AMERICAN UNIVERSITY OF BEIRUT

PHYSIOGNOMY AS A BASIS FOR PLANT SPECIES CONSERVATION IN URBAN AREAS: BEIRUT AS A CASE-STUDY

by
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AN ABSTRACT OF THE THESIS OF

Moustapha Abdallah Itani for Master of Science
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Title: Physiognomy as a Basis for Species Conservation in Urban Areas: Beirut As a Case-study

The Lebanese coast is rich in plant diversity and is simultaneously highly urbanized. This makes the conservation of endemic coastal plants very challenging. Semi-natural open urban spaces harboring remnant patches of endemic plants are being destroyed and re-designed to offer managed open spaces that do not consider plant conservation and do not seek to incorporate native species. In this study, commonly used vegetation description methods were applied in built areas as well as semi-natural and managed urban spaces, with the aim of assessing the growing requirements of native coastal plant species.

Case study species were selected following a revision of the literature to identify plant species that are endemic to the Lebanese coast, and that may be at high risk of extinction. Three such species were identified: *Limonium mouterdei*, *Limonium postii*, and *Matthiola crassifolia*. Field surveys of these three species in their historic locations were conducted between 2011 and 2015. Field investigations revealed that *L.mouterdei* is still found in only one site in Beirut. *Limonium postii* was found in 7 out of 8 reported locations in Lebanon whereas *M. crassifolia* was found in 4 out of the 5 previously reported locations. Red listing of the target species revealed *M. crassifolia* is Endangered (EN), *L. mouterdei* is Critically Endangered (CR), and *L. postii* is Endangered (EN).

Given that the three target plant species co-occur in a restricted area in Beirut, Lebanon's most urbanized coastal city, Beirut was selected as the case study location. Field surveys in the study location revealed the presence of both *Limonium mouterdei* and *L. postii* in one patch area and *M. crassifolia* in 73 patches.

Quadrats were set in selected patches to collect physiognomic, floristic, and environmental data on the three target species. Physiognomic findings revealed that *M. crassifolia* was highly associated with several perennial life-forms including tuft trees, low lying creeping succulents, caespitose dwarf-shrubs and tall perennial canes. *Matthiola crassifolia* generally grew on grounds characterized with sparse, dry litter and direct sunlight. Both *Limonium mourterdii* and *L. postii*, which still occupy parts of a single remnant seminatural sandstone cliff, grow among other dwarf-shrubs in a habitat that is exposed to

direct sunlight and characterized with much bare ground and dry and sparse litter. Both *M. crassifolia* and *L. mouterdei* were absent in patches that include high abundance of mat forming plant species, while *L.mouterdei* was absent in patches that include a high abundance of herbaceous plants with periodic shoot reduction.

Analysis of the results revealed that physiognomic data was more discriminatory in the case of our study area where ruderal species were abundant. In contrast to floristic data, physiognomic data classified quadrats in a less site-dependent manner and segregated out quadrats that excluded target species. Based on these findings this thesis discusses prospects of using life-form spectra and abundance measures of each life-form to guide planting designs and to contribute to the conservation of plants species in urban areas.

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ABBREVIATIONS

a	Aestivo
bulb	Bulbous
c	cheimo
caesp	Caespitose
Ch	Chamaephyte
e	Sparingly evergreen
frut	Frutescent
G	Geophyte
gram	Graminoid
H	Hemicryptophyte
herb	Herbaceous
I	Introduced
l	leaf
Mes	Mesophyllous
met	metoporino
Mi	Micro-
N	Nano-
NE	National endemic
P	Phanerophyte
pulv	Pulvinate

RE	Regional endemic
rept	Reptant
rhiz	Rhizome
ros	Rosulate
scap	Scapose
sem	Semi-rosette
succ	Succulant
suff	Suffrutescent
t	Thero
T	Therophyte
vp	Vascular parasite

CHAPTER I

INTRODUCTION

Urban areas are globally expanding at a high rate, greater than human population growth (McDonnell and Pickett, 1990; Pickett *et al.* 1997; Alberti *et al.*, 2001; Marzluff *et al.*, 2001). Given the current rates of urbanization, and the limited natural distribution of certain organisms, the distribution of some native plant species has become restricted to urban areas, and in order to survive these species have to persist in cities (Low, 2002; Schwartz *et al.*, 2006; Vähä-Piikkiö *et al.*, 2004; Wang *et al.*, 2007; Holmes *et al.*, 2012; Kantsa *et al.*, 2013;). The survival of plant species in urban areas and their eventual conservation depends on our ability to define their habitat requirements under these new conditions (Kent, 2012). Therefore, formulating reliable conservation plans for target species necessitates the study of plant species within their last remaining habitats, even if these are situated in the heart of an urbanized zone.

