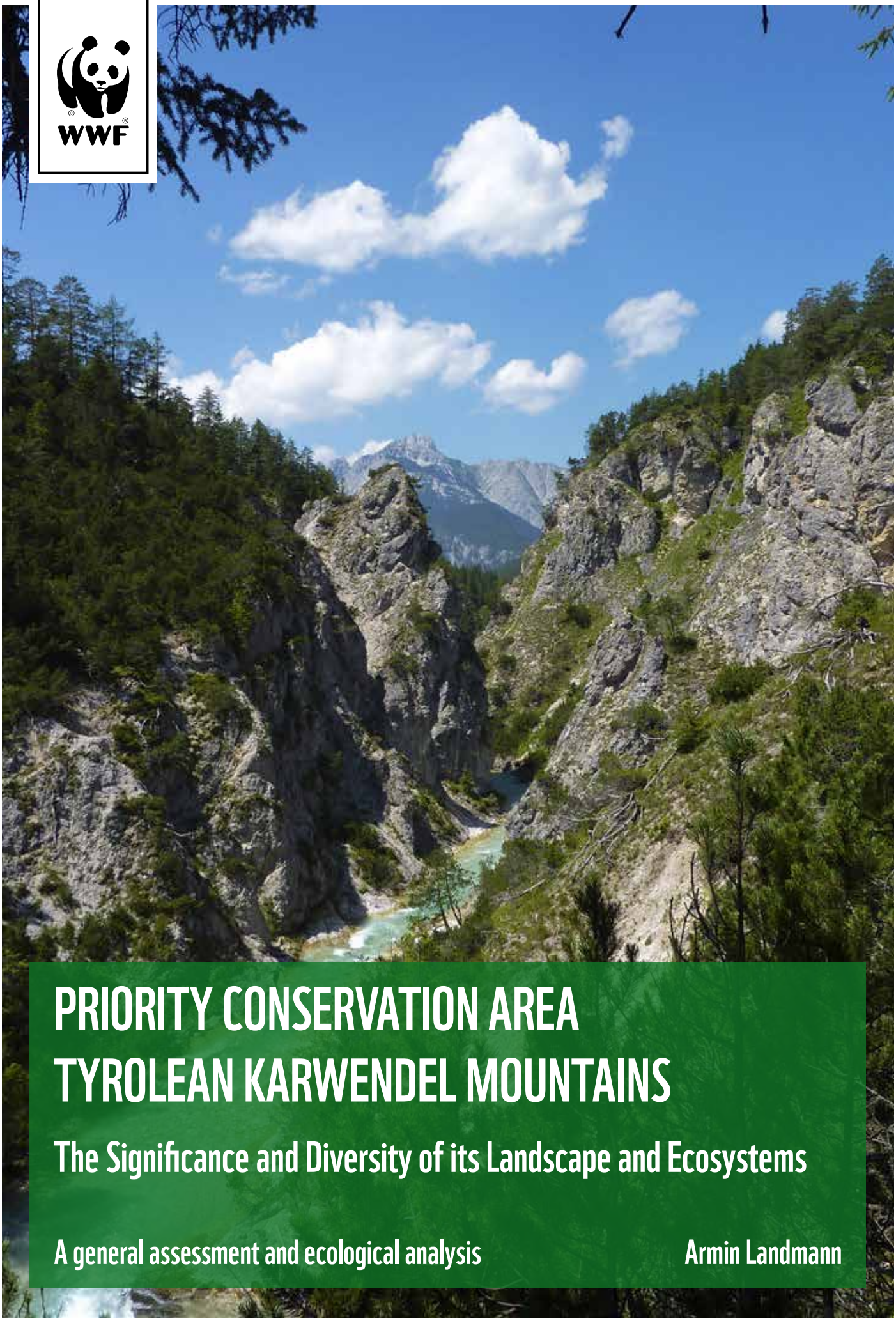

PRIORITY CONSERVATION AREA TYROLEAN KARWENDEL MOUNTAINS

The Significance and Diversity of its Landscape and Ecosystems

A general assessment and ecological analysis

Armin Landmann

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CONTENTS

PREFACE

In its Global 200 programme, the WWF published a list of the Earth's most biologically outstanding terrestrial, freshwater, and marine habitats (WWF 2000). In this list, the European Alps are featured as one of the most significant global ecoregions in terms of maintaining biodiversity. Unlike many other ecoregions, the Alps can look back on centuries of scientific research. There is extensive data available on landscape features and dynamics as well as on biodiversity patterns. The same applies, for many parts of the Alps, to information on climatic, ecological, and economic backgrounds and developments.

At the same time the Alps are also the most highly developed mountain system in the world. Topographical conditions restrict the space available for agriculture, settlements, traffic systems, and industrial development. This means that human activities have a strong impact on many alpine landscapes. High local population densities in combination with intensive tourism have led to an over-exploitation and strong fragmentation of natural habitats, especially at lower altitudes.

Large, nearly pristine areas can, however, still be found in all main countries within the alpine arc (France, Italy, Switzerland, Germany, Austria, and Slovenia – see Fig. 1).

The Alps are therefore ideal for conservation programmes on an ecoregional scale which is why the WWF decided to launch an Ecoregion Action Programme (EAP) for this region called the European Alpine Programme (MÖRSCHEL 2004, LASSEN & SAVOIA 2005, ARDUINO et al. 2006, VARINI 2006).

One of the very first and most important steps within this EAP was to identify Alpine regions meriting special attention and conservation. Such high priority conservation areas are referred to as Priority Conservation Areas (PCAs). The concept of PCAs has been in wide use on global to international and regional scales since the Earth Summit in Rio 1992 (e.g. WILLIAMS 1998, TOWNSEND-PETERSON, & NAVARRO-SIGÜENZA 1999, WILLIAMS & ARAUJO 2000, MARGULES et al 2002, BONN & GASTON 2005, KNIGHT et al. 2008, LIN et al. 2013).

Different approaches and criteria were used to select these priority areas. The PCAs were, for the most part, defined on the basis of high biodiversity and continental to regional uniqueness, incorporating aspects of ecological value, anthropogenic threat, and opportunity for conservation. In a broader sense and within the scale of a specific ecoregion, PCAs should be areas of regional significance that not only have wide community support but also provide important ecological values and ecosystem functions. They should also serve as an agricultural and natural resource and have historical, scenic, cultural and/or recreational value.

Given this broader concept, the Karwendel Mountains – the focus area of this study - represent an ideal candidate for a PCA, as will be shown in this overview, although they were selected as one of 24 PCA areas within the alpine arc on the basis of more classical faunal and floral biodiversity values. The map of PCAs as shown in Fig.1 was developed over a two year period. Scientists and representatives from organizations from all over the Alps were involved in the process. During a workshop in Gap, France, in May 2002, over 60 participants from all Alpine countries selected 5 focal species groups (Flora, Mammals, Birds, Amphibians and Reptiles, Insects) and one alpine key habitat (freshwater systems) for the identification of PCAs. Criteria

for identifying the most important areas for the various taxa and the key habitat type were established (see LASSEN & SAVOIA 2005), and priority conservation areas in the Alps were then identified by overlaying areas important for individual taxa (Fig.1). As it turned out, the Karwendel Mountains proved to be one of the very few areas in the Alps with priority value for almost all of the indicators selected for the PCA identification process.

AIMS:

Consequently, this study aims, on the one hand, to provide information about the present scientific level of knowledge pertaining to the specific ecosystems and organisms of the mountain region of the Karwendel Mountains and to put it into a larger context.
Moreover, this booklet also aims at giving a first and pilot full landscape-level analysis for this important PCA in accordance with the general concept of the WWF European Alpine Programme. This landscape approach tries to involve and synthesize detailed abiotic, biological and socio-economic data for a comprehensive overview of the natural and cultural values and resources in the PCA Karwendel Mountains. Ultimately, this data will help identify the core areas, buffer zones and special management areas within the PCA. In particular, the analysis aims to illustrate the ecological and practical possibilities of developing and delineating real wilderness reserves in this area, areas where fundamental ecological processes and a dynamic landscape development will be able to take place in the future without human influence or disturbance.
The study is based on a more detailed general assessment and ecological analysis of the PCA which has already been published in German (LANDMANN 2013). However, it has been complemented with new statistical data and GIS based maps compiled by Christoph Pluzar for WWF Austria.

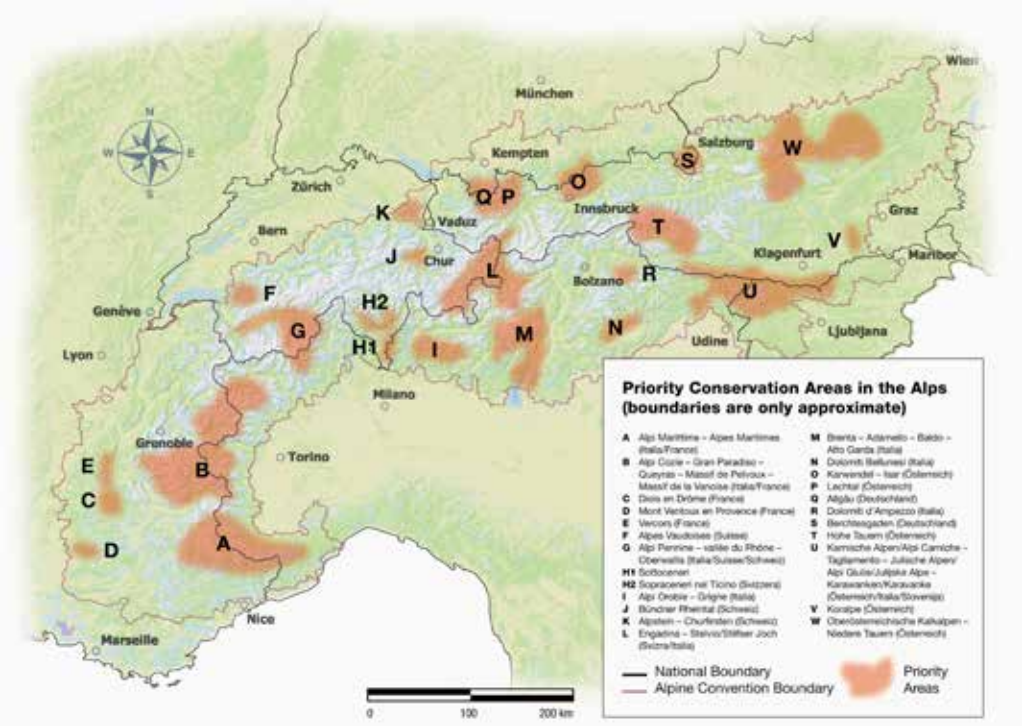


Fig.1: Priority Conservation Areas in the Alps based on floral and faunal richness (5 indicator taxons) and on the diversity of freshwater habitats (WWF; LASSEN & SAVOIA 2005). The focus area of this study, the Karwendel Mountains, is indicated with No. O

1. THE TYROLEAN KARWENDEL MOUNTAINS: GEOGRAPHICAL POSITION, BOUNDARIES AND SIZE

The Karwendel Mountains are the largest range of the Northern Calcareous Alps and stretch from the Inn valley between Zirl and Jenbach (Tyrol, Austria) to the Isar valley (Bavaria, Germany). To the west and east, the massif is bordered by the Seefeld saddle and the Achensee lowlands respectively. The greater Karwendel area, including minor parts of adjoining smaller mountain ranges to the west and east (Wetterstein, Rofan) and some protected foothills north of the Isar, represents the second largest undisrupted protected landscape of the entire Eastern Alps, encompassing an area of approximately 1000 square kilometres (details see LANDMANN 2013).

Although, from an ecological point of view, the bordering Bavarian nature reserve "Karwendel and Karwendel Promontory" forms a unit with the Austrian part, this overview focuses, for strategic and practical reasons, on the centrepiece of this wilderness area, the Karwendel Mountains within the Austrian borders (Fig. 2). These are fully protected as "Alpine Park Karwendel" under the Tyrolean Nature Conservation Act. The area selected here as a PCA is, therefore, under the administrative jurisdiction of a single authority and subject to one legislative scheme only. This facilitates management and conservation procedures.

The "Alpine Park Karwendel" encompasses an overall mountainous area of 726.7 km² in size and 202 km in circumference. It has a west-to-east extension of roughly 43 km (from Scharnitz, 47°24´N, 11°16´E, to the western banks of lake Achensee, 47°26´N, 11°42 E) and a north-to-south expansion of 25 to 30 km (from the Bavarian border at about 47°35´N, 11°17È, to the city limits of Innsbruck, 47°16´N 11°19´E).

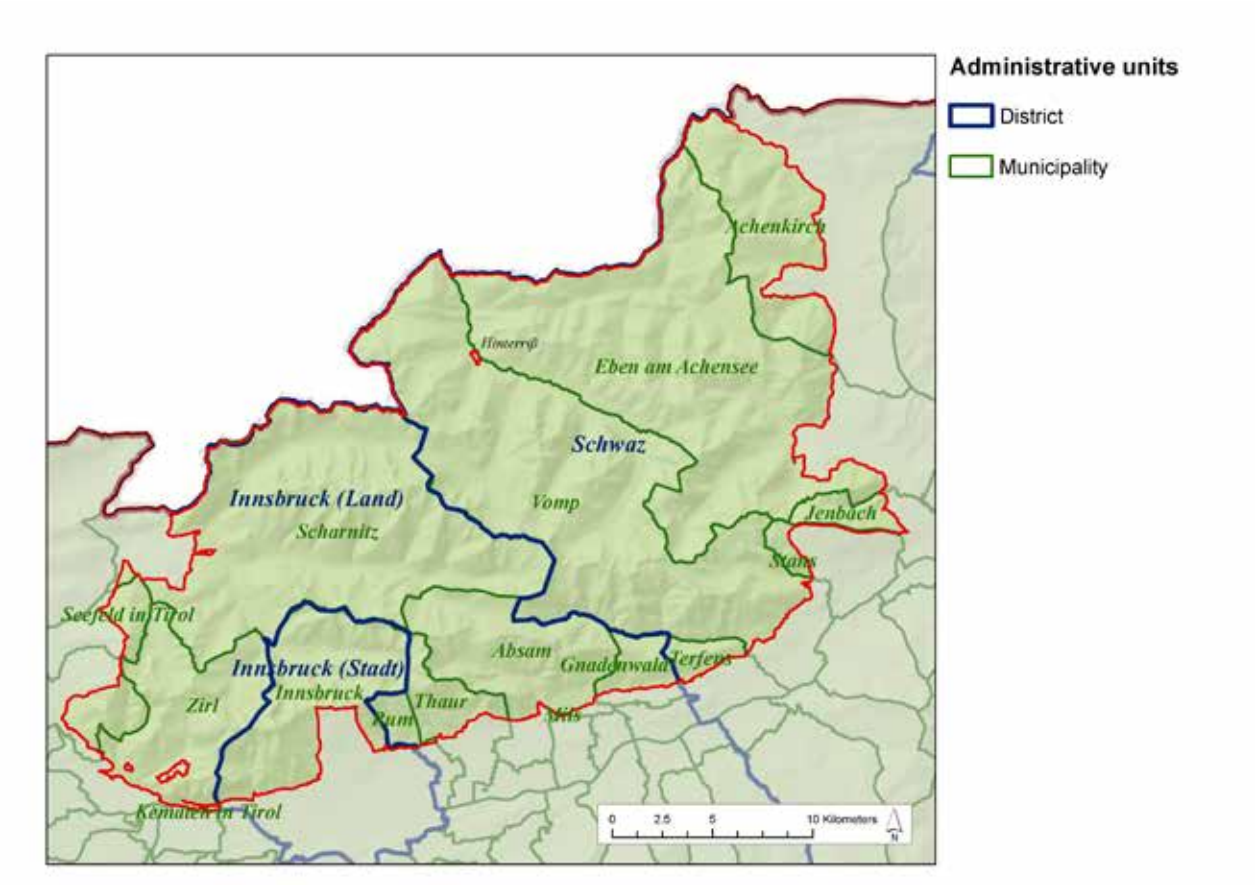


Fig.2: PCA Tyrolean Karwendel Mountains. Delineation (red line) and assignment to administrative units (3 districts with together 17 municipalities).

2. PCA KARWENDEL MOUNTAINS: GENERAL NATURAL CHARACTERISTICS AND LANDSCAPE SETTINGS

As already mentioned, the focus area of this study is part of the Northern Limestone Alps.

Three main factors shape the specific landscape and ecological conditions of the Karwendel Mountains: Their geographical position on the northern borders of the Alps with their sub-oceanic wet and snow-rich climate; the prevalence of limestone rocks (Wetterstein-chalks, dolomites), which are sensitive to mechanical weathering; and, thirdly, the steep altitudinal gradients.
These Mountains are, therefore, unique within Austria and the Eastern Alps in regard to the shape, size and dimension of land forms and ecosystems typical for the Calcareous Alps (e.g. Figs. 3 a-d).

CLIMATE

Overall, sub-oceanic wet weather conditions predominate. Due to the accumulation of wet air at the northern edges of the mountain chain and fostered by the high altitude of most areas, rather cool and moist summers and long snow-rich winter conditions prevail. For instance, mean summer (June to August) temperatures lie between 13 and 14° C for elevations of between 1000 and 1200 m a.s.l. (Pertisau, Seefeld), and a closed snow cover lasting for five to six months as well as mean snow heights of between 2 to 3 metres are quite normal for many locations in the northern and inner parts of the PCA; in the coombes and cirques of these areas even greater snow accumulations are possible.
However, total annual precipitation varies from a maximum of 2100 mm on the northern edges and over 1400 mm in the dry inner parts of the mountains to only about 900 mm on the south facing slopes to the Inn valley, and this gradient is important for the diversity and distribution of forest ecosystems and plant and animal communities within the PCA (see GEORGII & ELMAUER 2002, LANDMANN 2013).

a

b

c

d

Fig.3: Steep limestone cliffs and large scree fields in dry creek beds and cirques are dominant landscape features in many parts of the central and southern parts of the Karwendel Mountains. Spruce forests and extended dwarf pine stands are distinctive for mid to higher elevations in these dryer parts of the PCA (Photos: A. Landmann).

TOPOGRAPHY AND GEOMORPHOLOGY

The Tyrolean Karwendel extends over an altitudinal range of nearly 2.200 m from about 560 m a.s.l. (foothills of the Inn-valley) up to 2749 metres (Birkkarspitz, inner main chain). In many parts, steep altitudinal gradients spanning 1500 to nearly 2000 m within horizontal distances of less than 4 km shape the landscape.
The comparatively small mountain area is highly structured by four main chains stretching from west to east and by a large number of smaller landscape chambers (Fig. 4).

