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The vegetation of shallow waters and seasonally inundated habitats (Littorelletea and Isoëto-Nanojuncetea) in the higher parts of the Serra da Estrela, Portugal

by

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Zusammenfassung: Es wird eine Übersicht über die Littorelletea- und Isoëto-Nanojuncetea-Gesellschaften in den Hochlagen der Serra da Estrela gegeben. Elf Phytozönosen werden unterschieden, einschliesslich einer neuen Assoziation und dreier neuen Subassoziationen. Die floristische Zusammensetzung, die Syntaxonomie, die Synökologie und die Verbreitung jeder Vegetationseinheit werden behandelt. Abschließend werden Hinweise zu ihrem Schutz gegeben.

Summary: A survey is presented of the Littorelletea and Isoëto-Nanojuncetea in the upper parts of the Serra da Estrela. Eleven major plant communities are distinguished, including one new association and three new subassociations. All of them are discussed with respect to floristic composition, syntaxonomy, synecology, and distribution. General information on conservation is given.

1. Introduction

The first author visits the Serra da Estrela since 1989 in order to produce a synopsis of its vegetation. So far a major part of the fieldwork has been carried out and publication of the results is in progress (JANSEN 1993, 1994a,b, 1997, 1998, JANSEN et al. 1997, JANSEN & SÉRGIO 1999, subm.).

This paper deals with the seasonally-inundated vegetation of the supra- and oromediterranean belt only. Dwarfrush and Quillwort communities of the mesomediterranean belt were beyond the scope of this study.

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1.1 Topography, geomorphology and climate

The Serra da Estrela is situated in the central-east of the country and holds by far the highest peak (1993 m) of continental Portugal. It constitutes the western part of the Iberian Sistema Central.

The highest plateau of the Serra da Estrela was once covered by an ice-cap and from it several valley glaciers diverged towards the lower areas (VIEIRA & FERREIRA 1998). The geomorphology of some relevant biotopes is directly related to this glacial history, e.g. cirques containing numerous lakes and polished rocks.

The precipitation regime is marked by a clear Mediterranean influence in the annual rhythm and presents interannual and intermonthly irregularities (VIEIRA & MORA 1998). Data from the weather station at Penhas Douradas (alt. 1383 m) show a mean annual precipitation of almost 2000 mm. DAVEAU et al. (1985) calculate a maximum above 2500 mm in the central plateau, a minimum of ca. 1000-1200 mm in the northwest and southeast piedmont areas. Most of the area above 1400 m a.s.l. would receive a mean between 2000 and 2500 mm a year.

The mean annual sunshine at the weather station exceeds 2500 hours and the mean annual temperature is 8,9° C with January being the coldest month (2,4° C) and July the warmest (17,2° C). For more detailed information we refer to VIEIRA & MORA (1998).

1.2 Vegetation and land use

The variety of the climate is expressed by the mosaic of the biotopes joining mainly Mediterranean and Atlantic, but also Continental, Alpine and Boreal phytogeographic elements. The Serra da Estrela is considered a centre of endemic and narrowly distributed taxa (MORENO SAIZ & SAINZ OLLERO 1992). Numerous European plant species attain their southwestern limits here. According to JANSEN (1997) its flora includes about a quarter of the preliminary Portuguese red list of vascular plants (Lopes & Carvalho 1990). The area contains at least 36 habitats of the "Habitats Directive" (JANSEN l.c.), including the seasonally inundated habitats which have priority (Commission Européenne 1995).

Palynological studies show that human impact already started more than 7000 years ago (VAN DER KNAAP & VAN LEEUWEN 1997). The influence of man increased in various steps during several stages finally leading to the disappearance of the original forests.

In general burning and summer grazing are the major factors in the landscape of the central plateau. Here nature kept its oligotrophic character. In this landscape some short-lived communities occur like the Juncetum nanae and monospecific stands of *Molineriella laevis*. *Sparganium angustifolium* may be found in the littoral zone of lakes and small waters. At the margin of these waters and in slow-flowing intermittent rivulets the Fontinalo-Ranunculetum ololeuci occurs. Through the construction of hydro-electrical dams some of the lakes and basins have been transformed in artificial water storage reservoirs. The cirques and ancient glacial valleys host the Holco-Bryetum, both in the oro- and supramediterranean belt.

In the supramediterranean belt, especially in the plateaus of Folgosinho and Videmonte, the still functioning agricultural system shows affinities with the lost heathland culture in the Northwest-European planes. It is in this cultural landscape that fragments of Helodo-Sparganion communities occur as well as Dwarfrush communities like Cicendietum and Molineriello-Illecebretum.

2. Material and Methods

Fieldwork was mostly carried out in summer (1994-1998) at altitudes mostly exceeding 900-1000 m. Consequently communities with early vernal or autumnal development, especially from lower areas were beyond the scope of this study. Relevés were made by the first author according to the Braun-Blanquet method (BRAUN-BLANQUET 1964, WESTHOFF & VAN DER MAAREL 1973). Quantative occurrence was estimated according to the ninefold scale of BARKMAN et al. (1964) transformed to the nine Arabic numerals starting 1 up to and including 9. The relevés were stored in a database with the computer program TURBOVEG (HENNEKENS 1996). In the synthetic phase TWINSPAN (HILL 1979) was used for arranging the relevés into more or less homogeneous clusters. SHIFTTAB (HENNEKENS 1996) has been used for obtaining an optimal classification by relocating relevés and species based both on field knowledge and the literature involved.

