PERSPEKTIVEN FÜR UMWELT & GESELLSCHAFT umweltbundesamt

DISTRIBUTION AND CONNECTIVITY OF THE RED DEER (*CERVUS ELAPHUS*) IN THE ALPS

Workpackage 5: “Corridors and Barriers”

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econnect Restoring the web of life

Alpine SPACE
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1.1 Introduction

In this report the approaches taken to model the distribution and connectivity of *Cervus elaphus* in the Alps are described. This was undertaken within the project Econnect. The analysis was conducted with the following guidelines in mind:

1. Analysis of species habitat needs in terms of habitat connectivity (e.g. maximum distances, characteristics of corridors/stepping stones).
2. Spatial analysis of current and potential habitats, their lack of connectivity and its reasons (qualitative and quantitative assessment)
3. Characterization of the barriers by their origin, size, shape and degree of permeability and (economic) assessment of possibilities to diminish them.

In the consecutive sections the guidelines presented above are followed. In Section 1.5 a brief characterization of C*. elaphus* is provided, followed by its potential distribution in Section 1.6. Finally connectivity between patches of potential distribution is analysed by morphological spatial pattern analysis in section 1.7.

1.2 Graph theory

In the following sections graph theory related terms are used. To clarify the meaning in an ecological context a brief description is provided. A graph consist of nodes or vertexes and edges. Edges may connect any two nodes. In ecological terms nodes are habitat patches. Any two connected patches have an edge between them. A graph is considered as a full graph if all edges are connected with each other. The degree of an edge or vertex gives information about the number of adjacent edges. For a general introduction to graph theory in ecology see also (Minor & Urban, 2008). A planar graph is a graph which edges have been reduced so they do not intersect. Planar graphs have usually fewer edges, are better to illustrate and resemble ecological reality more closely (Theobald, 2006).

1.3 Study Area and resolution

For the spatial extend of the study area the area defined by the alpine convention was used. This encompasses an area of approximately 190.000 km^2. The GIS - analysis was implemented at a resolution of 1 hectare (100 x 100m^2). All Input Data were prepared in a resolution of 1 hectare.

1.4 Software

All GIS analysis was done with ArcGIS 10. Morphological spatial pattern analysis was done with GUIDOS. Maps were also produced with ArcGIS 10.

1.5 Characterization of *C. elaphus*

Disersal: The Red Deer (*Cervus elaphus*) is one of the largest deer species. Depending on taxonomy, the red deer inhabits most of Europe, the Caucasus Mountains region, Asia Minor**,** parts of western Asia, and central Asia. It also inhabits the Atlas Mountains region between Morocco and Tunisia in northwestern Africa, being the only species of deer to inhabit Africa. Red Deer have been introduced to other areas including Australia**,** New Zealand and Argentina**.**

Characteristics: Red deer has bright red-brown summer coat, longer, thicker & browner in winter, a buff-coloured rump. The male (stag) has antlers. The height at withers is up to 122cm. the length from 175cm to 285cm. The female (hind) is slightly smaller than the stag with a weight from 100 to 120 kg.

Red Deer live up to over 20 years in captivity and in the wild they average 10 to 13 years, though some subspecies with less predation pressure average 15 years (Lovari et al 2008).

Habitat: The European Red Deer is adapted to a woodland environment (Thomas 2002) The natural habitat of the red deer is forest, but as numerous great forests throughout Europe were felled over the centuries, most of them were forced to live on exposed land, moving into wooded plantations during severe winter weather.

Stags and hinds live in separate herds for most of the year, each keeping to a well-defined territory. Deer in woodland live in small groups but highland deer usually live in larger herds, moving up the hillsides by day to feed and shelter in the deeper heather or woods at night.

Females use areas with young replanted and pre-thicket crops and older stands with checked trees more in proportion to availability than old closed-canopy stands, open-hill ground and high-elevation newly-established forest. They use open areas more at night, dusk and dawn, and the more secluded thickets during the day. Compared to females, young males were found more in older stands, high-altitude young plantation and on open-hill ground according to a study of Catt & Staines (1987).

Home range size (406–1008 ha for females and1062–3059 ha for males) is smaller for animals with a high proportion of favourable habitats in their range. Individual ranges do overlapp.

Females use the same range from season to season and from year to year. Males disperse a mean distance of 15 km from their area of capture during their first or second year of age. (Catt & Staines 1987).

Summer and winter territories are different. Red Deer in Europe generally spend their winters at lower altitudes in more wooded terrain where there is more shelter. During the summer, they migrate to higher elevations where food supplies are greater for the calving season.

