Abstract: Although several techniques have been used to explore the spatial features of brown bear (Ursus arctos) range (e.g., potential distribution models, geographic information system [GIS] methodology), quality and quantity of data have often constrained the usefulness of the results. We used 12 environmental variables to identify potentially suitable areas for bears in the Italian part of the Eastern Alps. We used Mahalanobis distance statistic as a relative index of the environmental quality of the study area by calculating for each pixel (250 meters) the distance from the centroid of the environmental conditions of 100 locations randomly selected within known bear ranges. We used different levels of this suitability index to identify potential optimal and sub-optimal areas and their interconnecting corridors. The model identified 4 major areas of potential bear presence having a total size of about 10,850 km². Assuming functional connectivity among the areas and mean density for west European countries, the Eastern Alps could support 108-325 bears. Potential ranges were also compared with existing protected areas to evaluate gaps between bear range with adequate protection and range needing protection. Only 31% of existing protected areas was found suitable for bears. We suggest that bear conservation will depend more on establishing and managing effective corridors than other protected areas.

Key words: Alps, brown bear, geographic information system, GIS, habitat suitability, Italy, Mahalanobis statistic, potential distribution, Ursus arctos

Brown bear populations in European countries are drastically reduced from earlier sizes, with populations ranging as low as 4–5 up to 80–100 bears (Institut Royal des Sciences Naturelles de Belgique [IRSNB] 1992). Although some of these are still in contact with source populations (e.g., Pindus and Rhodope populations in Greece), the majority appear highly isolated (e.g., in the Cantabrian Mountains, Trentino, Abruzzo, and the Pyrenees) and in need of conservation. Small propagules of expanding populations, which are of paramount importance for natural recolonizations (e.g., the Tarvisian population in northeastern Italy), also need prompt conservation measures to ensure their protection and to foster their growth. Bears in the Eastern Alps survive in 2 small, isolated populations: 3–4 individuals in the Adamello-Brenta Natural Park, considered a relict population unable to reproduce since 1989 (Osti 1994), and a small Tarvisian population probably composed of bears immigrating from Slovenia (H. Roth, Abruzzo National Park, Pescasseroli, Italy, personal communication, 1996). Both populations are valuable for the survival of bears in the Italian Alps and have been the focus of several conservation initiatives. The effective conservation of these 2 populations, however, remains questionable as conservation efforts have been planned mostly on a local scale and have not considered spatially explicit models of habitat suitability and sustainable development (Ciucci and Boitani 1996).

Bears live at low densities and have large home ranges, thus any conservation strategy should have a broad-scale approach to accommodate viability requirements (Paquet and Hackman 1995). Because spatial requirements are evaluated in terms of availability, localization, and configuration of suitable areas with respect to a human-dominated land matrix, it is unlikely that available remnants of wilderness are large enough to accommodate viable bear populations. Rather, a network of protected (or appropriately managed) areas has been viewed as an alternative solution to meet viability requirements for large carnivores (Noss and Harris 1986). Such a system should be centered on critical areas of suitable environments connected through corridors and should be integrated into a human-dominated matrix which includes transitional areas (i.e., buffer zones) devoted to sustainable use. Furthermore, any local conservation measure (e.g., establishing a protected area) or management intervention (e.g., incentives for fruit tree plantations or alternative livestock husbandry), to be effectively implemented and monitored at the administrative level, needs to be planned within a broader land-use policy articulated through geographically explicit guidelines. Development of such a land-use matrix requires a broad-scale approach; this planning can be greatly enhanced by geographic information system (GIS) methodology which incorporates estimates of environmental quality into spatially explicit models.

As a first step toward this end, our aim was to develop a GIS-based model to assess location and configuration of potential ranges for the brown bear in the Eastern Alps of Italy. Our model, developed for the entire Eastern Alps region, was essentially aimed at: (1) producing an index of environmental quality for bears using available data
for environmental variables; (2) incorporating various
human land uses in the assessment of environmental qual-
ity for bears; (3) producing spatially explicit results; and
(4) finding connectivity among areas of potential bear
presence based on the environmental quality index.

The model, although severely limited in its current ap-
lication by the paucity of data on habitat use and selec-
tion by bears in the Alps region, represents a useful tool
to assess bear conservation options in the Eastern Alps
in terms of population viability. It also facilitates the
evaluation of existing protected areas and sets the ground
for an international approach to bear conservation.