Species nomenclature of vascular plants follows Flora iberica as far as issued (CASTROVIEJO et al. 1986-1997), Nova Flora de Portugal as far as issued (FRANCO 1971, 1984, FRANCO & AFONSO 1994), otherwise Flora Europaea 5 (TUTIN et al. 1980), except for *Agrostis truncatula* Parl. subsp. *truncatula* Romero García in Ruizia 7: 137 (1988), *Antinoria agrostidea* f. *agrostidea* and f. *natans* as treated by PINTO DA SILVA (1946) and MENEZES DE SEQUEIRA & DE KOE (1996), *Spergularia rubra* ssp. *capillacea* (Kindb. et Lge.) Rivas Mart. in Anal. Inst. Bot. Cavanilles 21(1): 210 (1963), and *Juncus tenageia* subsp. *perpusillus* Fdez.-Carvajal & Navarro in Pub. Dep. Bot. Fac. Farmacia Salamanca 1: 28 (1979). Lichens are named according to WIRTH (1987), mosses according to FREY et al. (1995), except for *Racomitrium hespericum* Sérgio, Muñoz & Ochyra in The Bryologist 98(1): 112 (1995). Nomenclature of syntaxa generally follows RIVAS-MARTÍNEZ et al. (1994). Missing or deviating names are written at length, only the first time in the text.

3. Results and Discussion

3.1 Littorelletea

The result of the classification is given in table 1 (annex).

3.1.1 BC *Sparganium angustifolium*-[Littorellion]

This is an extremely rare community, which is characterized by the dominance of *Sparganium angustifolium*, only sporadically accompanied by *Antinoria agrostidea* f. *natans* and *Drepanocladus fluitans* (see Tab. 1).

Palynological studies show that once *Isoëtes* sp. was present in some former glacial lakes (VAN DER KNAAP & VAN LEEUWEN 1997). Therefore the stands of *Sparganium angustifolium* may be considered relicts of former *Sparganium-Isoëtes* communities, containing boreal elements. They constitute the westernmost part of the network of five endemic Littorellion communities of some important mountainranges in the Iberian Peninsula (e.g. RIVAS-MARTÍNEZ et al. 1994).

Within Portugal *Sparganium angustifolium* is restricted to the higher parts of the Serra da Estrela. The small-sized stands may be found at the margin of former glacial lakes or other standing waters, always in the oromediterranean belt. Water depth varied from 30 to 150 cm. Mean conductivity was less than 20 μS/cm; pH varied from 5,5 to 6. All of the waters are situated in the granitic part of the mountain. The substratum exists mainly of mineral soil, only little-enriched with fine organic material. BOAVIDA & GLIWICZ (1994) classify the ten largest lakes of the Serra da Estrela as oligotrophic in the trophic state index for lakes (CARLSON 1977).

Zonation of the floating communities starts with stands of *Sparganium angustifolium* in the outer reaches of the littoral zone, followed by the Fontinalo-Ranunculetum antinorietosum with decreasing water depth.

3.1.2 Fontinalo antipyreticae-Ranunculetum ololeuci (lusitanici) Br.-Bl., P. Silva, Rozeira & Fontes 1952 nom. mut. em. Jansen

The Fontinalo-Ranunculetum is characterized by *Ranunculus ololeucos*. *Antinoria agrostidea* is locally a good differential species. In combination with the presence of *Ranunculus ololeucos* (= *R. lusitanicus*) the following mosses may be considered differential species as well: *Drepanocladus fluitans, Fontinalis antipyretica, F. squamosa*, and *Scapania undulata*. Without the prominent presence of vascular plants moss carpets may better be regarded as moss communities, i.c. Fontinaletum antipyreticae Kaiser 1926, Fontinaletum squamosae Hertel 1974 or Scapanietum undulatae Schwickerath 1944.

The original description was based on two incomplete relevés (BRAUN-BLANQUET et al. 1952). In one relevé cover abundance of *Fontinalis* was absent and in the other all cover abundances were absent. In this paper 26 relevés are presented (Tab. 1). Relevé 17 is chosen as lectotype of the association.

Two subassociations are proposed: Fontinalo-Ranunculetum fontinaletosum antipyreticae Jansen subass. nov. hoc loco (Tab. 1, nr. 6-16; lectotype is nr. 12), and Fontinalo-Ranunculetum antinorietosum agrostideae Jansen subass. nov. hoc loco (Tab. 1, nr. 18-32; lectotype is nr. 20). Differential species of the latter are *Antinoria agrostidea* (both forms), *Potamogeton polygonifolius, Juncus heterophyllus, Juncus bulbosus* and *Drepanocladus fluitans*. Differential species of the former are *Fontinalis antipyretica* and *Scapania undulata*.

The association occurs in oligo- to perhaps mesotrophic (in exceptional cases slightly dystrophic) waters. The subass. antinorietosum occurs in stagnant or slow-flowing waters, the subass. fontinaletosum in slowly to moderate-flowing waters. Conductivity is usually low (< 20 µS) with some exceptions. This may be related to excessive road gritting, recently constructed concrete gutters along the national road, and local dumps from an open sewer system near the summit (JANSEN 1997). We have only two measurements of pH (both 5.5). The substratum varies from sand and gravel (both often mixed with fine organic material) to peat or organic sludge.

In peaty situations the Fontinalo-Ranunculetum is replaced by stands of *Carex nigra*, which in turn transgrade into the so-called Junco squarrosi-Sphagnetum compacti Br.-Bl., P. Silva, Rozeira & Fontes 1952. Near springheads the association may be replaced by the Myosotidetum stoloniferae Br.-Bl., P. Silva, Rozeira & Fontes 1952 (JANSEN & SÉRGIO 1999). At lower altitudes in permanent streams with a larger catchment area the association is replaced by rheotolerant stands of *Ranunculus pseudofluitans* (Ranunculetum pseudofluitantis nom. prov.), which may also be accompanied by *Fontinalis*. In fast-flowing flushes at high altitudes the association is replaced by some moss synusiae, mentioned before.