Reproduction: Woodland red deer hinds (females) can breed at 16 months old. Smaller hill deer may not reach sexual maturity until they are 2 - 3 years old. The mating season, known as the rut, begins in mid September and continues to late October. Hinds normally give birth to single calves from late May to June.

In early summer, when forage quality is at its highest level in the mountainous regions, red deer leave the valleys and migrate to their summer home ranges up in the mountains. As forage quality decreases during summer and autumn, red deer migrate back to the valley regions. There forage of relatively high quality is available on cultivated meadows until late autumn (Atzler, 1984).

Diet: The deer are browsers by nature, pulling off leaves from deciduous trees. They will also eat twigs, ivy and lichen from trees, especially during the winter. In open habitats, the deer become mainly grazers, cropping grass and browsing from small shrubs such as heather. Feeding takes place mainly during the early morning and evening, the deer is resting and ruminating by day.

Threats: Aside from humans and domestic dogs, the Wolf is probably the most dangerous predator that most European Red Deer encounter. Occasionally, the Brown bear will predate on European Red Deer as well (Thomas 2002). Eurasian Lynx and wild boars sometimes prey on the calves. Eagles and foxes occasionally prey on very young calves. When numbers of red deer become too great for their habitat to support them, they can have a detrimental impact on plant species diversity and can cause damage to agriculture and forestry.

1.6 Distribution of *C. elaphus*

For the analysis of potential habitat distribution of red deer an expert-based approach was used due to a lack of observation records and suitable species specific models. The main factors for suitable habitat of red deer were defined by experts and this information served as baseline for the cartographic implementation. The geodata-set, consisting of Corine landcover 2006, JRC Forest map, digital elevation model and other GIS-data like ski areas, or river segments, was compiled (see Table 1).

Table 1: Data Sources for GIS-analysis

Source	**Input data for mapping**
EURAC	- Alpine- Convention Area - Alpine Space Regions - Ski Areas - River Segments - Main River Segments - Econnect Pilot Areas - Alpine Space Lakes - Nature Protected Areas - Digital Elevation Model (= DEM) - Hillshading (derived from DEM) - Slope (derived from DEM)
ESRI	- Railways - Streets
JRC	- Forest Area - Alpine Space Regions
UBA-AT	- Forest Area (project “forest monitoring”) - Corine land Cover 2006 (Raster)

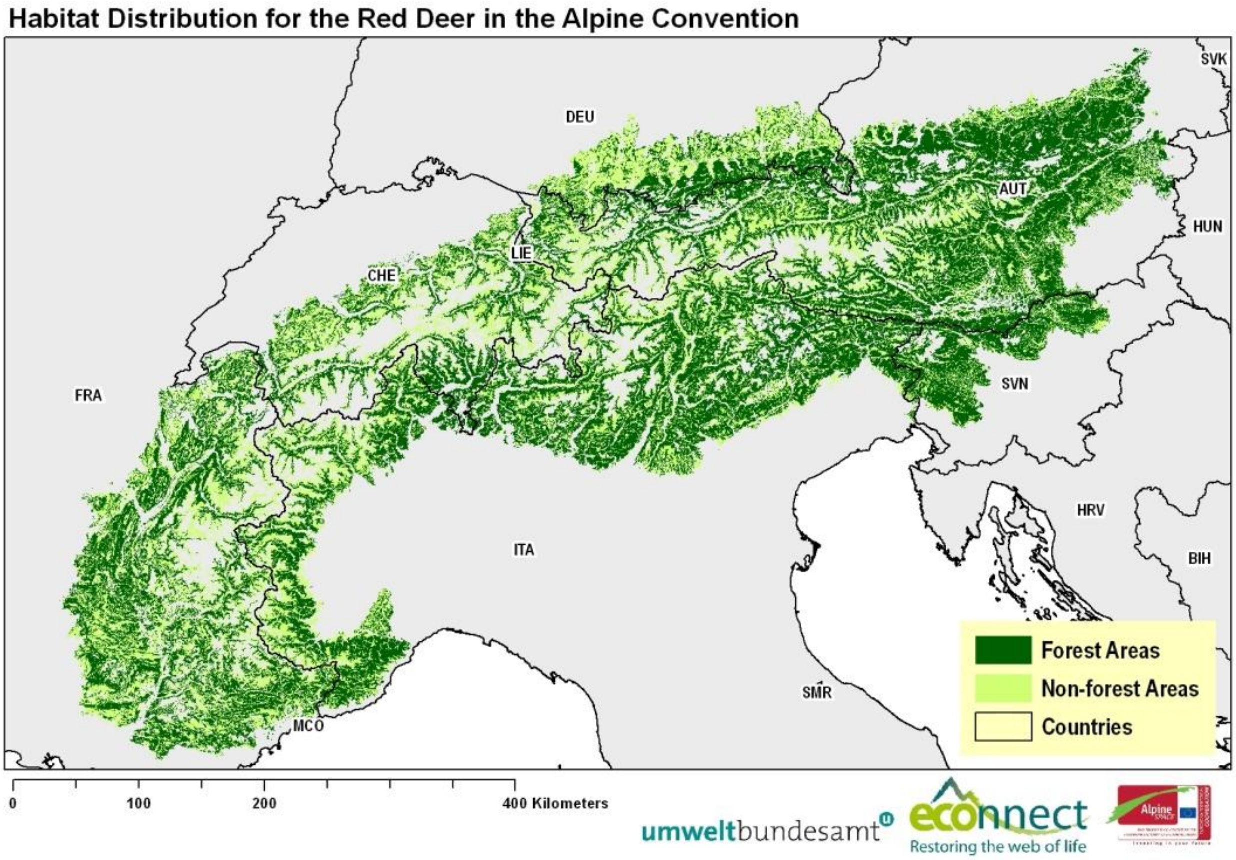
Experts information was used to tailor the geodata - maps and to discriminate absence and presence. Following estimated values – assessed by experts – were used for GIS-analysis:

