Abstract: One hundred years ago, the brown bear was extinct in Switzerland as in most other parts of the Alpine region. During the last few years, the remaining populations in Slovenia and especially in the Trentino, northern Italy, have been increasing once more. Thus, thanks to legal protection and reintroduction programs, bears are expanding and reclaiming areas of their former distribution. Since southeastern Switzerland is very close to the Trentino, a natural return to this country seems possible. This study deals with the basic question of whether there is any suitable habitat in the densely populated and intensely used landscape in Switzerland. Further, the study gives a first insight into potential migration routes for dispersing bears and possible conflicts that could arise, if the bear should indeed return. The study is based on a geostatistical model including bear presence data from the Trentino. The Ecological Niche Factor Analysis (ENFA) was used to determine the potential area of distribution. Areas of suitable bear habitat were found in the southern and northern parts of the Swiss Alps, namely the Engadin, the northern Grisons and in the region of Glarus. Dispersing bears from the Trentino could reach the core areas of suitable habitat in Switzerland along several corridors, with the longest corridor having a length of 87 kilometres. Since no insurmountable obstacles block the way, the return of the brown bear is highly possible in the near future. However, whether this large predator will be able to establish and survive in the long term will depend mainly on a positive attitude from the local inhabitants.
The return of the Brown bear to Switzerland – Suitable habitat distribution, corridors and potential conflicts

Petra Zajec, Fridolin Zimmermann, Hans U. Roth & Urs Breitenmoser
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Hans U. Roth & Urs Breitenmoser
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Lakes, rivers, and political boundaries: GEOSTAT © Swiss Federal Statistical Office; Euromaps © Bartholomew.
Settlements, roads, railways, and forest: Vector 200 © Federal Office of Topography; Euromaps © Bartholomew.
Digital elevation model: DHM25, RIMINI © Federal Office of Topography; MONA Pro Europe 250 m © GEOSYS DATA.
Land use: AS85r, AS97 © Swiss Federal Statistical Office GEOSTAT; CORINE Land Cover © Swiss Federal Statistical Office GEOSTAT for Switzerland and European Environmental Agency for the remaining areas.
The return of the Brown bear to Switzerland –
Suitable habitat distribution, corridors and potential conflicts

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Abstract

One hundred years ago, the brown bear was extinct in Switzerland as in most other parts of the Alpine region. During the last few years, the remaining populations in Slovenia and especially in the Trentino, northern Italy, have been increasing once more. Thus, thanks to legal protection and reintroduction programs, bears are expanding and reclaiming areas of their former distribution. Since south-eastern Switzerland is very close to the Trentino, a natural return to this country seems possible. This study deals with the basic question of whether there is any suitable habitat to be found in the densely populated and intensely used landscape that is Switzerland. Further, the study gives a first insight into potential migration routes for dispersing bears and possible conflicts that could arise, if the bear should indeed return.

The study is based on a geostatistical model including bear presence data from the Trentino. The Ecological Niche Factor Analysis (ENFA) was used to determine the potential area of distribution. Areas of suitable bear habitat were found in the southern and northern parts of the Swiss Alps, namely in the Engadin, the northern Grisons and in the region of Glarus. Dispersing bears from the Trentino could reach the core areas of suitable habitat in Switzerland along several corridors, with the longest corridor having a length of 87 kilometers. Since no insurmountable obstacles block the way, the return of the brown bear is highly possible in the near future. However, whether this large predator will be able to establish and survive in the long-term will depend mainly on a positive attitude from the local inhabitants.

Historic postcard illustrating the probably last observation of a brown bear in Switzerland. In the year 1914, a sentry posted at the national border near Punt Purif (Lower Engadin, GR) met a bear and chased it away by firing two warning shots. Archive SNP.
1. Introduction

Until the 19th century, the brown bear (*Ursus arctos*) was a widely distributed species in Switzerland and throughout the Alpine region. Sightings were common, but also was bear hunting. At that time, this large predator was generally considered as a threat to the lives of cattle, as well as to humans. Additionally, bears were competitors with Man in hunting. Therefore, hunting laws set the goal of exterminating bears and the government paid a considerable price for each animal killed (Metz 1990). The brown bear survived longest in the south-eastern part of the Grisons, mainly in densely forested mountain valleys far from human settlements (Capt et al. 2005). But the bear’s time in Switzerland soon ran out. In 1904, the last individual was shot in the valley of Scarl, lower Engadin. The two successful hunters, who had tracked the bear down, returned in triumph to their home village of Scuol. Since that time the brown bear is counted among the exterminated species in Switzerland, although the last sighting occurred only in 1914 (Metz 1990). This single stray bear that made its way from Italy was probably killed shortly afterwards in Austria. Yet, according to Swiss Federal hunting law, the species remained part of the legally hunted wildlife for almost fifty years. Not until 1962 was *Ursus arctos* finally granted legal protection.

The history of the brown bear’s distribution is similar in all countries of the Alpine region. Besides in the Engadin, small remnant bear populations only survived the 19th century in the French Alps, the Trentino in northern Italy and in parts of southern Austria. Despite critical population sizes bear hunting continued, often until the bitter end.

In Austria, the last bear was shot in 1913, but from time to time single animals continued to enter the country from Slovenia (Rauer et al. 2001). Only in 1971 did the species become fully protected by law and a young male settled down in the Kalkalpen, lower Austria, one year later. This lonely individual was afterwards named “Ötscherbär” and his long survival was the origin of the reintroduction program that was started in 1989. During the past decade, a few bears from Slovenia were released in southern Austria while simultaneously the number of naturally immigrating animals continued to rise. Consequently, a new population could be established and today, between 20 and 25 bears live in Austria once more (Rauer et al. 2001).

However successful this reintroduction was, in order to ensure their long-term survival, a permanent connection to the Slovenian bear population is required. Slovenia represents the link between the Dinaric mountain range and the Alps. Its bear population is part of the larger Balkan population, which counts several thousands of animals (Adamic 1998). This is where hope lies for the return of the brown bear to the Alpine region. In Slovenia there lives an estimated 400 individuals in a population that is highly reproductive and expanding towards the north and west (Kobler & Adamic 2004; Jerina et al. 2003). Thus, besides being the source population for natural dispersal, bears from Slovenia can also be used for reintroduction programs in other places of the Alps. They were released in Austria and also more recently in the Trentino in northern Italy (Rauer et al. 2001; www.parcoadamellobrenta.tn.it).

In the relatively remote areas of the Brenta mountain range, a small remnant of the formerly large bear population of the Alps was able to survive. But as poaching continued, their numbers dwindled throughout the 20th century. Only between 8 and 12 bears were left in 1970 – and numbers continued to decrease slowly (Knauer 1993). By 1989, the bear population of the Trentino was biologically extinct, as the remaining four or five animals no longer reproduced (Mustoni et al. 2003). The only way to keep this population alive was to release bears captured in Slovenia. A minor drawback of the reintroduction was the feared loss of traits specific to the Alpine bears as they were mingled with bears originating from the Balkan population of Slovenia (Roth 1994). Between 1999 and 2002, ten bears were released in the Trentino and two years ago the first cubs were observed. The population had increased to approximately 16 individuals and is now expanding again (www.parcoadamellobrenta.tn.it). After being released in 2001, the female “Vida” wandered off to the north along the Brenner highway and finally settled across the Austrian border near the National Park Hohe Tauern. Another female bear explored the area to the north-west as far as the Stelvio National Park, which is connected to the Swiss National Park.

