Proposals for improvement of Annex I of Directive 92/43/EEC: Sardinia

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Abstract

The ‘Habitats’ Directive (HD 92/43/EEC, henceforth: HD) is one of the primary legal tools aiming at conserving nature in Europe. Due to the complex iter to revise it, the habitats listed in the Annex I have been seldom updated after the HD adoption. Basing on already available information and expert knowledge, this paper presents a preliminary list of relevant habitats occurring in Sardinia, not yet considered and worth to be placed in the Annex I. Two new habitat proposals, one habitat new for Italy, and nine new subtypes of already existing HD habitats are here described. Most of the proposed new habitats and subtypes have a limited distribution range, due to the high number of narrow, often endangered, endemic species that characterize them. Being neglected, they are consequently poorly investigated, inconstantly monitored and unprotected. Thus, the main aim of this paper is to promote their conservation through implementation of HD and its interpretation manuals.

Keywords

Annex I habitats, endemic species, European ‘Habitats’ Directive, habitat types, habitat subtypes, Mediterranean Basin, Natura 2000 network, neglected habitats

Introduction

The ‘Habitats’ Directive (92/43/EEC, henceforth: HD) is, together with the Birds Directive (79/409/EEC, amended by Directive 2009/147/EC), the primary legal tool for nature conservation policy in Europe (Maiorano et al. 2017). Since its adoption, it went through several updates and corrections concerning Annex I, which provides a list of the habitats of community interest. These habitats fall into at least one of these criteria: 1) are in danger of disappearance in their natural range; 2) have a small natural range due to their regression or because of their intrinsically restricted distribution area; 3) present outstanding examples of typical characteristics of one or more of the eleven European biogeographical regions (Evans 2010).

The list of habitats should be subject to updates and amendments to accompany technical and scientific progress as established in article 19 of the HD, each time new countries join the European Union (EU; Cardoso 2012). Any changes, both new habitats introduction and names modification of existing habitats require a complex iter with the final approval by the European Parliament and the Council of Ministers. So far, there is considerable reluctance to revise the annexes. Nevertheless, pragmatic solutions have been accepted throughout the years, particularly in biogeographical seminars (Evans 2006). However, several criticisms and approximations remain in interpreting the habitat types caused by the highly heterogeneous description provided by the Interpretation Manual of EU Habitats (European Commission 2013). Indeed
for some of them, we have very detailed information (e.g., 5330); for others, too concise features (e.g., 6220*).

When additional habitats proposed by new member states were close to already listed habitats, the definition of the existing habitat was changed rather than adding a new habitat. EU accepted enlargement and amendment of new habitats for Eastern Europe (2004), Bulgaria, Romania (2007), and Croatia (2016). Some habitats initially considered restricted to one or a few countries are now recognized over a much more comprehensive range. For example, habitat ‘8240 Limestone pavements’ initially considered only in Ireland, the United Kingdom, and Sweden when it joined the EU in 1995, is now recognized in six other countries (updated from Gaudillat 2008).

Despite all these efforts and solutions, some interesting habitats do not appear in Annex I but probably fall within the definition of ‘habitats of community interest’ (Evans 2006). This issue significantly affects the Mediterranean area because the habitat classification is biased towards central and northern Europe. Consequently, many habitats from southern Europe are poorly defined or neglected. Moreover, there are still many problems in the habitat types identification, especially when they do not appear in Annex I of the HD.

Some of the above issues arise from the poor knowledge of the composition or distribution of some habitat types, others from sometimes overlapping types. This paper presents a preliminary list of selected relevant habitats in a Mediterranean region, Sardinia, not yet considered and challenging to be placed in Annex I of the HD. Here we also propose solutions to bring more attention and increase the information to support the monitoring activities on the proposed habitats (Gigante et al. 2016; Bonari et al. 2021).

Considering that the option of establishing new habitat types is generally rejected (Evans 2010), we formulate some proposals to include them in already listed habitats, mainly introducing well-defined subtypes. However, this procedure was not always possible and, in these cases, new habitats have been proposed.

Materials and methods

The selection of habitats of potential conservation concerns was based on bibliographic data, unpublished data, and expert knowledge. In addition, several critical issues have been examined through a shared scientific discussion among authors, including the motivation to include the habitat in the list.

The diagnosis and syntaxonomy started from the current scientific knowledge supported by a long experience acquired in the field, based on the European Interpretation Manual (European Commission 2013) and the Italian Interpretation Manual of the HD (Biondi et al. 2009, 2012). The syntaxonomy has been checked and updated with particular reference to the frame proposed in the Italian Vegetation Prodrome (Biondi et al. 2014; Biondi and Blasi 2015), used as a general base adapted to local conditions in Sardinia.

We considered three different cases: a) new habitat proposals, e.g., habitats not yet considered in the HD; b) habitats new for Italy, e.g., already listed in the HD but not considered for Italy; c) new subtypes in existing HD habitats already reported for Italy.

For each proposal, we detailed the following aspects:
- Motivation of the proposal;
- Macrotype;
- Name the new habitat proposed (case a) or reference to an already existing reference habitat (case b and c);
- Diagnostic sentence of the new habitat (a) or the proposed (c), including biogeographical and bioclimatic information. For the habitats already existing and new for Italy (b), arrangement of the diagnostic sentence;
- Reference list of diagnostic species;
- Phytosociological arrangement (mainly at the alliance level);
- Dynamics and/or catenal contacts.

Plant taxonomy follows Bartolucci et al. (2018).

