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SERPENTINE PLANT DIVERSITY AND VEGETATION IN A MEDITERRANEAN AREA (SIERRA DE MIJAS, SOUTHERN IBERIAN PENINSULA, SPAIN)

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Abstract - A study of the flora and vegetation of a serpentine outcrop in the south of the Iberian Peninsula (Malaga, Spain) has been carried out. The study area is located in the Bermejense biogeographical sector (Baetic province, Mediterranean region) and shows a Mediterranean pluviseasonal-oceanic bioclimate. Most of the outcrop is altered by urban planning linked to tourism and affected by invasive alien species. Three areas remain more intact. A catalogue of vascular flora has been completed, made up of 168 taxa, including three threatened species, four obligate serpentinophytes, one preferential serpentinophyte, and one subserpentinophyte (majority of populations on serpentine). Seven taxa are South-Iberian ultramafic endemics. *Silene inaperta* subsp. *serpentinicola* is an obligate serpentinophyte and threatened endemism. Twelve alien taxa have been identified showing invasive potential, 75% of them originating from inactive dumps. The richness of serpentinophytes/area fits in the trend of the southern outcrops of the Iberian Peninsula. Four associations and one community have been identified. The serpentine perennial grassland stands out for its abundance and dominance, for which a new association is proposed (*Scorzonero boeticae-Macrochloetum tenacissimae ass. nova*). There are three habitats included within the Directive 92/43/EEC: therophytic and perennial grasslands (6220), scrubland (5330) and oleander shrublands (92D0).

Keywords: serpentine; flora; serpentinophytes; vegetation; *Macrochloa tenacissima* association; invasive alien plants; southern Iberian Peninsula.

Introduction

Serpentine ecosystems occupy approximately 3% of the Earth's surface (Guillot & Hattori, 2013), showing a global but highly fragmented geographic distribution, and making these igneous rock outcrops a peculiar feature at the lithological level on Earth (Brooks, 1987). In the Iberian Peninsula, serpentine outcrops are found in Galicia, northern Portugal and Andalusia (Roberts and Proctor, 1992); in the latter region are located the largest outcrops in the Iberian Peninsula and Western Europe, with a total of 441.5 km^2 (Figure 1).

Serpentine soils are a hostile environment for plants, characterised by high Fe and Mg content, low Ca content, nutrient deficiency (N, P, K), infertility, toxic concentrations of heavy metals (Cr, Ni, Co, Va), very slow soil development, high xericity and strong soil temperature ranges (Whittaker, 1954; López González, 1975; Brooks, 1987). These characteristics make these habitats highly selective, causing endemicity by adaptation to the substrate (serpentinophytes). Serpentinophyte species can be classified according to their degree of presence in serpentine or other substrates in obligate, preferential and subserpentinophytes (Pérez-Latorre et al., 2013b). Serpentinophytes may have physiological mechanisms or adaptations to the toxic effects of the substrate (hyperaccumulators, serpentinomorphoses), which are of interest for the restoration of contaminated soils and studies of plant evolution in extreme habitats (Brady et al., 2005; Wójcik et al., 2017; Hidalgo-Triana & Pérez-Latorre, 2019).

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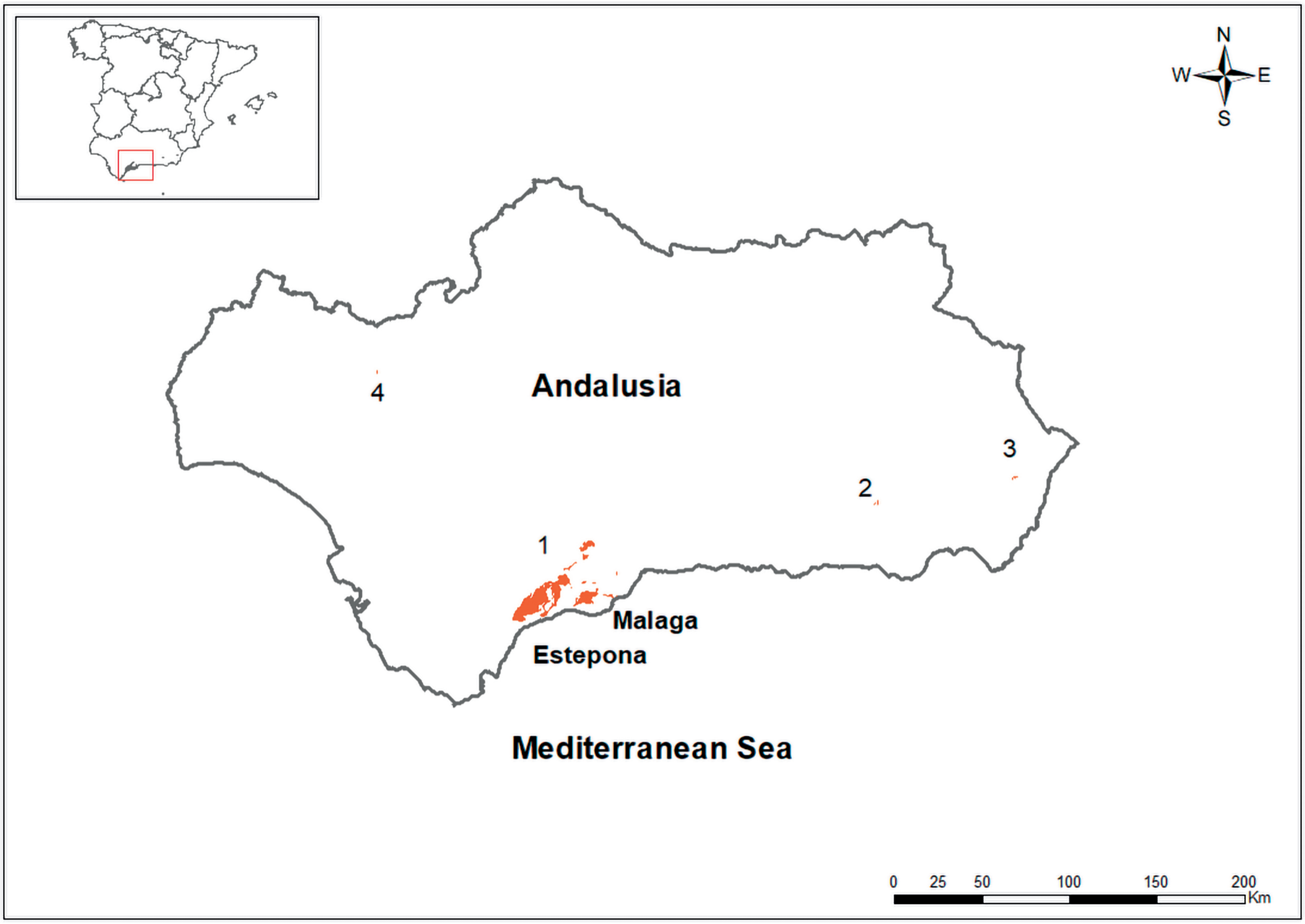

Figure 1. Ultramafic outcrops in the south of the Iberian Peninsula (Andalusia, Spain) (Pérez-Latorre *et al.,* 2018). 1. Sierras Bermejas (Malaga, 434.5 km^2), 2. Almirez Peak (Sierra Nevada, Granada, 3 km^2), 3. Lubrin (Almeria, 3 km^2), 4. El Ronquillo (Seville, 1 km^2). Modified from REDIAM (2004).

The Andalusian serpentine plant communities have a peculiar floristic composition (Pérez-Latorre et al., 1998, 2013a). Scrublands dominate the landscape, due to frequent fires, which destroy the climatic stage of pines (*Pinus pinaster* Aiton) and firs (*Abies pinsapo* Clemente ex Boiss.) (López González, 1975; Cabezudo et al., 1989, 1995; Pérez-Latorre et al., 1998). One serpentinophyte and most of the serpentine habitats are included in the annexes of the Directive 92/43/EEC (Pérez-Latorre et al., 2013b).

There are still no in-depth studies on the vegetation and flora of some of the South Iberian serpentine outcrops, although plant conservation focuses on different aspects relevant to plant diversity (Moreno-Saiz et al., 2018). This is the case of the Sierra de Mijas, about which there were only some data in the GBIF database (Global Biodiversity Information Facility) and in Pérez Sanz et al. (1987). Mijas is an area strongly affected by residential tourism and has large resorts, services (roads, dumps) and gardens, which causes the presence of non-native plant species (xenophytes) and the invasion of natural ecosystems (Dana et al., 2005).

The main goal of this study was to identify the vascular plant diversity of the serpentine outcrop and obtain a floristic catalogue, paying special attention to endemics, threatened taxa or protected by legislation, serpentinophytes, plants with serpentinomorphoses and invasive xenophytes. The second objective was to characterize the diversity of plant associations and communities and to identify which of them are included in the Habitats Directive 92/43/EEC. Attention was paid also to the richness of serpentinophytes and syntaxa in the studied area.