STUDY AREA

This model was developed for the Central and Eastern
Alps of Italy. The 41,129 km² study area was defined to
the north and east by the Italian border. Although obvi-
ously not an ecological limit for the bear, this border was
adopted for practical reasons of data availability and ho-
mogeneity—the major concerns for the final quality of
the model. The southern boundary was the interpolated
100-meter contour line: in fact, at lower elevations hu-
mans densities and an almost total absence of forests make
the environment inadequate for the brown bear. Lake
Maggiore was chosen as the western boundary as it geo-
graphically limits bear movements. The area is mostly
mountainous with extensive forests and relatively little
human disturbance.

METHODS

The environmental variables selected for the model
were greatly influenced by the paucity of digital data.
Based on data availability and quality and on the known
ecological needs of brown bears, we selected 12 vari-
bles (Table 1). Seven variables were obtained from the
land cover map to account for basic environmental qual-
ity; 2 variables were used as indicators of human distur-
bance (human density and road density), and the
remaining 3 variables were selected to describe topogra-
phy (elevation, slope, and aspect). We converted vari-
bles into co-registered raster with a pixel size of 250 x
250 meters.

To build the model, the data sets on the environmental
variables were combined with the information available
for existing bear ranges. We used these data to identify
the brown bear’s ecological requirements for the envi-
ronmental variables used in the model. Data on the brown
bears’ actual ranges were obtained from H. U. Roth
(Abruzzo National Park, Pescasseroli, Italy) and were
based on surveys carried out in the past 20 years in the
Province of Trento, the Adamello-Brenta Natural Park
and its surrounding areas, and in the northeastern part
of the Province of Udine near the Slovenia border. Four
areas of known bear presence were identified from
radiotracking data and other evidence of presence (tracks,
hair, droppings, and denning activities). Two large areas
were located in the Province of Udine, and 2 smaller
areas were located in the Province of Trento. The total
area of bear presence was 963 km², with 816 km² located
in the Province of Udine and the rest in Trento. A ran-
dom sample of 100 points was selected within these 4
areas and represented bear locations (RBL) in the subse-
quently analyses. One hundred RBLs were considered suf-
ficient to represent habitat variability within the relatively
small range of bear presence.

To account for bears’ awareness of the surrounding
environment, each variable was processed using a mov-
ing window of 30 km²; a function of all the pixel values
included in that window was assigned to the central pixel
(Tomlin 1990). The size of the window was equal to the
average home-range of individual bears in the area (Roth
and Osti 1979).

We overlaid the 100 RBLs onto the raster coverage
and calculated both the vector of the means and the vari-
ice-covariance matrix. These were used to calculate
the Mahalanobis ecological distance (Clark et al. 1993,
Knick and Dyer 1997) of each pixel of the study area
from the environmental conditions as measured at the
RBLs.

The resulting layer was a raster coverage whose val-
ues represented the ecological distance (D) from the av-
erage conditions as defined by the RBLs. The lower the
distance, the more similar the conditions were to those
observed in the areas of known bear presence and the
higher the environmental quality for the bear. The re-
sulting distance, which ranges from 0 to infinity, has no
absolute value but should be interpreted in a relative way.
Lower values are an index of higher environmental qual-
ity.

Based on the ecological distance raster, we divided the
study area in 4 suitability classes: optimal, sub-optimal,
connecting area, and area essentially avoided by bears.
The threshold values for the optimal and the sub-optimal
classes were arbitrarily set based on the mean and stan-
dard deviation of the ecological distance observed
within the original bear areas. We chose threshold val-
ues considering the percent of RBLs that would be in-
cluded within each threshold. The optimal zone was
defined as that enclosing D smaller than the mean plus the
standard deviation, which would include 90% of all
points inside the known bear ranges. The sub-optimal
zone was defined as D smaller than the mean plus 3 times
Table 1. Environmental variables used in the 1997 GIS model of brown bear habitat suitability in the Eastern Italian Alps and their source and resolution.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Origin and resolution of dataa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of arable land</td>
<td>Land use cartography (1962 86), scale 1:250,000</td>
</tr>
<tr>
<td>Area of tree cultivation</td>
<td>Land use cartography (1962 86), scale 1:250,000</td>
</tr>
<tr>
<td>Area of forest</td>
<td>Land use cartography (1962 86), scale 1:250,000</td>
</tr>
<tr>
<td>Area of pastures</td>
<td>Land use cartography (1962 86), scale 1:250,000</td>
</tr>
<tr>
<td>Area of bare soil</td>
<td>Land use cartography (1962 86), scale 1:250,000</td>
</tr>
<tr>
<td>Area of water bodies</td>
<td>Land use cartography (1962 86), scale 1:250,000</td>
</tr>
<tr>
<td>Area of urban settlements</td>
<td>Limit of urban settlements (1971), ENEL 1985, scale 1:25,000</td>
</tr>
<tr>
<td>Elevation</td>
<td>Italy's DTM, Sistema Informativo Nazionale 1995, resolution 250 m</td>
</tr>
<tr>
<td>Human density</td>
<td>13th general census of the population ISTAT 1991, aggregated by township.</td>
</tr>
<tr>
<td>Road density</td>
<td>Maps of the Italian Touring club of Italy 1994, scale 1:200,000</td>
</tr>
<tr>
<td>Aspect</td>
<td>Italy's DTM, Sistema Informativo Nazionale 1995, resolution 250 m</td>
</tr>
<tr>
<td>Slope</td>
<td>Italy's DTM, Sistema Informativo Nazionale 1995, resolution 250 m</td>
</tr>
</tbody>
</table>

