Article

Contribution to the Knowledge of Rocky Plant Communities of the Southwest Iberian Peninsula

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Abstract: The rocky habitats of southern Portugal are ecosystems with extreme xericity conditions, associated with special abiotic strains. In these unstable ecological conditions, a considerable diversity of plant communities occurs. The objective of this study, carried out in the Algarve and Monchique, and the Mariánica Range biogeographical sectors, is to compare chasmos-chromophytic communities of the southwestern Iberian Peninsula, using a phytosociological approach (Braun-Blanquet methodology) and numerical analysis (hierarchical cluster analysis). From these results, two new communities were identified, Sanguisorba rupestris-Dianthetum crassipes and Antirrhineum onubensis, as a result of floristic and biogeographical differences from other associations already described within the alliances Rumici indurati-Dianthon lusitanii and Calendulo lusitanicae-Antirrhinion linkiani, both included in the Phagnalo saxatilis-Rumiceta indurate class.

Keywords: phytosociology; numerical analysis; Phagnalo saxatilis-Rumiceta indurate class; southern Portugal; Dianthus crassipes; Antirrhinum onubensis

1. Introduction

Habitats are very important natural or semi-natural places that need to be continuously studied to preserve them and their inhabitants, especially the plant endemic species that characterize them [1,2]. In fact, different habitats in the world are threatened by different types of pressures and threats [3–10]. Among the wide spectrum of habitats, we focus on plant communities that develop on rocky habitats, which are often associated with crests, cliffs, lithosols, rocky soils or rock outcrops. In these edaphoxerophilous biotopes that appear to be evidence of extreme xericity conditions, namely great edaphic drought as a result of the soil’s reduced capacity for water retention [5,11]. In fact, this environment offers the ideal conditions for a highly specialized type of vegetation: the chasmo-chromophytic communities, which encompass rupicolous vegetation that colonizes earthy broad crevices, rocky soils and lithosols (chromophytes) or narrow rocky fissures (chasmophytes).

The perennial chasmo-chromophytic communities of the southwestern Iberian Pen-
insula are included in the Phagnalo saxatilis-Rumicetea indurati vegetation class [12,13]. The Phagnalo saxatilis-Rumicetalia indurati is the only order of this class and is further divided into six alliances in the Iberian Peninsula [13]. Because of the substrata nature given to the descriptions of the chasmo-chomophytic communities within the Phagnalo saxatilis-Rumicetalia indurati order, such as schist or greywacke, limestone and dolomite, Costa et al. [12] recognized the presence of two alliances in southern Portugal: Rumici indurati-Dianthion lusitani, which is ascribed to the communities developing on fissures of siliceous rocks of the West Iberian Mediterranean and Oroiberian territories, whereas the communities growing in the Dividing Portuguese Sector and Arrábida range (central and western Portugal), typically associated with limestone and dolomitic substrates, are classified within the Calendulo lusitanicae-Antirrhinin linkiani class.

The present paper aims to provide new knowledge of the chasmo-chomophytic communities of the southwestern Iberian Peninsula, included in the Phagnalo saxatilis-Rumicetea indurati class. The phytosociological and syntaxonomical vegetation analysis of the chasmo-chomophytic communities dominated by Dianthus crassipes (Rumici indurati-Dianthion lusitani alliance) and Antirrhinum onubensis (Calendulo lusitanicae-Antirrhinin linkiani alliance) allow us to distinguish two new communities: San-guisorbo rupicolae-Dianthetum crassipes and Antirrhitetum onubensis.

2. Materials and Methods

2.1. Study Area

Located in the southwest of the Iberian Peninsula, the study area covers two distinct units: the first, in the southern part of the Algarve and Monchique biogeographical sector, encompasses the sub-littoral lower altitude relics of Algarve limestone—Barrocal algarvio (maximum 480 m high), where there is frequent presence of basic rocky outcrops. The second includes the schist, greywacke and quartzite cliffs of the low-altitude range (with an altitude of less than 400 m) of the lower Guadiana valley, in the southwestern part of the Mariánica Range Sector. According to the most recent study of Peninsula Iberica bioclimatic characterization by Rivas-Martínez et al. [14], the study area is classified as mediterranean pluviseasonal oceanic, dry to subhumid thermomediterranean bioclimate.

2.2. Data Collection

Field research was carried out from 2011 to 2020. Phytosociological relevés were collected according to the Zurich–Montpellier phytosociological method [12,13,15–17], where we found two new distinct associations in the Algarve and Monchique, and Mariánica Range biogeographical sectors (Figure 1), based on the comparison of the phytosociological relevés, performed in Table 1. Following Biondi [18], each relevé is a floristically and ecologically homogeneous plant community that represents the plant association on the ground. Within this definition, for each relevé, all plants that are found in an area whose floristic, structural and ecological conditions are homogeneous, were identified and assigned a quantitative value or index for their coverage, using the conventional abundance–dominance scale of Braun–Blanquet.
Figure 1. Biogeographical map of the southwest of the Iberian Peninsula at sector level, following Rivas-Martínez et al. [19].

