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Distribution of 5 Red Data Book plants together with observations of their pollinators from the Akrotiri Peninsula, Cyprus

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Abstract. – The Akrotiri Peninsula hosts one of the largest and most ecologically complex ecosystems in Cyprus, supporting rare, vulnerable and endangered flora and fauna. The present study concerns 5 plants included in the Red Data Book of the flora of Cyprus, namely *Convolvulus lineatus*, *Linum maritimum*, *Lotus cytisoides*, *Mentha aquatica* and *Taraxacum aphrogenes* and contains information on their geographical distribution at the Akrotiri Peninsula, together with population estimates and observations of their insect flower visitors. The main threats for each of the plants are presented. Current conservation efforts are highlighted and conservation measures are proposed.

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Introduction

Cyprus, the third largest island of the Mediterranean area, phytogeographically related to Asia Minor and Syria, is very interesting floristically as it is home to a plethora of rare and endemic plant taxa (Meikle 1977). The flora of Cyprus consists of 1946 taxa of vascular plants, of which, 1649 belong to the category "Indigenous" and 254 to the various categories of neophytes (Hand & al. 2019). Most of the endemic plant taxa of Cyprus occur in the two mountain ranges. In total, 102 and 60 endemic plants can be found at Troodos and Pentadaktylos, respectively. Apart from those, 33 endemic taxa flourish at the Akamas Peninsula (Meikle 1977, Christodoulou & al. 2018).

The World Conservation Union (IUCN) has developed 5 quantitative criteria of vulnerability for evaluating the extinction probability of species (IUCN 1994, Ali-Shtayeh & Jamous 2018), Extinct (EX) (when there is no reasonable doubt that the last individual of the species has died), Critically Endangered (CR) (in great danger of extinction, considered as a species facing an especially high risk of extinction in nature), Endangered (EN = 50–75 % reduction) (in danger of extinction, considered as a species facing a very high risk of extinction in nature), Vulnerable (VU = >30–50 % reduction) (considered as a species facing a high risk of extinction in nature), and Near Threatened (NT) (expected to be endangered in the near future). These categories

have been widely accepted throughout the world and form the basis for the IUCN Red List of Threatened Plants. The IUCN criteria consist of a set of decision rules, based mainly on quantitative thresholds of population size, distribution range, rate of declining and extinction probability (IUCN 1994, Ali-Shtayeh & Jamous 2018). The Red List of threatened species has been used to guide conservation responses, influence conservation policies and legislation, plan protected area networks and prioritise sites to be safeguarded (Hoffmann & al. 2008).

Some of the flora taxa in Cyprus are rare and threatened and they are therefore allocated into the threat categories, according to evaluation against the IUCN Red List criteria. A total of 328 rare taxa are included in the Red Data Book of the flora of Cyprus (Tsintides & al. 2007). Rare plant species have intrinsic, ecological and aesthetic value, leading land managers and conservationists to advocate for their protection. Rare species can be locally rare but with large geographic ranges, locally abundant with small ranges, or locally rare with large ranges, and can therefore have wide or narrow habitat specificity (Myers & al. 2000, Pimm & al. 2001). Moreover, they may also be rare because of their life history characteristics, such as their dependency on a disturbance regime or a specific pollinator. With diverse life histories, species ranges may be at the periphery of protected land, with only one population or maybe even one individual (Laskey & al. 2020).

The present study presents the distribution of 5 plant taxa from the Red Data Book of the flora of Cyprus, namely, *Convolvulus lineatus* L., *Linum maritimum* L., *Lotus cytisoides* L., *Mentha aquatica* L. and *Taraxacum aphrogenes* Meikle, their distribution, population estimates and visiting insects in the Akrotiri Peninsula.