Considering the recent reproduction and expansion of this Italian bear population, the return of the brown bear to Switzerland seems very possible. By exploring a large area and settling far away from their release site, the two females mentioned above have proven that distance alone is not an issue. The main question arising from the potential return of this large predator is whether there is any suitable bear habitat in the densely populated country of Switzerland. This study gives a first insight into Switzerland’s possible future with bears. We used a Geographic Information System (GIS) based habitat model and data of the Trentino bear population to determine the existence of suitable bear habitat in south-eastern Switzerland. We also examined potential corridors connecting those parts of the country with the Trentino, which could be used by dispersing bears. However, a successful return depends not only on environmental factors, but also on human attitudes towards the bear. As seen in Austria, single bears can cause a lot of damage, especially in the first years of their return, and such events influence the public opinion (Rauer et al. 2001). We address possible conflicts in the third part of this study, with a focus on...
tourism and sheep herding, two highly important branches of human activities in the mountain regions of south-eastern Switzerland.

2. Methods

2.1. Study area

The study area comprises the Alpine region from the Trentino to the south-eastern parts of Switzerland (Fig. 1). This area was chosen according to the study aims and the origin of included data on bear presence (see chapter 1. and 2.2. respectively). In order to include all potential corridors for dispersing bears between the Trentino and Switzerland, the western limitation of the study area corresponds to the western border of the Ticino. In the east, the study area ends at the valley of the river Adige, a practically insurmountable barrier for dispersing bears (Boitani et al. 1999). In this densely populated valley lie the cities of Trento and Bolzano, as well as many traffic routes. Among them we find the Brenner highway, one of the main trans-alpine road connections that is highly used.

Potential conflicts of bears with tourism and sheep herding could only be studied in the Grisons and the Ticino, as we only had access to required data for those two cantons (for details see chapter 2.2.2.).

Figure 1: The study area (small square) and its location in the Alpine region. Delimitation of the Alpine Convention © Réseau Alpin des Espace Protégés.
2.2. Data

2.2.1. Bear presence data
All bear presence data included in this study was originally collected in the western part of the Province of Trento in northern Italy. We refer to the area of the Province still inhabited by bears as the Trentino – an area that lies northwest to the lake of Garda and covers about 1,640 km$^2$ (Fig. 2). Today, the area also includes the National Park of Adamello-Brenta.

The data on bear presence, which was originally gathered by Roth (1978), includes sightings of animals as well as the finding of tracks, droppings, winter dens or the remains of bear carcasses. Another 60 data points were added which represent the locations of damaged beehives, crops or cattle killed by bears. In total, we counted 654 observations that occurred in the years between 1913 and 1970 (Roth 1978). During that time, bears were still quite common in the Trentino, whereas in the last decades their population number dropped to less than ten individuals. Therefore, this subhistorical dataset is possibly less individually biased than recent data would be. Also the environmental conditions for bears in the Trentino have not changed much during the last 30 years.

All observations were originally filled into several maps of the Trentino (Roth 1978). In order to use these maps for our habitat modelling, we scanned the maps and transferred all observations into digital points using Arc View 3.3 (ESRI 1996; Fig. 3).

---

**Figure 2:** Location of the area inhabited by bears $\bigcirc$ in the Trentino, in relation to the entire study area. All bear presence data included in the analysis was originally collected in the Trentino. Delimitation of the Alpine Convention © Réseau Alpin des Espace Protégés.

**Figure 3:** Bear observations in the Trentino between 1913 and 1970 (Roth 1978). Symbol: ● 1913 – 1968; ○ 1969; ▲ bear damage 1913 – 1969.
2.2.2. Land use
The section of the Alps described in chapter 2.1. was chosen as the reference area, and was modelled as a raster map based on Lambert Equal Area Azimuthal projection (central meridian = 9°, reference latitude = 48°).

The land use data came from GEOSTAT for Switzerland (Swiss Federal Statistical Office; resolution 100 x 100 m), and from CORINE (European Topic Center on Land Cover, Environment Satellite Data Center, Kiruna, Sweden; resolution 250 x 250 m) for the remaining areas. Differences in the investigation methodologies used by the two classification systems results in a different nomenclature of the land use categories. In order to still perform the habitat modelling across international borders, we used categories of high similarity between the two datasets. Therefore, the originally 20 CORINE Land Cover categories had to be pooled into nine variables which correspond to categories of the Swiss dataset (Table 1).

Digital data on linear barriers (roads, railways, settlements and rivers) came from the Vector 200 database (Swiss Federal Topographic Office) for Switzerland, and from the European database Euromaps for all other areas.

All variables representing land use categories were normalized prior to the analysis using the Box-Cox transformation (Box & Cox 1964). Frequencies of arable land and crops were not continuous enough to be included. Thus arable land was combined with heterogeneous agricultural areas, while crops were removed from the analysis.

---

Table 1: Land use categories that were used for the analysis across international borders. The original CORINE Land Cover categories had to be pooled into 9 variables with high similarity to the Swiss dataset.

<table>
<thead>
<tr>
<th>Pooled categories</th>
<th>Original CORINE-categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settlement</td>
<td>Urban fabric</td>
</tr>
<tr>
<td></td>
<td>Industrial</td>
</tr>
<tr>
<td></td>
<td>Road and rail networks</td>
</tr>
<tr>
<td>Arable land</td>
<td>Arable land</td>
</tr>
<tr>
<td>Permanent crops</td>
<td>Vineyards</td>
</tr>
<tr>
<td></td>
<td>Fruit tree plantations</td>
</tr>
<tr>
<td>Pastures</td>
<td>Pastures</td>
</tr>
<tr>
<td>Heterogeneous agricultural areas</td>
<td>Annual and permanent crops</td>
</tr>
<tr>
<td></td>
<td>Complex cultivation patterns</td>
</tr>
<tr>
<td></td>
<td>Arable land with significant areas of natural vegetation</td>
</tr>
<tr>
<td>Forests</td>
<td>Broad-leaved forest</td>
</tr>
<tr>
<td></td>
<td>Coniferous forest</td>
</tr>
<tr>
<td></td>
<td>Mixed forest</td>
</tr>
<tr>
<td>Shrubs</td>
<td>Natural grassland</td>
</tr>
<tr>
<td></td>
<td>Shrubs</td>
</tr>
<tr>
<td>Open areas</td>
<td>Burnt areas</td>
</tr>
<tr>
<td></td>
<td>Sparsely vegetated areas</td>
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<tr>
<td></td>
<td>Bare rock</td>
</tr>
<tr>
<td></td>
<td>Perpetual snow and glaciers</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Wetlands</td>
</tr>
</tbody>
</table>
2.2.3. Tourism and sheep herding

The basic datasets used to examine potential conflicts with tourism and sheep herding were provided by the Swiss Federal Statistical Office and the Bureau of Agriculture of the Grisons respectively. Data on tourism included the number of overnight stays between 1998 and 2003 for the Grisons and the Ticino. From the average we calculated the number of overnight stays per unit area for each community. Because of data security reasons however, not all data was available on the community level, so instead had to be pooled.

We only had access to data on sheep herding for the Grisons, i.e. the number of sheep per community in summer 2002. From this original data we calculated, as for the overnight stays, sheep densities per square kilometer for each community. Both datasets were finally transformed into digital maps using Arc View 3.3 (ESRI 1996).