The four main separate mountain ranges are (from South to North): (1) the Inn-Valley and Solstein mountains (Nordkette – e.g. Fig. 3 a-c), with the highest peak at 2.637 m (Kleiner Solstein), (2) the Gleirsch-Halltalkette (e.g. Fig. 3d) peaking in the Großer Bettelwurf (2.725 m); (3) the Karwendel main ridge or Hinterautal – Vomp Chain, including the Birkkarspitze (2.749 m), the highest peak in the PCA, and (4) the Northern Karwendel Chain with the Östliche Karwendelspitze (2.537 m).
To the east, the latter mountain range is further subdivided by intramontane valleys into smaller mountain groups (Rappenspitz-, Falken-, Gamsjoch-, Sonnjoch- and Stanserjoch Group – see Fig. 4). The northern and especially the north-eastern parts of the PCA are much less steep and rough compared to the inner and southern parts, and the landscape here is predominated by mixed broadleaf forests and pastures.
This "Pre-Karwendel" area, which includes the Karwendel foothills, the Northern parts of which are located on German territory, are dominated by lower mountain groups, the Sojern Group (2.259 m), Schafreiter- and Mondscheinspitz Groups (2.105 m) and the Hochplatte-Juifen Groups (1988 m).

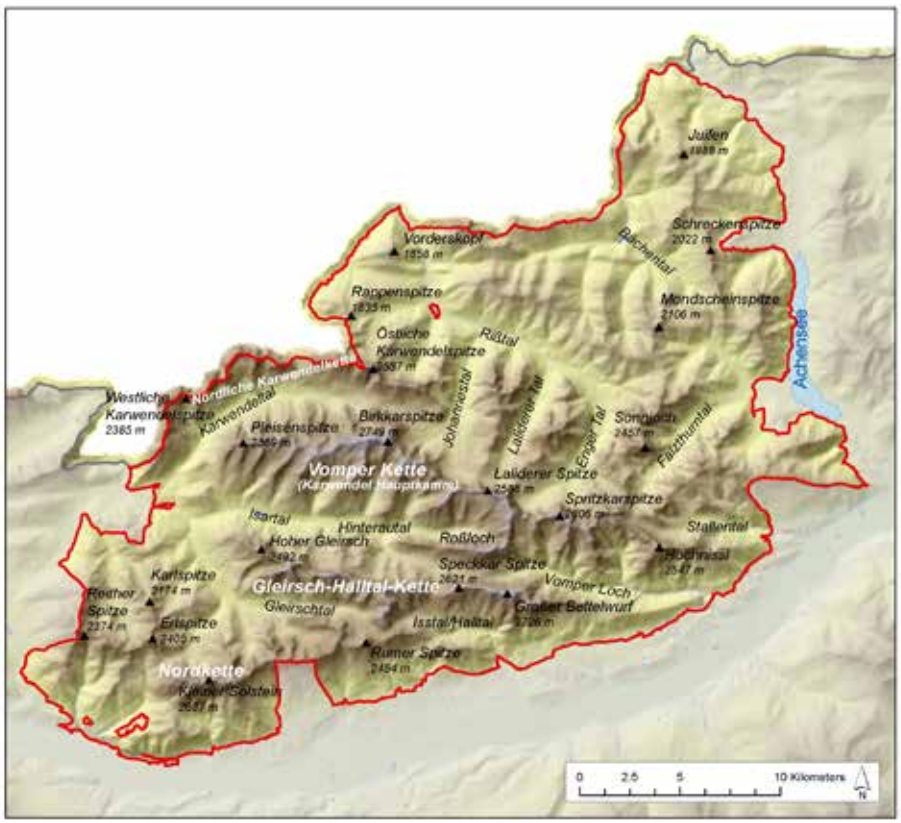


Fig.4: Topographical map of the PCA showing the four main chains, the names of the main inner valleys, and of some of the most important peaks.

The main mountain ridges are inclined versus south, and their scrap may form vertical rock faces of more than 1.000 metres. Impressive glacial moraine fields and huge scree fields dominate the landscape in many of the small and remote valleys and coombs of the Karwendel. These geomorphological features together with numerous calderon-like cirques (e.g. Fig. 3d), steep limestone cliffs (e.g. Fig. 3b), and rugged peaks (e.g. Fig 3a) contribute to an overwhelming impression of raw unspoiled nature. It is especially noteworthy in this context that probably no other area of the Eastern Alps can boast such a large number and such a vast surface area of such geomorphological features typical for Limestone Mountains.

The amount of small scale changes in the relief energy (vertical axis) and of separated single landscape chambers (horizontal axis) could serve as a major indicator for wilderness.
Based on the data at our disposal, these indicators suggest that the Karwendel Mountains may indeed be one of the most remote and undisturbed areas with the greatest small scale landscape heterogeneity in Austria, if not in the whole of the Alps.

My own rough analysis of the inner structure of the Karwendel revealed 66 separated landscape chambers with an average size of 12 km² (Fig. 5, Table 1). This high inner fragmentation results from a number of central, side, and fringe ranges (see above), pronounced ridges, deep potholes and cirques.

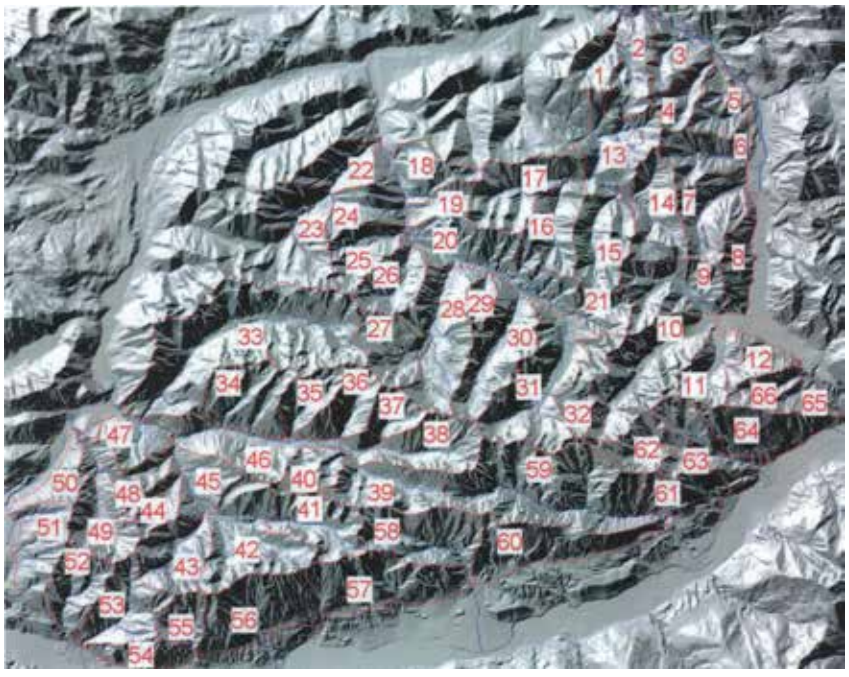


Fig.5: A typical and important feature of the PCA Karwendel is the pronounced small scale fragmentation and subdivision of the mountain landscape caused by numerous mountain groups, ridges, deep potholes, and cirques. The Isar valley forms the border of the PCA in the Northwest and North, the Inn valley in the South, and the Achensee valley in the East. For Basic data on the 66 identified landscape chambers – see Table 1. The chambers 1, 2, 18, 23 and 24 extend over the Bavarian border. At least 10 further (additional) adjoining chambers in the Bavarian Karwendel (to NW and N to the Isar valley) are – although neither delineated nor evaluated – clearly discernable! Some landscape chambers at the western and southern edges of the Karwendel (Seefeld saddle, Inn-valley) extend slightly over the borders of the PCA. Map source: digital Austrian Map BEV.

Table 1: Names and attributes of landscape chambers within the PCA Tyrolean Karwendel.
Most chambers are delineated easily through relief and topography; in some cases, additional ecological criteria were applied. Each chamber is allocated to one (of four) main catchment areas within the PCA. The following landscape features and indicators of wilderness and human impact are cited for each chamber: Area (km²); rH = elevation difference between lowest and highest point (m); G (n / km) = total number and overall length (in km) of all running waters with more than 1 km stretch; RI = Index of Remoteness: mean distance from the approximate centre of the landscape chamber to the next settlement or to the next public road or other traffic system (e.g. cable car).
HI (T/F): two indicators of human impact and landscape utilization: T= number of important tourist infrastructures (e.g. alpine huts, serviced alpine cabins); F = Dimension of unpaved forestry and other roads not open to the public: 0 = none; 1 = few, short, and marginal; 2 = one unpaved road traversing main parts of the chamber or several unpaved roads servicing parts of the chamber; wide areas still not accessible by car; 3 = wider areas of the chamber accessible by several unpaved (forestry) roads.

NO	Space units (I-IV) and landscape chambers	Area	ΔH (m)	G (n/km)	RI	$HI_{(T/F)}$
I	EDGEZONE NE & E – DRAINAGE VS. SEEACHE / ACHENSEE					
1	Demeljoch- Hühnersbachtal	5.5	1060	1 / 4.9	3.6	0 /1
2	Juifen Roßkopf - Rotwand & Pitzbach	11.0	1150	2 /4.6	3.9	0 / 3
3	Schulterberg - Taschbach	7.0	1080	1 / 3.7	1.8	0 / 2
4	Kafell - Dollmannsbach	6.0	1050	2 / 6.6	2.8	0 / 3
5	Hochplatte – Falkenmoos - Blaserbach	8.2	930	2 / 6.8	1.5	2 / 3
6	Sonntags-Schreckenspitze - Unteraubach	10.6	1080	3 / 8.6	1.7	2 / 3
7	Seebergspitze - Oberautal	12.7	1130	1 / 5.1	2.2	3 / 2
8	Seebergspitze - Achensee Osthang	7.5	1150	1 / 1.0	3.0	2 / 0
9	Bettlerkar - Mondscheinspitze - Gerntal	15.3	1280	2 / 7.0	2.3	3 / 2
10	Falzthurntal - Gramais	23.6	1540	3 / 11	2.5	3 / 2
11	Dristenautal	8.6	1200	1 / 3.8	2.7	0 / 3
12	Bärenbad - Perchertal	5.2	1180	1 / 1	1.7	2 / 1
II	N & NE CENTREZONE – DRAINAGE VS. RISSBACH / ISAR					
13	Bächental - Tiefenbach - Marlkopf	14.6	1090	5 /13.8	4.4	1 / 3
14	Tiefenbach - Taunnauerbach – Schleimsjoch	13.2	1080	3 / 9.3	5.4	0 / 1
15	Plums- & Schleimsbach NW Mondscheinspitze	13.0	1100	2 / 7.7	7.0	0 / 1
16	Grasberggebiet – Eiskönigbach - Kuppel	11.9	1030	1 / 5.0	6.3	0 / 1
17	Fleischbank - Baumgartental – Grenze BRD	15.4	1050	3 / 9.6	5.4	1 / 2
18	Grenzzone Scharfreiter - Delpsjoch - Rißbach	10.8	1250	5 / 8.0	2.3	2 / 2
19	Baumgartensattel - Leckbach - Rißtal	4.6	1030	2 / 3.9	2.2	0 / 1
20	Rißtal v. Hinterriß - Hagelhütte und Einhänge	19.3	1100	11 / 31	2.2	5 / 1
21	Plumssattel - Hasental bis Rißtal	6.4	900	3 / 7.0	6.2	1 / 1
22	Vorders - Galgenstangenkopf; Fermesbachtal	7.8	1100	6 /11.7	3.9	0 / 1
23	Rappenspitze - Stiftswald & Grenzzone -„-	10.0	1150	4 / 8.6	7.2	0 / 2
24	Rappenspitze – Vorderskopf; Seiten-Rißbach	8.3	960	5 / 9.3	2.7	2 / 3
25	Östl. Karwendelpitz – Rohntal -Hinterriß	8.9	1650	2 / 6	2.7	1 / 1
26	Lackenkarkopf – Torbach - Hinterriß	9.7	1500	1 / 5.1	2.4	1 / 1
27	Hochalmsattel – Birkkarspitz – Filztal	10.4	1580	1 / 2.6	5.6	1 / 1
28	Johannestal	20.0	1550	2 / 9.0	4.8	1 / 2

NO	Space units (I-IV) and landscape chambers	Area	ΔH (m)	G (n/km)	RI	$HI_{(T/F)}$
29	Falkenkar – Rißtal	3.0	1440	1 / 1.3	3.1	0 / 1
30	Laliderertal	16.9	1550	1 / 6.2	5.2	0 / 2
31	Enger Grund – Gr. Ahornboden – hint. Rißtal	23.5	1570	2 / 10.2	5.0	2 / 2
32	Lamsen- bis Bettlerkarspitze; Gramaisjoch	7.5	1320	2 / 3.3	4.8	2 / 1
III	CENTRE & NW EDGEZONE - DRAINGE WEST VS ISAR					
33	Nördl. Karwendelkette – Karwendeltal	49.8	1740	5 / 21.2	6.9	4 / 2
34	Hinterkar- & Breitgrieskargebiet - Hinterautal	14.0	1480	2 / 5.0	6.0	0 / 0
35	Ödkarspitz – Ödkar - Hinterautal	7.0	1580	1 / 2.5	9.2	0 / 0
36	Birkkarspitz – Birkkar - Hinterautal	9.0	1520	1 / 3.1	11.2	0 / 0
37	Moserkarspitz- Moserkar – Hinterautal	5.3	1380	1 / 1.3	13.3	0 / 0
38	Grubenkarspitz – Roßloch – Hinterautal	12.0	1370	1 / 1.5	15.5	0 / 1
39	Lafatschertal bis vor Hinterautal	13.8	1400	1 / 4.4	13.5	3 / 2
40	Hinterödgebiet – Jagdgraben - Hinterautal	6.0	1350	2 / 3.1	9.7	0 / 0
41	Samertal	12.9	1210	1 / 5.4	5.0	1 / 2
42	Kleinkristental – Mandltal - Grubach	21.0	1370	3 / 4.9	4.0	1 / 2
43	Großkristental	12.3	1320	2 / 6.7	7.3	1 / 2
44	Fleischbankspitze – Wengertal	5.1	1080	1 / 2.0	4.6	0 / 2
45	Äußeres Gleirschtal (Amtssäge – Hinterautal)	9.1	1470	2 / 6.9	4.9	0 / 3
46	Hinterautal & Einhänge Kastenalm-Gleirschh.	16.4	1500	3 / 13.6	6.8	1 / 2
47	Scharnitz – Gleirschhöhe & Einhänge im S	8.0	780	4 / 9.0	1.3	0 / 2
48	Karlspitze – Karl- & Isertal	5.4	830	2 / 4.2	3.8	1 / 2
49	Reither-+Erlspitze; Eppzirler Alm – Gießenb.	14.8	1390	2 / 5.8	5.0	1 / 2
50	Seefelderjoch – NW-Hänge vs. Seefelder Pl.	5.7	1040	1 / 1	2.0	0 / 1
51	Reither Spitze vs. Seefeld +Roßkopfgebiet	12.0	1220	3 / 7.4	1.3	6 / 3
IV	EDGEZONE SOUTH – DRAINAGE VS. INN (INN-VALLEY)					
52	Reither – Kujochspitze; Grieskar – Hochzirl	10.3	1650	3 / 8.0	2.5	2 / 1
53	Erlspitze – Gr. Solstein - Brunntal – Zirl	13,7	1880	2 / 7.5	3.0	3 / 3
54	Martinswand – Hechenberg	6.2	1320	0 / 0	1.3	0 / 1
55	Hechenberg - Sultzal – Kranebitter Klamm	6.2	1900	1 / 3.7	2.6	0 / 1
56	Nordkette Innsbruck	18.6	1900	2 / 4.2	1.3	9 / 2
57	Nordkette Rum bis Absam	18.5	1750	2 / 3.8	1.7	4 / 2
58	Isstal - Halltal	16.6	1900	2 / 6.0	3.4	4 / 2
59	Vomper Loch	38.3	2100	3 /16.5	6.0	1 / 1
60	Gnadenwald –Hinterhorn – Walder Joch	16.0	1730	1 / 1.0	0.8	2 / 3
61	Mittagspitze- Vomper Joch – Vomber Berg	8.1	1530	2 / 3.7	1.5	1 /3
62	Lamsenjoch –Inneres Stallental	8.7	1140	0 / 0	5.8	2 / 1
63	Stallental – Gamsgarten-+ Wolfsklamm	11.5	1620	1 / 6.8	2.9	0 / 2
64	Seiergraben – Stanser Joch – Jenbach	12.7	1620	1 / 2.5	1.7	2 / 2
65	Tiefental – Kasbach - Jenbach	4.6	1290	2 / 3.6	1.1	1 / 3
66	Weißenbachtal	5.2	1160	1 / 3.8	2.1	2 / 2

From an ecological and wilderness point of view, these unique vertical and horizontal landscape settings are, for several reasons, crucial for the PCA and for the overall conservation and biodiversity value of the Karwendel Mountains:

- They add to the remoteness and inaccessibility of many sub areas of the Inner Karwendel and are thus responsible for the low human impact and disturbance level still prevalent in many parts of the mountain system.

- The high relief energy fosters natural dynamics and stochastic events, thereby contributing to the impression of pristine wilderness. Dynamic natural processes such as avalanches, mud flows and the surface runoff still take place in many parts of the Karwendel without human intervention. The Karwendel Mountains are thus exceptional in terms of their value to nature as a wilderness. It may well be that no other area in Austria exhibits similar dynamic natural processes in comparable dimensions. These natural processes also have a significant impact on the diversity and function of local biocoenoses. For instance, habitats for pioneer organisms and specialists are on offer at all times; succession processes can be initiated, and avalanche strokes with a specific vegetation and wildlife are widespread and ecologically significant for the area. This includes the supply of carrion and thus surplus food for carnivores and scavengers, for example.

- Due to the pronounced and steep altitudinal gradients from the fringe foothills and inner valley floors to the mountain tops, a high diversity of plant and animal species with members of lowland, mid-elevation to sub alpine and alpine communities can be found in the close vicinity.

- In addition to this, the subdivision of the landscape into many chambers, each isolated from the other, could also enforce micro-evolutionary processes in less mobile species. Not only that, it contributes to high densities of territorial animals such as the golden eagle (see chapter 4.3.3) because it facilitates the portioning of territories.

