Botany Letters

ISSN: 2381-8107 (Print) 2381-8115 (Online) Journal homepage: https://www.tandfonline.com/loi/tabg21

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To cite this article: Massimo Terzi, Sandro Bogdanović, Francesco Saverio D'Amico & Nenad Jasprica (2019): Rare plant communities of the Vis Archipelago (Croatia), Botany Letters, DOI: 10.1080/23818107.2019.1684359

To link to this article: https://doi.org/10.1080/23818107.2019.1684359

BOTANY LETTERS
https://doi.org/10.1080/23818107.2019.1684359

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ARTICLE

Rare plant communities of the Vis Archipelago (Croatia)

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ABSTRACT

The Dalmatian coast (Croatia) represents the second largest Archipelago within the Mediterranean area and contributes considerably to the Mediterranean biodiversity. The islands of the Vis Archipelago, in particular, contain an exceptional richness of endemic and rare plant taxa. The aim of this paper is to provide a phytosociological description of the rare plants communities occurring in the Vis Archipelago and define their syntaxonomic position in the Mediterranean context. A data-set consisting of 90 phytosociological relevés was subjected to cluster analysis (Ward's method on a Chord distance matrix) and non-metric multidimensional scaling ordination. The Indicator Species Analysis was used to identify the diagnostic taxa of the main clusters of relevés. The occurrence of the *Anthyllidion barbae-jovis* in Croatia was documented with new relevés. Four new associations of the *Crithmo-Staticetalia* and four further new ones of the *Helichrysetalia italici* were described for the first time. A endemic alliance to the Vis archipelago (Croatia) and Tremiti islands (Italy), *Capparo orientalis-Aurinion leucadeae*, was validated in order to include plant communities of coastal rocky cliffs which are not directly exposed to sea-borne salt-spray but are still under the influence of sea-born salt due to the intense offing storms, in the middle Adriatic. The results were discussed in the light of the European syntaxonomic framework of the EuroVegChecklist. Several syntaxonomic interpretative problems regarding the interface between the *Helichrysetalia italici* and the *Centaureo-Campanuletalia* have arisen and they have been only partially solved with the validation of the *Capparo-Aurinion*. New investigations are required on this topic.

ARTICLE HISTORY
Received 30 July 2019
Accepted 21 October 2019

KEYWORDS
Cliff diversity; coastal habitat; *Crithmo-Staticetea*; endemic plants; endangered taxa; Mediterranean islands; salt-sprayed vegetation; syntaxonomy

Introduction

Islands contribute considerably to the earth's biodiversity due to their high endemic richness (Spellerberg and Sawyer 1999; Kier et al. 2009). On the other hand, their limited area affects their vulnerability to anthropogenic impacts. Many threat factors, such as tourism, overexploitation, habitat alteration, climate change and invasive species, can affect insular plant communities and cause a decline of island diversity (Caujapé-Castells et al. 2010; Médail 2017). Narrow endemic taxa are obviously at greater risk of extinction (Médail and Baumel 2018).

In the Mediterranean Basin – which has been recognized as one of the world's hotspot of biodiversity (Médail and Quézel 1997; Myers et al. 2000) – there are about 10,000 islands and islets, whose importance for biodiversity conservation has long been acknowledged (e.g. Heywood 1995; Blondel and Aronson 1999; Vogiatzakis et al. 2008; Médail 2017). The second largest Archipelago within the Mediterranean area is represented by the Dalmatian coast, in Croatia, with nearly 1200 islands, usually classified as islands (79), islets (525) or small rocks (642) (Duplančić Leder et al. 2004; Médail 2017). According to Nikolić et al. (2008), the floristic richness of these islands was estimated as comprising nearly 1,800 vascular taxa, with some islands and islets, such as those of the Vis Archipelago, in the central Dalmatia, showing an exceptional concentration of endemic species. The entire land area of the Vis Archipelago and its surrounding underwater area are part of the NATURA 2000 European Ecological Network (Anonymous 2013, 2014, 2015). Despite the small surface areas, islands and islets of this archipelago (Table 1) contain many endemic and rare taxa, especially of the genera *Centaurea* and *Limonium* (Alegro et al. 2010; Nikolić et al. 2015).

The island of Vis is experiencing increasing anthropogenic impacts, especially due to tourism flow. It was employed as a navy military base during the Cold War and was closed to foreigners until 1992. Since then, the number of tourist arrivals on Vis has increased (Glamuzina 2011). Other threat factors, such as habitat alteration, overexploitation and the introduction of invasive species may all follow the development of the tourism industry in the area. One case of plant extinction, concerning the narrow endemic *Dianthus multinervis* Vis., has already been documented (Greuter 1995).

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Supplemental data for this article can be accessed here.

Published online 10 Nov 2019

Table 1. Geographic and geological features of the main islands and islets of the Vis Archipelago (Croatia).

Island/Islet	Geology	Surface area (km^2)	Coastline length (km)	Altitude (m a.s.l.)
Vis	Predominantly Jurassic to Cretaceous carbonates, except of the Bay of Komiža (igneous rocks)	89.72	84.9	587
Biševo	Upper Cretaceous carbonates	5.915	18.147	239
St. Andrija (Svetac)	Cretaceous to Paleogene pelagic limestones	4.193	11.973	316
Brusnik	Triassic igneous rocks	0.049	1.097	30
Jabuka	Triassic igneous rocks	0.022	0.715	100
Kamik, near Svetac	Upper Cretaceous carbonates	0.007	0.546	40

The flora of the Vis Archipelago has been intensively investigated (e.g. Pavletić 1974, 1975, 1978, 1979; Trinajstić 1999; Lovrić and Rac 2002; Bogdanović and Mitić 2003; Bogdanović 2004; Bogdanović et al. 2012, 2014; Bogdanović and Brullo 2015) but, quite surprisingly, there are few detailed studies of communities of rare and endangered plant taxa. This knowledge is fundamental in order to describe habitats, assess and monitor their quality, search for new localities of endangered plant communities, re-establish them, evaluate the effects of management of protected habitats/species and, in the end, to plan appropriate conservation action (e.g. Loidi 1994; Nowak and Nowak 2006; Carli et al. 2018).

The aim of this paper is to provide a first phytosociological description of the rare plants communities occurring in the Vis Archipelago and define their syntaxonomic position and importance in the Mediterranean context. This information will be valuable in refining the European syntaxonomic system and might potentially be used to set future conservation and management plans.

Material and methods

Study area

The Vis Archipelago is located in a remote part of the Adriatic Sea and encompasses the islands (surface area > 1 km^2) of Vis, Biševo and Svetac, the islets (surface area between 0.01 and 1 km^2) Brusnik, Jabuka and Kamik, along with other many rocks or rock awash (Duplančić Leder et al. 2004, Table 1). Although the islets of Velika Palagruža and Mala Palagruža also belong to the Vis Archipelago, they represent a more isolated group of islets in the most southern part of the Archipelago, and they are not considered here (Figure 1).

