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Inland wetlands of the Northern Iberian Peninsula: Management and restoration of peatlands and wet environments'.

The Arxuri mire (Baztan-Navarre)

Peatland and lacustrine environments are the chief sources of information for palaeoenvironmental studies.

This is due to the significant concentrations of fossilised plant remains found in these organic deposits and their good state of conservation.

Wetlands store important palaeoenvironmental information

This is due to the significant concentrations of biological remains found in these organic deposits and their good state of conservation. If Archaeology studies human activity in the past by analysing the material remains generated by human activity, Palaeontology and Palaeoecology study the remains of living beings and reconstruct the ecosystems in which they lived.

Inorganic matter from the basin and the organic remains of organisms living in the wetland and those living in the surrounding area which are transported towards the wetland periodically come to form part of its sediments.

The peculiar conditions of the sediments in wetlands, permanent humidity and a low concentration of oxygen, favour the concentration of certain biological remains (wood, fragments of leaves, fruits, pollen, spores, small edaphic invertebrates, the remains of dragonflies/ damselflies and other arthropods, etc.).

Biological remains from the surrounding area build up gradually in wetlands and mires. This leads to the generation of sequences of sediments which record changes in the biological characteristics of the environment (flora and fauna) over long periods of time (5,000, 10,000 or 100,000 years). By studying the sediments which have built up, therefore, it is possible to reconstruct the changes which have taken place in the configuration of the flora and fauna of the wetland and its surrounding area in relation with climate change, and evaluate human impact on these processes.

Peatland sediments contain a lot of pollen and spores, both from the vegetation which forms part of the different wetland communities and from outlying vegetation, originally transported to the wetland by the wind, water or even insects. Many pollen grains can be carried a long way by the wind.

In Europe, this occurs with the pollens of most tree species (oak, elm, chestnut, willow, beech, ash, alder, hazel, lime, birch, etc), which may travel long distances before they are eventually deposited in wetlands. Other types (broom, gorse), on the other hand, are transported short distances by insects.

By studying the combinations of type and concentration of the pollen and spores obtained in different mires and wetlands, palaeoecologists can reconstruct the configuration and dynamics of the ecosystems, landscapes and the wetlands themselves at different territorial scales.

Palynology is the study of the pollen and spores found in wetland sediments.

Many human bodies from more than 2,000 years ago have been found in mires in Northern Europein exceptional states of conservation

The term pollen was coined by the botanist Carl Linnaeus to refer to the dust released from the anthers of flowers. The pollen of flowers and the spores of ferns, mosses and fungi are microscopic structures (10-100 µm) which, after release, can come to form part of sediments and remain in a good state of conservation for thousands of years. When analysed under a microscope, the external morphology of pollen and spores (size, shape, apertures and wall decoration) allows us to identify each type with a specific plant group (species) or with specific plant groups (genus, family).

Pollen was first analysed as part of palaeoenvironmental and palaeoclimatic studies in Scandinavian countries at the end of the 19th century, but the practice only began to spread to the rest of Europe and North America in the 1920s. The first pollen analyses carried out on the Iberian Peninsula were not conducted until 1945.

That year saw not only the publication of the results of the study of the mires of Galicia at the Botanic Laboratory of the University of Santiago by Francisco Bellot Rodríguez (1911, 1983), which he was able to carry out thanks to the collaboration of celebrated Swedish palynologist Gunnar Erdtman (1897,1973), but also the publication in Portugal of the first pollen analyses of Tertiary sediments.

Over the next few decades, the number of pollen studies gradually increased. In the 1950s, Doctors Josefa Menéndez-Amor (1926-1985) and Frans Florschüzt (1887-1865) conducted a pollen study of different deposits in the Northern Iberian Peninsula. Their work was then continued by research groups set up in the Basque Country, Cantabria, Asturias, Galicia and Castile and Leon, leading to a growing amount of coring and studies performed not only at wetlands, but also i caves and at anthropic deposits.

The first pollen analyses were carried out at the end of the 19th century at Scandinavian mires and wetlands. In the second half of the 20th century, studies of the plant remains found in different deposits led to new models and frontiers for research into the dynamics of the climate and ecosystems over time.

How are palaeoenvironmental studies performed at mires?

Palaeoenvironmental studies call for different technicians and specialists who come and work together to finally arrive at a reliable, comprehensive interpretation of the configuration of an ecosystem and its chief components, and the spatiotemporal changes which they have experienced, comparing and matching them with those obtained in other nearby areas. As with all scientific studies, the investigators must also ensure that the data obtained is reliable.

Palaeoenvironmental studies pass through several stages. The first stage is preparatory and consists of defining the preliminary area of study, the objectives of the study and an initial sampling strategy. In order to do this, it is necessary to compile and analyse the environmental and palaeoenvironmental information which already exists on the area and the data obtained from work performed in other areas.

In the second stage, data and sediments are taken from the area of study. It is necessary to evaluate the deposit to be sampled in detail, identifying areas which may have been affected by man, livestock or natural changes in hydrological dynamics. At the same time, test cores are taken by hand to obtain information on the different thicknesses and natures of the sediments in the deposit. This information is then used to select the point or points at which coring is to be performed.

Above: Detail of a sample taken at the Arxuri mire (Navarre).
Left: Using a Russian corer (manual extraction of the sample).
Right: Sampling in Urdaibai.

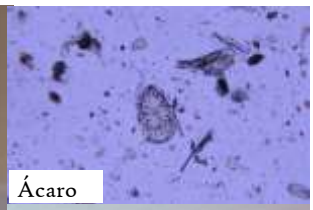
Sediment samples are taken using mechanical equipment. Manual core drills which penetrate the soil and take samples are used in shallow peatland (< 2 metres), particularly in places which are hard to reach, while mechanical core drills which penetrate the sediment with the aid of electrically driven drive hammers are normally employed for deeper peatland. The sediments obtained must be handled skilfully and delicately, minimising possible sources of contamination. The samples obtained from the core drills are packed in plastic and labelled, occasionally subdividing them into different samples beforehand. The samples are kept frozen in the laboratory until studied.

All efforts must be made to avoid altering the ecosystem and its components when prospecting and sampling in active mires and, in general, any natural environment. Sampling needs to be planned in such a way as to pre-empt any kind of impact on more sensitive parts of the wetland, minimising human traffic and trampling, and ensuring the absolute cleanliness of the field equipment used and the footwear worn by those involved, which may bring seeds or spores from other areas.

In the laboratory, the sediments are subjected to initial characterisation. The sample interval is normally set at 5 cm, although studies which require great environmental resolution normally work with sample intervals of 1-2.5 mm.

Each peat (1 g) or clay (30 g) sample is then successively subjected to the effects of different acids and alkalis depending on the characteristics of the sediments and the type of micro-remains it is hoped will be retrieved. A small residue consisting of organic micro-remains of different types is finally obtained by differential flotation in a high-density liquid.

The residue is then mounted in glycerine, sometimes stained, and observed under a light microscope. More than 250 pollen grains or spores must be identified per sample in a pollen analysis of peat, excluding those grains which appear in great abundance (>25%). In a sample of this kind, an expert palynologist can identify up to 1,000 pollen grains/spores per sample, which sometimes represent 50-60 different types (species, genus or family).