- non-forest as potential habitat areas for red deer
- Minimum habitat area = 1000 ha
- Maximum slope = 55°
- Maximum altitude = 2750 m
- Minimum distance from settlements = 200 m
- Minimum distance from Industrial or commercial units = 200m
- Minimum distance from Road and rail networks and associated land = 100m
- Minimum distance from Airports and associated land = 300m
- Minimum distance from Construction sites = 200m

The resulting maps were validated by observation records of NP Northern Limestone Alps (AT; 5.700 data points) and Swiss NP (CH; 16.600 data points) and Google Earth.

A continuous map of the potential distribution of *C. elaphus* in the Alps is shown in Figure 1. Forest and suitable non – forest areas are combined, the eastern part of the alpine arch shows a higer proportion of forest also due to lower altitude.

Figure 1: potential habitat distribution for C. elaphus in the Alps.



1.7 Morphological Spatial Pattern Analysis

At an alpine scale it difficult to identify corridors visually. A graph based approach can give some insight about the importance of individual patches in a network. But there only topological connectivity is treated. To pin point pixels that serve as corridors between core areas an analysis such as the morphological spatial pattern analysis is needed. GUIDOS is an implementation of the morphological spatial pattern analysis algorithm. GUIDOS classifies a binary image (e.g. a forest map or a map of suitable C. elaphus habitat) in different categories. The algorithm takes each pixel and compares it with the neighbouring pixels based on set of mathematically formulated rules. For a detailed description of the algorithm see (Vogt et al, 2008)

The different GUIDOS categories are described as follows:

Background (grey) Pixel that are classified as forest or unsuitable for red deer (i.e. predicted occurrence probability is below a threshold).

Core (green) Pixels that are classified as forest or suitable bear habitat (i.e. predicted occurrence probability is above a threshold) and pixels are surrounded by habitat.

Branch (orange) Branches of 1 pixel width that originate in core area and terminate in background (i.e. pixels that are unsuitable in the habitat matrix).

Edge (black) Edges have on one side core area and on the other side background.

Islet (brown) Suitable pixels that are surrounded by background.

Bridge (red) Corridors that connect core areas.

Perforation (blue) Pixels that are edges in forest wholes.

Loop (yellow) One pixel wide corridor that originate in a core area and terminates in the same pixel.

In Figure 2 and 3 the results of the morphological spatial pattern analysis are shown. Fig. 2 is based on forest and non-forest areas as possible habitat. The share of core habitat is bigger but does not resemble the preferred habitat for red deer but defines the possible expansion of red deer. The MSPA of Fig. 3 shows only the forest areas and represents the original habitat that is still preferred by this species.

Generally it can be said that for the conservation of *C. elaphus* core areas and corridors (= bridges), should be given priority. In Figure 3 it can be seen that in the eastern Alps there are larger areas of adjacent core areas. The western part of the Alps is a lot patchier with regard to *C. elaphus* habitat. This can be attributed to the fact that the eastern Alps are generally of less altitude with more red deer habitat consequently.