Material and Methods

Study area. – The study area includes the Sovereign Base Area (SBA) of the Akrotiri Peninsula (Fig. 1). The Akrotiri Peninsula is bounded roughly by northing 34°34′ and 34°39′ and easting 33°03′ and 32°54′, including military installations such as RAF Station Akrotiri and satellite communication sites, the built-up area of Akrotiri village, agricultural plantations, forest, but also an internationally important wetland complex. Most of it, is situated within the SBA of Akrotiri, only a few kilometers to the southwest of the city of Limassol. It is constrained by Episkopi Bay to the west and Akrotiri Bay to the east (SBA 2012).

Akrotiri Peninsula is the largest wetland complex in Cyprus and has one of the very few major salt lakes within the eastern Mediterranean in semi-natural condition that exhibits a wide range of saline and freshwater influences. It is of outstanding ecological and biodiversity value and supports an appreciable number of rare, vulnerable or endangered species or subspecies of plants or animals that are important for maintaining the biological diversity of the Mediterranean biogeographic region (SBA 2012).

Akrotiri Peninsula hosts 42 plant species included in the Red Data Book of the Flora of Cyprus. This study covers the distribution and abundance of 5 Red Book Plants (RBPs) within the SBA of Akrotiri Peninsula with some information regarding their insect visitors or pollinators.

Fig. 1: The study area of the SBA of Akrotiri Peninsula.

Distribution and abundance of the RBPs. – Field surveys took place from May 2022 to March 2024 to coincide with flowering season of all 5 RBP species studied. The primary focus of these surveys was to ascertain the current distributional range and population status of these plants on Akrotiri Peninsula. From previous work there was limited information regarding where they exist, therefore, a more detailed survey was undertaken in order to find their exact locations and distributions and update existing records.

To estimate the population of the target RBPs, a quadrat sampling (1 × 1 m plot) was used for each plant species. The following scale was applied: <50 plant individuals, 50–100 plant individuals, 100–500 plant individuals, 500–1000 plant individuals, 1000–5000 plant individuals, 5000–10000 plant individuals, 10000–15000 plant individuals, 15000–20000 plant individuals and >20000 plant individuals.

Pollinator surveys. – Pollination is considered as one of the most crucial plant–animal interactions, influencing the dynamics and diversity of plant communities (Tylianakis 2013), while widespread declines in pollinators had led to a concern about a global pollination crisis (Traveset & al. 2018).

Plant–pollinator communities are typically composed of a high number of plant species and an even greater number of pollinator species (Bosch & al. 2009). For this reason, deciphering the structure of plant-pollinator interactions is important to understand coevolutionary processes in species rich communities (Bascompte & Jordano 2007, Tylianakis 2013). Also, a good assessment of the structure of plant–pollinator interactions is essential to evaluate the stability of pollination systems (Bosch & al. 2009, Traveset & al. 2018).

For this study, each RBP was observed during its flowering season at least 5 times for 20 minutes and observations were spaced evenly throughout the day, excluding the hottest hours of the day (between 12:00–16:00 pm) when pollinators were not active (Harmon-Threatt & al. 2009).

Results and Discussion

Distribution and abundance of the RBPs

Fig. 2: Distribution map of the studied RBP species.

Convolvulus lineatus

C. lineatus is a Mediterranean plant that is found at altitudes between 0–50 m. According to the Red Data Book of the Flora of Cyprus, is classified as Vulnerable (VU) (Tsintides & al. 2007). It is a perennial hemicryptophyte, characterised by woody stocks and procumbent herbaceous stems. Rhizomes assure vegetative propagation in the immediate proximity and plants often form small clonal patches (Stace 1972, Fisogni 2010). Leaves are linear to elliptical or oblanceolate, typically silver-sericeous on both leaf sides. Flowers have been observed to be protandrous (Fisogni 2010). *C. lineatus* is widespread in N Africa, S Europe, Turkey, Caucasia, Syria, Iran and eastwards to Turkmenistan. In Cyprus, it is restricted in Akrotiri and it is threatened by uncontrolled access, development, clearing vegetation along roads (Tsintides & al. 2007, SBA 2012). Flowering occurs between April and June (Meikle 1985) and fruiting occurs from May to August when fruits fall on the ground once mature (Tsintides & al. 2007).