Results

As a result of our analysis, we present here: a) two new habitat proposals; b) one habitat new for Italy; c) nine new subtypes of already existing HD habitats. We also propose a new name for two of them, better fitting with the proposed subtypes and the new framework (Tab. 1).

a) New habitat proposals

MEDITERRANEAN HEATHS

Motivation: Despite the relevant biogeographical significance recognized to Ericaceae (Schwery et al. 2015) and to the species of the genus Erica (McGuire and Kron 2005; Désamoré et al. 2011), no clear identification exists in the HD for Mediterranean shrubs dominated by heaths (Ojeda 2009; European Commission 2013). In contrast, a wide variety of heath habitats is described under category 4 – Temperate heath and scrub and, particularly, the habitat 4030 – European dry heaths. Due to their historical and present biogeographic relevance (Beffa et al. 2016; Pedrotta et al. 2021), we propose including Mediterranean heaths as a new habitat within the macrotype 52. The communities in this habitat are often unique and rich in plant species endemic and/or with conservation concern, such as Gennaria diphylla and other orchids, and Chamaecops humilis in the thermophilous heaths (Bocchieri and Satta 1999; Biondi and Bagella 2005; Bagella and Urbani 2006); Amelanchier ovalis, Genista spp., Helloborus lividus subsp. corsicus, Ribes multiflorum subsp. sandalioticum and Rosa serafini in the montane heaths (Farris et al. 2007a; Chelli et al. 2019); Osmunda regalis and Hypericum hircinum in the hygrophilous heaths (Carta et al. 2014), among others.
This habitat can be referred to the CORINE biotope F5.22 – Dwarf ericoid shrubs (Lapresa et al. 2004).

**Macrotypes:** 52 - Mediterranean arborescent matorral.

**New habitat proposed:** Mediterranean communities dominated by species of the genus Erica. We recognized in Sardinia four subtypes (1–4).

**Diagnostic sentence:** Subtype 1) calcifuge thermophilous heaths on acidic substrata from thermo- to lower meso-Mediterranean belts; subtype 2) calciphilous thermophilous heaths on sedimentary substrata from thermo- to lower meso-Mediterranean belts; subtype 3) montane heaths from upper meso-Mediterranean to supra-temperate sub-Mediterranean variant) belts; subtype 4) hygrophyllous heaths, from thermo- to supra-Mediterranean belts, along streams, mainly on acidic soils.

**Reference list of diagnostic species:** Subtype 1) Erica arborea, Erica scoparia; subtype 2) Erica multiflora; subtype 3) Erica arborea, Erica scoparia, Genista spp., Rosa serafinii; subtype 4) Erica terminalis, Carex microcarpa, Hypericum hircinum, Osmunda regalis.

**Phytosociological arrangement:** Subtype 1) Ericion arboreae (Rivas-Martínez et al. 1986) Rivas-Martínez 1987; subtype 2) Oleo-Ceratonia siliqueae Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975; subtype 3) Ericion arboreae (Rivas-Martínez ex Rivas-Martínez, Costa & Izco 1986) Rivas-Martínez 1987; subtype 4) Pruno-Rubion umfili O. Bolös 1954 (Rivas-Martínez et al. 2002; Biondi et al. 2014).

**Dynamics and contacts:** Contacts with all other communities involved in the vegetation series: anthropogenic herb-dominated communities of Stellarieta mediae and Polygono-Poeta annuae Rivas-Martínez 1975; fringes of Galio-Urticetea Passarge ex Kopecký 1969 and Trifolio medii-Geranietae sanguineae Müller 1962; dwarf shrub communities of Cisto-Lavanduletea Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 and Rosmarinetalia officinalis Rivas-Martínez, Fernández-González, Loidi, Louss & Penas 2001; shrub communities of Rhamno-Prunetea Rivas-Goday & Borja ex Tüxen 1962 and Querco-illiscis Br.-Bl. ex A. & O. Bolös 1950 (Pistacio lentisci-Rhamnetalia alaterni Rivas-Martínez 1975); woods of Querco roboros-Fagetae sylvaticae Br.-Bl. & Vlieger in Vlieger 1937 and Quercetea ilicis (Bacchetta et al. 2009). The subtypes 1 and 3 are in contact with garrigues of Teucrion mari Gamisans & Muracciole 1984, Cisto-Lavanduletea (including montane aspects referred to Carici-Genistetalia lobelii Klein 1972) (Valsecchi 1994; Farris et al. 2007a); subtype 2 with communities of Rosmarinion officinalis Br.-Bl. ex Molinier 1934 (incl. Rosmarion-Ericion Br.-Bl. 1931); subtype 4 with edaphohyphrophilous woods of Hypericum hircinum-Alnetion glutinosae Dierschke 1975, with a Tyrrhenian distribution (Dierschke 1975; Angius and Bacchetta 2009), and rhizophyte vegetation of Caricion microcarpae Gamisans 1975 (Bacchetta and Mossa 2004).

**CAlaminarian vegetation of mining dumps, tailing dams and quarries**

**Motivation:** Natural revegetated post-mining dumps, tailing dams and quarries may act as important secondary habitats and can be considered a potential complement to existing protected ones (e.g., Angiolini et al. 2005; Řehounková et al. 2020). Due to the extreme and peculiar environmental conditions occurring there, the biological communities established on these substrates are often unique and rich in endemic plant species. Several threatened plants, such as Linum muelleri (a species listed in the Annex II of HD) or Iberis integerrima, are particularly adapted or even exclusive to this habitat. It might also support or be in contact with suitable conditions for different animals of conservation interest, such as birds, bats, amphibians and reptilians (Isaia et al. 2011; Lunghi et al. 2020). At the same time, the conservation and sustainable management of this habitat might facilitate the stabilization and phytoremediation of the contaminated substrata (Bacchetta et al. 2015, 2018; Boi et al. 2020). This habitat is present across Europe in different biogeographic and bioclimatic regions and further several subtypes with different species at the regional level can be included.

