has been judged unsuitable for Austrian territory and incorrect for some areas.

Nevertheless, considering once again the objectives of the present project, it seems more useful to look at the overall study area than to concentrate on specific geographical places, analysing the correct evaluation of environmental suitability on a big scale rather than on a small scale.

Entering into the details of each single reality would, in fact, highlight many discrepancies from the environmental interpretations of the "bear expert eye", leaving also much room to subjectivity. A detailed analysis on a small scale would however also point out local situations in which the applied model has not given correct predictions, thing that appears unavoidable on such a wide territorial scale.

On the contrary, it is evident that interpreting the predictions, deriving from scenarios 1a and 1b, focusing on the main goals of the project can help answering the following questions: will bears belonging to the already existing populations have the possibility to interact with each other, in the next future, frequently enough to create a metapopulation? Which are the most probable bear "routes of expansion" (colonization) in case the populations continue their territorial spreading?

Having already positively answered to the first one of the two questions, it appeared useful, in order to give an hypothetical answer to the second, to consider a map which could be a synthesis of scenarios 1a and 1b.

Such an applied model evidences the presence of various areas, not suitable from an environmental point of view for the stable presence of the species, but that can be considered suitable for bear passage. These transition areas can be corridors connecting stable presence areas and allowing the establishment of a metapopulation. Through the corridors, in other words, bears could in the next future manage to move from one area to the other, allowing individuals (and genes) exchanges among nuclei otherwise isolated, and therefore supporting the achievement of the genetic variability typical for the species.

In this sense we must also remind the possibility of the species to move through long distances, which allows it to travel tens kilometres in a single day and thus to fully exploit transition areas. In detail, the following two-ways "routes of expansion" seem to be evident:

Corridor path		Geografic interested area
1	East "Slovenia-Austria"	From Southern Slovenia forests (West core area part - Kočevje Reserve) going northwards, passing east of Ljubliana and south-west of Maribor. From here passing North-western Slovenia-Austria boundary, entering in Austrian Steiermark with a curvilinear path west and north of Graz.
2	West "Slovenia-Austria"	From Southern Slovenia forests (western part of the Slovenian core area - Jelen-Sneznik Reserve) going northwards to Triglav area, as far as ideally connecting with the corridor number 3 of the present table.
3	"Slovenia-Austria" boundary	Near and along Slovenia – Austria boundary: northern of Ljubliana, southern of Klagenfurt, almost until the border between Austrian Länder of Carinzia (Kärnten) and Tyrol. This corridor can be intended in continuity with the ones reported with number 1, 2, 4 and 5 in the present table.
4	East-West "Slovenia-Italy"	Wide potentially suitable area for bear movements, going from Southern Slovenia (western part of the core area) north-westwards. Beyond Slovenia-Italia boundary, passing from Friuli and Veneto until Trentino.
5	East "Italy-Austria"	On the Italian-Austrian border line (boundary between Friuli-Venezia-Giulia and Veneto regions) going northwards with a curvilinear path open westwards, in the western part of Austrian Land of Kärnten till 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 Tyrol, along Adige valley, western of Bolzano, along Venosta Valley to Engadina at one side and to Western Austria end at the other.
8	West-East in North part of Austria	From west to east in the northern part of Austria.

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 their only descriptive value.

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

Scarcity and dissimilarity of bibliographic data referring to brown bear population dynamics in Southern Europe has made impossible to produce reliable predictions concerning times of expansions and thus movements into the above mentioned corridors. It must, in fact, be considered that, without trustworthy sources, normal sinusoidal fluctuations that characterize animal population dynamics make even more aleatory the possible predictions on the timings of future colonization of the areas which are suitable for the species.

Nevertheless it appears evident that current environmental and anthropic attributes of the study area can be considered suitable for the development and steadying of a bear metapopulation. It must be however considered that population dynamic factors, which can bias this possibility, have a low predictability in time. In particular, all the factors increasing direct mortality of the animals will have to be carefully examined.