Open spaces in urban areas can be biologically productive and they represent unique combinations of environmental factors (Pickett *et al.*, 1997; McDonnell *et al.*, 2009). Conducting ecological studies in these urban areas is thus very likely to provide a better understanding of biodiversity conservation and the processes that influence it (McDonnell *et al.*, 2009).

Beirut (33.8869° N, 35.5131° E), the capital of Lebanon, is located on the eastern coast of the Mediterranean. Its geomorphology is defined by a 6 km long by 2 km wide promontory (Dubertret, 1940), bound to the west on two of its three sides by the sea, and on the third side by Mount Lebanon. Although human settlement in the region began since antiquity (Fleisch, 1946, Copeland & Wescombe, 1965; Copeland & Wescombe, 1966), recent archeological evidence shows that Beirut has been continuously occupied by humans for the last 5000 years (Mouterde, 1966; Hall, 2004). In modern times, Beirut's coastal location and capital status credited it with one of the highest urban densities in the Middle East. With an area of roughly over 20 km^2, its density is estimated at about 21,000 people per sq. km (Population and Development Strategies Programme, 2014; MOE/LEDO/ECODIT, 2001). Despite this reality, Chmaitelly (2007) showed that remnant seminatural habitats at the seafront of Beirut served as refuges for wild plants and some of her investigated sites hosted unique assemblages of plant species with cultural and natural value. Unfortunately, many of these patches are being destroyed and re-designed to exclude these species. The incorporation of native plant species in urban spaces has the potential to increase the species' patch area and allow for more connectivity among existing patches (Fahrig & Merriam, 1985). To guarantee the success of such incorporation attempts, requirements of these species must be understood (Kent, 2012). In this study, a new approach based on quadrat sampling and combining physiognomic (external morphology, life-form, stratification and size) and floristicic (plant species composition) vegetation description methods and environmental approaches is proposed to guide the incorporation of species of conservation interest in designed urban open spaces.

The aims of this study are:

- To investigate aspects of the ecology and conservation of plant species restricted to urban areas.
- To assess the relevance of physiognomic and floristic vegetation description methods in defining requirements of species restricted to urban areas.

CHAPTER II

LITERATURE REVIEW

A. Species Conservation in Cities

Not all plant species can persist in open urban spaces and several studies have shown that many species in these sites are non-native (McKinney and Lockwood, 1999; McKinney, 2002). In an urbanized area, habitats are considerably reduced and tend to be predominated by a relatively small number of plant species (Kent, 2012). Native species that do persist in urbanized areas and contribute to patch diversity tend to be present in locations not frequently visited by residents (Turner, 2004). Consequently, urban residents are usually exposed to urban landscapes that display biological uniformity (Miller, 2005). Such observed uniformity in urban open spaces emphasizes the supposed irrelevance of plant diversity among government agencies and professionals who shape urban areas through governance and design (Kellert, 1996). Furthermore, attempts to provide ecological refuges through greenways and open spaces are often viewed as an extravagance, and are more likely to be regarded as less important when compared to more persuasive socioeconomic concerns. In effect, they are the first candidates for omission from municipal budgets (Miller, 2005).

While urban expansion is on the rise, areas allocated for nature reserves are not expected to substantially increase. Recognizing this impasse, Rosenzweig (2003) proposes ‘reconciliation ecology’ as a new form of conservation science whose goal is to adapt spaces assigned to human activities in ways that would allow them to meet the requirements for persistence of more native species. He gives the example of the natterjack toad in the United Kingdom which started using artificial ponds as habitat and the example American crocodiles using cooling canals in South Florida for reproduction. Varying green roof depth and substrate material in Berlin was also given as an example to how the diversity plant and their associated insects and birds can be enhanced (Rosenzweig, 2003). Miller (2005) finds the concept of reconciliation ecology very appealing because it widens prospects of conservation, engages more stakeholders, and dilutes the distinction between disturbed and non-disturbed habitats.