Unlike other eastern Adriatic islands situated along the primary transgressive, highly indented archipelagic karstic coast, the islet of Jabuka is, together with the islet of Brusnik and the Bay of Komiža on the island of Vis, the only example of igneous rocks and pyroclastic sediments cropping out at the surface in the Adriatic Sea (Pikelj et al. 2015, and references

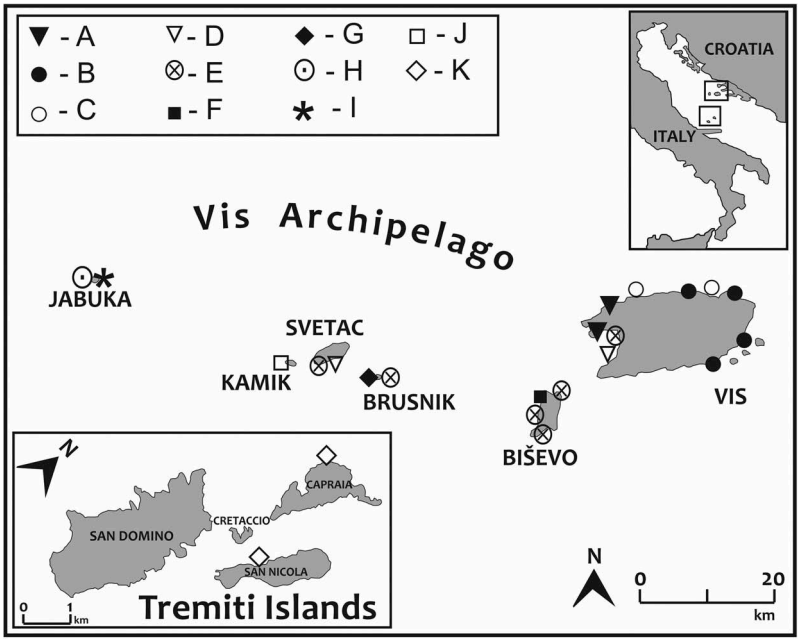

Figure 1. Map of the study area and geographical distribution of the plant communities within the Vis Archipelago (Croatia) and the Tremiti Islands (Italy): *Crithmo maritimi-Limonietum issaeae* (A), *Plantagino holostei-Limonietum subanfracti* (B), *Pimpinello lithophyllae-Centaureetum issaeae* (C), *Anthyllis barba-jovis community* (D), *Centaureetum ragusinae* (E), *Crithmo maritimi-Limonietum busiani* (F), *Crithmo maritimi-Limonietum brusnicensae* (G), *Centaureo jabukensis-Aurinietum leucadeae* (H), *Crithmo maritimi-Limonietum pomoense* (I), *Limonio vestiti-Puccinellietum teyberi* (J), *Centaureo diomedeae-Aurinietum leucadeae* (K).

therein, Table 1). Unlike Komiža's vulcanites formed by the cooling of molten rock on the brims of an ancient volcano, Brusnik and Jabuka are made of a subvolcanic diabase formed by the crystallization of magma on its way from the deep magmatic core to the surface.

In terms of soils, lithosol, Terra Rossa and anthropogenic soils are the most common types in the investigated area (Lozić et al. 2012).

The region experiences a typical Mediterranean climate (Krklec et al. 2012). Annually, average air temperature is 17.1°C and precipitation 752.7 mm yr^{-1} (data from the meteorological station at the town of Komiža, island of Vis, for 1998–2017, Meteorological and Hydrological Service of Croatia). Average temperature during the coldest months (January and February) is 9.9°C, and during the warmest (July) 26.0°C. The highest rainfall is from November to March. During the dry season (June–August) total rainfall is only 105.5 mm. On average the relative air humidity is 64%.

Phytogeographically, the majority of islets belong to the thermo-Mediterranean vegetation belt of the *Oleo-Ceratonion siliquae*Br.-Bl. ex Guinochet & Drouineau 1944 with orographically conditioned exclaves of the meso-Mediterranean *Fraxino orni-Quercion ilicis* Biondi et al. ex Biondi, Casavecchia et Gigante 2013 (Pavletić 1983).

Data source and analysis

Most of the rare and endemic plants of the Vis Archipelago (e.g. *Anthyllis barba-jovis* L., *Asperula staliana* Vis., *Aurinia leucadea* (Guss.) K.Koch, *Campanula teutana* Bogdanović et Brullo, *Centaurea crithmifolia* Vis., *C. friderici* Vis. subsp. *jabukensis* (Ginzb. et) Greuter, *C. issaea* Lovrić, *C. ragusina* L. subsp. *ragusina, Limonium brusnicense* (Trinajstić) Bogdanović et Brullo, *L. busianum* Bogdanović et Brullo, *L. issaeum* Bogdanović et Brullo, *L. pomoense* Bogdanović et Brullo, *L. subanfractum* Trinajstić, *L. vestitum* (C.E. Salmon) C.E.Salmon, *L. zankii* Bogdanović et Brullo, *Pimpinella tragium* Vill. subsp. *lithophila* (Schischk.) Tutin, *Puccinellia teyberi* Hayek) inhabit the halophytic and chasmophytic coastal and subcoastal habitats, whereas they occur only sparsely in the (halo-) nitrophilous communities (here including the ornithogenous-nitrophilous communities), garrigues and evergreen woods of the inner part of the islands (Pavletić 1985).

This study is based on a data-set consisting of 80 phytosociological relevés sharing 123 taxa, carried out according to the Braun-Blanquet approach (Westhoff and van der Maarel 1980). Twenty-two relevés were made by Pavletić (1973, 1983) on the rocky coasts and subcoastal cliffs of Biševo and classified in the *Plantagino-Staticetum cancellatae* and *Centaureetum ragusinae*, respectively (Pavletić 1992; Pandža et al. 2007; Terzi et al. 2018). A further five relevés were collected by Trinajstić (in Pavletić 1989) on the islets of Brusnik and Jabuka and classified in the *Crithmo-Limonietum vestiti*. The remaining 53 relevés are new. They were sampled on Vis, Jabuka, Svetac, Brusnik and Kamik, in areas characterized by the presence of rare and endemic plants. Due to the restricted distribution area of some species, such as for instance *Puccinellia teyberi* or *Campanula teutana* (Bogdanović et al. 2012, 2014), we were able to sample only few relevés for the relevant vegetation types.

Another 10 additional relevès from the Tremiti Islands (Italy) – including 7 new relevés and 3 already published by Brullo and De Marco (1989, tab. 3, rel. 40–42) – were considered only for further syntaxonomic information regarding the new alliance *Capparo-Aurinion* (see below).

Taxonomic nomenclature was standardized with FCD (Flora Croatica Database: https://hirc.botanic.hr/fcd/, accessed 1 October 2018) except for the genus *Limonium*, which nomenclature follows the recent revision carried out by Bogdanović and Brullo (2015). The nomenclature of taxa not occurring in Croatia, follows the Euro+Med PlantBase (http://ww2.bgbm.org/EuroPlusMed/query.asp, accessed 1 February 2019). Syntaxonomic nomenclature follows the Euro VegChecklist (EVC: Mucina et al. 2016) except for syntaxa of the *Asplenietea trichomanis* for which it follows Terzi et al. (2017)

The plot size of new relevés ranges from 10 m^2, for the *Limonium* spp. communities, to 100 m^2 for *Anthyllis barba-jovis* communities and cliff vegetation. For each vegetation plot, we recorded slope, exposition, vegetation cover and a complete list of vascular taxa. The taxa abundance-dominance scores were originally recorded according to the Braun-Blanquet or the Barkman-Doing-Segal scales but they were then replaced by the ordinal scale before the statistical analysis (see Westhoff and van der Maarel 1980, p. 309).

The data matrix was subjected to agglomerative hierarchical clustering by using the Ward's method on a Chord distance matrix. The Indicator Species Analysis (Dufrêne and Legendre 1997) was run for the first 20 dendrogram partitions in order to identify the level yielding the highest number of Indicator Species (IndSp). The dendrogram was then pruned at this level, considered as being the most informative of the dendrogram (cf. McCune and Grace 2002). The Indicator Value of each IndSp (IndVal; Dufrêne and Legendre 1997) was tested for significance ($p < 0.05$) by means of a Monte Carlo test with 10,000 permutations. In order to improve the readability of results, each IndSp was associated to only one cluster, that is the one for which the IndVal first reached its maximum value along the hierarchical descending typologies of the dendrogram (Appendix 1).

The results were interpreted from a syntaxonomic standpoint. Nomenclatural decisions concerning new syntaxa follow the third edition of the International Code of Phytosociological Nomenclature (Weber et al. 2000).