**Macrotypes:** 81 – Scree.

**New habitat proposed:** Calaminarian vegetation of mining dumps, tailing dams and quarries. We recognized in Sardinia one subtype.
Diagnosis sentence: Mediterranean communities dominated by suffruticose chamaephytes and hemicyryptophytes, specifically adapted to extreme environments determined by long-term historical mining activities, growing on soils often characterized by medium to very high levels of heavy metals (e.g., lead and zinc). Edaphic conditions can vary from gross-grained, hard-sloping dunes to impermeable and temporarily inundated fine-grained deposits.

Reference list of diagnostic species: Echium anchooides, Epipactis helleborine subsp. tremolisi, Euphorbia pithysa subsp. cupanii, Helichrysum microphyllum subsp. tyrrenicum, Iberis integerrima, Limonium merxmulleri subsp. merxmulleri, Linum muelleri, Lysimachia monelli, Ptilostemon casabonae, Santolina insularis, Scrophularia canina.

Phytosociological arrangement: Ptilostemono casabonae-Euphorbion cupanii Angiolini, Bacch., Brullo, Casti, Giusso Del Galdo & Guarino 2005 and, partially, Teucrion mari Gamisans & Muracciole 1985 (Bacchetta et al. 2007a).

Dynamics and contacts: Contacts with therophytic grasslands of Tubarion guttaeae Br.-Bl. 1931 or, when roots can stabilize soils and the concentration of heavy metals decreases, with garrigues of Cisto-Lavanduletalia Br.-Bl. in Br.-Bl., Molinier & Wagner 1940, shrubs and micro-forests of the Pistacio-Rhamnetalalia alaterni Rivas-Martínez 1975 and Quercetalia ilicis Br.-Bl. ex Molinier 1934 (Bacchetta et al. 2007b). Especially in temporarily inundated fine-grained deposits, it can also be in contact with helophytic communities of Phragmitetalia australis Koch 1926, while, in other contexts, with different rocky habitats and caves.

b) Habitat new for Italy

DUNES WITH EUPHORBIA TERRACINA

Motivation: There is increasing evidence of the continuous loss and degradation of Mediterranean coastal habitats, particularly those located on dunes, affected by severe impacts from mass tourism (Sperandii et al. 2021). Therefore, it is urgent to protect the remnant well-preserved dune habitats and those with average conservation status, supporting future conservation and restoration actions. The Mediterranean formations on dunes with Euphorbia terracina, included in the HD with the code 2220, are a good example of this situation. This habitat has been reported for a single Italian site in Veneto (Petrella et al. 2005). However, it was later wholly excluded from Italy because of its poor conservation relevance (Biondi et al. 2009). Here, we underline the opportunity (previously raised by Farris et al. 2007b) to refer to this habitat perennial herb communities often growing on disturbed Mediterranean dunes (Farris et al. 2013a), characterized by some species already mentioned by the Interpretation Manual of HD (European Commission 2013), and by several Boraginaceae of the genera Echium and Anchusa. This inclusion would justify conservation efforts on semi-degraded Mediterranean dunes, which can be recovered after appropriate management actions.

Macrotype: 22 – Sea dunes of the Mediterranean coast. Reference habitat: 2220 – Dunes with Euphorbia terracina.

Diagnostic sentence: Euphorbia terracina and/or Echium spp. dominated psammophilous communities present in almost all Italian coastal dune systems. Rosette hemicyryptophytes dominated communities represent the prevalent subtype when trampling is a relevant disturbance factor.

Reference list of diagnostic species: Echium arenarium, E. sabulicola, Euphorbia terracina, Silene nicaensis and S. subconica. In Sardinia, the habitat is of particular interest for the endemic Anchusa crispa and A. sardoa, the first being a priority species of the Annex II of the HD.

Phytosociological arrangement: Crucianellion maritimae Rivas Goday & Rivas-Martínez 1958.

Dynamics and contacts: These communities are degraded aspects of Crucianellion maritimae at the transition and often in a patchy contact with annual herb communities belonging to Alkanno-Maresion nanae Rivas Goday ex Rivas Goday & Rivas-Martínez 1963 corr. (Rivas-Martínez et al. 2002; Biondi et al. 2014) and to the CORINE biotope B1.44 – Central-eastern Mediterranean stable coastal dunes (Lapresa et al. 2004). It can also be found in contact with usually very degraded fragments of perennial geophyte communities of Ammophiletea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946.

c) New subtypes in already existing HD habitats

EPHEDRA DISTACHYA MANTLES ON CLAY SUBSTRATES

Motivation: This habitat, very rare and prone to shrinkage due to coastal erosion (Biondi et al. 2009), represents the mantle step dynamically linked to Juniperus spp. communities. In Sardinia, it occurs on fine clay substrates along the coastal ponds or along the temporary retrodunal ponds (Fenu et al. 2012); it deserves a special interest the presence of species that generally live on the sand such as Scrophularia ramosissima and Armeria pungens, interesting taxon both from the phytogeographic and conservation points of view.

Macrotype: 22 – Sea dunes of the Mediterranean coast. Reference habitat: 2210 - Crucianellion maritimae fixed beach dunes. We recognized in Sardinia one subtype.