2.3. Analysis

2.3.1. Modeling the virtual distribution

In order to examine suitable bear habitat we used the Ecological Niche Factor Analysis (ENFA) (Hirzel et al. 2002). This multivariate analysis requires only presence data in order to compute a habitat suitability model by comparing the environmental niche of the species to the environmental characteristics of the entire study area. Thus the resulting habitat suitability map shows areas where the environmental conditions correspond with those of areas where the species was actually observed. Assuming that the species could survive in every patch of habitat with similar environmental conditions as found in its actual range, the habitat suitability map also represents a map of the potential distribution.

The Ecological Niche Factor Analysis has been performed with Biomapper 3.1 (Hirzel et al. 2003). We run the ENFA based on three different resolutions, at sample areas of 1, 2 and 5 km. This method allowed us to find the model with the highest accuracy in predicting the species’ potential distribution. Additionally, we used two different algorithms, the geometric mean and median (Hirzel & Arlettaz 2003). All results were finally tested on their reliability in predicting the species occurrence by using the jack-knife cross validation (Huberty’s rule, 10 bins; Fig. 4). During cross validation, the model is trained iteratively on three of the four data set using ENFA analyses. Validation was based on the remaining testing set. As bear observations provide only presence data, but no absence data, we decided to use a resource selection approach to evaluate the model. A Spearman-rank correlation between area-adjusted frequencies of cross-validation points within individual bins and the bin rank was calculated for each cross-validated model as described in Boyce et al. (2002).

Thus we found the highest accuracy of predictions when the habitat suitability model was based on the smallest sample area of 1 km, and the geometric mean (Table 2). This was the only combination that resulted in a Spearman’s rank correlation Rs of more than 0.8. All further analyses are based on this model.

The area of suitable habitat was determined by including 50 % of all original data points from the Trentino, whereas its size and fragmentation were not considered.

On the other hand, core areas represent only patches of suitable bear habitat of more than 50 km² in size. This limit was chosen because it equals the average size of a female’s home range in the Trentino (Roth 1983). Additionally, core areas could not be intersected by highly frequented traffic routes (highways, railways and main roads that were less than 1 km away from the first two) or large rivers. Although such linear barriers can be overcome by dispersing bears, they usually represent a border of their home ranges (Kaczynsky et al. 1995).

<table>
<thead>
<tr>
<th>Sample area</th>
<th>Marginality</th>
<th>Specialisation</th>
<th>Rs (geom. mean)</th>
<th>Rs (median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km</td>
<td>0.95</td>
<td>1.83</td>
<td>0.81</td>
<td>0.72</td>
</tr>
<tr>
<td>2 km</td>
<td>0.72</td>
<td>1.67</td>
<td>0.60</td>
<td>0.70</td>
</tr>
<tr>
<td>5 km</td>
<td>0.98</td>
<td>2.56</td>
<td>0.56</td>
<td>-</td>
</tr>
</tbody>
</table>
Methods

2.3.2. Corridors
In order to determine potential corridors that could serve as dispersal routes for bears from the Trentino to south-eastern Switzerland, we used the Cost Distance and Cost Path Analysis in Arc View 3.3 (ESRI 1996).

In the Cost Distance matrix, the connectivity of each square is calculated in relation to its environmental quality (type of land use) and distance to suitable habitat patches. The calculation of this matrix was based on expert knowledge (see complete questionnaire in appendix I). Five bear experts from Switzerland, Italy, Austria, Germany and Slovenia assessed the permeability of each environmental variable for an average dispersing animal. The variables were chosen according to the CORINE land use categories (see chapter 2.2.2.) and were given a value between 1 (unlimited passing) and 5 (passing impossible) by the experts. Based on this assessment, we assigned the according friction value to each environmental variable (Table 3). The friction value is a relative value, which describes the costs for a dispersing bear if it would pass through a patch of the according landscape feature. The higher the friction value, the higher are the costs of passing. The friction values of the categories 1 to 4 were assigned according to a linear distribution between the values of 1 and 100. To insurmountable barriers (category 5) a friction value of 1,000 was assigned arbitrarily.

The permeability of some environmental variables were assessed very differently by the five experts (see appendix I). Thus, we chose to perform the Cost Distance Analysis based on three different assessments. First, we included the results of the questionnaire with the lowest friction values over all. Second, we chose the one with the highest friction values on average and then lastly, we calculated the median (Table 4).

The second part of the questionnaire was related to the ability of an average dispersing bear to overcome selected landscape features (complete questionnaire see appendix II). On one hand, we wanted to know how far an individual would move over open areas of different structure, but always without cover. On the other hand, physical limitations should be assessed in regard of moving in high Alpine regions (indicated by the height above sea level), wandering in steep slopes and the swimming of lakes and rivers (Table 5). The maximum values (limits) as given by the experts were also included in the Cost Distance Analysis. Whenever height, slope or width of lakes and rivers surpassed the limit, the feature was treated like an insurmountable barrier and thus given a friction value of 1,000.

<table>
<thead>
<tr>
<th>Table 3: Categories of permeability and the according friction values. The permeability describes how difficult or costly it would be for an average dispersing bear to pass through a path of the according landscape feature.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeability</td>
</tr>
<tr>
<td>Unlimited passing</td>
</tr>
<tr>
<td>Minor difficulties</td>
</tr>
<tr>
<td>Passing limited</td>
</tr>
<tr>
<td>Major difficulties</td>
</tr>
<tr>
<td>Passing impossible</td>
</tr>
</tbody>
</table>

Figure 4: Jack-knife cross validation diagram. Example including 4 partitions (Huberty’s rule) and 10 bins, sample area of 1 km, algorithm geometric mean, Rs = 0.81.
Table 4: Friction values of all environmental variables that were included in the Cost Distance Analysis. The higher the friction value, the more difficult is it to overcome a patch of the according landscape feature. To insurmountable barriers a value of 1,000 was assigned.

<table>
<thead>
<tr>
<th>Category</th>
<th>Environmental variable</th>
<th>Friction value</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ø lowest assessment</td>
<td>Ø highest assessment</td>
<td>median</td>
<td></td>
</tr>
<tr>
<td>Land use</td>
<td>Forest</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Shrubs</td>
<td>1</td>
<td>34</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Natural grassland</td>
<td>1</td>
<td>67</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Pastures</td>
<td>1</td>
<td>67</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Burnt areas</td>
<td>1</td>
<td>67</td>
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<td>34</td>
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<tr>
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<td>Sparsely vegetated areas</td>
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<td></td>
<td>Bare rock</td>
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<td>34</td>
<td>34</td>
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<td>Perpetual snow and glaciers</td>
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<td>67</td>
<td>67</td>
<td>67</td>
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<td></td>
<td>Vineyards</td>
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<td>100</td>
<td>34</td>
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<td></td>
<td>Fruit tree plantations</td>
<td>1</td>
<td>100</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Arable land</td>
<td>1</td>
<td>1,000</td>
<td>67</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Permanent crops</td>
<td>1</td>
<td>100</td>
<td>34</td>
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</tr>
<tr>
<td></td>
<td>Complex cultivation patterns</td>
<td>1</td>
<td>100</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Arable land with natural vegetation</td>
<td>1</td>
<td>67</td>
<td>67</td>
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</tr>
<tr>
<td></td>
<td>Wetlands</td>
<td>1</td>
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<td>Towns</td>
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<td>1,000</td>
<td>1,000</td>
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<td></td>
<td>Lakes</td>
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<table>
<thead>
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<td></td>
<td>Main roads</td>
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<td></td>
<td>Highways</td>
<td>100</td>
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<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Railways</td>
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<td>34</td>
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</tr>
<tr>
<td></td>
<td>Medium rivers</td>
<td>1</td>
<td>34</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Large rivers</td>
<td>1</td>
<td>67</td>
<td>67</td>
<td>67</td>
</tr>
</tbody>
</table>

* Friction values of the two experts, whose assessment was on average the lowest and highest respectively.

