

# **Alpine collections at high altitudes: Implementing a new educational strategy in the Central Pyrenees**

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## **Abstract**

Successful biodiversity conservation strategies and action in alpine regions many times depend on the availability of educational plans able to raise public concern to take a proactive role in the conservation of these fragile environments.

With the aim of promoting an interest in all aspects of natural resources at high altitudes we use the results from a survey of plants assemblages in an area comprising a total of 357 glacial lakes and pools from the National Park of French Pyrenees to setup a thematic alpine collection that summarise the most valuable features from our extended study.

Discriminant statistic analysis was used to cluster the plants in eight main chorological groups that are displayed in eight distinct areas of the collection. Species of conservation concern are given special importance when displayed.

GIS modelling techniques are used for designing the landscape of the garden and finding the most suitable places for the elements composing it.

Finally, we propose the Fluctuating Asymmetry as technique for periodically assess the fitness state of populations within the collection.

Located on a degraded land proposed for restoration, next to an important high touristic flow cabin at 2200m altitude in the Piedrafita cirque, central Pyrenees, the collection is designed to fulfil two main objectives: educate people on the importance of alpine environment conservation and in situ research through extended study of plant and animal populations within the collection infrastructures.

## **Introduction**

In today's world, sustainability is a term largely employed when talking about nature conservation programmes but regarding the mountain regions the echo of this word has not produced substantial concern because of their isolation, physical, political and educational.

On the other side, Europe has the greatest concentration of botanic gardens in the world with very good educational programs but most of them are traditionally organised as lowland collections, majority of specimens cultivated out of the range country and dominated by non-wild origin accessions and do not contribute to a specific conservation project (Maunder et al 2001).

With the present work we come to answer these needs by implementing a new education strategy for the central Pyrenees. For this we used a degraded area close to a tourist resort in the Piedrafita

cirque, to set up an open alpine collection and make use of two core components of a collection: education for conservation and research.

We adopted the principle that open collections can model alternatives and create new ways for human beings to relate to the natural environment.

## **Study area**

Field work has been carried out in Piedrafita cirque, a granitic glacier basin in the alpine zone of central Pyrenees, Aragon, Spain near the French border since June 2002. On this plain of about 2-3 km<sup>2</sup>, close to Respomuso cabin we were assigned c. 5000m<sup>2</sup> for the collection, located at 2200m altitude (42.817N, 0.287W).

The average yearly temperature is 4.48 Co whereas for the touristic season (from May to September) is 9.13 Co with a maximum average of 13.8 Co and minimum of 5.08 Co. The main terrain orientation is to the South.

The area is accessible by c. three hours foot walking from the closest car parking at the foot of the mountain, from May to September

The site placement we considered of priority for our purposes because it is located at the cross front of four biogeographic regions of Europe: Atlantic and Continental from the north, Mediteranean from the south and Alpine (EEA 2003) and therefore it fulfils the needed microclimatic conditions for maintaining a sustainable collection.

It is subsequently visited by a great number of tourists in the aestival season which gives it a good educational and marketing value.

## **Planning and results**

Previously of design beginning, a brief survey was conducted on 500 randomly selected visitors of Respomuso area in the summer of 2000 to get an outline description of our target audience.

The survey reveals that from at least 7000 tourists visiting the area each aestival season, 69.6% believe that Piedrafita Cirque is not overexploited, 76.5% consider that it is not contaminated but 85% admit having seen contamination spots, mainly human origin debris.

Regarding the personal hygiene behaviour, 37% of visitors do not make use of soap or any detergents for personal hygiene, 9.8% use eco-friendly ones and 52% just ordinary detergents. Frome this last group, 77% were having the hygiene outside, whereas 22% were having it inside the resort.

The composition of interviewed groups was: 84.4% males and 15.6 women; 56.3 % between 16 and 30 years old, 82.5% were Spanish and 17.5% foreign visitors.

We adopted the following objectives in designing the garden: (1) focus on the most important ecosystem types in the collection area and select the communities to display function of the aesthetical, scientific and educational value, (2) modelling the collection design and create the database in GIS environment which will allow easier further improvements (3) create a basis for education and research.