Diagnostic sentence: Primary garrigues of the Mediterranean bioregion, with few species that develop mainly on the inland-facing slope of mobile dunes with stable and compact sands belonging to Crucianellion maritimae Rivas Goday & Rivas-Martínez 1958.

Reference list of diagnostic species: Ephedra distachya, Helichrysum microphyllum subsp. tyrrenicum, Scrophularia ramosissima and Armeria pungens.
**Phytosociological arrangement:** Partially included in the coenosis described in Sardinia as Ephedro-Helichrysetum tyrrenhenici Valsecchi & Bagella 1991 corr., belonging to Crucianellion maritimae Rivas Goday & Rivas-Martínez 1958 (Biondi and Bagella 2005; Biondi et al. 2014).

**Dynamics and contacts:** These formations are in contact with Juniperus macrocarpa and J. turbinata formations included in habitat 2250*, belonging to the alliance Juniperion turbinatae Rivas-Martínez (1975) 1987, and with the communities dominated by Calamagrostis arae-naria subsp. arundinacea included in habitat 2120 in the inland-facing slopes of mobile dunes on consolidated and humified substrates.

**DWARF VEGETATION WITH NANAN THEA PERPU-SILLA**

**Motivation:** Temporary wet habitats are among the most interesting in the Mediterranean bioclimatic region (Médail et al. 1998). Issues related to their detection and classification are due at least partly to their intrinsic characteristics and to the traits of the plants that they host (Bagella et al. 2016; Bagella et al. 2018). They cover minimal surface areas, are ephemeral, and show high variability in terms of duration of the flooding period. Furthermore, the species which colonize them are often inconspicuous (e.g., dwarf annuals or dwarf geophytes), exhibit a very short life cycle, and are often poorly known (Bagella et al. 2007). Among these habitats, the most interesting from a conservation point of view are those with shallow waters (a few cm) located on small areas, referred to as priority habitat 3170*. However, the description of this habitat refers exclusively to communities of the class Isoeto-Nano-juncetee Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946, thus excluding communities that are structurally similar but develop in small coastal ponds where the marine aerosol reaches. In these contexts, paucispecific communities, characterized by Nananthea perpusilla, develop (Biondi et al. 2001). Although it is already included in the physiognomic reference combination of habitat 3170* (Biondi et al. 2009), the peculiarity of the coenoses in which this species becomes dominant is not sufficiently valued. We, therefore, propose to establish within habitat 3170* a subtype characterized by the presence of slightly brackish water.

**Macrotype:** 31 – Standing water.

**Reference habitat:** 3170* - Mediterranean temporary ponds. We recognize in Sardinia one subtype.

**Diagnostic sentence:** Mediterranean amphibious vegetation, dominated by small-sized therophytes and geophytes, with predominantly winter/early-spring pheno-logy, linked to shallow-water temporary pond systems influenced by the presence of saltwater or marine aerosol, distributed in coastal areas of Sardinia and Corsica prone to thermo-mediterranean thermotype.

**Reference list of diagnostic species:** Nananthea perpusilla, Bellium bellidioides, Hypochaeris globra, Plantago bellardi, Romulea requienii, Senecio leucanthemifolius subsp. leucanthemifolius.

**Phytosociological arrangement:** Saginion maritimae Westhoff, Leeuwen & Adriani 1962, Saginetea maritimae Westhoff, Leeuwen & Adriani 1962.

**Dynamics and contacts:** The communities included in this habitat in Sardinia take part of the coastal signetum Euphorbio characcae-Junipero turbinatae (Biondi et al. 2001; Biondi and Bagella 2005; Pisanu et al. 2014).

**MEDITERRANEAN PRUNO-RUBION COMMUNITIES**

**Motivation:** The Mediterranean formations belonging to the Pruno spinosae-Rubion ulmifolii O. Bolòs 1954 are not adequately considered in the HD. In Sardinia, they are referable to the CORINE biotope +31.8A – Submediterranean vegetation with Rubus ulmifolius (Lapresa et al. 2004). In Sardinia, they deserve a special interest for the presence of several endemics belonging to the genera Rubus and Ribes, which are exclusive to this habitat. Among them, R. sardoum is a priority species of the Annex II of the HD.

**Macrotype:** 51 - Sub-Mediterranean and temperate scrub.

**Reference habitat:** 5130 - Juniperus communis formations on heaths or calcareous grasslands. We recognized in Sardinia one subtype.

**Diagnostic sentence:** shrub deciduous meso-hygrophilous communities of the Pruno spinosae-Rubion ulmifolii of the Mediterranean bioregion.

**Reference list of diagnostic species:** The subtype is of particular interest for the presence of endemic plants belonging to the genera Rubus (R. arrigonii, R. laconensis, R. limbarae, and R. pignattii) and Ribes (R. multiflorum subsp. sandalioticum and R. sardoum).

**Phytosociological arrangement:** Pruno spinosae-Rubion ulmifolii.

**Dynamics and contacts:** It can be in contact with wood communities of Querco roboris-Fagetea sylvatica Br.-Bl. & Vlieger in Vlieger 1937 and Quercetea ilicis Br.-Bl. ex A. & O. Bolòs 1950 (Bacchetta et al. 2009) and with hygrophilous grasslands of the Molinio-Arrenatheretea Tüxen 1937, and woodlands of the Osmunto-Alnion glutinosae (Biondi et al. 2002; Farris et al. 2007a; Biondi et al. 2009).