Table 5: Maximum height above sea level, slope and width of lakes and rivers that can be overcome by an average dispersing bear (limit). Median and range were calculated from the results of the questionnaire (see appendix II).

<table>
<thead>
<tr>
<th>Feature</th>
<th>Limit (median)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>3,937 m a.s.l.</td>
<td>3,000 – 4,774 m a.s.l.</td>
</tr>
<tr>
<td>Slope</td>
<td>50 °</td>
<td>45 – 70 °</td>
</tr>
<tr>
<td>Lakes</td>
<td>3,000 m</td>
<td>200 – 5,000 m</td>
</tr>
<tr>
<td>Rivers</td>
<td>1,000 m</td>
<td>30 – 3,000 m</td>
</tr>
</tbody>
</table>
Based on the results of the Cost Distance Analysis, we used the Cost Path Analysis to determine potential corridors that bears could use while dispersing from their actual habitat in the Trentino to Switzerland. The Cost Path Analysis calculated the travel routes between a source and a destination area with the lowest total costs.

In order to produce the highest possible accuracy in the model, we used the original dataset of land use categories as far as possible. Therefore, the Italian part of each corridor was based on the CORINE Land Cover dataset, whereas the pooled land use categories had to be applied for the Swiss part (see also chapter 2.2.2.). In this process, the highest friction value that was assigned to one of the more detailed variables was also given to the pooled land use category.

Starting point for all corridors was the core area of the Trentino, while several core areas in the southeastern Grisons were chosen as destinations. The three main potential dispersing routes were further examined. We analysed over all length, the vertical profile and the percentage of each environmental variable the corridor was leading through. Finally, the results were compared with the limits given by the experts in regard to the ability of dispersing bears to overcome selected landscape features.

### 3. Results

#### 3.1. Potential distribution

The highest performance in predicting the species distribution was achieved with the model based on the sample area of 1 km. The relatively high Spearman’s rank coefficient (0.81; see Table 2 in chapter 2.3.1.) shows a significant correlation between the model’s prediction and the actual species occurrence.

According to the results of the Ecological Niche Factor Analysis (ENFA), potential bear habitat is clearly different from the average environmental conditions of the study area (Marginality = 0.95; Specialisation = 1.83). The most important factors describing suitable bear habitat are the distance to settlements and roads, slope and height above sea level (Table 6). Furthermore, forest and shrubs have a positive influence on habitat suitability, whereas pastures and arable land are expected to be avoided by bears.

According to our model, suitable bear habitat is found not only in the Trentino, but also in the Ötztal mountains and in the region of the Arlberg in Austria (Fig. 5). In Switzerland, areas of potential distribution stretch from the Engadin to the Misox, as well as along the northwestern territory of the Grisons and as far as central Switzerland. Thus, suitable bear habitat still ex-

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**Table 6: Results of the Ecological Niche Factor Analysis (ENFA). M=Marginality, S1 – S3=Specialization. Bold are factors with an absolute value above | >0.2 | .**

<table>
<thead>
<tr>
<th>Factor</th>
<th>M</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of S explained</td>
<td>39.43</td>
<td>15.37</td>
<td>11.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Distance to towns</td>
<td>+0.543</td>
<td>0.657</td>
<td>0.340</td>
<td>0.033</td>
</tr>
<tr>
<td>Slope</td>
<td>+0.446</td>
<td>0.210</td>
<td>0.213</td>
<td>0.331</td>
</tr>
<tr>
<td>Distance to roads</td>
<td>+0.328</td>
<td>0.007</td>
<td>0.124</td>
<td>0.691</td>
</tr>
<tr>
<td>Height</td>
<td>+0.326</td>
<td>0.343</td>
<td>0.340</td>
<td>0.204</td>
</tr>
<tr>
<td>Shrubs</td>
<td>+0.267</td>
<td>0.126</td>
<td>0.018</td>
<td>0.003</td>
</tr>
<tr>
<td>Forest</td>
<td>+0.204</td>
<td>0.221</td>
<td>0.080</td>
<td>0.123</td>
</tr>
<tr>
<td>Distance to main roads</td>
<td>+0.185</td>
<td>0.186</td>
<td>0.262</td>
<td>0.308</td>
</tr>
<tr>
<td>Distance to minor roads</td>
<td>+0.148</td>
<td>0.002</td>
<td>0.255</td>
<td>0.452</td>
</tr>
<tr>
<td>Open area</td>
<td>+0.032</td>
<td>0.129</td>
<td>0.045</td>
<td>0.070</td>
</tr>
<tr>
<td>Pasture</td>
<td>-0.235</td>
<td>0.141</td>
<td>0.749</td>
<td>0.038</td>
</tr>
<tr>
<td>Arable land (heterogeneous)</td>
<td>-0.258</td>
<td>0.521</td>
<td>0.071</td>
<td>0.221</td>
</tr>
</tbody>
</table>
ists not only in the southern parts of the Alps, but also along their northern edge. Furthermore, the areas of suitable bear habitat in the Engadin are directly connected to the areas in the Trentino.

The analysis of the potential distribution was based on a geostatistical model, including parameters that are relevant to the biology of bears. Thus, the map showing potential distribution (Fig. 5) may also be interpreted as a map of suitable bear habitat.

The main factor describing suitable bear habitat is the distance to areas of high human activity, such as settlements and roads (Table 6). Corresponding to the ENFA results, those areas are found mainly in less populated regions of the mountains, away from larger cities and valleys that are intensively used with traffic routes. Additional to the areas of suitable bear habitat, the map in Figure 5 also shows main cities and highways then situated within the study area. Suitable bear habitat is mainly characterised by forested areas where human activity is low. In contrast, high alpine regions with no vegetation are not suitable for bears. Therefore, no suitable habitat patches are found in the mountain ranges of the Bernina, Ortler and Adamello.

The map of potential distribution includes all areas of suitable bear habitat without considering their size or fragmentation. The core areas represent patches of suitable habitat that are at least 50 km² in area, and are not intersected. Similar to the distribution of suitable bear habitat, core areas are mainly situated in the Trentino, the Ötztal mountains and Arlberg (Fig. 6). In Switzerland, they are found all over the Engadin, but also in the northwestern parts of the Grisons and in the region of Glarus.
3.2. Potential corridors
To determine potential corridors leading from the Trentino to Switzerland, we used the Cost Path Analysis. It was based on the opinion of experts who completed a questionnaire on the permeability of environmental variables for dispersing bears (for details see chapter 2.3.2.). Based on the median, we found three main corridors that could potentially be used by bears from the Trentino (Fig. 7). Corridor A leads first towards the north before turning west into the valley of Venosta. Part of this route runs through the Stelvio National Park, and eventually ends in the Swiss valley of Müstair. Over all, corridor A measures 87 km and is the longest of all three potential dispersing routes. The shortest route is corridor C, measuring less than 40 km and connecting the Trentino directly with the valley of Poschiavo. The third route (corridor B, 74 km) shares its first kilometres with corridor C, but then turns north and ends in the region of Zernez, where the Swiss National Park is also located. All three corridors lead mainly through or along core areas.

