

3.7 The Vegetation of the Alpine Zone in the Pyrenees

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3.7.1 Geography

The 100-km-wide chain of the Pyrenees extends over 400 km in a west-east direction from the Atlantic Ocean to the Mediterranean Sea. About 1760 km² (4.5 %) of its ca. 40,000 km² total area is in the alpine zone, with the treeline being at 2300 m a.s.l. (Sesé et al. 1999). In spite of the small area, 130 peaks exceed 3000 m in altitude (Buyse 1993).

The Pyrenees are bordered by the Aquitaine Plain to the north and the Ebro Valley to the south. There is a sharp contrast between the topography of the northern and southern slopes and the watershed separates the eurosiberian and Mediterranean biogeographic regions. To the west, the hills gradually descend into the Basque Depression from the Balaitus (3144 m) over 150 km; to the east, there is a sharper decline to sea level over 70 km from the Puigmal (2910 m) and Canigó (2784 m).

3.7.2 History, Geology, Soils and Climate

The eastern Pyrenees (from Andorra to the Mediterranean Sea) are predominantly siliceous; between Pallars-Ariège and Ossau-Tena there are siliceous and calcareous rocks and to the west limestones dominate. During the Hercynian orogeny, an underlying axis uplifted and Palaeozoic granites, sandstones and schists formed. The highest peak, Aneto (3404 m), is found among these mountains in the central Pyrenees. During the Alpine folding, at the early Tertiary, Mesozoic rocks, mainly limestone mountains, formed on both sides of the Axial Pyrenees, including Monte Perdido (3355 m), the second highest peak of the range (the highest calcareous mountain in Europe). There are also conglomerates of Oligocene and Miocene origin and Eocene marls. Patchily there are rocks of volcanic origin. All these rocks were subject to glacial activity during the Quaternary, and therefore

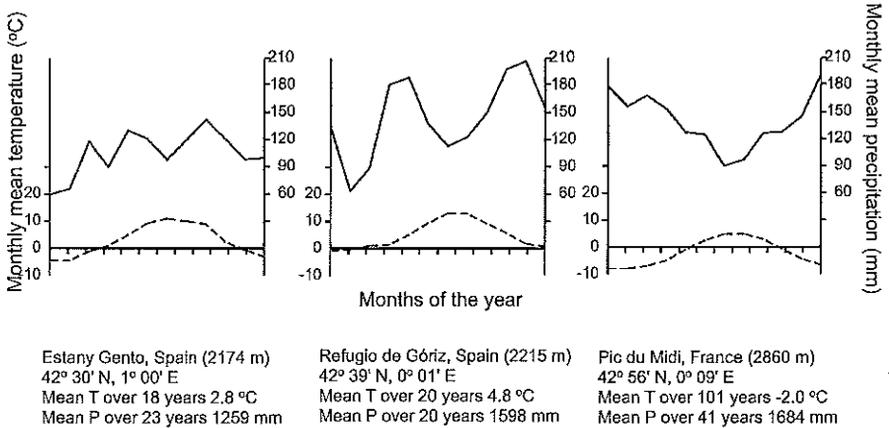


Fig 3.7.1. Climatic diagrams for three weather stations in the treeline ecotone and alpine zone in the Pyrenees. *Solid line* precipitation; *dashed line* temperature

there are till deposits above 800 m together with gravel beds and alluvial terraces.

The northern and western slopes have an oceanic climate with precipitation throughout the year, mild winters and cool summers. The southern slopes are drier and more continental (much insolation, torrential rainfalls at the equinoxes, dry summers, strong temperature variations and very cold winters). Finally, near the Mediterranean, both the northern and southern sides are influenced by a coastal Mediterranean climate.

Snowfalls begin in October and snow lies until June or July, especially above 2000 m, mostly in the western section. Persistent snowbeds and isolated glaciers can be found above 2800 m and are under protection as 'natural monuments'. In the central and eastern area, mainly in Spain, many peaks have long dry periods between snowfalls, so that winter is the driest season (e.g. the Refugio de Góriz, Monte Perdido massif, Spain, at 2215 m, only registers 16 % of the total annual precipitation; Fig. 3.7.1).

At 2000 m or above, it may freeze or snow throughout the whole year. The average annual air temperature is 2.4 °C at 2300 m; -0.9 °C at 2900 m; and -3.2 °C at 3300 m. By using the regression equations of Barrio et al. (1990), the length of the growing season in the alpine belt has been estimated to be 22 days at 2300 m; 19 days at 2900 m, and none at 3300 m or above (Gómez et al. 1997).