a ENEL = Ente Nazionale Energia Elettrica; DTM = Digital Terrain Model; ISTAT = Istituto Nazionale di Statistica. The digital land-use maps are produced by the cartographic offices of the Regions Veneto, Lombardia, Friuli e Venezia Giulia, and by the Provinces of Trento and Bolzano.

Fig. 1. Potential areas for bear presence in the Italian Eastern Alps from a 1997 model: optimal, sub-optimal, and corridor areas shown against the location of the major protected areas of the region.

The standard deviation, including 98% of the points. The limit of the connectivity zone was set by $D$ smaller than twice the mean plus 3 times the standard deviation, including 99.6% of the points (i.e., including about 80% of the points that were excluded by the previous level). The last zone included all $D$ values greater than the third threshold.

We then compared the area obtained using the above method with the distribution of existing protected areas. Information on extension and location of the protected areas was obtained from maps (Ministero dell'Ambiente 1992). Although current boundaries and extensions of some protected areas have since changed slightly, new data are not yet available in digital format. We believe, however, that these changes do not seriously affect the estimates of suitable ranges within the protected areas, at least in light of the limited aim of our model.

Projections of bear density in the study area were obtained from available estimates of bear density in Trentino and in other southwestern European countries (Roth...
suitable bear areas
major protected areas
areas of bear presence
major towns
lakes

Fig. 2. The 4 zones of potential bear presence (A–D) in the Italian Eastern Alps include all optimal and sub-optimal areas from a model developed in 1997. Total size is about 10,850 km².

Table 2. Brown bears’ suitable ranges found in each protected area of the Italian Eastern Alps from a model developed in 1997.

<table>
<thead>
<tr>
<th>Protected area</th>
<th>Type</th>
<th>Area (ha)</th>
<th>Suitable bear ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ha</td>
</tr>
<tr>
<td>Stelvio</td>
<td>National Park</td>
<td>135,049</td>
<td>5,317</td>
</tr>
<tr>
<td>Orobie</td>
<td>Regional Park</td>
<td>124,015</td>
<td>34,266</td>
</tr>
<tr>
<td>Adamello-Brenta</td>
<td>Regional Park</td>
<td>116,779</td>
<td>35,374</td>
</tr>
<tr>
<td>Prealpi Carnicche</td>
<td>Regional Park</td>
<td>77,230</td>
<td>71,202</td>
</tr>
<tr>
<td>Dolomiti Bellunesi</td>
<td>National Park</td>
<td>32,390</td>
<td>9,525</td>
</tr>
<tr>
<td>Alto Garda Bresciano</td>
<td>Regional Park</td>
<td>30,437</td>
<td>16,707</td>
</tr>
<tr>
<td>Gruppo di Tessa</td>
<td>Regional Park</td>
<td>30,051</td>
<td>0</td>
</tr>
<tr>
<td>Fanes-Sennes-Braies</td>
<td>Regional Park</td>
<td>25,339</td>
<td>396</td>
</tr>
<tr>
<td>Vedrette di Ries</td>
<td>Regional Park</td>
<td>19,405</td>
<td>0</td>
</tr>
<tr>
<td>Dolomiti d’Ampezzo</td>
<td>Regional Park</td>
<td>18,046</td>
<td>6,579</td>
</tr>
<tr>
<td>Lessinia</td>
<td>Regional Park</td>
<td>16,953</td>
<td>8,576</td>
</tr>
<tr>
<td>Paneveggio- Pale di S. Martino</td>
<td>Regional Park</td>
<td>15,974</td>
<td>5,710</td>
</tr>
<tr>
<td>Alpi Giulie</td>
<td>Regional Park</td>
<td>15,162</td>
<td>14,710</td>
</tr>
<tr>
<td>Sciliar</td>
<td>Regional Park</td>
<td>11,157</td>
<td>3,766</td>
</tr>
<tr>
<td>Dolomiti di Sesto</td>
<td>Regional Park</td>
<td>9,730</td>
<td>291</td>
</tr>
<tr>
<td>Puez-Odle</td>
<td>Regional Park</td>
<td>8,738</td>
<td>0</td>
</tr>
<tr>
<td>Monte Corno</td>
<td>Regional Park</td>
<td>6,684</td>
<td>3,852</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>693,139</td>
<td>216,271</td>
</tr>
</tbody>
</table>