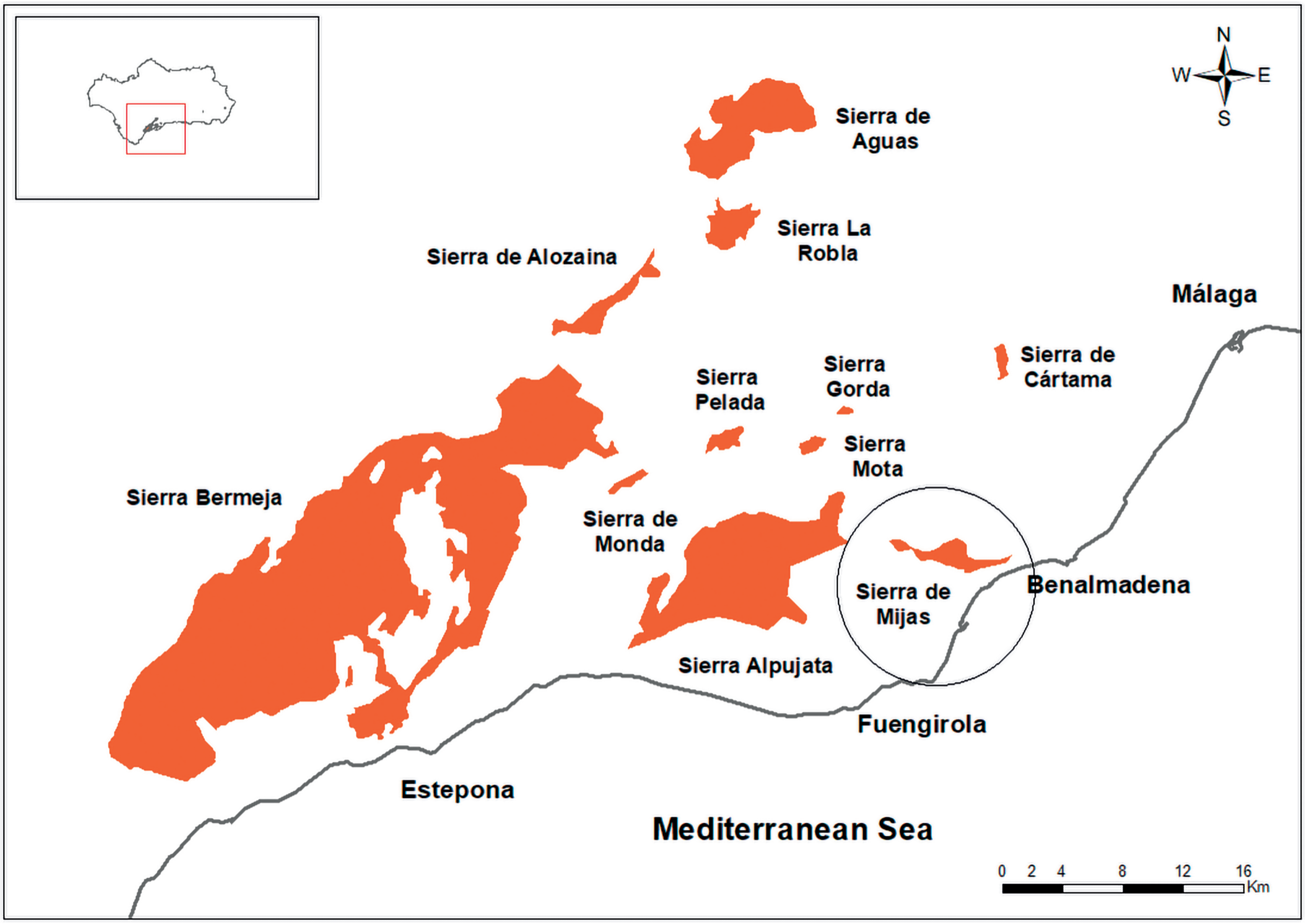

Figure 2. Ultramafic outcrops in the province of Malaga (Andalusia, Spain). They are subdivided into four minors: Bermeja (Sierras Bermeja, Palmitera, Real and Parda), Alpujata (Sierras Alpujata and Mijas), Aguas (Sierra de Aguas-La Robla) and Guadalhorce Valley (Sierra Mota, Sierra Gorda and Sierra de Cartama) (Pérez-Latorre et al., 2013a). The sampled area (Sierra de Mijas outcrop) is identified with a circle. Modified from REDIAM (2004).

Materials and Methods

Study area

The study area of this work (Figure 2) corresponds to the ultramafic outcrop of the Sierra de Mijas in the province of Malaga, in the south of the Iberian Peninsula (Andalusia, Spain). This outcrop is included in the municipality of Mijas and to a lesser extent in the municipalities of Fuengirola and Benalmadena. It has an area of 7 km^2, and altitude ranges from 100 to 485 m.

The lithology is constituted by a continuum of serpentine rocks (Piles Mateo et al., 1978) and the soils correspond to eutric cambisols, eutric regosols and chromic luvisols with lithosols (Balsera, 1989). The location and information on the area of the outcrop comes from the Andalusian Lithological Map (REDIAM, 2004).

The macrobioclimate is Mediterranean with an oceanic pluviseasonal bioclimate. Thermotype (bioclimatic belt) in the area is thermomediterranean with 17.3 °C annual average temperature and the ombrotypes vary from dry to subhumid with 644 mm as mean annual rainfall (Marbella weather station, 36° 32' N / 4° 57' W, Rivas Martínez et al., 2007; Pérez-Latorre et al., 2019).

The phytogeographical location and description of the study area are as follows: Holarctic Kingdom, Mediterranean region, Western-Mediterranean sub-region, Iberian-Moroccan-Atlantic super-province, Baetic province, Bermeja sector, Bermeja subsector (Pérez-Latorre and Cabezudo, 2002; Pérez-Latorre et al., 2019).

Field visits to the outcrop were carried out to determine the area occupied by anthropized spaces and natural areas, since only the latter has been sampled. With these data, the area of the territory occupied by anthropized or natural surface was measured. Finally, the natural zones were divided into three study sub-zones, free of anthropic use (Figure 3).

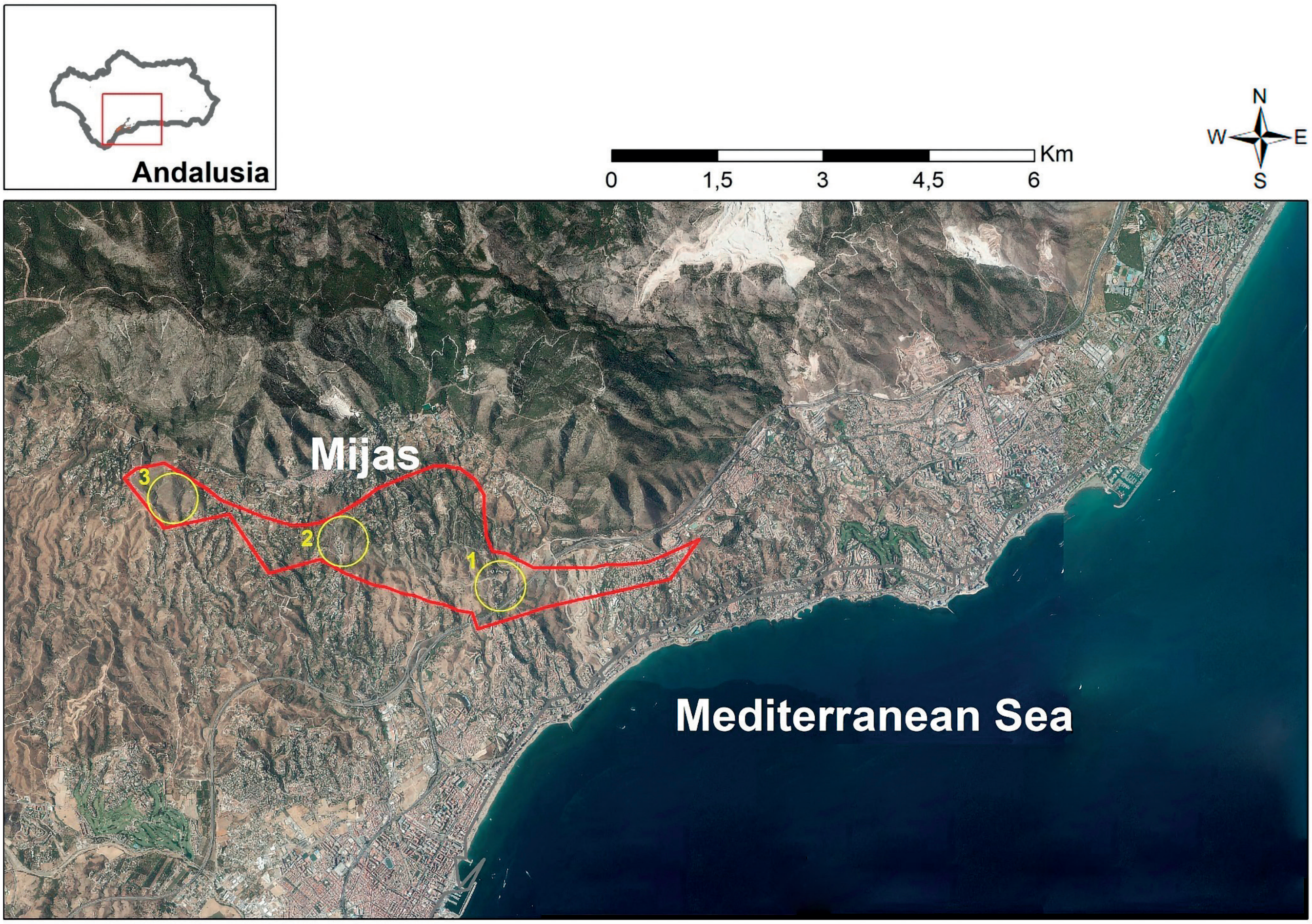

Figure 3. Location of the studied area with three natural areas surveyed (yellow circles) within the serpentine outcrop (red line): 1. Fuengirola, 2. Los Espartales (Mijas), 3. Cerrajón (Mijas).

Methodology

The field work was carried out from January to May 2019.

Floristic study

The specimens of vascular plants collected in the area were deposited in the MGC herbarium of the University of Malaga. Species identification was based on "Vascular Flora of Eastern Andalusia" (Blanca et al., 2011) and "Flora iberica" (Castroviejo et al., 1986-2018). Taxa from GBIF.org and Pérez Sanz et al. (1987) recorded in the study area were also searched for. Taxonomic nomenclature follows POWO (2019).

A selection of taxa of interest in the final catalogue was made consulting the following: a) "Vascular Flora of Eastern Andalusia" (Blanca et al., al., 2011) for endemisms and growth-forms, b) Royal Decree 139/2011 for the list of protected species at the Spanish level and the Decree 23/2012 for the list of protected species at the Andalusian level; c) the Spanish red book (Bañares et al., 2010) and the Andalusian red list (Cabezudo et al., 2005) for threatened species, d) Pérez-Latorre et al. (2013b, 2018) for types of serpentinophytes (obligate, preferential and subserpentinophyte) and growth forms; and e) Royal Decree 630/2013 with the catalogue of exotic species, and Dana et al. (2005) for alien invasive species. The location in the area and the origin according to the field work was indicated; the abundance following the criteria of Blanca et al. (2011), the type of metaphyte following Kornas (1990) (epecophyte in gardens and field crops, holoagriophyte in natural habitats and hemiagryophyte in seminatural habitats) and whether it is considered invasive in the legislation were indicated.

To estimate the floristic and biogeographic similarity between outcrops, the floristic catalogue was compared with those of other nearby serpentine outcrops (Figure 2): Sierra de Cartama (Hidalgo-Triana and Pérez-Latorre, 2013) and Sierra de Alpujata and La Robla (Pérez-Latorre et al., 2013a). The number of taxa present in the study area which are also found in each of these outcrops was determined.

The "serpentinophyte richness by area" was calculated using an adjustment function of the logarithm of the area (Whittaker & Fernández-Palacios, 2007; Pérez-García et al., 2012) and compared with the result obtained by Pérez-Latorre et al. (2013b) for the rest of the southern Iberian outcrops.

Vegetation and data analysis

Vegetation was analysed with the Braun-Blanquet (1979) phytosociological method, and the description of the vegetation units took into account the updates provided by Schuhwerk (1990) and Gehú and Rivas Martínez (1981). Fourteen vegetation relevés were carried out regularly distributed in ecologically homogeneous spaces, with the estimation of the minimum area at the surveyed localities (Figure 2).