3.7.3 History of the Flora

Plant names follow Flora Europaea (Tutin et al. 1964, 1968–1980) or, when names of authorities are given, Flora Iberica (Castroviejo et al. 1986, 1993). Together with some of the ancient vascular plants of the world, such as the Selaginellaceae or the Lycopodiaceae, some palaeoendemic species and genera have survived in the Pyrenees. On limestone cliffs and screes, two species of the genus *Borderea* (Dioscoreaceae) testify that a subtropical climate dominated in the central Pyrenees in the Tertiary. *B. pyrenaica* reaches the alpine zone while *B. chouardii* is restricted to the montane zone. The genus *Ramonda* (Gesneriaceae) appears to be ancient, although related genera and species are found on the southern Balkan Peninsula (e.g. Montenegro, Bulgaria, Macedonia). Among the Umbelliferae, there is an endemic and monotypic genus (*Xatardia*), restricted to the eastern Pyrenees, between Andorra and Puigmal, and two species of an endemic genus of the Pyrenean and Cantabrian mountains, *Endressia castellana* (west) and *E. pyrenaica* (east). More recent, but presumably of pre-glacial origin, are many endemics such as, for example, *Minuartia cerastifolia*, conserved on nunataks, some *Petrocoptis* (Caryophyllaceae), *Androsace* (Primulaceae) and *Cirsium* (Compositae) species. Many alpine species reach their extreme distribution in SW Europe, such as, for example, *Carex bicolor* and *C. curvula*, which perhaps arrived during the last cold period. Others, such as *Hippophaë rhamnoides* spp. *fluviatilis*, reached the Pyrenees during an interglacial period and yet others, such as *Salix daphnoides*, colonised morainic deposits. Post-glacial forests, mainly beech, fir and pines, established 4000–6000 years ago (Jalut 1988). The genera *Saxifraga*, *Festuca*, *Veronica* and *Oxytropis* are much diversified in the alpine zone of the Pyrenees.

3.7.4 Today's Flora

The Pyrenees are one of the European centres of plant diversity (Villar and Dendaletche 1994). According to Dupias (1985), the total vascular plant flora of the Pyrenees is about 3500 species and subspecies. Of bryophytes, about 530 species have been recorded (Casas 1986). J. Etayo (pers. comm.) estimated that there were about 1500 species of lichens in the Pyrenees of which 150–200 could colonise the alpine zone. In addition, many undescribed species of fungi (parasymbionts, parasites, saprophytes or hyperparasymbionts) normally live on other lichens.

The alpine flora of the Pyrenees (above 2300 m a.s.l.) is of 809 species and subspecies (31 ferns, three Gymnospermae and 775 Angiospermae) belonging to 294 genera and 78 families. Sixty-three percent (about 500 species) are abundant (39%) or frequent (24%) and we consider them true alpine and the

remaining 37% as accidental. Twenty-two species occur exclusively in the alpine zone.

Not including apomictic genera such as *Alchemilla*, *Taraxacum* and *Hieracium*, the 10 best-represented families in the alpine zone are Compositae (79 taxa, 9.7% of the total occurring in the alpine zone), Gramineae (66, 8.1%), Caryophyllaceae (48, 5.9%), Cyperaceae (48, 5.9%), Cruciferae (44, 5.4%), Rosaceae (47, 5.7%), Scrophulariaceae (42, 5.2%), Ranunculaceae (38, 4.7%), Leguminosae (35, 4.4%), and Saxifragaceae (29, 3.6%). The best-represented genera are *Carex* (29 taxa), *Saxifraga* (28), *Festuca* (20), *Ranunculus* (20), *Potentilla* (15), *Veronica* (14), *Androsace* (12), *Sedum* (12), and *Poa* (11). Some genera, such as *Androsace*, *Carex*, *Draba*, *Gentiana*, *Oxytropis*, *Pedicularis*, *Primula*, *Saxifraga*, and *Sedum*, occur mainly in the alpine zone.

About 180 taxa (excluding apomictic microspecies) are confined to the Pyrenees chain, or to one or more of its three sectors (eastern, central, and western). The western Pyrenees are rich in calcicolous endemics, such as *Androsace cylindrica* ssp. *hirtella*, *Buglossoides gastonii*, *Cirsium carniolicum* ssp. *rufescens*, *Saxifraga hariotii* and *Thalictrum macrocarpum*. This sector also harbours some endemic plants such as *Aster pyrenaicus*, *Dethawia tenuifolia*, *Euphorbia chamaebuxus*, *Ranunculus parnassifolius* ssp. *favargerii* K pfer and *Rumex cantabricus*, or extending some isolated populations into the Cantabrian Mountains. In the eastern Pyrenees, there exist also some endemic plants such as, for example, *Senecio leucophyllus* and *Salix ceretana* (P. Monts.) Chmelar. In the central section, there are siliceous or calcareous, and Pyrenees-wide endemics, e.g. *Ramonda myconi*, *Veronica aragonensis*, *Cirsium glabrum*, *Silene borderei*, and *Salix pyrenaica*.