**SHRUB COMMUNITIES SURROUNDING MEDI- TERRANEAN TEMPORARY PONDS**

**Motivation:** These formations dominated by Myrtus communis and Oenanthe pimpinelloides are very rare transitional formations between Mediterranean temporary ponds and Mediterranean maquis representing a buffer area (Bagella et al. 2009).

**Macrotype:** 53 - Thermo-Mediterranean and pre-steppe brush.

**Reference habitat:** 5330 - Thermo-Mediterranean and pre-desert scrub. We recognized in Sardinia one subtype.

**Diagnostic sentence:** Maquis with sclerophyllous Mediterranean species, characteristic of the thermo-and meso-mediterranean bioclimatic belts, on different substrates (granites and effusive volcanites), typical of hydro-morphic soils with a clay texture and slow drainage.
Reference list of diagnostic species: Myrtus communis, Oenanthe pimineloides, Pistacia lentiscus, Pyrus spinosa, Rubus ulmifolius, Rubia peregrina, Philyrea latifolia, Asparagus acutifolius, Smilax aspera.

Phytosociological arrangement: In Sardinia, this community is referred to the *Oleo-Ceratonion siliquae* Br.-Bl. ex Guinotec & Drouineau 1944 em. Rivas-Martinez 1975, *Calicotomo-Myrtetum* Guinotec in Guinotech & Drouineau 1944 em. O. Bolos 1962 (Farris et al. 2007b).

**Dynamics and contacts:** These formations establish contacts with Mediterranean amphibious vegetation of *Isoeto-Nanojuncetalia* ex Guinotec & Drouineau 1944 and West Mediterranean clifftop vegetation of *Astragalo-Plantaginetum subulatae*. We reported their existence along the coasts of Sardinia. These communities deserve a special interest due to the presence of several endemics such as Polygala sinisica, which is exclusive to this habitat, and other plants of phytogeographic interest, like Polygala rupestris, which, in Italy, is only present in these formations.

**Macrotypes:** Semi-natural grasslands host high levels of plant diversity and habitat richness at different spatial scales (Biurrun et al. 2021), responding to different drivers such as grazing intensity, soil and topographical variables (Napoleone et al. 2021). Moreover, they support several ecosystem services (Bagella et al. 2020a). Mediterranean semi-natural grasslands are already included in the HD with the priority code 6220* ‘Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea’ but only one and half rows of explanation in the Interpretation Manual of EU Habitats is provided for Italy: “In Italy this habitat mainly exists in the South and on the islands (Thero-Brachypodietea, Poetea bulbosae, Lygeo-Stipeetea)” (European Commission 2013). Several interpretations were proposed because of the scarcity of information and the complexity of recognizing this habitat in the field (Farris et al. 2007c, San Miguel 2008). Moreover, the class *Thero-Brachypodietea* Br.-Bl. in Br.-Bl., Emberger & Molinier 1947 is now considered as a synonym of the class *Lygeo-Stipeetea* Rivas-Martinez 1978 (Rivas-Martinez et al. 2002; Biondi et al. 2014). Later, new contributions provided experimental and phytosociological evidence to discriminate pastures with conservation concern, belonging to *Poetea bulbosae* Rivas Goday & Rivas-Martinez in Rivas-Martinez 1978, from nitrophilous herb-dominated communities, belonging to *Stellarioetalia mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951 (Farris et al. 2010). The high conservation value of supra-mediterranean and supra-temperate sub-mediterranean humid pastures referred to the *Cynosurion cristati* Tüxen 1947 of the *Molinio-Arhenatheretea* Tüxen 1937 was also underlined (Farris et al. 2013b). Therefore, we propose changing the name of the habitat to “Mediterranean semi-natural grasslands” in which several subtypes can be considered.

**Macrotypes:** Semi-natural dry grasslands and scrubland facies.

**Reference habitat:** 62 - Semi-natural dry grasslands and scrubland facies.

**New name proposed:** Mediterranean semi-natural grasslands. We recognized in Sardinia five subtypes (1–5).

**Diagnostic sentence:** Thermo- to supra-mediterranean (up to supra-temperate sub-mediterranean), mostly open, annual and perennial grasslands. Subtype 1) Short-grass annual grasslands rich in therophytes and small geophytes on oligotrophic soils; subtype 2) thermo-mediterranean arid to dry, tall size, perennial grasslands; subtype 3) meso-mediterranean dry to subhumid, medium size, perennial grasslands; subtype 4) thermo- to supra-mediterranean (up to supra-temperate sub-mediterranean) pastures rich in therophytes and geophytes; subtype 5) supra-mediterranean to supra-temperate perennial grasslands, rich in endemics and boreal-temperate taxa.
**Reference list of diagnostic species**: Subtype 1) Brachypodium distachyon, Tuberaria guttata; subtype 2) Hyparrhenia hirta, Lygeum spartum; subtype 3) Brachypodium retusum, Dactylis glomerata subsp. hispanica; subtype 4) Poa bulbosa, Ranunculus paludosus, Trifolium subterraneum (in Sardinia Crocus minimus, Ornithogalum chorisum and Romulea requienii differentiate the endemic sub alliances Ornithogalo corsici-Trifolejion subterranei Farris, Rosati, Secchi & Filigheddu, 2013); subtype 5) Agrostis capillaris, Cynosurus cristatus, Danthonia decumbens, Festuca morisiana subsp. morisiana, Lotus corniculatus subsp. alpinus, Oenanthe lisa, Ramunculus corderi. Each subtype can be referred to one or more CORINE biotopes: subtype 1) E1.A - Mediterranean arid grasslands, from acridophilous to neutrophilous, with low cover; subtype 2) E1.42 - Lygeum spartum steppe and E1.43 - Mediterranean steppe dominated by tall Graminaeae; subtype 3) E1.31 - western-Mediterranean xeric grasslands; subtype 4) E1.32 - south-western-Mediterranean stable pastures; subtype 5) E1.51 - montane supra-mediterranean steppe, E1.72 - grasslands with Agrostis spp. and Festuca spp. and E2.14 – multi-specific communities of flooded grasslands (Lapresa et al. 2004).