So far the Fontinalo-Ranunculetum is only reported from the Serra da Estrela. The second author observed *Ranunculus ololeucos* growing together with *Antinoria* in the Carris and Marinho lagoons in the Serra do Gerês. Considering the distribution area of both *Ranunculus ololeucos* (PIZARRO 1995) and *Antinoria agrostidea* (MORENO SAIZ & SAINZ OLLERO 1992), the association may be present in the northwestern quadrant of the Iberian Peninsula.

3.1.3. Other assemblages of the alliance Helodo-Sparganion

In the northern part of the Serra da Estrela *Hypericum elodes* mainly grows in seepage areas of irrigated hay-meadows (Molinietalia), sometimes accompanied by *Baldellia alpestris*. In the Serra de Montemuro, situated ca. 75 km NW of the Serra da Estrela, we found stands of *Hypericum elodes* and *Baldellia alpestris* luxuriously mingling with *Potamogeton polygonifolius*, *Juncus heterophyllus* and *Antinoria agrostidea*. Such vegetation can easily be assigned to the Hyperico-Potametum (Tab. 1 nr. 33-37). The area shows a stronger Atlantic influence (s. TELES 1970), and the altitudes of the sampled stands (ca. 1000 m a.s.l.) are more or less the same as those from the Serra da Estrela. The presence of *Baldellia alpestris* is striking. As far as we know, this is the first time that relevés containing this Iberian endemic are published. The number of relevés is too low to assess the position of *Baldellia alpestris*. Therefore it is not clear wether a new subassociation is concerned or perhaps a new association.

The more or less monospecific stands of *Scirpus fluitans* are described as Scirpetum fluitantis. These occurred sometimes in mosaic with the Hyperico-Potametum in the Serra de Montemuro (Tab. 1, nr. 38,39).

Other stands may be described as fragments or basal communities (Tab. 1, nr. 40-49). Stands dominated by *Ranunculus omiophyllus* are assigned to Montio-Cardaminetea (JANSEN & SÉRGIO 1999).

We have no measurements of the water quality. The trophic state may be higher than in the Fontinalo-Ranunculetum, since the Hyperico-Potametum baldellietosum occurs in lower situated areas with usually more accumulation of nutrients and a stronger influence of the agriculture. In the Serra de Montemuro we observed that the stands were partly trampled by cattle.

3.2 Isoëto-Nanojuncetea

The result of the classification is given in table 2 (annex).

3.2.1 Juncetum nanae (Tab. 2, nr. 1-4)

Character-species is *Juncus tenageia* subsp. *perpusillus* (= *Juncus tenageia* f. *nana* P. Cout.). Differential species is *Spergularia rubra* ssp. *capillacea*, a second Iberian endemic. Relevé nr. 4 can be seen as a transition to the Molineriello-Illecebretum (or vice versa).

The stands of the Serra da Estrela can be assigned to the Juncetum nanae typicum, originally decribed from the Sierra de Gredos (RIVAS-MARTÍNEZ 1963). In Spain the association is assigned to the Preslion (RIVAS-MARTÍNEZ et al. 1994). The few relevés of the Serra da Estrela show strong affinities to the Cicendion. Because a small amount of relevés is involved and considering the local character of the study, we choose to follow the opinion of RIVAS-MARTÍNEZ et al. (l.c.).

The Juncetum nanae occurs in seasonally inundated hollows (Portuguese: charcos, poças) in *Nardus* grasslands, which are subjected to summer grazing (sheep mainly, but also goats and cows). The association is well-developed in summer, when the hollows run dry. The presence of the Juncetum nanae in the Serra da Estrela was already noticed by RIVAS-MARTÍNEZ (1981).

3.2.2 Cicendietum filiformis Allorge 1922 (Tab. 2, nr. 5-7)

Characteristic species is *Cicendia filiformis.*

From Spain the closely related Hyperico humifusi-Cicendietum filiformis is reported. It seems that the few relevés from the Serra da Estrela show more affinities with the Cicendietum, the latter being less Mediterranean than the Hyperico-Cicendietum.

From all in this paper described communities of the Cicendion, this is the best example of a "warp-and-woof" community sensu TÜXEN & LOHMEYER (1962). The Cicendietum consists of dwarf plants occupying microsites (the warp) within taller formations (the woof). The micro-stands in question seem to be replaced by grasslands of the Molinio-Arrhenatheretea in the course of the season. This is assumed to happen somewhere by the end of spring or the beginning of summer, depending on the altitude and the fluctuation of the climate.

All three microsites occurred on gentle slopes receiving seepage water, at least during the time of sampling. In a wet-dry gradient they may occupy a small traject in places with favourable moisture contents, which may vary from year to year, indeed depending on the fluctuation of the weather conditions (LEMAIRE et al. 1998). The three microsites concerned are less dependent on the fluctuation of precipitation, because they receive seepage water too, be it intermittent or permanent. In all three sites the soil consisted of loamy sand over metasediment rocks (schist-grauwacke). Altitude varied from 700 to 1070 m, all in areas with extensive grazing.

The Cicendietum is the rarest Dwarfrush community in the study area, the Molineriello-Illecebretum is relatively the most common one.

3.2.3 Molineriello laevis-Illecebretum verticillati Rivas Goday (1953) 1964 nom. mut. (Tab. 2, nr. 8-33)

Of the six characteristic species mentioned by RIVAS GODAY (1964) the following are present: *Illecebrum verticillatum, Hypericum humifusum, Juncus capitatus* and *Radiola linoides. Spergularia rubra* ssp. *capillacea* and *S. rubra* ssp. *rubra* do not occur in the stands originally described from lower mountainous zones in the Extremadura. Therefore a new subassociation is proposed: Molineriello-Illecebretum spergularietosum capillaceae Jansen subass. nov. hoc loco. Lectotype is rel. 8 (Tab. 2). Both subspecies of *Spergularia rubra* are differential species.

