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Thoughts on the ecology and syntaxonomy of some vegetation typologies of the Mediterranean coast

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Abstract
We here present and discuss some considerations around the syntaxonomic collocation of the vegetation that has developed along both the sandy and rocky coasts of the Mediterranean. In particular, for the sandy coasts, after a consideration of the general distribution of the various vegetation typologies of the dune systems, there is an analysis of the ecological and syntaxonomic aspects of the chamaephitic vegetation of the alliance *Crucianellion maritimae*. This concludes that this alliance cannot be attributed to the class *Ammophiletea*, as has been recently proposed in the introduction to the vegetation of Spain and Portugal, but to the class *Helichryso-Crucianelletea maritimae*. For the vegetation of the rocky cliffs, after the presentation of its distribution according to a general scheme, the aspects of the rupicolous halotolerant vegetation that are proposed to be included in the new order *Senecetalia cinereae*, for which the type is the alliance *Anthyllidion barbae-jovis*, will be discussed in detail. The other aspects of the rocky vegetation that are discussed are those regarding the primary and subprimary garrigue of the summit sectors of the coast of the order *Helichrysetalia italici*, within which the creation of a new alliance *Helichrysion litorei* is proposed, which includes the garrigue of southern Italy.

Key words: *Crucianellion maritimae*, phytosociology, *Helichrysion litorei*, Mediterranean, *Senecetalia cinereae*, coastal vegetation.

Riassunto
Considerazioni sull'ecologia e la sintassonomia di alcune tipologie di vegetazione costiera mediterranea. Vengono presentate e discusse alcune considerazioni sulla collocazione sintassonomia della vegetazione che si sviluppa sulle coste, sia sabbiose sia rocciose, del Mediterraneo. In particolare per le coste sabbiose, dopo un accenno sulla distribuzione generale delle diverse tipologie vegetazionali nei sistemi di dune, vengono approfonditi gli aspetti ecologici e sintassonomici della vegetazione camefitica dell'alleanza *Crucianellion maritimae*, concludendo che questa non può essere attribuita alla classe *Ammophiletea*, come recentemente proposto nel prodromo della vegetazione di Spagna e Portogallo, ma alla classe *Helichryso-Crucianelletea maritimae*. Per la vegetazione delle falesie rocciose, dopo la presentazione della distribuzione di questa secondo uno schema generale, vengono discussi approfonditamente gli aspetti della vegetazione rupicola alo-tollerante che si propone di inquadrare nel nuovo ordine *Senecetalia cinereae*, il cui tipo è l'alleanza *Anthyllidion barbae-jovis*. Gi altri aspetti della vegetazione rocciosa che vengono discussi sono quelli riguardanti le gariche primari e subprimarie del settore sommitale delle coste dell'ordine *Helichrysetalia italici*, nell'ambito del quale si propone l'istituzione della nuova alleanza *Helichrysion litorei*, inquadrante le garighe dell'Italia meridionale.

Parole chiave:*Crucianellion maritimae*, fitosociologia, *Helichrysion litorei*, Meditteraneo, *Senecetalia cinereae*, vegetazione costiera

Introduction

The coastal vegetation develops under conditions that are at the limits of the possibility of vegetal life. The main ecological factors that influence the coastal biotypes are: the salinity, the dryness, the winds, the lack of soil and sometimes the mobility of the substratum. In these environments, small variations in the geomorphology of the biotypes can therefore cause considerable variations in the main ecological factors. This can result in environments that are particularly different for both the sandy and the rocky areas, even if they are but a few centimetres apart along the same coast; they can thus be colonised by communities and organisms with significantly different ecological niches.

A careful phytosociological analysis of the coastal biotypes allows the recognition of these microhabitats in which vegetal communities are found, defining them according to their exact floristic composition, along with the variation in ecological factors that characterise their ecological niche. The associations that are found under these conditions are typically stenotope, being characterised by a limited ecological valence. They can therefore be considered to be very good bioindicators, as their distribution reveals the complexity of the sites in which they live and allows the characterisation of these in ecological terms (Biondi & Géhu, 1994; Andreucci *et al.*, 2000; Biondi & Zuccarello, 2000; Biondi, Feoli & Zuccarello, 2004).