Table 1. Synoptic table of southwestern Iberian Peninsula chasmo-chomophytic communities linked to the Rumici indu-rati-Dianthion lusitani and Calendulo lusitanicae-Antirrhinion linkiani alliances.

| Association No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------|---|---|---|---|---|---|---|---|
| **Association Characteristics** |   |   |   |   |   |   |   |   |
| *Dianthus crassipes* R. Roem. | V | . | . | . | . | . | . | . |
| *Sanguisorba rupicola* (Boiss. & Reut.) A. Braun & C.D. Bouché | IV | II | . | . | . | . | II | . |
| *Rumex induratus* Boiss. & Reut. | IV | . | V | IV | . | . | . | . |
| *Phagnalon saxatile* (L.) Cass. | IV | III | V | . | . | V | III | . |
| *Antirrhinum onubensis* (Fern. Casas) | Valdés | . | V | . | . | . | . | . |
| *Sedum mucizonia* (Ortega) Raym.-Hamet | . | IV | . | . | . | . | . | . |
| *Dianthus lusitanus* Brot. | . | . | III | V | V | V | V | . |
| *Anarrhchinum bellidifolium* (L.) Willd. | . | . | . | III | . | . | . | . |
| *Digitalis thapsi* L. | . | . | . | V | II | . | . | . |
| *Silene acutifolia* Link ex Rohrb. | . | . | . | V | . | . | . | . |
| *Conopodium majus* subsp. *marizianum* (Samp.) | . | . | . | V | . | . | . | . |
| López Udías & Mateo | . | . | . | . | V | . | . | . |
| *Silene x montistellensis* M. Ladero et al. | . | . | . | . | . | V | . | . |
| *Narcissus rapicola* Dufour | . | . | . | . | V | . | . | . |
| *Dianthus barbatus* L. | . | . | . | . | . | V | . | . |
| *Antirrhinum linkianum* Boiss. & Reuter | . | . | . | . | V | V | . | . |
| *Calendula suffruticosa* subsp. *lusitanica* (Boiss.) | . | . | . | . | . | . | IV | . |
| Ohle | . | . | . | . | . | . | . | III |
| *Avenula lodunensis* subsp. *occidentalis* (Delastre) | . | . | . | . | . | . | . | . |
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|-----------------------|
| Arabis sadina (Samp.) Cout. | . . . . . . | II |
| Rumex intermedius DC. | . . . . . . | II |
| Saxifraga cincta Willk. | . . . . . . | I |

**Alliance, Order and Class Characteristics**

| Erysimum linifolium Rivas Goday & Bellot | . . . III | . . . . . |
| Antirrhinum graniticum Rothm. | . . . III | I . . . . |
| Sedum hirsutum All. | . . . . . . | V III . |