## Phase I

By visual inspection of the existing natural features we decided for 6 main ecosystem types to be restored and displayed: on one side a stream, pools, marshland and peat beds shaping together a wetland corridor, and on the other hand a dry area, comprising a rock garden, and the grassland.

The data source for the statistical analysis is represented by lists of plant species from a more extensive survey conducted in 2000, 2001 and 2002 by our team in an area comprising c. 360 glacial origin lakes and pools from the Parc National des Pyrénées, France (see. Soler et al. 2002). By running a principal component analysis and discriminant analysis we outline eight main chorological communities based on the associative affinity of plant species (see appendix I).

The list of species of conservation concern includes extinct, threatened and species of regional protection, as described by international, European or national catalogues (see appendix II).

The selected plants are the most representative components of the aestival vegetal cover of the glacial cirques and valleys from central Pyrenees, between 1861 to 2747m altitude.

## Phase II

The collection design began with a visual topographic survey followed by the creation of a digital elevation model of the terrain into ArcGIS 3D Analyst and the subsequent calculation of aspect, slope and shadow.

Site boundary, existing topological features such as rocks and slopes, and the walkways and steps were generated as separate layers using on-screen digitizing tool in ArcEdit module of ARC/INFO.

A conceptual drawing of planting sites was finally developed in ArcMap integrating our data on species and ecosystems.

The collection map modelling resulted in a suite of 10 focus areas to be displayed in two groups: on one hand the ecosystems scenario including wetland (stream with a waterfall, pools, marshland and peat beds) grasslands, and rocks garden and on the other hand the eight plant associations and the species of conservation concern.

Within the wetland ecosystem we created special habitats for protected amphibians such as *Rana temporaria*, *Bufo bufo*, *Alytes obstetricans*, *Euproctus asper*, *Triturus helveticus* and *Salamandra salamandra*.

The map of the planting beds, experimental designs and other vectorial data are stored as layers in a GIS database. This, together with recordings on phenology, habitat temperatures, growth and other point data will entail further analysis which will improve the collection management.

Principles of ecological restoration, maintaining the natural diversity, natural landscaping, display (Harker et al 1999) and interpretation and education (Leadlay and Greene 1998) served as theoretical framework in which the collection was designed.

### Phase III

A welcome map and a signalized pathway give the starting point and direction of the visit. Spots of interest are designed to catch visitors' attention on their way through the collection on the major features while providing detailed information on its constitutive elements.

A special didactic area aimed to rise the public concern on the importance of an eco-friendly behaviour in these high altitude environments was designed using clear antonymic examples such as past versus present and time permanency in the case of solid materials, and clean-drinkable versus contaminated water in the case of liquid wastes.

CDs and other educative printed materials about the collection and the wild resources of Central Pyrenees are made available to the large public and university students together with summer training and scientific programs.

For research purposes, long time data loggers for temperature recordings are installed inside the collection area and offers substantial amount of information for better understand the ecological processes at these altitudes.

For periodically assess the fitness state of populations inhabiting the collection we propose the use of fluctuating asymmetry of symmetric characters as leaf for plant species or using body exuviae for aquatic insects. For this, a study was initiated in 2003 on *Boyeria irene* larval exuviae, a dragonfly species from the ponds of the area.

Fluctuating asymmetry (FA) indicate random variation in size of bilaterally-produced traits, which occurs during development (Van Valen 1962). Stress is often considered to increase both the asymmetry and phenotypic variability of bilateral traits in plants (Freeman et al. 2005) and animals (Parsons 1990). It has also been referred to fluctuating asymmetry as "measure of maladaptation" (Watson and Thornhill 1994).

### Discussions and conclusion

By visual inspection, running statistical analysis and GIS modelling we identified focus areas and plants communities to inhabit them and consequently launched the basic scenario of an alpine collection in the central Pyrenees aimed for both education and research. This scenario incorporates significant opportunities for public education while restoring a human impacted alpine area and creating a protective site for endangered species and an open laboratory for supporting scientific activity.

While not revolutionary and extends over a relatively small area, we believe that our open collection represents a positive step for achieving a sustainable biodiversity conservation attitude for high altitudes in the light of the United Nations Decade of Education for Sustainable Development.