The syntaxonomic collocation of the individual coastal communities is obviously a consequence of these variations, meaning that also along a limited section of the coast it is possible to find associations that can be referred to very different higher level syntaxa. On this basis, the intention is to present syntaxonomic proposals that help to clarify the position of the communities from the various microhabitats within sectors of the coastal vegetation. This applies both to the beach and to the

cliffs, taking into account the structural and floristic composition of these communities and their specific ecological characteristics.

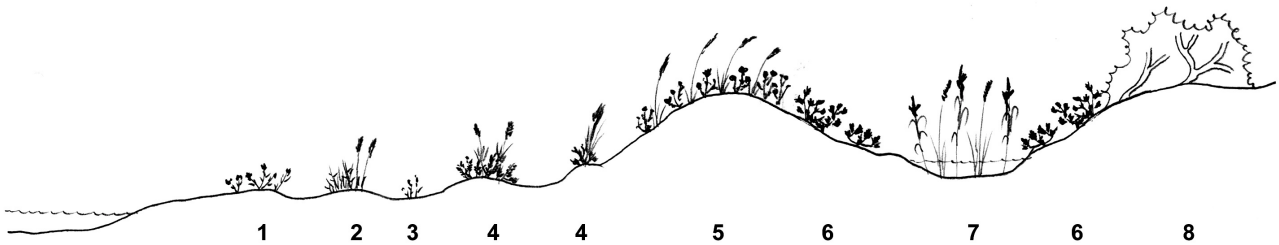
The psammophylic vegetation

The variation in the ecological gradients on the sandy dunes of the Mediterranean result in important modifications to the floristic composition and the structure of the vegetation typologies. These typologies are distributed typically from the sea to the more internal and stable, above-water, areas of the beach, according to sectors that can be interpreted as follows (Fig. 1):

1. Halo-therophytic vegetation (the prevalent association of the Italian Mediterranean is *Salsolo kali-Cakiletum maritimae* Costa & Manzanet 1981);
2. Psammophylic geophytic vegetation of the embryonic dunes (the prevalent association of the Italian Mediterranean is *Echinophoro spinosae-Elymetum farcti* Géhu 1988, of which the vicariant in Sardinia is the association *Sileno corsicae-Elymetum farcti* (Malcuit 1926) Bartolo *et al.* 1992);
3. Therophytic vegetation (of different associations of the order *Malcolmietalia ramosissimae* Rivas Goday 1958);
4. Psammophylic geophytic vegetation of the more internal embryonic dunes, more stable and continuous (usually of *Echinophoro spinosae-Elymetum farcti* Géhu 1988 subass. *othanthetosum maritimae* Géhu & Biondi 1984);
5. Psammophylic geophytic vegetation of the white dunes (the prevalent association of the Italian Mediterranean is *Echinophoro spinosae-Ammophiletum arundinaceae* Géhu, Riv.Mart. & R. Tx. in Géhu *et al*. 1984, of which the vicariant in Sardinia is the association *Sileno corsicae-Ammophiletum arundinaceae* Bartolo *et al*. 1992);
6. Chamaephytic vegetation (found in the Italian Mediterranean with different associations attributed to the alliance *Crucianellion* Rivas Goday & Riv.-Mart. 1958);
7. Various hygrophylic vegetation typologies (alophylic, subalophylic and fresh water) of the interdunal depressions;
8. Phanerophytic vegetation of *Juniperus oxycedrus* subsp. *macrocarpa* and/or that of *J. turbinata* or *Quercus ilex* (attributed in the Italian Mediterranean to different associations of the alliances *Juniperion turbinatae* Riv.-Mart. 1975 corr. 1987 or *Fraxino orni-Quercion ilicis* Biondi, Casavecchia & Gigante 2003).

The transitions between the uniform vegetation zones are usually not abrupt, following the theory of a continuum that inevitably results in a certain intermixing between the species that make up the communities that are in contact. In many cases, moreover, the disturbing actions of natural factors, when particularly violent, or of anthropic origins tend to destabilise the system to various degrees, favouring therefore the remixing of the floristic contents.