The main environmental variable influencing the course of any corridor is forest coverage (Table 7). More than 90 % of the two corridors A (Trentino – Val Müstair) and C (Trentino – Poschiavo) lead through forests, as well as 87.5 % of corridor B (Trentino – Zernez). The remaining parts of the routes lead through shrubs. These results correspond to the assessment of environmental variables provided by the experts. For-
est was the only variable considered by all experts to allow unlimited passing to dispersing bears (see chapter 2.3.2.). In contrast, open area is generally avoided by bears, whereas main roads and medium rivers have to be crossed at least once. Thus the costs per kilometre, given in relative numbers, are similar for all three corridors (Table 7).

All three main corridors were found to be situated between 500 and 2,500 m above sea level, although 2,000 m were rarely surpassed (Fig. 8). According to the geography of the region, the ending point of each corridor lies on a higher altitude than the Trentino, as the way leads from the lower southern Alps to the central Alps of Switzerland.

<table>
<thead>
<tr>
<th>Feature</th>
<th>corridor A</th>
<th>corridor B</th>
<th>Corridor C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>87.0 km</td>
<td>74.4 km</td>
<td>37.5 km</td>
</tr>
<tr>
<td>Costs per km</td>
<td>7.1</td>
<td>5.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Environmental variables**

- through forest: 92.5 %, 87.5 %, 92.6 %
- through shrubs: 7.5 %, 10.5 %, 5.2 %
- over open area: 0 %, 0.4 %, 0 %

**Linear barriers**

- Main roads: 1, 1, 0
- Railways: 1, 0, 0
- Medium rivers: 0, 3, 2

**Table 7**: Features of the three potential corridors A, B and C. All corridors lead mainly through forest. Costs per kilometer are given in relative numbers.

**Figure 8**: The vertical profiles of the three potential dispersing routes connecting the Trentino and Switzerland. A) Trentino – Val Müstair: 87.0 km; B) Trentino – Zernez: 74.4 km; C) Trentino – Poschiavo: 37.5 km.
Figure 9 shows potential dispersing routes for bears from the Trentino, which were based on the average lowest and highest friction assessments (for details see chapter 2.3.2.). The corridors based on the lowest friction values differ considerably from all other routes. They lead in an almost straight line from the source area in the Trentino to the destination areas in southeastern Switzerland and thus represent the shortest connections (Fig. 9a). In contrast, corridors based on the highest friction values (Fig. 9b) are nearly identical to those that were calculated using the median (see Fig. 7).

As the course of the corridors based on the highest friction values correspond to the routes that were determined using the median, their features are also highly similar. By contrast, the features of corridors based on the lowest assessment are very different (Table 8). The example of corridor A (Trentino – Val Müstair) shows their unusual features: only 42.6% of the total length is covered by forests or shrubs, while 40% of the route leads through open areas. A bear using this corridor would also have to cross pastures and arable land. The same corridor based on the median is located mainly in forest (90%), while any open areas would strictly be avoided.

Likewise, we detected huge differences in the costs per kilometer for these two corridors (Table 8). If the calculation is based on the lowest friction values, the relative cost is given by 3.9 units per km. This is almost half of the value we get for the corridor based on the median (7.1 units). But, if the relative costs for both corridors are calculated using the same criteria, which would be the more restrictive median, the value for the shorter route (based on the lowest assessment) is propelled to 162 units per km (Table 8). Thus, we can assume that an average dispersing bear could not use the direct connection between the Trentino and the valley of Müstair, although it would be the shortest way.

In accordance with the varying course and features mentioned above, we also found the vertical profile of the corridor Trentino – Val Müstair to be very specific, with a considerable part of the route located above the height of 2,500 m (Fig. 10a). At one point it surpasses even 3,000 m. This large coverage of alpine terrain explains why nearly half of this route would lead through open area, which are mainly naturally non-vegetated areas in the alpine region, such as bare rock, perpetual snow and glaciers.

By contrast, the potential dispersing route that was based on the median never surpasses the height of 2,500 m above sea level, and it leads exclusively through forests and shrubs (Fig. 10b).

Figure 9: Comparison of the potential corridors based on a) the lowest friction values and b) the highest friction values respectively. The latter corresponds mainly to the corridors based on the median.
Table 8: Comparison of the features of the corridor Trentino – Val Müstair based on the lowest friction values and their median. Course and features of the corridors based on the highest friction values correspond to those that are based on the median.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Ø lowest friction value</th>
<th>median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>44.6 km</td>
<td>87.0 km</td>
</tr>
<tr>
<td>Costs per km</td>
<td>3.9 *</td>
<td>7.1</td>
</tr>
<tr>
<td>through forest</td>
<td>30.5 %</td>
<td>92.5 %</td>
</tr>
<tr>
<td>through shrubs</td>
<td>12.1 %</td>
<td>7.5 %</td>
</tr>
<tr>
<td>over open area</td>
<td>43.7 %</td>
<td>0 %</td>
</tr>
<tr>
<td>over pastures and arable land</td>
<td>13.8 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

* If calculated using the median, the costs for the same route rise up to 162 units per kilometer.

Figure 10: Two vertical profiles of the corridor A leading from the Trentino to the Valley of Müstair, based on a) the lowest friction values and b) its median. The circle plots show the different percentage of forest, shrubs, open areas, pastures and arable land the corridors are leading through.
3.3. Tourism and sheep herding

Should the brown bear return to Switzerland, he would come back to an environment that has existed for more than 100 years without bears. During this time, Switzerland has developed into a densely settled and highly used environment, which arises the question, what impact could the return of this large mammal have on the local inhabitants? In this study, we looked at two specific areas of human interest where conflicts with bears could occur – tourism and sheep herding.

Tourism is widely distributed in all parts of Switzerland and it is an important economic branch. Especially in the mountain regions of the Grisons, tourism takes place year-round and is present both in the city and in the wilderness. Visitors come during all seasons to enjoy nature and do activities such as hiking, biking or skiing. Therefore, bear encounters should be expected to occur, especially in areas which surround human settlements. We used the number of over night stays per community as an indicator of tourism intensity in the corresponding region. We have assumed that the probability of bear encounters increase with the increasing number of visitors in a certain area (tourist density). Thus, in areas of high tourism intensity, the potential for human-bear interactions is also higher than in areas of low tourism intensity. Potential interactions may involve the disturbance of bears by tourists, or vice versa.

As shown in Figure 11, intense tourism in southeastern Switzerland is mainly restricted to a few well known holiday destinations. Only the regions of Lugano in the Ticino and St. Moritz in the Engadin count more than 5,000 overnight stays per km² per year. Also highly frequented are the regions of Locarno (TI), including the valley of Maggia, and in the Grisons Maloja, Pontresina, Davos and Arosa. In all of these regions, we counted between 2,000 and 5,000 overnight stays per year (Fig. 11). Other parts of the Ticino and the Grisons account for less than 2,000 overnight stays per area unit per year.

As with tourism, we also used densities to examine potential conflict areas with sheep herding. We would expect conflicts, i.e. damage on sheep herds caused by bears, to arise mainly in areas with high sheep densities because in such areas, the probability of encounters is higher than in areas with fewer sheep.