Ácaro

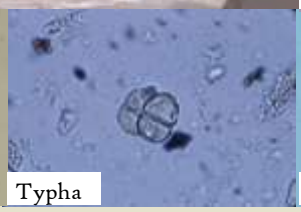

Betula


Juglans


Erica-umbellata


Hongo Glomux


Espora-polypodium

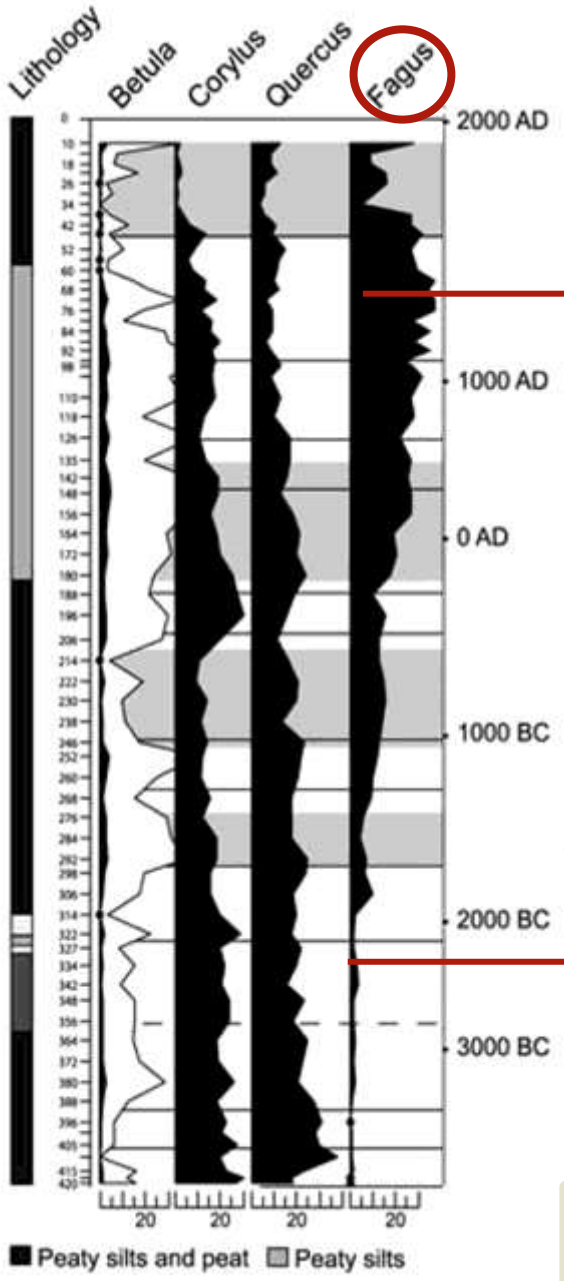

Typha


Ilex-aquifolium

The identification of the pollen grains and spores obtained from wetland sediments is a complex task. Bearing in mind the external morphology of the pollen and spores, and their size, it is possible to identify them as belonging to a specific family of plants with some precision. The identification of different genera, however, is only possible with certain groups, such as tress (Quercus, Fagus, Castanea) and most shrubs (Calluna, Erica, Arbutus). Distinguishing categories beyond genera is normally very difficult.

Researchers have reference collections (pollen, seeds and wood), photographic files and descriptive atlases at their disposal to facilitate the task of recognising types of pollen, spore, seed, fruit and wood from wetlands and other deposits.

After identifying the macro- and micro-remains in the different samples, the data obtained is graphically represented in diagrams. These diagrams provide an overall description of the sedimentological, palaeobiological and chronological information obtained from single samples to make it easier to interpret them and correlate them with other sequences.



The **Y-axis** is a full-scale representation of the points in the column from which the samples were taken (depth, lithostratigraphy and the age of the different samples arrived at by isotopic methods).

500 years ago, *beech trees figured greatly in the plant formations which surrounded the mire described in this pollen diagram.*

The X-axis identifies the different taxa and their prevalence as a percentage of the total

2000 years ago, *however, there were hardly any beech trees in among the vegetation at this location.*

If a lot of pollen, seeds and other micro-remains are found in the samples, then different diagrams using the same axis criteria are arranged side by side.

Control of all the processes involved in sedimentological recording leads to more reliable palaeoenvironmental reconstructions.

The following are some of the factors which need to be taken into account when interpreting pollen diagrams:

- The type of dispersion and quantity of pollen/spores produced by each plant.
- The conservation capacity of pollen/spores in wetland sediments.
- The resistance of different groups of pollen/spores to the extraction method employed.
- The geographical configuration of the area in which the wetland is located.
- The biogeograhical configuration of the region.

What do palaeoenvironmental studies conducted at mires reveal?

In 1883, the botanist Alphonse de Candolle (1806-1893) published one of his best-known works: L'origine des plantes cultivées. In it, he constructed the scientific method of palaeobotany, based on the study and consolidation of data from different sources; from fossils and plant remains, principally micro-remains, through to the writings of ancient and classic writers, particularly Persian, Greek, Roman, Mediaeval and Arabian naturalists and agriculturalists, and information gleaned from the study of the portrayal of plants in sculptures, mosaics and paintings. Nevertheless, the information available on many plants was not decisive enough and it proved hard to determine the native or exotic nature of certain species.

In 1945, Professor Bellot applied the technique of pollen analysis for the first time, obtaining samples from different mires in Galicia in order to clarify the autochthonous or exotic nature of pine formations in the northwest of the Iberian peninsula.

The increase in the number of analyses of pollen and micro-remains in mire and wetland sediments since then has led to recognition of the presence of certain conifers and cupressaceae on the Iberian Peninsula since the Mid-Mesozoic (166 million years ago). The number and territorial representation of gymnosperms (conifers, cupressaceae, junipers, etc), however, has gradually dropped over the last 100,000 years and has been overtaken by species bearing flowers and fruits, angiosperms.

Pollen and micro-remain analyses of mire and wetland sediments has led to recognition of the presence of certain “gymnosperms” on the Iberian Peninsula since the Mid-Mesozoic (166 million years ago). The number and territorial representation of conifers, however, has gradually dropped over the last 100,000 years and has been overtaken by species bearing flowers and fruits, angiosperms.

As for angiosperm species, palaeobotanical studies have confirmed the presence of trees such as oaks, holm oaks, hazels, birches, chestnuts, beeches, elms, tilia, hornbeams, willows, ashes, etc. in both the Tertiary period (66-2.5 million years ago) and certain more recent stages of the Quaternary period prior to the appearance of the earliest agricultural activity (120,000–5,000 yeas ago). These can, therefore, be considered autochthonous species.

In the late Quaternary, the autochthonous species significantly changed their area of distribution, adjusting to climate changes or competition from other species. Pollen analyses show us that species such as the hornbeam, wild populations of which are currently restricted to small areas of the Basque Country, were present throughout the Northern Iberian Peninsula in the Holocene (10,000 – 0 year ago), reaching as far as Galicia. It has also been demonstrated that these changes affected the altitudinal distribution of these species. Approximately 90,000 years ago, mixed beech woodland with hornbeams and oak trees grew in low-altitude areas near the coastline, but later, between 4,000 –2,000 years ago, beech woods, bereft of hornbeams, only occupied higher mountainous zones.