According to the findings of this research, the population of *C. lineatus* at the Akrotiri Peninsula is estimated between 5000–10000 individuals, a significant increase compared to the findings during 2007, where the population was estimated at about 2000 individuals (Tsintides & al. 2007). The majority of individuals were found south of the Salt Lake of Akrotiri, while scattered individuals were recorded throughout the Akrotiri village (Fig. 3). However, it is speculated that the population of *C. lineatus* has wider distribution (P. Charilaou, personal communication).

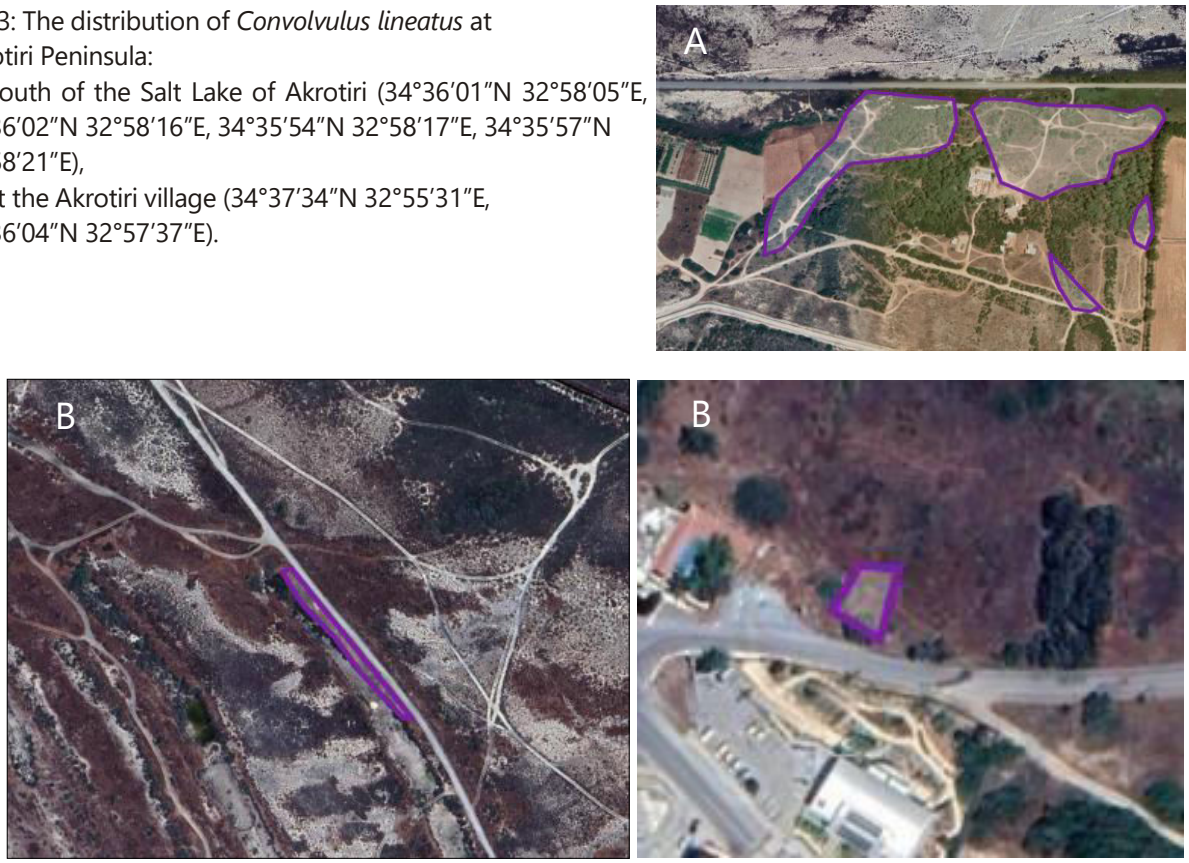

Fig. 3: The distribution of *Convolvulus lineatus* at Akrotiri Peninsula:
A) South of the Salt Lake of Akrotiri (34°36′01″N 32°58′05″E, 34°36′02″N 32°58′16″E, 34°35′54″N 32°58′17″E, 34°35′57″N 32°58′21″E),
B) At the Akrotiri village (34°37′34″N 32°55′31″E, 34°36′04″N 32°57′37″E).