**Phytosociological arrangement**: Subtype 1) Helianthemetalia guttatai (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martinez 1963 em. Rivas-Martinez 1978; subtype 2) Lygeo-Stipetea; subtype 3) Brachypo dio ramosi-Dactyletalia hispanicae Biondi, Filigheddu & Farris 2001 (Artemisietea vulgaris Lohmeyer, Preising & Tüxen ex von Rochow 1951); subtype 4) Poetea bulbosae; subtype 5) Cynosurion cristati (Molinio-Arrhenatheretea) (Farris et al. 2007c, 2013).

**Dynamics and contacts**: The communities included in this habitat take contact with all other communities involved in the vegetation series: annual anthropogenic herb communities of Stellariochea mediae and grasslands of Polygono-Poetalia annuae Rivas-Martinez 1975; fringe communities of Galio-Urticetea Passarge ex Kopecký 1969 and Trifolio medii-Geranietae sanguinei Müller 1962; dwarf shrub communities of Cisto-Lavanduletalia Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 and Rosmarinetalia officinalis Rivas-Martinez, Fernández-González, Loidi, Lousá & Penas 2001; shrub communities of Rhamno-Prunetea Rivas-Goday & Borja ex Tüxen 1962 and Quercetea ilicis Br.-Bl. ex A. & O. Bolós 1950 (Pistacio lentiscus-Rhamnetalia alaterni Rivas-Martinez 1975); wood communities of Querceto roboris-Fagetea sylvaticae Br.-Bl. & Vlieger in Vlieger 1937 and Quercetea ilicis Br.-Bl. ex A. & O. Bolós 1950 (Bacchetta et al. 2009).

**MEDITERRANEAN WOODED PASTURELANDS**

**Motivation**: Shade is a biotic filter and, under a novel climate, we need to consider the presence or absence of forest shade, as species are likely to respond individually only within their forest or non-forest biome, and not across biomes (Pausas and Bond in press). Mediterranean dehesas with evergreen Quercus spp., already included in the HD with the code 6310, are well known to provide high levels of biodiversity (Rossetti et al. 2015) and ecosystem services (Seddaiu et al. 2018). However, there is increasing evidence that wooded pastures belong to several phytosociological types (Bergmeier et al. 2010). Moreover, the highest diversity and area of Italian silvopastoral systems (wooded pastures, grazed woodlands) is in Sardinia (Paris et al. 2019). Therefore, we propose changing the name of the habitat to “Mediterranean wooded pasturelands” in which several subtypes can be included. As a consequence, the macrotype 63 – Sclerophyllous grazed forests should be expanded as “Wooded pasturelands”, to host several habitats corresponding to the main groups proposed by Bergmeier et al. (2010): Hemiboreal and boreal wood-pastures, Nemoral old-growth wood-pastures, Nemoral scrub and coppice wood-pastures, Meridional old-growth wood-pastures = Mediterranean wooded pasturelands. Meridional scrub and coppice wood-pastures.

**Macrotypes**: 63 - Sclerophyllous grazed forests (dehesas). **Reference habitat**: 6310 – Dehesas with evergreen Quercus spp.

**New name proposed**: Mediterranean wooded pasturelands. We recognized in Sardinia five subtypes (1–5).

**Diagnostic sentence**: Mediterranean wooded pasturelands with at least 20% tree cover. When at least 25% of the trees can be considered monumental, the habitat should have a priority status.

**Reference list of diagnostic species**: Subtype 1) wooded pasturelands dominated by evergreen Quercus spp.; subtype 2) wooded pasturelands dominated by wild olive and carob trees; subtype 3) wooded pasturelands dominated by junipers; subtype 4) wooded pasturelands dominated by deciduous oaks; subtype 5) wooded pasturelands dominated by other trees, on small areas but with high phytogeographic meaning (Acetum, Celtis, Fraxinus, Ilex, Ostrya, Taxus). All these subtypes can be referred to the CORINE biotope E7.3 – Iberian wooded pasturelands (dehesa) (Lapresa et al. 2004).