The floristic relationships among the main syntaxonomic units were visualized by means of non-metric multidimensional scaling ordination (NMDS). The latter was run with the Chord distance and by using the "slow and thorough" autopilot mode in Pc-Ord (McCune and Mefford 2011). On the basis of the life-forms and chorotypes reported in Pignatti et al. (2005), life-form and chorological spectra weighted with taxa scores, were calculated for all the relevés. The relationships between life-forms or chorotypes and the ordination scores were shown by a joint plot. The cut-off threshold was set at $r^2 > 0.3$.

The plant communities with *Anthyllis barba-jovis* from the Vis Archipelago (cluster 4B in Figure 2) were compared with other already described associations – represented by 133 relevés recorded in Italy, Tunisia and France (Supplement S1). The floristic relationships among these communities were visualized through a non-metric multidimensional scaling (NMDS) ordination. Before running the NMDS, the relevés with a sparse presence of *Anthyllis barba-jovis* (recorded with + or r on the Braun-Blanquet abundance-dominance scale) and those sampled on plot size exceeding the range 10–100 m^2, were removed from the data matrix. Taxa occurring in only one relevés of the data matrix were also removed.

The statistical analyses were carried out by using Pc-Ord, version 6.22 (McCune and Mefford 2011).

Results

The results of cluster analysis and ordination were used to identify the main plant communities of rare and endemic plants of the Vis Archipelago. The results of the comparison of the *Anthyllis barba-jovis* community from the Vis archipelago with other similar vegetation types already described in Italy, France and Tunisia, allowed us to assess their syntaxonomic autonomy.

Vegetation of the Vis Archipelago

Cluster analysis

The dendrogram was pruned at the 10th partitioning level, giving 10 main clusters of relevés (Figure 2). Six IndSp (Appendix 1) were associated with the first trivial partition including all the relevés (cluster C1). *Crithmum maritimum* L., *Lotus cytisoides* L., and *Silene sedoides* L. indicate the proximity to the coastline, being character taxa of the *Crithmo-Staticetea* and subordinated syntaxa. The other three taxa, namely *Reichardia picroides* (L.) Roth, *Helichrysum italicum* (Roth) G.Don and *Capparis orientalis* Veill., are frequently associated with both cliff

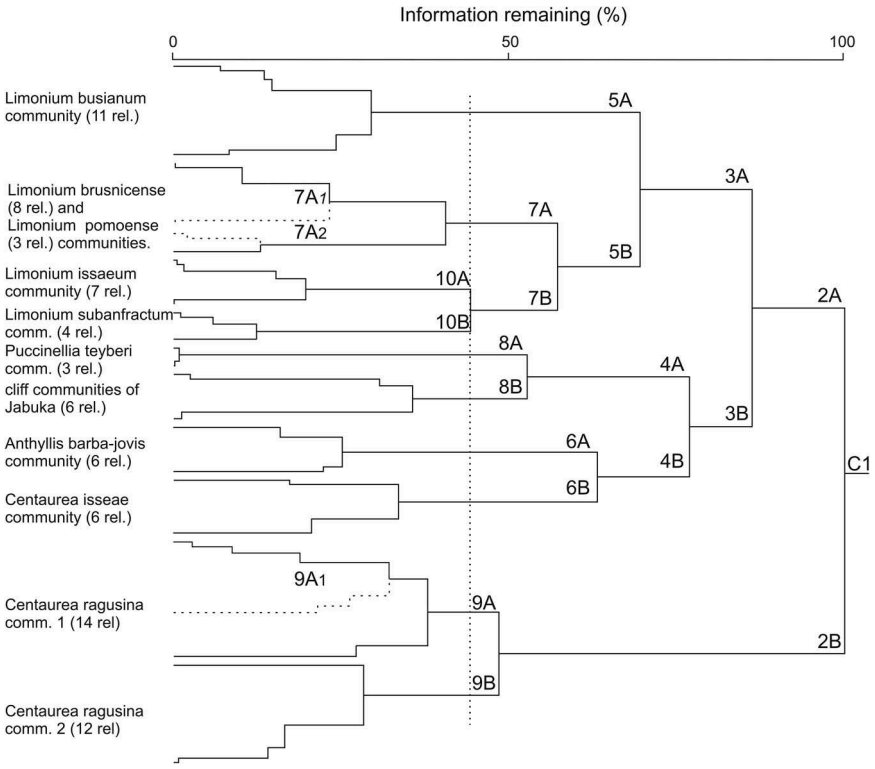

Figure 2. Cluster analysis of the relevés from the Vis Archipelago. The numbers indicate the partitioning levels; the letters indicate the two clusters (A and B) originating at each partition. C1 indicates the first level. The dotted line marks the 10th partitioning level where the dendrogram has been pruned.

and coastal vegetation (Terzi et al. 2018; Terzi and Jasprica 2018; Tomaselli and Terzi 2019).

The first partitions of the dendrogram distinguish four main and ecologically differentiated groups of relevés. The first group (cluster 3A) represents phytocoenoses directly exposed to sea-born salt-spray, belonging to the *Crithmo-Staticetalia*. Five associations (corresponding to the clusters 5A, $7A_1$, $7A_2$, 10A and 10B) characterized by different narrow endemic *Limonium* species can be recognized in this group.

The second group of relevés (cluster 2B) includes the cliff vegetation of the *Centaureetum ragusinae*. The IndSp of this cluster were already considered as character taxa of this association: *Centaurea ragusina* subsp. *ragusina, Convolvulus cneorum* L., and *Phagnalon graecum* Boiss. et Heldr. (Terzi et al. 2018; Terzi and Jasprica 2018).

The third (cluster 4A) and fourth (4B) groups of relevés include halotolerant plant communities which are transitional between the seaboard vegetation belt directly affected by sea waves and sea-born salt-spray on one side, and garrigue, maquis and cliff vegetation less markedly influenced by sea-born salt on the other. Four, well-differentiated plant communities can be recognized (Figure 2): *Anthyllis barba-jovis* community (cluster 6A); *Centaurea issaea* community (cluster 6B); *Centaurea crithmifolia* community (cluster 8B) and *Puccinellia teyberi* community (cluster 8A).

Ordination

The NMDS ordination of the relevés from the Vis Archipelago resulted in a three axes solution (the diagram of axis 1 vs. 2 is shown in Figure 3), with a final stress of 14.2. The NMDS accounted for 73.0% of the total variation (axis 1: 29.0%, axis 2: 29.6%, and axis 3: 14.4%). Axis 1 is negatively correlated with both eastern steno-Mediterranean and northeastern eury-Mediterranean taxa; axis 2 is positively correlated with western steno-Mediterranean plants and phanerophytes. On the left side of the ordination diagram, the *Centaureetum ragusinae* is clearly separated from the relevés of the clusters representing the *Crithmo-Staticion s.l.* communities. The *Anthyllis barba-jovis* community is separated on axis 2, whereas the *Centaurea issaea* community has an intermediate position towards the *Centaureetum ragusinae*. Vegetation from Kamik with *Puccinellia teyberi* and cliff vegetation from Jabuka with *Centaurea crithmifolia* are well differentiated on the first axis.