In the whole of the Pyrenees, less than 3% of the flora (about 90 species) is endemic whereas, in the alpine zone (above 2300 m), this proportion is 11.8%. The higher value in the alpine zone might be explained in relation to the glacial events and vertical movements of the flora during the Quaternary (Ses  et al. 1999; Villar 1999). Furthermore, the abundance of screes and crevices could have provided habitats to colonise and to survive for several species, such as: *Androsace ciliata*, *A. hirtella*, *A. pyrenaica*, *Buglossoides gastonii*, *Onosma bubanii*, *Saxifraga hariotii*, *S. media*, *S. pubescens* ssp. *pubescens*, *Vicia argentea*, and other endemics. In addition to the endemics, orophytes (35%), eurosiberian species (21%), boreo-alpines (14.4%) and others (17.8%) complete the chorological spectrum for the alpine zone.

Many high mountain taxa such as *Leontopodium alpinum*, *Rhododendron ferrugineum*, *Saxifraga bryoides*, *Androsace helvetica*, and *Artemisia umbelliformis* reach their westernmost limit of distribution in the Pyrenees.

Ses  et al. (1999) have shown that in the Pyrenees as a whole, hemicryptophytes (45%) predominate with annuals (20%) and chamaephytes (14%); geophytes, hydrophytes and phanerophytes are scarce. In the alpine zone, hemicryptophytes (64.6%), together with chamaephytes (21.5%), make up

about 85 % of the flora. Above 2900 m, chamaephytes and hemicryptophytes further increase in dominance and are exclusive above 3200 m.

3.7.5 Vegetation

The lower limit of the alpine zone is 2300 m (Rivas Martínez 1988). The *Pinus uncinata* treeline ranges from 2100 m on the northern slopes in the western sector (Anie massif) to 2600 m in the more continental central sector (e.g. Néouvielle massif and the Encantats area, Boí-Aigües Tortes National Park). The climatic treeline in many places has been lowered by fire, grazing and logging; however, forest recovery has been observed in some localities since about the 1950s (Métailié 1999). The plant cover in the alpine zone is mostly <50 % and there are frequent screes, cliffs and outcropping rock. Above 2800–3000 m, there is a discontinuous subnival zone.

About 70 plant communities have been described from the alpine zone of the Pyrenees (Table 3.7.1) and the whole range harbours >300 communities (Rivas Martínez 1988). Some of them, such as the *Androsace ciliata* screes (with *Saxifraga iratiana*, *Androsace ciliata*, *Minuartia cerastiifolia*, and *M. sedoides*) or some snowbed communities with *Carex pyrenaica* and *Cardamine alpina* type are exclusive to the Pyrenean high mountains (Vigo 1976; Rivas Martínez 1988).

Species richness decreases by about 58 taxa every 100 m of altitude between 1200 and 3404 m. This decline is steeper above 2300 m and, above 3000 m (Fig. 3.7.2), a possible indication of the beginning of alpine and subnival belts. Species richness per 25 m² varies between 2–4 species for aquatic vegetation and 26–30 species for stony open pastures on limestone (Table 3.7.1, last column). Scree communities are species poor (8–14 species) whilst closed grasslands, especially on calcareous bedrock, e.g., the *Kobresia* (= *Elyna*) *mysuroides* or the *Primula intricata* type and snowbeds, are species rich (22–28).

The vegetation of the Pyrenees, especially its northern slopes in the central and western sectors, is similar to that of the Alps. The eastern sector and some isolated areas on southern slopes are more similar to the Iberian mountains and the Sierra Nevada, where the so-called subalpine and alpine zones are replaced by oro-Mediterranean and cryoro-Mediterranean zones. The climatic contrast between the western oceanic side and the Mediterranean and continental southern, central and eastern sectors and the varied bedrock results in a rich mosaic of flora and vegetation (Atlantic, alpine, montane and sub-Mediterranean elements). When compared with the Alps, the Pyrenees have a smaller number of vascular plants and plant communities, but with a slightly higher proportion of endemics in the alpine zone (12 % in the Pyrenees vs. 10 % in the Alps). The number of endemic or subendemic genera exceeds that in the Alps, where there is a single one.