**Phytosociological arrangement**: Subtype 1) Clemati dio cirrhosae-Quercion ilicis Bacchetta, Bagella, Biondi, Farris, Filigheddu & Mossa 2004 of the alliance Fraxino orni-Quercion ilicis Biondi, Casavechia & Gigante 2003; subtype 2) Oleo-Ceratonion siliquae Br.-Bl. ex Guinchoet & Draineau 1944 em. Rivas-Martinez 1975; subtype 3) Juniperion turbinatae Rivas-Martinez 1975 corr.; subtype 4) suballiance Paeonio corsicae-Quercion ichnusae Bacch., Biondi, Farris, Filigheddu & Mossa 2004 corr. of the alliance Pino calabricae-Quercion congestae Bruullo, Selci, Siracusa & Spampinato 1999; subtype 5) several alliances included in the classes Querceto roboris-Fagetea sylvaticae Br.-Bl. & Vlieger in Vlieger 1937 and Quercetea ilicis Br.-Bl. ex A. & O. Bolós 1950 (Bacchetta et al. 2009). The pasture communities are included in Echino plantaginei-Galactition tomentosae O. Bolós & Molinier 1969 of Stellariochea mediae Tüxen, Lohmeyer & Preising ex von Rochow 1951, and Ornithogalo corsici-Trifolejion subterranei Farris, Secchi, Rosati & Filigheddu 2013 of Poetea bulbosae Rivas Goday & Rivas-Martinez in Rivas-Martinez 1978 (Farris et al. 2013b).
Dynamics and contacts: The communities included in this habitat take contact with all other communities involved in the vegetation series: annual and perennial herb communities of the Helianthemetalia guttati (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martinez 1963 em. Rivas-Martinez 1978, Poetalia bulbosae Rivas Goday & Rivas-Martinez in Rivas-Martinez 1978, Molinio-Arrhenatheretalia Tüxen 1937 and Stellario-Assietaelia Tüxen, Lohmeyer & Preisng ex von Rochow 1951; fringe communities of Galio-Urticeta Passarge ex Kopecký 1969 and Trifolio medi-leranietalia sanguinei Müller 1962; dwarf shrub communities of Cisto-Lavanduletalia Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 and Rosmarinetalia officinalis Rivas-Martinez, Fernández-González, Loidi, Lousá & Penas 2001; shrub communities of Rhamno-Prunetalia Rivas-Goday & Borja ex Tüxen 1962 and Quercetalia ilicis Br.-Bl. ex A. & O. Bolós 1950 (Pistacio lentisci-Rhamnetalia alaterni Rivas-Martinez 1975); wood communities of Querco roboris-Fagetea sylvatica Br.-Bl. & Vlieger in Vlieger 1937; and Vlieger in Vlieger 1937 and Quercetalia ilicis Br.-Bl. ex A. & O. Bolós 1950 (Bacchetta et al. 2009).

MEDITERRANEAN TALL HUMID HERB GRASSLANDS

Motivation: Part of the Mediterranean tall humid herb grasslands, especially in the western part of the basin, cannot be included in the presently described habitat 6420, although they share several species and have a similar physiognomic structure, ecology and distribution of the grasslands of the Molinio-Holoschoenion (=Agrostio stoloniferae-Scirpoidion holoschoeni De Foucault 2012). They are indeed differentiated by taxa, such as Hordeum bulbosum or the rare Ranunculus macrophyllus. Therefore, they are attributable to Gaudinio fragilis-Hordeion bulbosi Galán, Deil, Haug & Vicente 1997, within the same Molinio-Arrhenatheretalia Tüxen 1937 class. These communities are the habitat where a wide range of arthropods and the herpeto-avifauna live, feed and breed. Some geophytes of conservation concern in Sardinia are also frequent, such as Anacamptis laxiflora and Leucojum aestivum subsp. pulchellum. The conservation value of these grasslands has also been underlined for the Iberian and Italian peninsulas (Deil et al. 1997; Cano-Ortiz et al. 2009). The habitat 6420 is shrinking mainly due to the abandonment of traditional extensive grazing practices and/or land reclamation (Gigante and Buffa 2016). Here, we propose changing the habitat’s name to ‘Mediterranean tall humid herb grasslands, especially in the western Mediterranean, in inland hills and plains, mainly within the meso-Mediterranean thermotype.

Reference list of diagnostic species: Phalaris coerulescens, Hordeum bulbosum, Anacamptis laxiflora, Ranunculus macrophyllus, Leucojum aestivum, Carex divisa, Carex otrubae, Anthoxanthum aristatum, Serapias spp., Lythrum salicaria.

Phytosociological arrangement: Gaudinio fragilis-Hordeion bulbosi.

Dynamics and contacts: The persistence of this subtype is, similarly to the rest of the habitat 6420, affected by non-intensive grazing. Without such agro-pastoral activities, these would be replaced by meso-hygrophilous shrub communities, such as the ones referable to the alliance Ulmus, Fraxinus and Populus spp. The subtype is in topographic contact with most of the helophytic plant communities reported for the rest of the habitat in the Italian Manual (Biondi et al. 2009). In inland Sardinian contexts, it is also often in contact with mesophilous cork-oak series on alluvial clay soils (Bacchetta et al. 2009).

RHAMNUS PERSICIFOLIA WOODLANDS

Motivation: The habitat 91E0* includes alluvial, riparian and marshy woodlands dominated by Alnus spp., Fraxinus excelsior, F. oxycarpa and Salix spp. It develops on flooded alluvial soils: along the waterways in the mountains and hilly sections; in the plain or on the shores of lakes and in areas with water stagnation. It prefers a temperate macroclimate, but penetrates also into the Mediterranean, where the humidity is high. It is present in almost all Italian regions; being more frequent in the Alpine and Continental bioregions and more sporadic in the Mediterranean bioregion, where it is quite common only in Tuscany, Sardinia and Calabria. The proposed subtype, endemic to Sardinia, deserves a particular interest for the restricted distribution limited to the mountain areas of central Sardinia and for its uniqueness due to the presence of several narrow endemic plants. In Sardinia, the proposed subtype and another subtype, which includes the western Mediterranean riparian forests with Alnus glutinosa (Osmundo-Alnion glutinosae alliance defined by the Corine code 44.5; Biondi et al. 2009), would contribute characterizing the habitat 91E0* in detail, including woodlands of extreme conservation interest.

Macrotypes: 91 - Forests of temperate Europe.