On the basis of these considerations, it is important to focus the attention on the transition between the psammophylic geophytic vegetation (microhabitats 4 and 5) and the chamaephytic vegetation (microhabitat 6). In the syntaxonomic scheme proposed by Rivas-Martinez *et al.*, (2001) for Spain and Portugal, the



Zona afitoica	Zona di deposito	Duna embrionale	Duna bianca	Duna grigia	Depressione umida	Duna stabilizzata

Fig. 1 - Scheme of the typical chain succession of the microhabitats present in a dune of the Italian Mediterranean to which there correspond various vegetation typologies (see text for details)

vegetation of these microhabitats are grouped together and attributed to the class *Ammophiletea* Br.-Bl. & Tx. ex Westhoff, Dijk & Tx. 1952 and to the orders *Ammophiletalia* Br.-Bl. 1933 and *Crucianelletalia* Sissingh 1974, respectively. Previously, the latter order was included in the class *Helichryso-Crucianelletea maritimae* Géhu, Riv.-Mart. & Tx. in Géhu 1975.

The reason for this interpretation originates from the presence of some geophytic species specific of the microhabitat 4 and 5 vegetation within the chamaephytic vegetation, which reveals the syntaxonomic link with the class *Ammophiletea*. Although it is seen along a large part of the coast, this phenomenon, however, does not justify this syntaxonomic attribution. This is because in the dune systems, and even in the particularly large ones that have not been greatly disturbed, the mixing of these elements is very rare or even absent, giving the vegetation of the alliance *Crucianellion* an absolutely uniform chamaephytic structure.

An excellent example of this vegetation condition is seen in the large dune system of the coast of Liscia, in northern Sardinia. In this area, there have been two chamaephytic vegetation associations described: *Armerio-Scrophularietum ramosissimae* and *Ephedro-Helichrysetum microphylli*, both of the class *Helichryso-Crucianelletea maritimae* and the alliance *Crucianellion maritimae* (Valsecchi & Bagella, 1991). A careful examination of the phytosociological Tables 2 and 3 (in Valsecchi & Bagella, 1991) and of the photograph of the chamaephytic vegetation of the coast of Liscia (Fig. 2) actually show how the species of the class *Ammophiletea* are absolutely sporadic in these phytocoenoses. Analogous situations are also seen in other areas of Italy, even if unfortunately the vegetation of these typologies is always more rarely seen and is badly compromised by the management of the beaches.

On the basis of these considerations, the syntaxonomic grouping of these associations in the class *Helichryso-Crucianelletea maritimae* is optimal. This class has already been amended by Géhu & Biondi (1994), inserting the order *Helichrysetalia italici* Biondi & Géhu in Géhu & Biondi 1994, extending in this way its ecological significance by the inclusion of the sub-halophytic chamaephytic vegetation of the coastal garrigue of the thermo-Atlantic and Mediterranean rocky coasts .

Nevertheless, if the class *Helichryso-Crucianelletea maritimae* is not accepted, so as to reduce the general number of classes of vegetation, the order *Crucianelletalia maritimae* would be better included in the class of chamaephytic vegetation of *Rosmarinetea officinalis*, as was recently proposed by Géhu (2006);

Fig. 2 -Vegetation of the association *Armerio-Scrophularietum ramosissimae*, in the more internal sectors of the dune complex of the mouth of the Liscia river, in the north-western part of Sardinia (photograph, E. Biondi)

in this case, however, a change in the designation would be necessary, since this class would include not only the secondary chamaephytic formations of the order *Rosmarinetalia italici*, but also those primary on sand of the order *Crucianelletalia maritimae*, and those on rocky substrata of the order *Helichrysetalia italici*.