1987, IRSNB 1992, Schröder 1992, Osti 1994). As bear density was assumed to be homogeneously distributed across the study area, predictions on the viability of a potential bear population in the Eastern Alps region are to be considered optimistic.

RESULTS

The ecological distance ($D$) thresholds for the 4 zones were $D \leq 15$ for the optimal areas, $D \leq 25$ for the sub-optimal areas, $D > 35$ for the avoided areas. Optimal zones were concentrated in areas covered by forest and in the elevation range of 800–2000 m. (Fig. 1). In Italy and particularly in the study area, elevation is correlated to human disturbance. Sub-optimal areas are useful to reduce the fragmented mosaic of optimal areas and are to be considered as areas of lower quality within the bear range or areas that can support lower bear densities. The third level of areas surrounding the sub-optimal bear ranges should be
considered as buffer areas: they are not suitable for permanent bear presence, but can be used as corridors connecting patches of suitable habitat.

Merging the first 2 classes of areas and selecting only polygons >900 km$^2$, the model identified 4 major areas for potential bear presence (identified as A–D in Fig. 2) with a total size of 10,850 km$^2$. These appear highly fragmented and discontinuous, a tendency that increases in an east–west direction. Areas of potential bear presence are well connected only in the easternmost section of the Eastern Alps (Provinces of Udine and Belluno; zone A in Fig. 2), while suitable bear areas are highly fragmented and isolated in the remaining central and western parts of the study area (zones B, C, and D in Fig. 2).

When the corridor class was also considered, the total size of all suitable areas was 21,333 km$^2$. This does not, however, provide a functional connection among the various zones of the Eastern Alps region (see Fig. 1). The valley of the river Adige (flowing through Bolzano and Trento), in particular, can be an effective barrier to bear dispersal and movements, due to its high density of human activity and roads, highways, and railways. If the present conditions are not changed, it is quite unlikely that immigration from the east could ever reach the relict Adamello-Brenta bear population in zone C.

Assuming that the connections among all optimal and sub-optimal areas in the Eastern Alps were effectively functional (Fig. 2) and that bear density would fluctuate between that found in Trentino (about 1 bear/100 km$^2$; Roth 1987, Osti 1994) and the mean value in west European countries (about 3 bears/100 km$^2$; IRSNB 1992), the model indicates that the region could support 108–325 bears, corresponding to an effective population size of 30–78 individuals (Harris and Allendorf 1989, Randi et al. 1994).

The model showed the overlap between potential bear ranges and the existing Natural and National Parks (Figs. 1, 2). Total protected areas within the Eastern Alps region was about 6,930 km$^2$; 31% (2,160 km$^2$) of this area was identified by the model as areas of potential bear presence. However, overlap between protected areas and suitable bear habitat was not homogeneously distributed across the entire region, ranging from no overlap to >90% (Table 2). The degree of overlap between protected areas and suitable bear ranges followed the same westward trend shown by the fragmentation of suitable areas and was higher in the eastern portion of the study area (Prealpi Carniche, Alpi Giulie) and less in the central and western regions (Gruppo di Tessa, Vedrette di Ries, Puez-Odle; Table 2).