To group vegetation relevés based on their degree of floristic similarity, a multivariate analysis was conducted with the free software PAST ver. 2.17 (Hammer et al., 2001). This allowed to obtain homogeneous groups of inventories, or clusters, and to refer them to communities or associations. Cover values of the taxa were transformed according to the method proposed by Der Maarel (1979). Hierarchical clustering on the final matrix of Euclidean distances was carried out using the flexible beta linkage.

The new syntaxonomical nomenclature proposals follow the International Code of Phytosociological Nomenclature (Weber et al., 2000). The proposal of Rivas-Martínez et al. (2011) is followed to identify the vegetation series, the characteristic species of the syntaxa and the most precise geo-ecological nomenclature. We follow Pérez-Latorre et al. (2004, 2008) to identify the zone-potential vegetation of the areas and the cryptoclimatic vegetation (climactic vegetation almost disappeared today from its potential territory).

The clusters of vegetation plots were interpreted, identified and assigned to their corresponding associations and finally grouped into syntaxa of higher level.

A syntaxomical scheme was made following the vegetation classification system proposed by Rivas Martínez et al. (2011). To identify the Habitats included in the Directive 92/43/EEC, Annex I was consulted and also the Atlas and Manual of Habitats of Spain (Rivas-Martínez et al., 2003). The importance of the serpentine outcrop of Mijas was estimated in terms of the number of syntaxa in the South Iberian ultramafic complex using the data collected in Pérez-Latorre et al. (2013a).

Results and Discussion

Flora

The floristic list of the Mijas ultramafic outcrop consists of a total of 168 taxa (Supplementary material). The selected taxa are listed below, divided into native and alien taxa.

Native taxa

Serpentinophytes, threatened taxa, and local endemics, as well as their families, are alphabetically listed below.

Alyssum serpyllifolium Desf. (*Alyssum serpyllifolium* Desf. subsp. *malacitanum* Rivas Goday) (Brassicaeae)
Chamaephyte/Hemicryptophyte multi-shooted. Obligate serpentinophyte if it is considered as subsp. *malacitanum* (Pérez-Latorre et al., 2013b), local endemic (Malaga) (Blanca et al., 2011), nickel hyperaccumulator (Rufo et al., 2004; Díez-Garretas et al., 2009).

Arenaria retusa Boiss. (Caryophyllaceae)
Erect therophyte. Subserpentinophyte (Pérez-Latorre et al., 2013b), local endemic (mainly in Malaga) (Blanca et al., 2011).

Centaurea prolongi Boiss. (Asteraceae)
Scapiform hemicryptophyte.VU (Red Lists of Spain and Andalusia), local endemic (mainly in Malaga) (Blanca et al., 2011).

Thapsia asclepium (L.) Bertol. (Apiaceae)
Scapiform hemicryptophyte. Local endemic (mainly in Malaga) (Blanca et al., 2011).

Galium boissierianum (Steud.) Ehrend. & Krendl (Rubiaceae)
Herbaceous chamaephyte. Preferential serpentinophyte (Pérez-Latorre et al., 2013b), VU (Red Lists of Spain and Andalusia), local endemic (mainly in Malaga) (Blanca et al., 2011).

Genista hirsuta Vahl subsp. *lanuginosa* (Spach) Nyman var. *lanuginosa* Hidalgo-Triana & Pérez Lat. (Fabaceae)
Cushion chamaephyte. Obligate serpentinophyte, local endemic of the ultramafic outcrops of Malaga and plant with serpentinomorphoses (Hidalgo-Triana and Pérez-Latorre 2019).

Linum carratracense (Rivas Goday and Rivas Mart.) Mart. Labarga & Muñoz Garm. (Linaceae)
Chamaephyte (scrub). Obligate serpentinophyte (Pérez-Latorre et al., 2018), local endemism (Malaga) (Martínez Labarga and Muñoz Garmendia 2015).

Silene inaperta L. subsp. *serpentinicola* Talavera (Caryophyllaceae)
Erect therophyte. Obligate serpentinophyte (Pérez-Latorre et al., 2013b), EN (Red Lists of Spain and Andalusia), local endemism (Malaga) (Blanca et al., 2011).

Alien taxa

The 7.1% (12) of the total taxa found in the study area are considered as alien/invasive and are mentioned below. The 75% of the taxa originate from old dumps (zones 1 and 3; Figure 3) and several of them have invaded stream habitats.

Acacia saligna (Labill.) H. L. Wendl. (Fabaceae)
Evergreen phanerophyte. All the outcrop. Dumps and urbanized areas. Frequent. Epecophyte.

Agave americana L. (Agavaceae)
Succulent chamaephyte. Zone 3. Dumps. Rare. Epecophyte. Invasive according to Royal Decree 630/2013.

Ageratina adenophora (Sprengel) R.M. King and H. Rob. (Asteraceae)
Evergreen phanerophyte. Zone 3. Stream. Very rare. Holoagriophyte.

Ailanthus altissima (Mill.) Swingle (Simaroubaceae)
Deciduous phanerophyte. Zone 3. Dumps. Rare. Epecophyte. Invasive according to Royal Decree 630/2013.

Ambrosia artemisiifolia L. (Asteraceae)
Erect therophyte. Recorded from MGC. Ornamental urban origin (flowerbeds). Epecophyte. Invasive according to Royal Decree 630/2013.

Arundo donax L. (Poaceae)
Herbaceous phanerophyte. Zone 3. Streams, dumps. Frequent. Hemiagryophyte.

Cenchrus setaceus (Forssk.) Morrone (Poaceae)
Grassy hemicryptophyte. Zones 1 and 3. Vials and dumps. Rare. Epecophyte. Invasive according to Royal Decree 630/2013.

Gomphocarpus fruticosus (L.) Ait. (Apocynaceae)
Evergreen phanerophyte. Recorded from GBIF.

Nicotiana glauca Graham (Solanaceae)
Evergreen phanerophyte. Zones 1 and 3. Dumps and wastes, vials. Rare. Epecophyte.

Oxalis pes-caprae L. (Oxalidaceae)
Bulbous cryptophyte. Zone 3. Dumps, wastes and streams. Frequent. Epecophyte-Hemiagryophyte. Invasive according to Royal Decree 630/2013.

Phoenix dactylifera L. (Arecaceae)
Palm phanerophyte. Zone 3. Dumps. Very rare. Epecophyte.

Ricinus communis L. (Euphorbiaceae)
Evergreen phanerophyte. Zones 1 and 3. Streams, dumps. Very rare. Epecophyte-Hemiagryophyte.

Comparison with floras of other outcrops

The studied outcrop shows a 14% coincidence of taxa with that of Sierra de Cartama (Hidalgo-Triana and Pérez-Latorre, 2013) and 42% with that of Sierra de Alpujata and La Robla (Pérez-Latorre et al., 2013a) (Figure 2). These data could be expected because the Mijas outcrop is almost a continuation to the east of the Sierra de Alpujata and the Sierra de Cartama constitutes a small edaphic island (Mota et al., 2011) and is further away (Pérez-Latorre et al., 2013b).

Serpentinophyte richness/outcrop area

The value obtained for Mijas outcrop is 2.06, a value close to that of Guadalhorce outcrop (1.54), which shows a similar area (7 km^2) (Figure 4). The difference may lie in the fact that the Mijas outcrop is continuous while that of Guadalhorce is made up of small isolated edaphic islands, which may cause its lower number of serpentinophytes (Whittaker & Fernández-Palacios, 2007; Pérez García et al., 2012; Pérez-Latorre et al., 2013b). In any case, the value fits into the trend observed for the whole of serpentine outcrops in the south of the Iberian Peninsula (Figure 4).

Vegetation

Clustering

As a result of the cluster analysis, five main groups of vegetation plots were obtained, which correspond to five plant communities or phytosociological associations: Group 1. Vegetation relevés 4, 14, 1, 6, 7, 11 and 13; Group 2. Inventories 8 and 2; Group 3. Inventory 5; Group 4. Inventories 3, 9 and 12 and Group 5. Inventory 10 (Figure 5).

Plant associations and communities

The five associations and communities identified in the studied area are:

Helosciadietum nodiflori Maire 1924

Helophytic vegetation dominated by *Apium nodiflorum* (L.) Lag., with broadleaved and small grasses, living in surface waters rich in nitrogen, with part of its structure submerged but subjected to summer desiccation and with a cosmopolitan distribution (Rivas-Martínez et al., 2011). It appears in the territory integrated in the oleander (*Nerium oleander*) vegetation series. This syntaxon is a new record for the South Iberian serpentine vegetation (Pérez-Latorre et al., 2013b). Relevé. Location: 1. Malaga. Mijas. Cañada Real. 30S 350985/4050918. Slope face: S, Slope inclination: 5°, Area: 5 m^2, Lithology: serpentine, Altitude: 255 m, Vegetation height: 20 cm., Cover: 60%. Characteristic of association: *Apium nodiflorum* (L.) Lag. 3, Companions: *Adiantum capillus-veneris* L. 1, *Dittrichia viscosa* (L.) Greuter +, *Equisetum ramosissimum* Desf.1, *Mentha suaveolens* Ehrh. 2, *Nerium oleander* L. 1, *Pteris vittata* L. +, *Samolus valerandi* L. +, *Scirpoides holoschoenus* (L.) Soják 1.

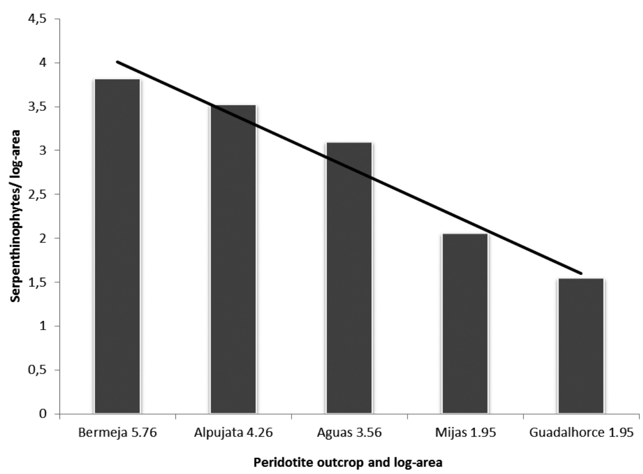

Figure 4. Serpentinophyte richness of the Mijas outcrop compared to the rest of the South Iberian outcrops (linear adjustment R^2 = 0.91) (data recalculated from Pérez-Latorre et al., 2013b).

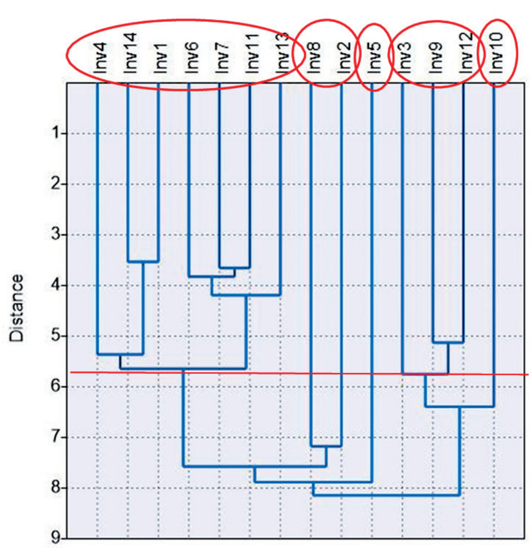

Figure 5. Dendrogram from the cluster analysis showing the associations (relevés). Five groups corresponding to plant communities or phytosociological associations have been recognized.