According to RIVAS GODAY (1970) the association takes an intermediate position between the Nanocyperion and Cicendion. The Molineriello-Illecebretum spergularietosum may be considered a European south-Atlantic counterpart of the Digitario-Illecebretum Diemont, Sissingh et Westhoff 1940 (= Spergulario rubrae-Illecebretum Sissingh 1957) described from Atlantic to sub-Atlantic parts of the Netherlands and Germany (LEMAIRE et al. 1998, TÄUBER 1999). Analogously *Agrostis capillaris*, a differential species so frequent in the latter, is replaced by the southern closely related *Agrostis castellana*, a differential species, so frequent in the former.

Because of the small amount of relevés involved, a subtype with *Lythrum portula* and *Spergularia rubra* (nr. 28-33) from relatively wetter habitats, is considered a variant only.

Stands of the Molineriello-Illecebretum spergularietosum occur around the edges of pools, rivers, shallow ditches, gravel pits, rye-fields, footpaths, road verges, car tracks, drove-roads, etc.. The (shallow) soils may be bare or sometimes covered with a poorly developed humus layer. They are mostly sandy, sometimes silty and they frequently contain coarse-grained quartz granules, especially with increasing altitude. Periodical inundation or percolation at low water levels is assumed during a considerable part of the rainy season (from October until July). The water mostly comes from direct precipitation or indirectly from run-off, more rarely from seepage. Mostly standing waters are concerned, but sometimes slowly running. The altitude of the relevés varies from 550 up to 1630 m. From all species occurring in the Molineriello-Illecebretum spergularietosum, only *Spergularia capillacea* and *Molineriella laevis* (occasionally *Juncus capitatus*) seem to reach the highest plateaus of the Serra da Estrela.

So far the presence of the Molineriello-Illecebretum spergularietosum is noticed in the Serra da Estrela and in the Serra de Montemuro (Tab.2, nr. 32,33).

3.2.4 BC *Molineriella laevis*-[Cicendion]

In the high plateaus (alt. > 1600 m) *Molineriella laevis* occasionally occurs in open grasslands, but it may form densely populated small-sized stands in shallow hollows on sandy coarse-grained soils, little enriched with fine organic material. These stands are decribed as BC *Molineriella laevis*-[Cicendion] (Tab.2, nr. 34-36).

3.2.5 Holco gayani-Bryetum alpini ass. nov. Jansen hoc loco (Tab. 2, nr. 37-55; lectotype nr. 45)

The Holco-Bryetum is characterized by *Bryum alpinum* in combination with the presence of *Holcus gayanus* and/or *Molineriella laevis*. The association consists of two synusiae. In the perennial moss carpets of *Bryum alpinum* many therophytes may occur, like *Holcus gayanus*, *Molineriella laevis*, *Montia amporitana*, *Sedum maireanum*, *Ornithopus perpusillus*, *Logfia minima*, and *Micropyrum tenellum*. Another characteristic feature is the presence of a large number of geophytes, so typical for Mediterranean Isoetion communities (MOOR 1937). To mention some: *Merendera montana*, *Narcissus bulbocodium*, *Ornithogalum concinnum*, and many rare species, most of which seem differentials (Tab. 2, addenda). From a total of 49 vascular plants 24 are therophytes, 14 geophytes and 11 hemicryptophytes. The vascular plants in the perennial *Bryum* carpets have a typical southern growth rhythm. Some annuals can be observed already in early winter. In early spring the aspect may be formed by the flowered specimens of *Narcissus bulbocodium* and *Crocus carpetanus*. However most species have a late vernal or early aestival maximum, depending on the weather conditions. Then the blond of *Holcus gayanus* is often hiding the green to reddish-brown moss layer of *Bryum alpinum*, which can only be seen then at the fringe of the stands. *Merendera montana* is the last species to flower (medio to late summer).

The Holco-Bryetum is both floristically and ecologically well-defined, but its syntaxonomical position is quite uncertain. In recent syntaxonomical surveys of relatively nearby situated mountains SÁNCHEZ-MATA (1987) and AMOR et al. (1993) consider *Holcus gayanus* a character-species of the Tuberarietea. However, both authors notice its preference of (periodically) inundated habitats. Some species commute from Isoëto-Nanojuncetea to Tuberarietea. This feature was already noticed by Rivas Goday, who proposed a so-called Pre-Isoëtion suballiance within the Agrostion salmanticae for such shuttle vegetation (RIVAS GODAY 1964). A similar shift is known from dune slacks on the Westfrisian islands (WESTHOFF & VAN OOSTEN 1991, p. 228). For the moment it seems the most appropriate way to consider both *Holcus gayanus* and *Bryum alpinum* local character-species of the Isoëto-Nanojuncetea. The clear presence of *Molineriella laevis*, but also the marked presence of the rare *Sedum maireanum*, together with the scattered occurrence of *Radiola linoides* and *Juncus capitatus*, may justify the Holco-Bryetum to be assigned to the Cicendion.

Bryum alpinum acts as a pioneer on open sandy soils in Dwarfrush communities in the Serra da Estrela. However in cirques and higher parts of the glacial valleys it grows extremely well. There it forms cushions in intermittent, slowly percolating flows on warm gently sloped granitic rocks, polished by the ancient glaciers.

From October to July there is a chance of freezing. One day in December 1998, the first author observed that *Bryum* carpets lit by the sun thawed during the day, but shaded carpets stayed frozen. The thawed cushions in question showed hibernating juvenile specimens of *Holcus gayanus* and others. Meltwater influence declines in the course of spring, admitting an increasing influence of rain water. It is then that temperatures of the *Bryum* carpets rise and the vascular plants start to come out, most of them reaching their maximal development from late spring to early summer.