Linum maritimum

L. maritimum, is a species widespread in SE Europe and Mediterranean countries. It is threatened by fire, drainage, invasive *Acacia saligna* and *Phragmites australis,* maintenance of forest roads and ditches (Tsintides & al. 2007, SBA 2012) and has been characterised as Vulnerable (VU) according to the IUCN. *L. maritimum* is an erect or spreading perennial herb with woody rootstock growing up to 1 m high. The lower leaves are opposite, distinctly 3-nerved and the upper leaves are alternate. *L. maritimum* petals are yellow, sepals are ovate and stigmas are clavate. Flowering occurs from May to October, while fruiting occurs from August to November (Tsintides & al. 2007).

In Cyprus, *L. maritimum* grows only within the Akrotiri peninsula (Tsintides & al. 2007). According to the findings, the population of *L. maritimum* is estimated between 1000–5000 individuals, close to the Salt Lake of Akrotiri (Fig. 4).

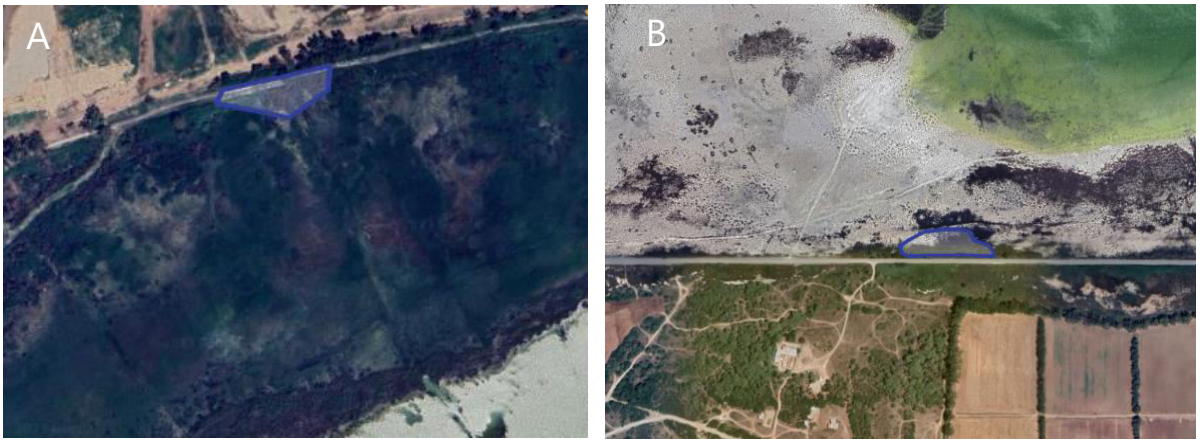

Fig. 4: The distribution of *Linum maritimum* at Akrotiri Peninsula: A) NE of the Salt Lake of Akrotiri (34°38′29″N 32°58′47″E), B) S of the Salt Lake of Akrotiri (34°36′05″N 32°58′21″E).

Lotus cytisoides

L. cytisoides is a species of the Mediterranean basin and, for Cyprus, it is characterised as Endangered (EN). The flowers are yellow, the plant is 10–30 cm high, with a woody base. It grows in coastal areas with sandy and gravel stable shores, near sea level, often forming communities with *Thymbra capitata* and *Elymus farctus* (Christou & al. 2014). Flowering occurs from March till May and fruiting occurs from May to July. The main threats include road works and coastal recreational activities such as extension of parking areas, off road driving and trampling (Tsintides & al. 2007, SBA 2012).