The vegetation of the rocky coasts

For the Mediterranean rocky cliffs, a generic scheme of the vegetation distribution can be outlined as follows (Fig. 3):
1. The halo-rupicolous chasmophytic vegetation of the areas reached by the spray from the waves and directly by the marine aerosol (in the Mediterranean this is usually represented by different vicariant associations of the type of *Crithmo-Limonietum* s.l. in the various coastal sections, since the genus *Limonium* is rich in agamospecies);
2. The halotolerant chamaephytic garrigue vegetation of the ledges of the cliffs with early soil (this vegetation was attributed to the order *Helichrysetalia italici* Biondi & Géhu in Géhu & Biondi 1994, and in Sardinia and southern Corsica to the alliance *Euphorbion pithyusae* Biondi & Géhu 1994);
3. The therophytic vegetation (belonging to various associations of the order *Malcolmietalia ramosissimae* Rivas Goday 1958);
4. The halotolerant nano-phanerophytic and chamaephytic vegetation of the more-or-less vertical rocky cliffs and therefore in an almost total absence of soil (this vegetation was referred to the alliance *Anthyllidion barbae-jovis* Brullo & De Marco 1989);
5. The bushy and small trees vegetation which shape is more or less wind-moulded and evolved with *Juniperus turbinata* or with *Quercus ilex* (in the Italian Mediterranean this is included in various associations of the alliance *Juniperion turbinatae* Riv.-Mart. 1975 corr. 1987, or in the alliance *Fraxino orni-Quercion ilicis* Biondi, Casavecchia & Gigante 2003);
6. The rupicolous chasmophytic vegetation in the summit areas of the cliffs that are very high, which do not feel the effects of the marine aerosol (in the Mediterranean this is usually represented by various associations of the order *Asplenietalia glandulosi*).

Usually the areas closer to the sea are not colonised by the higher plants, but by algae, since they are frequently reached by the waves (the aphytoic zone). The first pioneer vegetation of a halo-rupicolous type (*Crithmo-Limonietalia*) is found in the areas above the waterline zone, on the rocks that are occasionally reached by the spray from the waves and constantly hit by the marine aerosol that is rich in salt. If the cliffs are particularly high or if their exposure to the salty winds changes, on the basis of the “continuum” theory there is a more-or-less gradual reduction in the salt gradient seen by the vegetation, which progressively loses the

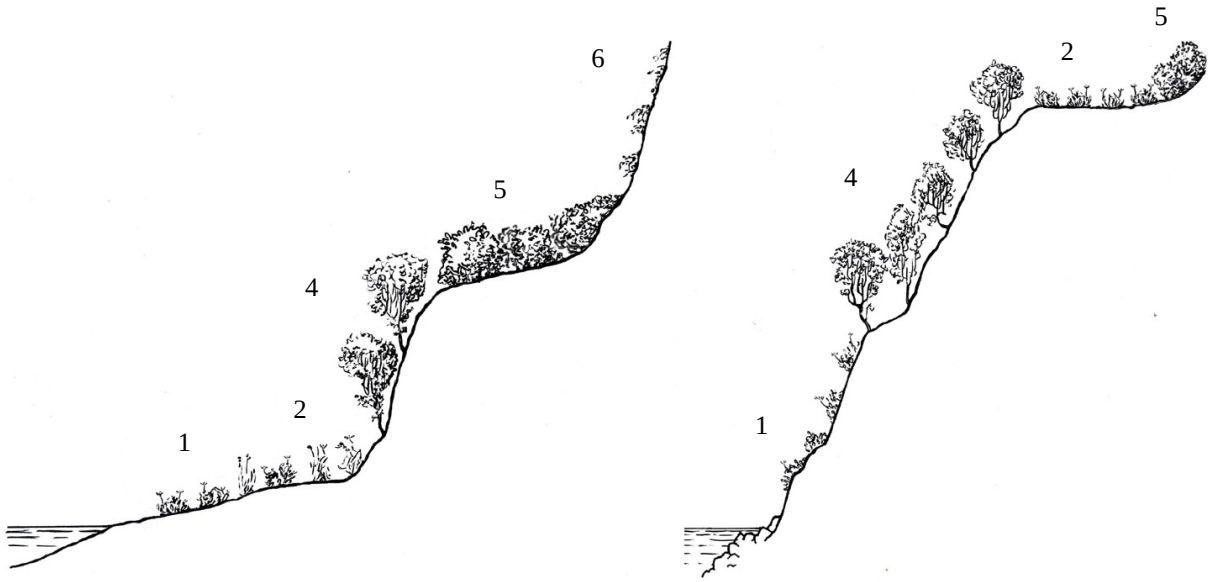


Fig. 3 - Schemes of the typical chain succession of the microhabitats present on cliffs of the Mediterranean to which there correspond various vegetation typologies (see text for details)