Brachypodium dystachion community sensu Pérez-Latorre et al., 2008 (Table 1)

Structure and ecology: Annual grassland of small size which grows in basic and clayey oligotrophic soils and shows spring flowering (Pérez-Latorre et al., 2008; Hidalgo-Triana and Pérez-Latorre 2013). It appears in clearings of scrublands and perennial grasslands of *Macrochloa* and on lane edges. The most abundant species are *Brachypodium distachyon* (L.) P. Beauv. and *Linaria micrantha* (Cav.) Hoffmanns. & Link. along with *Silene colorata* Poir. It has silicicolous bioindicator taxa (for example *Tolpis barbata* (L.) Gaertner or *Festuca myuros* L.) due to the neutral pH of the soil, typical of serpentine soils. These therophytic grasslands do not include strict endemics in the study area (Pérez-Latorre et al., 2013b).

Table 1. *Brachypodium dystachion* community sensu Pérez-Latorre et al., 2008 (*Tuberarietea guttatae*, *Brachypodietalia distachyi*, *Brachypodion distachyi*).

Relevé	1	2
Slope face	-	E
Inclination (°)	0	8
Area (m^2)	1	2
Lithology	serp	serp
Altitude (m)	228	305
Vegetation height (cm)	5	10
Cover (%)	60	95
Characteristics of community		
Brachypodium distachyon (L.) P.Beauv.	.	4
Linaria micrantha (Cav.) Hoffmanns. & Link.	2	.
Characteristics of upper syntaxonomical units		
Atractylis cancellata L.	1	1
Euphorbia exigua L.	+	+

Other characteristics. In 1: *Silene colorata* Poir. 3. In 2: *Biscutella boetica* Boiss & Reut. +, *Tolpis barbata* (L.) Gaertner +, *Trifolium arvense* L. +, *Dianthus nudiflorus* Griff. +, *Festuca myuros* L. 2.

Companions. In 1: *Lobularia maritima* (L.) Desv. +, *Filago pygmaea* L. 1, *Medicago doliata* Carmign. 3, *Plantago albicans* L. 1, *Senecio vulgaris* L.+. In 2: *Lysimachia arvensis* (L.) U.Manns & Anderb. +, *Cota altissima* (L.) J.Gay.1, *Leontodon longirostris* (Finch & P.D. Sell) Talavera 1, *Linum tenue* Desf. 2, *Plantago lagopus* L. +, *Trifolium cherleri* L.+.

Locations (Malaga province. Mijas municipality): 1. Los Espartales. 30S 353752/4050200. 2. Casa Alta. 30S 350830/4050959. Serp: serpentines.

Scorzonero boeticae-Macrochloetum tenacissimae Pérez-Latorre, Gálvez and Hidalgo-Triana **ass. nova hoc loco** (Table 2, holotypus relevé 3).

(Community with *Scorzonera boetica* (Boiss.) Boiss and *Macrochloa tenacissima* (L.) Kunth sensu Pérez-Latorre et al., 2015)

Structure and ecology: the serpentine perennial grasslands were described at the community level from the peridotites (harzburgites and pyroxene dunites) of the Sierra de Alcaparain (Malaga) (Pérez-Latorre et al., 2015). These were characterized by the dominance of *Macrochloa tenacissima* and the presence of serpentinophytes such as *Alyssum serpyllifolium* Desf. subsp. *malacitanum* Rivas Goday or *Centaurea carratracensis* Lange (territorial taxon) and *Scorzonera boetica*, plants with high affinity for peridotite substrates. It is a basophilic vegetation (due to the tendency to neutral pH of peridotite soils -lithosols and regosols- and serpentine) in areas with little annual rainfall (dry to subhumid ombrotype).

Some facts point in the direction of elevating this community to the rank of association: the large extension occupied by this community in the study area, its presence in other peridotite outcrops (Pérez-Latorre et al., 2015) (Table 2), the constant occurrence of serpentine species associated with *Macrochloa tenacissima* (L.) Kunth, such as *Linum carratracense* (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm. and *Scorzonera boetica* (Boiss.) Boiss. This community is distributed throughout the Bermejense sector (Baetic province, Western Mediterranean subregion), although it has not yet been found in Sierra de Alpujata, the second largest south Iberian outcrop (Pérez-Latorre et al., 2013a). It differs from the closest association, *Lavandulo multifidae-Stipetum tenacissimae* Pérez-Latorre & Cabezudo 2008 (Malacitanean-Axarquiensean sector) and the community with *Macrochloa tenacissima* (L.) Kunth (Ronda sector) by the presence of serpentinophytes and *Eryngium amethystinum* L. (Pérez-Latorre et al., 1998, 2008, 2019). The *Macrochloa* perennial grassland is linked to the frequency of fires, being favoured with respect to scrubland (Pérez-Latorre et al., 2015). In the study area it is frequent in the central zone (Zone 2; Figure 3) where the ombrotype is dry and signs of previous fires were observed (coal, ash, sprouts).

Calicotomo villosae-Genistetum lanuginosae Martínez Parras, Peinado & De la Cruz 1987 corr. Pérez-Latorre, Galán de Mera, Deil & Cabezudo 1996.

subass. ***halimietosum serpentinicolae*** Asensi & Díez (1988) 1991.

Variant with ***Thymbra capitata* (L.) Cav.**

Structure and ecology: the association is a silicicolous and serpentinicolous scrubland rich in *Cistaceae* and *Fabaceae* taxa that develop in the thermomediterranean thermotype with a dry to subhumid ombrotype. The subassociation is distributed along the base of the south Iberian peridotite outcrops. It is characterized by *Calicotome villosa* (Poir.) Link and especially *Genista hirsuta* Vahl subsp. *lanuginosa* (Spach) Nyman var. *lanuginosa* in its variety *lanuginosa* (serpentinophyte) and *Linum carratracense* (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm. (serpentinophyte) which are accompanied by other silicicolous taxa such as *Ulex borgiae* Rivas Mart. and *Lavandula stoechas* L., although *Cistus atriplicifolius* Lam. is not present. The xericity and thermicity of the habitat is indicated by a variant with the presence of the thyme *Thymbra capitata* (L.) Cav. The association appears in zone 1, in shady sites. This scrubland maintains a pool of common taxa with the scrubland that develops in a different outcrop (Figure 2, Guadalhorce Valley, Pérez-Latorre *et al.,* 2013b): *Thymbra capitata* (L.) Cav, *Helictochloa gervaisii* subsp. *gervaisii* (Holub) Romero Zarco, *Cistus monspeliensis* L., *Carex atrata* subsp. *atrata* L., *Dactylis glomerata* L. subsp. *hispanica* (Roth) Nyman, *Fumana thymifolia* (L.) Webb, *Macrochloa tenacissima* (L.) Kunth and *Pinus halepensis* Mill. Both outcrops share the fact that they are the easternmost and least rainy among the South-Iberian outcrops in Malaga. In the nearby Sierra de Alpujata (Figure 2) the scrubland corresponds to another association: *Digitali laciniatae-Halimietum atriplicifolii* Rivas Goday & Rivas Martínez 1969, richer in serpentinophytes as *Staehelina boetica* DC. and other differential taxa as *Digitalis obscura* L. subsp. *laciniata* (Lindl.) Maire (Pérez Latorre et al., 2013a).

Relevé. Location: 1. Malaga. Fuengirola. Cortijo Higuerón. 30S 356611/4049709. Slope face N, Inclination 10°, Area 200 m^2, Lithology: serpentines, Altitude 160 m, Vegetation height: 75 cm., Cover: 95%. Characteristic and differential species of association: *Genista hirsuta* Vahl subsp. *lanuginosa* (Spach) Nyman var. *lanuginosa* Hidalgo-Triana & Pérez Lat. 3, *Ulex borgiae* Rivas Mart. 3, *Lavandula stoechas* L. 1, *Linum carratracense* (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm. +, *Calicotome villosa* (Poir.) Link +. Characteristic of variant: *Thymbra capitata* (L.) Cav. 1. Characteristics of upper syntaxonomical units: *Cistus monspeliensis* L. 3. Companions: *Aphyllanthes monspeliensis* L. 1, *Arenaria retusa* Boiss. +, *Arisarum vulgare* Targ. – Tozz. +, *Asparagus horridus* L. +, *Helictochloa gervaisii* subsp. *gervaisii* Romero Zarco +, *Brachypodium retusum* (Pers.) P. Beauv. subsp. *retusum* 2, *Carex atrata* subsp. *atrata* L. 1, *Chamaerops humilis* L. +, *Dactylis glomerata* L. subsp. *hispanica* (Roth) Nyman 1, *Daphne gnidium* L. +, *Daucus setifolius* Desf. +, *Thapsia asclepium* L. +, *Fumana thymifolia* (L.) Webb +, *Iris filifolia* Boiss. +, *Lavandula multifida* L. +, *Macrochloa tenacissima* (L.) Kunth +, *Melica minuta* L. +, *Olea europaea* var. *sylvestris* (Mill.) Lehr 1, *Paronychia suffruticosa* (L.) DC. subsp. *suffruticosa* +, *Phlomis lychnitis* L. +, *Phlomis purpurea* L. 1, *Pinus halepensis* Mill. +, *Ptilostemon hispanicus* (Lam.) Greuter 2, *Sanguisorba verrucosa* (Link ex G.Don) Ces. +, *Scorzonera boetica* (Boiss.) Boiss 1, *Drimia maritima* (L.) Stearn +.

Table 2. *Scorzonero boeticae-Macrochloetum tenacissimae* Pérez-Latorre, Gálvez & Hidalgo-Triana *ass. nova* (*Lygeo sparti-Stipetea tenacissimae*, *Lygeo sparti-Stipetalia*, *Stipion tenacissimae*).