DISCUSSION

Among large carnivores, the brown bear represents one of the greatest challenges for conservationists. Biological characteristics such as long generation time, low juvenile proportion in the population, sensitivity to low mortality levels, low density and extensive spatial requirements, reduced dispersion capabilities, high habitat selectivity and seasonal requirements, and large foraging needs all interact to cause the brown bear to be a species of low resilience (Weaver et al. 1996). This characterization could be particularly true in alpine regions, where environmental instability is greatest and natural barriers to dispersion are more frequent. However, the conservation value of the bear is enhanced by its role both as an umbrella (Soulé 1987) and flag species (Noss et al. 1996). Bear conservation, especially in highly populated countries such as Italy, therefore needs to be rigorously planned to promote viability, but at the same time, to allow a functional coexistence with human land-uses. A bear conservation strategy based on land-use planning requires a large-scale approach and a concerted effort addressing all the different aspects of bear conservation. Such planning should include not only the ecological and biological facets, but also economical, socio-political, and administrative factors that are too often neglected in conservation practice (Clark et al. 1996). One of the reasons conservation plans fail to be implemented effectively is the lack of geographically explicit guidelines for administrators (Clark et al. 1996). Models of habitat suitability for the brown bear which are spatially explicit may go a long way toward solving this problem, not only by identifying areas of critical values for bear protection, but also by providing an effective tool to plan, on a large scale, the area, location, and configuration of a zoning system. This system could include critical areas, connecting corridors, and buffer zones, which would allow for functional solutions to the coexistence of bears and humans. By providing spatially explicit information, a GIS-based environmental suitability model allows evaluation of the effectiveness of local management interventions within a broader conservation strategy and the options to translate conservation indications into action.

Models are seldom valuable only for their predictive power: they are most useful as tools to explore the dynamics of the system being modeled and the relative strength of the parameters being used. In this perspective, the arbitrary set of threshold values could be manipulated to test various levels in different scenarios: this is currently being done in the framework of a new brown bear conservation strategy for the Alps. We believe, how-
ever, that the thresholds being proposed here hold sufficient biological and conservation significance to be retained in a large-scale spatial analysis.

Given the current condition of the brown bear in the Eastern Alps, we believe the problem of its conservation resides mainly in the ability to plan and prepare for a successful natural recolonization from the east and northeast. Additionally, such a plan would foster the establishment of a self-sustaining population and facilitate its future expansion westward (Ciucci and Boitani 1996). One of the main problems to bear survival is disturbance by humans, which both directly and indirectly may alter the availability of suitable areas for the species (Paquet and Hackman 1995). Construction of roads, mining, logging, presence of highways and railways, excessive tourism, livestock grazing, and hunting are all activities which, if undertaken at critical places or seasons, may drastically affect environmental quality for the bears. On a local scale, environmental degradation and fragmentation may disrupt the connectivity among areas required by bears on a seasonal basis (e.g., foraging and wintering territories). Similar environmental change on a larger scale may lead to an increasing fragmentation of the suitable habitat at the regional level, thus leading to a decrease in viability of the population. The same probabilities of persistence of a metapopulation would dramatically decrease if the connectivity (i.e., effective dispersal) among the different sub-units was not assured. It is therefore of paramount importance, especially in a human-dominated environment, to identify, enhance, and protect the existing corridors between subpopulations (Noss et al. 1996). This process is important for the brown bear in the Eastern Alps, where suitable areas are highly fragmented into 4 major zones (Fig. 2). Individually, the different zones are not large enough to support a self-sustaining bear population in the long term. Instead, if connectivity within the 10,850 km² of suitable environments were ensured, a population of 100–300 bears might be achieved. Although not viable in the long term, this population may represent a realistic goal for a conservation program for the brown bear in the Eastern Alps of Italy. Prospects are even more encouraging if, as already planned, the brown bear conservation program is integrated in the near future at the international level.

As outlined above, we believe environmental suitability evaluated by GIS is of particular relevance in terms of assessment and planning for bear viability for 2 reasons. First, given the paucity of data on the brown bear in the Eastern Alps and the low numbers of surviving bears, projections of viability per se are not very reliable even though they are projected on a large scale (Schröder 1992). Conversely, once the availability of suitable areas is estimated, it is possible to estimate carrying capacity for the brown bear and therefore assess the practicality of the conservation goal in terms of viability. Second, where the spatial requirements for viability exceed the land available for total protection (Belovsky 1987), GIS offers a unique opportunity to plan an alternative design and site-specific management of a zoning system which would account for viability requirements (Noss and Harris 1986, Noss 1992, Mech 1995, Paquet and Hackman 1995). For example, even though the target of 500 grizzly bears for the northern Rockies recovery plan would necessitate more than 129,000 km² of undisturbed land (Metzgar and Bader 1992), this goal does not necessarily need to be represented by a single, continuous protected area. Alternatively, given that a sufficient flow of individuals between the critical areas is maintained across generations, a system of interconnected critical areas interspersed in a matrix with different forms of land-use may still meet viability requirements (Noss et al. 1996, Primm 1996). Similarly, our model for the Eastern Alps suggests the establishment of a network of protected areas whose connectivity, assured by enhancement and protection of potential corridors, would facilitate the persistence of a recovering bear population. Where recovery of the brown bear in the Eastern Alps appears a realistic target in terms of viability, our spatially structured model indicates that the connectivity among areas of potential bear presence needs to be greatly enhanced. Alternatively, bear reintroductions or translocations from source populations should be considered to foster propagation and persistence of the species in the western portions of the Italian Alps (Ciucci and Boitani 1996).