Sheep herding is widely distributed and sheep densities per square kilometer are similar throughout the Grisons (Fig. 12). The more or less even densities also result from the regulation of sheep densities by law, where maximum numbers for alpine summer pastures are given. Therefore, the number of 20 animals per square kilometer is exceeded in very few communities, including the valley of Vals, Safien and the area of Susch-Ardez.

![Figure 11: Number of overnight stays per km², given for each community of the Grisons and the Ticino. Most tourists visit the region of Lugano, St. Moritz, Maloja and Arosa.](image)
Figure 12: Sheep density in the Grisons. Numbers are given per km$^2$ and for each community. Highest densities are found in the valley of Vals and in the region of Susch-Ardez, lower Engadin.

Figure 13: Distribution of core areas (suitable bear habitat patches of more than 50 km$^2$ in size) in the Grisons and the Ticino. Also the figure shows all community boundaries.
By comparing the location of communities with intense tourism (Fig. 11) and the location of core areas (Fig. 13), we find a relatively high potential for tourist-bear interactions only in the region of St. Moritz-Pontresina and Maloja. This is the only region where communities with high tourism densities lie close to or overlap with patches of suitable bear habitat. By contrast, bear encounters are highly improbable in the regions of Lugano and Locarno in the Ticino and Arosa in the Grisons. Although they are among the communities with the highest numbers of visitors, those two areas do not provide any suitable bear habitat.

The situation is very different when we consider sheep herding. Since sheep herding is widely distributed, we find overlap with the core areas of suitable bear habitat all over the Engadin, the valley of Poschiavo and the Misox, as well as along the northwestern border of the Grisons. Should the bear return to those areas, we cannot exclude the possibility of conflicts. Furthermore, the probability of conflicts should be estimated as particularly high in the region of Susch-Ardez, lower Engadin. This is one of the three regions where there exists very high sheep densities, as well as core areas of suitable bear habitat.

4. Discussion

4.1. Potential distribution

According to our model, suitable bear habitat is found not only in the Trentino, but also in the mountains of Ötztal, the region of Arlberg in Tirol and in the southern and northern Swiss Alps. In Switzerland, the area of potential distribution in the southern Alps stretches from the lower Engadin to the Misox and the northern parts of the Ticino. In the northern Alps, suitable bear habitat is located in the northern Grisons, the region of Glarus and extends as far as central Switzerland. These areas of potential distribution were determined using a geostatistical model, which was based on bear presence data from the Trentino – the one area in the Alps where bears survived throughout the 20th century. The results of our model suggest that similarly suitable bear habitat is also found in Switzerland, especially in the Engadin, but also in the northern parts of the Alps. If bears return to this country, we can therefore assume that they could possibly survive and establish a viable population. Our model was based on data of a relict population that only survives today because the bears adapted and lived in strict retreat from human beings (Roth 1994). Also, the model included only 50 % of all bear presence data and thus can be considered to be rather conservative. Furthermore, any environmental changes of the last decades were rather in favour of bears, so the actual distribution of suitable bear habitat may well include additional areas that were not identified by this study model.

Distance to settlements and roads, slope and height above sea level were, according to the results of the Ecological Niche Factor Analysis (ENFA), the most important factors in describing the suitability of areas as potential bear habitat. In addition, a positive relation was found for the two environmental variables shrubs and forest. Suitable bear habitat is mainly located in higher altitudes of mountainous regions, which are difficult for access by humans and are therefore less used. By contrast, valley bottoms, where the main settlements, traffic routes and agricultural lands are situated, do not provide any suitable bear habitat according to our model. The results suggest that suitable bear habitat is mainly found in areas with a low amount of disturbance through human activities. Where human disturbance is low, bears should prefer to live in forests and adjacent shrubs where they can find sufficient food and cover.

Our results basically correspond to the findings of other studies conducted in the Alpine region, as well as those in North America. In Slovenia, Kobler & Adamic (2000) also found a positive relation between the suitability of bear habitat and its distance to settlements, whereas in Italy height above sea level was shown to be correlated with the amount of human disturbance (Boitani et al. 1999). In the United States of America and Canada, where the influence of human activities on the behaviour of brown bears was examined, it was found that grizzly bears avoid highly frequented traffic routes and human settlements (Mace et al. 1996, Gibeau et al. 2002). Even otherwise suitable habitat in the Canadian Rocky Mountains is not used by bears, if the level of human activity within is too high (Hood & Parker 2001). Since the environmental conditions in North America are highly different from the European Alpine region, the comparability of study results from these two areas is limited. There are no large areas of wilderness remaining in the Alpine region that are comparable to those in the Rocky Mountains. Therefore, bears in the Alps must always live in an environment that is relatively densely populated by humans. By comparing the results, we can assume that given the choice, bears would generally prefer to live in areas of low human disturbance. But since the brown bear is a highly adaptive species, it is quite capable of surviving in densely settled areas as well. The newly reinstated populations of brown bears in Austria and large areas of Scandinavia are living proof of this capability (Rauer et al. 2001; Swenson et al. 2000). In Austria, some individual bears adapted to the extent where they allowed close observation by humans in broad daylight.

In this model, a considerable part of suitable bear habitat is also located above the border of forest growth. The finding that forest coverage was not more important to the suitability of bear habitat could be
partly due to a slight data bias. Bear presence data included sightings, as well as findings of bear traces and damage, but no data based on telemetry. Therefore, our data is restricted to areas or linear structures that allow human access, such as roads and paths, or to areas that at least cover accessible terrain. Additionally, it is much more improbable to see a bear in the forest than in open area, which means that a considerable portion of all observations that were included in the ENFA were located outside of forest areas. On the other hand, shrubs of the subalpine area can provide abundant food and can thus be part of suitable bear habitat.

The land cover data upon which the model was based also influences the accuracy of results. Some data had to be pooled into superior variables because the categories used in the CORINE dataset do not match those of the Swiss dataset. Thus, some highly heterogeneous variables were created, such as the variable called “shrubs”, which includes shrubs and natural grasslands (mainly alpine meadows). These heterogeneous variables unite types of vegetation that can represent completely different conditions for bears. Database compatibility is therefore of great importance for future international studies dealing with habitat modeling. Also, more detailed data on forests could further improve the accuracy of habitat modelling because forest type is a very important determinant of suitable bear habitat. Bears in Austria were clearly shown to prefer mixed forests, whereas only small evidence of bear presence was found in leaf forest (Rauer et al. 2001). In order to provide a more detailed study on the features of suitable bear habitat and its use, additional data on food sources, areas of retreat and winter den sites must be considered. The aim of this study however, was to determine if there exists any suitable bear habitat in the study area. As for that objective, this model of the potential distribution provides a first insight into the location of areas to where brown bears could potentially return and settle in the long-term.

4.2. Potential corridors

Three potential corridors were established that could be used by dispersing bears on their way from the Trentino towards Switzerland. The shortest route links the western Trentino and the valley of Poschiavo and measures 37.5 kilometers. The longest corridor (87 km) leads first towards the north before turning west, reaching Switzerland through the valley of Venosta. Approximately 90% of all three potential corridors are covered by forests, whereas open areas, settlements and arable land are avoided. Thus, the most important feature of a corridor seems to be sufficient cover, although dispersing bears are able to move short distances over open areas as well.

These results correspond with how the experts assessed the permeability of different environmental variables for dispersing bears. The category “unlimited passing” was assigned to only one variable by all experts: forest. Other variables such as arable land or natural grasslands were assessed highly differently among experts. Those variables were considered to be anything between “freely passable” to a “major obstacle”. According to the experts, only settlements would mostly not be crossed by dispersing bears, while even fenced highways do not represent an insurmountable barrier (see Appendix I). Furthermore, highly different values were given concerning the maximum distance an average dispersing bear would walk over open areas with various features, and the distance to which it would dare to approach settlements (see Appendix II).