In conclusion, the greatest benefit of this work lie not only in the availability of a didactic and scientific instrument but also represent a challenge to use native plants in designing the gardens of lowland touristic valleys and a constructive example for the political class and state agencies, invited to act cooperatively beyond political and financial interests to implement sustainable alternatives able compensate the fast growing touristic industry in the area and to rise human concern on the importance to have a more eco-friendly expansive behaviour and so enhancing the

legacy of the world's natural heritage handed on to present and future generations as stated in all major international conventions agenda.

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## Biography

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Born on 22 April 1978 in Romania

At present PhD student, Vigo University, Spain & Kingston University, London working on landscape ecology of high altitude glacial origin lakes.

## Appendix I

Combined intra-group correlations between discriminant variables and canonical typified discriminant functions. The resulted eight plants associations are displayed in the following tables.

Variables are arranged on the size of correlation with the function

(\*) Major absolute correlation between each variable and any discriminant function

(a) This variable is not employed in the analysis

Functions of contrast	Lambda of Wilks	Chi-square	gl	Sig.
1 a la 8	0,000	2586,083	1288	0,000
2 a la 8	0,000	1983,797	1120	0,000
3 a la 8	0,000	1552,225	954	0,000
4 a la 8	0,000	1154,910	790	0,000
5 a la 8	0,000	828,748	628	0,000
6 a la 8	0,003	588,374	468	0,000
7 a la 8	0,028	367,998	310	0,013
8	0,219	156,399	154	0,431

Specie	Function 3
Dethawia tenuifolia	-0,090(*)
Myosotis scorpioides(a)	-0,090(*)
Saxifraga aizoides	-0,074(*)
Anthyllis vulneraria	-0,055(*)
Carex frigida	-0,055(*)
Silene acaulis	-0,053(*)
Geum montanum	-0,037(*)
Carex curvula	-0,035(*)
Geranium cinereum	-0,026(*)
Carum carvi	0,015(*)

Specie	Function 1
Primula farinosa	0,022(*)
Carex brachystachys	0,022(*)
Carex riparia(a)	0,022(*)
Sorbus aucuparia	0,015(*)
Rhamnus pumilus	0,015(*)
Globularia repens	0,015(*)
Eriophorum latifolium	0,015(*)

Specie	Function 2
Parnassia palustris	0,056(*)
Betula pendula	0,055(*)
Plantago lanceolata	0,048(*)
Rumex scutatus	0,035(*)
Ranunculus aquatilis	0,035(*)
Sphagnum sp.	0,032(*)
Sanguisorba officinalis	0,030(*)
Cardamine raphanifolia	0,030(*)
Anthoxanthum odoratum	0,027(*)
Swertia perennis	0,026(*)
Arnica montana	0,026(*)
Luzula desvauxii	0,021(*)
Luzula sudetica	0,021(*)

Specie	Function 4
Rhododendron ferrugineum	-0,127(*)
Vaccinium myrtillus	-0,076(*)
Primula integrifolia	-0,073(*)
Pinguicula vulgaris	-0,070(*)
Vaccinium uliginosum	-0,066(*)
Trifolium repens	0,065(*)
Trichophorum cespitosum	-0,062(*)
Thymus serpyllum	0,057(*)
Calluna vulgaris	-0,054(*)
Homogyne alpina	-0,053(*)
Ranunculus reptans	0,052(*)
Draba aizoides	0,048(*)
Pedicularis mixta	-0,045(*)
Luzula alpinopilosa	-0,044(*)
Meum athamanticum	-0,036(*)
Carex nigra	-0,030(*)
Selaginella selaginoides	-0,028(*)
Veratrum album	-0,022(*)
Phleum alpinum	-0,020(*)
Allium schoenoprasum	-0,017(*)
Carex atrata	-0,016(*)
Carex pulicaris	-0,015(*)
Molinia caerulea	-0,015(*)
Huperzia selago	-0,014(*)
Carex sempervirens	-0,013(*)
Luzula luzuloides	-0,012(*)
Luzula nutans	-0,011(*)
Equisetum variegatum	-0,011(*)
Oxyria digyna	-0,009(*)
Sesamoides pygmaea	-0,009(*)
Carex rostrata	-0,006(*)
Succisa pratensis	-0,006(*)
Carex hallerana	-0,006(*)
Carex caryophyllea	-0,006(*)
Rumex alpinus	-0,006(*)
Carex flacca	-0,006(*)
Cochlearia officinalis	-0,006(*)