B. Plant Biodiversity of Mediterranean Cities

Of all Mediterranean countries, recent and thorough floristic surverys of cities were only conducted in Greece, Italy and Spain (Celesti-Grapow, 1995; Celesti-Grapow & Blasi, 1998; Chronopoulos, 2002; Dana *et al.*, 2002; Tsiotsiou & Christodoulakis, 2004; Krigas, 2004; Chronopoulos & Christodoulakis, 2006; Kantsa *et al.*, 2013). Table 1 summarizes the main findinings of these studies.

In their floristic investigation of the urban ecosystems in the city Ioannina, NW Greece, Kantsa *et al.* (2013) noted that urban ecosystems in the Mediterranean are underrepresented in biodiversity studies and that data on species of conservation interest in cities is needed. They also showed that endemic taxa and ones included in conservation lists comprised 7.1% of the flora of the city thus demonstrating the prospective refuge function of cities. Identified plants of conservation interest in this study inhabited all investigated habitats regardless of their seminatural or anthropogenic type.

Table 1: Percent alien and endemic plant species in the flora of recently studied Mediterranean cities.

Source: Kantsa, A., Tscheulin, T., Junker, R. R., Petanidou, T., & Kokkini, S. (2013). Urban biodiversity hotspots wait to get discovered: The example of the city of Ioannina, NW Greece. Landscape and Urban Planning, 120, 129-137. (With modification)

Country	City	Alien species %	Endemic species %	Reference
Greece	Alexandroupolis	8.7%	2.4%	Chronopoulos and Christodoulakis (2006)
	Ioannina	11.3%	4.8%	Kantsa *et al.* (2013)
	Mesolongi	13%	0.9%	Tsiotsiou and Christodoulakis (2004)
	Patras	12.4%	3.2%	Chronopoulos (2002)
	Thessaloniki	14.5%	3.7%	Krigas (2004)
Italy	Ancona	11.9%	n.a.	Celesti-Grapow and Blasi (1998)
	Cagliari	11.9%	n.a.	Celesti-Grapow and Blasi (1998)
	Milan	25.6%	n.a.	Celesti-Grapow and Blasi (1998)
	Palermo	14.3%	n.a.	Celesti-Grapow and Blasi (1998)
	Rome	12.4%	0.8%	Celesti-Grapow (1995) and Celesti-Grapow and Blasi

				(1998)
Spain	Almeria	17.0%	n.a.	Dana *et al.* (2002)

Given that human population growth and increasing urbanization are favoring anthropogenic habitats, the preservation of biodiversity in Mediterranean cities that naturally include wildlife will constitute a "future paradigm". Whether biodiversity conservation can occur in these cities and whether this can be accounted for in urban planning are pressing questions that researchers in this region are supposed to address (Kantsa *et al.*, 2013).

C. Urbanization as a major threat to plant diversity along the Lebanese Coast

The Lebanese coast exemplifies the surge in urbanization witnessed across the Mediterranean biodiversity hotspot. An estimated 64% of Lebanon's population is clustered along the coast, mostly in Beirut, Greater Beirut Area, and Tripoli (UNH, 2009). Rising land values, Makhzoumi *et al.* (2012) warns, invariably poses a threat of gradually destroying remnant natural and seminatural coastal habitats in Lebanon.

Recent studies on the biodiversity of the Lebanese coast have shown that native species are becoming more scarse in coastal landscapes (Zahreddine *et al.*, 2004; Talhouk *et al.*, 2005). More alarmingly, a survey of the Beirut waterfront showed the number of taxa occupying the coastal zone has, in comparison to the 1930's, significantly decreased (Chmaitelly, 2007).

D. Endemic Species Restricted to the Lebanese Coast

A review of the literature revealed the presence of three species of plants endemic to the Lebanese coast (Post, 1932; Mouterde, 1966-1984; Dardas, 2000; Domina *et al.*, 2008). One species belongs to the genus *Matthiola* (Brassicaceae), *M. crassifolia* (Boiss. & Gaill.), while the other two species belong to the genus *Limonium* (Plumbaginaceae), *L. mouterdei* (Domina, Erben & Raimondo) and *L. postii* (Domina, Erben & Raimondo). These three coastal endemics were chosen as the target species investigated in this study. Figure 1 includes an image of each.