3. AQUATIC AND TERRESTRIAL ECOSYSTEMS: AN OVERVIEW AND BALANCE

3.1 FRESHWATER SYSTEMS

In the Alps, only about 10% of all rivers are (at least partly) in a natural or near-natural condition. Throughout the Alps, valleys, rivers and streams have been dammed, straightened and regulated (LASSEN & SAVOIA 2005). Freshwater conditions and threats in Austria are very similar to those in other areas of the Alps, the rates of destruction and regulation of rivers and streams being only slightly below the overall rate of the Alps.
For instance, SCHMUTZ et al. (2010) classified only 14 % of all Austrian rivers and streams as being "in very good ecological condition", and according to an analysis by WALDER & LITSCHAUER (2010), only about 20% of all rivers with a catchment area above 10 km² have an unregulated free run off regime. Under such circumstances, for a landscape to still have undisturbed freshwater ecosystems over a larger area is prima facie evidence of its great value for nature. This is why the state of freshwater systems was chosen as a prime criterion in the selection process of PCA landscapes in the Alps (see preface).
In this respect, the Karwendel Mountains received high rankings from experts during the first PCA selection steps, even though detailed data was not as yet available. This appraisement has subsequently been affirmed with detailed data.

Fig.6: Unspoilt freshwater systems with free flow and natural discharge dynamics are one of the most distinctive and valuable features of the PCA Karwendel Mountains. Upstream section of the Rißbach (Photo: O. Leiner).

The Tyrolean Karwendel Mountains encompass 24 larger streams, each with a catchment area of >10 km² and an overall flow length of approximately 211 km (e.g. Fig. 6). In addition to this, there are at least 100 tributary streams with more than 1 km in length and a further overall length of approximately 230 km, and another 220 smaller creeks, flumes and moist gullies (details see Table 3 in LANDMANN 2013). Most streams are rather small with less than 5 m bed breadth. A GIS-based calculation revealed only 22.3 km of rivers with more than 5 m width, but a 398 km overall flow length of streams with less than 5 m breadth and an additional 380 km of very small waters and gullies with mostly only periodical water flow (Fig 7). Altogether, this means that the area as a whole has more, and more varied freshwater ecosystems than most other areas in the Eastern Alps.

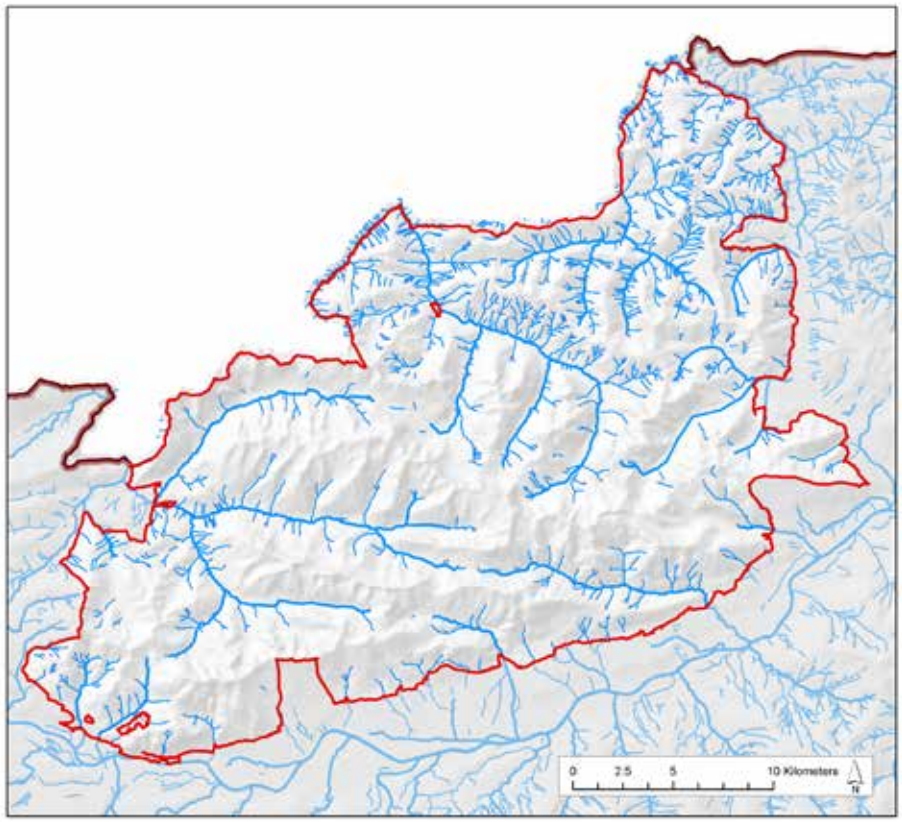


Fig.7: Small and medium sized rivers, streams, rivulets and temporary water run offs in small gullies form an extensive network of unspoiled freshwater ecosystems in the PCA Karwendel Mountains. Note the especially high density of this network in the lower north-eastern areas of the PCA which receive more precipitation.

The freshwater systems in the PCA are of immense ecological value, mainly because they have not been modified or tampered with. Even the larger stream and rivers are in an excellent ecological state, their hydromorphological conditions almost completely natural; they have a free, unspoilt flow with natural discharge dynamics. It must be stressed that such conditions are extremely rare today in the Northern Limestone Alps of Bavaria and Austria, a region that has generally been under disproportional anthropogenic pressure for centuries.

The two main rivers “Isar” and “Rißbach” with their main tributaries in particular, are in excellent ecological condition and thus especially deserving of protection (Fig. 8, compare Figs. 13a-b, chapter 4.1). These two mountain rivers may not only be classified as “sites of national importance” but need to be regarded as high quality sites and model streams for limestone freshwater systems on an international scale. These braided river systems are, among others, also refuges for endangered plant and animal species; this is dealt with in chapter 4.1.

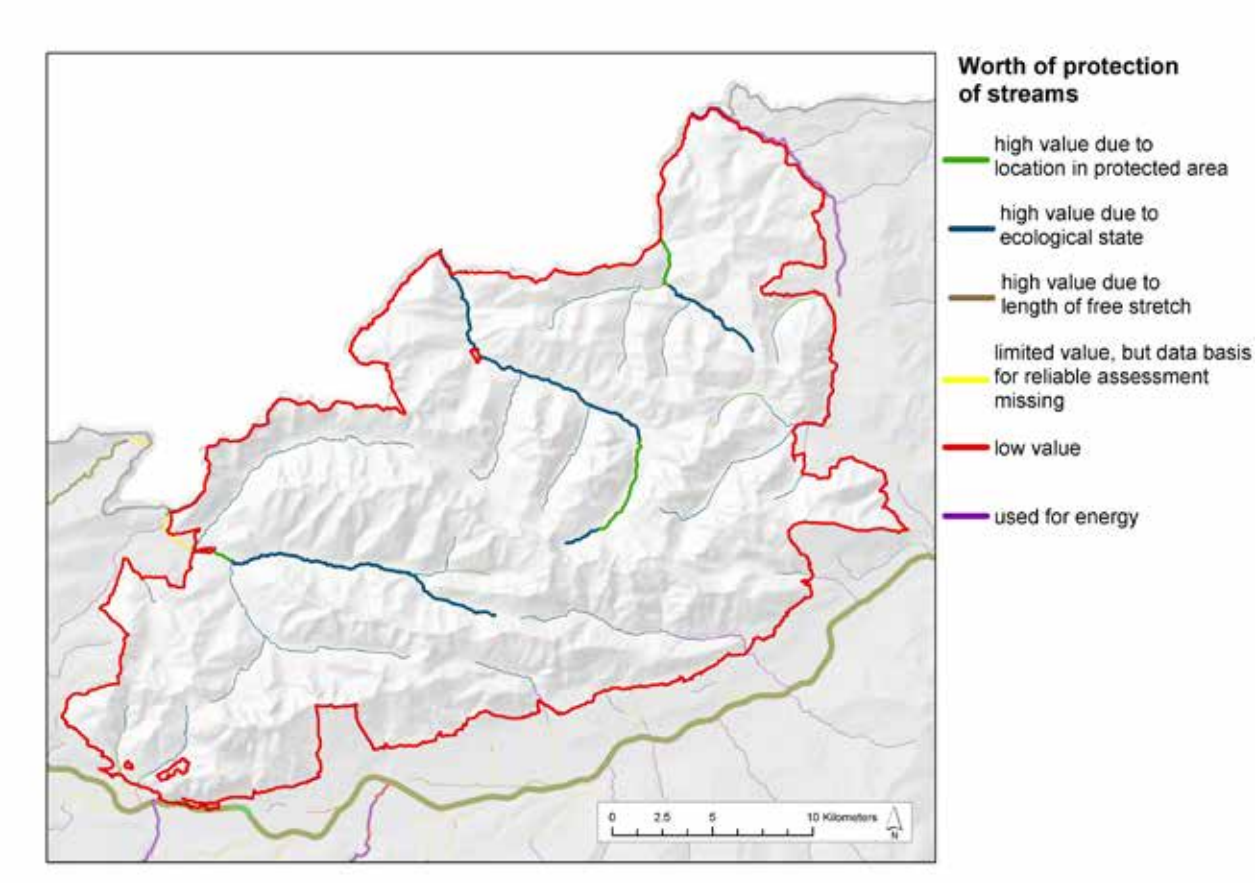
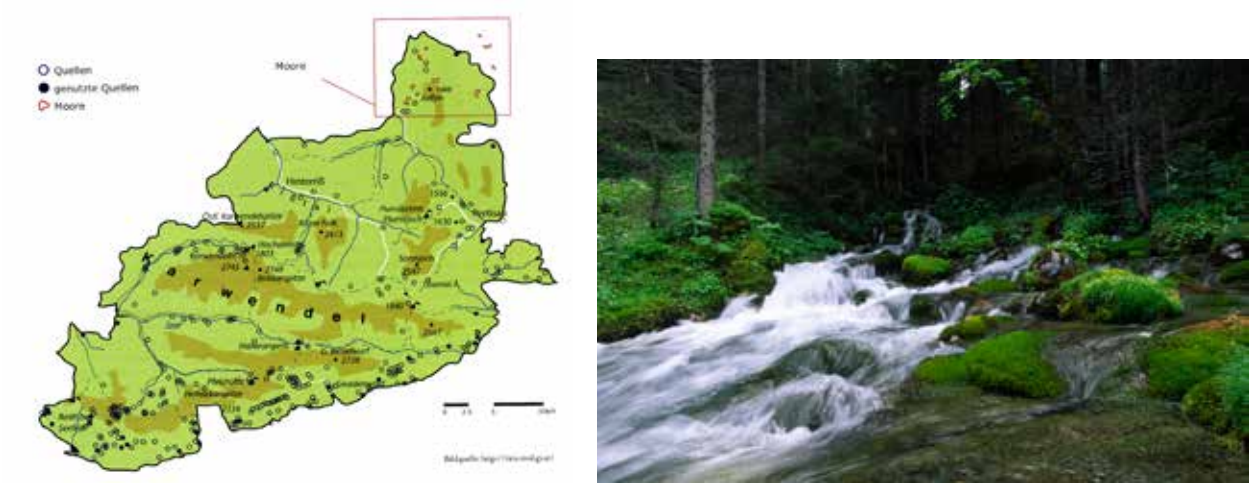


Fig.8: Main river systems of the PCA Karwendel Mountains and their protection value from a national (Austrian) viewpoint. The 3 main systems from SW to NE are: Isar (with Karwendelbach), Rißbach and Dürrach. Map based on a WWF-study by WALDER & LITSCHAUER (2010).

SPRINGS AND DRINKING WATER SOURCES

The Tyrolean Karwendel is perhaps one of the most important drinking water reservoirs in Europe. The total number of sources of the Karwendel is assumed to be about 350 (SONNTAG 2009; Fig.9a). Approximately 50-60 of these are rather large, with water run off of more than 10 litres per second (e.g. Fig. 9b). Not only do these sources supply settlements in the vicinity of the PCA (esp. the urban area around Innsbruck) with irreplaceable human drinking water, many source horizons also form important, specific habitats for a specialized protist, animal and plant life.



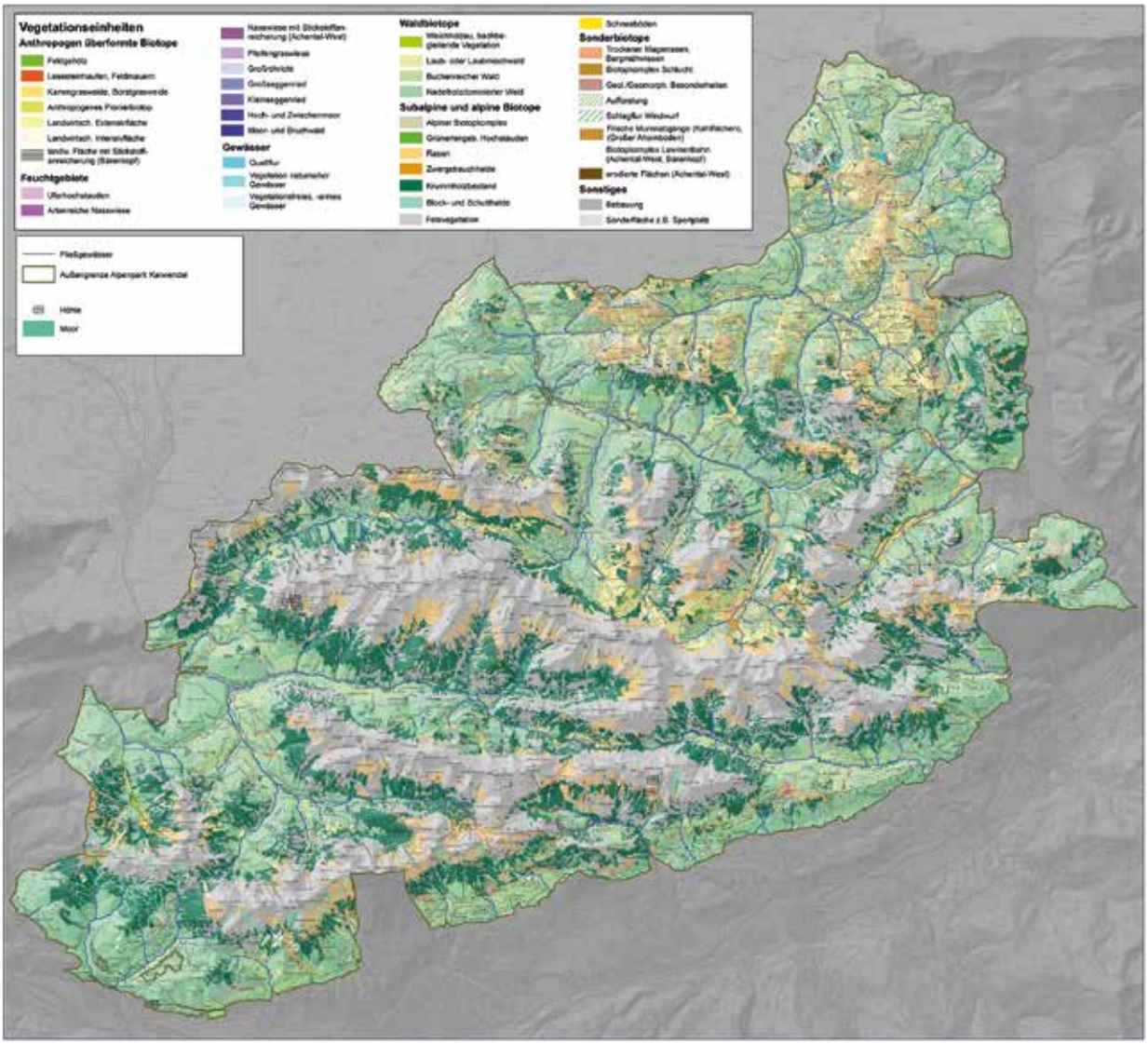
a b

Fig.9: a. Density and distribution of springs (open symbols) and exploited drinking water sources (filled) within the PCA Karwendel Mountains. In addition, greater bogs (Moore) are shown.
b. One of the largest Karwendel springs, the “Black water” in the centre of the mountain System (Photo: O. Leiner).

3.2 TERRESTRIAL ECOSYSTEMS AND HABITATS

Three main habitat components dominate the landscape of the Karwendel Mountains: Rock and debris (e.g. Fig.3), forest (each covering about a third of the area) and Krummholz (about 17% land cover). However, an actual survey of the vegetation communities in the core area (i.e. the central 540 km² nature conservation area) as well as in several protected fringe areas (192 km²) of the Tyrolean Karwendel Mountains revealed that these main habitats are composed of many quite different sub-units and are supplemented by a variety of other specific habitats which cover smaller areas but contribute to the highly diverse mosaic of the PCA landscape and determine the extraordinary floral and faunal biodiversity of the Karwendel.
Table 2 summarizes these findings by giving figures about the number of separate habitat units and their overall landscape cover within two sub areas of the PCA with different conservation status.
A total of 47 habitat types are distinguished in the Tyrolean biotope mapping scheme for the Karwendel Mountains and 40 of them cover more than 10 ha.
The Figs. 10a and 10b give an overview of the habitat mosaic and the distribution of the most important landscape units within the PCA. It should be noted that the patterns in Fig 10a are more detailed and more accurate because they are based on a stringent regional survey (Table 2).
The Corine Land Cover (land use and habitats) Assessment (Fig 10b) on the contrary is based on remote sensing data. The analysis of such Land sat pictures produces only a raw overview and is prone to assignment errors and misinterpretations. For example, most of the area in

the northeast part of the PCA shown as “natural grassland” (Corine Type 321) in Fig 10b, is in reality alpine pasture (mainly cattle grazed). Differences also apply to figures of the landscape cover of main habitats. For instance, overall forest cover is stated with 27.290 ha (37.2 %) in the regional study, but forests cover 28.031 ha (38.6%) according to the Corine dataset, and the area of dwarf pine habitats differs between 12.355 ha (16.8%) and 13.280 ha (18.3%, Corine value) respectively. Notwithstanding, both maps are shown here because in many parts of the Alps only Corine data will be available for future comparisons of PCAs.