Comparison of the *Anthyllis barba-jovis* vegetation

The NMDS of the relevés with *Anthyllis barba-jovis* from Croatia, France, Italy and Tunisia produced a three-dimensional solution (the diagram of axis 1 vs. 2 is shown in Figure 4) with a final stress of 16.4. The three axes accounted for 31.7%, 17.4% and 17.6% of the variation. Relevés originally classified in the *Rosmarinetalia officinalis* and *Pistacio lentisci-Rhamnetalia alaterni* are in the left part of the diagram (marked as empty circle if they are from France and as filled circle if they are from northwestern Italy). Besides *Anthyllis*

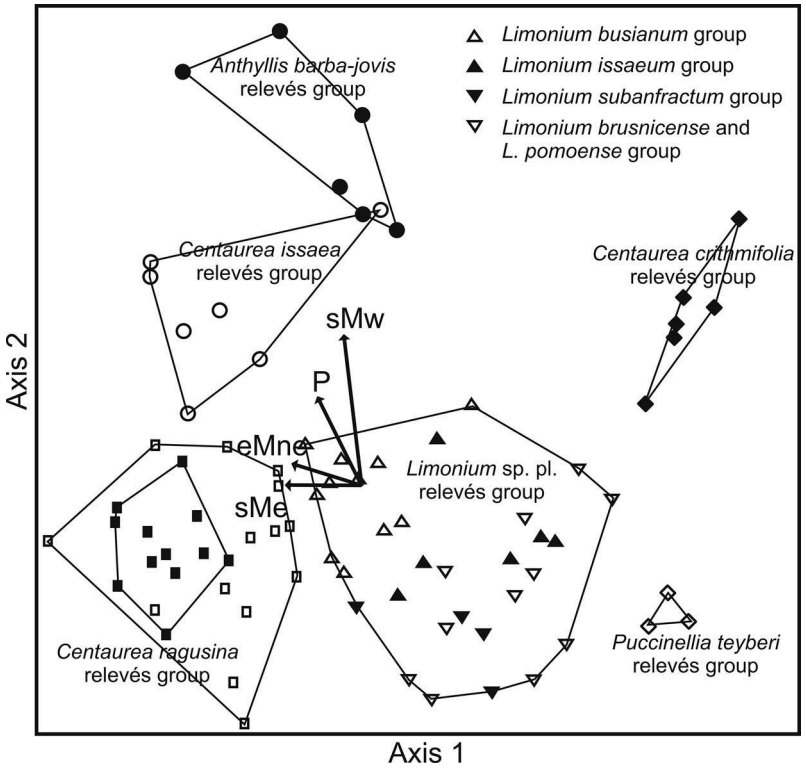

Figure 3. NMDS ordination of the relevés from the Vis Archipelago. sMe = eastern steno-Mediterranean chorotype; eMne = northeastern eury-Mediterranean chorotype; P = Phanerophytes; sMw = western steno-Mediterranean chorotype.

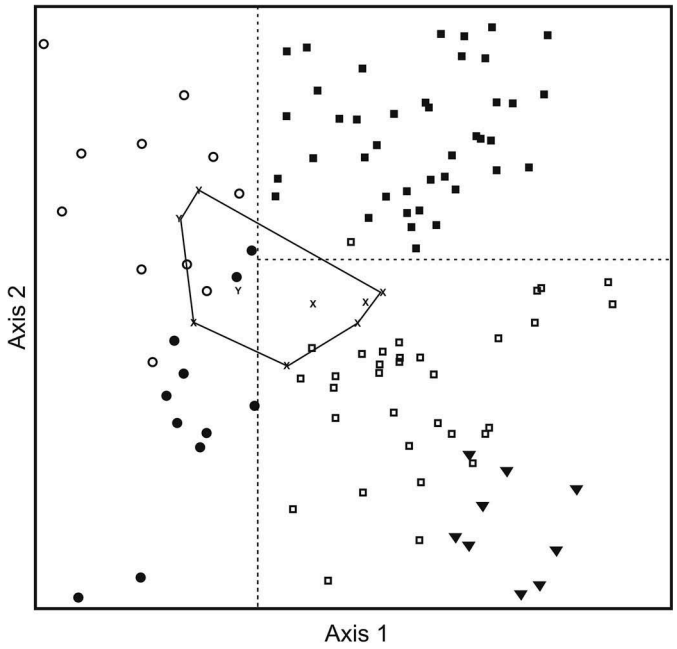

Figure 4. NMDS ordination of the relevés with *Anthyllis barba-jovis* from Italy, Tunisia, France and Croatia. Circles = relevés classified in the *Rosmarinetalia officinalis* and *Pistacio lentisci-Rhamnetalia alaterni* (empty circle if they are from France and filled circle if they are from north-western Italy); squares and triangles = relevés classified in the *Anthyllidion barbae-jovis* (triangles = relevés from Tunisia; empty squares = relevés from central and southern Italy; filled squares = relevés from north of Italy and France).

barba-jovis, the other dominant and frequent taxa of this group of relevés turned out to be the following: *Rosmarinus officinalis* L., *Pistacia lentiscus* L., *Cistus incanus* L., *Quercus ilex, Calicotome villosa* (Poir.) Link s.l. (incl. *Calicotome infesta* (C. Presl) Guss.), *Smilax aspera* L., *Rubia peregrina* L., *Juniperus phoenicea* L. and *Lonicera implexa* Aiton.

On the right side of the diagram, there are the relevés already classified in the *Anthyllidion barbae-jovis*. Those from the northern part of the alliance distribution range are concentrated in the upper part of the diagram. Relevés from the Cap Bon (Tunisia) are at the bottom, drawn with a triangle symbol. Frequent species of the *Anthyllidion barbae-jovis* are *Anthyllis barba-jovis, Reichardia picroides, Crithmum maritimum, Daucus gingidium* aggr. and *Lotus cytisoides*. Some species, such as *Senecio bicolor* (Willd.) Tod., *Helichrysum stoechas* (L.) Moench, *Helichrysum italicum* and *Thymelaea hirsute* (L.) Endl., are more frequent in the northern part of the alliance distribution area whereas other species, such as *Helichrysum litoreum, Matthiola incana* (L.) R. Br., *Centaurea cineraria* L. and *Dianthus sylvestris* Welfen subsp. *longicaulis* (Ten.) Greuter et Burdet, are more represented in the southern part.

The relevés from Croatia are arranged at the intersection of the three main subdivisions of the ordination diagram described above. However, due to the occurrence and dominance of *Anthyllis barba-jovis* and *Matthiola incana*, they belong to the *Anthyllidion barbae-jovis*.

Discussion

In rocky coastal habitats, the halophilous plant communities directly exposed to sea-born salt spray can be distinguished from the subaerohaline halotolerant vegetation occurring further inland, from ecological, floristic and syntaxonomic standpoints (Fanelli et al. 2004; Biondi 2007; Mucina et al. 2016). There are several syntaxonomic interpretations concerning these two vegetation belts that have been separated at different syntaxonomic ranks (cf. Mucina et al. 2016; Brullo et al. 2017). We follow the EuroVegChecklist (EVC) where they are separated as two orders of the *Crithmo-Staticetea*: the halophilous belt, usually characterized by *Limonium* species, is included in the *Crithmo-Staticetalia* whereas the halotolerant belt is classified in the *Helichrysetalia italici.*

Halophilous vegetation (Crithmo-Staticetalia)

In the Vis Archipelago, the halophilous vegetation (i.e. cluster 3A in Figure 2) includes five associations (Supplement S2). The *Limonium* vegetation of the Biševo Island was originally classified in the *Plantagino-Limonietum cancellati* (Pavletić 1973, 1992). However, as shown by Bogdanović and Brullo (2015), *Limonium cancellatum* is restricted to the North Adriatic calcareous rocky coasts, whereas it is replaced by *Limonium busianum* on the Biševo Island. For this reason, the relevés of cluster 5A, are here included in the new endemic association *Crithmo maritimi-Limonietum busiani* (Appendix 2). Although this cluster was

associated with several Indicator Species (Appendix 1), only *L. busianum* can be indicated as a character species and *Allium ampeloprasum* L. can be used as differential species, the other species being widespread in coastal habitats. The sub-association *Plantagino-Limonietum cancellati schoenetosum nigricantis*, described for this Archipelago and differentiated by *Schoenus nigricans* L. and *Dorycnium hirsutum* (L.) Ser. (Pavletić 1992), is here considered as part of the variability of the *Crithmo-Limonietum busiani*.