Figure 1: The three target species investigated in this study, *Limonium mouterdei* (left), *L. postii* (middle) and *Matthiola crassifolia* (right)

Before the two *Limonium* species were described in 2008, several studies were conducted on the Lebanese coastal biodiversity and came out with conclusions concerning *M. crassifolia*. Dardas (2000) identified it as one of the 93 littoral specific species to be found in Lebanon. Rteil (2002) conducted the most comprehensive survey of this species to that date. Chmaitelly (2007) considered it ornamentally interesting and highlighted its horticultural value and potential landscape use.

The Illustrated Flora of Lebanon (Tohme & Tohme, 2007; Tohme & Tohme, 2014) which features the distribution of these species is considered the most recent flora of Lebanon.

1. The geographic distribution of Matthiola crassifolia

The most comprehensive record of the distribution and status of *M. crassifolia* was provided by Rteil (2002) who performed a systemic survey of the Lebanese coast for that purpose. She confirmed the existence of three out of five previously reported sites, Beirut, Ras Beirut and Byblos.

Tohme and Tome (2014) also include Saida, Khaldeh and Amchit as localities for *M. crassifolia*. A comprehensive survey of these localities confirmed the extinction of *M. crassifolia* in Saida and confirmed its continued presence in Khalde and Amchit.

2. The geographic distribution of Limonium mouterdei

Limonium mouterdei was described in 2008 based on herbarium specimens collected by Post, Mouterde and Pabot from Beirut. So far this species is only known from Beirut and is therefore a stenoendemic of the Lebanese coast (Domina *et al.* 2008).

3. The geographic distribution of Limonium postii

Limonium postii was described in 2008 based on herbarium specimens collected from Beirut, Nahr el Kelb, Jounieh, Jbail, Ras Chekka and Amshit (Domina *et al.* 2008).

A comprehensive survey for all the aforementioned localities was not attempted. Of special relevance to this study were the highly urbanized localities in which this species is thought to occur. The species' continued presence in Beirut was confirmed. Its presence was also confirmed in Nakhl, the only nature reserve within which it is present.

The current distribution of these three species is shown in Figure 2. The only locality that includes all three endemic species along the Lebanese coast is Beirut. Byblos and Amchit include both *L. postii* and *M. crassifolia.* The other localities include *L. postii* only.