Reference habitat: 91E0* Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae). We recognized in Sardinia one new subtype.

Diagnostic sentence: Sardinian endemic meso-hygrophilous woodlands of the Mediterranean region dominated by Rhamnus persicifolia.

Reference list of diagnostic species: This subtype is of particular interest for the presence of many Sardinian endemic vascular plants belonging to the genus Aquilegia (A. barbaricina, A. nugorensis) as well as other rare
endemics such as Rhamnus persicifolia and Ribes multiflorum subsp. sandalioticum.

**Phytosociological arrangement:** Pruno spinosae-Rubion ulmifolii O. Bolòs 1954.

**Dynamics and contacts:** As reported in the study of Sardinian woodland dominated by Alnus glutinosa (Angius and Bacchetta 2009) and the Italian interpretation manual of the 92/43/EEC Directive Habitats (Biondi et al. 2009).

**Discussion and conclusions**

This research aims to present a preliminary list of valuable vegetation types occurring in Sardinia and not currently adequately represented in any of the habitat types listed in Annex I of the HD, as a base to promote actions for their conservation.

Our proposals for improving the HD result from a careful review of the plant communities present in Sardinia based on already available information and expert knowledge.

Considering that any changes to Annex I, both new habitats and changes to the names of existing habitats, require a co-decision of the EU parliament and the council of ministers, these solutions are only applied if strictly necessary. Therefore, whenever possible, we defined new subtypes as this is the most preferable and feasible solution.

As expected, given the high number of endemic plant species that characterize the vascular flora of Sardinia, the proposed new habitats and subtypes mainly answer to the 'restricted distribution' criterion, which is one into which a habitat must fall to be a candidate to be included in the HD (Evans 2010). Thus, the narrow size of the habitats/subtypes proposed is mainly dependent on endemic plant species with very restricted distribution areas. Indeed, out of more than 100 taxa listed in the 'physiognomic reference combination', 34 are endemic. Of these, 20 are exclusive to the Sardinian flora (Arrigoni 2006-2015; Peruzzi et al. 2014; Bartolucci et al. 2018; Bagella et al. 2020b).

It is also worthy of attention that five species mentioned here, i.e. Anchusa crispa, Centaurea horrida, Helianthemum caput-felis, Linum muelleri and Ribes sardoum are included in the Annex II of the HD. Further animals from the same list might also benefit from the conservation of the proposed habitats and subtypes. Special attention should be thus paid to the habitats in which they develop.

The two new proposals are finalized to consider 'Mediterranean heath' and 'calaminarian vegetation of mining dumps, tailing dams and quarries' as new habitats, which cannot be included in any existing typologies. We suppose that 'calaminarian vegetation of mining dumps, tailing dams and quarries' is also present in other European areas with different floristic composition. Our proposal may be enlarged by adding several bioclimatically and biogeographically differentiated subtypes. The same new habitat might also include abandoned quarries, a similar context where communities of conservation interest were already depicted in several European countries (e.g., Mota et al. 2004; Gentili et al. 2011; Pitz et al. 2018). Also 'Mediterranean heaths', due to their peculiar and diversified composition, deserve in our opinion the inclusion in the HD as a new habitat with four different subtypes, defined according to their different soil and wetness conditions. The Sardinian Pruno-Rubion communities were instead proposed as a Mediterranean mesophilous subtype of the habitat 5130, with which share similar structural and ecological characteristics but a different floristic composition, enriched by the presence of some species of particular conservation interest. Other proposals regard specific transitional habitats, which are very vulnerable and often neglected for their peculiar position. It is the case of 'Dunes with Euphorbia terracina', already considered in Europe but not yet in Italy, 'Ephedra distachya mantles on clay substrates', 'Dwarf vegetation with Nananthea perpusilla', and 'Shrub communities surrounding Mediterranean temporary ponds'.

This last case is a straightforward example of the problematic attribution of transitional communities to an already existing reference habitat. 'Shrub communities surrounding Mediterranean temporary ponds' are in fact a transitional subtype between thermo-xerophilous conditions, which are typical of the habitat '5330 - Thermo-Mediterranean and pre-desert scrub', and the seasonally inundated conditions that characterize the surrounded habitat '3170* - Mediterranean temporary ponds'. For the similar structure, distribution and shared species, 'Shrub communities surrounding Mediterranean temporary ponds' were thus debatably referenced as a subtype of the habitat 5330, despite their different ecology linked to moist conditions.

It is also challenging to solve the definitions of Mediterranean semi-natural grasslands and Mediterranean tall humid herb grasslands. Therefore, we identify different subtypes for these typologies and propose a new name for the two corresponding habitats (i.e., 6220* and 6420), typical examples of the brevity of description and scarcity of information given for many habitats by the Interpretation Manual (European Commission 2013). As far as wooded pastures are concerned, we hypothesized a more inclusive vision and not only limited to the presence of evergreen oaks, following previous authors (Bergmeier et al. 2010). However, even this vision necessarily implies a change in the name of habitat 6310 (and probably the macro-type 63).

Among the direct and concrete consequences of the failure to consider our proposals, the following should be the more relevant: they will not be mapped in the Natura 2000 network areas; they will not be targeted by specific measures; their conservation status will not be subject to the mandatory periodic monitoring and reporting actions under Article 17 of the HD; they will not be protected through the establishment of specific conservation areas.

Although we formulated our proposals looking at the regional scale, we expect many of our observations to reflect common situations in the Mediterranean area. We hope that synergies with other territories can strengthen them.
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