**Companions**

| Lavandula luisieri (Rozeira) Rivas Mart. | IV . . . . . . | . . . . |
| Genista polyanthos R. Roem. Ex Willk. | IV . . . . . . | . . . . |
| Cistus ladanifer L. | IV . . . . . . | . . . . |
| Rosmarinus officinalis L. | III . . . . . . | . . . . |
| Scilla autumnalis L. | III . . . . . . | . . . . |
| Phlomis purpurea L. | III . . . . . . | . . . . |
| Cheilanthes maderensis Lowe | III . . . . . . | . . . . |
| Quercus rotundifolia Lam. | II . . . . . . | . . . . |
| Polypodium interjectum Shivas | II . . . . . . | . . . . |
| Leucojum autumnale L. | II . . . . . . | . . . . |
| Campanula lusitanica L. | II . . . . . . | . . . . |
| Cheilanthes guanchica Bolle | II . . . . . . | . . . . |
| Pistacia lentiscus L. | II . . . . . . | . . . . |
| Olea europaea var. sylvestris (Mill.) Rouy ex Hegi | II . . . . . . | . . . . |
| Cosentinia vellea (Aiton) Todaro | II . . . . . . | . . . . |
| Centaurea melitensis L. | II . . . . . . | . . . . |
| Thyone masticina (L.) L. | III II . . . . . | . . . . |
| Dactylis hispanica subsp. lusitanica (Stebbins & Zohary) Rivas Mart. & Izco | III . . . . . . | . . . . . III . |
| Sedum forsterianum Sm. | III . . . . . . | . . . . I |
| Rhamnus oleoides L. | II III . . . . . | . . . . |
| Hyparrhenia sinica (Delile) Llauradó ex G. López | II . . . . . . | . . . . . III . |
| Helichrysum stoechas (L.) Moench | II . . . . . . | . . . . . III . |
| Rhamnus alaternus L. | II . . . . . . | . . . . I |
| Umbilicusrapetris (Salisb.) Dandy | III II IV IV V III . . . |
| Prasium majus L. | IV . . . . . . | . . . . |
| Asplenium petrorchae (Guérin) DC. | IV . . . . . . | . . . . . |
| Genista hisruta subsp. algarbiensis (Brot.) Rivas Mart. et al. | . . . . . . . | . . . . . |
| Aristolochia baetica L. | . III . . . . . | . . . . . |
| Asparagus albus L. | . III . . . . . | . . . . . |
| Juniperus turbinata Guss. | . II . . . . . | . . . . . |
| Valantia hispida L. | . II . . . . . | . . . . . |
| Thelargonium cynocrambe L. | . II . . . . . | . . . . . |
| Pistacia terebinthus L. | . II . . . . . | . . . . . |
| Elaeoselinum tenuifolium (Lag.) Lange in Willk. & | . II . . . . . . | . . . . |
| Campanula sicula L. | . II . . . . . . | . . . . |
| Campanula erinus L. | . II . . . . . . | . . . . . |
| Sedum seleriforme Jacq.) Pau | . IV . . . . . . | . . . II |
| Asplenium billotii F.W. Schultz | . . . . . . IV | I . . . . |
| Melica minuta L. | . . . . . . IV | . . III |
| Polypodium cambricum L. | . . . . . . III | . . . I |
| Galium glaucum subsp. austral L. | . . V . . . . . . | . . . . |
| Cheilanthes hispanica Mett. | . . . . II | . . . . . |
| Sanguisorba minor Scop. | . . . . II | . . . . . |
| Lavandula pedunculata (Mill.) Cav. | . . II | . . . . . |
| Isatis platyloba Link ex Steud. | . . II | . . . . . |
| Lactuca serriola L. | . . II | . . . . . |
| Plant Name                              | Row 1   | Row 2   | Row 3   | Row 4   | Row 5   |
|----------------------------------------|---------|---------|---------|---------|---------|
| Lagurus ovatus L.                      |         |         |         |         |         |
| Crambe bituminosa (Em. Schmid)         |         |         |         |         |         |
| Silene aristata Boiss.                 |         |         |         |         |         |
| Calluna vulgaris (L.)                   |         |         |         |         |         |
| Galium verum L.                        |         |         |         |         |         |
| Quercus robur L.                       |         |         |         |         |         |
| Linaria vulgaris subsp.                  |         |         |         |         |         |
| Bituminaria bituminosa (L.)             |         |         |         |         |         |
| Koeleria crassipes Lange                |         |         |         |         |         |
| Jasione salsugineus Boiss. & Reut.     |         |         |         |         |         |
| Biscutella valentina (Loefl. ex L.)    |         |         |         |         |         |
| Lactuca viridis subsp. chondrilliflora |         |         |         |         |         |
| Scleranthus annuus (L.)                 |         |         |         |         |         |
| Scrophularia nodosa                     |         |         |         |         |         |
| Polygala vulgaris L.                    |         |         |         |         |         |
| Sedum brevifolium DC.                  |         |         |         |         |         |
| Arrhenatherum elatius subsp. sardoum   |         |         |         |         |         |
| (Em. Schmid) Gamisans                  |         |         |         |         |         |
| Hypochaeris radicata L.                |         |         |         |         |         |
| Armeria x friorii J.C. Costa Capelo     |         |         |         |         |         |
| Rumex acetosella subsp. angiocarpus (Murb.) |         |         |         |         |         |
| Mur.                                    |         |         |         |         |         |
| Pteridium aquilinum L.                  |         |         |         |         |         |
| Quercus pyrenaica Willd.               |         |         |         |         |         |
| Calluna vulgaris (L.) Huds.             |         |         |         |         |         |
| Micropyrum tenellum (L.) Link.          |         |         |         |         |         |
| Festuca indigesta Lag. x Lange         |         |         |         |         |         |
| Digitalis purpurea L.                  |         |         |         |         |         |
| Juniperus communis subsp. alpina (Suter) |         |         |         |         |         |
| Agrostis deliciata Pourr. ex Lapeyr.   |         |         |         |         |         |
| Murbeckiella boryi (Boiss.) Rothm.     |         |         |         |         |         |
| Phalaris conglomerata (Brot.) Willk.   |         |         |         |         |         |
| Micromeria alpina (L.) Rchb.            |         |         |         |         |         |
| Urginea maritima (L.) Baker             |         |         |         |         |         |
| Carex hallerana Asso                   |         |         |         |         |         |
| Thymus sylvestris Hoffmans. & Link     |         |         |         |         |         |
| Linaria supina (L.) Mill.               |         |         |         |         |         |
| Piptatherum miliiaceum (L.) Coss.      |         |         |         |         |         |
| Melica magnoli (Gren. & Godr.) K. Richt.|         |         |         |         |         |
| Sanguisorba vespertina (Link ex G. Don) Ces |         |         |         |         |         |
| Galium lucidum subsp. fruticosum All.  |         |         |         |         |         |
| Silene gracilis DC.                    |         |         |         |         |         |
| Ceratophyllum officinarum DC.           |         |         |         |         |         |
| Geranium pyrenaicum Vill.              |         |         |         |         |         |
| Bituminaria bituminosa (L.) C.H. Stirt |         |         |         |         |         |
| Coincya johnstonii (Samp.) Greuter & Burdet |         |         |         |         |         |
| Scabiosa columbaria subsp. affinis (Gren. & Godr.) |         |         |         |         |         |
| Nyman                                  |         |         |         |         |         |
| Crambe hispanica L.                    |         |         |         |         |         |
| Lagurus ovatus L.                      |         |         |         |         |         |
| Anthyllis vulneraria subsp. maura (G. Beck) Lindb. |         |         |         |         |         |
| Hyparrhenia hirta (L.) Stapf in Prain  |         |         |         |         |         |
| Allium paniculatum L.                  |         |         |         |         |         |
| Asplenium trichomanes subsp. quadrivalens D.E. |         |         |         |         |         |
Association: No. 1 Sanguisorbo rupicolae-Dianthetum crassipes (Table 2 of this paper, 8 relevés; clusters 1–8); No. 2 Antirrhinetum onubensis (Table 3 of this paper, 8 relevés; 9–16); No. 3 Phagnalo saxatilis-Rumicetum indurati Rivas-Martinez ex F. Navarro & C. Valle in Ruiz 1986 ([20]: Table 12, 5 relevés; clusters 17–21); No. 4 Digitali thapsi-Dianthetum lusitani Rivas-Martinez ex V. Fuente 1986 ([21]: Table 12, 10 relevés; clusters 22–31); No. 5 Silene acutifolias-Dianthetum lusitani Vicente & Galán 2008 ([22]: Table 3, 9 relevés; clusters 32–40); No. 6 Sileno montisellensis-Dianthetum lusitani Rivas-Martinez 1981 corr. Ladero, Rivas-Martinez, Amor, M.T. Santos & Alonso 1999 ([23]: Table 6, 4 relevés; clusters 41–44); No. 7 Phagnalo saxatilis-Dianthetum barbati C. Lopes, Pinto-Gomes, Louss & Ladero 2012 ([24]: Table 20, 6 relevés; clusters 45–51); No. 8 Sileno longicilias-Antirrhinetum linkiani Ladero, C. Valle, M.T. Santos, Amor, Espírito Santo, Louss & J.C. Costa 1991 ([25]: Table 1, 13 relevés clusters 52–64). The highlighted cells indicate the characteristic species of each association.