Gentiana lutea	-0,017(*)
Androsace carnea	0,108(*)
Armeria alliacea	-0,094(*)
Sparganium angustifolium	-0,093(*)
Plantago alpina	-0,083(*)
Bellis perennis	-0,082(*)
Epilobium alsinifolium	0,082(*)
Sagina procumbens	0,082(*)
Minuartia sedoides(a)	0,078(*)
Myosotis alpina(a)	0,078(*)
Oxytropis pyrenaica(a)	0,078(*)
Potentilla anserina(a)	0,078(*)
Armeria maritima alpina	0,076(*)
Leucanthemopsis alpina	0,073(*)
Trifolium alpinum	-0,070(*)
Potentilla erecta	-0,067(*)
Sibbaldia procumbens	0,066(*)
Merendera pyrenaica	-0,063(*)
Juncus filiformis	-0,063(*)
Plantago media	-0,059(*)
Galium verum	-0,059(*)
Campanula rotundifolia	-0,058(*)
Linaria alpina	0,055(*)
Salix reticulata	0,053(*)
Prunella vulgaris	-0,052(*)
Viola palustris	-0,051(*)
Galium pyrenaicum	0,048(*)
Botrychium lunaria	-0,047(*)
Juncus articulatus	-0,046(*)
Rumex crispus	-0,045(*)
Gnaphalium sylvaticum	-0,045(*)
Hieracium pilosella	-0,044(*)
Salix herbacea	0,044(*)
Ranunculus repens	-0,043(*)
Veronica fruticans	0,042(*)
Thalictrum alpinum	0,042(*)
Deschampsia cespitosa	-0,042(*)
Sempervivum arachnoideum	-0,040(*)
Alchemilla alpina	-0,038(*)
Menyanthes trifoliata	-0,038(*)
Veronica officinalis	-0,038(*)
Glyceria fluitans	-0,038(*)
Sempervivum montanum	0,036(*)
Carex demissa	0,036(*)
Primula viscosa	0,033(*)
Chara foetida	-0,031(*)
Fontinalis antipyretica	0,029(*)
Saxifraga oppositifolia	-0,027(*)
Rhinanthus minor	-0,027(*)
Thesium alpinum	-0,026(*)
Carex flava	-0,023(*)
Veronica beccabunga	-0,019(*)

Specie	Function 6	Specie	Function 7
Leontopodium alpinum	0,172(*)	Pinguicula grandiflora	0,156(*)
Oxytropis campestris(a)	0,172(*)	Alchemilla vulgaris s.l.	0,113(*)
Geranium sylvaticum	0,172(*)	Caltha palustris	0,111(*)
Ranunculus alpestris	0,120(*)	Gnaphalium supinum	-0,071(*)
Lychnis alpina	0,116(*)	Gentiana acaulis	-0,071(*)
Nigritella nigra	0,112(*)	Viola biflora	0,066(*)
Veronica nummularia(a)	0,112(*)	Cryptogramma crispa	-0,058(*)
Adenostyles alliariae	0,101(*)	Doronicum austriacum	-0,045(*)
Carex macrostylon	0,088(*)	Hutchinsia alpina	-0,045(*)
Empetrum nigrum	0,074(*)	Kobresia myosuroides	-0,041(*)
Soldanella alpina	0,074(*)	Phyteuma orbiculare	-0,030(*)
Ranunculus pyrenaicus	0,073(*)		
Gentiana verna	0,072(*)		
Poa annua	-0,062(*)		
Polygonum viviparum	0,051(*)		
Juniperus communis ssp. nana	0,048(*)		
Polygala alpina	0,046(*)		
Agrostis capillaris	0,043(*)		
Hypericum montanum	0,033(*)		
Bartsia alpina	0,033(*)		
Carex echinata	0,032(*)		
Leontodon autumnalis	0,025(*)		