The environmental information obtained from mires and wetlands, together with archaeobotanical data from archaeological sites, has allowed us to characterise the impact which the development of the different cultural periods observed on the Iberian Peninsula has had on the landscape and the environment. These studies mean we can pinpoint both the dates at which agricultural practices were adopted in different areas and the way in which unspoiled ecosystems were eventually replaced with agricultural systems.

The characteristic climate conditions on the oceanic watersheds of the Northern Iberian Peninsula after the Ice Age (Würm, 17,000 years ago) have favoured the formation and development of wetlands and blanket and raised bogs in which the rate of sedimentation has remained constant over several thousand years, thereby providing high-resolution sequences for palaeoclimatic and palaeoecological studies.

Deposits more than 4 metres deep recording changes in the Holocene (last 10,000 years) to a high degree of precision can be found in active raised and blanket bogs. Some active mires and wetlands can even take us as far back as 17,000 years ago. Fossilised bogs, meanwhile, have produced sequences between 17,000 and 110,000 years old.

The application of palaeoenvironmental studies to wetland conservation and management.

Palaeoenvironmental information is key when it comes to managing and restoring wetlands, particularly mires, because it gives us an insight into temporal changes in the configuration of the wetland in question, of its different environments and of its characteristic species or groups of species, providing us with a means of assessing the effects which natural processes (climate changes, hydrological changes, competition between species) and disruption caused by man (livestock grazing, tree felling, burning, drainage, etc.) have had on different processes of change.

Just as variations in the concentration of pollen and spores can be registered in sedimentological sequences, so it is equally possible to evaluate the presence of gravel and sand in more recent sediments, linking the rate of deposition in with increased erosion in the basin caused by man, or observe the presence of certain chemical compounds and elements (lead, zinc, weedkillers, etc.), also introduced as a result of human activity on the land.

Dinámica del clima y del paisaje en el norte de la Península Ibérica durante los últimos 100.000 años

Until the end of the 20th century, it was widely believed that the succession of cold periods occurring in the Quaternary led to the extinction in large areas of the tropical, thermophilic and mesophilic species which dominated the ecosystems of the Tertiary. It was accepted that, unlike the Italian and Balkan Peninsulas, no areas of refuge for these species remained on the Iberian Peninsula and that, once they became extinct, their presence was due to migratory flow across the Pyrenees after the last glacial period, meaning that their presence on the peninsula had lasted less than 10,000 years.

This hypothesis was definitively invalidated on the basis of pollen information obtained from fossilised organic samples taken in the Cantabrian-Atlantic area recording that many mesophilic species had survived in the area ever since the end of the Tertiary.

Different levels of clay and peat were deposited at the Area Longa deposit (Foz, Lugo), an inland wetland which formed in 85,000 BP on a sea beach believed to date from the Eemian period (>110.000 BP.). Pollen analysis of these strata point towards a wooded landscape containing a large number of deciduous woody species, both mesophilic (oaks, hazels, beeches, elms, ashes) and thermophilic (tilia, hornbeams, chestnuts, walnuts, strawberry trees, etc.), and a limited presence of gymnosperms (pines, yews, junipers). Tropical species from the Tertiary were not found.

In the period **79,000-59,000 BP**, the Polar front descended southwards to the mouth of the River Miño. A period of extremely cold conditions commenced on the Northern Iberian Peninsula, marked by the development of large glaciers in mountainous areas which spread down towards lower areas. In areas not permanently covered by snow, shrubs and herbaceous plants were the main forms of vegetation. The woodland contracted and was confined to the bottoms of narrow valleys, where numerous species sought refuge. The samples taken at Area Longa indicate a landscape consisting mainly of heath and graminoid steppes, the latter probably in areas further inland and with junipers displacing the heath.

Then in the period **58,000-28,000**, the Polar front retreated to higher latitudes, the area covered by glaciers shrinking and different types of wetland forming both on the coast and inland. By combining the pollen information obtained from fossilised organic deposits and palaeontological and palaeobotanical data from caves and shelters occupied either by man or animals, it is possible to reconstruct the climate and environmental conditions of the period fairly accurately.

From a landscape perspective, while woodland prospered, it failed to dominate, and cohabited alongside open spaces consisting of shrubland, grassland and wetland. The main tree species were deciduous mesophiles (oaks, chestnuts, beeches, birches, hazels), accompanied by a small number of more thermophilic species (tilia, hornbeam, holm oaks, strawberry trees, etc) and a range of conifers. Although at first glance the landscape may have appeared similar to that of the present day, it was not, for in this largely open landscape, there lived herds of large herbivores (bison, horses, deer, chamois, wild boars, mountain goats), which were most probably preyed upon by a large number of predators (cave bears, cave lions, panthers, hyenas, etc), and other species associated with large-scale wetlands (hippopotamuses, beavers, otters, etc).

Between 28,000 and 16,000 BP, the Polar front descended once again, affecting the entire northern coastal area. Snow took hold of mountainous areas once more and the glaciers grew back to their previous dimensions. The woodland shrank considerably, but did not vanish altogether, and the shrubland and graminoid steppes expanded as they had before. The new cold period affected the distribution of most species and even those best adapted to the cold, such as the woolly mammoth (*Mammuthus primigenius*), the woolly rhinoceros (*Coelodonta antiquitatis*), the reindeer (*Rangifer tarandus*), the artic fox (*Alopex lagopus*), the muskox (*Ovibos moschatus*) and the saiga antelope (*Saiga tatarica*), disappeared from most of continental Europe. Some did manage to migrate south and found refuge at certain points on the Northern Iberian Peninsula, but eventually even they succumbed.

Between 16,000 and 11,700 BP, the Polar front gradually withdrew to the north, marking the beginning of the end of the glaciers. Woodland partly reappeared on the landscape, although open areas of shrubland and grassland continued to predominate. The retreat of the ice left depressions in mountainous areas in which water built up and these began to work as wetland or peatland systems. Many of these still exist today.

A warmer period was registered **between 11,700 BP and AD 1,850**, the Holocene. In climate terms, this period is normally divided into three substages: an initial stage (11,700–8,000 BP.), a period of continuous changes in the climate, but one which, at global level, involved the gradual warming of the sea and the emerging land adjoining it; then came a warm period, the Climatic optimum (8,000 –2,500 BP), a warmer period in Southwest Europe and a particularly wet one in specifically oceanic areas; finally, a third stage (2,500 BP–AD 1850), which can be defined as a succession of hot and cold substages which eventually led to the current climate.

Exceptionally, the specific mesoclimatic conditions of the sub-coastal Cantabrian mountains (particularly favourable for the development of peatland and shrubs) limited the ascent of the tree line to about 700-600 m. This meant that the heathland which had been a natural component of the area, at least during the Würm, still played a significant role in the Holocene, making formations of this kind particularly important in landscape and ecological terms.