2.3. Nomenclature

Syntaxonomical typings followed Rivas-Martinez [13,26,27], Costa et al. [12] and Mucina et al. [28]. Plant identification follows Coutinho [29], Franco [30], Franco and Rocha Afonso [31], Castroviejo [32] and Valdés et al. [33]. Taxonomic nomenclature was updated using Iberian lists elaborated by Rivas-Martinez et al. [27], Sequeira et al. [34] and Costa et al. [12]. The biogeographical and bioclimatological information was collected according to Rivas-Martinez et al. [14,19], and substratum affinity information was collected from the literature: Quinto-Canas [35], Meireles [36], Orellana and Galán de Mera [22] and Lopes [24]. The phytosociological name of the new vegetation unit is given according to the International Code of Phytosociological Nomenclature [37].

2.4. Data Analysis

For statistical data processing of the samples, we first generated a data matrix that included 64 relevés and 135 species from our field sampling (Table 2; Table 1, association 1; Figure 2, clusters 1–8; Table 3, association 2; Figure 2, clusters 9–16) and relevés taken from the literature [20–23,25,35,36]. The matrix was subjected to the unweighted pair-group method using arithmetic averages (UPGMA), with Bray–Curtis distance, to produce the dissimilarity measure, using the software Primer 6 [38,39].

The transformation of Braun–Blanquet’s abundance–dominance values follows Van der Maarel [40]. This transformation is required as a solution for converting the non-numerical values into numerical scale and in this form used as input data for numerical analysis, with the following equivalence: $r = 1, + = 2, 1 = 3, 2 = 4, 3 = 5, 4 = 6$ and $5 = 7$.