Relevé	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Slope face	SW	SW	E	E	SW	SE	W	SW	NW
Inclination(°)	25	20	25	55	20	28	15	40	10
Area (m^2)	240	250	150	150	210	135	300	200	200
Lithology	serp	serp	serp	serp	serp	serp	serp	per	pei
Altitude (m)	245	225	385	350	300	275	277	410	150
Vegetation height (cm)	90	110	70	100	100	70	70	170	150
Cover (%)	90	65	60	75	75	60	60	70	65
Characteristics and differentials of association									
Macrochloa tenacissima (L.) Kunth	4	2	3	3	4	4	3	4	4
Linum carratracense (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm	.	1	1	1	1	+	+	+	.
Teucrium haenseleri Boiss.	.	.	1	+	1	2	.	1	+
Galium boissierianum (Steud.) Ehrend. & Krendl	.	+	+	.	+	1	.	.	+
*Scorzonera boetic*a (Boiss.) Boiss	.	.	+	+	.	+	.	1	+
Alyssum serpyllifolium Desf. subsp. *malacitanum* Rivas Goday	.	.	+	+	.	.	.	+	+
Genista hirsuta Vahl subsp. *lanuginosa* (Spach) Nyman var. *lanuginosa* Hidalgo-Triana & Pérez Lat.	.	.	+	+	1	+	.	.	.
Centaurea carratracensis Lange	.	.	.	.	.	.	.	+	.
Characteristics of upper syntaxonomical units									
Brachypodium retusum (Pers.) P. Beauv.	+	+	.	+	.	2	1	.	.
Eryngium amethystinum L.	.	.	+	+	1	+	.	.	.
Phlomis lychnitis L.	.	.	+	+	1	1	.	+	.
Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman	.	.	+	.	1	+	.	+	.
Hyparrhenia sinaica (Delile) G. López	+	.	.	.	.	+	+	.	.
Other characteristics. In 3: *Daucus setifolius* Desf. +. In 6: *Arrhenatherum albus* (Vahl) Clayton +. In 8: *Convolvulus althaeoides* L. 1, *Dipcadi* (L.) Medil. subsp. serotinum +, *Xiphion filifolium* 1. In 9: *Asphodelus macrocarpus* subsp. *rubescens* Z. Díaz & Valdés +.									
Companions									
Fumana thymifolia (L.) Webb	2	1	1	2	2	2	1	2	1
Chamaerops humilis L.	+	+	+	1	+	1	+	.	1
Genista umbellata (L'Hér.) Dum. Cours. subsp. *equisetiformis* (Spach) Rivas Goday & Rivas Mart.	+	+	.	+	+	+	+	+	.
Lavandula stoechas L.	+	1	.	+	+	.	1	+	.
Phagnalon saxatile (L.) Cass.	+	+	+	+	.	.	1	.	+
Phlomis purpurea L.	.	+	+	+	1	+	.	.	1
Salvia rosmarinus Spenn.	.	3	1	4	3	2	.	1	.
Aphyllanthes monspeliensis L.	.	1	2	2	2	3	.	.	.
Calicotome villosa (Poir.) Link	+	.	.	+	+	+	+	.	.

Relevé	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Coris monspeliensis L.	+	+	+	.	+	.	+	.	.
Cuscuta epithymum (L.) L. subsp. *kotschyi* (Desmoul.) Arcang.	+	.	.	.	+	+	+	.	1
Pinus halepensis Mill.	+	2	.	+	+	.	2	.	.
Ulex borgiae Rivas Mart.	2	.	1	+	.	.	+	.	1
Carex atrata subsp. *atrata* L.	.	+	+	+	+	.	.	.	.
Celtica gigantea (Link) F. M. Vázquez & Barkworth	.	.	+	1	+	+	.	.	.
Thapsia asclepium L.	.	+	+	+	.	.	.	+	+
Olea europaea var. *sylvestris* (Mill.) Lehr	+	.	.	+	+	+	.	.	.
Ptilostemon hispanicus (Lam.) Greuter	.	.	+	.	+	+	.	.	+
Thymbra capitata (L.) Cav.	2	3	.	+	.	.	2	.	.
Drimia maritima (L.) Stearn	+	.	.	+	.	+	+	.	.
Asparagus horridus L.	+	.	.	+	.	.	+	.	.
Carlina corymbosa L.	.	.	.	.	+	+	.	.	+
Cistus monspeliensis L.	.	+	+	1	.	.	.	.	.
Convolvulus aitchisonii C.B.Clarke.	+	+	.	.	.	.	+	.	.
Fumana laevipes (L.) Spach	+	+	.	+	.	.	.	.	.
Fumana ericoides (Cav.) Gand.	+	2	.	.	.	.	+	.	.
Melica minuta L.	.	.	+	+	.	+	.	.	.
Sanguisorba verrucosa (G. Don) Ces.	.	.	+	+	.	+	.	.	.
Sesamoides purpurascens (L.) G. López subsp. *purpurascens*	.	.	+	.	.	+	.	1	.
Teucrium lusitanicum Screb.	+	1	.	.	.	.	+	.	.
Thymelaea argentata (Lam.) Pau	.	.	+	.	+	.	.	.	+
Argyrolobium zanonii (Turra) P.W. Ball subsp. *zanonii*	.	+	.	.	.	.	+	.	.
Centaurium erythraea	+	.	.	.	.	.	+	.	.
Cistus salviifolius L.	.	.	+	.	.	.	.	+	.
Helianthemum marifolium (L.) Mill. subsp. *origanifolium* (Lam.) G. López	1	.	.	.	.	.	+	.	.
Helichrysum stoechas (L.) Moench	.	+	.	.	.	.	+	.	.
Juniperus oxycedrus L.	.	+	+	.	.	.	.	.	.
Ruta montana (L.) L.	.	.	.	.	.	+	1	.	.
Ulex baeticus subsp. *scaber* (Kunze) Cubas	.	2	.	.	.	1	.	.	.

Other companions. In 1: *Teucrium pseudochamaepitys* L. +. In 3: *Dianthus sylvestris* subsp. *boissieri* (Willk.) Dobignard +, *Quercus coccifera* L. +, *Petrosedum sediforme* (Jacq.) Grulich +. In 4: *Cistus crispus* L. +, *Cistus albidus* L. x *Cistus crispus* L. +. In 5: *Centaurea prolongi* Boiss.ex DC. +. In 6: *Crepis vesicaria* L. +, *Linum tenue* Desf. +, *Ruta montana* (L.) L. +. In 7: *Cistus albidus* L. +, *Polygala rupestris* Pourr.+. In 8: *Carex halleriana* Asso +, *Convolvulus siculus* L. 1, *Reichardia picroides* (L.) Roth +, *Ulex baeticus* Boiss. subsp. *baeticus* +, *Drimia maritima* (L.) Stearn 1. In 9: *Anarrhinum bellidifolium* (L.) Willd.+ , *Biscutella sempervirens* L. 1, *Dittrichia viscosa* (L.) Greuter +, *Echium asperrimum* Lam. +, *Leontodon longirostris* (Finch & P.D. Sell) Talavera 1, *Misopates orontium* Raf. +, *Ranunculus gramineus* L. +, *Retama sphaerocarpa* (L.) Boiss. +, *Selaginella denticulata* (L.) Spring +.

Locations (Malaga province. Mijas municipality): 1. Cruz de la Alberca. 30S 353664/4050135. 2. Cruz de la Alberca. 30S 353859/4050145. Málaga. Mijas. 4. Casa Alta. 30S 35077/4051155. 5. La Cantilar. 30S 351074/4050873. 6. La Cantilar. 30S 351283/4050744. 7. Los Espartales. 30S 353648/4050483. 8. Malaga. Carratraca. Sierra of Alcaparaín. Minas del Rosario. 30SUF3878. 9. Malaga. Benahavis. Meseta de Algarrobales. 30S 317596/4041780. serp: serpentines. per: (peridotites) harzburgites and pyroxenic dunite. pei: rough peridotite. Relevé 8 taken from Pérez-Latorre et al. (2015).

Rubo ulmifolii-Nerietum oleandri O. Bolós 1956 (Table 3)

subass. ***nerietosum oleandri***

subass. ***brachypodietosum retusi*** Alcaraz 1984

Structure and ecology: this association is constituted by shrub vegetation dominated by *Nerium oleander* L. and *Rubus ulmifolius* Schott. that develops over intermittent freshwater beds and ravines. They grow in the thermomediterranean and lower mesomediterranean thermotypes in a dry to subhumid ombrotype. They have a south eastern Iberian distribution. In the study area, the typical association (*nerietosum*) presents greater development and benefits from a greater permanence of water during the year. The *brachypodietosum retusi* subassociation, typical of semi-arid to dry areas, has been identified (Alcaraz-Ariza et al., 1989) and occupies riverbeds and slopes dry practically all year round. It is cited for the first time as part of the serpentine vegetation (Pérez-Latorre et al., 2013b). The relevés sampled in the territory have not been included in the typical serpentine association and subassociation (*Erico terminalis-Nerietum oleandri galietosum viridiflori* Rivas Goday & Esteve 1972) due to the absence of both *Erica curvifolia* Salisb. and *Galium viridiflorum* Boiss. & Reut.

Climatic, mature vegetation

Species such as *Juniperus oxycedrus* L., *Quercus coccifera* L., *Olea europaea* var. *sylvestris* (Mill.) Lehr, *Chamaerops humilis* L. and *Aristolochia baetica* L. are remnants of what may have been the climatic mature vegetation of the study area (today cryptoclimatic and so unrecognizable). This would be a shrub formation characterized by *Juniperus oxycedrus* L. subsp. *oxycedrus* with naturalized *Pinus halepensis* Mill. This community could correspond to the *Juniperus oxycedrus* L. Basal Community (BC), described by Pérez-Latorre et al. (2015) from the peridotites of the Sierra of Alcaparain, La Robla and Sierra Prieta. Those species and community could constitute, probably as derived from fire, a substitution of the climatic pine-kermes oak forest, typical of the southern Iberian peridotites and serpentines (*Querco cocciferae-Pinetum pinastri* Cabezudo, Nieto & Pérez-Latorre 1989). In the study area, they could have constituted a variant with *Pinus halepensis*, well adapted to the dry ombrotype and so more similar to the edaphoxerophilous basophilic eastern Iberian pine forests (Pérez-Latorre et al., 2004; Rivas Martínez et al., 2011).

Syntaxonomical scheme

The syntaxa surveyed in Mijas are reported in the following syntaxonomical scheme. For each association, subassociation, community and variant, a diagnosis is provided with physiognomic data, phytoecological data for the study area and/or synchorology. The code of Annex I of Directive 92/43EEC "Habitats" is indicated in brackets and bold where appropriate.

A. Aquatic vegetation, lakes, fountains and bogs

MAGNOCARICI ELATAE-PHRAGMITETEA AUSTRALIS Klika in Klika & V. Novák 1941 nom. inv.

+ *Nasturtio officinalis-Glycerietalia fluitantis* Pignatti 1953
* *Rorippion nasturtii-aquatici* Géhu and Géhu-Franck 1987 nom. mut.
1. *Helosciadietum nodiflori* Maire 1924 [Helophytes vegetation]

G. Grassland and meadow vegetation. Therophytic grasslands

TUBERARIETEA GUTTATAE (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 nom. mut. propos.