This high variability in the results of the questionnaire is possibly due to the personal experiences of the participating experts, who have been working with bears in different regions of the Alps. On one hand, bears have strong personalities with individual behaviour patterns. In addition, there are general differences between populations of the Alpine region, namely in their behaviour towards men, as stated by Roth (1994). Bears from the Trentino had to adapt to living in secrecy in a densely settled area in order to survive human persecution. By contrast, they can still find relatively large and undisturbed forest areas in Slovenia (Kobler & Adamic 2000, Jerina et al. 2003). At least some of these behavioural differences could be lost by mingling bears from Slovenia with autochthon bears from the Trentino (Roth 1994).

The distance dispersing bears can cover is based on general patterns, but it is strongly influenced by individual behaviour. Females usually settle near the home range area of their mother, whereas young males tend to cover larger distances while looking for their own new territory (Knauer 2000). Wiegand et al. (2004) used an average dispersing distance of 65 kilometers for female bears and approximately 145 kilometers for males in the eastern Alps. The famous “Ötscherbär” covered more than 200 kilometers on his way from Slovenia to Austria. In the Trentino however, it was the female bears that dispersed over the largest distances after release. The female “Vida” was tracked moving north from Trentino for more than 70 kilometers before she finally settling across the Austrian border (www.parcoadamellobrenta.tn.it).

In considering these distances, Switzerland can absolutely be reached by dispersing bears of both sexes from the Trentino. There is only one major traffic route that has to be crossed, which is the main road connecting Bolzano and Como. Since bears are capable of crossing even fenced highways (Kobler & Adamic 2004; Kaczensky et al. 1995), this road should not represent an insurmountable barrier to the dispersal of bears from the Trentino to Switzerland. Besides, the major part of all corridors leads through relatively remote areas located around the Stelvio National Park. If the population in the Trentino continues to increase over the next few years, it can only be a matter of time until the first bear crosses the Swiss border.
So far, the bears of the Trentino have mainly settled in the north-eastern parts of the region (www.parcoada-
mellobrenta.tn.it). While dispersing, they moved prin-
cipally towards the north, which resulted in one bear
settling down in Austria and a second near the Stelvio
National Park. If we compare these movements with
the corridors established by this study, we basically
find an overlap with the most eastern of the three iden-
tified corridors. This most eastern corridor leads from
the north-eastern corner of the core area in the Tren-
tino, first towards the north and then turns west through
the Val Venosta, reaching Switzerland in the valley of
Müstair. Considering the actual distribution of bears in
the Trentino and their movements, this can be the ex-
pected route that they would use first, although it is the
longest route.

4.3. Tourism and sheep herding

Tourism and sheep herding are widely distributed
throughout south-eastern Switzerland. The highly fre-
quented areas in the Ticino and the Grisons are re-
stricted to only a few well known holiday destinations
such as Lugano, St. Moritz and the region of Davos-
Arosa, and most of these areas of intense tourism do
not provide any suitable bear habitat in their vicinity.
Basically three interactions between visitors and bears
are possible: First, tourists can disturb bears while
seeking tranquillity or adventure in nature, thus reduc-
ing habitat quality for bears. Second, a bear encounter
can prove to be dangerous to human beings under cer-
tain circumstances. Third, the presence of bears can
also attract people who want to experience wildlife.

Generally, it is highly improbable that human be-
ings are in danger from bears. There have been no
known bear attack neither from Italy (Trentino and
Abruzzi), nor from Austria (Roth 1994; Rauer et al.
2001). Even in Slovenia, where the population counts
several hundred bears, attacks on humans are just sin-
gular cases. Overall, the return of the brown bear
would probably rather increase the number of visitors –
if there would be any effect at all. Every year millions
of tourists visit the Canadian Rocky Mountains and it
is not them who back off because of bears, but the
bears retreat (Hood & Parker 2001). In Austria, where
bears returned to areas of their former range, people
visited to see bears during the weekends – bear watch-
ing instead of visiting the zoo (Rauer et al. 2001). We
can therefore assume that the most important human-
bear interaction would be the disturbance of the bear.
The holiday destinations in the mountains of the Gri-
sons are famous for summer and winter sports, includ-
ing the necessary infrastructure, such as hiking paths,
ski runs, etc. Human disturbance of animals occurs
during all seasons in these areas, but mainly in the
summer and winter – though bears are especially vul-
nerable during their hibernation in winter (Petram et al.
2004).

Sheep herding is more or less evenly distributed over
the entire area of the Grisons, including several places
that overlap or are in close proximity to suitable bear
habitat. We found such places in the Engadin, Misox
and along the north-western border of the Grisons.

Even within these areas of suitable habitat, the
probability of conflict is rather low because of rela-
tively small sheep densities and because, in general,
bears rarely attack sheep or cattle. In past decades, it
was mainly beehives and fruit tree plantations that
were damaged by bears in the Alpine region
(Kaczensky 1996). Also, the analysis of damages
caused by bears showed that the level and type of dam-
age is highly variable over space and years, and the
damage can strongly depend on the behaviour of single
so called ‘problem bears’. In the Trentino, the amount
of damage caused by bears during the past three de-
decades was very low. In total, only seven sheep were
killed and 19 beehives destroyed. By contrast, in Aus-
tria, damage increased heavily during the first years of
the reintroduction of Slovenian bears, but it was two
single bears that were responsible for most of the dam-
age. In 1994 alone, these two individuals destroyed
dozens of fish ponds and beehives and killed 60 sheep
(Kaczensky 1996; Rauer et al. 2001). By introducing
different protective measures to such human develop-
ments, the level of damage was lowered drastically
during the last few years, although the population of
bears is still increasing.

Essentially, the occurrence of conflict cannot be ex-
cluded in any area where the bear is reintroduced and
or where to it returns independently. Since bears are a
highly mobile species, they can also be found outside
the established core areas of suitable habitat. There-
fore, areas of potential conflict cannot be restricted to
certain sole areas. Highest bear densities could once be
reached in areas of suitable habitat, but the probability
of conflicts is rather to be estimated higher in areas that
are less suitable to live in for bears.

Besides causing economic damage, such conflicts
can strongly influence the public opinion. The attitudes
of local inhabitants toward bears change rather quickly,
as was the case in Austria when a heavy increase in
damages caused by bears brought local attitudes from
positive to negative surprisingly fast (Rauer et al.
2001). In the summer of 1994, this heavy increase of
bear-caused damages in upper Austria was the main
subject being discussed among the public, with nega-
tive headlines dominating all press releases. Eventu-
ally, two bears were shot and since no further damage
occurred afterwards, it can be assumed that these were
the two problem bears.

In Switzerland and especially in the Ticino, the ma-
majority of inhabitants have a positive attitude towards the
natural reintroduction of bears to this country (Wild-
Eck & Zimmermann 2001). Should the bear actually
return to Switzerland, its long-term survival will
strongly depend on the task to maintain this positive
human attitude. This study shows that large areas of suitable bear habitat still remain, not only in the southern parts of the Swiss Alps, but in the northern regions as well. Only the bear has to be allowed to reclaim his place in our environment.