Table 2. Sanguisorbo rupicolae-Dianthetum crassipes ass. nova hoc. loco (Rumici indurati-Dianthion lusitani, Phagnalo saxatilis-Rumicetalia indurati and Phagnalo saxatilis-Rumicetalia indurati).

| Relevé No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 * |
|-----------|---|---|---|---|---|---|---|----|
| Surface (m²) | 20 | 30 | 25 | 10 | 25 | 35 | 25 | 30 |
| Altitude (m) | 160 | 210 | 210 | 270 | 185 | 135 | 215 | 220 |
| Cover Rate (%) | 70 | 50 | 70 | 50 | 35 | 35 | 55 | 70 |
| Orientation   | NE  | E   | O   | O   | NE  | O   | NO  | O   |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Slope (%)     | 35  | 60  | 80  | 50  | 25  | 65  | 35  | 80  |
| Average Height (m) | 0.4 | 0.3 | 0.4 | 0.35 | 0.4 | 0.3 | 0.4 | 0.4 |
| No. of Species | 11  | 6   | 9   | 10  | 6   | 8   | 8   | 12  |

### Association Characteristics of Association and Higher Units

| Species          | NE | E  | O  | O  | NE | O  | NO | O  |
|------------------|----|----|----|----|----|----|----|----|
| Dianthus crassipes | 4  | 3  | 4  | 3  | 2  | 2  | 3  | 4  |
| Sanguisorba lusitana | +  | -  | -  | 1  | -  | +  | +  | +  |

### Alliance and Higher Ranks Characteristics

| Species          | NE | E  | O  | O  | NE | O  | NO | O  |
|------------------|----|----|----|----|----|----|----|----|
| Phagnalon saxatile | -  | +  | +  | 1  | +  | -  | -  | +  |
| Rumex induratus  | -  | -  | -  | +  | +  | +  | +  | +  |

### Companions

| Companions          | NE | E  | O  | O  | NE | O  | NO | O  |
|---------------------|----|----|----|----|----|----|----|----|
| Lavandula lusitana  | -  | 1  | -  | +  | +  | +  | -  | r  |
| Cistus ladanifer    | r  | -  | r  | -  | -  | +  | +  | r  |
| Rosmarinus officinalis | +  | +  | +  | -  | -  | +  | +  | -  |
| Dactylius hispanica lusitana | +  | -  | -  | +  | -  | -  | -  | -  |
| Umbilicus rupestris | -  | +  | -  | -  | -  | +  | +  | -  |
| Scilla autunnalis  | 1  | -  | +  | -  | -  | -  | +  | -  |
| Phlomis purpurea    | -  | -  | +  | -  | -  | -  | -  | -  |
| Thymus mastichina   | -  | +  | -  | 1  | -  | -  | -  | -  |
| Sedum forsterianum | 1  | -  | 1  | -  | -  | -  | -  | -  |
| Cheilanthes madensis | -  | -  | +  | -  | -  | -  | -  | r  |

### Other taxa—Companions:
+Quercus rotundifolia, +Rhamnus oleoides, +Polypodium interjectum, +Leucojum autunnale in 1; +Campanula lusitana in 2; 1 Cheilanthes guanchica, r Rhamnus alaternus in 4; +Helichrysum stoechas in 5; +Pistacia lentiscus, +Olea europaea var. sylvestris in 6; +Hyparrhenia sinaica, +Cosentinia vellea, +Asparagus albus, +Centaurea melitensis in 8. **Location of the relevés:** 1—Monte da Ribeira (near Cachopo; lat 37°17’45.23” N, long 7°44’54.44” W); 2—Pão Duro (near Vaqueiros; lat 37°23’08.67” N, long 7°44’54.94” W); 3—Madeiras (lat 37°20’02.44” N, long 7°43’38.15” W); 4—Tavilhão (near Amelxial; lat 37°22’31.81” N, long 8°00’00.15” W); 5—Azinhosa (near Relvais; lat 37°18’14.40” N, long 7°44’24.49” W); 6—Galego (lat 37°20’17.16” N, long 7°43’26.65” W); 7—Plenganas (near Vaqueiros; lat 37°24’15.03” N, long 7°44’16.45” W); 8 (* holotypus)—Madeiras (lat 37°20’06.03” N, long 7°43’38.82” W).

**Figure 2.** Classification analysis (UPGMA clustering dendrogram (with Bray–Curtis distance) on chasmo-chomophytic associations from the Southwestern Iberian Peninsula (included in both Rumici indurati-Dianthetum lusitani and Calendulo lusitanicae-Antirrhinion linkiani alliances): 1—Silene acutifoliae-Dianthetum lusitani (32–40); 2—Sileno montistellensis-Dianthetum lusitani (41–44); 3—Digitali thapsi-Dianthetum lusitani (22–31); 4—Antirrhinetum onubensis (9–16); 5—Sileno
longiciliae-Antirrhinetum linkiani (52–64); 6—Sanguisorbo rupicolae-Dianthetum crassipes (1–8); 7—Phagnalo saxatilis-Rumicetum indurati (17–21); 8—Phagnalo saxatilis-Dianthetum barbati (45–51).