On the island of Vis, two new endemic associations, *Plantagino holostei-Limonietum subanfracti* (cluster 10B) and *Crithmo maritimi-Limonietum issaeae* (cluster 10A), can be recognized. They are characterized by the narrow endemic *Limonium subanfractum* and *L. issaea*, respectively. Despite numerous IndSp that turned out to be associated to their clusters (clusters 10A and 10B), most of them are ingressives from the surroundings or widespread on coastal habitats. According to Pavletić (1989), *Limonium subanfractum* is included in the "*Sporobolo-Elymetum farcti*", occurring on the coastal sands of the island of Vis. On the other hand, the *Plantagino holostei-Limonietum subanfracti* occurs only on coastal limestone cliffs.

The cluster 7A includes halophilous vegetation from the volcanic islets of Jabuka and Brusnik; two further subclusters ($7A_1$ and $7A_2$), each one including relevés from only one islet, can be recognized. Trinajstić (in Pavletić 1989) classified the sea-born salt sprayed cliff vegetation of these islets in the *Crithmo-Limonietum vestiti*, characterized by *Frankenia pulverulenta* L., "*Limonium vestitum* subsp. *vestitum*" (on Jabuka), and "*L. vestitum* subsp. *brusnicense*" (on Brusnik). As holotypus of this association, Pavletić (1989, rel. 1, tab. 2) designated the sole relevé recorded on the islet of Jabuka. According to Bogdanović and Brullo (2015), *Limonium vestitum* occur only on the limestone islet of Kamik, whereas it is substituted on the volcanic islets of Jabuka and Brusnik by *L. pomoense* and *L. brusnicense* (i.e. "*Limonium vestitum* subsp. *brusnicense*"), respectively. For this reason, we correct the association name *Crithmo-Limonietum vestiti* Trinajstić (in Pavletić 1989, tab. 2, p. 400) as *Crithmo-Limonietum pomoense* and describe the new association *Crithmo-Limonietum brusnicensae* for Brusnik.

These five associations are characterized by different species of *Limonium*. In practice, it is well known that this genus consists of a high number of species, often with a narrow distribution area (e.g. Dolcher and Pignatti 1971; Brullo and Guarino 2019). This situation has led to a great number of associations (e.g. Bartolo et al. 1992; Brullo et al. 2017) often characterized by only one *Limonium* species and often representing geographic vicariant units with a similar ecology (De Marco and Dinelli 1984). A detailed knowledge of the association richness/diversity might be useful, for instance, for conservation purposes. However, for other purposes, such as those relating to land planning and management, the level of alliance seems more appropriate. The EVC lists only four alliances of the *Crithmo-Staticetalia* for the whole of Mediterranean Europe. For the Adriatic area, the halophilous coastal vegetation is included in the *Limonion anfracticancellati* and therefore the five associations from the Vis Archipelago were provisionally classified in this alliance. The character taxa of the *Limonion anfracticancellati* are however poorly represented in our associations and, in accord with Tomaselli and Terzi (2019), we think that this alliance requires an in-depth revision in order to clarify its floristic relationships with the other alliances of the *Crithmo-Staticetalia*.

Halotolerant vegetation (*Helichrysetalia italici*)

As regards the halotolerant belt, the transitional position of the *Helichrysetalia italici* – which occurs between the coastal vegetation under the direct influence of sea-born salt spray and a vegetation belt notably less influenced by salt spay – has given rise to different syntaxonomic interpretations (e.g. Géhu and Biondi 1994; Fanelli et al. 2004; Biondi 2007). For instance, the *Anthyllidion barbae-jovis* was classified in the *Helichrysetalia italici* (EVC), but also in the *Crithmo-Staticetalia* (Bartolo et al. 1992) or in the *Senecionetalia cinerariae* (Biondi 2007). In Croatia, the *Anthyllis barba-jovis* communities were classified in associations of the *Centaureo-Campanuletalia* (Horvatić 1971; Trinajstić 1995). Škvorc et al. (2017) were the first to recognize the occurrence of the *Anthyllidion barbae-jovis* alliance in Croatia and therefore our relevés with *Anthyllis barba-jovis* (cluster 6A, Supplement S3) are included in this alliance, for the presence and cover values of the two main character species, *Anthyllis barba-jovis* and *Matthiola incana*.

For the Vis Archipelago, Lovrić (in Lovrić and Bedalov 1987) invalidly (Art. 2b of ICPN) described two halotolerant associations, "*Puccinellio-Centaureetum crithmifoliae*" and "*Aurinio leucadeae-Brassicetum frutescentis*". These associations were classified in the (invalid for Art. 2b) alliance "*Aurinio-Capparion*" (see also Lovrić and Rac 1991; Bertović and Lovrić 1992). This alliance includes chasmophytic plant communities not directly exposed to sea-borne salt-spray "but anyway under the influence of sea-born salt due to the intense Adriatic offing storms". For this reason, Lovrić and Rac (1991) differentiated the "*Aurinio-Capparion*" (and the corresponding order: "*Aurinetalia orientalis*" Lovrić in Lovrić and Rac 1991 nom. inval.) from the chasmophytic vegetation not affected by the sea that they classified in the *Moltkietalia petraeae* consisting in their view of two alliances: *Centaureo-Campanulion* and *Edraianthion tenuifolii* (see Terzi and Jasprica 2018 for a revision of this topic). This syntaxonomic differentiation between the halotolerant cliff vegetation and the chasmophytic vegetation not

affected by the sea, is also considered in the EVC that distinguishes the *Helichrysetalia italici* (*Crithmo-Staticetea* class) from the *Centaureo dalmaticae-Campanuletalia pyramidalis* (*Asplenietea trichomanis* class). The ecology of the "*Aurinio-Capparion*" perfectly fits in the *Helichrysetalia italici* and, in fact, the EVC reports the main alliance character species, *Aurinia leucadea* and *Centaurea crithmifolia* (see below), within the diagnostic taxa of the *Crithmo-Staticetea* and subordinated units. On the other hand, the EVC inconsistently considers the "*Aurinio-Capparion*" as a synonym of the *Centaureo-Campanulion* (*Centaureo-Campanuletalia* order).

The name-giving taxa of the "*Puccinellio-Centaureetum*", i.e. *Puccinellia teyberi* and *Centaurea crithmifolia*, do not occur together the first one being endemic to the islet of Kamik and the second endemic to Jabuka and Palarguža. As a consequence, this association is not validated here whereas two new associations are described, namely the *Limonio vestiti-Puccinellietum teyberi* from Kamik and the *Centaureo jabukensis-Aurinietum leucadeae* from Jabuka (Supplement S3).

Owing to their particular ecology and floristic composition, these associations cannot be classified in any of the alliances of the *Helichrysetalia italici* listed in the EVC. In fact, two out of three character species of the *Anthyllidion barbae-jovis* are missing (*Anthyllis barba-jovis, Dianthus longicaulis*) and the third, *Matthiola incana*, was recorded in the *Centaureo jabukensis-Aurinietum leucadeae* but with very low cover value. Moreover, the two new associations represent plant communities occurring on sub-coastal cliffs whereas the *Anthyllidion barbae-jovis* usually occur on quite gentle crumbling slopes, in a close catenal relationship with evergreen maquis.

Nor can the two new associations be classified in the *Helichrysion litorei*, describing garrigue-like sub-coastal halotolerant communities, whose physiognomy is mainly due to some Italian endemic *Helichrysum* taxa (Tomaselli and Terzi 2019).