It is import to be aware that red pixels (bridges or corridors) are not threatened per se, they are merely highlighted to state their importance of connecting two or more core areas. Whether or not they are threatened requires further investigation.

Figure 2: shows the results of a morphological spatial pattern analysis based on the potential habitat distribution in forest and non-forest areas of C. elaphus in the Alps.

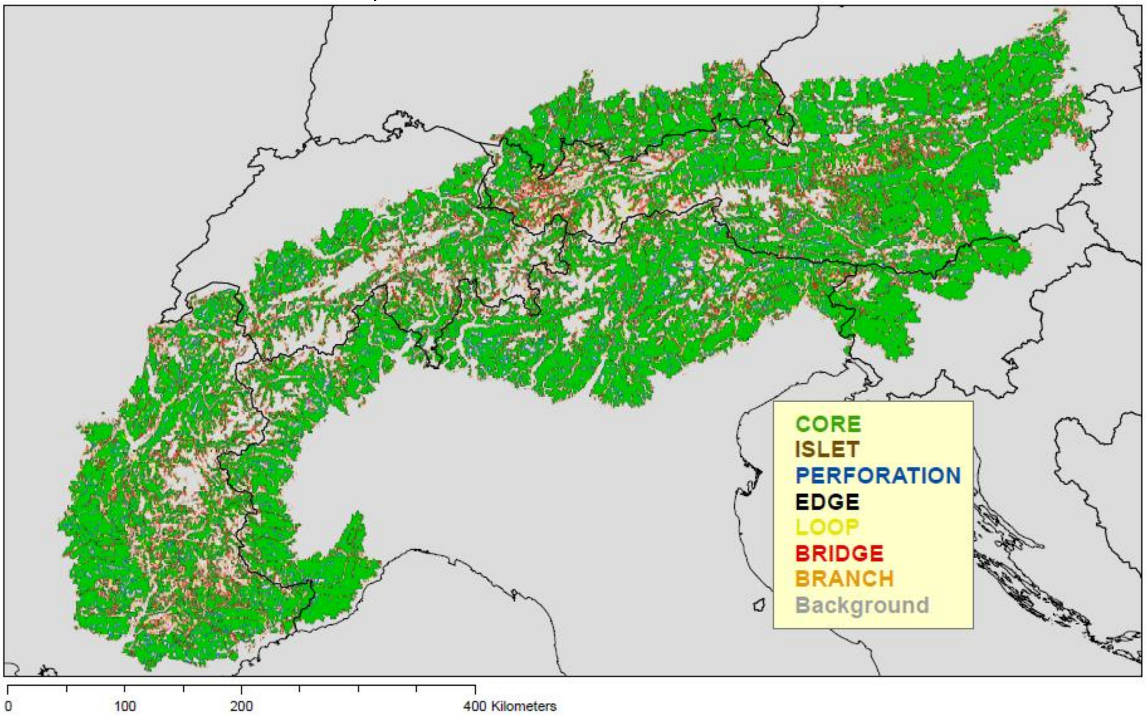
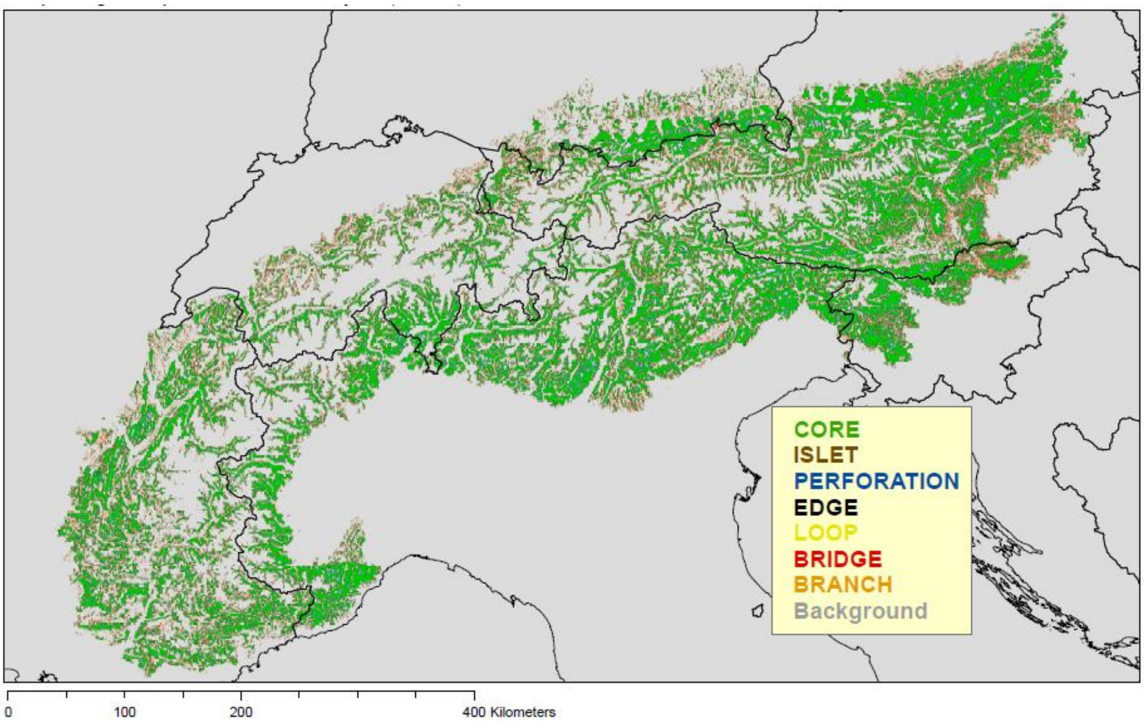