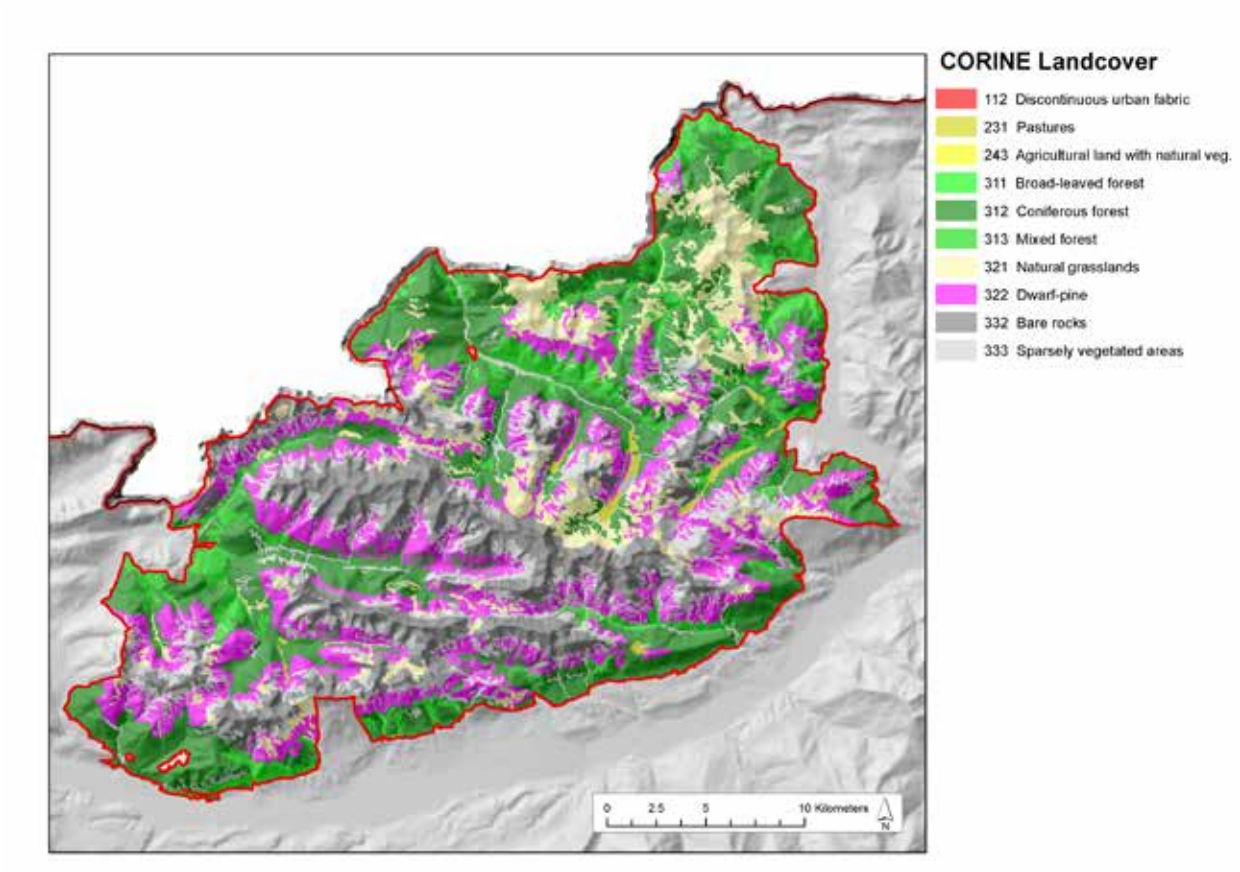


Fig.10: Vegetation communities and land use patterns in the PCA Karwendel Mountains
10a (top) Tyrolean biotope mapping scheme (TIRIS 2008); 10b (bottom) Actual Corine data

Table 2: Land cover of vegetation communities and other habitat types in the PCA Tyrolean Karwendel Mountains. Habitats are arranged according to the Tyrolean biotope mapping scheme. The first letter in each BIK-Code indicates the main habitat (A = alpine habitats; F = wetland habitats; M = man made / influenced habitats; W = woodland, forests; WW = riparian habitats). For each habitat, the number of spatially separated units and the overall land cover (area) is shown. Data are given for two sub areas of the PCA: the central nature conservation area Karwendel, and for 7 smaller areas at the various edges of the „Alpenpark Karwendel“ (Data source TIRIS; APK, data status approx. 2002).

Habitat main types and subunits according to the Tyrolean biotope mapping scheme (BIK)		PCA Karwendel central parts		PCA Karwendel fringe parts	
BIK-Code	Habitat Type (vegetation unit)	number of units	Total area (ha)	number of units	Total area (ha)
ABSK	Rock heaps and alpine calcschist scree fields	-?	-?	461	865,3
AFVK	Bare rocks and sparsely vegetated cliffs	3.858	18.371,9	823	2.101,2
AGH	Green alder scrubs & (sub)alpine tall forb stands	46	27,7	5	2,4
AKB	Dwarf mountain pine stands (incl. Rh. hirsutum)	3.257	9.419,6	1.109	2.934,8
ARSK	Calciphilous alpine and subalpine grasslands	1.871	4.727,1	860	1.133,6
AZH	Alpine dwarf heaths	-?	-?	9	14,6
BKA	Alpine biotope complexes (not specified)	?	?	35	389,9
BKS	Biotope complexes in gorges (not specified)	-?	-?	7	6,9

Habitat main types and subunits according to the Tyrolean biotope mapping scheme (BIK)		PCA Karwendel central parts		PCA Karwendel fringe parts	
BIK-Code	**Habitat Type (vegetation unit)**	**number of units**	**Total area (ha)**	**number of units**	**Total area (ha)**
FGR	Reedbeds	15	2.1	-	-
FGS	Beds of large sedges	117	25,9	11	1.7
FHM	Open peat bogs	18	20,7	-	-
FKS	Small sedge alkaline fens	147	21,8	28	9,6
FMB	Bog and mire woods (not specified)			2	1,0
FMBP	Pinus mugo & P. unicinata bogs (bog woods)			1	0,9
FNW	Species rich wet meadows	69	13,1	22	13,3
FPW	Purple moorgrass meadows	8	1,4		
GQK	Calcareous springs (Cratoneuron communities)	85	7,5	16	**1,9**
SV	Bare ore sparsely vegetated water bodies	314	304,7		
MLE	Pastures and meadows (extensively used) icultural	1.018	3.462,7		
MKB	Alpic mat-grass swards and related communities	-?	-?	103	356,5
MLI	Pastures and meadows (intensely used)	-	-	28	47,1
MMRK	Oligothropic swards (mountain hay meadows)	-	-	23	50,1
SA	Reafforestation areas	-?	-?	495	402,8
SK	Clear cuttings, windfall areas in woodland	2.574	998,2	213	180,0
WB	Mixed forests – dominated by common beech lder	38	24,2	30	180,8
WBA	Beech-fir mountain forests	?	?	4	5,1
WB F & K	Montane beech forests(limestone beech forests)	103	125,1	164	244,0
WBP	Mixed spruce – fire- beech forests	2.291	4.557,6	201	1.130,2
WL	Broad-leaved and mixed forests (not specified)	113	225,8		
WLAB	Grey alder–birch slope woodland	-	-	10	2,1
WLAP	Montane Sycamore forests	bei WL?	bei WL?	14	93,9
WLUF	Ravine forests (Mountain Elm & Common Ash)			6	12,0
WNFF	Spruce-Scots Pine forests	46	114,1	311	2.963,0
WNFW	Scots pine forests	234	537,4	164	1.344,1
WNF-WS	Montane to subalpine Pinus uncinata forests	66	43,5		
WNLA	Semiopen larch forests and larch meadows			7	119,6
WNLN	Subalpine Larch forests			101	325,9
WNLP	Larch- spruce forests	602	1.431,2	177	1.267,0
WNPA	Spruce-fir forests	764	2.028,1	39	291,4
WNPC	Arolla pine forests	160	545,0		
WNPW	Spruce forests	3.531	6.402,7	580	1.936,5
WWA	Riverine forest (montane grey alder stands)	49	34,1	30	23.6
WWB	Rivarine willow and grey alder galleries	?	?	46	17,5
WWG	Riverine gravel fields (unvegetated)			83	106,9
WWW	Riparian willow formations (S. eleagnos stands)	130	34,3	10	10,4
Others	Mostly anthropogenic altered / influenced areas	623	674,43	**205**	**109,2**
Total		22.147,0	54.181,6	6.625	19.157,0

For each of the major habitats the following aspects can be highlighted:

LIMESTONE CLIFFS, ALPINE CALCAREOUS SCREES AND ALPINE CALC-SCHIST SCREES

These habitats, including interspersed grasslands, are not only exceedingly important for the landscape pictures and for determining the value of this mountain range as a wilderness (see Figs. 3a-d); they are also highly significant in that they are inhabited by specific plant and animal communities (e.g. Limestone flora, butterflies) including many rare species including Austrian endemits (see chapter 4.3.1).

MOUNTAIN FORESTS

The forests of the PCA Karwendel Mountains belong to two different forest ecoregions. The central and northern parts of the PCA belong to the "Northern peripheral Alps-West" ecoregion, and the forests on the South facing slopes of the "Nordkette" are part of the "Northern Slate Alps-West" ecoregion (KILIAN et al. 1994).

Despite centuries of forestry activities, the Karwendel still has an unusually high proportion of natural to semi-natural stands of mountain forest and, in wide areas, a low degree of human impact. And even those forests which, to some degree, have been disturbed show a relatively high potential for restoration within short time spans (see also chapter 5.1, Fig.16).

With respect to features like small scale diversity and specificity of forest types, the Karwendel Mountains can be regarded one of the most valuable forest areas in Austria.

The following details should be emphasized:

Completely different types of deciduous, mixed and coniferous forests can be found within a few kilometres of horizontal distance. These include stands of Mediterranean hop hornbeam *(Ostrya carpinifolia)* and manna ash *(Fraxinus ornus)* oak-hornbeam forests, European ravine forests and riverine ash-alder woods, several types of basophilic but also neutrophilic and acidophilic Medio-European beech *(Fagus sylvatica)* forests, subalpine beech woods and limestone beech forests, as well as xerocline mountain pine *(Pinus uncinata)* and scots pine *(Pinus sylvestris)* forests, eastern alpine calcicolous larch *(Larix decidua)* forests, mountain bog woods and a variety of montane to subalpine spruce *(Picea abies)* and mixed spruce-fir *(Abies alba)* or beech-fir forests.

For instance, in a biotope inventory for the central parts of the mountain range alone, 65 different forest types including 10 types of various deciduous and mixed deciduous habitats were identified by STÖHR et al. (1995): 21 types of conifer-dominated forests and, in addition, 7 types of Krummholz habitat (see below). Among the 93 main forest habitat types described for Austria and among the 77 for the Northern Alps (see ESSEL et al. 2002), 36 are also known from the Karwendel Mountains, which, for a number of those forest types, represent the most important or even the main area of occurrence on a regional to national scale (details compare LANDMANN 2013).

With respect to cover, naturalness, and structural diversity, mixed montane spruce-fir-beech forests (about 5.700 ha) are the most important proper forest type in the Karwendel Mountains. These impressive forests of the montane belt (e.g. Fig. 11) are especially noteworthy because of their importance for animals (see chapter 4.3.3).

Fig.11: The PCA Karwendel still has a high proportion of natural stands of mountain forest, the mixed montane beech-fir-spruce forests being the most important and animal rich type. (Photo: Steinmüller; Alpine Park Karwendel)

Fig.12: Extensive dwarf mountain scrubs dominate many parts of the PCA from montane to high subalpine elevations. (Photo: A. Landmann)

KRUMMHOLZ-HABITATS

The 7 types of Krummholz habitat distinguished by STÖHR (1995) include various stands of *Alnus viridis* and *Fagus sylvaticus*. The latter tree, especially on the south facing slopes of the "Nordkette", dominates a very remarkable plant community (Allio victorialis-Fagetum, Saxifrago rotundifoliae-Fagetum p.p.) which is protected under the EU FFH directive (Code 9140) and is rare in Austria occurring only in few parts of the Austrian limestone alps (cf. ESSEL et al. 2002).

However, there is one Krummholz habitat of overwhelming importance and specificity in the Karwendel – the **Carbonate dwarf mountain pine** *Pinus mugo* **scrub**. This habitat is classified as priority habitat (Type 4070) in Annex 1 of the EU-Fauna Flora & Habitat Directive. This Krummholz-type (e.g. Fig 12) not only covers vast areas (12,355 ha) but also shows high structural and floristic variability within the Karwendel area (STÖHR 1995 distinguishes 5 subtypes). These areas are, for the most part, truly pristine habitats – a real wilderness and a natural treasure.

Despite their wide distribution in the Limestone Alps and their potential role as key ecosystems of subalpine regions, very little is known about the abiotic and biotic properties of dwarf pine habitats (see LANDMANN 1995 and literature therein).
In the Karwendel, dwarf pine habitat patches are scattered along the altitudinal gradient and show marked differences in size, structure and degree of isolation. Above the timberline, dwarf pine fields may form more or less continuous belts with a few kilometres of horizontal and a few hundred meters of vertical extension (Fig. 12).
Although dwarf pine Krummholz appears to be relatively homogeneous on first sight, it proves to be a surprisingly variable environment in terms of micro-climatic conditions, soil characteristics, biotic resource dynamics as well as in the arrangement of abiotic and biotic structures (LANDMANN 2013).
Subalpine shrub belts are, therefore, not only scientifically challenging habitats, they are also interesting from a socio-economical viewpoint: They are important for the soil formation (as sinks for raw humus), for stabilising mass movements, for deterring avalanches, and they play a key role in the hydrography and water regime of mountain environments.
There is probably no other area in the Alps that can provide such excellent conditions for studying this unique and very specific habitat type of the Limestone Alps.

4. BIODIVERSITY AND CONSERVATION VALUE OF HABITATS, PLANT AND ANIMAL COMMUNITIES

4.1 AQUATIC AND RIVERINE HABITATS AND ORGANISMS

As mentioned earlier, most rivers and streams of the PCA are in a nearly pristine state and in "very good ecological condition". The two main rivers systems (Isar, Rißbach) cannot only be classified as "sites of national importance" which deserve special protection (Fig. 8, chapter 3.1); these braided rivers and other streams of the PCA with their adjoining specific riverine habitats are also refuges for highly specific plant and animal communities and for a number of endangered species.

A total of six freshwater habitats protected by the EU-FFH directive (Annex 1) are represented in the PCA (Habitat Codes: 3140, 3220, 3230, 3240, 3260, 3270 – see Table 3). Representative examples of the three montane river gravel communities No 3220, 3230 and 3240, in particular, with the highly endangered Tamarisk *(Myricaria germanica)* can be found on the banks of the Rißbach and (in less valuable extensions) the Tyrolean Isar.
It should be emphasized that these river ecosystems of the PCA extend directly into and are connected to the Bavarian side of the Karwendel where similarly valuable stretches of these rivers exist (see PLACHTER 1986, REICH 1991, REICH et. al. 2000, KUHN 2006, SCHÖDEL 2007, cf. Fig.13a).
However, it should also be mentioned that the Bavarian Isar is already affected by the production of hydro energy (the Sylvenstein Reservoir). This causes a disruption of the river continuum, a decrease of the water flow, and water shortages during some parts of the year. The extensive recreational use of the area during the summer months is another source of disturbance which, to a certain extent, impoverishes the original ecosystems and species composition (GEORGII & ELMAUER 2002; SCHÖDEL 2007a).

Not much is known yet about the species composition of most fresh water systems of the PCA, and even the species inventories of higher plants and larger animals on the main rivers are either incomplete or available for single sites only (cf. KATHREIN 1993, WERHONIG 1997, KAHLEN 1995, CERNY & HUEMER 1995; PAGITZ 2009).

a b

Fig.13: River jewels of the PCA Karwendel Mountains: a (left) Rißbach near the mouth into the Isar (Photo H. Sonntag). b (right) Karwendelbach, the main tributary of the Tyrolean Isar (Photo: S. Hoelscher)

Little is therefore known about composition and diversity of the benthic or free-water organisms of the Karwendel freshwater systems. However, a large percentage of all freshwater algae so far reported from the Karwendel are listed in the Austrian and/or German Red Data Books. The brooks and rivers of the Alpine Park are furthermore inhabited by several species of (some) rare water insects (e.g. Mayflies, see Table 6 in LANDMANN 2013 and by *Cottus gobio* (a fish species of the EU-FFH Directive). The riparian zones and their gravel fields (Fig. 13) are inhabited by a representative set of strongly adapted and rare ripicole spiders (e.g. *Arctosa cinerea*) and insects (e.g. the specialised grasshoppers *Bryodema tuberculatum, Chortippus pullus, Tetrix tuerki*); they also serve as breeding grounds for the Common Sandpiper *(Actitis hypoleucos)*, a bird classified as “endangered” in the national Red List (FRÜHAUF 2005).

4.2 PROTECTED AND ENDANGERED TERRESTRIAL HABITATS AND PLANT COMMUNITIES

A survey of the local vegetation communities revealed that two thirds of all habitat types occurring in Austria as listed in Annex 1 of the EU Fauna Flora & Habitats Directive can be found,

at least on a small scale, in the Karwendel (Table 3). In this connection, the high number (13) and significance (with respect of size and representativeness) of Annex 1 priority habitats in the area needs to be emphasized. Habitat types No 6170 (alpine and subalpine calciphile grasslands), 7220 (Middle European calcareous springs – Cratoneurion) and 8160 (calcareous screes and calcschist screes) are particularly well represented in many parts of the PCA Karwendel, and bog ecosystems (Habitat Type 7110 and others) with a remarkable floristic and faunal composition can be found, especially in the wet north-eastern parts of the Karwendel (promontory areas; compare Fig 9a; see HASELWANTER 2008).
Furthermore, nearly three quarters (34) of the 49 specific plant communities listed as endangered in the Tyrolean Nature Protection Ordinance 2006 (Appendix 4) can also be found in the Karwendel and its fringe areas. A survey (STÖHR 1995) of the vegetation communities in the core area (i.e. the central 540 km² nature conservation area) revealed a total of 263 individual habitat areas with a total area of 15 km² and a further 19 biotope complexes with a total area of 45.6 km² belonging to one or another type of protected habitat under the Tyrolean Nature Conservation Act.
Moreover, of the 36 forest habitat types known to occur in the Karwendel Mountains, no fewer than 25 are classified as endangered in Austria or at least in the forest ecoregions of the Northern Alps (ESSEL et al. 2002; for details compare Table 10 in LANDMANN 2013); they are also listed in the EU-FFH directive or belong to one of the listed main forest types (see Table 3). The PCA Karwendel Mountains harbour highly representative stands of several of these forest types. In some cases the PCA is the most important, even the main area of occurrence on a regional to national scale. This applies, in particular, to the EU-FFH priority habitats No 9189 (Ravine forests, Tilio-Acerion) and No 9430 (Mountain Pine forests – Pinus uncinata) as well as the FFH-habitats No 9130 (Beech forests- Asperula fagetum) and the priority habitat type 4070 (Dwarf pine shrubs, Pinus mugo rhododendretum hirsuti).
In addition to forest habitats, at least 19 other (open area) habitat-types listed as endangered and/or vulnerable in the Red List of threatened biotope types in Austria (TRAXLER et al. 2005) can be found in the Tyrolean Karwendel. Austria has a major international responsibility for the conservation of 5 to 8 of these habitat types, and at least ten of them cover large areas of the PCA and they are at the same time well conserved representative examples of the respective habitat type. These habitats belong to the main habitat groups “mires, marshes and vegetation of springs”; “high mountain grassland and grassland fragments” and to “biotope types shaped by geomorphological features” (TRAXLER et al. 2005).