major part of the specifically halophytic species. The gradient of the reduction in salinity is seen by the appearance of an intermediate halo-tolerant, rupicolous vegetation, made up of associations that have been grouped into the alliance *Anthyllidion barbae-jovis* Brullo & De Marco 1989. In the summit areas of the cliffs, where the slope of the coast is notably reduced, there is, moreover, a vegetation of primary or subprimary chamaephytic garrigue that develops on the early soil (*Helichrysetalia italici*). Further inland, where the vegetation is spared from the effects of the marine aerosol, the soil gradually becomes more evolved and there is the shrub vegetation of the Mediterranean bush (*Pistacio-Rhamnetalia alterni*) or of secondary garrigue (*Rosmarinetea officinalis* or *Cisto-Lavanduletea*) through substitution following fire.

To carefully interpret the distribution of the vegetation prevalent to the cliffs in terms of the scheme presented, some syntaxonomic aspects are revealed that merit further discussion. In particular, our attention is concentrated on the transition from the truly halo-rupicolous vegetation (microhabitat 1), which is referred to the alliance *Crithmo-Limonion* (order *Crithmo-Limonietalia*), to that which is halotolerant and of the alliance *Anthyllidion barbae-jovis* (microhabitat 4). This problem has already been examined for the ecological aspects through quantitative analyses of the vegetation of the Circeo coasts by Fanelli *et al*. (2004). These revealed the importance of distinguishing the specifically halophylic vegetation from that which is halotolerant.

On the basis of the syntaxonomic proposal of Brullo & De Marco (1989) that has since been confirmed with the description of the new associations for the western Mediterranean (Brullo & Minissale, 1997), this halotolerant vegetation can be included in the alliance *Anthyllidion barbae-jovis* and in the order *Crithmo-Limonietalia.* Biondi, Vagge & Mossa (2000) did not agree with this interpretation, and proposed to include the alliance *Anthyllidion barbae-jovis* in the order *Helichrysetalia italici*, of the class *Helichryso-Crucianelletaea maritimae*, therefore uniting the rupicolous halotolerant vegetation with that of garrigue, also itself halotolerant, specific of the vegetation of the upper areas of the cliffs. Reconsidering this proposal more recently on the basis of the original definition of Brullo & De Marco (1989), it can been seen that the two vegetation typologies cannot actually be considered homologous. This is because the vegetation of the alliance *Anthyllidion barbae-jovis* does in effect have a rupicolous character that the vegetation of the summit sectors, which is typically of rock garrigue, does not have, even if they are both halotolerant.

In their studies on the syntaxonomy of Spain and Portugal, Rivas-Martinez *et al*. (2002) defined the vegetation of the class *Crithmo-Limonietea* as: "Coastal chasmophytic communities of cliffs and lithosoils by marine salt spray under a Mediterranean bioclimate". In the same study, they also considered species that are not precisely chasmophytic, but chomophytic and chamaephytic, as being characteristic of the class and of the subordinate syntaxa. According to Géhu (2006), in reality the vegetation of the class *Crithmo-Staticetea* (= *Crithmo-Limonietea*) can be defined as "A class of pioneering salt-spray chasmo-chomophytic vegetation of the thermo-Atlantic and Mediterranean cliffs". If this interpretation is to be followed, the ecological meaning of the class would be larger. Therefore, it would be opportune to separate within it the vegetation of the first zone of the cliffs with a strictly halo-rupicolous character and made up of chasmophytic species of the order *Crithmo-Limonietalia*, from that with a chomophytic prevalence, and sometimes with chamaephytic species as well as nano- and micro-phanerophytes. These have a different ecology, acting like halotolerant species, and they can be included in a new order that we propose here and to which the name of *Senecetalia cinerariae* has been given. Of this, the type alliance is *Anthyllidion barbae-jovis* Brullo & De Marco 1989.