Figure 3: shows the results of a morphological spatial pattern analysis based on the potential habitat distribution only in forest areas of C. elaphus in the Alps.



1.8 Barriers to the connectivity of *C. elaphus*

Red deer is a very adaptive species. Originally adapted to woodland environment, the large scale reduction in tree cover over centuries, for e.g. in the Netherlands and in Great Britain, has forced them to adapt to life also on the open land. This very adaptive character also influences their migratory behavior.

To picture man made barriers and the influence of political and land management decisions we collected datasets of red deer free zones (areas where red deer is excluded although the habitat would be suitable).

The datasets we received were patchy. Not all countries or federal states had records on designated red deer free zones or where willing to provide this information. We got datasets from the federal Austrian provinces Carinthia, Salzburg and Vorarlberg. Datasets that confirm the occurrence of red deer were available for Bavaria (including a classification of occurrence) and Northern Italy. Fig 4 shows this synopsis for the Alpine Arch, Fig. 5, 6, 7, 8 illustrate the datasets on a regional level and in more detail.

The dataset in the background is based on Corine land Cover 2006 and also gives information on forest areas. In comparison with the red deer occurrence classification it is obvious that major parts of the red deer free zones are suitable as habitat but this species is excluded from these areas (see also Fig. 6, 7 and 8).

Fig. 4: Synopsis of the collected red deer occurrence datasets for the Alpine Arch

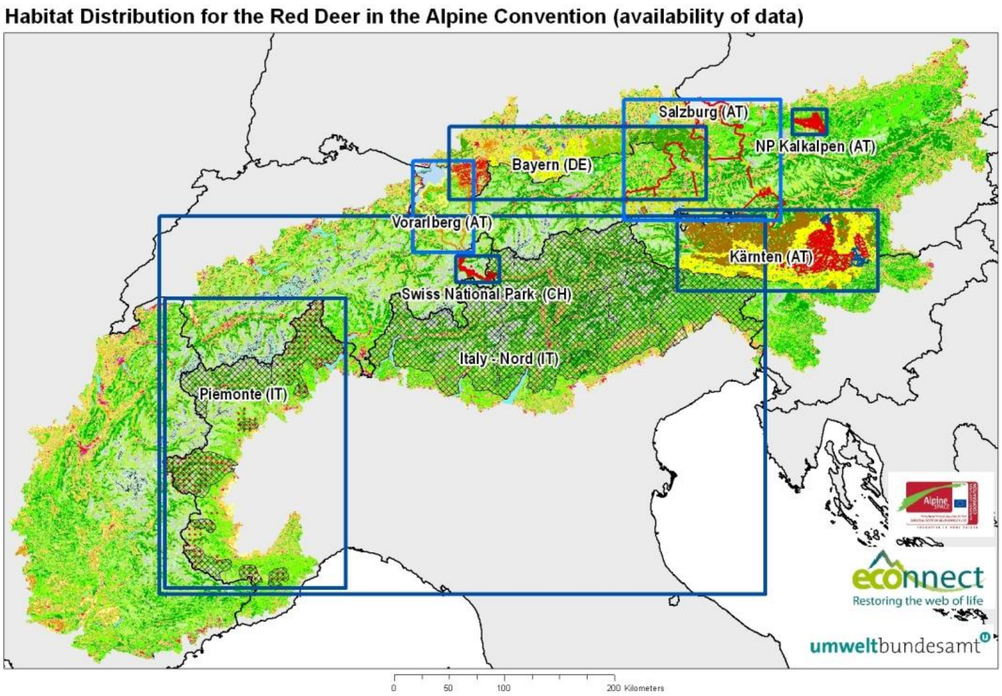


Figure 5. shows the different densities of red deer population in Bavaria. The NP Berchtesgaden has very low numbers, only up to 10 individuals per 1000 hectars were counted. Moving westwards the numbers of individuals increase to 120 per 1000 hectars.