Table 3. Antirrhinetum onubensis ass. nova hoc. loco (Calendulo lusitanicae-Antirrhinion linkiani, Phagnalo saxatilis-Rumicetalia indurati and Phagnalo saxatilis-Rumicetcea indurati).

| Relevé No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------|---|---|---|---|---|---|---|---|
| Surface (m²) | 15 | 10 | 20 | 15 | 10 | 20 | 15 | 15 |
| Altitude (m) | 235 | 245 | 380 | 250 | 240 | 245 | 260 | 250 |
| Cover rate (%) | 30 | 20 | 20 | 30 | 35 | 30 | 35 | 30 |
| Orientation | NO | S | S | N | SO | N | O | S |
| Slope (%) | 70 | 80 | 30 | 40 | 60 | 80 | 50 | 60 |
| Average Height (m) | 0,5 | 0,4 | 0,4 | 0,5 | 0,5 | 0,5 | 0,4 | 0,5 |
| No. of Species | 8 | 6 | 9 | 7 | 5 | 10 | 6 | 9 |

**Association Characteristic**

| Antirrhinum onubensis | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |

**Alliance and Higher Rank Characteristics**

| Sisymbrium nigricans | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |

**Companions**

| Melica minuta | + | + | + | - | - | + | - | + |
| Asplenium petrarchae | - | + | + | - | r | + | - | + |
| Sedum sylvaticum | - | - | + | + | - | - | + | - |
| Prasum majus | + | + | + | - | - | - | - | - |
| Genista hispida subsp. algarbiensis | + | - | - | - | + | + | - | + |
| Asplenium ceterach | + | - | - | - | - | + | - | - |
| Aristolochia baetica | - | - | + | + | - | - | - | + |
| Rhamnus oleoides | + | - | - | - | 1 | - | - | - |
| Asparagus albus | - | - | + | - | - | + | - | - |
| Polygodium cambricum | - | - | - | + | - | + | - | - |

**Other taxa**—Companions: 1 Juniperus turbinata, +Valantia hispida in 1; +Theligonum cynocrambe in 2; +Campanula erinus, +Umbilicus rupestris in 3; +Thymus mastichina in 4; +Pistacia terebinthus in 7; +Elaeolium tenuifolium; +Ceratonia siliqua in 8. **Location of the relevés**: 1—Barrocal da Tôr (near Tôr; lat 37°10′24.9° N, long 8°08′26.9° W); 2—Cerro da Cabeça (near Moncarapacho; lat 37°06′33.9° N, long 7°46′54.8° W); 3—Rocha da Pena (near Salir); 4—Malhada Velha (near Loulé; lat 37°10′20.4° N, long 8°00′37.0° W); 5—Varejota (near Pargal; lat 37°10′19.3° N, long 8°04′50.3° W); 6—Barrocal da Tôr (near Tôr; lat 37°10′25.3° N, long 8°02′39.4° W); 7—Malhada Velha (near Loulé; lat 37°10′18.7° N, 8°00′44.2° W); 8—Varejota (near Pargal; lat 37°10′16.8° N, 8°04′47.6° W).

3. Results and Discussion

3.1. Classification of Southwestern Iberian Peninsula Chasmo-Chromophytic Communities

The dendrogram and the synoptic table reveal a clear separation between all phytosociological chasmochromophytic communities of the Southwestern Iberian Peninsula, included in both alliances: Rumici indurati-Dianthion lusitanus and Calendulo lusitanicae-Antirrhinion linkiani. The cluster analysis (Figure 2) produces two main groups of associations (group A and group B), which represent eight community types: Sanguisorbo rupicolae-Dianthetum crassipes (clusters 1–8), Antirrhinetum onubensis (9–16), Phagnalo saxatilis-Rumicetum indurati (clusters 17–21), Digitalis thapsi-Dianthetum lusitanus (clusters 22–31), Silene acutifoliae-Dianthetum lusitanus (clusters 32–40), Sileno montistellensis-Dianthetum lusitanus (clusters 41–44), Phagnalo saxatilis-Dianthetum barbati (clusters 45–51) and Sileno longiciliae-Antirrhinetum linkiani (clusters 52–64).