The end of this period is reflected in the stabilisation of tree pollen percentages in almost all the sequences studied in the northwest of the peninsula at around their maximum values in the Holocene, which can be interpreted as evidence that tree expansion came to a definitive end.

The Climatic optimum was in all probability the most propitious period for the expansion of woodland on the Northwestern Iberian Peninsula in the current interglacial.

The sequences retrieved from ombrotrophic deposits in the area, such deposits being particularly sensitive when it comes to reflecting changes in conditions in the North Atlantic region, indicate two stages of woodland expansion during this long time span, separated by a slightly colder period which led to the development of more open landscapes dominated by grasslands, heathland and peat deposits on the tops of medium-sized mountains near the Cantabrian coast.

pollen grains: *Fraxinus y Quercus*

The end of the Climatic optimum was marked by higher temperatures, reflected in the dissemination or expansion of thermophilic species (*Arbutus, Hummulus, Ulmus, Celtis*, etc), though at no point was the population significant enough to overcome its mesophilic counterparts (*Quercus, Corylus, Alnus, Fagus*).

Almost all pollen sequences from the Northwestern Iberian Peninsula describe **the last 2,500 years** as a period marked by a significant reduction in the representation of regional woodland and considerable expansion of heath. In general, this process can be divided into at least two substages. **In the first stage**, the drop in tree pollen observed in samples taken from mires in the Cantabrian mountains coincides with a slight recovery in the types of vegetation most characteristic of these mountain wetlands, that is to say, gramineae, sedges, heather (*Erica, Calluna, Daboecia*) and other types of hydrophilic vegetation (*Drosera, Potamogeton, Ranunculaceae*, etc.). Meanwhile, indicators of human activity in the environment (*cereals, Brassicaceae, Plantago, Polypodium, Pteridium*) also increase significantly.

The last stage in the earth's climate history is the Anthropocene (AD 1850 to the present). Human impact on the planet has increased dramatically since the start of the Industrial Revolution, leading to ecosystem modifications which go beyond local or sub-regional levels to reach regional or even global scales, affecting not only the components of biodiversity, but also the very structures and functioning of ecosystems. Global Change has equally affected the planet's climate system, which has, since the Industrial Revolution, suffered from a dynamic in which certain variations detected at continental and regional scales can be directly linked in with human activity.

In the Anthropocene, the global temperature of the Earth's surface has risen by an average of 1.0-0.74ºC, reaching values of 1.2-1.5ºC in more northern areas, such as the Iberian Peninsula, with average increases in maximum temperatures of 0.12ºC/decade and in minimum temperatures of 0.10ºC/decade. At the same time, the area covered by natural woodland and natural habitats has shrunk, and both reforested areas and areas occupied by major agricultural systems have grown.

AD = Anno Domini or Common era. *BP = Before Present, taking AD 1950 as zero.*

Palaeoenvironmental Studies... in Navarre

Not many palaeoclimatic and palaeoenvironmental studies were conducted in Navarre until the end of the 1980s. New methods and technologies have, however, been adopted in the last 30 years with which to progress in these fields, current knowledge of the environment also being applied to historical research.

Archaeological sites have provided a priceless source of palaeobotanical information on specific areas of Navarre and in recent years samples taken from organic peat deposits have been studied in order to obtain information at a regional scale.

Significant **peat deposits** are known to exist at 5 sites in Navarre: Belate (Ultzama and Baztan), Arxuri (Baztan), the Anue mire (Anue), the Esteribar mire (Esteribar) and Azaldegi (Baztan). Palaeoenvironmental information of great interest has also been obtained from the wetland of Jauregiaroztegi (Auritz-Burguete) although it has no peat deposit as such.

Within the framework of LIFE TREMEDAL, Navarre has compiled all the information from palaeoenvironmental studies generated to date and is also completing palaeoecological studies of the mires in Belate, Arxuri and Anue. It should be pointed out that the results of the studies being conducted in Navarre (and also others which began before TREMEDAL started) have not yet been published and may not be published before the end of the project in itself.

A peat deposit with a depth of more than 4 m and which may be more than 6,370 years old according to latest studies (not yet published) has been described at the **Arxuri mire (Ibainetako Zelaia)**.

Coring in Arxuri with a Russian core drill

A peat deposit which is almost 4 m deep has been described at the **Belate mire**. Peñalba's study (1989) included a range of dating references for this deposit: 6,600 BP at 216 cm, 2,960 BP at 50 cm, etc. Moreover, the plant remains collected from the deeper reaches of the deposit indicated that the mire was formed at a much earlier date, in the Late Glacial Maximum (13,000-10,000 years ago).


Belate mire

Later, as part of the physical-chemical characterisation work on the deposit performed in 2008-2009, a mass of plant remains was detected at a depth of 215 cm, which, thanks to its extraordinary state of conservation, could be identified as belonging to the species *Palustriella commutata* (Heras et al 2009). These remains proved to date from 17,980-18,620 BP, a surprising discovery which provided fresh information on the date of sedimentation of the clay deposit beneath the layer of peat.

The Belate discovery is the only occasion on which sub-fossil macro-remains of *Palustriella commutata* have been found on the Iberian Peninsula.

Their presence would seem to indicated that strong floodwater ripped some of the moss from its place on one of the slopes surrounding the basin at Belate and dragged it along before depositing it in clay at the point at which it was found.

Palustriella commutata has not been found in studies of Belate conducted in recent decades although it may be present at humid spots on the slopes near the basin.

The presence of this alkaline-loving moss buried in the clay horizon is striking because its ecological preferences stand in stark contrast to the acidophilic conditions which prevail in the Belate basin and led to the development of the significant peat deposit there.

This discovery would seem to indicate that environmental conditions around the Belate basin were, in the relatively distant past (long before the appearance of the mire and the start of the peat deposit), very different to those found today.


Palustriella commutata

Palaeoenvironmental Studies... in the Basque Country

From the Basque Country comes an example of a palaeoenvironmental study conducted within a different context: a lacustrian environment.

Organic matter is not deposited in the Lake of Arreo - Caicedo Yuso in the form of peat. The lake currently has calcareous mires, environments very different to mires like those found in Belate, Navarre.

But this has not always been the case, another significant difference being the site's dynamism, as highlighted in the study by Corella et al. 20131 prior to the TREMEDAL project.