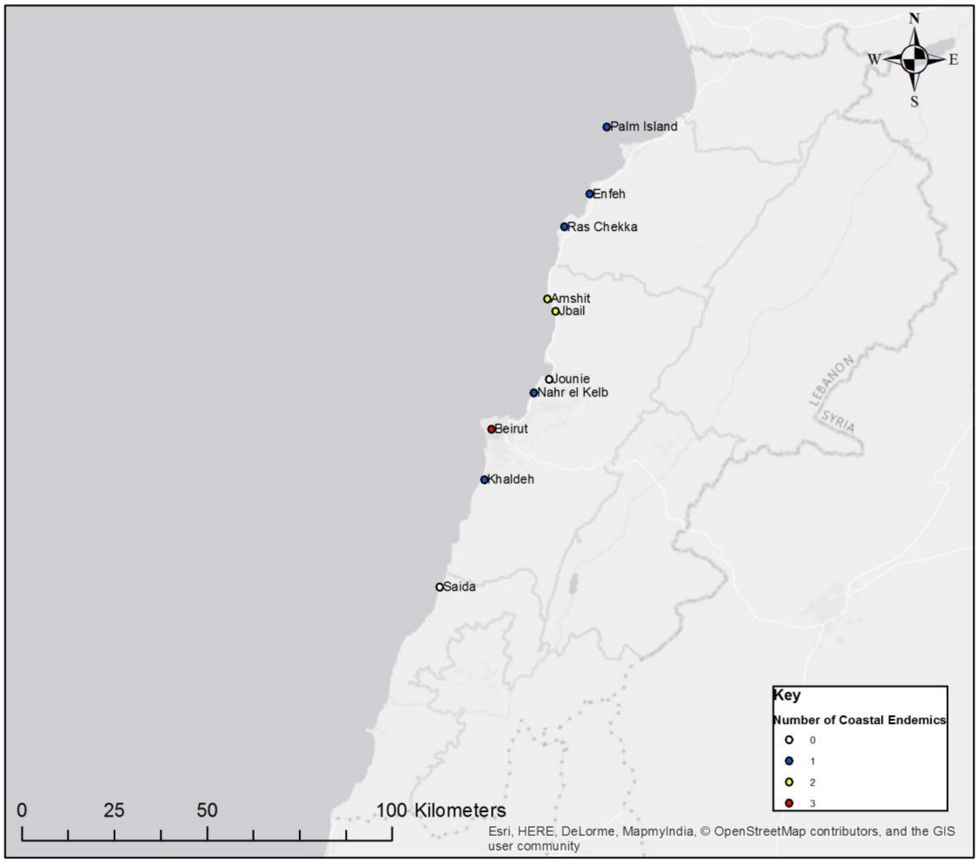

Figure 2: The distribution of endemic species restricted to the Lebanese coast

E. Methods of Vegetation Description

Ecology lies at the heart of conservation (Dansereau, 1970) and information pertaining to rare species' autecology and synecology is required to formulate reliable management practices (Baskin & Baskin, 1978; Soberen, 1992). Such management practices are essential for the success of conservation efforts (Kent, 2012).

Vegetation description is essential for obtaining baseline information for conservation of native species (Kent, 2012). There are two main methods for vegetation description:

(a) Floristic methods describe the vegetation on the basis of taxonomic identification and abundance measures of identified species

(b) Physiognomic and structural methods describe the vegetation of a site on the basis of external morphology, life-form, stratification and size of each species present

From the perspective of floristic vegetation description, a community is formed of species that are capable of coexisting. Clements defined plant communities as distinct clearly recognizable units that repeat themselves regularly in a given area of land (1916; 1928). Gleason (1917; 1926; 1939) argued that plants respond to variations in many environmental factors and therefore an assemblage of plant species found at any point in an area is unique. Today, plant ecologists agree that beside environmental and biotic factors that control which species grow at a certain location, physiognomic and physiological characteristics of the plants themselves, including the notion of species life-history strategies and population biology, are also important (Grime, 1974, 1977, 1993, 2001; Harper, 1977; Tilman, 1982, 1988; van der Maarel, 1984, 2005; Silvertown and Charlesworth, 2001).

Several techniques have been published that either focus on physiognomy and structure, floristics or a combination of both. Table 2 briefly presents major vegetation description techniques.

Table 2: Methods used to describe vegetation

Technique / reference	Type	Description of method	Presentation of results
Raunkiaer's life-form classification (Raunkiaer 1934, 1937; Ellenberg & Mueller-Dombois, 1965/1966; Mueller-Dombois and Ellenberg, 1974)	Physiognomic	All species in a study area categorized into Raunkiaer life-forms of which five main categories were described by Raunkiaer himself on basis of the height of perennating buds above the ground.	Bar graph for identified life-forms showing percent species
Dansereau's method (1951, 1957)	Physiognomic and structural	Structure of vegetation described based on six criteria sets including life-form, size, cover, function and leaf size, shape and texture	Symbolic profile diagrams of site
Kuchler's method (1967)	Physiognomic and structural	Subdivides site vegetation on a hierarchy that starts with categorizing it into woody and herbaceous and further into seven and three classes respectively. Each physiognomic class can be further described on bases that include leaf characteristics, height and cover.	Formulae that employ letters and numbers
Fosberg's method (1961)	Physiognomic and structural	Subdivides site vegetation on a hierarchy of four levels. The first of which categorizes vegetation as open, closed or sparse. At the second level, 31 formation classes are recognized based mainly on height and continuity. The third and fourth levels respectively describe plant function and leaf and growth form of dominant species. Mapping of formation groups can be conducted at the last level.	Formulae that employ letters and numbers
Habitat	Structural	Divides habitat systems into categories.	Lists of

classification (Elton and Miller, 1954; Elton, 1966)		The terrestrial habitat system is subdivided into four. Based on height of dominant vegetation, the habitat of a site can be categorized as open ground, field layer or woodland. Ecosystem structure and diversity is assessed after measurements of area covered by each habitat type are obtained. Number of species can be counted by using sample quadrats in each habitat type for comparison purposes.	groups of sites representing main habitat types in an area that can be mapped
Community classification (Summarized in Kent, 2012)	Floristic	Quadrats help establish standard areas for inspecting the vegetation. Plants occurring in each sampling quadrat are identified to the species level and the abundance of each is measured. Floristic data is used to classify quadrats into groups based on how similar they are.	Lists of species and quadrat groups representing communities
EcoVeg (Faber-Langendoen *et al.*, 2014)	Physiognomic, floristic and Ecological	Follows hierarchal classification based on a set of vegetation criteria in conjunction with ecological characteristics and according to whether vegetation is natural or cultural, the method follows different rationales.	Upper, mid and lower levels subdivided into various classification