The species characteristic of this order are: *Senecio cineraria* DC. [quoted in Conti *et al*., 2005, as *S. gibbosus* (Guss.) DC. subsp. *cineraria* (DC.) Peruzzi, N.G. Passal. & Sodano]; *Allium commutatum* Guss.; *Daucus gingidium* L.; *D. gingidium* L. subsp. *mauritanicus* (L.) Onno; *D. gingidium* L. subsp. *polygamus* (Guan) Onno [which are all halotolerant carrots that were quoted in Conti *et al*., 2005, as different subsp. of *D. carota* L.]; and *D. carota* L. subsp. *maritimus* (Lam.) Batt. The differentials of this order are *Lotus cytisoides* L. and *Reichiardia picroides* (L.) Roth var. *maritima* (Boiss.) Fiori.

Matthiola incana (L.) R. Br. subsp. *incana* and *Anthyllis barba-jovis* L. are the true characteristic species of the alliance *Anthyllidion barbae-jovis* Brullo & De Marco 1989, even if this last has a large ecological valence that allows it to occupy sites within the marine coastal environment that are ecologically very different (Biondi *et al.*, 2000). Many endemic species of some of the coastal stretches, as for example *Centaurea cineraria* L. subsp. *cineraria*, *C. cineraria* L. subsp. *circae* (Sommier) Cela-Renzoni & Viegi, and *C. diomedea* Gasparr, and many other species and entities

at different taxonomic levels, clearly indicate the variability at the level of the vegetal community of the alliance *Anthyllidion barbae-jovis*, as can be seen in the summary table, (Table number 6 in Brullo & Minissale, 1997).

Therefore, there remains the consideration of the garrigue vegetation of the summit areas of the cliffs and of the intermediate plains that should be referred to the order *Helichrysetalia italici*. The ecological significance of this vegetation is clearly illustrated in a phytosociological Table of the association *Senecioni-Helichrysetum litorei*, as Table 4 of Barbagallo, Brullo & Signorello (1983), from surveys of the cliffs of the Eolie Islands. In this table, there are few species that are truly characteristic of the order *Crithmo-Limonietalia*, which are *Crithmum maritimum* and *Limonium multiflorum* (the latter species is not even present in relevé 5, which is given as the type of the association). In fact, these show their true colonising ability in the stretch of the cliffs exposed to the salt winds and occupied by the halo-rupicolous vegetation, which on the Eolie Islands is attributed to the association *Limonietum multiflori* Barbagallo, Brullo & Signorello 1983. The low garrigue of *Helichrysum litoreum* on the other hand occupies the summit areas of the cliffs, in early soil in a more sheltered environment with respect to the salt winds, and therefore under ecological conditions substantially different from those colonised by the truly halophytic vegetation (Fig. 4).

It appears, therefore, more appropriate not to include the primary rock garrigue formations in the class *Crithmo-Limonietea*; instead, as indicated, they are to be referred to the class *Helichryso-Crucianelletea maritimae*, which includes the garrigue vegetation of both the dune and rocky systems. Here, the vegetation of the rocky coasts is referred to the order *Helichrysetalia italici*, of which there has been described the alliance *Euphorbion pithyusae* Biondi & Géhu 1994 with a Sardo-Corsico-Balearic distribution. However, to include the vegetation of the Italian peninsula and islands, with their thermoMediterranean bioclimate, it is necessary to describe the new alliance *Helichrysion litorei*, of which the association *Senecioni-Helichrysetum litorei* Barbagallo, Brullo & Signorello 1983 is the type. This new alliance includes the vegetation of the primary and subprimary garrigue present along the Italian coasts, with the exception of Sardinia. These are species characteristic of the alliance: *Helichrysum litoreum* Guss., a plant of the southern coasts of the Italian peninsula and islands, including the Sicilian islands; *Helichrysum italicum* var. *pseudo-litoreum* Fiori of the more northern areas of the Mediterranean coasts of the Italian peninsula (Argentario, Gargano and Mount Conero); and