5. Conclusions

Despite the dense population and intense landuse in Switzerland, there are still areas which are at least as suitable for bears as in the Trentino. Since bears have survived in the Trentino until today, we can assume that they could survive in this country as well – should they return. Contrary to general expectations, we found suitable bear habitat not only in the southern parts of the Swiss Alps, but in northern parts as well. The areas of potential distribution stretch from the Engadin to the Misox, and from the northern Grisons to central Switzerland. In all these parts of the country, there remains sufficient remote areas that are not heavily disturbed by human activity, which could be used by bears.

Several corridors with lengths between 38 and 87 kilometers connect the Trentino with areas of suitable bear habitat in south-eastern Switzerland. Considering the small distance, and since no insurmountable barriers stand in the path of dispersing bears from the Trentino, the return of bears to Switzerland may only be a matter of time. Because of their actual distribution in the north-eastern Trentino and their principal movements towards the north, the first individuals can most probably be expected to show up in the Engadin. Thus, after the successful reintroduction of the bearded vulture, the Grisons could soon become the first region of Switzerland with the complete original fauna restored. Besides the bearded vulture and the ibex, this would also include the three large predators lynx, wolf and bear.

The environmental conditions would allow a natural return of bears to Switzerland. If the bear returns, its long-term survival will mainly depend on a positive attitude from local inhabitants. As in other regions of the Alps, conflicts cannot be totally excluded and will mainly concern cattle. As a necessary precaution in the Grisons, the government has already adapted the law in order to improve traditional protective herding practices.

As bears do not represent a direct threat to human life, tourism could increase in response to the bear’s return, as people visit to enjoy this new symbol of intact nature and wilderness. In order to maintain the people's positive attitude and to minimize damage, the return of the bear should be closely monitored and involve experts from the beginning. In other countries, protective measures and a transparent, accessible bear management program resulted in a successful reintroduction or natural repopulation. Public awareness and an intense exchange of experiences on an international level will be of great importance to the survival of bears in Switzerland.
6. References


Brown bear (Ursus arctos) in enclosure at Wildpark Langenberg. © Christof Angst
Appendix I: Results of the questionnaire on the permeability of all environmental variables that were included in the Ecological Niche Factor Analysis (ENFA). The permeability describes the ability of an average dispersing bear to pass through a certain landscape feature of 200 m in width, and to overcome linear barriers. While assessing the permeability of both, the animals’ physical and psychological limitations were considered. (SI = Slovenia, AT = Austria, IT = Italy; HR = Croatia)

<table>
<thead>
<tr>
<th>Environmental variable</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SI/AT</td>
</tr>
<tr>
<td>Forest</td>
<td>1</td>
</tr>
<tr>
<td>Shrubs</td>
<td>1</td>
</tr>
<tr>
<td>Natural grasslands</td>
<td>2</td>
</tr>
<tr>
<td>Pastures</td>
<td>2</td>
</tr>
<tr>
<td>Burnt areas</td>
<td>2</td>
</tr>
<tr>
<td>Sparsely vegetated areas</td>
<td>2</td>
</tr>
<tr>
<td>Bare rock</td>
<td>2</td>
</tr>
<tr>
<td>Perpetual snow / glaciers</td>
<td>3</td>
</tr>
<tr>
<td>Fruit tree plantations</td>
<td>2</td>
</tr>
<tr>
<td>Vineyards</td>
<td>2</td>
</tr>
<tr>
<td>Irrigated arable land</td>
<td>3</td>
</tr>
<tr>
<td>Perpetual crops</td>
<td>2</td>
</tr>
<tr>
<td>Complex cultivation patterns</td>
<td>2</td>
</tr>
<tr>
<td>Arable land with areas of natural vegetation</td>
<td>2</td>
</tr>
<tr>
<td>Wetlands</td>
<td>1</td>
</tr>
<tr>
<td>Lakes</td>
<td>3</td>
</tr>
<tr>
<td>Settlements</td>
<td>4</td>
</tr>
<tr>
<td>Main roads</td>
<td>2</td>
</tr>
<tr>
<td>Highways</td>
<td>3</td>
</tr>
<tr>
<td>Railways</td>
<td>2</td>
</tr>
<tr>
<td>Medium rivers</td>
<td>2</td>
</tr>
<tr>
<td>Large rivers</td>
<td>3</td>
</tr>
</tbody>
</table>

Categories of permeability:
1 = unlimited passage, 2 = minor difficulties, 3 = passage limited, 4 = major difficulties, 5 = passing impossible
**Appendix II**: Results of the questionnaire on the ability of dispersing bears to overcome specific landscape features. Data on forest patches indicate the minimum size that is required for a bear to use while dispersing. All other figures represent the maximum size or distance (limit) of the selected landscape features, which a dispersing bear could overcome. Landscape features with a value above the limit can be assumed to represent insurmountable barriers for an average dispersing bear. (SI = Slovenia, AT = Austria, IT = Italy; HR = Croatia)

<table>
<thead>
<tr>
<th>Landscape feature</th>
<th>SI/AT</th>
<th>IT</th>
<th>IT/HR</th>
<th>AT</th>
<th>SI</th>
<th>median</th>
</tr>
</thead>
<tbody>
<tr>
<td>usable forest patch (min. size; km$^2$)</td>
<td>1</td>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>min. width of a forest patch (km)</td>
<td>1</td>
<td>1</td>
<td>0.3</td>
<td>0.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Grassland (km)</td>
<td>3</td>
<td>5</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Arable land (km)</td>
<td>3</td>
<td>5</td>
<td>0.25</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Bare rock (km)</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>0.5</td>
<td>3</td>
</tr>
<tr>
<td>Perpetual snow / glaciers (km)</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>max. width of lakes (m)</td>
<td>3,000</td>
<td>3,000</td>
<td>200</td>
<td>5,000</td>
<td>0</td>
<td>3,000</td>
</tr>
<tr>
<td>max. width of rivers (m)</td>
<td>1,000</td>
<td>1,000</td>
<td>30</td>
<td>3,000</td>
<td>80</td>
<td>1,000</td>
</tr>
<tr>
<td>min. distance to settlements (m)</td>
<td>100</td>
<td>0</td>
<td>1,000</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>max. height above sea level (m)</td>
<td>4,774</td>
<td>3,100</td>
<td>4,774</td>
<td>3,000</td>
<td>(1,700)*</td>
<td>3,937</td>
</tr>
<tr>
<td>max. slope (°)</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>45</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>max. dispersing distance (km)</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>200</td>
<td>70</td>
<td>150</td>
</tr>
</tbody>
</table>

* Due to geographic differences (no comparable high Alpine regions) Slovenia was not included when calculating the median.
KORA Bericht Nr. 28  

KORA Bericht Nr. 28 e  

KORA Bericht Nr. 27  

KORA Bericht Nr. 26  

KORA Bericht Nr. 25  

KORA Bericht Nr. 24  

KORA Bericht Nr. 24 f  

KORA Bericht Nr. 23  

KORA Bericht Nr. 22  

KORA Bericht Nr. 21  

KORA Bericht Nr. 20  

KORA Bericht Nr. 19 e  

KORA Bericht Nr. 18 e  

KORA Bericht Nr. 17 f  

KORA Bericht Nr. 17 d  

KORA Bericht Nr. 16 f  

KORA Bericht Nr. 16  

KORA Bericht Nr. 15 f  

KORA Bericht Nr. 15  

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KORA Bericht Nr. 12 e  

KORA Bericht Nr. 11 f  

KORA Bericht Nr. 11 d  

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