Group A has a high dissimilarity in relation to the other associations and includes relevés dominated by Dianthus lusitanus. The Digitalis thapsi-Dianthetum lusitanus is an association co-dominated by Dianthus lusitanus and Digitalis thapsi which occur in the mesomediterranean to supramediterranean bioclimatic stages of the Lusitania and Extremadura, Carpetana and León, and Oroiberian Subprovinces, on rocky fissures of schist,
quartzite and granite [21]. The *Silene acutifoliae-Dianthetum lusitani* occur mostly on quartzitic outcrops in the mesomediterranean belt of the São Mamede mountains (São Mamede Sierran District, Oretana Range and Tajo Sector), well characterized by the presence of *Silene acutifolia* [22]. The *Sileno montistellensis-Dianthetum lusitani* is found in submediterranean areas, with the supramediterranean to oromediterranean themotype, on granitic fissures of the Estrela mountain biogeographical territory, and is characterized by the presence of *Silene x montistellensis* (hybrid between *Silene acutifolia* and *Silene foetida*) [36].

The cluster analysis also shows a group of relevés clearly separated from the rest, which are included in the cluster group B, divided into two subgroups. The relevé cluster subgroup B1 corresponds to the association *Antirrhinetum onubensis*, which is proposed here as a new association, largely confined to the limestones of Algarve District (Algarve and Monchique Sector). The subgroup B2 comprises samples ascribed to both silicicolous and calcicolous associations included in the alliances *Rumici indurati-Dianthion lusitani* (such as *Phagnalon saxatilis-Rumicetum indurati* and *Sanguisorbo rupicolae-Dianthetum crassipes*) and *Calendulo lusitanicae-Antirrhinion linkiani* (such as *Phagnalon saxatilis-Dianthetum barbati* and *Sileno longiciliae-Antirrhinetum linkiani*), respectively. The floristic similarities between these four associations are a result of the high presence of *Phagnalon saxatilis* and *Sanguisorba rupicola* in its characteristic species set, both with indifferent soil preferences, and also, in the scope of companion species, the presence of *Dactylis hispanica* subsp. *lusitanica*, *Sedum forsterianum*, *Hyparrhenia sinaica*, *Helichrysum stoecha*, *Sedum sediforme*, *Melica minuta*, *Polypodium cambricum* and *Sedum album*. The *Phagnalon saxatilis-Rumicetum indurati* is dominated by *Phagnalon saxatilis* and *Rumex induratus*, and is widely distributed throughout the thermomediterranean to supramediterranean areas of the West Iberian Mediterranean, and Coastal Lusitanian and West Andalusia Provinces. The *Sanguisorbo rupicolae-Dianthetum crassipes*, a new association physiognomically characterized by *Dianthus crassipes*, occurs in the thermomediterranean to mesomediterranean dry areas of the East Mariánica District (Mariánica Range Sector). The *Phagnalon saxatilis-Dianthetum barbati*, a calcicolous community characterized by the co-dominance of *Dianthus barbatus* and *Phagnalon saxatilis*, is found in the northern part of the Divisório Portuguese Sector [24]. The *Sileno longiciliae-Antirrhinetum linkiani*, which has been described by Ladero et al. [25] in the limestones of the Divisório Portuguese Sector and Arrabida Sierran District (Ribatejo and Sado Sector), is characterized by the dominance of species from the *Calendulo lusitanicae-Antirrhinion linkiani* alliance, such as *Antirrhinum linkianum*, *Silene longicilia*, *Calendula suffruticosa* subsp. *lusitanica*, *Biscutella valentina*, *Arabis sedina*, *Avenula iodunensis* subsp. *occidentalis* and *Saxifraga cinnara*.

As evidenced in Table 1, in the main characteristics and companion species group, the associations of subgroup B2 encompass differential and territorial species, which support the ecological concept of divisions proposed by Ladero et al. [25] for the *Phagnalon saxatilis-Rumicetalia indurati* order in the West Iberian Mediterranean territories: the alliance *Rumici indurati-Dianthion lusitani* for the siliceous rocks and *Calendulo lusitanicae-Antirrhinion linkiani* for the outcrops of limestone and dolomitic rocks.

3.2. Description of the New Chasmo-Chomophytic Associations

I—*Sanguisorbo rupicolae-Dianthetum crassipes* ass. nova hoc loco (Table 2; clusters 1–8)

The relevés of the new association *Sanguisorbo rupicolae-Dianthetum crassipes* (holotypus Table 2, relevé 8) appear to be clearly defined in group A (clusters 1–8; Figure 2). It is a perennial chasmo-chomophytic community, which develops on acid rocky fissures of schist or greywackes and quartzitic outcrops of the Guadiana basin, in the southeastern part of Portugal (East Mariánica District, Mariánica Range Sector). The *Sanguisorbo rupicolae-Dianthetum crassipes* is an association characterized by *Dianthus crassipes* and *Sanguisorba rupicola* [41] (Figure 3). As shown in Table 2, the floristic composition also contains other chasmo-chomophytic species from the *Phagnalon saxatilis-Rumicetalia indurati*
class, such as Phagnalon saxatile and Rumex induratus. The rupicolous character is emphasized by the presence, in the companion species group, of chasmophytic elements from the Asplenietea trichomanis class, such as Cheilanthes maderensis, Cheilanthes guanchica and Cosentinia vellea. Regarding the xerophilous position, this new association develops on the most exposed sector of the cliffs or crests and is distributed in holm oak woodland domains of the Myrto communis-Quercetum rotundifolii or, in the driest siliceous areas of the lower part of the Guadiana valley, on potential areas of the sclerophyllous shrubs of Juniperus turbinata, from the Phlomido purpureae-Juniperetum turbinatae.