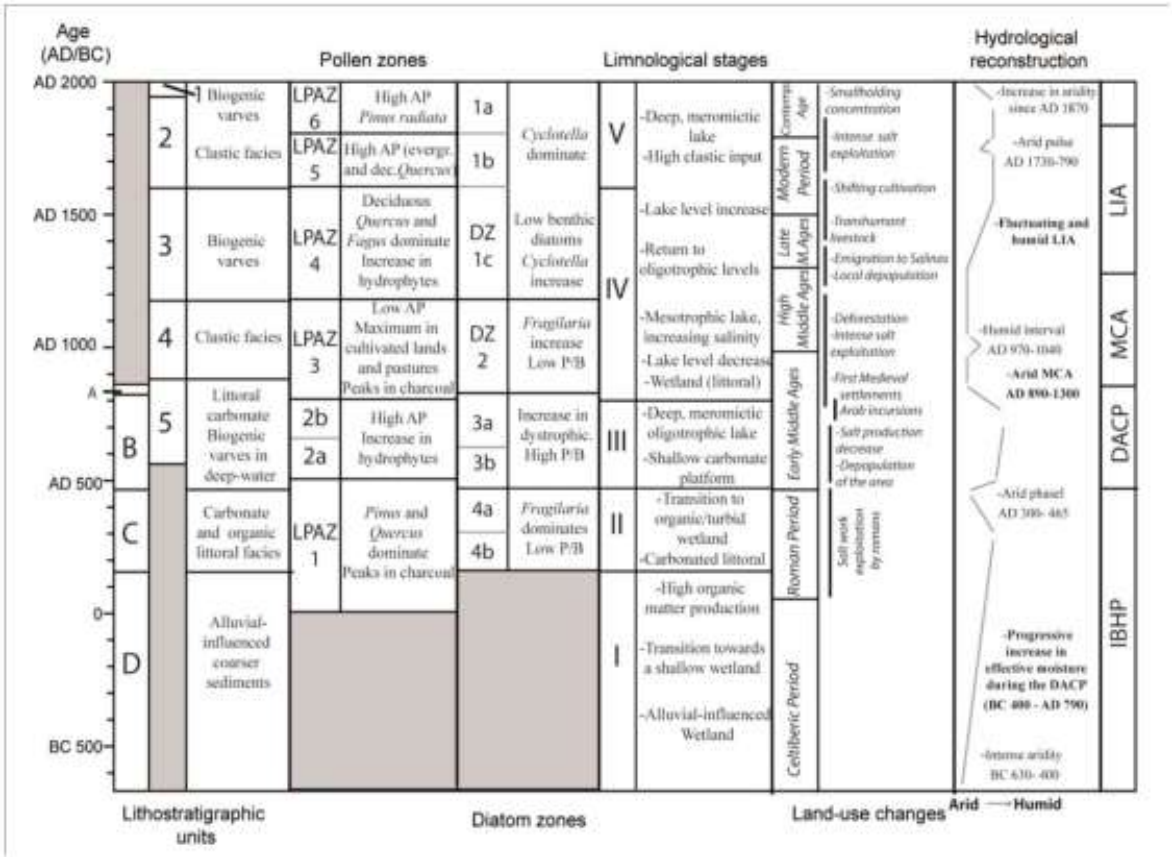
Unlike the stable mires on which this project focuses –which have remained stable for thousands of years-, this site has changed a great deal over the period under study.

It has undergone significant changes in terms of salinity and has switched from being a river-influenced wetland to the lake we know today, with a ring of marsh vegetation in which plant remains build up along with calcareous matter.

These changes have taken place at an extremely fast rate, from a geological point of view, in just 2,500 years. Human activity has also changed a great deal over this time and makes it hard to distinguish between human impact and natural processes.

Different study techniques need to be combined in order to distinguish between human influence and environmental processes.

In order to make such a distinction, it is necessary to take a multidisciplinary approach combining geochemical studies, stratigraphic studies, radioisotope studies, etc.



[1] JP Corella, V Stefanova, A El Anjoumi, E Rico, S Giralt, A Moreno, A Plata-Montero, BL Valero-Garcés. *A 2500-year multi-proxy reconstruction of climate change and human activities in northern Spain: The Lake Arreo record.* Palaeogeography, Palaeoclimatology, Palaeoecology. Vol 386, 15 September 2013, p 555–568.

Following this approach, Juan Pablo Corella's team core-sampled both the shallow part of the lake, now a reedbed/saw-sedge habitat, and its deeper waters.

The core selected for analysis from the shallow area reaches a depth of 5 m, corresponding to 620 BC, and is interrupted at surface level in the year AD 840± 60, indicating recent alterations through erosion processes.

The core taken from the deeper part of the lake, which reaches a depth of 6.79 m, reaches back to AD 585 and sequences continuously up to the present. Combining the two lacustrian sediment samples permits study of a period of 2,570 years with an overlap of approximately 300 years between the two.

As previously explained, the two cores were processed using different techniques, permitting analysis of their content in terms of pollen, diatomaceous earth, relative isotopic abundance, sediment size, presence of carbon remains and other factors.

Two examples illustrate the type of information which can be obtained through this multi-sided approach:

1. In the **Ibero-Roman period (570 BC – AD 400)**, the lake was used intensively, the nearby woodland and the wetland itself being burnt and used as pastures. This is consistent with the need to provide for the pack animals used to exploit the Salt Springs of Añana (1 km) and for transportation on the Roman road Ab Asturica Burdigalam (5 km).

2. In the **Early Middle Ages (400dC – 900dC)**, the salt springs and the pastures were used less, and woodland began to take hold once again. Crop farming increased in the area around the lake and activity affecting it directly decreased. Fire was also used less as a means of forest management, although the presence of fire rose in around AD 800, which may be associated with the burning of wooded areas as part of the Arab raids which took place in the period.

Salt Valley of Añana (Mikel Arrazola)

(Mikel Arrazola)

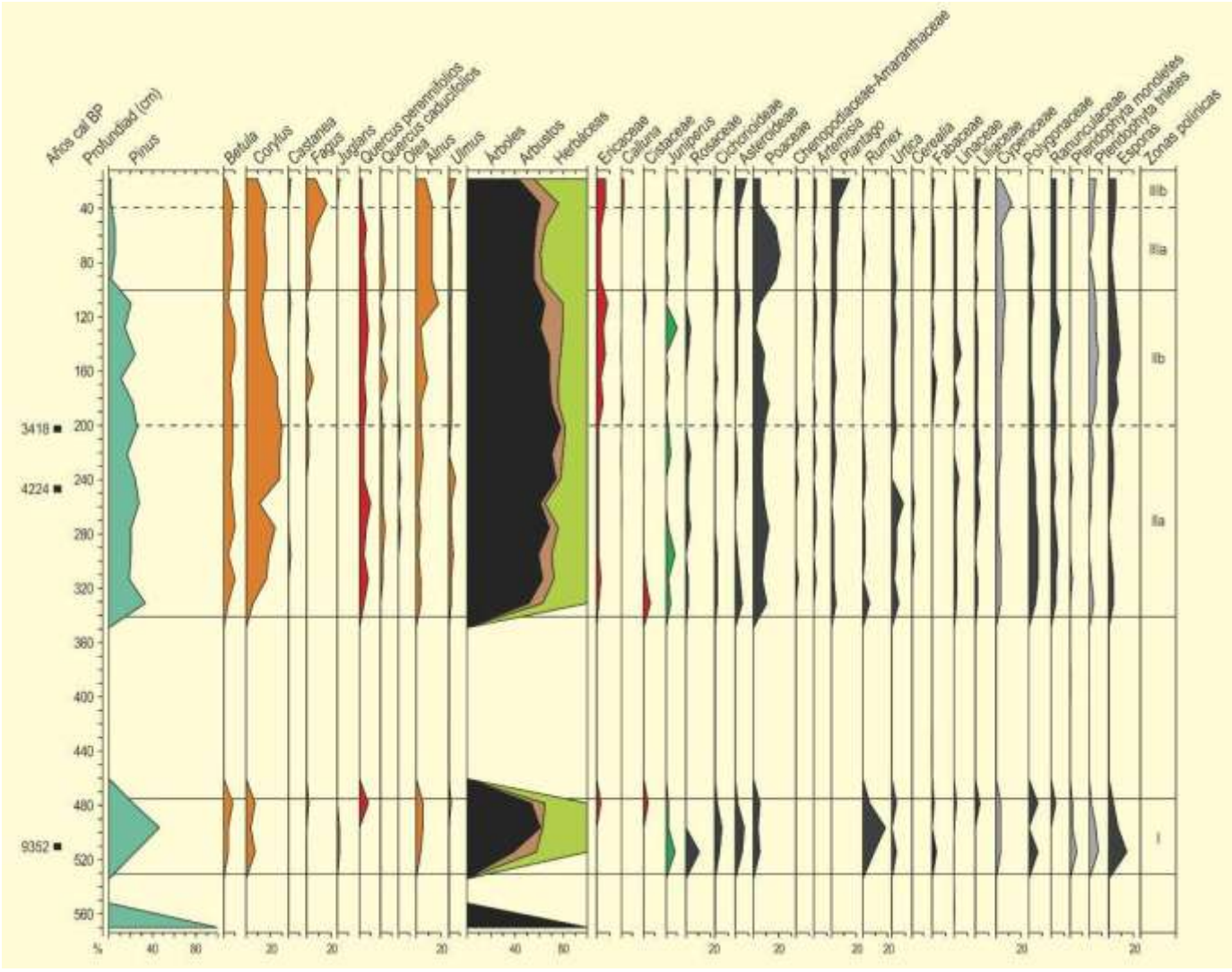
(Euskonews-Euskoikaskuntza)