In Cyprus, *L. cytisoides* is restricted to the Akrotiri Peninsula and according to the findings, the population is estimated between 1000–5000 individuals (Fig. 5). However, it is speculated that the population of *L. cyticoides* has a wider distribution (P. Charilaou personal communication, unpublished data).

Fig. 5: The distribution of *Lotus cytisoides* at Akrotiri Peninsula: A) Lady's mile beach (34°37'36"N 33°00'23"E, 34°26'29"N 33°00'16"E) and B) Akrotiri Bay (34°35'18"N 33°00'53"E).

Mentha aquatica

M. aquatica occurs in Africa, Europe and eastward towards the countries of the Caucasus Mountains and Iran. it is characterised as Critically Endangered (CR) for the Cypriot flora. *M. aquatica* is a vigorous, herbaceous perennial up to 1 m high and the leaves are ovate to ovate lanceolate, petiolate and serrate. Flowering occurs between June to August and fruiting occurs between August to September (Tsintides & al. 2007). It grows in wet, often flooded areas, and riparian areas usually near sea level. It emerges from shallow water, especially alkali and tolerates water fluctuation and atrophic conditions (Christou & al. 2014, Tsintides & al. 2007, SBA 2012).

In Cyprus, *M. aquatica* occurs at Fassouri Marsh and RAMSAR site, among other places, and according to the findings, its population in the marsh area is estimated between 50–100 individuals only (Fig. 6). The population of *M. aquatica* has significantly dropped compared to its population over the last decade (Tsintides & al. 2007), mainly due to changes in the hydrological regime at Fassouri Marsh (SBA 2012).

However, seeds and saplings of *M. aquatica* have been planted at Fassouri Forest during 2023, in the context of Darwin Plus Initiative, therefore its population is estimated to increase during the next few years (Fig. 7).

Fig. 6: The distribution of *Mentha aquatica* at Akrotiri Peninsula: A) Fassouri Marsh (34°37′37″N 32°56″52″E) and B) Fassouri Forest (34°37′42″N 32°56′26″E).

Fig. 7: Planting *Mentha aquatica* at *Eucalyptus* Forest on 6.4.2023 in collaboration with the Department of Forests and SBA.

Taraxacum aphrogenes

T. aphrogenes, is an endemic species of Cyprus, which occurs along the coastline of Akrotiri, Episkopi Bay, Paphos, Akamas and Latchi and it is characterised as Vulnerable (VU). Flowering occurs between October to March and fruiting occurs between November to May. It is a perennial, lactiferous, rosulate, hairless herb, up to 12 cm high. The leaves grow in a rosette and have suborbicular lobes. The flowers are ligulate, golden yellow, the phyllaries are erect (Tsintides & al. 2007).

T. aphrogenes is found in cracks of coastal cliffs, sandy or pebble beaches along the coastline and it is threatened by tourist and human development, outdoor coastal recreational activities, including off road driving, especially from Kato Paphos to Agios Georgios Pegeias (SBA 2012).

According to the findings, its population within Akrotiri Peninsula is estimated at 1000–5000 individuals (Fig. 8).

Fig. 8: The distribution of *Taraxacum aphrogenes* at Akrotiri Peninsula: A) RAF Akrotiri (34°34′30″N 33°01′41″E, 34°33′53″N 33°01′22″E, 34°24′14″N 33°00′01″E, 34°34′18″N 32°59′11″E) and B) Episkopi Bay (34°37′41″N 32°55′05″E).

Pollinator surveys

Convolvulus lineatus

In general, plants in the family *Convolvulaceae* are known to be pollinated by a variety of insects, including bees, wasps, butterflies, moths and flies (Inoue & Takenaka 2012), while a study by Khudhur & al. (2018), highlights the role of bees as primary pollinators within the genus *Convolvulus*. During this fieldwork, several small insects visited *C. lineatus* flowers (Tab. 1). They were mainly *Coleoptera* and *Hymenoptera*, which fed on pollen or played dead when disturbed. In either way, pollen was attached on different body parts and insects touched stigmas during their movements, so they could be potential pollinators (Fig. 9).

