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Abstract: We evaluated the habitat suitability and connectivity for the lynx in the Alps in order to reveal (1) the suitable habitat patches (sub-populations), (2) the potential size of the sub-populations, and (3) connections between sub-populations.

Lynx habitat fragmentation of the Alps – a preliminary model

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Habitat quality throughout the Alps has considerably improved since the eradication of the lynx in the early 20th century. But the mountain range is more fragmented than ever; high altitude ridges and valleys with human settlements and traffic lines hinder the movements of terrestrial animals. The lynx is a "conservative" disperser from its biology. An important step towards the convergence of the two existing Alpine populations is the evaluation of biological, ecological and geographic possibilities and constraints for the movements of individuals.

We evaluated the habitat suitability and connectivity for the lynx in the Alps in order to reveal (1) the suitable habitat patches (sub-populations), (2) the potential size of the sub-populations, and (3) connections between sub-populations.

Ecological Niche Factor Analysis (ENFA) (Hirzel *et al*. 2002) was used to predict the potential distribution of lynx in the Alps. After thorough analysis in biomapper 2.1 (Hirzel *et al*. 2001), seven environmental variables describing land use and human disturbance were used in the final model. The response variable is the presence of lynx in each square kilometre. Lynx was considered to be present in each square containing one or more telemetry fix/kill site. We divided the presence data into cross-validation groups following a k-fold partitioning design. Huberty's rule of thumb was used to determine the model training to testing ratio. A testing ratio of 29% was determined and a k-fold partition of four groups considered. Using cross-validation procedures, we trained our model iteratively on three of the four data sets using ENFA analysis. Validation was based on the remaining testing set. 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). Predictions have been divided into 10 equal-interval bins, scaled between 0 and 100.

The four factors retained according to the Broken-stick rule (Hirzel *et al*. 2002) accounted for 100% of the marginality and 79.5% of the total specialisation. The marginality factor alone accounted for 29% of the total specialisation and showed that lynx were essentially linked to forest and shrubs and/or herbaceous vegetation. On the other hand, lynx tended to avoid areas of heterogeneous agriculture. The second (20.61% of the total variance explained), the third (19.46% of the total variance explained) and the fourth (10.47% of the total variance explained) factor accounted for more specialisation, mostly regarding distance to large and medium town, heterogeneous agriculture, forest and open space frequencies. Cross-validated Spearman-rank correlation (*rs*) between RSF bin ranks and area-adjusted frequencies for individual and average model displayed significant positive rank values (r_S: 0.891-0.939, $p<0.001$).

The cut off value of the habitat suitability map was fixed in a way that 80% of the presence cells were included in the boundaries of the potential distribution map. The resulting map has been smoothened in order to remove small isolated patches. To do this, we only used the pre-

defined cells of the potential distribution map and calculated the frequency of more cells of that type in a circular window of 5 kilometres radius, which corresponds approximately to the size of a female home range in the Alps (Breitenmoser-Würsten *et al*. 2001). We set the threshold in a way that 70% of the presence cells were included in the boundaries. This map was then overlaid with the barriers map (highways, main roads, and railways less than one kilometre apart from highways, elevation above 2,500 meters, settlements, and lakes) in order to identify sub-units of habitat.

The model divides the Alps in 37 suitable habitat patches (Fig. 1) ranging from 50 to 18,711 km^2 when all patches smaller than 50 km^2 are removed. Even within some patches, there were larger plots of suitable habitat connected through small bands of habitats only (e. g. patch no. 6 between the north-western Alps, the Valais north and the Valais south), which may act as bottle-necks and may impede movements of lynx.

The total area of suitable habitat in the Alps is about 93,579 km^2. Using the moderate density found in the Jura Mountains (Breitenmoser *et al*. 1993, Breitenmoser-Würsten *et al*. submitted) or the higher density found in the north-western Alps (Breitenmoser-Würsten *et al*. 2001), we estimate that the Alps could host a population of 961 to 1,827 resident lynx.

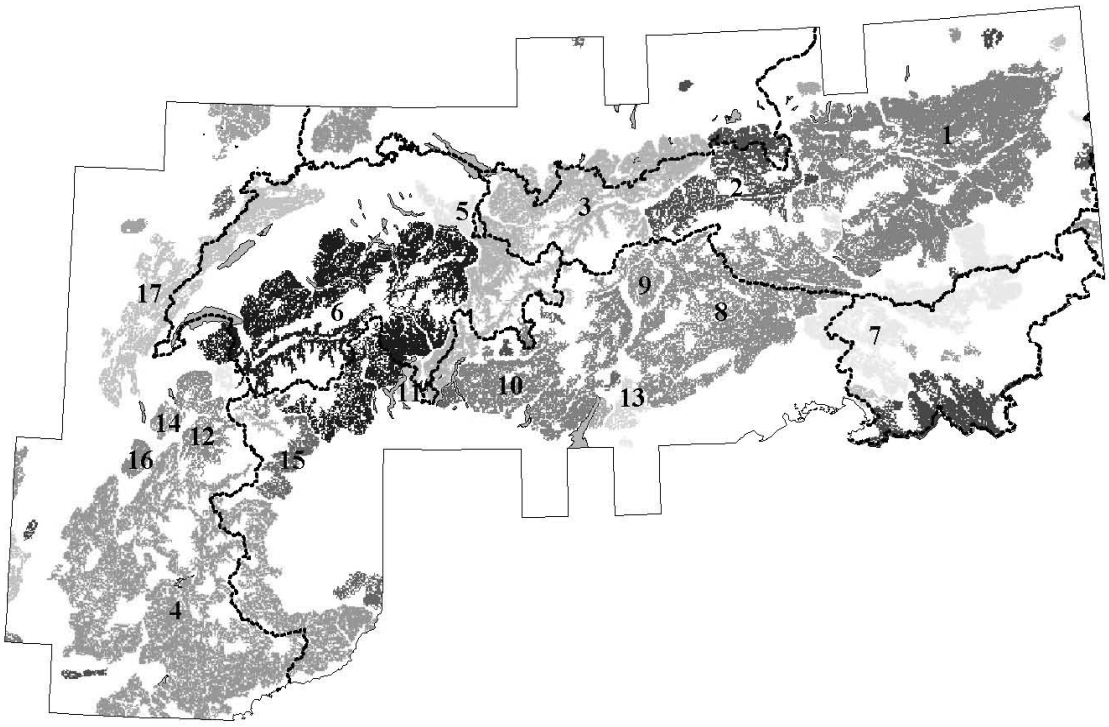

Figure 1. Suitable lynx habitat and fragmentation of the Alps. The different coloured areas represent distinct patches. Labelled are all patches >400 km^2.

Connectivity was calculated in the GIS using a friction grid and a cost distance function. The friction value attributed to each land use variable was assessed from our observations of the dispersal of radio-tagged subadult lynx.

The results of the cost distance analysis showed that all patches were within the range of dispersal cost of subadult lynx moving through unfavourable habitat. But experience suggests that only few dispersers will cross unsuitable areas and barriers such as (fenced) highways. During a peak of the lynx population in the north-western Swiss Alps from 1997-2000, only four out of fourteen radio-tagged subadult lynx, all males, went beyond the edge of suitable habitat, and only one reached a new compartment. This low migration rate may be enough to grant genetic exchange between established sub-populations, but seems not to allow the natural spread of the population into un-settled areas. As an alternative to spontaneous dispersal, artificial transfer of individuals across the barriers should be considered.

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