Table 3: Tab.3: EU-FFH (Annex I) ecosystems and habitats listed in the Standard Data Sheet for the Natura 2000 area „Karwendel," complemented with some other habitats not listed there (= absent) but known to occur in the Karwendel (STÖHR et al. 1995, DOBLER 2007, HASELWANTER 2008 and other sources). Code numbers in bold and with an * = priority habitats; SD-F = proportion of area covered by the habitat according to the Standard Data Sheet; SD-R = representativeness according to the SDS, Conservation value (own assessment): ++ = internationally important; + = important & representative on regional scale; x = locally important; ? = occurrence of the specific habitat type in the PCA is doubtful.

Code	Ecosystems / habitat type (abbreviated)	SD-F	SD-R	Value
	Freshwater Habitats			
3140	Oligo-mesotrophic waters	1	C	x
3220	Alpine rivers with herbaceous vegetation along river banks	3	B	++
3230	Alpine rivers with ligneous veg. with *Myricaria germanica*	absent	+	+
3240	Alpine rivers with ligneous veg. with *Salix eleagnos*	1	A	++
3260	Water courses of plain to montane levels	1	B	++
3270	Rivers with muddy banks.	1	B	?
	Temperate Heath and Scrub			
4060	Alpine and boreal Heaths	1	B	**x**
4070*	Bushes with *Pinus mugo* and Rhododendron hirsutum	3	A	++
	Sclerophyllous Scrub			
5130	Juniperus communis formations on calcareous ground	1	B	x
	Natural and Seminatural Grassland Formations			
6110*	Rupiicolouse basophile grasslands of the Alysso-Sedion albi	1	B	++
6150	Siliceous alpine and boreal grassland	1	B	?
6170	Alpine and subalpine calcareous grasslands	4	A	++
6210*	Semi-natural dry grasslands and scrubland facies on calcareous substrates	1	B	+
6230*	Species-rich Nardus grasslands on siliceous substrates in mountain areas	3	A	+
6410	Molinia meadows on calcareous soils *(Molinion caeruleae)*	1	B	x
6430	Hydrophilous tall herb formations of montane to alpine levels	absent	+	x
6520	Mountain hay meadows	1	B	x
	Raised bogs and Mires and Fens			
7110*	Active raised bogs	1	B	+
7120	Degraded raised bogs still capable of natural regeneration	absent	+	x
7140	Transition mires and quaking bogs	absent	+	x
7150	Depressions on peat substrates of the Rhynchosporion	1	C	x
7210*	Calcareous fens with species of the Caricion davalliana	1	B	+
7220*	Petrifying springs with tufa formation (Cratoneurion)	1	B	++
7230	Alkaline fens	1	B	+
	Rocky habitats and Caves			
8120	Calcareous and calcshist screes of montane to alpine levels	absent	+	+
8130	Western Mediterranean and thermophilous scree	1	B	x
8160*	Medio-European calcareous scree of hill and montane levels	10	A	++
8210	Calcareous rocky slopes with chasmophytic vegetation	2	A	++
8230	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion etc.	1	A	?

Code	Ecosystems / habitat type (abbreviated)	SD-F	SD-R	Value
8240*	Limestone pavements	1	B	x
8310	Caves not open to the public	absent	+	x
Forests				
9110	Luzulo-Fagetum beech forests	absent	+	+
9130	Asperulo-Fagetum beech forests	absent	+	+
9140	Medio-European subalpine beech woods with Acer and Rumex arifolius	absent	+	++
9150	Medio-European limestone beech forests of the Cephalanthe-ro-Fagion	1	B	x
9170	Galio-Carpinetum oak-hornbeam forests	absent	+	x
9180*	Tilio-Acerion forests of slopes, screes and ravines	1	B	++
91D0*	Bog woodland	1	B	+
91E0*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior	2	A	+
9410	Acidophilous Picea forests of the montane to alpine levels	2	A	+
9420	Alpine Larix decidua and/or Pinus cembra forests	absent	+	+
9430*	Subalpine and montane Pinus uncinata forests on limestonee	1	C	++

4.3 ENDEMISM, BIODIVERSITY AND SPECIFICITY OF TERRESTRIAL ORGANISMS

4.3.1 ENDEMISM

Analysis of the geographic concentrations of endemic taxa is often used to determine priorities for conservation action (TOWNSEND, PETERSON & NAVARRO-SIGUENZA 1999). The Karwendel Mountains also serve as a refuge for endemic organisms in Austria and the Alps.

According to the available data, a total of at least 167 cryptogam, plant and animal species or subspecies (taxa) whose range lies entirely (endemics) or predominantly (subendemics) within the political borders of Austria have been recorded as occurring within the five larger protected mountain areas of the Tyrol, the Ötztal-, Stubai- and Zillertal Alps, the National Park Hohe Tauern and the Karwendel Mountains (RABITSCH & ESSEL 2009, LANDMANN 2012).

After all, 41 (or 25%) of them also occur in, or exclusively in the Karwendel Mountains (Table 4). This is especially significant if one takes into account that, in Austria, due to the location of refugia during the glaciations, endemic taxa (species) occur predominantly in the North-Eastern Calcareous Alps, the Eastern Central Alps, and especially in the Southern Alps and/or Lower Austria, Styria and Carinthia. Table 4 gives a (presumably very incomplete) list of cryptogams, plants, and animals, which according to the current level of knowledge, can be regarded as Austrian endemites or subendemites, and which have been recorded within the PCA and directly adjoining areas.

In addition to these species, the Karwendel is also a refuge for other, more widely distributed endemic species of the Alps or Eastern Alps. At least 20 butterfly species, for instance, most of them endemic to the East Alps, some of them also, however, of northeast and southwest alpine provenience, are recorded as occurring in the Karwendel Mountains (for more details see the compilation by LANDMANN 2013).

Table 4: Austrian endemic or subendemic cryptogams, plants, and animal species known to occur in the PCA Tyrolean Karwendel Mountains (compiled from data and maps in RABITSCH & ESSEL 2009).
ET = Type of endemism: S = subendemic, A = species endemic for Austria; A? = uncertain status of endemism, partly pseudoendemic species; A*, S* species described from the PCA Karwendel (Locus typicus). In the KA-column, the specificity of the Karwendel-occurrence is assessed and for each species roughly assigned to one of the following categories: P = point endemism: so far only known from the PCA; L = local endemism: very restricted range within Austria, only few records in mountain areas, for the most part in the Tyrol. R = regional endemism in Austria, more or less confined to the western parts of the Eastern Alps; N = national endemism, scattered findings in several regions of Austria. L+, R+, N+ = most records and/or emphasis of occurrence of the endemic species in the PCA although found elsewhere. Species for which the PCA Karwendel Mountains are of singular importance are shown in bold. I = insect

ET	Group	Genus	Species / subspecies	KA
S	Plant	*Braya*	*alpina*	R
S	Plant	*Papaver*	*alpinum sendtneri*	R
S	Plant	*Pedicularis*	*aspleniifolia*	R
S	Plant	*Pedicularis*	*rostratospicata rostratospicata*	N
A	**Plant**	***Pulsatilla***	***oenipontana***	**P**
S	Plant	*Salix*	*mielichhoferi*	N
S	Plant	*Valeriana*	*chamaedrys micans*	(N)
A?	Lichen	*Rinodina*	*ventricosa*	N
A?	Lichen	*Verrucaria*	*poeltii*	R
A	Snail	*Orcula*	*dolium edita*	N
S	Spider	*Meioneta*	*alpica*	N
S	**Spider**	***Metobactrus***	***nodicornis***	**L+**
A	**Spider**	***Mughiphantes***	***severus***	**L+**
S	Spider	*Mughiphantes*	*variabilis*	R
S	Spider	*Arctosa*	*renidescens*	L
S	Spider	*Pardosa*	*giebeli*	R
S	Spider	*Pardosa*	*saturatior*	R
S	**Spider**	*Cryphoeca*	*lichenum nigerrima*	**L+**
S	Spider	*Halpodrassus*	*aenus*	R
S	Spider	*Thanatus*	*firmtorum*	L
S	Harvestman	*Megabunus*	*lesserti*	N
A	I-Apterygota	*Pseudanurophorus*	*quadrioculatus*	L
S	I-Apterygota	*Machilis*	*lehnhoferi*	R+
S	I-Bug	*Camptozygum*	*pumilio*	N
S	I-Bug	*Eurygaster*	*fockeri*	R
S	I-Beetle	*Carabus*	*alpestris hoppei*	N
S	I-Beetle	*Nebria*	*germari norica*	N

ET	Group	Genus	Species / subspecies	KA
S	I-Beetle	*Trechus*	*glacialis*	R+
S*	**I-Beetle**	***Asaphidion***	***cyanicorne tyroliense***	**P**
S	I-Beetle	*Pterostichus*	*panzeri*	N
S	I-Beetle	*Hydraena*	*alpicola*	N
S*	**I-Beetle**	***Leptusa***	***woerndleii***	**L+**
S*	**I-Beetle**	***Zoosetha***	***pechlaneri***	**L+**
S	I-Beetle	*Pharatora*	*polaris leederi*	N
S	I-Beetle	*Otiorhynchus*	*pigrans*	N
A	**I-Diptera**	***Dactylolabis***	***pechlaneri***	**P**
S*	**I-Lepidoptera**	***Kessleria***	***burmanni***	**L**
S	**I-Lepidoptera**	***Pediasia***	***ardiella ludovicellus***	**L+**
S	I-Lepidoptera	*Erebia*	*nivalis*	N
S	I-Lepidoptera	*Melitea*	*asteria*	
S	I-Lepidoptera	*Psodos*	*noricana*	N
S	Mammal	*Microtus*	*bavaricus*	L+?

4.3.2 BIODIVERSITY AND VALUE OF VASCULAR PLANTS, FUNGI, MOSSES AND LICHENS

Another criterion in favour of classifying the PCA Karwendel Mountains as an area of exceptional value in regard to the protection of a unique alpine environment is the large number of species that not only occur in the area but are also listed in the Red Data Books and/or are protected by regional conservation regulations or international directives (e.g. the EU Council FFH).

As already mentioned in the preface, international experts selected the Karwendel Mountains as a prime PCA-candidate in an initial raw analysis due to the high diversity and specificity of focal plant and animal groups known from the area. Only few other areas have priority value for almost all indicator groups (compare Fig. 20 in ARDUINO et al. 2006).

The following detailed data and comparisons will corroborate this initial rating as they demonstrate the extraordinarily high biodiversity and conservation values of the PCA according to regional, national and international criteria and scales.

All in all, more than 3000 vascular plants (2950 – 3428 species / taxa: see ADLER et al. 1994, RABITSCH & ESSEL 2009) occur in Austria, which, by the way, is a country of superior plant and animal diversity in comparison to other Central European states. The Alps in their entirety host about 4500 different vascular plant species, whereby floral diversity shows pronounced regional variation dependent mainly on the climatic history, the intensity of the Pleistocene glaciations, and the location of glacial refuges.

There are, for instance, 1.5 times more species to be found on the southern edge of the Eastern Alps than on the northern edge (LASSEN & SAVOIA 2005). The wide variety of plant species

in the PCA Karwendel, which has high standards in every respect anyway, has to be seen in relation to its location on the northern edge (!) of the Eastern Alps, its comparatively small size, and in relation to the richness of the national flora. To date, at least 1600 taxa of vascular plants have been verified as occurring in the focus area (727 km²) of this study (details see LANDMANN 2013). This means that approximately two thirds of the regional and half of the entire Austrian flora occur on only 6.8% and less than 1% of the area of North Tyrol and Austria respectively.

The PCA not only shows high plant species diversity, it is also a regional and in part even national hotspot for threatened and protected species, which I shall prove with a few data and examples:

- More than 600 plant taxa known to occur in the Karwendel are featured in one or another of the threat categories of the Red List of North Tyrol, East Tyrol or Vorarlberg (NEUNER & POLATSCHEK 2001). In other words, more than one third (42%) of all species (taxa) known to be endangered in the Tyrol or Vorarlberg occur on the focus area of this study (i.e. on 4.4% of the total area of the Tyrol and Vorarlberg).
- In total, 64 (17.4%) of the 367 plant taxa regarded as “critically endangered” in North Tyrol are known to occur in the Karwendel (plant list see LANDMANN 2013). Most of them are either typical for subalpine to alpine calcareous screes and grasslands or are species confined to the xerotic south facing slopes on the fringes of the Inn Valley. From a regional point of view this means that the study area is of paramount importance for the survival of these species.
- The Species Conservation Regulations for the Tyrol list 89 different taxa of ferns, club mosses and flowering plants that can be categorized as under full or partial protection. At least 51 of these taxa and 164 species of protected plants occur in the focus area (species list see LANDMANN 2013).
- One example of this: The Karwendel Mountains are a regional and nationwide diversity hotspot for orchids. Members of all 24 regional orchid genera with 41 species and 57 taxa can be found in the area. Thus, this comparatively small mountain range harbours two thirds of the Austrian and 84% of the Tyrolean orchid diversity (examples see Fig. 14)!

At least 18 vascular plant, moss and lichen species listed in the annexes of the FFH Directive and also under the full protection of the conservation laws of the Tyrol occur in the PCA (Table. 5).

Fig.14: Orchid and butterfly hotspot Karwendel Mountains. *Epipactis palustris* with *Zygaena purpuralis* (left) and *Ophrys insectifera* with *Coenonympha arcania* (right). Photos: M. Loner.

Table 5: Cryptogams and vascular plants of the PCA Karwendel Mountains listed in the EU- FFH-directive (Annexes II, IV, V). Data sources: * = Species mentioned in the „official" Natura 2000 „Karwendel" Standard data Sheet; x = Species occurrence in the PCA according to the data base of the regional Museum Ferdinandeum, Tyrol or mentioned in POLATASCHEK 1996-2001; # = Species occurrence in the PCA according to data in HASELWANTER 2008, HOFMAN 1988 or TÜRK et al. 2009.

Species (Taxon)	FFH- Annex	Data source
Vascular Plants		
Gladiolus palustris	IV	x
Cypripedium calceolus	IV	x
Liparis loeselii	IV	x
Spiranthes aestivalis	IV	x
Apium repens[1]	IV	*
Aquilegia alpina	IV	x
Arnica montana	V	x
Gentiana lutea	V	x
Lycopodium annotinum	V	x
Lycopodium clavatum	V	x
Mosses and Lichens		
Tayloria rudolphiana[2]	II	*
Orthotrichium rogeri	II	*
Sphagnum spp.	V	#
Cladonia subgen. Cladina[3]	V	#

[1] = Species not in the data base of the regional museum but listed in POLATSCHEK 1997.
[2] = Epiphyt on sycamore maple and beech. Globally concentrated in the Northern Limestone Alps!
[3] = According to Data given by HOFMAN 1988 and TÜRK et al. 2009 at least 21 species of the Cladonia group occur in the PCA, 3 species C. arbuscula, C.rangiferina & C. symphycarpa belonging to subgenus Cladina!

4.3.3 BIODIVERSITY AND VALUE OF ANIMALS: SELECTED INVERTEBRATES AND VERTEBRATES

Invertebrates

The exact number of animal species in the Alps is unknown, although estimates place the number at about 30.000 (LASSEN & SAVOIA 2005), a figure which, in my opinion, may be a substantial underestimation.
There exist only few studies on the terrestrial invertebrates of the PCA Karwendel Mountains, and these are local. Most of them focus on xerothermic sites on the south-facing slopes of the "Nordkette"

(e.g. Butterflies: HUEMER & ERLEBACH 2007; wild bees: STÖCKL 1995, Spiders: STEINBERGER 1987). Some studies, however, also deal with important indicator groups of highly valuable and specific habitats in other parts of the Karwendel. Examples of this are studies on beetles, butterflies, and other arthropods of riparian habitats of the Rißbach (KAHLEN 1995, CERNY & HUEMER 1996) and the Isar (KOPF & STEINBERGER 2009), studies on the butterflies of the Vomper-Loch valley (CERNY 1997) – an area of special interest because it could serve as core area for a future delineation of a real wilderness area within the PCA, or also studies on xylobiotic beetles of Karwendel forest ecosystems (KAHLEN 1997).
All these studies not only hint at an overwhelming diversity of invertebrates in the habitats and groups thus far investigated, they also provide evidence for the occurrence of many highly specialised, rare and endangered invertebrates within the PCA (e.g. chapter 4.1., see Table 4 & 6 for details and compare LANDMANN 2013).

Fig.15: Prey and (potential future) predator in the PCA Karwendel Mountains. The area probably has one of the largest populations of chamois in the Eastern Alps and has high potential for a re-introduction of the Lynx. Photos: H. Speckle (left) and R. Hofer (Alpenzoo Innsbruck, right)

Table 6: Invertebrates and Vertebrates listed in the EU-FFH-directive (Annexes II, IV, V) and breeding birds of the EU Bird Conservation Directive known to occur on a permanent basis within the PCA Karwendel Mountains, or at least to marginally intrude (mostly from the Inn Valley) into habitats of the PCA.
Data sources: Natura 2000 „Karwendel“ Standard data Sheet; KAHLEN 1997, LANDMANN & LENTNER (2001), LENTNER & WARBANOFF 2009, OBERWALDER et al. 2014, SCHMIDTLER & SCHMIDTLER 1997, 2001, WALDER & VORAUER (2014), SPITZENBERGER (2001), and own enquiries.
A separate status and abundance assessment within the PCA is given for each species:
x = marginal occurrence at the very least proved;
+ = regular occurrence in some parts of the PCA;
++ = wide distribution within the PCA and/or important population hosted by the PCA.
A-D = abundance categories (size of population) according to the Natura 2000 “Karwendel” Standard data Sheet.