This study is in line with the study implemented by Fisogni (2010), where several *Coleoptera* visited *C. lineatus* flowers.

Tab. 1: Insects visiting flowers of *Convolvulus lineatus* during fieldwork.

Order	**Family**	**Subfamily**	**Genus**	**Species**
Coleoptera	*Melyridae*	*Dasytinae*		
	Buprestidae	*Polycestinae*	*Acmaeoderella*	
	Tenebrionidae	*Pimeliinae*	*Trachyderma*	
	Chrysomelidae	*Bruchinae*		
Diptera	*Syrphidae*	*Syrphinae*	*Sphaerophoria*	*scripta*
Hymenoptera	*Megachilidae*	*Megachilinae*		

Fig. 9: Small insects on open flowers of *Convolvulus lineatus*: A) Two *Trachyderma* sp. and A) Species of Tribe *Osmiini* (*Megachilidae*) feeding on pollen from dehiscent anthers.

Linum maritimum

Studies have shown that insect pollinators are important for the reproduction and genetic diversity of *L. maritimum*, and that the plant is adapted to attract a wide range of insect pollinators through the production of nectar and pollen and the bright yellow colouration of its flowers (Vela-Acosta & Meléndez-Ramírez 2014, Dafni 2018). *Linum* species are typically visited by a variety of insect pollinators, including bees, flies and butterflies, with bees being the most frequent visitors (Dajoz & Pham-Delègue 1992, Kulkarni & al. 2013, Stanescu & Delaplane 2015, Ward & al. 2017)

Our observations show that *Lepidoptera* and *Diptera* are frequent visitors of *L. maritimum* followed by *Hymenoptera* and *Coleoptera* (Tab. 2, Fig. 10).

Tab. 2: Insects visiting flowers of *Linum maritimum* during fieldwork.

Order	**Family**	**Subfamily**	**Genus**	**Species**
Lepidoptera	*Hesperiidae*	*Pyrginae*	*Carcharodus*	*alceae*
	Lycaenidae	*Polyommatinae*	*Polyommatus*	*icarus*
	Pieridae	*Pierinae*	*Pontia*	*daplidice*
Hymenoptera	*Halictidae*	*Halictinae*	*Lasioglossum*	
Diptera	*Syrphidae*	*Eristalinae*	*Syritta*	*pipiens*
	Tachinidae			
	Syrphidae			
Coleoptera	*Chrysomelidae*	*Alticinae*		

Fig. 10: Pollinators of *Linum maritimum*: A) A *Lasioglossum* sp. B) A female *Polyommatus icarus*.

Lotus cytisoides

Several studies reveal that the yellow coloured flowers of *L. cytisoides* are visited by various species of bees for nectar and pollen, including honeybees, bumblebees and solitary bees. The role of pollinators in the conservation of *L. cytisoides* (García-Camacho & al. 2012) has shown that bees were the primary pollinators of *L. cytisoides*, with honeybees and bumblebees being the most frequent visitors. Another study confirmed the role of bees as pollinators of *L. cytisoides*, with honeybees and solitary bees being the most common visitors (Gómez-Bellver 2017), while a further study indicates that honeybees, bumblebees and solitary bees were the main pollinators of *L. cytisoides* (Porras-González & al. 2019).

This study agrees with the above-mentioned studies, since the main pollinator for *L. cyticoides* identified was the honeybee *Apis mellifera* (Fig. 11A).

Fig. 11: *Apis mellifera* – a pollinator of A) *Lotus cytisoides* and B) *Mentha aquatica*.