Pictures of the Roman road Ab Asturica Burdigalam

Palaeoenvironmental Studies... in Picos de Europa (Asturias, Castile and Leon)

Many palaeoenvironmental studies have been conducted in Asturias, Cantabria and the north of Castile and Leon over the last 50 years, principally related to mires, caves and lacustrian environments. Palynological studies have also been carried out at many of these archaeological sites, enabling their palaeoenvironmental characterisation. Most of these studies have been compiled for inclusion in LIFE TREMEDAL's documentary database.

The deepest mire is in the Comeya depression, in Picos de Europa, one of the sites included in the Tremedal project. This polje basin is lined with a quaternary deposit 56.7 m deep and the top layer, consisting of peat, has a depth of 5 m. According to the dating process and the palynological study of the Comeya deposit performed in 2001, the peat began to form about 9,000 years ago..



Pollen diagram of the surface peat deposit at the Comeya depression. (Taken from Ruiz Zapata, M.B., Farias, P, Jiménez Sánchez, M., Gil García, M.J., Dorado Valiño, M. & Valdeolmillos Rodríguez, A. 2001. Secuencia polínica de un depósito de la depresión de Comeya (Picos de Europa, Asturias): implicaciones paleoclimáticas.) (Incomplete sequence, without data between 340 and 485 cm).

More recent investigations include not only carbon-14 dating and pollen analysis, but also organic geochemical studies analysing molecular biomarkers, such as alkanes, ketones, triterpenoids and steroids.

The data on the relative proportions of these molecules throw up information about the types of plants they come from and their abundance, which is particularly useful in many mires where the high degree of humification hinders the identification of the species which generated the peat. (López Días, V. 2013. *Geoquímica orgánica y evolución ambiental de turberas de las rasas costeras asturianas*. Doctoral thesis. University of Oviedo).

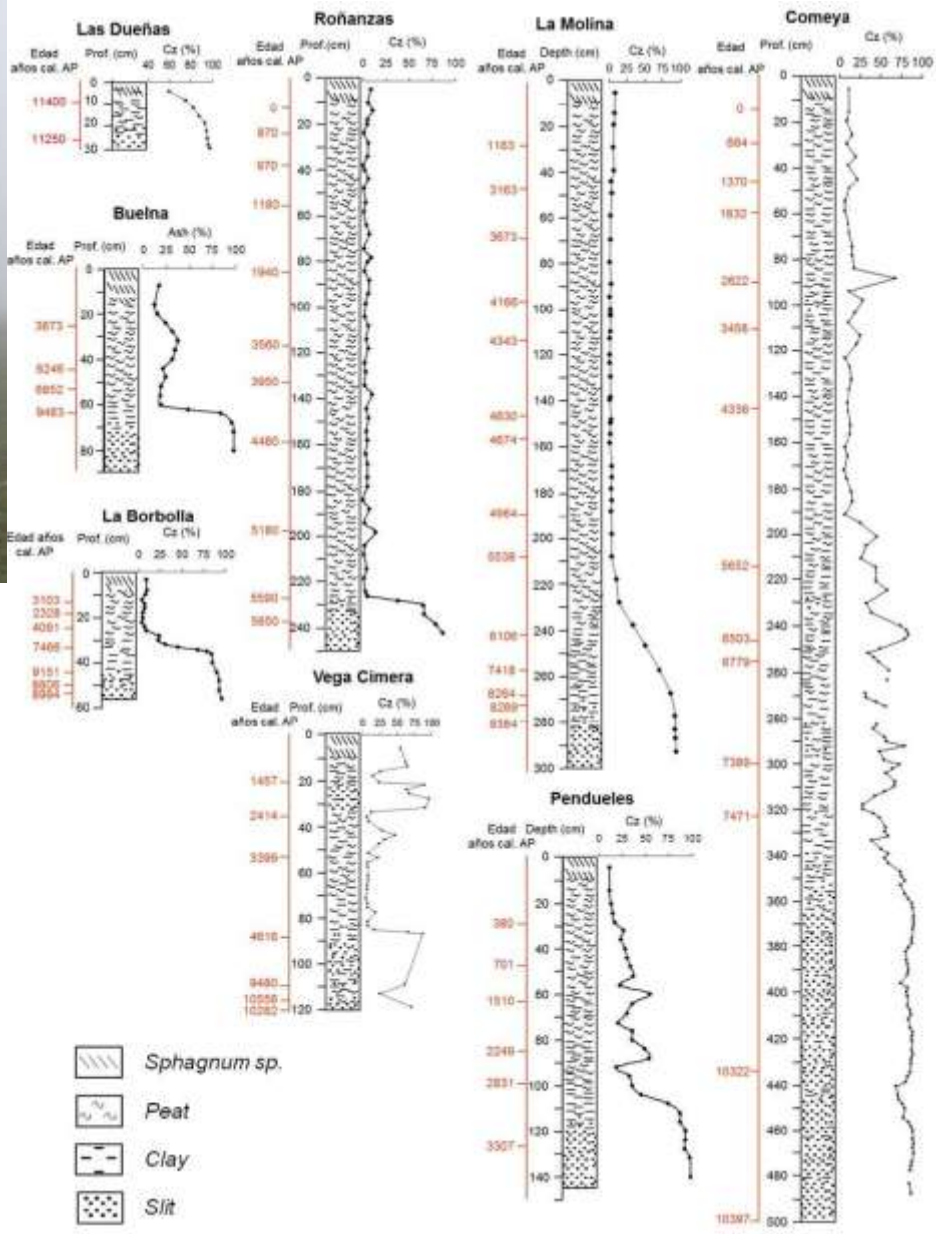
In the project "*Mires as a record of climate change in the Holocene in the Northern Peninsula*", carried out by the National Carbon Institute and the University of Oviedo, 8 mires located at medium-altitude and low sites (Cantabrian Atlantic coastal and sub-montane mires), and in mountainous areas (temperate Orocantabrian mires) in Asturias were studied using organic geochemical and palynological techniques, and macro-remain analysis.