Fig. 5: Classification of red deer occurrence in Bavaria

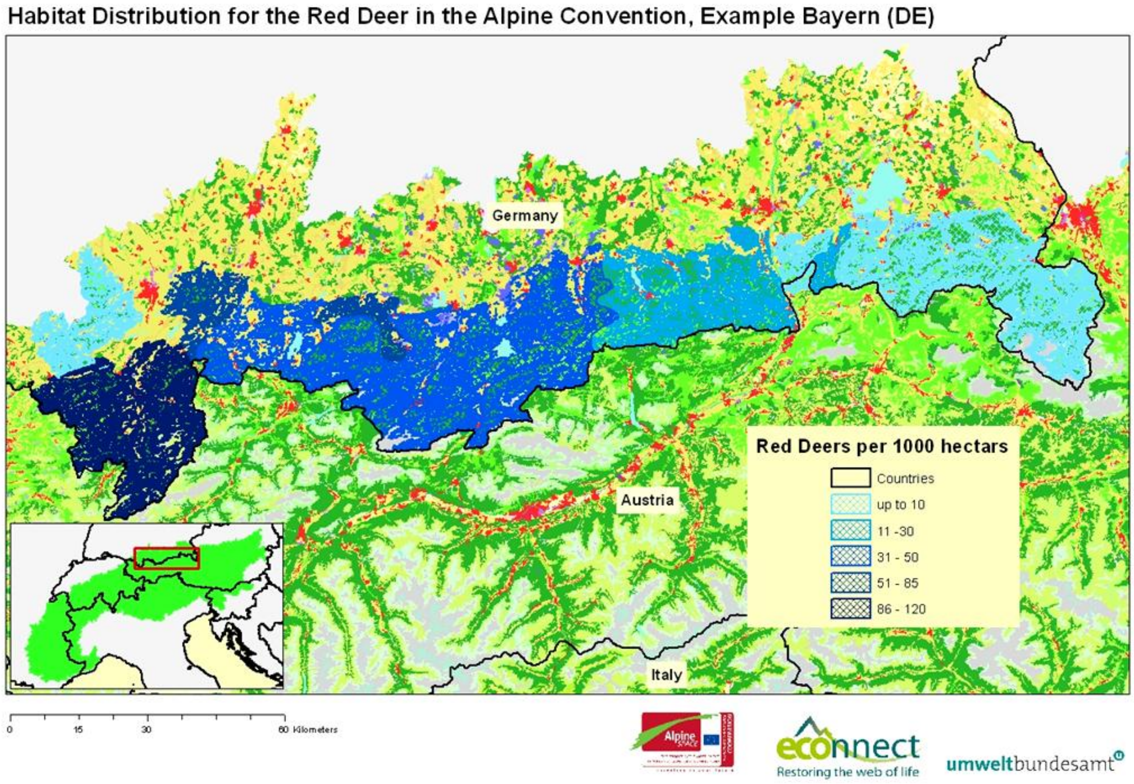
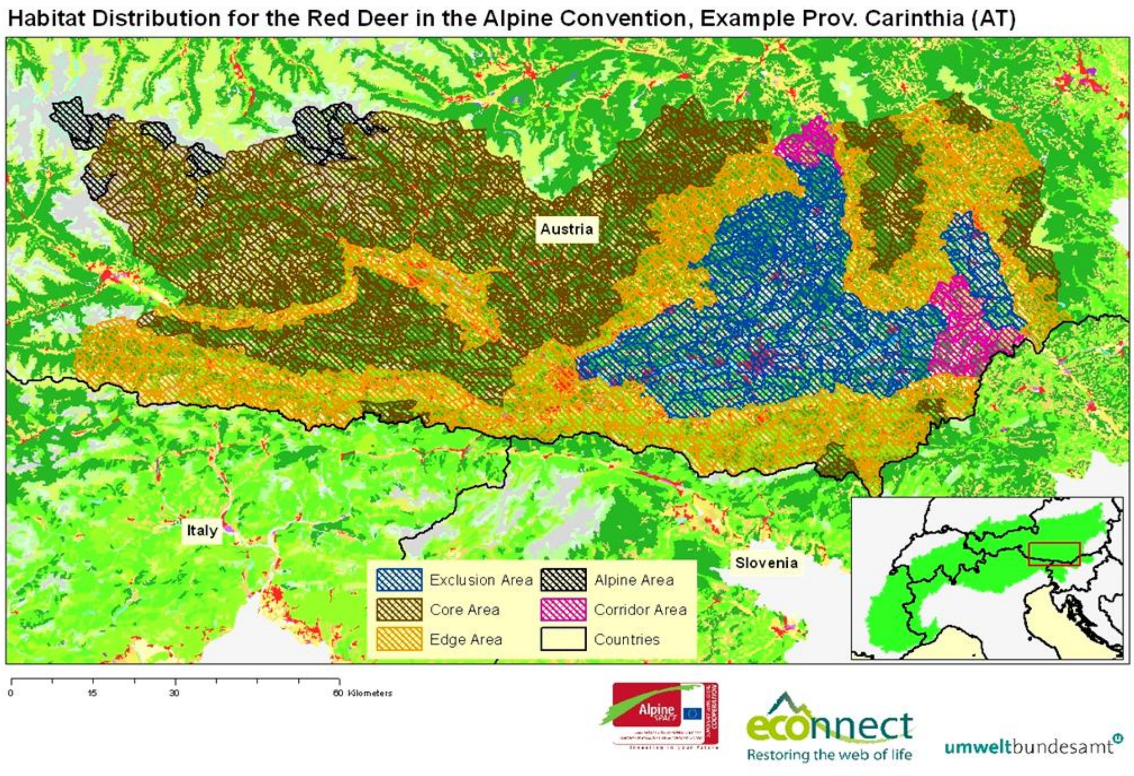