Mentha aquatica

M. aquatica, similar to other *Mentha* species, is known to attract various pollinators, including bees and hoverflies. Amin & al. (2014) and Faria (2021) confirm the attraction of honeybees, bumblebees and solitary bees to *Mentha* species for nectar and pollen, while Chishti & al. (2015) highlight bees' importance in the pollination of *M. spicata* and *M. arvensis*. Moreover, another study shows the importance of hoverflies and their potential contribution to *Mentha* pollination (Gilbert 1981).

During the present study, individuals of the thick legged hoverfly *Syritta pipiens* and *Apis mellifera* were observed on *M. aquatica* flowers (Fig. 11B).

Taraxacum aphrogenes

The genus *Taraxacum*, commonly known as dandelions, typically attracts various pollinators, including honeybees, bumblebees and solitary bees (Barth 2007, Garibaldi & al. 2013). Another study by Muñoz & Cavieres (2019) shows that the main insect visitors of *T. officinale* are *Hymenoptera* from *Andrenidae* family (*Lipanthus* sp.) representing 51 % of all visits, followed by *Diptera* of the *Syrphidae* family (*Scaeva melanostoma*) and *Tachinidae* family, representing 15 % and 14 % respectively and *Hymenoptera* of the *Apidae* family representing 10 % of all visits.

During the present work, solitary bees (*Andrena* sp. and *Lasioglossum* sp.) were observed on *T. aphrogenes* flowers (Fig. 12).

Fig. 12: Pollinators of *Taraxacum aphrogenes*: A) *Andrena* sp. B) *Lasioglossum* sp.

Conclusions

Common anthropogenic threats of the protected wetlands at the Akrotiri peninsula include the urbanization, pollution, overexploitation of natural resources, agricultural intensification, invasive species and climate change. Fragmentation of the landscape due to urbanization is particularly threatening and can affect native plants. Unauthorised trail usage and the high density of invasive plant species such as *Acacia saligna* and of spreading native taxa such as *Phragmites australis* can also affect natural habitats and endemic plants and, in certain cases, make them susceptible to human-caused fires (Laskey & al. 2020, Christodoulou 2003). Roads and trails can spread invasive species into habitats that are important for rare species and negatively impact the recruitment and persistence of rare plants (Christou & al. 2014).
Identifying the plant species and the ecosystems that are of high conservation priority and outlining the importance of certain taxa that will enable conservation efforts to be targeted and impactful especially when resources are limited are key (Sapir & al. 2003). Plant conservation efforts have been based on estimations of vulnerability, which varies among countries and conservation organizations. For the rare species of the Akrotiri Peninsula ex-situ conservation measures have been applied to date including: The collection of genetic material (seeds) for storage and preservation at the Agricultural Research Institute, at the Dahlem Seed Bank at the Botanic Garden Berlin and at the Fassouri Department of Forest at Akrotiri, as well as the plantation within botanical gardens.

In order to protect the populations of RBPs, further research is needed to be undertaken to monitor their populations and try to find additional locations of these plants throughout the island. A further conservation measure may include the fencing of the RBPs, to maximise their protection from human and/or vehicle trampling. Collection of RBP seeds needs is a vital conservation measure for their population success. Education is also key for the conservation of rare plants and their pollinators. Through educational and raising awareness programs at the Akrotiri Environmental

Education Centre (AEEC) the importance and the need for conservation measures for RBPs could be highlighted. Volunteer contribution can be particularly helpful in data collection on rare plants at local scale, over a considerable time span (Buldrini & al. 2015).

In addition, through citizen science initiatives or with the help of volunteers RBP seeds that are collected could be planted. However, this should only be done under scientific supervision and be properly documented. Plants could be distributed during workshops or events organised at the AEEC widely and observations by using applications such as the Flower Insect Timed (FIT Count) App or iNaturalist platform could provide additional information on the distribution of these plants especially for the RBPs that are found within the urbanised areas as well as information on their flower visitors. Furthermore, with the help of new technologies and tools such as artificial intelligence, remote sensing and sensors we could also explore the pollinators and other flower visitors as well as address the impacts of pressures such as climate change and urbanisation (Roy & al. 2024).

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