The preponderant rocky environment functions as a storage heater. It affects the microclimate of the Holco-Bryetum by direct thermal conduction and by the radiation of collected solar heat. Temperature extremes are pronounced on rocky surfaces. As long as the moss carpets are soaked, temperature fluctuations stay relatively attenuated (water has a high thermic capacity). A comparison of temperatures measured from June to August during the day in and about 2 m above the moss carpets shows frequently higher temperatures of the air in the beginning against frequently higher temperatures in the moss carpets in the course of the growing season. In July moss carpets may be easily heated more than two times higher than its surrounding atmosphere. Temperatures of 40° C or more are not exceptional then. Desiccation triggers the "shrinking" of the carpet showing a verge of bare rock around it.

A striking characteristic of the Holco-Bryetum is the high number of accidental species, most of which are rare, at least in the Serra da Estrela. This may be the result of the frequent wildfires (JANSEN et al. 1997). For some species the temporarily irrigated Holco-Bryetum functions as a sanctuary. On the other hand the stands occupy more or less natural habitats, calling up associations with the ephemeral flushes from tropical inselbergs described by POREMBSKI (1999). Those habitats often carry a large number of endemics. This also applies to the Holco-Bryetum. A quarter of the vascular plants consists of Iberian endemics, of which *Scilla ramburei* subsp. *beirana* is extremely rare. So far it was known from one confirmed locality only (MORENO SAIZ & SAINZ OLLERO 1992).

Ephebe lanata, Marsupella sphacelata, Racomitrium aciculare and other *Racomitrium* species are transgressive cryptogams from contact communities, which are subjected to both shorter and faster irrigation. *Racomitrium* is represented by at least 12 species in the Serra da Estrela. Many of them can be found growing in intermittent flushes over siliceous rocks. *Ephebe lanata* and *Polychidium muscicola* have a similar ecology in Baden-Württemberg (WIRTH 1987). *Polytrichum commune* may form dense carpets next to the Holco-Bryetum. In such circumstances the substratum consists of a little bit of coarse-grained soil enriched with fine organic material, usually measuring less than a few centimetres thickness. It is assumed that stream velocity is the lowest in such *Polytrichum* populations. Accidental flushes from extremely heavy showers may cause disturbance both in the *Polytrichum* stands and the Holco-Bryetum.

Besides the aforementioned populations of cryptogams, contact communities belong to Asplenietea, Montio-Cardaminetea, Pino-Juniperetea, Calluno-Ulicetea or Cytisetea scopario-striati. Several millennia ago when climax forests still existed, stands of the Holco-Bryetum were perhaps more rare than today. Burning must have triggered the increase of its range. However, its habitats are relatively hostile to tall perennial species. Only an occasional large shrub or tree is assumed to grow in nearby situated rock fissures.

At low altitudes the first author observed a mixed moss carpet of *Campylopus pilifer* and *Bryum alpinum* in which an annual *Sedum* predominated. This *Sedum* may be an undescribed species. The ecology of the stand seems similar to that of the Holco-Bryetum, except for its altitude (550 m). The study should be continued in the lower parts of the Serra da Estrela in order to complete this survey and to solve taxonomic problems.

The Holco-Bryetum occurs in the Serra da Estrela and the Serra da Gardunha. In North-Portugal we observed poorly developed stands in the Serra do Gerês. In herbaria the second author found collections from Asturias containing specimens of both *Holcus gayanus* and *Bryum alpinum.* Considering the range of *Holcus gayanus* (MORENO SAIZ & SAINZ OLLERO 1992) and *Bryum alpinum* (STÖRMER 1969), the Holco-Bryetum may be expected in other parts of the northwest quadrant of the Iberian Peninsula.

3.3 Conservation management

Main causes of vulnerability, threats and main actions to be taken are listed in JANSEN (1997). We stress that the continuation of traditional land-use practices will be the best way to guarantee the conservation of Littorelletea and Isoëto-Nanojuncetea communities. Of course the local farmers and shepherds should be supported by the authorities, also by capitalizing on new developments (organic farming, eco-tourism, cultural heritage protection, ecologically sound water collection, etc.).

The area is roughly covered by the Serra da Estrela Natural Park, which measures about 1000 km^2. The central area (ca. 5 km^2) is a biogenetic reserve, approved by the Council of Europe in 1993. For various reasons an adequate management of the total area is impossible (a.o. logistic problems, small number of employees, many different landowners, many different interests, insufficient legislation, insufficient knowledge, strong human pressure at lower altitudes and the very summit area). At least the major part of the Park should be included in the "Natura 2000 network" (JANSEN 1997). This will raise extra funding in order to improve the quality of its management.

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Tab. 1: Littorelletea communities in the Serra da Estrela

	A	B	C	D	E
Number in table	12345	678911111111112222222222333 0123456789012345678 9012	33333 34567	33 89	4444444444 0123456789
Littorelletea					
Sparganium angustifolium	97777	....	.....	..	....
Ranunculus ololeucos	.....	223568889997999633256677335	.....	..	....
Antinoria natans	.22..	..............522...5577778	62...	6.	...8....58
Antinoria agrostidea	.....	..................95.......	.....	6.	..5.....5.
Potamogeton polygonifolius	.....	....................886....	22925	..	....
Hypericum elodes	.....	....	88222	..	787.......
Scirpus fluitans	.....	....	52...	89	..5.......
Juncus bulbosus	.....	........3...222.2967.2.73..	...2.	..	76.2.82955
Juncus heterophyllus	.....	87	3522.	..	...78.....
Baldellia alpestris	.....	....	...85	..	2...78....
Eleocharis multicaulis	.....	....	.....	..	..7.......
Other classes					
Fontinalis antipyretica	.....	899997667567..5............	.....	..	....
Fontinalis squamosa	.....	........2.....99...........	.....	..	....
Scapania undulata	.....	.222...22.5..2.............	.....	..	....
Carex nigra	.....	3..........2.....2.........	.....	..	....
Sphagnum recurvum complex	.....	.......52...3..............	.....	..	....
Drepanocladus fluitans	.5...	................3559...26..	.....	6.	..2.....86
Sphagnum denticulatum	.....	.......52.......2..3.2.....	.....	..	52
Ranunculus omiophyllus	.....	....	.....	..	.2...22...
Ranunculus cf *peltatus*	.....	....	2..2.	3.	..5.......