Specie	Function 8
Callitriche palustris	0,293(*)
Juncus inflexus	0,188(*)
Nardus stricta	-0,109(*)
Jasione montana	0,085(*)
Saxifraga stellaris	0,080(*)
Festuca eskia	0,062(*)
Veronica alpina	0,056(*)
Sedum album	-0,048(*)
Lotus alpinus	-0,037(*)
Carduus carlinoides	-0,031(*)
Chenopodium bonus- henricus	-0,023(*)
Antennaria dioica	-0,022(*)
Kobresia simpliciuscula	-0,021(*)

## Appendix II

The list of species of conservation concern from the Central Pyrenees that are used in the design of collection

Plant species	Conservation status
<i>Aconitum variegatum</i> L. ssp. <i>pyrenaicum</i> Vivant & Delay	Vulnérable: Livre Rouge flore menacée de France (T1) Vulnerable : Catalogación de la UICN (D2)
<i>Allium schoenoprasum</i> L.	Protection régionale : Bretagne
<i>Antennaria dioica</i> (L.) Gaertner	Protection régionale : Basse-Normandie
<i>Arnica montana</i> L.	Protection régionale : Bourgogne
<i>Bartsia alpina</i> L.	Protection régionale : Auvergne
<i>Betula pendula</i> subsp. <i>fontqueri</i> (Rothm.) G. Moreno & Peinado	Vulnerable: Catalogación de la UICN (C2a,D2)
<i>Botrychium lunaria</i> (L.) Swartz	Protection régionale : Alsace
<i>Callitriche palustris</i> L.	Espèces végétales déterminantes en Sarthe Vulnerable Catalogación de la UICN (B1+2bc)
<i>Campanula rotundifolia</i> L.	Espèces végétales déterminantes en Sarthe
<i>Cardamine raphanifolia</i> subsp. <i>gallaecica</i> M.Lajnz	Vulnerable: Catalogación de la UICN (B1+2b)
<i>Carex frigida</i> All.	Protection régionale : Alsace
<i>Carex halleriana</i> Asso	Protection régionale : Alsace
<i>Carex nigra</i> (L.) Reichard	Espèces végétales déterminantes en Sarthe
<i>Carex pulcaris</i> L.	Protection régionale : Lorraine
<i>Carex rostrata</i> Stokes	Espèces végétales déterminantes en Sarthe
<i>Cochlearia officinalis</i> L.	Protection régionale : Nord-Pas-de-Calais
<i>Cryptogramma crispa</i> (L.) R. Br. ex Hooker	Protection régionale : Limousin
<i>Deschampsia cespitosa</i> (L.) P. Beauv. ssp. <i>littoralis</i> (Gaudin) Gremlin	<b>Éteint : Livre Rouge flore menacée de France (T1)</b>
<i>Doronicum austriacum</i> Jacq.	Protection régionale : Provence-Alpes-Cote-d'Azur
<i>Draba aizoides</i> L.	Protection régionale : Alsace
<i>Empetrum nigrum</i> L.	Protection régionale : Franche-Comté
<i>Empetrum nigrum</i> L. ssp. <i>hermaphroditum</i> (Hagerup) Böcher	Protection régionale : Auvergne
<i>Empetrum nigrum</i> L. subsp. <i>Nigrum</i>	Vulnerable: Catalogación de la UICN (D2)
<i>Epilobium alsinifolium</i> Vill.	Protection régionale : Franche-Comté
<i>Equisetum variegatum</i> Schleicher	Protection régionale : Bourgogne
<i>Eriophorum latifolium</i> Hoppe	Protection régionale : Basse-Normandie
<i>Gentiana acaulis</i> L.	Protection régionale : Franche-Comté
<i>Gentiana lutea</i> L.	Protection régionale : Champagne-Ardenne
<i>Gentiana lutea</i> subsp. <i>auranthiaca</i> Lajnz	Vulnerable: Catalogación de la UICN (D)
<i>Gentiana verna</i> L.	Protection régionale : Alsace
<i>Geranium sylvaticum</i> L.	Protection régionale : Picardie
<i>Huperzia selago</i> (L.) Schrank & C.F.P. Mart.	Protection régionale : Alsace