+ *Brachypodietalia distachyi* Rivas-Martínez 1978
* *Brachypodion distachyi* Rivas-Martínez 1978 nom. mut. propos.
2. Community of *Brachypodium dystachion* sensu Pérez-Latorre et al., 2008 [Graminoid basophilous therophytic grassland] **(6220)**

LYGEO SPARTI-STIPETEA TENACISSIMAE Rivas-Martínez 1978

+ *Lygeo sparti-Stipetalia* Br-Bl. and O. Bolós 1958
* *Stipion tenacissimae* Rivas-Martínez ex Alcaraz 1984
3. *Scorzonero boeticae-Macrochloetum tenacissimae* Pérez-Latorre, Gálvez and Hidalgo-Triana *ass. nova* [Perennial xerophytic grasslands] **(6220)**

H. Heathland, dwarf scrub and scrub vegetation

CISTO-LAVANDULETEA STOECHADIS Br.-Bl. in Br.-Bl., Molinier & Wagner 1940

+ *Lavanduletalia stoechadis* Br.-Bl. in Br.-Bl., Molinier & Wagner 1940
* *Ulici argentei-Cistion ladaniferi* Br.-Bl., P. Silva & Rozeira 1965
** *Ulici borgiae-Calicotomenion villosae* Pérez-Latorre, P. Navas, Nieto & Cabezudo 1997
4. *Calicotomo villosae-Genistetum lanuginosae* Martínez Parras, Peinado and De la Cruz 1987 corr. Pérez-Latorre, Galán de Mera, Deil and Cabezudo 1996
halimietosum serpentinicolae Asensi and Díez (1988) 1991 **(5330)**

Var. with *Thymbra capitata* [Serpentine scrubland, xerophytic variant]

Table 3. *Rubo ulmifolii-Nerietum oleandri* O. Bolós 1956 subass. *nerietosum,* subass. *brachypodietosum retusi* Alcaraz 1984 (*Nerio oleandri-Tamaricetea, Tamaricetalia africanae, Rubo ulmifolii-Nerion oleandri*).

Inventory	**1**	**2**	**3**
Slope face	-	S	-
Inclination (°)	0	5	0
Area (m²)	80	125	175
Lithology	serp	serp	serp
Altitude (m)	216	250	260
Vegetation height (m)	2.5	4.5	6.0
Cover (%)	85	90	100
Characteristics of association and order			
Nerium oleander L.	5	5	5
Rubus ulmifolius Schott.	·	·	2
Characteristic of subassociation			
Brachypodium retusum (Pers.) P. Beauv. subsp. *retusum*	3	·	·
Companions			
Scirpoides holoschoenus (L.) Soják	+	3	+
Aristolochia baetica L.	2	·	+
Chamaerops humilis L.	+	·	+
Equisetum ramosissimum Desf.	·	+	+
Oxalis pes-caprae L.	·	+	+
Pteris vittata L.	·	+	+
Rhamnus alaternus L.	2	·	1
Samolus valerandi L.	·	+	+

Other companions. In 1: *Acacia saligna* (Labill.) H. L. Wendl. +, *Asparagus albus* L. +, *Asparagus horridus* L. +, *Bituminaria bituminosa* (L.) C. H. Stirt. +, *Calicotome villosa* (Poir.) Link +, *Ceratonia siliqua* L. +, *Coris monspeliensis* L. +, *Foeniculum vulgare* Mill. +, *Olea europaea* var. *silvestris* (Mill.) Lehr 1, *Ruta montana* (L.) L. +, *Ulex baeticus* subsp. *scaber* (Kunze) Cubas +, *Drimia maritima* (L.) Stearn +. In 2: *Ageratina adenophora* (Sprengel) R.M. King & H. Rob. +, *Apium nodiflorum* (L.) Lag. 1, *Dittrichia viscosa* (L.) Greuter +, *Mentha suaveolens* Ehrh. 2, *Oloptum miliaceum* (L.) Röser & Hamasha +, *Rubia agostinhoi* Dans. & P. Silva +, *Salix pedicellata* Desf. +, *Trachelium caeruleum* L. +, *Tripidium ravennae* (L.) H. Scholz. +, *Vicia benghalensis* L. +. In 3: *Adiantum capillus-veneris* L. +, *Ricinus communis* L. +.

Locations (Malaga province. Mijas municipality): 1. Cruz de la Alberca. 30S 353777/4050207. 2. Cañada Real. 30S 350985/4050918. 3. La Cantilar. 30S 351327/4050765. serp: serpentines.

I. Forest, woodland, potential natural vegetation

NERIO OLEANDRI-TAMARICETEA Br.-Bl. and O. Bolòs 1958

\+ *Tamaricetalia africanae* Br.-Bl. and O. Bolòs

* *Rubo ulmifolii-Nerion oleandri* O. Bolòs 1985

5. *Rubo ulmifolii-Nerietum oleandri* O. Bolós 1956 **(92D0)**
   nerietosum [Oleander shrublands]
   brachypodietosum retusi Alcaraz 1984 [Oleander shrublands in irregular streams]

Comparison on richness of syntaxa between outcrops

Table 4 shows the syntaxa richness of the Mijas outcrop compared to the rest of the South Iberian outcrops. The outcrop is located at the corresponding level in syntaxa richness by area (5), although it presents the originality of its state of anthropization and of hosting two syntaxa mentioned for the first time on serpentines. It is noteworthy that it has several syntaxa identical to that of another outcrop of a similar size (La Robla) and a number very close to one of a much larger size (Sierra of Aguas).

Table 4. Number of syntaxa of the South Iberian peridotite outcrops, including Mijas (Data from Pérez-Latorre *et al.,* 2013a, except for Mijas).

Outcrop (km²)	Bermeja (282)	Sierra Parda (36)	Alpujata (71)	Aguas (28)	Robla (7)	Alozaina (1)	Mijas (7)
Total of syntaxa	18	15	11	6	5	2	5

Table 5. Vegetation landscape of the serpentine outcrop of the Sierra de Mijas (Malaga, Spain).

Vegetation type	Habitat	Plant community	Characteristic species
Edaphoxerophilous mature climatic vegetation	Regosols, slopes	Open pine forest	*Pinus halepensis* Mill., *Juniperus oxycedrus* L.
Edaphoxerophilous serial stage vegetation	Lithosols, rocky slopes	Scrublands	*Genista hirsuta* Vahl subsp. *lanuginosa* (Spach) Nyman var. *lanuginosa* Hidalgo-Triana & Pérez Lat*, Cistus monspeliensis* L.*, Thymbra capitata* (L.) Cav.
Edaphoxerophilous pioneer vegetation	Sandy lithosols,	Low-sized annual grasslands	*Brachypodium dystachion* (L.) P.Beauv*, Linaria micrantha* (Cav.) Hoffmanns. & Link.
Edaphoxerophilous fire-favoured	Regosols, slopes with signs of fires	Big-sized perennial grasslands	*Macrochloa tenacissima* (L.) Kunth*, Scorzonera boetica* (Boiss.) Boiss, *Linum carratracense* (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm.
Edaphohygrophilous-mature climatic vegetation	Permanent or intermittent streams	Oleander shrublands	*Nerium oleander* L., *Scirpoides holoschoenus* (L.) Soják

Vegetation series and zone-potential vegetation

The successional dynamic in the study area is detailed below. Table 5 summarizes the types of vegetation on the outcrop according to the coenotope and the characteristic species.

Edaphohygrophilous series

Rubo ulmifolii-Nerio oleandri sigmetum

Oleander shrublands assigned to the *nerietoso oleandri* subseries are frequent in streams that show longer surface circulation and include helophytic vegetation of *Helosciadietum nodiflori*. The oleander shrublands of the *brachypodietoso retusi* subseries, develop in dry riverbeds without water circulation almost all year round, they are very poor in hygrophilic species and do not present serial stages, although they do show an introgression of taxa from the adjacent edafoxerophilic series.

Edaphoxerophilous series

Querco cocciferae-Pino pinastri sigmetum

The pine forest with kermes oak is considered cryptoclimatic, although some characteristic species have been found that allow hypothesizing the past presence of a community with *Pinus halepensis* and *Juniperus oxycedrus*. Today, a mosaic of associations is recognized in the domain of this series, dominated by the *Scorzonero boeticae-Macrochloetum tenacissimae ass. nova*, favoured by recurrent fires which, on the contrary, harm the scarce scrublands of *Calicotomo villosae-Genistetum lanuginosae halimietosum serpentinicolae* var. of *Thymbra capitata*. In the clearings of the two previous associations, grows the therophytic grassland of *Brachypodium dystachion* community.

Conclusions

The serpentine outcrop of Mijas shows a high botanical value, despite having suffered the direct and indirect consequences of urban development. The catalogue of more than 150 taxa corresponds to only one-tenth of the area of the outcrop. This number of taxa is very high and possibly exceeds that of other South Iberian serpentine places. It is noteworthy that despite the importance of alien species in the outcrop, these are limited to the surroundings of landfills, gardens, streams and roads, being practically absent in plant communities with no other anthropic impact than fire, such as the *Macrochloa* perennial grasslands and the scrublands. The presence of some endemic serpentinophytes and the number of syntaxa are the expected according to the area of the outcrop and compared to other south Iberian outcrops. Although the site is not protected at present, elements are pointing to the need for protection in some ways: 1) the existence of strict endemics

(*Linum carratracense* (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm., *Alyssum serpyllifolium* Desf. subsp. *malacitanum* Rivas Goday, *Genista hirsuta* Vahl subsp. lanuginosa (Spach) Nyman var. lanuginosa Hidalgo-Triana & Pérez Lat. and *Silene inaperta* L. subsp. *serpentinicola* Talavera; 2) the presence of a threatened species at state and regional level (*S. inaperta* subsp. *serpentinicola* itself); 3) the development of habitats of Directive 92/43EEC, one of them new as an association (*Scorzonero boeticae-Macrochloetum tenacissimae ass. nova*.); and 4) the rarity of the serpentine outcrop itself. This could be enough for the inclusion of at least some of the three studied areas in protection figures at European level (Special Area of Conservation, SAC) or at the regional level (Andalusia) as an Ecological Reserve. This declaration could save these spots of high floristic originality from the advance of urban planning linked to tourism.

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References

Alcaraz Ariza F.J., Díaz González T.E., Rivas Martínez S., Sánchez Gómez P., 1989. Datos sobre la vegetación del sureste de España provincia biogeográfica Murciano-Almeriense (IV Excursión Internacional de Fitosociología). Itinera geobotanica, 2, 5-133.

Balsera J. (coord.), 1989. Mapa de suelos de Andalucía. CSIC-Junta de Andalucía.

Bañares A., Blanca G., Güemes J., Moreno J.C., Ortiz S., 2010. Atlas y Libro Rojo de la Flora Vascular Amenazada de España (Adenda 2010). Madrid: Dirección General de Medio Natural y Política Forestal (Ministerio de Medio Ambiente y Medio Rural y Marino)-Sociedad Española de Biología de la Conservación de Plantas.