Species	German Name	FFH/Bird Directive	Karwendel Mountains
INVERTEBRATES: SPECIES OF FFH-ANNEXES II, IV			
Rosalia alpina	Alpenbock	II	++
Cucujus cinnabarinus	Purpurroter Blattkäfer	II	+
Stephanopachys substriatus	Gekörnter Bergwald-Bohrkäfer	II	+
Parnassius apollo	Apollofalter	IV	++
VERTEBRATES: SPECIES OF FFH-ANNEXES II, IV, V, IV			
Lepus timidus	Schneehase	V	+
Martes martes	Baummarder	V	++
Capra ibex	Steinbock	V	+
Rupicapra rupicapra	Gämse	V	++
Muscardinus avellanarius	Haselmaus	IV	+
Rhinolophus ferrumequinum[1]	Große Hufeisennase	II, IV	x
Rhinolophus hipposideros[1]	Kleine Hufeisennase	II, IV	x
Myotis blythii (oxygnatus)[1]	Kleines Mausohr	II, IV	x
Myotis myotis[1,2]	Mausohr	II, IV	+
Myotis nattereri[1,2]	Fransenfledermaus	IV	++
Myotis emarginatus[1]	Wimperfledermaus	II, IV	x
Myotis mystacinus[1,2]	Bartfledermaus	IV	+
Myotis daubentonii[1]	Wasserfledermaus	IV	x
Pipistrellus pipistrellus	Zwergfledermaus	IV	+
Pipistrellus nathusii[1]	Rauhhautfledermaus	IV	x
Pipistrellus kuhlii[1]	Weißrandfledermaus	IV	X
Hypsugo savii[1,2]	Alpenfledermaus	IV	x
Nyctalus leisleri[1]	Kleinabendsegler	IV	x
Nyctalus noctula[1,2]	Abendsegler	IV	+
Eptesicus nilssonii[1,2]	Nordfledermaus	IV	x
Eptesicus serotinus[1]	Breitflügelfledermaus	IV	+
Vespertilio murinus[1,2]	Zweifarbfledermaus	IV	+
Barbastella barbastellus[1]	Mopsfledermaus	II, IV	x
Plecotus auritus	Braunes Langohr	IV	+
Plecotus macrobullaris[1]	Alpen-Langohr	IV	x
Tadarua teniotis	Bulldoggfledermaus	IV	x
Cottus gobio	Koppe	II	++

Species	German Name	FFH/Bird Directive	Karwendel Mountains
Lacerta agilis	Zauneidechse	IV	+
Lacerta horvathi	Kroatische Gebirgseidechse	IV	x
Podacris muralis	Mauereidechse	IV	++
Coronella austriaca	Schlingnatter	Iv	x
Salamandra atra	Alpensalamander	IV	+
Bombina variegata	Gelbbauchunke	II,IV	x
Bufo viridis	Wechselkröte	IV	x
Rana temporaria	Grasfrosch	V	++
Birds – Species of Annex I of the EU Bird Directive			
Aquila chrysaetos	Steinadler	I	B / ++
Pernis apivorus	Wespenbussard	I	D / x
Falco peregrinus	Wanderfalke	I	D /++
Bonasa bonasia	Haselhuhn	I	# / ++
Lagopus mutus helveticus	Schneehuhn	I	# / ++
Tetrao tetrix tetrix	Birkhuhn	I	C / ++
Tetrao urogallus	Auerhuhn	I	C / ++
Alectoris graeca saxatilis	Steinhuhn	I	# / x
Bubo bubo	Uhu	I	C /++
Aegolius funereus	Rauhfußkauz	I	C / ++
Glaucidium passerinum	Sperlingskauz	I	C* / ++
Picus canus	Grauspecht	I	C / ++
Dendrocopos leucotos	Weißrückenspecht	I	C / ++
Picoides tridactylus	Dreizehenspecht	I	C*/ ++
Dryocopus martius	Schwarzspecht	I	C / ++
Ficedula parva	Zwergschnäpper	I	# / +
Lanius collurio	Neuntöter	I	D / x

[1] = Bats: PCA habitats mainly used for foraging and (in part) for hibernation. Records mainly stem from marginal areas, particularly from the Nordkette and the edge of the Inn Valley.
[2] = Similar to 1, but records also exist from more central parts of the PCA .
* = The cited assessment of Population size in the Natura 2000 Standard data Sheet is clearly wrong
# = Species not listed in the „Standard Data Sheet" although the species does occur within the PCA.

Vertebrates

There are roughly 200 different breeding bird species and about 80 mammalian species to be found in the Alps. In addition to this, a total of 21 amphibian and 15 reptile species are known to occur.
The Karwendel Mountains harbour approximately half of this vertebrate species diversity on an area of less than 1000 square km, the Amphibians being the only group underrepresented in the core area (4 species in central parts and an additional 3 species recorded on the margins – see CABELA, GRILLITSCH & TIEDEMANN 2001, LANDMANN 1998, LANDMANN & FISCHLER 2000, SCHMIDTLER & SCHMIDTLER 2001).

The Karwendel Mountains are important not only because of this impressive overall diversity of terrestrial vertebrates but also in terms of vertebrate conservation, biogeography and population ecology. In fact, the area can be regarded as a conservation hotspot, a refuge, and a gene reservoir for a number of endangered species as well as for widespread and at the same time highly representative vertebrates of the Alps.

Reptiles

The Karwendel Mountains with 8 recorded species (3 snakes, 4 lizards and the blind worm *Anguis fragilis*) are home to nearly two thirds of the extant Austrian reptile fauna (13 species). Given the northern location of the PCA this is a surprisingly high number although most species are confined to marginal valleys in the east and west, and to the south-facing slopes near the Inn valley (distribution maps in CABELA et al. 2001, SCHMIDTLER & SCHMIDTLER 1996). Two species in particular deserve a closer look with regard to biogeography and conservation.

- The central Inn valley around Innsbruck and the adjoining south facing slopes of the Karwendel (up to 1200 m a.s.l.) are the clear population centre in the Tyrol of the xerophilic Wall lizard *(Podacris muralis)* (LANDMANN 1998), and thus, at the same time, the most important refuge for the *subspecies P. m. maculiventris* which, in Austria, is confined to the Tyrol (see SCHMIDTLER et al. 2006).

- The Croatian Rock-lizard *(Lacerta horvathii)*, a southeast-alpine species, has its northernmost and sole isolated occurrence north of the main chain of the Alps in the northeast of the PCA and the adjoining Bavarian Karwendel (SCHMIDTLER & SCHMIDTLER 1996 with further references).

Birds

Recent surveys (LENTNER & WARBANOFF 2009, OBERWALDER et al. 2014) have provided evidence of surprisingly high breeding bird species diversity within the area (about 100 species). This is significant. An even more important result of these surveys, at least in terms of the conservation of nature on a regional as well as international level, is the observation that various flagship species exhibit extraordinarily high densities. For instance, there are more than 20 pairs of Golden Eagles *Aquila chryseato*s in the greater Karwendel area (LANDMANN & MAYRHOFER 2001, MAYRHOFER & LANDMANN 2006). With about 17 pairs per 1000 km², the Karwendel area, mainly due to the highly structured rocky landscape (Fig.5), has one of the highest eagle densities of the entire Alps and can therefore be regarded as a key area for the protection of this magnificent bird. There are also disproportionally high densities of various endangered character species of the montane to subalpine forest ecosystems. This is especially true for the Pygmy Owl *(Glaucidium passerinum)*, the Tengmalm´s Owl *(Aegolius funereus)*, and for the Grey headed-, White-backed- and Three-toed Woodpecker *(Picus canus, Dendrocopos leucotos. Picoides tridactylus)*. More than 3 – 5% of the Austrian breeding populations of these species, listed in Annex I of the EU Bird Directive (Tab. 6), occur in the study area.

Similar percentages can be observed in regard to the Austrian breeding populations within the PCA of other Annex I species of the alpine zone and of dealpine cliffs *(Lagopus mutus helveticus, Bubo bubo, Falco peregrinus)*. In addition to this, the Karwendel is an important breeding area and regional centre for many more regionally rare, endangered, or habitat specific rock-dwelling birds such as *Pyrrohocorax graculus* (see STELZL & LANDMANN 2000), *Mergus merganser, Ptyonoprogne rupestris, Tichodroma muraria, Corvus corax* and *Prunella collaris*, or for forest-dwelling birds such as *Scolopax rusticola, Turdus torquata, Phylloscopus bonelli, Ph. sibilatrix,* and *F. hypoleuca* (see Data in LENTNER & WARBANOFF 2009, OBERWALDER et al. 2013). And furthermore, the vast areas covered by the Dwarf Mountain Pine together with adjoining alpine pastures and forest margins are a national population centre of the Citril Finch, *Serinus citrinella* and probably also of more widespread scrub-dwelling songbirds like *Sylvia curruca, Prunella modularis* and *Carduelis flammea*.
Given this background, it is hardly surprising that the Tyrolean Karwendel Mountains have been designated as an "Important Bird Area" (IBA) by BirdLife Austria (DVORAK 2009). They represent one of the most important and largest (rank 4 out of 56 Austrian IBAs) areas for a sustainable protection of birds and alpine bird communities in Austria and the Alps.

Mammals

The mammalian fauna of the Karwendel has not been investigated in as great a detail as its bird fauna. It is, however, almost equally important. This can be highlighted with some facts:

- 25 of the 28 Austrian bat species, including 6 species of Annex II of the FFH directive (Tab.6), are known to occur – at least sporadically – in the Karwendel and its outlying areas to the Inn valley (WALDER & VORAUER 2014).

- There are very few alpine endemic mammals. One of them is the Bavarian Short-eared Vole *(Microtus bavaricus)*, probably the rarest mammal of the Alps with the most restricted distribution (SPITZENBERGER 2001). Its status in the Limestone Alps of the Tyrol and Bavaria is very unclear, the species may, however, already be extinct in Bavaria (SPITZENBERGER IN RABITSCH & ESSEL 2009; http://www.n-tv tv.de/wissen/Bayern-sucht-die-Kurzohrmaus-article7324326.html). The northern parts of the PCA (together with the Rofan Mountains adjoining to the east) may therefore well be the sole remaining refuge for this species.

- The Karwendel Mountains are home to probably the largest stock of native (autochthonous) Alpine Marmots *(Marmota marmota)* in the Northern Alps and are important as a refuge for a genetically diverse alpine population of this well-known and popular species (see BRUNS et al. 1999, PRELEUTHNER 1999, compare LANDMANN 2012).

- The Karwendel is rich in ungulates (compare data in STÖHR et al. 1995, GEORGII & ELLMAUER 2002). In particular, the area probably has one of the largest and most vital populations of chamois (Fig. 15) in the Alps, and is therefore a valuable model region for the study of this species (e.g. HAMR 1984, 1988, HAMR & CZAKERT 1988).

- The Brown Bear *(Ursus arctos)* and the Lynx *(Lynx lynx)* were probably quite common and roamed freely in the Karwendel Mountains well into the 18th century. This we know from various sources, and is also evident if you look at local topographic names. Many of these hint at the occurrence of both carnivores (e.g. Bärenkopf, Bärenwand, Bärenlahner, Bärenalp, Bärengrub, Luxeck, Luxgraben, Luchsegggraben, Luxbödele - see STÖHR et al. 1995). However, both species became extinct locally at the end of the 19th century (NIEDERWOLFSGRUBER 1980), although there were last sightings of Brown Bears in 1906. Nowadays they have reappeared in the Alps, and you can expect migrating Brown Bears to show up any time in the Karwendel.
  In fact, certain parts of the area would be suitable as a habitat for single bears. The size of the PCA, its remoteness, habitat supply, low human disturbance level and high prey densities offer an even better natural basis for the Lynx (Fig.15). In fact, all things considered, the area is without doubt one of the most suitable regions in the Alps for successfully re-introducing the Lynx at some point in the future. The results of two habitat modeling studies in the Bavarian and Austrian Alps (WOTISCHOWSKY 2003, RÜDISSER 2001; compare Fig. 45 in LANDMANN 2013) also indicate that the Karwendel area is probably uniquely suitable within the Eastern Alps for re-introducing this large carnivore.

5. DIMENSION AND SIGNIFICANCE OF HUMAN IMPACT; CULTURAL AND SCIENTIFIC VALUES

As mentioned in the preface, this study not only aims at synthesizing the abiotic and biological features of the PCA, it also tries to integrate socio-economic data to form a comprehensive overview of both – the natural as well as the cultural values and resources in the PCA Karwendel Mountains. This area is located in one of the most prosperous and densely populated regions of the Alps; it is also one of the most highly developed areas tourist-wise. In view of a sustainable protection of nature values, it is therefore also important to emphasize the cultural values of the area, the need to support the traditional agricultural economy of the region, and the necessity to protect and further the soft development of the region's scenic areas and recreational opportunities.

5.1 CULTURAL HISTORY AND VALUES; DIMENSION AND DEGREE OF HUMAN IMPACT

As mentioned earlier, the Karwendel Mountains also have a considerable economical & cultural history (e.g. mining, hunting, forestry, management of alpine pastures):

- **Forestry:** As already demonstrated in chapter 3.2, the Karwendel, in spite of centuries of forestry activities, still has a high proportion of natural to semi-natural stands of mountain forest and, in large areas, a low degree of human impact. Nowadays many forests of the PCA are owned and managed by the Austrian Federal Forests (ÖBF; see Fig.16). Although the company is profit-oriented, the protection of nature and the environment as well as the re-naturalization of disturbed forest stands constitutes an integral part of its activities, especially within conservation reserves. From a strategic point of view, this and the fact that large forest areas of the PCA are under the supervision of one principle owner and

user is an advantage for the future of the PCA and its forest ecosystems. In this respect it is both important as well as promising that a recent ÖBF study reveals that even those forests which have been disturbed show a relatively high potential for restoration within short time spans (PLETTENBACHER 2011; see Fig. 16). What is more, 10 areas of distinctive primeval forest reserves covering a total area of 557 ha have already been designated within the Karwendel Alpine Park (Table 7; map and details see LANDMANN 2013). These areas (e.g. in the Vomperloch and Halltal) could in part be used as a nucleus for establishing larger wilderness reserves that are free from human influence.

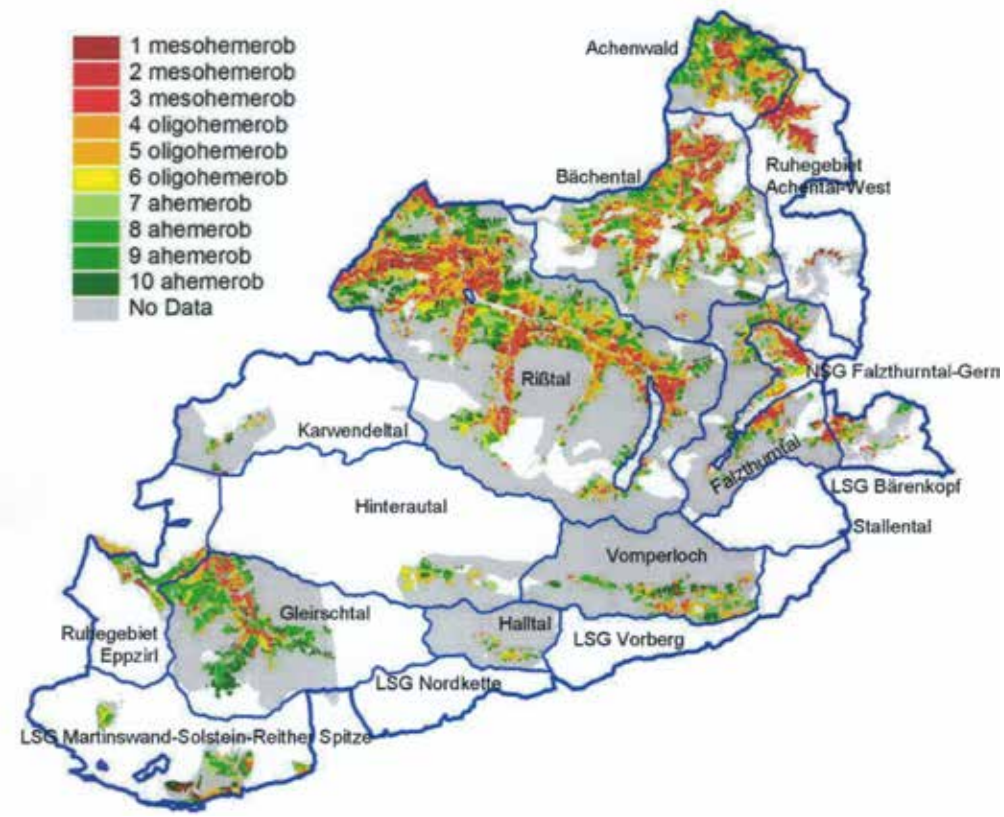


Fig.16: Naturalness (in regard to tree species composition) of forests managed by the Austrian Federal Forests (ÖBF) in the PCA Karwendel. Situation as it was in 2010. Hemerobic categories in the PCA range from mesohemerob (= seminatural, moderate human impact) over oligohemerob (= nearly natural, low impact) to ahemerob (natural, no human impact). From PLETTENBACHER 2011.

- **Alpine pastures (Almen):** Currently, there exist about 170 alpine pastures in the Karwendel. They cover a total area of more than 100 km² (Fig. 17). Some of them, however, have already been abandoned or are extensively managed and their boundaries to the surrounding landscape are ill-defined. For instance, STÖHR et al. (1995) and GEORGII & ELMAUER (2002) only quote 60 managed "Almen" for the 1990ies with a total of 290 huts in all and a summer stock of 4700 cattle (including calves and young cattle) and 1000 sheep. However, as can be deduced from Fig. 17, alpine pastures are concentrated in the lower

and wetter north-eastern parts of the PCA; many southern and central parts show only low grazing impact (see also land-use patterns in Figs 10 a & b). Given the long history of these pastures and their important function for local biodiversity patterns and ecosystem processes as well as for recreational and tourism purposes, these habitats should be incorporated in a broader "wilderness" and PCA concept.