<i>Hypericum montanum</i> L.	Protection régionale : Basse-Normandie
<i>Jasione montana</i> L.	Protection régionale : Nord-Pas-de-Calais
<i>Juniperus communis</i> L.	Protection régionale : Nord-Pas-de-Calais
<i>Leontopodium alpinum</i> Cass.	Règlementation préfectorale (Ar. du 13-10-1989)
<i>Linaria alpina</i> (L.) Miller	Protection régionale : Bourgogne
<i>Luzula luzuloides</i> (Lam.) Dandy & Wilmott	Espèces végétales déterminantes en Bourgogne
<i>Menyanthes trifoliata</i> L.	Protection régionale : Centre
<i>Meum athamanticum</i> Jacq.	Protection régionale : Limousin
<i>Nardus stricta</i> L.	Protection régionale : Nord-Pas-de-Calais
<i>Nigritella nigra</i> (L.) Reichenb. fil.	Protection régionale : Auvergne
<i>Parnassia palustris</i> L.	Protection régionale : Alsace
<i>Phyteuma orbiculare</i> L.	Protection régionale : Alsace
<i>Phyteuma orbiculare</i> L. ssp. <i>tenerum</i> (R. Schulz) P. Fourn.	Protection régionale : Alsace
<i>Pinguicula grandiflora</i> Lam.	Protection régionale : Auvergne
<i>Pinguicula grandiflora</i> Lam. ssp. <i>grandiflora</i>	Protection régionale : Auvergne
<i>Pinguicula vulgaris</i> L.	Protection régionale : Alsace
<i>Pulsatilla alpina</i> (L.) Delarbre	Protection régionale : Franche-Comté
<i>Rhamnus pumila</i> subsp. <i>legionensis</i> Rothm.	Vulnerable: Catalogación de la UICN (DD)
<i>Rhamnus pumila</i> Turra	Protection régionale : Franche-Comté
<i>Rumex scutatus</i> L.	Protection régionale : Ile-de-France
<i>Rumex scutatus</i> subsp. <i>gallaecicus</i> Lago	Vulnerable: Catalogación de la UICN (DD)
<i>Salix herbacea</i> L.	Protection régionale : Auvergne
<i>Sanguisorba officinalis</i> L.	Protection régionale : Basse-Normandie
<i>Sedum album</i> L.	Espèces végétales déterminantes en Sarthe
<i>Sempervivum arachnoideum</i> L.	Protection régionale : Centre
<i>Sesamoides pygmaea</i> (Scheele) O. Kuntze ssp. <i>pygmaea</i>	Protection régionale : Auvergne
<i>Sibbaldia procumbens</i> L.	Protection régionale : Alsace
<i>Soldanella alpina</i> L.	Protection régionale : Auvergne
<i>Soldanella alpina</i> subsp. <i>cantabrica</i> Kress	Vulnerable: Catalogación de la UICN (D2)
<i>Sparganium angustifolium</i> Michaux	Protection régionale : Franche-Comté
<i>Swertia perennis</i> L.	Protection régionale : Auvergne
<i>Taraxacum bessarabicum</i> (Hornem.) Hand.-Mazz.	Protection régionale : Auvergne
<i>Taraxacum cucullatum</i> Dahlst. gr.	Vulnérable : Livre Rouge flore menacée de France (T1)
<i>Taraxacum palustre</i> (Lyons) Symons gr.	Protection régionale : Ile-de-France
<i>Thesium alpinum</i> L.	Protection régionale : Champagne-Ardenne
<i>Trichophorum cespitosum</i> (L.) Hartman	Protection régionale : Bourgogne
<i>Trichophorum cespitosum</i> (L.) Hartman ssp. <i>germanicum</i> (Palla) Hegi	Protection régionale : Basse-Normandie
<i>Vaccinium myrtillus</i> L.	Protection régionale : Nord-Pas-de-Calais
<i>Vaccinium uliginosum</i> L.	Règlementation préfectorale (Ar. du 13-10-1989)
<i>Veratrum album</i> L.	Protection régionale : Alsace
<i>Viola palustris</i> L.	Protection régionale : Ile-de-France