Addenda Tab. 1:
A = BC Sparganium angustifolium-[Littorellion]; B = Fontinalo-Ranunculetum; C = Hyperico-Potametum; D = Scirpetum fluitantis; E = fragments or basal communities.

In less than 4 relevés: *Agrostis canina*:40,2; 41,3. *Archidium alternifolium*:38,2; 42,2. *Aulacomnium palustre*:14,2. *Bryum pseudotriquetrum*:21,2. *Callitriche stagnalis*:33,2; 36,2. *Carex echinata*:40,2; 48,3. *Drepanocladus exannulatus*:14,2; 18,7. *Drepanocladus* sp.:20,3. *Eleocharis palustris*:24,2; 48,8. *Galium palustre*:40,2. *Galium* sp.:33,2. *Glyceria declinata*:33,2; 39,2. *Gymnocolea inflata*:22,2. *Hypericum humifusum*:41,2. *Illecebrum verticillatum*:41,2; 42,2. *Juncus acutiflorus*:40,2; 41,3. *Juncus articulatus*:24,2. *Jungermannia gracillima*:14,2. *Jungermannia* sp.:9,2. *Lotus pedunculatus*:41,2. *Lythrum portula*:33,2; 39,5; 48,2. *Marsupella emarginata*:13,2; 14,6. *Marsupella* sp.:16,2. *Marsupella sphacelata*:9,2. *Montia amporitana*:7,6; 8,2. *Myosotis secunda*:45,2. *Myosotis* sp.: 33,2. *Myosotis stolonifera*:7,8; 41,3. *Philonotis seriata*:48,2. *Pohlia elongata*:9,2. *Polytrichum commune*:14,2; 25,2; 48,2. *Racomitrium hespericum*:16,2. *Ranunculus flammula*:33,3; 40,5. *Salix salviifolia* (j):48,2. *Sphagnum capillifolium*:14,2. *Sphagnum* cf *cuspidatum*:29,6. *Sphagnum compactum*:14,2. *Sphagnum* sp.:19,2; 20,2; 41,5. *Sphagnum subsecundum* s.l.:18,3. *Veronica serpyllifolia* ssp. *langei*:6,5; 17,2. *Veronica scutellata*:33,3; 36,2; 40,2. *Viola palustris*:41,2.

Nr. in table, running nr., year, month, utm 29TPE (* = 29TNF in stead), altitude (m), conductivity (µS/cm):

01 624 96 7 178-665 1845 <20	02 625 96 7 184-663 1845 <20	03 628 96 7 185-663 1845 <20
04 627 96 7 185-663 1845 <20	05 888 97 7 170-660 1740	06 393 95 8 174-636 1895 10
07 441 95 8 171-640 1870 15	08 361 95 7 189-647 1870 45	09 383 95 7 173-642 1915 11
10 442 95 8 171-640 1870 15	11 363 95 7 189-647 1870 40	12 364 95 7 189-647 1870 28
13 371 95 7 143-684 1605 25	14 372 95 7 143-684 1605 25	15 382 95 7 174-642 1920 10
16 391 95 7 157-655 1660 13	17 394 95 8 174-636 1895 8	18 452 95 8 171-675 1820 10
19 413 95 8 172-663 1765 11	20 415 95 8 171-663 1750 35	21 430 95 8 159-702 1570 10
22 375 95 7 193-656 1620 9	23 366 95 7 189-647 1870	24 536 96 6 154-700 1480
25 559 96 7 163-700 1620	26 560 96 7 169-699 1620	27 561 96 7 169-699 1620
28 951 98 8 153-663 1790	29 498 96 6 158-692 1640 10	30 626 96 7 184-663 1845 <20
31 570 96 7 209-670 1410	32 571 96 7 209-670 1410	33 939 97 7*590-454 940
34 947 98 7*59 -45 940	35 948 98 7*59 -45 940	36 943 98 7*590-454 960
37 946 98 7*59 -45 1000	38 944 98 7*590-454 945	39 945 98 7*59 -45 1110
40 623 96 7 311-851 1160 10	41 868 97 7 327-849 1080	42 941 98 7*590-454 945
43 572 96 7 209-670 1410	44 949 98 7*59 -45 940	45 933 97 7 312-862 1170
46 934 97 7 312-862 1170	47 742 97 6 195-751 1400	48 537 96 6 154-700 1480
49 889 97 7 170-660 1740		