Table 3.7.1. Mean species richness in alpine plant communities in the Pyrenees. Species richness values are from a vegetation sample (relevé) database

Habitat type	Principal species in community types on siliceous (Si) or calcareous (Ca) substratum	Number of plant associations	Species richness (no. of species/25 m ²)
Snowbed communities	<i>Salix herbacea</i> , <i>Cardamine alpina</i> , <i>Omalotheca supina</i> (Si)	4	10–14
	<i>Salix retusa</i> , <i>S. reticulata</i> , <i>Carex parviflora</i> (Ca)	2	13–17
Rock communities	<i>Androsace vandellii</i> , <i>A. pyrenaica</i> , <i>Primula hirsuta</i> (Si)	6	11–16
	<i>Cystopteris fragilis</i> , <i>Viola biflora</i> , <i>Asplenium viride</i> (Ca)	3	10–14
	<i>Saxifraga iratiana</i> , <i>Valeriana globulariifolia</i> , <i>Potentilla nivalis</i> (Ca)	4	10–14
Scree communities	<i>Senecio leucophyllus</i> , <i>Luzula alpinopilosa</i> , <i>Oxyria digyna</i> (Si)	1	8–12
	<i>Dryopteris oreades</i> , <i>Cryptogramma crispa</i> (Si)	1	8–12
	<i>Androsace ciliata</i> , <i>Minuartia cerastiifolia</i> , <i>Festuca borderei</i> (Ca, Si)	2	10–14
	<i>Iberis spathulata</i> , <i>Veronica aragonensis</i> , <i>Borderea pyrenaica</i> (Ca)	7	12–16
	<i>Saxifraga praetermissa</i> , <i>Arenaria purpurascens</i> , <i>Veronica nummularia</i> (Ca, Si)	2	9–14
	<i>Festuca eskia</i> , <i>Campanula ficarioides</i> , <i>Trifolium alpinum</i> (Si)	5	20–24
	<i>Festuca airoidis</i> , <i>Gentiana alpina</i> , <i>Minuartia recurva</i> (Si)	4	21–25
Grasslands	<i>Nardus stricta</i> , <i>Ranunculus pyrenaicus</i> , <i>Meum athamanticum</i> (Si)	5	15–19
	<i>Kobresia</i> (= <i>Elyna</i>) <i>myosuroides</i> , <i>Oxytropis pyrenaica</i> , <i>Carex curvula</i> (Ca)	2	24–28
	<i>Primula intricata</i> , <i>Trifolium thalii</i> , <i>Horminum pyrenaicum</i> (Ca)	2	22–26
	<i>Festuca scoparia</i> , <i>Sideritis hyssopifolia</i> , <i>Saponaria caespitosa</i> (Ca)	3	26–30
	<i>Saxifraga aquatica</i> , <i>S. stellaris</i> , <i>Epilobium alsinifolium</i> (Si)	3	5–9
	<i>Potamogeton gramineus</i> , <i>P. alpinus</i>	1	2–4
	<i>Cratoneuron commutatum</i> , <i>Cochlearia pyrenaica</i> , <i>Philonotis calcarea</i> (Ca)	1	4–7
	<i>Carex nigra</i> , <i>Juncus filiformis</i> , <i>Leontodon duboisii</i> (Si)	2	10–15
<i>Carex davalliana</i> , <i>Juncus alpinus</i> , <i>Primula farinosa</i> (Ca)	3	14–18	
Spring, flushes and aquatic vegetation			

Table 3.7.1. (Continued)

Habitat type	Principal species in community types on siliceous (Si) or calcareous (Ca) substratum	Number of plant associations	Species richness (no. of species/25 m ²)
Prostrate dwarf shrub heath	<i>Loiseleuria procumbens</i> , <i>Vaccinium uliginosum</i> , <i>Arctostaphylos alpina</i> (Si)	2	14-19
Dwarf shrub heath and scrub	<i>Rhododendron ferrugineum</i> , <i>Vaccinium myrtillus</i> , <i>Sorbus chamaemespilus</i> (Si)	2	12-16
Tall-forb vegetation in livestock resting areas	<i>Rumex pseudoalpinus</i> , <i>Chenopodium bonus-henricus</i> , <i>Sisymbrium pyrenaicum</i> (Ca, Si)	1	11-16
Treeline ecotone	<i>Pinus uncinata</i> , <i>Cotoneaster integerrima</i> , <i>Juniperus communis</i> ssp. <i>alpina</i> (Ca, Si)	1	12-17

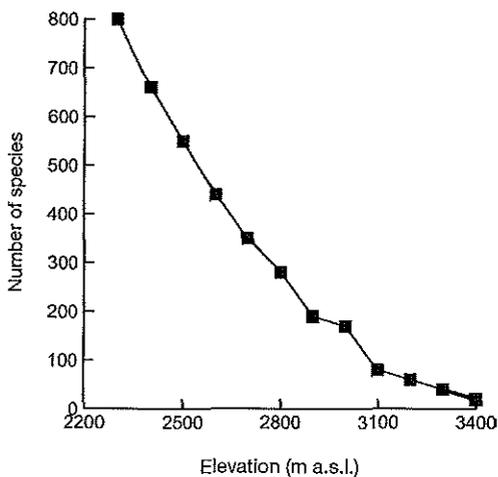


Fig. 3.7.2. The decrease with altitude in vascular plant species numbers from the treeline (2300 m a.s.l.) to the highest peaks in the Pyrenees. Data are from herbarium and field records

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