Blanca G., Cabezudo B., Cueto M., Morales Torres C., Salazar C., 2011. Flora Vascular de Andalucía Oriental. Consejería de Medio Ambiente. Junta de Andalucía. Sevilla.

Brady K.U., Kruckeberg A.R., Bradshaw H.D., 2005. Evolutionary ecology of plant adaptation to serpentine soils. Annu. Rev. Ecol. Evol. S. 36, 243-266.

Braun-Blanquet J., 1979. Fitosociología. Ed. Blume. Madrid.

Brooks R., 1987. Serpentine and its vegetation. A multidisciplinary approach. Dioscorides Press. Portland.

Cabezudo B., Nieto Caldera J.M., Pérez Latorre A.V., 1989. Contribución al conocimiento de la vegetación edafófilo-serpentinícola del sector Rondeño (Málaga; España). Acta Bot. Malacitana 14, 291-294.

Cabezudo B., Pérez Latorre A.V., Nieto J.M., 1995. Regeneración de un alcornocal incendiado en el Sur de España (Istán, Málaga). Acta Bot. Malacitana 20, 143-151.

Cabezudo, B., Talavera, S., Blanca, G., Salazar, C., Cueto, M., Valdés, B. & Navas, D. (2005). Lista roja de la flora vascular de Andalucía. Sevilla: Consejería de Medio Ambiente, Junta de Andalucía.

Cabezudo, B. and Talavera, S. (coords.). 2005. Lista Roja de la Flora Vascular de Andalucía. Sevilla: Consejería de Medio Ambiente, Junta de Andalucía.

Castroviejo S. (Ed.), 1986-2018. Flora iberica. R. Jard. Bot. CSIC, Madrid.

Dana E.D., Sanz M., Vivas S., Sobrino E., 2005. Especies vegetales invasoras en Andalucía. Consejería de Medio Ambiente. Junta de Andalucía.

Díez Garretas B., Asensi A., Rufo L., Rodríguez N., Sánchez Mata D., Amils R., de la Fuente V., 2009. *Saxifraga gemmulos*a Boiss. (Saxifragaceae), an endemic nickel bioindicator from ultramafic areas of the Southern Iberian Peninsula. Northeast. Nat. 16, 56-64.

Global Biodiversity Information Facility website (GBIF), 2019. Available from: https://www.gbif.org/.

Gehú J.M., Rivas Martínez S., 1981. Notions fondamentales de Phytosociologie. Syntaxonomie. Berichte der Internationalen Symposien der Internationalen Vereinigung für Vegetationskunde.

Guillot S., Hattori K., 2013. Serpentinites: essential roles in geodynamics, arc volcanism, sustainable development, and the origin of life. Elements 9, 95-98.

Hammer Ø, Harper D.A.T., Ryan P.D., 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4, 1-9.

Hidalgo Triana N., Pérez Latorre A.V., 2013. Vegetación y flora de la Sierra de Cártama (Valle del Guadalhorce, Málaga, España). Acta Botanica Malacitana 38, 119-149.

Hidalgo Triana N., Pérez Latorre A.V., 2019. A study of functional traits reveals serpentinomorphoses and new taxa in populations of Mediterranean *Genista* (Fabaceae). Phytotaxa 394, 4.

Kornas J., 1990. Plant invasions in Central Europe: historical and ecological aspects. In: Di Castri F., Hansen A.J., Debussche M., (Eds.). Biological Invasions in Europa and the Mediterranean Basin, 19-36. Kluwer Academic Publishers, Dordrecht. The Netherlands.

López González G., 1975. Contribución al estudio florístico y fitosociológico de Sierra de Aguas. Acta Botanica Malacitana 1, 81-205.

Martínez Labarga J.M., Muñoz Garmedia F., 2015. *Linum* L. In: Muñoz F., Navarro C., Quintanar A., Buira A. (Eds.). Flora iberica IX, 257-260. R. Jard. Bot., CSIC, Madrid.

Moreno Saiz J.C., Martínez García F., Gavilán R., 2018. Plant Conservation in Spain: strategies to halt the loss of plant diversity. Mediterranean Botany 39(2), 65-66.

Mota J.F., Sánchez Gómez P., Guirado J.S. (Eds.), 2011. Diversidad vegetal de las yeseras ibéricas. El reto de los archipiélagos edáficos para la biología de la conservación. ADIF- Mediterráneo Asesores Consultores. Almería.

Pérez García F.J., Medina Cazorla J.M., Martínez Hernández F., Garrido Becerra J.A., Mendoza Fernández A.J., Salmerón Sánchez E., Mota J.F., 2012. Iberian Baetic endemic flora and the implications for a conservation policy. Annales Botanici Fennici 49, 43-54.

Pérez Latorre A.V., Navas P., Navas D., Gil Y., Cabezudo B., 1998. Datos sobre la flora y vegetación de la Serranía de Ronda (Málaga, España). Acta Botanica Malacitana 23, 149-191.

Pérez Latorre A.V., Cabezudo B., 2002. La flora y el paisaje vegetal de la provincia de Málaga: importancia y conservación. Jábega 90, 25-39.

Pérez Latorre A.V., Navas Fernández D., Gavira O., Caballero G., Cabezudo B., 2004. Vegetación del P. N. de las Sierras Tejeda, Almijara y Alhama. Acta Botanica Malacitana 29, 117-190.

Pérez Latorre A.V., Caballero G., Casimiro Soriguer F., Gavira O., Cabezudo, B., 2008. Vegetación del sector Malacitano-Axarquiense (comarca de la Axarquía, Montes de Málaga). Acta Botanica Malacitana 33, 215-270.

Pérez Latorre A.V., Hidalgo Triana N., Casimiro Soriguer F., Cabezudo B., 2013a. Flora y vegetación serpentinícola ibérica: Sierras de Alpujata y de La Robla (Málaga, España). Lagascalia 33, 43-74. Universidad de Sevilla. I.S.S.N. 0210-7708.

Pérez Latorre A.V., Hidalgo Triana N., Cabezudo B., 2013b. Composition, ecology and conservation of the south-Iberian serpentine flora in the context of the Mediterranean basin. Anales del jardín botánico de Madrid 70(1), 62-71.

Pérez Latorre A.V., Casimiro Soriguer F., Cabezudo B., 2015. Flora y vegetación de la Sierra de Alcaparaín (Málaga, España). Acta Botanica Malacitana 40, 107-156.

Pérez Latorre A.V., Hidalgo Triana N., Cabezudo B., 2018. New data on the southern Iberian serpentinophyte flora (Andalusia, Spain). Mediterranean Botany 39(2), 151-155.

Pérez Latorre A.V., Hidalgo Triana N., Cabezudo B., Martos Martín J., 2019. Mapa biogeográfico de la provincia de Málaga (España). Diputación provincial de Málaga y Universidad de Málaga.

Pérez Sanz S., Nieto J.M., Cabezudo B., 1987. Contribución al conocimiento de la flora de la sierra de Mijas (Málaga, España). Acta Botanica Malacitana 12, 189-208.

Piles Mateo E., Estévez González C., Barba Martín A., 1978. Coín (Hoja 1066). Magna 50. 2ª Serie. IGME.

Plants of the World Online (POWO), 2019. Facilitated by the Royal Botanic Gardens, Kew. Available from: http://www.plantsoftheworldonline.org/ (accessed 1st January 2021).

Red de Información Ambiental de Andalucía (REDIAM), 2004. Mapa Litológico de Andalucía: Unidades Litológicas. Available from: http://www.juntadeandalucia.es/medioambiente/mapwms/REDIAM_Litologico_Andalucia?

Rivas Martínez S., Penas A., Asensi A., Costa M., 2003. Atlas y Manual de los Hábitats de España. Tragsa, Área de Medio Ambiente.

Rivas Martínez S., 2007. Memoria del mapa de vegetación potencial de España. Itinera geobotanica, 17, 1-433.

Rivas Martínez S., Penas A., Díaz T.E., Ladero M., Asensi A., Díez B., Molero J., Valle F., Cano E., Costa M., López M.L., Fernández J.A., Llorens L., Del Arco M., Pérez P.L., Wildpret W., Sánchez D., Fernández F., Masalles R., Ladero M., Izco J., Amigo J., Loidi J., Alcaraz F., Del Rio S., Herrero L., 2011. Mapa de Series, Geoseries y Geopermaseries de Vegetación de España. Memoria del Mapa de Vegetación Potencial de España. Parte I. Itinera geobotanica, 18(1), 5-424.

Roberts B.A., Proctor J., 1992. The ecology of areas with serpentinized rocks. A world view. Kluwer academic publishers. Dordrecht.

Rufo N., García V., Sánchez Mata D., Rodríguez Rojo M., 2004. Studies on Iberian Peninsula ultramafic flora: a selected nickel accumulation screening. Lazaroa 25, 161-167.

Schuhwerk F., 1990. Relikte und Endemiten in Pflanzengesellschaften Bayerns- eine vorlaufige Ubersicht. Ber. Bayer. Bot. Ges. 61, 303-323.

Van Der Maarel E., 1979. Transformation of cover-abundance values in phytosociology and its effects on community similarity. Vegetatio 39, 97-114.

Weber H.E., Moravec J., Theurillat J.P., 2000. International Code of Phytosociological Nomenclature. J. Veg. Sci. 11, 739-768.

Wójcik M., Gonnelli C., Selvi F., Dresler S., Rostanski A., Vangronsveld J., 2017. Chapter One - Metallophytes of serpentine and calamine soils - Their unique ecophysiology and potential for phytoremediation. In: Cuypers A, Vangronsveld J, (Eds.). Phytoremediation 83, 1-42.

Whittaker R.H., 1954. The ecology of serpentine soils. Ecology 35, 258-288.

Whitaker R.J., Fernández Palacios J.M., 2007. Island biogeography, ecology, evolution, and conservation, 2nd edn. Oxford University Press. Oxford.

Supplementary material

Floristic list of the study area

♦ Serpentinophyte. Data from Pérez Latorre *et al.* (2013b) and Pérez Latorre *et al.* (2018)

● Threatened. Data from Bañares *et al.,*(2010) and Cabezudo *et al.* (2005).

■ Alien plant. Data from Spanish Legislation Royal Decree 630/2013.

◊ Endemic of the natural area of Ronda following Blanca *et al.* (2011).

PTERIDOPHYTA

ADIANTACEAE
Adiantum capillus-veneris L.

EQUISETACEAE
Equisetum ramosissimum Desf.

PTERIDACEAE
Pteris vittata L.

SINOPTERIDACEAE
Hemionitis guanchica (Bolle) Christenh.

GIMNOSPERMAE

CUPRESSACEAE
Juniperus oxycedrus L.

PINACEAE
Pinus halepensis Mill.