We place this new Dianthus crassipes community, at association rank, within the Rumici indurati-Dianthion lusitani alliance, which comprises the heliophilous and xerophilous chasmo-chromophytic communities growing on acid siliceous rocks of the West Iberian Mediterranean Province [12].

Figure 3. Sanguisorbo rupicolae-Dianthetum crassipedis on rocky cliff fissures in the lower Guadiana basin (Ribeira da Foupanilha, near Vaqueiros—Alcoutim), included in the southwestern part of the Mariánica Range Sector.

II—Antirrhinetum onubensis ass. nova hoc. loco (Table 3; clusters 9–16)

The new association Antirrhinetum onubensis (holotypus Table 3, relevé 6) occurs in the thermomediterranean, dry to sub-humid belts of the Algarve District (Algarve and Monchique Sector), on sub-coastal cliffs or rocky fissures of limestones from southern Portugal (Barrocal algarvio reliefs) (Figure 4). Thus, Antirrhinetum onubensis is a calcico-lous association developed in potential areas of the edaphoxerophilous woodlands dominated by Quercus rotundifolia (Rhamno oleoidis-Quercetum rotundifolii), Juniperus turbinata (Aristolochio baeticae-Juniperetum turbinatae) and Ceratonia siliqua (Vinco difformis-Ceratonietum siliquae).
The new *Antirhinum onubensis* chasmo-chomophytic community proposed here is characterized by other species from the class *Phagnalo saxatilis-Rumicetea indurati*, such as *Sedum mucizonia* and *Phagnalon saxatile*, and other thermophile differential species (Table 1): *Asplenium petrarchae*, *Genista hirsuta* subsp. *algarbiensis*, *Aristolochia baetica*, *Elaeoselinum tenuifolium*.

We place the *Antirrhinetum onubensis* at the association rank, in the *Calendulo lusitanicae-Antirrhinion linkiani* alliance, which encompasses the rupicolous vegetation of calcareous crevices of central and western Portugal (in the Divisório Portuguese Sector and Arrabida Sierran District) [10,26]. Nevertheless, according to our results, we propose to modify the alliance diagnosis, extending over the biogeographical territories of the southern Portugal (Algarve District, Algarve and Monchique Sector). Moreover, this community should be classified as a priority habitat from Habitats Directive 92/43/EEC, under the Natura 2000 code: *6110 Rupicolous calcareous or basophilic grasslands of the Alyso-Sedion albi*, from the Annex I habitat types of the Council Directive 92/43/EEC of 21 May 1992.

3.3. Syntaxonomical Scheme

**PHAGNALO SAXATILIS-RUMICETALIA INDURATI** (Rivas Goday & Esteve 1972)
Rivas-Martínez, Izco & Costa 1973

**PHAGNALO SAXATILIS-RUMICETALIA INDURATI** Rivas Goday & Esteve 1972
Rumici indurati-Dianthion lusitani Rivas-Martínez, Izco & Costa ex V. Fuente 1986
Phagnalo saxatilis-Rumicetum indurati Rivas-Martínez et al. ex F. Navarro & C. Valle in Ruiz 1986
Silene acutifoliae-Dianthetum lusitani Vicente & Galán 2008
Sileno montistellensis-Dianthetum lusitani Rivas-Martínez 1981 corr. Ladero, Rivas-Martínez, Amor, M.T. Santos & Alonso 1999
Sanguisorba rupicolae-Dianthetum crassipes Quinto-Canas, Cano-Ortiz, Musarella, del Río, M. Raposo, Piñar Fuentes & Pinto-Gomes ass. nova huc loco Calendulco lusitanicae-Antirrhinion linkiani Ladero, C. Valle, M.T. Santos, Amor, Espirito Santo, Lousã & J.C. Costa 1991
Phagulo saxatilis-Dianthetum barbati C. Lopes, Pinto-Gomes, Lousã & Ladero 2012 Sileno longiciliæ-Antirrhinetum linkiani Ladero, C. Valle, M.T. Santos, Amor, Espirito Santo, Lousã & J.C. Costa 1991 Antirrhinetum onubensis Quinto-Canas, Cano-Ortiz, Musarella, del Río, M. Raposo, Piñar Fuentes & Pinto-Gomes ass. nova huc loco

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