The data obtained from the study reveal that these mires are growing at two different rates (slow growth (0.05-0.1 mm/year) and rapid growth (0.5-0.7 mm/year)) and indicate the existence of two wet periods, dated at 4,000-5,200 and 2,200-3,000 BP. Together with other earlier studies, they point towards intervals with a great deal of vascular plant life in the Mid-Holocene, reflected in high levels of tree pollen, followed by wetter, colder conditions, favouring the development of Sphagnum in the mires.

Coring the 5-metre layer of peat in Comeya (Picos de Europa) in 2011.

Palynological studies are yet to be performed or completed on several mires within this project, including the Comeya mire, where only the pollen remains from the shallowest level of peat have been analysed to date.

The final results of the pollen studies are not expected to be available before the end of the Tremedal project.



Profiles of the different mires with age indication provided by AMS C14 dating and showing mineral matter content in the peat.

(Gómez Borrego, A. (coord.) & Díaz González, T.E. 2012. Las Turberas como registro del cambio climático en el Holoceno del Norte Peninsular. 1: Indicadores basados en biomarcadores moleculares. 2: Estructura e indicadores fitoclimáticos. Informe para la DGICYT, Ministerio de Economía y Competitividad).

To find out more...

The LIFE TREMEDAL project's "Work Group on Peatlands" met in Lugo from the 17th to the 19th of November for a work session focusing on analysis of the different types of peatland found in the north of the Iberian Peninsula. The group consists of scientists, technical officers and managers specialising in wetlands in the north of Spain and other countries in the European Union.

The types of peatlands found in the north of the Iberian Peninsula, the keys and issues involved in their identification and characterisation, management guidelines and potential conservation and restoration actions were discussed at the meeting. Local reference sites of different types of peatland in the mountains in the north of Lugo, in what is known as the Sierra do Xistral, were also visited. This area, which belongs to the Natura 2000 network, is home to the finest examples of blanket bogs found in continental Europe and is both unique and extremely important in terms of biodiversity conservation.

The group visits Serra do Xistral

6th TREMEDAL Technical Committee meeting LUGO

...in Picos de Europa

Germination and cultivation protocols for 20 peatland and wet environment species of interest to the LIFE TREMEDAL project completed.

Following the collection, cleaning and storage of reproductive material of the project's 20 target taxa, and the relevant germination tests having been performed at the Germplasm Bank at the Atlantic Botanical Garden in Gijón, the Germination and Cultivation Protocols for each of the taxa have now been written up.

In addition to including general information on the habitats, distributions and blooming periods of these species, the Protocols also describe the relevant biological features of their seeds (type and weight, method of dispersion and adaptation to the method, type of dormancy, optimum germination temperature, response to temperature alternation, need for light), a set of basic methodological guidelines for propagation (collection period, need for antifungal or other previous treatment, percentage of empty seeds, planting period and depth, average germination time at ambient temperature, vegetative reproduction system and suitable period for reproduction) and different factors to bear in mind regarding cultivation and development (type of container, substratum composition and pH, frequency and type of irrigation, hardness of the water, fertilisation, special requirements, definitive planting period).

With this information, it is possible to develop optimum practices for propagation from seeds and/or vegetative parts, and define the cultivation requirements for each species according to its particular ecophysiology.

...in Galicia

Recovery of priority habitat 7210* Calcareous fens with *Cladium mariscus*. Saw-sedge planted in Ollos de Begonte.

Continuing with the work of the LIFE TREMEDAL project, Ibader technical staff have planted individuals belonging to the species Cladium mariscus in different parts of Ollos de Begonte. The formations of this species constitute the priority habitat Calcareous fens with *Cladium mariscus* (HCI 7210*), which is targeted for recovery within the framework of the LIFE TREMEDAL project. Formations of this kind are relatively frequent on the Galician coast, but the SCI Parga-Ladra-Támoga is the only inland location in the Galician Natura 2000 network where such a habitat can be found, highlighting the importance of the LIFE TREMEDAL project, one of whose objectives is to recover areas with this type of habitat in the region.


Cladium mariscus

The autumn rains continue the work of the LIFE TREMEDAL project

The work carried out at the different sites in the SCI Parga-Ladra-Támoga, the Wetland of Cospeito, Ollos de Begonte and the Island of San Roque, has been completed by the action of the autumn rains, the effects of which are clear to see. The pictures show the effects on a pool on the Island of San Roque.

Endangered species take root at the action sites in Galicia

The work performed at the Wetland of Cospeito (SCI Parga-Ladra-Támoga) to improve different types of habitats of Community interest and, more specifically, that of *Eryngium viviparum* have benefited other aquatic species. Not only have populations of Eryngium viviparum (a priority species in Europe) taken root, but two other endangered species of flora have also been found: Luronium natans and *Pilularia globulifera*, both aquatic plants.

Luronium natans can live in large expanses of water, small pools, rivers and slow-flowing brooks. Spain marks the southernmost boundary of its area of distribution and is home to extremely scattered populations in small areas isolated from one another, leading to the species' inclusion in the Spanish Catalogue of Endangered Species as In Danger of Extinction.

Pilularia globulifera is a fern measuring just a few centimetres (3-15) which spends a good deal of the year under water. There are not many populations in Spain, those in the Terra Chá wetlands being the most noteworthy due to their relative abundance. The plant's state of conservation has led to its being classified as In Danger of Extinction in the Galician Catalogue of Endangered Species.

Luronium natans and Pilularia globulifera (both pictures were taken in action areas in the Wetland of Cospeito)

Researchers from Japan visit the LIFE TREMEDAL project's action sites

Researchers from the Universities of Hokkaido, Tukushima and Obihiro attended the presentation of the project LIFE TREMEDAL as an example of actions which aim to recover and improve wetland habitats. Afterwards, they visited different areas in which the project is being implemented in order to check the results obtained for themselves.

This activity formed part of a set of work and knowledge-exchange days organised for researchers from Japanese universities and their counterparts in Ibader and Proepla.

New population of the endangered damselfly *Coenagrion mercuriale*

The diagnosis and monitoring work on the populations of odonata at the LIFE TREMEDAL wetlands in Navarre coordinated/organised by GAN and the Government of Navarre, and performed by Biosfera Consultoría Medioambiental, is not only throwing up useful information, but also revealing pleasant surprises on the species of damselfly of Community interest *Coenagrion mercuriale*.