Protected areas seem critical for the protection of large carnivores and their habitat and, if properly designed, may represent the core system for their conservation (Paquet and Hackman 1995). In the Italian Eastern Alps there seems to be an adequate number of protected areas, and proposals to enlarge the existing areas or to establish new ones have been scrutinized in these past years. However, the 630,000 ha of protected areas currently established in the Italian Eastern Alps do not seem sufficient to support a viable bear population, especially with regard to the configuration and relative distribution of those areas. There are 3 major problems in this regard. First, not all of the protected areas are administered and managed as required, with cases of development plans, infrastructures, and massive seasonal tourism. Second, the establishment of the existing protected areas most often reflects scenic and landscape criteria rather than wildlife spatial and habitat requirements. The result in the Eastern Alps is that most protected lands are distributed at the higher elevations and do not include produc-
tive, seasonally important areas for the bear. Instead, these productive seasonally important areas are located at low-medium elevations where fragmentation and disturbance by man is higher. Third, protected areas are most often planned locally and independently; their relative distribution and configuration (including connectivity) has not evolved considering large carnivore conservation. On a regional scale, the existing protected areas and the areas suitable for the bear significantly overlap only in the eastern portion of the Eastern Alps (i.e., Friuli Venezia Giulia, Fig. 2). In the remaining portion of the territory (Veneto, Trentino, Lombardia), the land is protected mainly at higher elevations where productivity and the other landscape features do not seem to allow bear presence.

Similar problems have been reported for Slovenia, where ecological features of the environment and its suitability for bears have not been sufficiently considered as leading criteria for the establishment of the central protection area (Adamic 1994). In the Eastern Alps of Italy, this means that even though there are large suitable areas available in the region, they may not be properly configured, protected, or managed to allow bear presence. Consequences of this fragmentation include: (1) significantly reduced carrying capacity for the bear, (2) increased fragmentation of suitable areas, (3) interference with the habitat and the spatial requirements of the bear on a seasonal basis, and (4) increased potential for conflict between bears and humans (Ciucci and Boitani 1996). This problem is more relevant in the central and western portion of the study area. However, it seems quite impractical to call for remodelling the current system with shifts or an enlargement of the existing protected areas as well as the establishment of new ones. Consequently, a system of interconnected protected areas seems to represent the only alternative solution to bear conservation in the Eastern Alps of Italy.

Corridors based on our model do not seem sufficient to ensure connectivity and dispersal of bears in the region because fragmentation increases in the central and western portions of the Eastern Alps, where chances of natural recolonization from source populations is unlikely. However, we stress that the effective functionality of the corridors should be assessed on a larger scale (i.e., local) because the data in our GIS model was tuned on a regional scale and may not account for land features on a local scale following field surveys. Thus, even though from our model the region of Tarvisio, which represents an important connection between the Alpi Giulie and the Alpi Carniche, appears well suited for bear presence without any significant barrier to its movements (Fig. 2), the system of roads, highways, and railways crossing the area from the border to Gemona seems to prevent bear movement in about 91% of its length (P. Molinari, 1996, Studio sui potenziali corridoi faunistici con particolare riferimento all’orso bruno nelle estreme Alpi sud-orientali. Associazione Italiana per il World Wildlife Fund, Roma, Italy). The areas we identified as important connecting corridors between critical areas for the bear in the Eastern Alps should then be further evaluated on a local scale for presence of infrastructure and its potential impact on bear movement. To be effective, the system of protected areas and their connecting corridors need to be complemented by buffer zones or areas where land use by humans is modulated to allow coexistence between bears and humans.

ACKNOWLEDGMENTS

We appreciate the help of H.U. Roth, who provided data on bear distribution in the northeastern Alps. Worldwide Fund for Nature-Italy contributed partial financial support to the Istituto di Ecologia Applicata. E.C. Meslow, W. Schroder, M.R. Vaughan, and an anonymous reviewer provided useful comments to earlier drafts of the manuscript.

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