Therefore, these two associations are classified in the *Capparo orientalis-Aurinion leucadeae* [holotypus: *Centaureo jabukensis-Aurinietum leucadeae ass. nov.*, see below], here validated with the following diagnostic species: *Aurinia leucadea, Centaurea crithmifolia, Capparis orientalis* and *Lavatera arborea* L. The latter is a differential species whose presence is due to the high concentration of nutrients in soils determined by bird colonies (Okusanya and Fawole 1985). According to Plazibat (2009, p. 416), *Aurinia leucadea* is represented in the Vis and Tremiti archipelagos – that is, along the distribution area of the *Capparo orientalis-Aurinion leucadeae* – by the endemic subspecies *Aurinia leucadea* subsp. *scopulorum* (Ginzb.) Plazibat.

The *Capparo orientalis-Aurinion leucadeae* (Supplement S3) represents an endemic alliance of the central Adriatic offing islands and islets – including also vegetation communities from the Tremiti (Italy) and Palagruža (Croatia). On San Nicola and Capraia (Tremiti islands), the new association *Centaureo diomedeae-Aurinietum leucadae*, is here described on the basis of unpublished data and other relevés already published but erroneously classified (Appendix 2, Supplement S3). This association, here reported in order to provide fuller information on this alliance, mainly occurs on cliffs of the northwestern side of the islands, exposed to the prevailing wind, and above the halophilous *Limonium* vegetation belt. The abundance and dominance of *Aurinia leucadea*, especially on Capraia Island, together with the endemic *Centaurea diomedea*, characterize this plant communities.

The other association described by Lovrić, "*Aurinio-Brassicetum frutescentis*" (cf. Lovrić and Bedalov 1987) also cannot be validated. In fact, in the relevés of the *Centaurea issaea* community (cluster B), "*Brassica frutescentis*" – that is one of the association name-giving taxa – is missing. Therefore, we describe a new endemic association *Pimpinello lithophyllae-Centaureetum issaeae*, characterized by *Centaurea issaea* and differentiated by two other very rare taxa along the Dalmatian coasts: *Pimpinella tragium* subsp. *lithophila* and *Brassica incana* Ten. This plant community includes many narrow endemic taxa (e.g. *Centaurea issaea, Campanula teutana, Limonium issaeum*) together with some diagnostic taxa of the *Centaureo-Campanuletalia* (*Inula verbascifolia* (Willd.) Hausskn., *Pimpinella tragium* subsp. *lithophila* (Schischk.) Tutin, *Sesleria tenuifolia* Schrad.) and some others of the *Crithmo-Staticetea /Helichrysetalia italici* (*Crithmum maritimum, Helichrysum italicum, Allium commutatum* Guss.).

Since the ecology of this association fits in that of the alliance *Capparo orientalis-Aurinion leucadeae*, it is provisionally classified in this alliance even though *Aurinia leucadea* – which is the main alliance character species – is here poorly represented. The syntaxonomic position of the *Pimpinello-Centaureetum*, however, needs to be revised together with the *Helichrysetalia italici*.

Chasmophytic vegetation (Centaureo-Campanuletalia)

The *Centaureetum ragusinae* (cluster 2B, Supplement S4) – which is usually considered as an association of the *Centaureo-Campanuletalia* (Horvat 1942; Horvatić 1963; Trinajstić 1980) – lacks many of the character species of higher syntaxonomic units, as already pointed out by Terzi et al. (2018) and Terzi and Jasprica (2018). This association always occurs near the seashore where two coastal subassociations

have also been described (Terzi et al. 2017; Terzi and Jasprica 2018). On the Vis archipelago, we found some garrigue-like plant communities (subcluster $9A_1$) dominated by *Centaurea ragusina* and *Helichrysum italicum*, with a lot of taxa of the *Crithmo-Staticetea* and *Helichrysetalia italici*, such as *Crithmum maritimum, Lotus cytisoides, Silene sedoides, Limonium busianum, Limonium issaeum, Anthyllis barba-jovis*, indicating that the stands are still under the influence of sea (especially for cluster 9A). The interface between the *Crithmo-Staticetea* and the *Asplenietea trichomanis*, however, has been little investigated. Therefore, although the floristic composition of our relevés suggests some similarities with the vegetation of the *Helichrysetalia italici*, we provisionally followed a conservative approach and left this association within the *Centaureo-Campanuletalia*.

Threats and conservation

Each of the new associations has a distribution area restricted to only one or few islands or islets (Figure 1). Halophilous associations, mainly differentiated by endemic *Limonium* species, are threatened by tourism which directly affects the coasts of the Vis island as well as, by one-day trips, those of the other islands and islets of the Archipelago. In fact, as written above, tourism is an emerging industry in the area.

Halotolerant associations, reunited in the endemic *Capparo-Aurinion*, contain more endemic and endangered taxa but are usually localized in conservative and well-preserved habitats, with few exceptions (Table 2). All these associations have a nearly punctual distribution and some endemic taxa populations (e.g. *Campanula teutana, Centaurea friderici* subsp. *jabukensis*) are represented by few individuals concentrated in small areas. Kamik and Jabuka, in particular, represent the Adriatic islets with the greater concentration of narrow endemics (Nikolić et al. 2008). Islands and islets of the Vis Archipelago are already included in several Natura 2000 protected sites. However, the rarity of these communities and taxa claims for a combined *in-situ* and *ex-situ* conservation strategy, with collecting, multiplying and conserving *ex-situ* the germplasm of the more threaten taxa (see Table 2).

In the end, this work has provided new insight on the coastal and sub-coastal vegetation of the Vis Archipelago, its rarity and threats. New endemic syntaxa have been described and they have been discussed in the European syntaxonomic framework of the EVC. Several syntaxonomic interpretative problems regarding the interface between the *Helichrysetalia italici* and *Centaureo-Campanuletalia* have arisen. They have been only partially solved with the description of a new alliance, but deserve further investigations.

Syntaxonomic scheme

Class: *Crithmo-Staticetea* Br.-Bl. in Br.-Bl. et al. 1952
Order: *Crithmo-Staticetalia* Molinier 1934
Alliance: *Limonion anfracti-cancellati* (Horvatić 1934) Mucina in Mucina et al. 2106

- *Crithmo maritimi-Limonietum busiani* ass. nov. hoc loco
- *Crithmo maritimi-Limonietum brusnicensae* ass. nov. hoc loco
- *Crithmo maritimi-Limonietum issaeae* ass. nov. hoc loco
- *Crithmo maritimi-Limonietum pomoense* Trinajstić corr. hoc loco
- *Plantagino holostei-Limonietum subanfracti* ass. nov. hoc loco

Order: *Helichrysetalia italici* Biondi et Géhu in Géhu et Biondi 1994
Alliance: *Anthyllidion barbae-jovis* S. Brullo et De Marco 1989

- *Anthyllis barba-jovis* community

Alliance: *Capparo orientalis-Aurinion leucadeae* Lovrić ex all. nov. hoc loco

- *Centaureo jabukensis-Aurinietum leucadeae* ass. nov. hoc loco
- *Limonio vestiti-Puccinellietum teyberi* ass. nov. hoc loco
- *Pimpinello lithophyllae-Centaureetum issaeae* ass. nov. hoc loco
- *Centaureo diomedeae-Aurinietum leucadeae* ass. nov. hoc loco (from Tremiti Islands, Italy)

Class: *Asplenietea trichomanis* (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977
Order: *Centaureo dalmaticae-Campanuletalia pyramidalis* Trinajstić ex Terzi et Di Pietro 2016
Alliance: *Centaureo cuspidatae-Portenschlagiellion ramosissimae* Trinajstić ex Terzi et Di Pietro 2016

- *Centaureetum ragusinae* Horvat ex Terzi, Jasprica et Caković 2017

Table 2. List of the plant communities, their geographic distribution within the Vis Archipelago (Croatia) and Tremiti Islands (Italy), taxa of conservation interest (CR: critically endangered; EN: endangered; end: endemic taxa; LC: least concern; NT = near threatened; VU: vulnerable), and NATURA 2000 habitat (H) and site (S) codes. IUCN-Red list taxa were determined according to Nikolić and Topić (2005), Nikolić et al. (2015), Orsenigo et al. (2018), and Nikolić (2019).