This species of damselfly is included in Spain's List of Specially Protected Species and is also listed as "vulnerable" in the Red Book of Invertebrates of Spain. A new population of the species has been located in Argintzu, highlighting the importance of this unique montane wetland in Navarre.

There is extremely little data on its distribution in Navarre because until recently it had not been detected in the community. So the new population will allow us to find out more about and conserve both the species and Navarre's mires.

Collection of plant material

In 2014, plant material belonging to different species was collected from a number of mires and wetlands in Navarre for reproduction in nursery conditions.

Most of the plants were collected in the summer and the beginning of autumn, painstakingly classified and then replanted in growing trays. 100% natural blond peat without additives of any kind was used as substratum.

The trays were placed outdoors in the shade, facing northwest, at the Miluce nursery (Pamplona).

The results have been satisfactory (practically no failures) and some of the plants have grown quite considerably.

These pictures taken at the nursery show the progress made by *Carex echinata and Sphagnum*

The field work performed to survey the area and revise the actions to be carried out as part of Tremedal has led to the discovery of areas with remarkable features:

- **in Okolin**, a Habitat of Community Interest 7140 area has been located interspersed in among the beech wood;

- **in Mendaur**, new clusters of both Soldanella villosa, a plant species listed in the Annexes of the Habitats Directive, and another protected plant in Navarre, *Illecebrum verticillatum*, have been detected.

Collaboration with the rangers service has also led to the discovery of new areas of a plant of great conservation interest, *Carex hostiana*, in Arxuri, and confirmation of the expansion of another species, *Sanguisorba officinalis*, in Jauregiaroztegi since the management of the wetland was adapted to the phenology of the plant (A. Senosiain pers. comm.)

Picture of the area located in Okolin

Restoration work was performed in 2014 in 6 areas of Navarre: Xuriain, Okolin, Maulitx, Arxuri, Belate and Mendaur.

The work was varied in nature and, in general, on a small scale. The remote locations of some of these wetlands, however, meant that the material had to be transported by helicopter (Xuriain and Mendaur).

"The work performed in Xuriain to encourage plant recolonisation in the area is worthy of special mention. The area has been fenced off and natural fibre mesh has been laid to favour the regeneration of vegetation in the most eroded areas. Plans also exist to replant the area with plants reproduced in a nursery and using plants present in nearby areas"

The work was performed by a local social welfare company (TASUBINSA).

Pictures of Xuriain

Left, area affected by fire, erosion, etc.

Right, details of the natural fibre mesh laid in the most eroded areas.

...in the Basque Country,

The DFA performed the following work in 2014:

Purchase of land parcels: The 16 land parcels around the lake planned for purchase were all bought between the end of 2013 and the beginning of 2014. The five largest of these were being used for agricultural production and covered a total of 9.6 hectares. Eight of the parcels, covering a total of 1.3 ha, formed part of the wetland's mires; three parcels, covering a total of 0.9 ha, formed an area of woodland on the steepest slopes alongside the lake populated by holm oaks; the last three parcels, which account for a total of 0.9 ha, had been left fallow and were covered with pastures.

Environmental restoration project and actions: The environmental restoration project for the lake and the land parcels purchased was produced in May 2014, and work began in November. The actions carried out in 2014 were:

1. **Morphological restoration of the lake basin.** The aim is to restore the original basin of the lake at those points where agricultural land meets the base of the lake. First of all, the contours were analysed to located those areas which had been raised to stop or hinder water from the lake flooding the land. Ridges and earth build-ups were identified along the entire shore of the lake adjoining farm land. Transversal test holes were also made across the land to define the original level of the lake, easily identifiable because the soil is dark as a result of the organic matter deposited. This outline guided the depth of excavation required to restore these areas. A total floodable area of some 12,000 m2 was recovered, which will generate reedbed/saw-sedge and mire habitats. These areas were immediately occupied by water from the lake, which has now regained its original physiognomy.

2. **Restoration of vegetation:**

Planting woodland. Holm and Portuguese oaks, together with a selection of shrubs to accompany them, were planted in areas nearest the forest ring, the steepest slopes, covering a total of 17,000 m2. The approximate distribution was: 80% oaks Q fagiea- Q rotundifolia, 10% Juniperus communis, 5% Crategus monogyna, 1% Pinus sylvestris and 4% other shrub species.

Regeneration of lakeside woodland over a total area of some 3,900 m2 in 6 stretches on the edges of the agricultural land on the south shore of the lake by staking willows.

Scattered stands. 18 scattered stands were created to recover and extend the wood coverage of holm and Portuguese oak, and a range of shrubs, consisting of:

40% of the surface	Sowing of *Quercus faginea and Quercus rotundifolia*
40% of the surface	Planting and staking of nurse species
40% of the surface	Planting of species characteristic of holm and Portuguese oak woodland: 45 % *Quercus faginea* 30 % *Quercus rotundifolia* 10 % *Quercus pyrenaica* 5 % *Juniperus communis* 4 % *Crataegus monogyna* 1 % *Pinus sylvestris* .....5 % *other shrub species*

These areas overlap. In all, these stands occupy about 5.200 m^2

Sowing of herbaceous species. Approximately 15% of the agricultural land, the most sensitive areas, is to be sowed using the hay-spreading method or the green remains of local reaping activities, secured in certain places with organic mesh.

Development of herbaceous habitats. Partial enclosure of those fallow parcels with 6210 herbaceous habitats is proposed in order to observe spontaneous development in comparison with areas which are not closed off.

Wild grapevines: Wild grapevines will be planted in the SE area of the lake using the free-standing or staked system. Grapevines will be planted in scattered formation along the lake's brook, next to the trees and shrubs which already exist or those planted.

Vid silvestre: En la zona SE del lago se realizará una plantación de vid silvestre, con formación de viña en parra o en vaso. Se plantarán vides dispersas a lo largo del arroyo del lago, junto a los árboles o arbustos ya existentes o los plantados.

3. Fencing. Perimeter fencing is planned to protect the tree and shrub plantation, and the grassy areas generated by the intervention.
They will also enclose the pre-existing natural areas with shrubs and grassland, and the areas reserved for spontaneous regeneration, which will allow us to compare their development with that of areas open to livestock and wild areas.

4. Pools for amphibians. The characteristics of the lake and the area in general meant that there were no wet sites suitable for the reproduction of amphibians and so two pools fed by up-welling and runoff were created in the parcel south of the lake to encourage amphibians to stay
.

Picture of one of the pools created for amphibians

Tasks remaining for 2015

The small parcel acquired next to the chapel by the lake will, in the future, be used as a **parking area**, integrated into the environment with permeable surfaces aesthetically in line with the landscape, trees and bushes, and a sustainable drainage system which will not have any impact on the local hydrological system.
Perimeter path, walkway and jetty. A possible route for a path on which to complete a walk around the edge of the lake from the chapel and future car park has been proposed. It will include a short wooden walkway section through the edge of the saw-sedge area and, after going round the salt spring, will join up with the path which already exists to the north of the lake, the GR1.
Access to the open water of the lake can be gained from the western shore. Due to the muddy bottom and natural fluctuations in the water level, the plan is to build a simple wooden jetty for the local maintenance and conservation services.

Eryngium viviparum

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