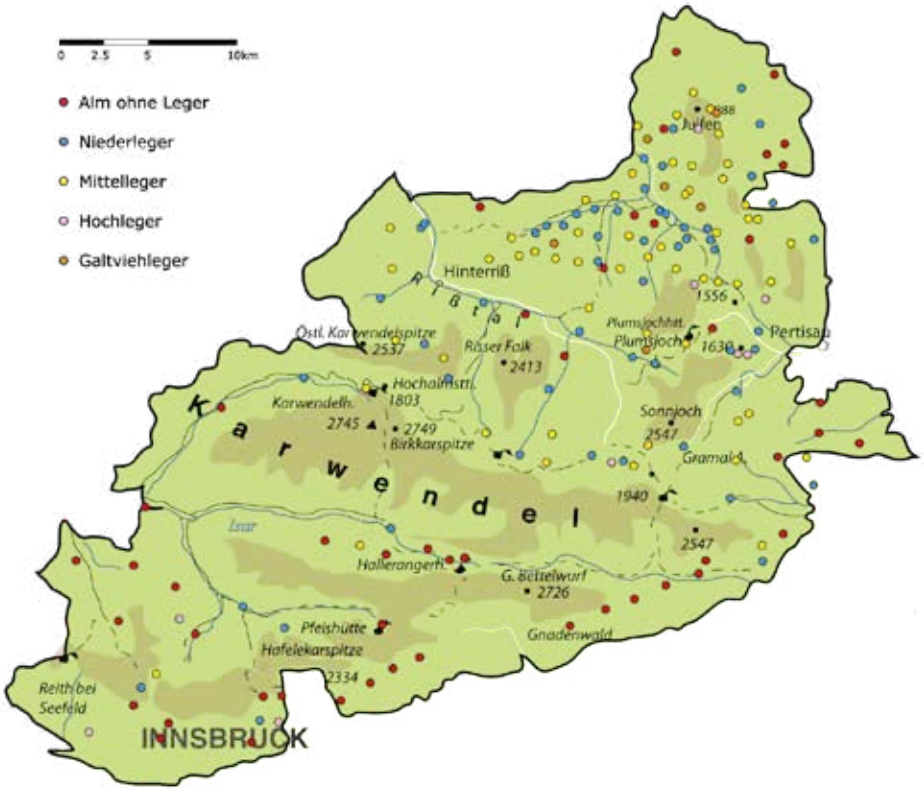


Fig.17: Distribution of alpine pastures („Almen") within the Alpine Park Karwendel (APK). Almen are differentiated regarding altitude (low to high: Nieder - Hochleger). Orange circles: Almen used to graze young cattle only. Map source: APK.

- **Mineral Sites:** The Karwendel mountain range is also of great significance in regard to mineral resources. Particularly relevant are deposits and beds of lead, zinc, oil shale and salt. These inanimate natural resources of the Karwendel are no longer exploited directly; they are, however, of great value for the local history, economy and tourism of the area as well as for science.

- **Hydropower, Water Resources:** Given the abundance of water in this mountain range, it is highly remarkable that the area has largely been spared from direct use for the production of hydropower. Currently, there are only two tiny hydropower plants in the entire PCA, and they produce power for local demand only. As already stated in chapter 3.1, the Tyrolean Karwendel is perhaps one of the most important drinking water reservoirs in Europe,

and the storage of clean water in the subsoil of the Karwendel limestone is vital for the urban area around Innsbruck, and irreplaceable as well. However, only about 10 % of about 350 surface sources (SONNTAG 2009, Fig. 9) are in use and many source areas in the PCA are so called “spring reserves” and thus protected by Tyrolean Law.

- **Traffic:** The number and dimension of public roads and other traffic systems (e.g. railroads, cable cars, and ski lifts) is a very good indicator of human impact and landscape utilization, and for the remoteness and naturalness of an area respectively.
  Although the Karwendel lies in the centre of a highly developed region in terms of tourism, the PCA remains remarkably unaffected. There are a couple of ski lifts on the margins (but outside) of the PCA in the Achensee region, but apart from these, direct public access to important wilderness areas is only possible via the “Nordkettenbahn” cable car in Innsbruck or the public toll road leading from the Bavarian Border to the so called “Eng” in the heart of the Karwendel (Fig.18, 22). There are two other short public toll roads (4.2 and 6.5 km long and not shown in the map Fig.18) which lead from Pertisau (Achensee) into two valleys on the south-eastern border of the PCA. These roads are mainly used for bus-tourism servicing hostelry at the “Gernalm” and “Gramaisalm”.
  The dimension of unpaved forestry and other roads not open to the public is shown in detail for each landscape chamber in Table 1 and is further illustrated in the “track-map” (Fig. 19) which shows unpaved forestry roads and other tracks not open to the public, servicing parts of the Almen.

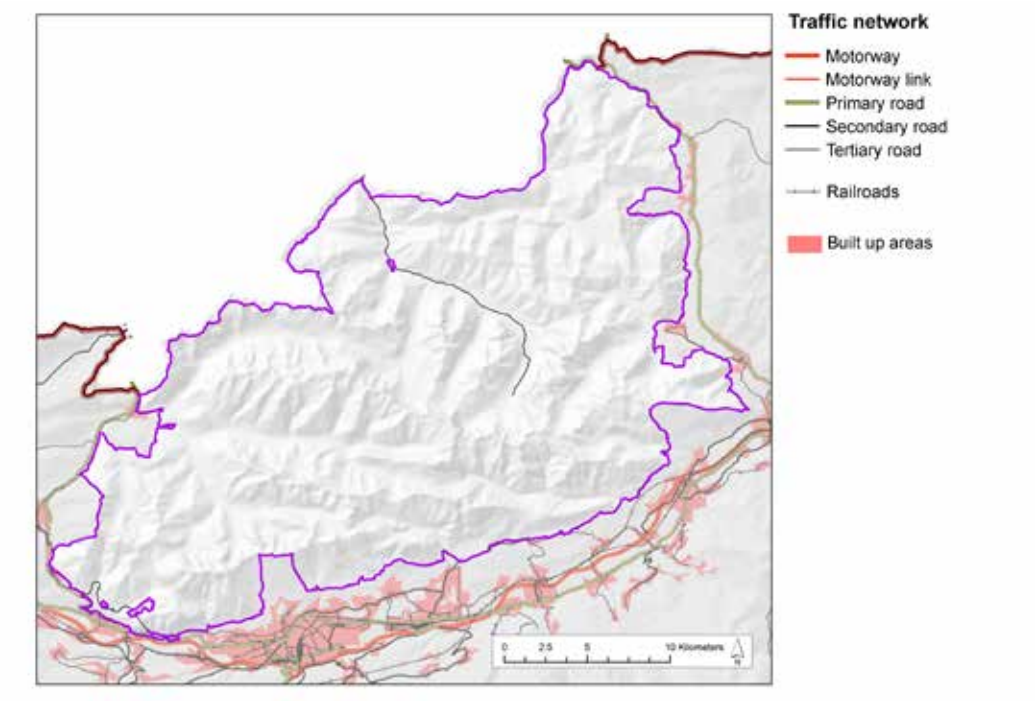


Fig.18: Traffic network in the PCA Karwendel Mountains and its surroundings (only Tyrolean parts shown). Note that there is only one greater public road (toll road!) leading into the inner parts of the PCA and virtually no soil sealing within the entire PCA.

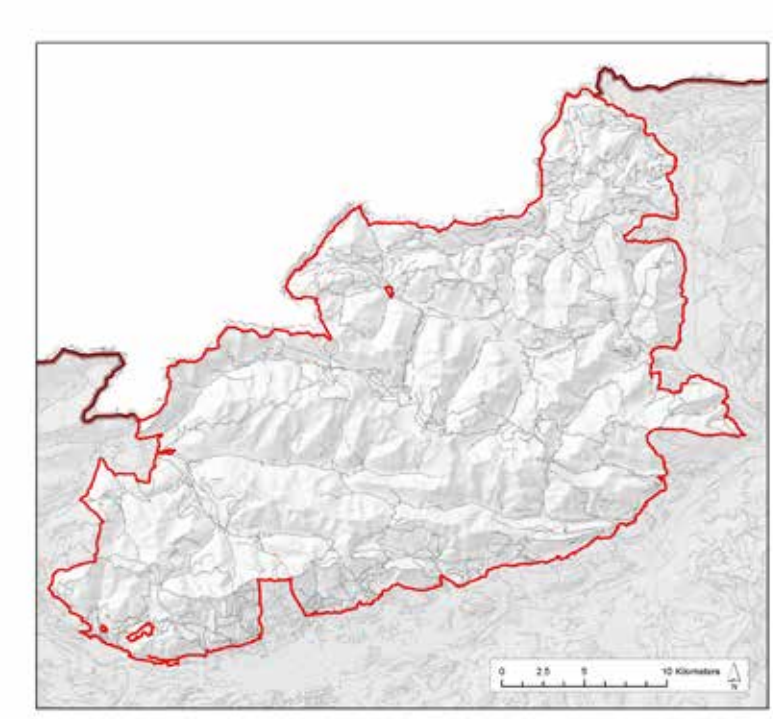


Fig.19: Track network within the PCA Karwendel Mountains. Mostly unpaved forestry and other roads not open to the public. Note the comparatively high density of tracks in the Northeast, servicing alpine pastures parts and forest plots there.

If you compile all relevant information pertaining to human impact on an area it is possible, with the aid of modern GIS technologies, to both calculate and illustrate wilderness quality and to indicate the level of anthropogenic disturbance and of wilderness continuum for whole landscapes respectively.
This was done for the WWF Austria by C. Pluzar, who did it for the entire country. By calculating, weighing and overlaying values for many small landscape cells for different important impact-indicators, one gets a "Wilderness Quality Index". In Fig. 20 the results of such an analysis for the area of the PCA Karwendel Mountains are shown using values for (1) remoteness from settlements, (2) remoteness from access, (3) remoteness from human infrastructures in the open landscape (e.g. power plants, dams, buildings, tourist infrastructures), and (4) for apparent naturalness.

It is obvious that about three quarters of the PCA have (very) high wilderness quality and that no part of the area has low quality (Fig. 20). This is extremely good for such a large area when compared to other landscapes in Austria (compare Fig. 11 in LANDMANN 2013).

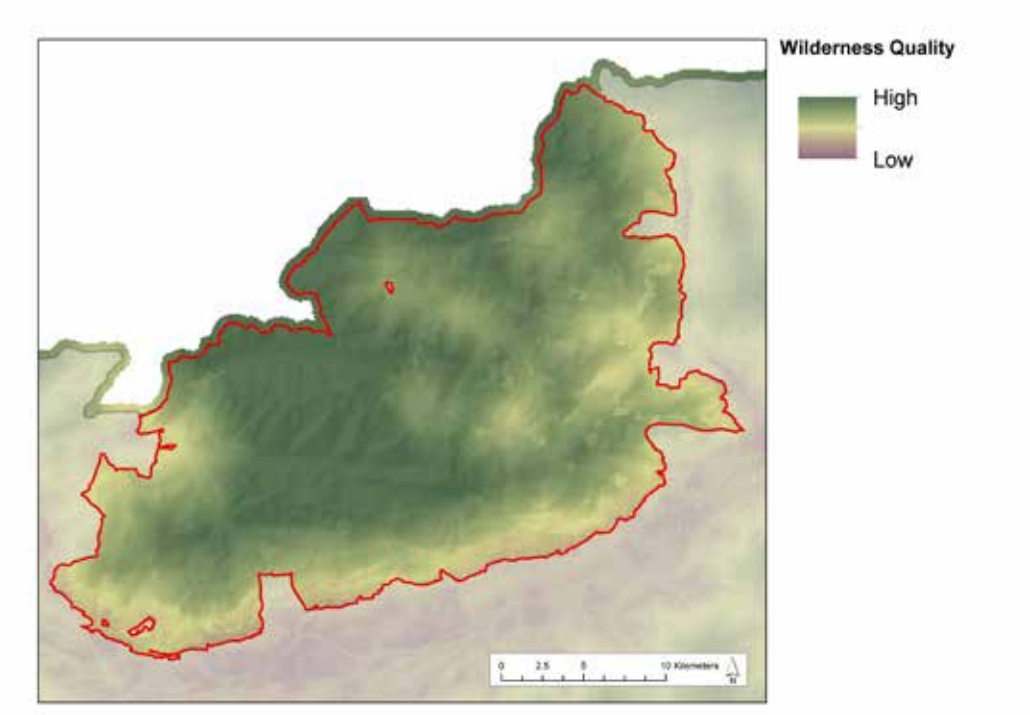


Fig.20: Wilderness Quality Index for the PCA Karwendel Mountains and its subareas. Details see Text.

5.2 SCIENTIFIC VALUE; RESEARCH

The geological and paleontological significance of the Karwendel Mountains is considerable which is why the area has become a focal point of geological and paleontological research and discoveries.
Geological structures such as the fossil-rich, Triassic reefs in the northern chain just above the Tyrolean capital of Innsbruck are not only of value for science and interesting for the general public, they are also easily accessible in some parts of the mountain range (e.g. FROMME 1955, KMENT 2000, 2004, BRANDNER 2012). Perhaps the most interesting geological treasures of the region, however, can only be found in the far more remote north-eastern parts of the Alpine Park. Here, in the rocks surrounding the Kuhjoch, the transition between the Triassic and the Jurassic geological eras manifests itself so vividly and in such unrivalled detail that the geological committee of the UNESCO has chosen this site as the global reference point (Golden Spike) for all geological research pertaining to the transition between these geological eras. The transition is denoted with an accuracy of less than a centimetre due to the rare occurrence of the ammonite species *Psiloceras spelae (ssp. tirolicum)*.
It should be noted that such geological "Golden Spikes" are already located at 60 sites all over the world, but the Karwendel now harbours the first such site in Austria (HILLEBRANDT & KMENT 2009, HILLEBRANDT & KRYSTYN 2009).
For decades now, the Karwendel as a research site has played an important role in contributing to the clarification of many aspects of other geological issues as well (orogeny of the Alps, dating and stratigraphy of geological periods).
Due to the remoteness of large areas, the PCA still exhibits natural undisturbed hydrology and terrestrial surface dynamics (weathering, landslides, and avalanches). The Karwendel has therefore unusual potential as a reference and model space for studying landscape and ecosystem processes and depending biodiversity patterns (e.g. animal ecology, hunting issues, and forest dynamics.)

6. CONSERVATION AND THREATS

6.1 DIMENSION AND SIGNIFICANCE OF CONSERVATION RESERVES

The largely pristine landscape of the greater Karwendel area is covered by a dense network of international and regional conservation reserves, including the EU-Natura 2000 area “Karwendel” which covers the entire area of the regional Nature Park “Alpenpark Karwendel” (Fig. 21).

The region classified as a conservation reserve covers, in total, an interconnected mountainous area of more than 920 km² and includes the adjoining Bavarian nature reserve “Karwendel and Karwendel Promontory”. Thus the greater study area represents the second largest protected landscape of the Eastern Alps and one of the largest conservation areas of the entire Alps. As such it is not only of enormous significance for the environment and for science but also ideally suited for the designation of a priority conservation area.

The core area of the “Alpenpark Karwendel” consists of the Nature reserve “Karwendel”, which covers most of the central and northern parts of the PCA (543 km²; see Fig. 21, Table 7). The reserve is flanked to the West, East and South by several smaller conservation reserves of differing legal status (two small other real nature reserves, two quiet areas, and six landscape protection areas).
Under the Tyrolean Nature Conservation Act, these different conservation reserve categories provide varying levels of protection, prohibiting or permitting varying levels of human influence. For details see Tyrolean Nature Conservation Act (LGBL 10, 2005) §10 (for landscape protection areas), § 11 (for quit areas), § 12 (for Nature parks), § 14 (for Natura 2000 areas) and § 21 for true nature reserves.

Table 7: Categories, size and altitudinal extension of conservation reserves in the area of the PCA Karwendel Mountains. In addition, the dates and appellation of the legal declarations are given.

Conservation reserve (German appellation)	Reserve category & statutory provision	Area (km²)	Altidudinal extension (m asl)
Alpenpark Karwendel	Naturpark §12 TNSchG; LGBl 26-58 /2009	727	~591 - 2749
Natura 2000 Karwendel	Natura 2000 PSC; EU- FFH Directive & Natura 2000 SPA; EU- Bird Directive, 1995	727	~630 - 2749
NSG Karwendel	Nature reserve §21 TNSchG; LGBl Nr 26 (New decree 23.3.1989)	543	~800 – 2749
NSG Martinswand	Nature reserve §21 TNSchG; LGBl Nr 26 (LGBl. 22 /1989; decree: 20.12.1988)	0.5	~650 – 1350
NSG Fragenstein	Nature reserve §21TNSchG; LGBl Nr 26 (Verordn: 20.12.1988)	0.1	~600 – 900
RG Eppzirl	Quiet Area §11 TNSchG; LGBl Nr 26 /2005 (decree:24, 20.12.1988)	33,4	~979 - 2405
RG Achental-West	Quiet area §11T NSchG; LGBl Nr 26 /2005 (decree:25, 20.12.1988)	38,1	~826 – 2085
Großer Ahornboden	Landscape protetction area §10 TNSchG; LGBl Nr 26 /2005 (decree:28, 20.12.1988)	2,7	~1080 – 1300
Vorberg	Landscape protetction area §10 TNSchG; LGBl Nr 26 /2005 (decree: 2012.1988)	24,5	~630 - 2726
Bärenkopf	Landscape protetction area §10 TNSchG; LGBl Nr 265 /2005 (decree:26, 20.12.1988)	13,0	~1005 - 2102
Falzthurntal- Gerntal	Landscape protetction area §10 TNSchG; LGBl Nr 26 /2005 (decree: 27, 20.12.1988)	8,6	~970 - 1665
Martinswand-Solstein-Reither Spitze	Landscape protetction area §10 TNSchG; LGBl Nr 26 /2005 (decree: 20.12.1988)	47.7	~800 - 2641
LSG Nordkette	Landscape protetction area §101 TNSchG; LGBl Nr 45 /2006 (decree:30, 20.12.1988)	18,5	~870 - 2454
10 Forest reserves	By declaration ÖBF, Tyrolean Government and private forest owners.	5.5	variable

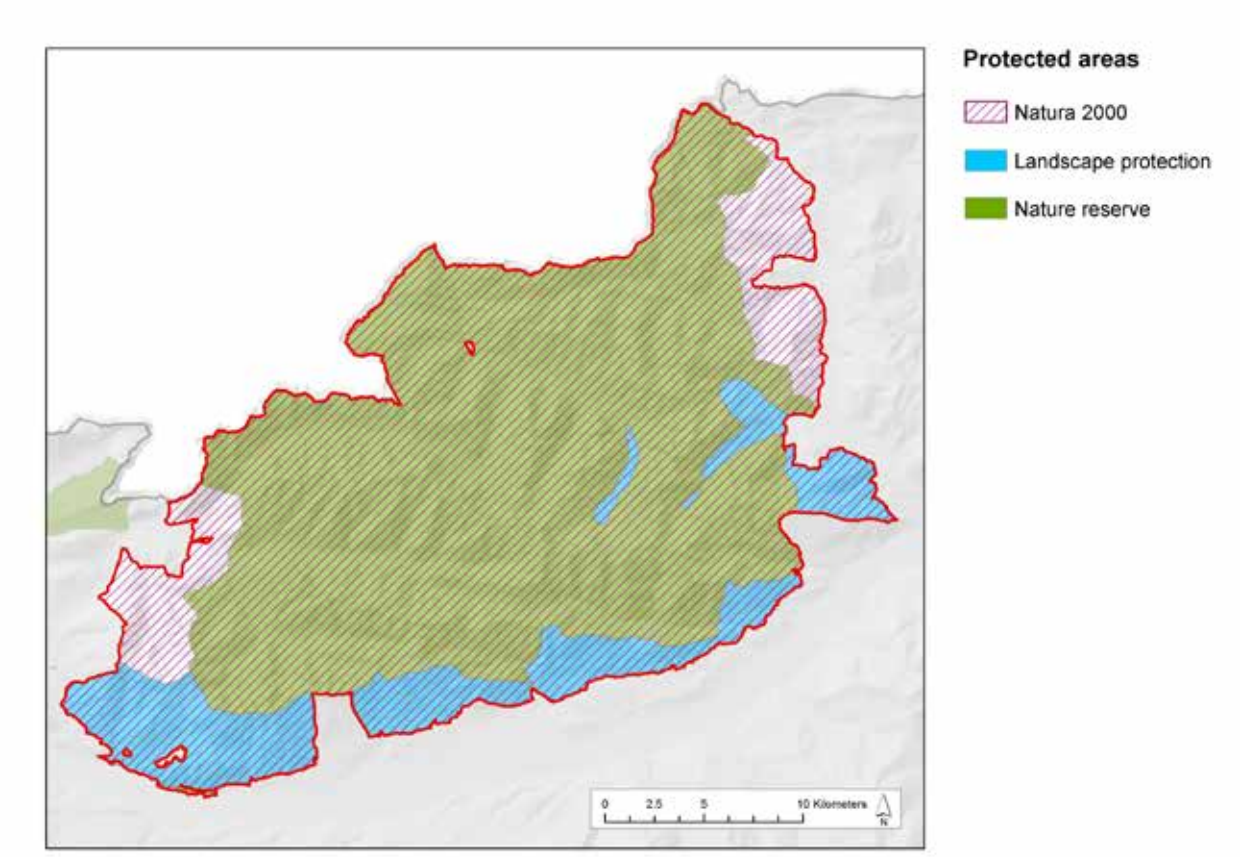


Fig.21: Areas covered by different categories of conservation reserves in the PCA. The two Quiet areas in the Northwest (Eppzirl) and Northeast (Achental) are included in the Natura 2000 area.