Plant community	Distribution area (see also Figure 1)	Regionally rare and endemic taxa	IUCN – Red list taxa	Conservation status, threats	Natura2000 habitat and site codes
Crithmo maritimi-Limonietum busiani	Community is developed on a few sites on the island of Biševo (limestone).	*Limonium busianum* (end), *Centaurea ragusina* (end)	*Elymus farctus* (CR), *Sporobolus pungens* (CR), *Desmazeria marina* (VU), *Parapholis incurva* (VU), *Convolvulus cneorum* (NT), *Centaurea ragusina* (NT)	The habitat is well preserved, but the growth of tourists and visitors represents a threat for these taxa.	H: 1240; S: HR2001097
Crithmo maritimi-Limonietum brusnicensae	Community is developed on the islet of Brusnik (igneous rock).	*Limonium bruscinense* (end), *Centaurea ragusina* (end)	*Centaurea ragusina* (NT), *Frankenia pulverulenta* (NT)	The habitat is well preserved, but potential threat is soil properties alteration due to large colony of seagulls.	H: 1240; S: HR4000009
Crithmo maritimi-Limonietum issaeae	Narrow endemic syntaxon, developing in a few sites on the northern and western cliffs of the island of Vis (limestone).	*Limonium issaeum* (end), *Centaurea ragusina* (end)	*Centaurea ragusina* (NT), *Convolvulus cneorum* (NT)	Sites are locally well preserved. Potential threats are indirect risks related to the possible pollution from the polluted marine aerosols.	H: 1240; S: HR2000942
Crithmo maritimi-Limonietum pomoense	Community is developed on the islet of Jabuka (igneous rocks).	*Limonium pomoense* (end)	*Frankenia pulverulenta* (NT)	Potential threat is soil degradation for chemical and physical alteration due to high number of seabirds; rocks can be damaged by the number of visitors making the climb.	H: 1240; S: HR4000008
Plantagino holostei-Limonietum subanfracti	Endemic syntaxon found on the northern and southern coasts of the island of Vis (limestone).	*Limonium subanfractum* (end)	*Desmazeria marina* (VU)	Although habitat is preserved, coastal erosion, tourism and recreation areas included construction of roads for access to the sea and the installation of touristic infrastructure present a threats.	H: 1240; S: HR2000942
Anthyllis barba-jovis community	Community is localized on the south-western coast of the island of Vis, in the Bay of Komiža, Svetac (both limestone, igneous rock).	*Anthyllis barba-jovis* (rare), *Limonium issaesum* (end).	-	The habitat is well preserved, while invasive alien species *Opuntia ficus-indica* presents a threat.	H: 5320; S: HR2000942
Centaureo jabukensis-Aurinietum leucadeae	Community is developed on the islet of Jabuka (igneous rocks).	*Limonium pomoense* (end), *Centaurea friderici subsp. jabukensis* (end), *C. crithmifolia* (end), *Aurinia leucadea* subsp. *scopulorum* (end).	*Centaurea friderici subsp. jabukensis* (NT), *C. crithmifolia* (NT), *Aurinia leucadea* (NT)	Potential threat is soil degradation for chemical and physical alteration due to high number of seabirds; rocks can be damaged by the number of visitors making the climb.	H: 5320–8210; S: HR4000008
Limonio vestiti-Puccinellietum teyberi	This syntaxon is circumscribed to the small islet of Kamik (limestone).	*Limonium vestitum* (end), *Puccinellia teyberi* (end.), *Aurinia leucadea* subsp. *scopulorum* (end).	*Puccinellia teyberi (VU), Suaeda vera* (VU), *Limonium vestitum* (NT), *Frankenia pulverulenta* (NT)	The habitat is conservative and quite well preserved, except of *P. teyberi population* found in the low number of individuals (Bogdanović et al. 2012).	H: 1240–5320
Pimpinello lithophyllae-Centaureetum issaeae	Narrow endemic syntaxon, developing only in a few sites of the northern coastal cliffs on the island of Vis (limestone).	*Centaurea issaea* (end), *Campanula teutana* (end) *Aurinia leucadea* subsp. *scopulorum* (end), *Limonium issaesum* (end), *Pimpinella tragium* subsp. *lithophila* (rare)	*Campanula teutana* (EN, Bogdanović et al. 2014), *Brassica incana* (NT), *Aurinia leucadea* (NT).	The habitat is conservative and quite well preserved. *C. teutana* is a threatened taxon at risk of extinction because of extremely low number of individuals (Bogdanović et al. 2014).	H: 5320–8210; S: HR2000942
Centaureo diomedeae-Aurinietum leucadeae	Narrow endemic syntaxon, developing only in few sites of the limestone islands of San Nicola and Capraia (Tremiti Archipelago, Italy).	*Centaurea diomedea* (end), *Aurinia leucadea* (end), *Asperula staliana* subsp. *diomedea* (end), *Allium diomedeum* (end), *Anthyllis barba-jovis* (rare).	*Asperula staliana* subsp. *diomedea* (EN), Allium diomedeum (NT), *Aurinia leucadea* (LC).	The habitat is conservative and quite well preserved, except of *Aurinia leucadea* population of San Nicola Island (Orsenigo et al. 2019).	H:5320–8210; S: IT9110011, IT9110040.
Centaureetum ragusinae	Community occurs on the islands of Vis, Biševo and Svetac (limestone) and on the islet of Brusnik (igneous rock).	*Centaurea ragusina* (end), *Limonium busianum* (end), *L. issaesum* (end), *L. zankii* (end), *Aurinia leucadea* subsp. *scopulorum* (end), *A.l.* subsp. *leucadea* (end), *Asperula staliana* subsp. *issaea* (end), *A. visianii* (end), *Anthyllis barba-jovis* (rare).	*Centaurea ragusina* (NT), *Convolvulus cneorum* (NT), *Anthyllis barba-jovis* (NT) *Aurinia leucadea* (NT), *Asperula staliana* (NT).	Populations of *C. ragusina* are stable. Collection as ornamental plant may presents as threat.	H: 8210; S: HR2000942, HR2001097, HR2000941 HR4000009

Acknowledgments

Many thanks are due to S. Latham for improving the English and G. Mazziconi (IAC-CNR Library) for helping us in finding references. Authors thank the Croatian Meteorological and Hydrological Service for providing the meteorological data from the Komiža station, the island of Vis. Authors also thank Frédéric Médail, another anonymous referee and the Editor-in-Chief, Sophie Nadot, for their useful suggestions and comments.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1. Indicator species associated to the main dendrogram clusters (Figure 2). The indicator value of each indicator species is reported within brackets after the taxon name