ANGIOSPERMAE

AGAVACEAE
■ *Agave americana* L. - Alien

AMARYLLIDACEAE
Iris filifolia Boiss.
Lapiedra martinezii Lag.

APHYLLANTHACEAE
Aphyllanthes monspeliensis L.

APIACEAE
Apium nodiflorum (L.) Lag.
Bupleurum gibraltaricum Lam. - GBIF
Daucus setifolius Desf.
Thapsia asclepium L. – Endemic of Aljíbico and Ronda Sectors.
Eryngium amethystinum L.
Foeniculum vulgare Mill.
Thapsia villosa L.

APOCYNACEAE
- ■ *Gomphocarpus fruticosus* (L.) W.T. Aiton - GBIF - Alien
- *Nerium oleander* L.

ARACEAE
- *Arisarum vulgare* Targ. – Tozz.

ARECACEAE (=PALMAE)
- *Chamaerops humilis* L.
- *Phoenix dactylifera* L.

ARISTOLOCHIACEAE
- *Aristolochia baetica* L.

ASPARAGACEAE
- *Asparagus albus* L.
- *Asparagus horridus* L.

ASTERACEAE
- *Ageratina adenophora* (Sprengel) R.M. King & H. Rob.
- ■ *Ambrosia artemisiifolia* L. - Alien - GBIF
- *Atractylis cancellata* L.
- *Calendula arvensis* L. subsp. *arvensis*
- *Carlina corymbosa* L.
- ● *Centaurea prolongi* Boiss.ex DC. - VU B2ab(i,ii,iii,iv,v) – Endemic of Trevenque-Almijara and Ronda Sectors.
- *Cota altissima* (L.) J.Gay.
- *Crepis vesicaria* L.
- *Dittrichia viscosa* (L.) Greuter
- *Eupatorium cannabinum* L. - GBIF
- *Filago pygmaea* subsp. *pygmaea* L.
- *Galactites galactites* Druce
- *Helichrysum stoechas* (L.) Moench
- *Klasea flavescens* (L.) Holub subsp. *leucantha* (Cav.) Cantó & Rivas Mart.
- *Leontodon longirostris* (Finch & P.D. Sell) Talavera
- *Phagnalon rupestre* (L.) DC. - GBIF
- *Phagnalon saxatile* (L.) Cass.
- *Ptilostemon hispanicus* (Lam.) Greuter
- *Reichardia tingitana* (L.) Roth
- *Scorzonera boetica* (Boiss.) Boiss
- *Senecio vulgaris* L.
- *Tolpis barbata* (L.) Gaertner

BORAGINACEAE
- *Cynoglossum creticum* Mill.

BRASSICACEAE
- ♦◊ *Alyssum serpyllifolium* Desf. (*Alyssum serpyllifolium* Desf. subsp. *malacitanum* Rivas Goday) Obligate serpentinophyte – Endemic of Ronda and Axarquia Sectors.
- *Biscutella auriculata* L.
- *Biscutella baetica* Boiss. & Reut.
- *Diplotaxis virgata* (Cav.) DC. subsp. *virgata*
- *Lobularia maritima* (L.) Desv.

CAESALPINIACEAE
- *Ceratonia siliqua* L.

CAMPANULACEAE
- *Campanula rapunculus* L.
- *Trachelium caeruleum* L.

CARYOPHYLLACEAE
- *Arenaria leptocados* (Rchb.) Guss.
- ♦◊ *Arenaria retusa* Boiss. – Subserpentinophyte – Endemic of Ronda and Axarquia Sectors.
- *Dianthus nudiflorus* Griff.
- *Dianthus sylvestris* subsp. *boissieri* (Willk.) Dobignard
- *Paronychia capitata* (L.) Lam.
- *Paronychia suffruticosa* (L.) DC. subsp. *suffruticosa*
- *Polycarpon tetraphyllum* (L.) L. subsp. *tetraphyllum*
- *Silene colorata* Poir.
- *Silene apetala* Willd.
- ♦●◊ *Silene inaperta* L. subsp. *serpentinicola* Talavera - Obligate serpentinophyte - EN B2b(iii,iv)c(ii,iv); C2a(i) – Endemic of Ronda sector

CISTACEAE
- *Cistus albidus* L.
- *Cistus crispus* L.
- *Cistus albidus* L. x *Cistus crispus* L.
- *Cistus monspeliensis* L.
- *Cistus salviifolius* L.
- *Fumana ericoides* (Cav.) Gand.
- *Fumana laevipes* (L.) Spach
- *Fumana scoparia* Pomel - GBIF
- *Fumana thymifolia* (L.) Webb
- *Helianthemum marifolium* (L.) Mill. subsp. *origanifolium* (Lam.) G. López
- *Helianthemum syriacum* (Jacq.) Dum. Cours.

CONVOLVULACEAE
- *Convolvulus aitchisonii* C.B.Clarke.
- *Cuscuta epithymum* (L.) L. subsp. *kotschyi* (Desmoul.) Arcang.

CRASSULACEAE
- *Petrosedum sediforme* (Jacq.) Grulich

CYPERACEAE
- *Carex atrata* subsp. *atrata* L.
- *Scirpoides holoschoenus* (L.) Soják

EUPHORBIACEAE
- *Euphorbia exigua* L. subsp. *exigua Mercurialis annua* L.
- *Ricinus communis* L.

FABACEAE
- *Dorycnopsis gerardi* (L.) Boiss.
- *Argyrolobium zanonii* (Turra) P.W. Ball subsp. *zanonii*
- *Bituminaria bituminosa* (L.) C. H. Stirt.
- *Calicotome villosa* (Poir.) Link
- ♦◊ *Genista hirsuta* Vahl subsp. *lanuginosa* (Spach) Nyman var. *lanuginosa* Hidalgo-Triana & Pérez Lat. - Obligate Serpentinophyte - Endemic of Ronda sector.
- *Genista umbellata* (L'Hér.) Dum. Cours. subsp. *equisetiformis* (Spach) Rivas Goday & Rivas Mart.
- *Lotus ornithopodioides* L.
- *Medicago doliata* Carmign.
- *Ononis natrix* L.
- *Retama sphaerocarpa* (L.) Boiss.
- *Scorpiurus muricatus* L.
- *Trifolium arvense* L.
- *Trifolium cherleri* L.
- *Ulex baeticus* subsp. *scaber* (Kunze) Cubas
- *Ulex borgiae* Rivas Mart.
- *Ulex parviflorus* Pourr. - GBIF
- *Vicia benghalensis* L.

FAGACEAE
- *Quercus coccifera* L.
- *Quercus suber* L. - Pérez-Sanz et al. (1987).

GENTIANACEAE
- *Centaurium erythraea* Rafn.
- *Rhaponticoides centaurium* (L.) M.V.Agab. & Greuter

HYACINTHACEAE
- *Dipcadi serotinum* (L.) Medil. subsp. *serotinum*
- *Prospero autumnale* (L.) Speta
- *Drimia maritima* (L.) Stearn

LAMIACEAE
- *Pseudodictamnus hirsutus* (Willd.) Salmaki & Siadati
- *Lavandula multifida* L.
- *Lavandula stoechas* L.
- *Mentha suaveolens* Ehrh.
- *Micromeria graeca* (L.) Benth. ex Rchb. -Pérez-Sanz et al. (1987).
- *Phlomis lychnitis* L.
- *Phlomis purpurea* L.
- *Salvia rosmarinus* Spenn.
- *Teucrium haenseleri* Boiss.
- *Teucrium lusitanicum* Screb.
- *Teucrium pseudochamaepitys* L.
- *Thymbra capitata* (L.) Cav.

LINACEAE
- ♦◊ *Linum carratracense* (Rivas Goday & Rivas Mart.) Mart. Labarga & Muñoz Garm. – Obligate serpentinophyte – Endemic of Ronda sector.
- *Linum tenue* Desf.

MIMOSACEAE
- ■ *Acacia saligna* (Labill.) H. L. Wendl. - Alien

OLEACEAE
- *Olea europaea* var. *sylvestris* (Mill.) Lehr

ORCHIDACEAE
- *Ophrys fusca* Link.

OXALIDACEAE
- ■ *Oxalis pes-caprae* L. - Alien

PLANTAGINACEAE
- *Plantago albicans* L.
- *Plantago lagopus* L.

POACEAE
- *Aristida adoensis* Hochst. ex A.Rich.
- *Arrhenatherum albus* (Vahl) Clayton
- *Arundo donax* L.
- *Avena fatua* L.
- *Brachypodium retusum* (Pers.) P. Beauv. subsp. *retusum*
- *Celtica gigantea* (Link) F. M. Vázquez & Barkworth
- *Dactylis glomerata* L. subsp. *hispanica* (Roth) Nyman
- *Festuca myuros* L.
- *Helictochloa gervaisii* (Holub) Romero Zarco
- *Hordeum marinum* L. subsp. *leporinum* (Link) Arcang.
- *Hyparrhenia hirta* L. Stapf - GBIF
- *Hyparrhenia sinaica* (Delile) G. López
- *Macrochloa tenacissima* (L.) Kunth
- *Melica minuta* L.
- *Oloptum miliaceum* (L.) Röser & Hamasha
- ■ *Cenchrus setaceus* (Forssk.) Morrone- Alien
- *Stipellula capensis* (Thunb.) Röser & Hamasha.
- *Trachynia distachya* (L.) Link
- *Tripidium ravennae* (L.) H. Scholz.

POLYGALACEAE
- *Polygala rupestris* Pourr.

POLYGONACEAE
- *Rumex induratus* Boiss. & Reut.

PRIMULACEAE
Coris monspeliensis L. subsp. *monspeliensis*
Lysimachia arvensis (L.) U.Manns & Anderb.
Samolus valerandi L.

RESEDACEAE
Sesamoides purpurascens (L.) G.López subsp. *purpurascens*

RHAMNACEAE
Rhamnus alaternus L.

ROSACEAE
Rubus ulmifolius Schott.
Sanguisorba verrucosa (G. Don) Ces.

RUBIACEAE
♦● *Galium boissierianum* (Steud.) Ehrend. & Krendl – Preferential Serpentinophyte– VU D2 – Endemic of Trevenque–Almijara, Ronda and Axarquía Sectors.
Galium verrucosum Huds. subsp. *verrucosum*
Rubia agostinhoi Dans. & P. Silva

RUTACEAE
Ruta angustifolia Pers. - GBIF.
Ruta montana (L.) L.

SALICACEAE
Salix pedicellata Desf.

SIMAROUBACEAE
■ *Ailanthus altissima* (Mill.) Swingle - Alien

SOLANACEAE
Nicotiana glauca Graham

THYMELAEACEAE
Daphne gnidium L.
Thymelaea argentata (Lam.) Pau

VERONICACEAE
Linaria micrantha (Cav.) Hoffmanns. & Link.