6.2 THREATS AND MANAGEMENT

Due to the fact that the entire area of the PCA enjoys legal protection to a certain extent, the Karwendel is not at present subject to the usual direct threats to Central European landscapes. There is therefore no imminent threat of landscape and habitat fragmentation or the direct destruction of biotopes resulting from the construction of power plants, roads and other greater artificial structures or soil sealing, at least not in the near future.

However, the Karwendel Mountains and their ecosystems still face certain problems.

- Some alpine pastures and the adjoining wetland and forest ecosystems suffer from overgrazing and eutrophication (nitrification). Under the “Tyrolean Nature Conservation Act”, “normal” agricultural and forestry activities are permitted within nature reserves in spite of their being under protection. This generally poses a challenge for the Alpine Park Ad-

ministration because it makes it more difficult to supervise the management of (some) alpine pastures. This is especially true for the eastern (Achensee region) and north-western (Scharnitz region) borders of the PCA. Here, on the outer edges of the Karwendel, tourism is a greater issue. One the one hand, farmers like to make their alpine pastures (and thereby their alpine huts) more accessible by upgrading gravel roads. This, of course, attracts people. On the other hand, they tend to over-fertilize their pastures. Both activities pose a threat to local plant and animal communities.

- The impressive and famous stands of sycamore maples *(Acer pseudoplatanus)* in the landscape protection area "Großer Ahornboden" (Fig. 22), show an impaired vitality in their canopy development, and have been the object of intense investigations and management actions (TAPPEINER et al. 2007).
- The sensitive peat bogs in the north-eastern part of the area (see Fig. 9a), some of which were drained in the 1960ies, are being subjected to and suffering from a certain extent of air pollution (diffuse nitrification and eutrophication), as well as being disturbed by grazing and trampling.
  A detailed management plan for these habitats has been developed recently (HASELWANTER 2008). Parts of this plan, for example the revitalization of various bogs, have already been implemented.
- High densities of ungulates (red deer, roe deer, chamois) may pose a threat to the regeneration of valuable forest stands, especially if these animals are disturbed by humans and forced to alter their temporal and seasonal patterns of space use (see STÖHR et al 1995, GEORGII & ELLMAUER 2002).

However, the growing pressure from tourism and local recreational demands cause the greatest problems. Tourist guidance and canalization programs are thus a priority and have already been developed in general terms (GOERGII & ELLMAUER 2002, JUNGMEIER et al. 2008) as well as in detail for areas facing disproportionally high anthropogenic pressure (SPRENGER & SCHREINER 2004).
The updating of such programs with prioritization of conservation needs in mind will present the greatest challenge for the future.
Modern adventure sports, however, pose one of the greatest threats to the area in terms of wildlife disturbance:

- Paragliders and kite flyers in the vicinity of eyries may cause problems because they disturb some territories of the Golden Eagle, especially in the southern parts of the PCA. (see LANDMANN & MAYRHOFER 2001).
- Rock climbing can be a problem at single breeding sites of the Eagle Owl and Peregrine Falcon in areas in the vicinity of the Inn valley.
- Tourists and cattle trampling on river banks pose a threat to breeding Common Sandpipers, especially on the banks of the Rißbach. This specific problem, however, has already been dealt with (STECHER 1995, 1996, GRIMM & SCHWARZENBERGER 2010).
- Nowadays, various tracks and forest roads are being used by a growing number of hikers, downhill bikers and, in particular, mountain bikers. The remotest parts of the Karwendel have thus become accessible, even at dawn, and this can disturb ungulates, grouse and other wildlife (see Warbanoff and others in GOERGII & ELLMAUER 2002).

This study, however, overall illustrates the exceptional and international value of this unique and as yet largely unimpaired mountain area for the conservation of natural resources and alpine species, as well as for science and the regional environment and economy of the Tyrol.

6.3 PROPOSED ACTIONS

In view of the already high conservation and management status of the PCA, no immediate urgent action need be taken to preserve the area. However, given the main problems mentioned above, a few recommendations for the future come to mind which might improve the conservation value of the impressive Karwendel Mountains:

- Alpine pastures form an integrative part of the PCA. They are important for local biodiversity patterns, ecosystem processes, and the overall landscape impression. However, human influence is relatively strong and alteration pressure is growing. Alpine pastures should therefore be directly incorporated in a broader “wilderness” and PCA concept. This means that a general development concept for the entire area (and not for single pastures only) is needed. Such a management plan could, for instance, - bearing in mind the prioritization of conservation needs – define thresholds for the intensity of pasture management (e.g. in terms of fertilization values, cattle stock per area unit).

- Although some areas of distinctive primeval forest reserves have already been designated within the Karwendel Alpine Park, the network of such forest reserves could and should be intensified. They should also be supplemented by the re-naturalization of adjacent semi-natural forest stands. Of course, such actions necessitate the close coordination between park management and the Austrian Federal Forests as well as other local forest owners and can only be realised step by step following a specific schedule (in time and space). A detailed plan such as this still has to be developed.

- Plans to establish larger wilderness reserves that are free from human influence should be realised as soon as possible. The first step of such a plan would necessarily be the clear delineation of appropriate areas (e.g. in the Vomperloch and Halltal) according to ecological and practical criteria. This is imperative because straightforward arguments will be needed in negotiations with land owners and public authorities as such negotiations are bound to be complicated.

- As stressed in chapter 4.3.3, the Karwendel Mountains are one of the most suitable regions in the Alps for successfully re-introducing the Lynx. If this goal is to be achieved within the PCA for subareas which could serve as primary release points, more detailed data on habitat configurations and prey densities are needed. In addition to this, it will be necessary to clarify at an early stage whether such plans are acceptable to public authorities and

the local (and powerful) hunting lobby. Educational advertising will also be needed. These activities should therefore commence as soon as possible if this large carnivore is to be successfully re-introduced to the area.

- Tourist guidance and canalization programs which have already been developed should be updated regularly, bearing in mind that conservation needs are a priority.

- If the ongoing and future challenges mentioned above are to be met, park management will need a broader basis on which to work. This would necessitate more support on the part of the Tyrolean government as well as local tourist boards in terms of staff (e.g. more nature guides, park rangers), money, and logistic resources.

Fig.22: The impressive and famous stands of sycamore maples *(Acer pseudoplatanus)* at the "Großer Ahornboden" grow right in the heart of the Priority Conservation Area Karwendel Mountains (Photo: O. Leiner)

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SUMMARY

About 10 years ago, the WWF launched an Ecoregion Action Programme (EAP) for the Alps called the European Alpine Programme. Within this EAP Alpine regions meriting special attention and conservation were identified and referred to as Priority Conservation Areas (PCAs). During the process, 5 focal species groups (Flora, Mammals, Birds, Amphibians and Reptiles, Insects) and one alpine key habitat (freshwater systems) were selected for the identification of PCAs. The Karwendel Mountains on the borders between Bavaria and the Tyrol in the northern limestone Alps proved to be one of the very few areas in the Alps with priority value for almost all of the indicators.

Scope and Aims: This overview focuses on the Karwendel Mountains within the Austrian borders – the centrepiece of this wilderness area. They are already fully protected as the "Alpine Park Karwendel" under the Tyrolean Nature Conservation Act. The proposed PCA encompasses an overall mountainous area of 727 km² in size and 202 km in circumference. The study aims to provide information on the present scientific level of knowledge pertaining to the specific ecosystems and organisms of the PCA and to put it into a larger context. Moreover, this booklet also aims at giving a first and pilot full landscape-level analysis including socio-economic data for a comprehensive overview of the natural and cultural values and resources in accordance with the general concept of the WWF European Alpine Programme.

General natural characteristics and landscape settings: Three main factors shape the specific landscape and ecological conditions of the PCA: (1) The geographical position on the northern borders of the Alps with its suboceanic wet and snow-rich climate; (2) the prevalence of limestone rocks which are sensitive to mechanical weathering; and (3) the steep altitudinal gradients. These Mountains are, therefore, unique within Austria and the Eastern Alps in regard to the shape, size and dimension of land forms and ecosystems typical for the Calcareous Alps. The Tyrolean Karwendel extends over an altitudinal range of nearly 2.200 m from about 560 m a.s.l. up to 2749 metres, and in many parts steep altitudinal gradients spanning 1500 to nearly 2000 m within short horizontal distances are eye-catching. The PCA is highly structured: Four main chains stretch from west to east and there are a large number of smaller landscape chambers. The amount of small scale changes in the relief energy and of separated single landscape chambers could serve as a major indicator for wilderness. All things considered, these indicators suggest that the Karwendel Mountains may indeed be one of the most remote and undisturbed areas with the greatest small scale landscape heterogeneity in Austria, if not in the whole of the Alps. These unique landscape settings are, in fact, believed to be crucial for the PCA and for the overall conservation and biodiversity value of the PCA.

Freshwater systems: The PCA encompasses 24 larger streams with an overall flow length of 211 km, about 100 tributary streams (with together 230 km), as well as another 220 smaller creeks and moist gullies. Altogether the area has more, and more varied freshwater ecosystems than most other areas in the Eastern Alps. Even the larger streams and rivers are in an excellent ecological state, their hydromorphological conditions almost completely natural.

This includes the two main rivers “Isar” and “Rißbach” which merit special protection. These two mountain rivers may not only be classified as “sites of national importance”, they need to be regarded as high quality sites and model streams for limestone freshwater systems on an international scale. These braided river systems are, among other things, also refuges for endangered plant and animal species.
In addition to this, the Tyrolean Karwendel is perhaps one of the most important drinking water reservoirs in Europe. The Karwendel is believed to have about 350 sources in all, and many source horizons also form important, specific habitats for a specialized protist, animal, and plant life.

Terrestrial ecosystems and habitats: Three main habitat components dominate the landscape of the PCA: (1) Rock and debris, (2) forests (each covering about a third of the area) and (3) Krummholz, dominated by the Dwarf Mountain Pine (17% land cover). These main habitats are composed of many very distinct sub-units and are supplemented by a variety of other specific habitats which cover smaller areas but contribute to the highly diverse mosaic of the PCA-landscape and determine the extraordinary floral and faunal biodiversity of the Karwendel.
The land cover and distribution of vegetation communities and land use patterns in the PCA are illustrated in detail in this study. For each of the major habitats, ecological and structural characteristics and values on a regional to international scale are highlighted in chapter 3.
In short, two points may be stressed in this summary. (1) The PCA still has an unusually high proportion of natural to semi-natural stands of mountain forest. With respect to features like small scale diversity and specificity of forest types and forest animals, the Karwendel Mountains can be regarded as one of the most valuable forest areas in Austria.
(2) The Carbonate dwarf mountain pine *Pinus mugo* scrub, classified as priority habitat (Type 4070) in Annex 1 of the EU-FFH Directive not only covers vast areas (125 km²) but also shows high structural and floristic variability. These areas are, for the most part, truly pristine habitats and there is probably no other area in the Alps that can provide such excellent conditions for the conservation and scientific exploration of this unique and very specific habitat type of the limestone Alps.

Biodiversity and conservation value of specific habitats, plant and animal communities:
Aquatic and riverine habitats and organisms: A total of six freshwater habitats protected by the EU-FFH directive (Annex 1) are represented in the PCA. Among others, representative examples of montane river gravel communities, in particular, with the highly endangered Tamarisk *(Myricaria germanica)* can be found on the banks of some rivers. The riparian zones and their gravel fields are also inhabited by a representative set of strongly adapted and rare ripicole invertebrates and serve as breeding grounds for the endangered Common Sandpiper *(Actitis hypoleucos)*.
Terrestrial habitats and plant communities: Two thirds of all habitat types to be found in Austria as listed in Annex 1 of the EU FFH Directive occur in the PCA, and the high number (13) and significance of Annex 1 priority habitats in the area needs to be emphasized. Furthermore, nearly three quarters (34) of the 49 specific plant communities listed as endangered in the Tyrolean Nature Protection Ordinance 2006 can also be found in the PCA, and of the 36 forest habitat types known to occur, no fewer than 25 are classified as endangered in Austria or at least in the forest ecoregions of the Northern Alps.

Endemism, biodiversity and specificity of terrestrial organisms: The Karwendel Mountains also serve as a refuge for organisms endemic in Austria and the Alps. At least 41 plant and animal species that are Austrian **Endemits** occur in the Karwendel Mountains, and the PCA is also a refuge for other, more widely distributed endemic species of the Alps or Eastern Alps. The large number of **vascular plants, fungi, mosses and lichen** species that not only occur in the area but are also listed in the Red Data Books and/or are protected by regional conservation regulations or international directives (e.g. the EU Council FFH), is another criterion which emphasizes the exceptional value of the PCA as a unique alpine environment meriting protection. With at least 1600 taxa of vascular plants (i.e. half of the entire Austrian flora on less than 1% of its area), the plant species richness of the PCA is extraordinarily high on all standards. Moreover, the PCA is also a regional and even national hotspot for threatened and protected species, harbouring, for instance, two thirds of the Austrian orchid diversity and at least 18 vascular plant species as well as moss and lichen species that are listed in the annexes of the FFH Directive. There are only few studies on the terrestrial **invertebrates** of the PCA, but they all hint at an overwhelming diversity and provide evidence for the occurrence of many highly specialised, rare and endangered invertebrates within the specific habitats of the PCA. Even more important is the impressive diversity of terrestrial **vertebrates** (approximately the half of all terrestrial vertebrate species of the Alps occurs in the PCA!). All things considered, the Karwendel can be regarded as a conservation hotspot, a refuge and gene reservoir for a number of endangered as well as of widespread, but at the same time highly representative reptiles (e.g. Wall- & Croatian Rock-Lizard), birds (e.g. high densities of Golden eagles and specialised grouse, owls and woodpeckers of mountain forests and treeline habitats) and mammals (e.g. high species diversity of bats, high densities of ungulates, in particular of chamois). Size, remoteness, habitat supply, low human disturbance and high prey densities of the PCA could also become key factors for the future comeback of large carnivores to the PCA. This area, in particular, is probably one of the most suitable regions for the successful re-introduction of the Lynx.

Dimension and significance of human impact; cultural and scientific values: The PCA is located in one of the most prosperous and densely populated regions of the Alps; the area is also highly developed tourist-wise. It looks back on a long and continuous economic and cultural history (mining, hunting, forestry, the management of alpine pastures). Despite centuries of such activities, most parts of the PCA still have a high proportion of largely unimpaired landscapes and ecosystems. Many forests, for instance, are owned and managed by the Austrian Federal Forest Company. This is an advantage in regard to future management programs aiming at preserving natural and restoring altered forest stands. Primeval forest reserves covering a total area of 5,5 km² have already been designated within the PCA. This could serve as a nucleus for creating larger wilderness reserves free from human influence. About 170 alpine pastures (100 km²) exist in the PCA, and many of them play an important role for local biodiversity patterns and ecosystem processes. The area has also, to a great extent, been spared from being used for the production of hydropower. The centre of the PCA can only be accessed by a single public toll road.

Conservation, threats and management: The PCA is covered by a dense network of international and regional conservation reserves including the EU-Natura 2000 area “Karwendel” which covers the entire area of the proposed PCA. If you include the adjoining Bavarian nature reserve “Karwendel and Karwendel Promontory, the greater study area represents one of the largest conservation areas of the entire Alps. For this reason, some of the usual threats to alpine land-

scapes, such as habitat fragmentation or destruction caused by the construction of artificial structures, are hardly likely to pose any great problems, at least not in the near future. Some alpine pastures and the adjoining wetland and forest ecosystems, however, are suffering from overgrazing and eutrophication. Ultimately, the greatest threat to habitats and wildlife is the growing pressure from tourism and local recreational demands. Tourist guidance and canalization programmes for the PCA are thus a priority, and although there are such programmes in operation at this time, they need to be updated and adapted regularly. This will be the greatest challenge for the future.

In short, this study illustrates the exceptional and international importance of a unique and as yet unimpaired mountain area for the conservation of natural resources and alpine species, as well as its value for science and for the regional environment and economy of the Tyrol.

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PRIORITY CONSERVATION AREA TYROLEAN KARWENDEL MOUNTAINS FACTS

1600

taxa of vascular plants

727 KM²

overall mountainous area

2/3

of all Austrian Orchids

41

Austrian Endemits

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