Cluster 1: *Crithmum maritimum* (92.5); *Reichardia picroides* (68.75); *Lotus cytisoides* (57.5); *Helichrysum italicum* (47.5); *Silene sedoides* (45); *Capparis orientalis* (42.5);
Cluster 2A: -; Cluster 2B: *Centaurea ragusina* subsp. *ragusina* (93.6); *Juniperus phoenicea* (40.7); *Convolvulus cneorum* (37.2); *Phagnalon graecum* (11.5);
Cluster 3A: -; Cluster 3B: -;
Cluster 4A: *Aurinia leucadea* (85.9); *Lavatera arborea* (74);
Cluster 4B: *Brachypodium retusum* (Pers.) P. Beauv. (80.1); *Coronilla valentina* L. subsp. *valentina* (15.4);
Cluster 5A: *Limonium busianum* (87.4); *Allium ampeloprasum* (62.3); *Silene vulgaris* (Moench) Garcke subsp. *angustifolia* Hayek (49.9); *Orobanche minor* Sm.(36.4); *Sedum ochroleucum* Chaix (36.4); *Dittrichia viscosa* (L.) Greuter (32.9); *Parapholis incurva* (L.) C. E. Hubb. (27.3); *Urospermum picroides* (L.) Scop. ex F. W. Schmidt (27.3); *Schoenus nigricans* (26.1); *Plantago coronopus* L. subsp. *commutata* (Guss.) Pilg. (18.2); *Atriplex prostrata* Boucher ex DC. in Lam. et DC. (15.5); *Dorycnium hirsutum* (15);
Cluster 5B: -
Cluster 6A: *Anthyllis barba-jovis* (91.7); *Matthiola incana* (65.3); *Pallenis spinosa* (L.) Cass. (47.3); *Dactylis glomerata* L. subsp. *hispanica* (Roth) Nyman (32); *Rosmarinus officinalis* (27.8); *Brachypodium distachyon* (L.) P. Beauv. (24.8); *Phagnalon rupestre* (L.) DC. (24.3); **Cluster 6B**: *Centaurea*

issaea (100); *Brassica incana* (71.4); *Pimpinella tragium* subsp. *lithophila* (57.1); *Inula verbascifolia* (52.7); *Erica manipuliflora* Salisb. (48.8); *Desmazeria rigida* (L.) Tutin (36.6); *Sesleria tenuifolia* (28.6); *Asparagus acutifolius* L. (21.5);
Cluster 7A: *Limonium brusnicense* (72.7); *Parietaria judaica* L. (36.4); *Senecio leucanthemifolius* Poir. (19.6); **Cluster 7B**: -;
Cluster 8A: *Limonium vestitum* (100); *Puccinellia teyberi* (100); *Frankenia pulverulenta* (67.7); *Allium commutatum* (51.5); *Lolium rigidum* Gaudin (33.3); *Suaeda vera* J. F. Gmelin in L. (33.3); **Cluster 8B**: *Centaurea crithmifolia* (66.7); *Centaurea friderici* subsp. *jabukensis* (66.7); *Olea europaea* L. (50); *Euphorbia dendroides* L. (41.7); *Daucus carota* L. subsp. *hispanicus* (Gouan) Thell. (39.7); *Limonium pomoense* (34.9); *Chenopodium album* L. (33.3);
Cluster 9A: *Erica multiflora* L. (38.4); *Pistacia lentiscus* (36.8); *Asperula staliana* subsp. *issaea* Korica (28.6); *Limonium zankii* (28.6); *Petrorhagia saxifraga* (L.) Link (28.6); *Aethionema saxatile* (L.) R. Br. subsp. *scopulorum* (Ronniger) I. A. Anderson, A. Carlström, Franzén, Karlenet H. Nybom (23.7); **Cluster 9B**: *Ficus carica* L. (33.3); *Teucrium flavum* L. (22.2);
Cluster 10A: *Limonium issaeum* (64.7); *Arthrocnemum fruticosum* (L.) Moq. (33.3); *Atriplex littoralis* L. (33.3); *Desmazeria pauciflora* Merino (33.3); **Cluster 10B**: *Limonium subanfractum* (100); *Plantago holosteum* Scop. (75); *Desmazeria marina* (L.) Druce (33.2).

Appendix 2. Holotypes of the new associations

Crithmo maritimi-Limonietum busiani [Bisevo Island; holotypus: rel. 1 of Supplement S2: *Valantia muralis* L. (1); *Urospermum picroides* (+); *Sonchus asper* (L.) Hill subsp. *glaucescens* (Jord.) Ball (+); *Silene vulgaris subsp. angustifolia* (2); *Silene sedoides* (+); *Sedum ochroleucum* (+); *Reichardia picroides* (1); *Plantago coronopus* subsp. *commutata* (+); *Parapholis incurva* (+); *Lotus ornithopodioides* L. (+); *Lotus edulis* L. (+); *Lotus cytisoides* (1); *Limonium busianum* (2); *Helichrysum italicum* (+); *Dittrichia viscosa* (+); *Desmazeria marina* (+); *Dactylis glomerata* subsp. *hispanica* (+); *Crithmum maritimum* (2); *Brachypodium retusum* (+); *Allium ampeloprasum* (+)]
Crithmo maritimi-Limonietum brusnicensae [Brusnik islet, holotypus rel. 17 of Supplement S2: *Crithmum maritimum* (2); *Frankenia pulverulenta* (+); *Limonium brusnicense* (3); *Lotus cytisoides* (2); *Reichardia picroides* (+); *Senecio leucanthemifolius* (1); *Silene sedoides* (+)]
Crithmo maritimi-Limonietum issaeae [Vis island, holotypus rel. 23 of Supplement S2: *Aethionema saxatile* subsp. *scopulorum* (+); *Capparis orientalis* (1); *Centaurea ragusina* subsp. *ragusina* (+); *Crithmum maritimum* (3); *Desmazeria rigida* (+); *Limonium issaeum* (3); *Lotus cytisoides* (2); *Reichardia picroides* (1); *Silene sedoides* (1)]
Plantagino holostei-Limonietum subanfracti [Vis island, holotypus rel. 30 of Supplement S2: *Crithmum maritimum* (3); *Limonium subanfractum* (3); *Plantago holosteum* (2); *Lotus cytisoides* (1); *Silene sedoides* (+); *Reichardia picroides* (+); *Helichrysum italicum* (+)]
Centaureo jabukensis-Aurinietum leucadeae [Jabuka islet, holotypus rel. 38 of Supplement S3: *Aurinia leucadea* (4); *Capparis orientalis* (r); *Centaurea crithmifolia* (+); *Centaurea friderici* subsp. *jabukensis* (2); *Euphorbia dendroides* (r); *Matthiola incana* (r); *Melilotus officinalis* (L.) Lam. (+); *Silene sedoides* (r); *Sonchus asper* subsp. *glaucescens* (2)]
Limonio vestiti-Puccinellietum teyberi [Kamik islet, holotypus rel. 33 of Supplement S3: *Allium commutatum* (1); *Aurinia leucadea* (+); *Capparis orientalis* (2); *Crithmum maritimum* (1); *Frankenia pulverulenta* (+); *Lavatera arborea* (1); *Limonium vestitum* (2); *Lolium rigidum* (+); *Lotus cytisoides* (1); *Puccinellia teyberi* (3); *Suaeda vera* (+)]
Pimpinello lithophyllae-Centaureetum issaeae [Vis island, holotypus rel. 50 of Supplement S3: *Brachypodium retusum* (2); *Brassica incana* (2); *Centaurea issaea* (2); *Coronilla valentina* subsp. *valentina* (+); *Crithmum maritimum* (+); *Desmazeria rigida* (+); *Dorycnium hirsutum* (r); *Erica manipuliflora* (+); *Helichrysum italicum* (2); *Inula verbascifolia* (2); *Juniperus phoenicea* (+); *Limonium issaeum* (1); *Pimpinella tragium* subsp. *lithophila* (2); *Reichardia picroides* (+); *Silene vulgaris* subsp. *angustifolia* (+); *Valantia muralis* (1)]
Centaureo diomedeae-Aurinietum leucadeae [Capraia island, Tremiti Archipelago, Italy, holotypus rel. 87 of Supplement S3: *Allium commutatum* (1); *Artemisia arborescens* L. (1); *Aurinia leucadea* (2); *Capparis orientalis* (1); *Centaurea diomedea* Gasp. (+); *Hyoscyamus albus* L. (+); *Parietaria judaica* (r); *Pistacia lentiscus* (+); *Roccella fucoides* Ach. (+); *Sedum hispanicum* (+); *Xanthoria calcicola* Oxner (2); *Umbilicus horizontalis* (1)]