Fig. 4 - Cliffs of the island of Vulcano in the Eolie archipelago, north-eastern Sicily, showing the distinct vegetation typologies (photograph, E. Biondi): 1 - *Limonietum multiflori;* 2 - *Senecioni-Helichrysetum litorei*

Helichrysum rupestre (Rafin.) DC., a widespread species with varieties along the coasts of Sicily and the para-Sicilian islands, including: var. *rupestre* of the coast between Palermo and Trapani; var. *errerae* (Tineo) Pign. of the island of Pantelleria; var. *messerii* Pign. of the island of Marettimo; and var. *melitense* Pign. of the Maltesi Islands, at Gozo. As well as the species of the genus *Helycrisum* indicated, *Senecio bicolor* (Wild.) Tod. should also be recognised as the characteristic species of the alliance [quoted in Conti *et al*., 2005, as *S. gibbosus* (Guss.) DC. subsp. *bicolor* (Wild.) Peruzzi, N.G. Passal. & Sodano].

Recent ecological investigations into the halotolerant vegetation of the maritime cliffs of the central Tyrrhenian part of the Italian peninsula (Fanelli *et al.*, 2004) have recognised the confused interpretation that has been given to the vegetation of *Helichrysum litoreum* that is found within a decreasing salt gradient and is referred to the order *Helichrysetalia italici*.

Sintaxonomic listing

Sintanonomy to the alliance level of the coastal garrigue primary vegetation in Italy

Helichryso-Crucianelletea maritimae (Sissingh 1974) Géhu, Rivas-Martínez & Tüxen in Géhu 1975 em. Géhu & Biondi1994
- *Crucianelletalia maritimae* Sissingh 1974
  - *Crucianellion maritimae* Rivas-Goday & Rivas-Martínez 1958
- *Helichrysetalia italici* Biondi & Géhu in Géhu & Biondi1994
  - *Euphorbion pithyusae* Biondi & Géhu 1994
  - *Helichrysion litorei all. nova hoc loco*.

Sintaxonomy to the alliance level of the coastal garrigue primary and secondary vegetation in Italy, if the class *Helichryso-Crucianelletea maritimae* in not recognized

Rosmarinetea officinalis Rivas-Martínez, T.E.Díaz, F. Prieto, Loidi & Penas 1991
- *Rosmarinetalia officinalis* Br.-Bl. ex Molinier 1934
  - *Rosmarinion officinalis* Br.-Bl. ex Molinier 1934
  - *Aphyllanthion* Br.-Bl. 1952
  - *Cisto eriocephali-Ericion multiflorae* Biondi 2000
    - *Alyssion bertolonii* Pignatti 1977
    - *Artemisio albae-Saturejion montanae* Allegrezza, Biondi, Formica & Ballelli 1997
  - *Erysimo bonanniani-Jurinetalia bocconei* Brullo 1983
    - *Cerastio tomentosi-Astragalion nebrodensis* Pignatti & Nimis in Pign. et al. ex Brullo 1983
- *Crucianelletalia maritimae* Sissingh 1974
  - *Crucianellion maritimae* Rivas-Goday & Rivas-Martínez 1958
- *Helichrysetalia italici* Biondi & Géhu in Géhu & Biondi1994
  - *Euphorbion pithyusae* Biondi & Géhu 1994
  - *Helichrysion litorei all. nova hoc loco*

Sintaxonomy to the alliance level of the chasmophytic, halophytic and sub-halophytic vegetation of the rocky coasts in Italy

Crithmo-Staticetea Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
- *Crithmo-Staticetalia* Molinier 1934
  - *Crithmo-Staticion* Molinier 1934
  - *Erodion corsici* (Gamisan & Muracciole 1984) Géhu & Biondi 1994
- *Senecetalia cinerariae ord. novo hoc loco*
  - *Anthyllidion barbae-jovis* Brullo & De Marco 1989

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