Fig. 6: Classification of red deer habitat in Carinthia (AT)



In Fig. 6 the red deer habitat in Carinthia is categorized into exclusion area, core, edge and corridor area and additionally high altitude areas are excluded. According to potential habitat distribution maps (Fig.1) and the GUIDOS-analysis (Fig 2 and 3) the majority of the area is potentially suitable for red deer. The exclusion area (shown in blue) relies completely on anthropogenic criteria's of land use.

Fig. 7: Classification of red deer habitat in Salzburg (AT)

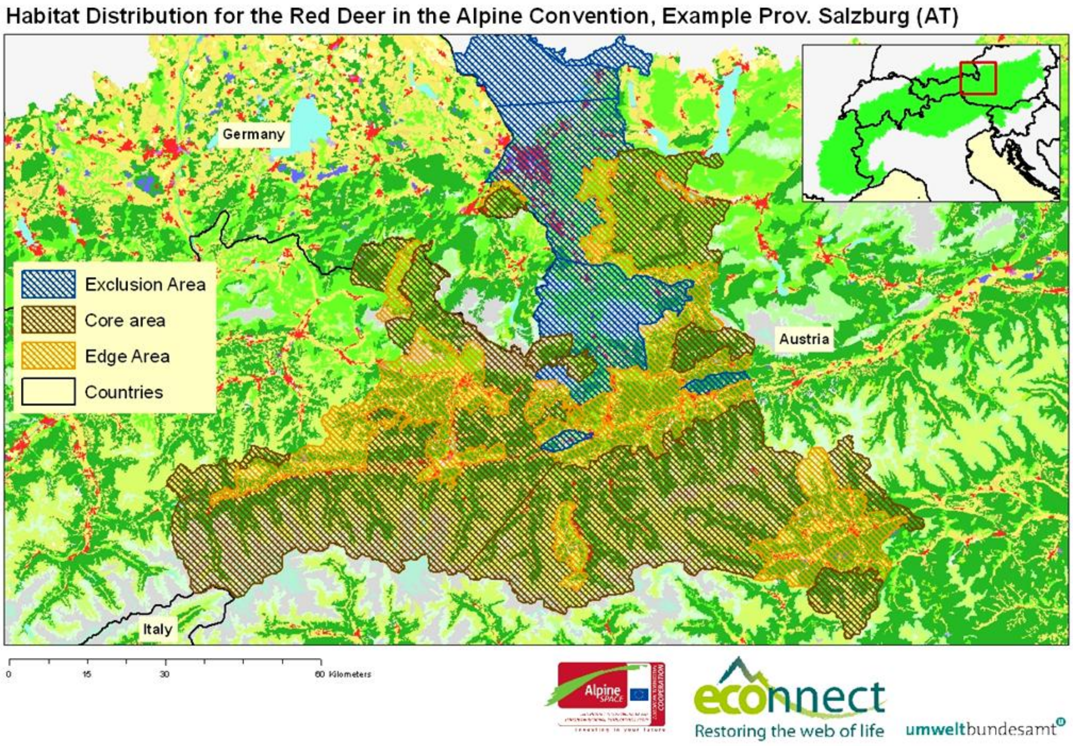
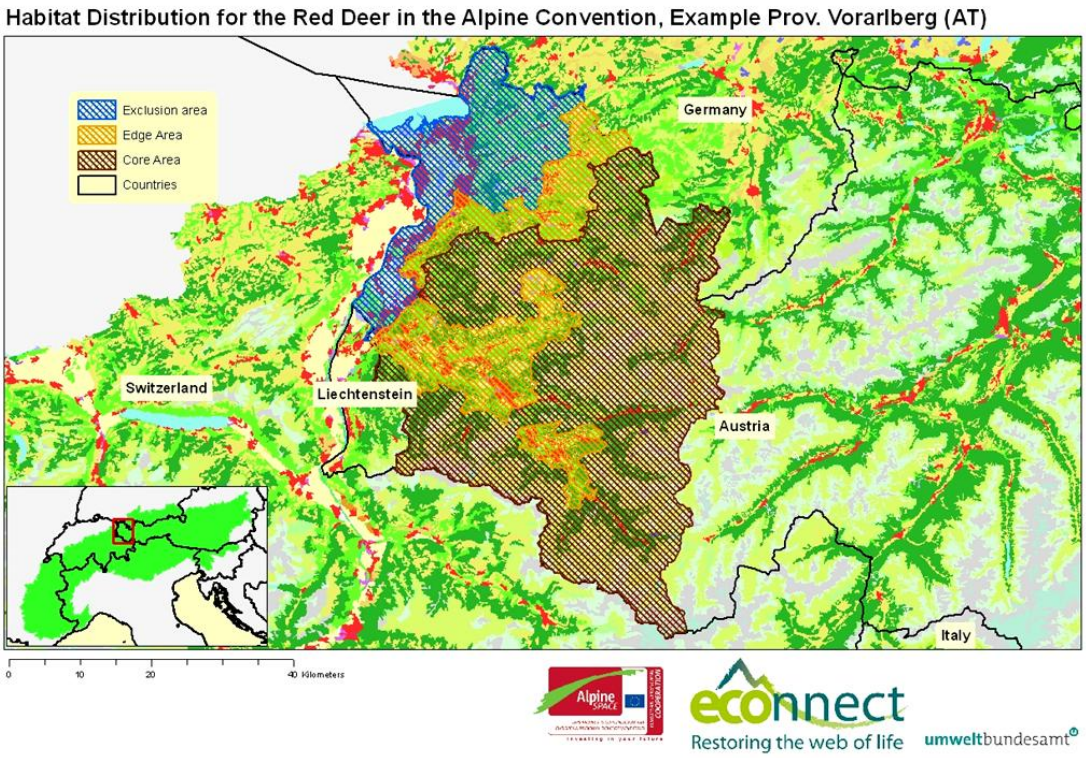


Fig. 8: Classification of red deer habitat in Vorarlberg (AT)



The exclusion areas in Salzburg and Vorarlberg (Fig. 7 and 8) are also - at least partly – suitable for red deer habitat.

1.9 Conclusion

The existence of red deer free zones raises the question of management conflicts and densities of animal population that are capable for forests. Relationships between levels of deer densities, hunting pressure and ungulate damage in forests have often been discussed in literature (Mayer & Ott 1991, Ammer 1996, Rooney 2001). There is a need for a more conscious and active intergration of wildlife species into cultivated landscapes, providing proper biotopes for plants and animals and thereby reducing damage (Reimoser 2003). In doing so natural interactions – like reintroducing large predators like the wolf – should be better utilized to achieve sustained regulation.

The principles of a proposed integration strategy to manage for an acceptable (that means tolerable) level of ungulate damage require:

- Definition of land-use aims for various areas
- Coordination of habitat and ungulate management (regarding compostion, area and saisonality)
- Inclusion of game as a site factor in land use planning and the planning of hunting programs, ensuring that local vegetation has the capacity to support the intended game density with tolerable impact.

Silvicultural measures alone cannot sustainably solve the problems of wildlife management; complementary inputs are required from all stakeholders – foresters, hunters, farmers, tourist authorities, conservationists, regional planning authorities and local communities – with plans coordinated over large enough regions to be relevant for the red deer and other game species of interest (Reimoser, 2003).

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