Tab. 2: Isoëto-Nanojuncetea communities in the Serra da Estrela

Number in table	1234	567	89111111111122222222223333 012345678901234567890123	333 456	3334444444444555555 7890123456789012345
Juncetum nanae (1-4)					
Juncus perpusillus	4645	...	....	...	....
Cicendietum filiformis (5-7)					
Cicendia filiformis	....	443	....	...	....
Molineriello laevis-Illecebretum verticillati spergularietosum capillaceae(8-33)					
Illecebrum verticillatum	....	...	548772............7...2.28	...	....
Hypericum humifusum	....	...	5..5..22..........2.7.2.22	...	....
Spergularia capillacea	6872	...	5.2...522.2522322262......	..6	....
Spergularia rubra	....	...	23222	...	....
d association or syntaxa of higher rank					
Juncus capitatus	...2	425	44....5..644536.....3...2.	...	..........2........
Juncus bufonius	...6	4.2	756.6633.33.75.258..3..23.	...	....2.2...3..2.....
Sedum maireanum	....	...	........6......7..........	...	..2....3..66.......
Mentha pulegium	....	...	...5.2...........2...722..	...	....
Lythrum portula	....	...	237852	...	....
Juncus tenageia	...5	...	.......7.....4.....5....7.	...	....
Radiola linoides	....	.3.	........234...............	...	.3..2..............
BC Molineriella laevis-[Cicendion] (34-36)					
Molineriella laevis	..32	...	3.......4.34...32.........	898	.23333433.63.2.5322
Holco gayani-Bryetum alpini (37-55)					
Bryum alpinum	26.2	352	2....3..2.5.3..53.2.......	.2.	3338999998987879999
Holcus gayanus	....	...	..........2...2......2....	...	7837778786553333...
d from other classes					
Juncus bulbosus	6.52	...	.......2..........2....2.5	...	..............2....
Briza minor	....	22.	....	...	....
Agrostis castellana	...2	352	2.3.35..353222552.2..33..2	...	2................22
Leontodon tuberosus	....	.5.	....2...5.2...22......2...	...	....
Ceratodon purpureus	....	...	3.2.....2.....5...2.2.....	.3.	....
Juncus effusus	....	...	....2..2............352..2	...	.............2.....
Chamaemelum nobile	....	..7	.....2........6..2...2..2.	...	....
Lotus pedunculatus	....	25.	...2..2..2................	...	....
Juncus acutiflorus	....	22.	....3.......2.............	...	....
Ornithopus perpusillus	....	.2.	2.2.....65................	...	25222.2.2..2.......
Montia amporitana	....	...	............2.............	...	.2...532..2.2.22...
Merendera montana	....	...	....	...	2.5.22222..2.2.....
Nardus stricta	2.2.	...	....	...	..2.....2..355.....
Narcissus bulbocodium	....	...	....	...	..2....2.2.2.222...
Ephebe lanata	....	...	....	...	...223..3..2...2...
Sedum anglicum	....	...	....	...	.........2..322.5..
Racomitrium heterostichum	....	...	....	...	222....2....3......
Philonotis seriata	....	...	....	...	....2....23.5......
Racomitrium aciculare	....	...	....	...	..........22...2..2
Polytrichum piliferum	....	...	....	...	25.....3.......2...
Ornithogalum concinnum	....	...	....	...	222....2...........
Companions					
Agrostis truncatula	..2.	2..	22....2.2.22.3.3..........	525	2.2.....22.232222..
Polytrichum commune	82.2	5..	2.3......6..5.3...7.......	...	6.973..2.22336.3...
Polytrichum sp.	..5.	.5.	........7......5..........	...	......3.........2..
Sedum arenarium	....	...	...........2...2..........	..5	........2........26
Anthoxanthum aristatum	....	...	........6.2....3..........	...	2.2.......22......5
Rumex angiocarpus	....	...	...2.......2..............	...	3.......2.......2..
Teesdalia nudicaulis	....	...	........2.................	...	22...2..........3..

Addenda Tab. 2 (in less than 4 relevés)

D. ass. or syntaxa of higher rank within Isoëto-Nanojuncetea:

Scirpus setaceus:5,2; 29,2; 30,5. *Gnaphalium uliginosum*:26,2; 31,5; 32,2. *Pohlia camptotrachela*:8,3; 20,3; 28,7. *Antinoria agrostidea*:26,7; 27,7. *Archidium alternifolium*:2,2. *Anthoceros caucasicus*:28,2. *Riccia beyrichiana*:28,7. *Fossombronia pusilla*: 5,3. *Fossombronia* sp.:16,3. *Juncus pygmaeus*:32,2.

Other species:

Agrostis stolonifera:15,2. *Aira praecox*:17,2;18,2. *Alisma lanceolata*:31,2. *Allium roseum*:38,2. *Alnus glutinosa* seedling:28,2. *Anthemis arvensis*:25,2. *Apium nodiflorum*:12,2. *Arnoseris minima*:16,2; 37,2. *Aulacomnium androgynum*:50,2. *Aulacomnium palustre*:50,2. *Barbula convoluta*:7,2. *Bidens* sp.:12,2; 30,2; 31,2. *Brachythecium albicans*:45,2. *Bromus hordeaceus*:54,2. *Bryum* cf *minii*:7,2. *Bryum pseudotriquetrum*:26,2. *Callitriche* sp.:31,2. *Carex binervis*:15,1. *Carex leporina*:26,5. *Cephaloziella* cf *rubella*:22,2. *Cephaloziella* cf *stellulifera*:16,2. *Cerastium ramosissimum*:19,2. *Cladonia furcata*:38,3; 39,2; 53,2. *Cladonia gracilis*:37,2. *Coelocaulon aculeatum*:37,2; 53,2. *Conopodium majus*:37,2; 38,2. *Corrigiola telephiifolia*:20,2; 26,2; 28,2. *Crassula tillaea*:28,2. *Crocus carpetanus*:50,2. *Cyperus longus*:28,2; 29,6. *Danthonia decumbens*:6,2. *Dryptodon patens*:45,3. *Epilobium obscurum*:17,2. *Epilobium* sp.:28,2. *Erophila verna*:38,3. *Eurhynchium pulchellum*:45,2. *Festuca ampla*:17,2. *Festuca henriquesii*:49,2; 51,2. *Festuca rubra*:21,2. *Filago pyramidata*:13,2. *Fontinalis antipyretica*:50,2. *Gaudinia fragilis*:25,2. *Gladiolus illyricus*:38,2. *Glyceria declinata*:12,6. *Grimmia montana*:46,2. *Grimmia* sp.:48,2. *Herniaria lusitanica*:28,2. *Holcus lanatus*:12,7; 29,3. *Hyacinthoides hispanica*:38,2. *Hypericum linariifolium*:38,2. *Hypnum cupressiforme* s.l.:45,2. *Hypochaeris radicata*:5,2; 38,2; 46,2. *Juncus articulatus*:32,2. *Juncus heterophyllus*:33,2. *Juncus squarrosus*:46,2; 50,2; 52,2. *Leontodon taraxacoides*:13,2. *Linum bienne*:29,2. *Logfia minima*:38,2; 41,2; 53,2. *Marsupella sphacelata*:46,2. *Mentha suaveolens*:11,2; 12,2; 28,2. *Mibora minima*:53,2. *Micropyrum tenellum*:37,3; 53,2; 55,2. *Moenchia erecta* ssp. *erecta*:7,2; 19,3. *Narcissus rupicola*:37,2. *Ornithopus pinnatus*:7,2. *Pedicularis lusitanica*:6,5. *Pedicularis sylvatica*:46,2; 51,2. *Philonotis fontana*:5,2; 49,5. *Philonotis* sp.:20,3; 51,6; 54,2. *Physcomitrium pyriforme*:28,2. *Plantago lanceolatum*:23,2. *Poa annua*:13,2; 15,2; 55,2. *Pogonatum aloides*:49,2. *Polychidium muscicola*: 41,2. *Polygonum aviculare*:11,3; 25,2; 30,2. *Polygonum* sp.:12,2; 31,2. *Polytrichum juniperinum*:20,2; 37,2; 38,6. *Pseudocrossidium hornschuchiana*:7,2. *Pulicaria dysenterica*:29,2. *Racomitrium hespericum*:40,3; 50,2. *Racomitrium macounii*:49,3. *Ranunculus bulbosus* ssp. *alae*:49,2. *Ranunculus muricatus*:54,5. *Ranunculus ollissiponensis* ssp. *ollissiponensis*:38,2. *Ranunculus paludosus*:39,2; 44,2. *Sagina apetala*:28,2. *Salix atrocinerea* (s):31,2; 32,2. *Scilla ramburei* ssp. *beirana*:16,2; 38,5; 44,2. *Sedum brevifolium*:34,2; 53,2. *Sedum pruinatum*:37,5. *Sedum* sp.:28,2. *Serapias cordigera*:16,2. *Serapias lingua*:7,2. *Spergula arvensis*:31,2. *Spergula morisonii*:53,2. *Stellaria alsine*:17,2. *Tortula subulata*:45,2. *Trifolium glomeratum*:13,6. *Trifolium repens*:11,2; 12,5; 26,2. *Ulex minor* (j):18,2. *Vulpia bromoides*:54,2. *Vulpia* sp.:5,2; 19,2. *Wahlenbergia hederacea*:5,2; 6,2. *Xolantha guttata*:5,2; 48,2.

Nr. in table, running nr., year, month, utm 29TPE (* = 29TNP in stead), altitude (m), exposure, inclination (°):

01	389	95	7	152-648	1815			02	411	95	8	182-642	1900			03	420	95	8	182-666	1760		
04	521	96	6	200-761	1360			05	543	96	6	333-852	1070	E	3	06	867	97	7	333-852	1070		
07	660	97	5	413-865	700	E	10	08	845	97	6	210-739	1530			09	292	94	8	218-737	1490		
10	800	97	6	275-832	1310			11	661	97	5	250-783	980			12	791	97	6	307-709	550		
13	853	97	7	261-762	1110	W	1	14	914	97	7	175-755	1320			15	358	95	7	216-727	1495		
16	806	97	6	365-875	1030	S	2	17	915	97	7	175-754	1320			18	935	97	7	310-862	1175		
19	529	96	6	216-737	1490			20	809	97	6	292-832	1100	SE	1	21	306	94	8	199-647	1630		
22	931	97	7	339-913	925			23	872	97	7	363-875	1030	S	4	24	918	97	7	201-750	1400		
25	932	97	7	317-906	740	SW	3	26	535	96	6	153-700	1480	SE	5	27	448	95	8	152-693	1600		
29	711	97	5	277-883	580			30	930	97	7	413-864	700			32	929	97	7	413-864	700	S	3
33	936	97	7	311-890	840	E	3	31	942	98	7	590-454	960			28	938	97	7	590-454	940		
34	796	97	6	176-664	1845			35	828	97	6	140-675	1780	N	1	36	830	97	6	143-685	1600		
37	784	97	6	268-653	1340	E	10	38	724	97	5	250-699	1340	NE	3	39	749	97	6	199-738	1445	W	5
40	425	95	8	201-653	1430	NE	20	41	453	95	8	157-700	1505	W	3	42	540	96	6	145-693	1540	SW	5
43	569	96	7	198-670	1430	SW	5	44	747	97	6	199-738	1445	W	3	45	891	97	7	162-660	1680	S	5
46	414	95	8	172-663	1770	S	1	47	896	97	7	146-657	1500	SW	3	48	531	96	6	155-702	1515	SW	5
49	410	95	8	182-642	1910	SE	55	50	419	95	8	185-668	1660	S	10	51	416	95	8	172-662	1750	SW	30
52	495	96	6	153-663	1800	S	50	53	496	96	6	201-749	1415	NE	5	54	750	97	6	213-738	1520	E	5
55	734	97	6	270-401	1090	N	30																