F. Application of Vegetation Methods at the Community level in Urban Areas

Vegetation studies in urban areas have only recently become a central theme of plant ecology (Kent, 2012). Besides the work of Shenstone (1912) and Salisbury (1943), vegetation studies in urban areas began to appear in the literature in the mid-70s (Davis, 1976; Nature Conservancy Council, 1979; Haigh, 1980; Whitney & Adams, 1980; Kunick, 1982; Whitney, 1985; Emery, 1986; Gilbert, 1989; Sukopp *et al.*, 1990; Kent *et al.*, 1999; Pyˇsek *et al.*, 2004; Thompson *et al.*, 2004; Loram *et al.*, 2008).

Due to high levels of human interference, sites in urban areas are often at early successional stages. Plant species colonizing bare and disturbed land are referred to as ruderals. Such plants benefit from the absence of interspecific competition that would otherwise occur in later successional stages. These colonizers are often recruited from nearby semi-natural vegetation. Consequently, plant diversity may vary a lot even for relatively close sites. This wide variety of early natural colonizers limits the value of vegetation description using floristic methods in urban areas (Kent, 2012).

For these reasons, an assessment of the array of plant communities in which a rare species occurs is among the requirements for its conservation (Kent, 2012). Examples of plant community studies can be found on rare species (*e.g.* Dinsdale *et al.* 1997) and on ecologically and economicly important species (*e.g.* Siddiqui *et al.* 2009). Plant community studies are usually conducted in least disturbed habitats and disturbed areas are sometimes deliberately avoided from sampling (Siddiqui *et al.* 2009).

Physiognomic and structural vegetation description methodologies were developed to describe vegetation over large areas, however these methods are currently considered as potentially more useful tools than floristics in the case of highly modified sites (Kent, 2012). Down (1973) resorted to physiognomy in studying reclamation of spoil heaps. The use of these methods at both large and small scales is feasible due to the responses of plant species to macro- and micro-climate conditions (Kent, 2012) and to recently found effects of physiognomy on other ecological processes (Nelis, 2012; Meiners, 2014). Life history and life form were, for instance, found to be stronger predictors of underlying population processes than native status (Nelis, 2012). In 2014, Meiners found that life-history and life-form also explain allelopathic potential (Meiners, 2014).

CHAPTER III

MATERIALS AND METHODS

A. Distribution and state of the target species in Beirut

In this study, a patch is defined as a relatively homogeneous area that differs from its surroundings by the general environmental factors that influence it (Forman, 1995). Field surveys were conducted to map patches that are occupied by target species in Beirut. Patches that were inaccessible physically or for security reasons were either checked from a distance or excluded from this study. All the other patches were monitored for a period of six years starting in 2009 for *Matthiola crassifolia* and for a period of four years starting in 2011 for both *Limonium* spp. Threats to existing patches were identified. The dominant habitat type of each patch was described based on naturalness (semi-natural or anthropogenic). Semi-natural patches were further classified based on their geology while anthropogenic patches were classified based on whether they are managed or are abandoned (Kantsa *et al.*, 2013, with modification).

Locations where the plants were observed were not recorded via a GPS device. This is primarily because from a technical perspective, Modsching *et al.* (2006) showed that GPS location precision was greatly impacted by build-up in cities. The authors examined the actual positioning accuracy of GPS receivers in different areas of Gorlitz, Germany, by comparing a dense network of reference points and readings of GPS devices. The error that was documented resulted from interactions between constellations of GPS satellites and the immediately proximate built-up; it averaged at

24.5 meters for all runs and was characterized with significant variation depending on area (Modsching *et al.,* 2006). As an alternative, an aerial map of the city was used to identify sites that were visited in the field. These locations were later traced on a basemap on GIS and were presented on point maps for each species.

B. Floristic, Physiognomic and Environmental Analyses

A floristic, physiognomic and environmental survey was conducted in 2014. Considering that in urban settings high levels of disturbance make it difficult to distinghish community types and their boundaries (Goldsmith, 1974) the survey included three semi-natural patches that harbored large populations (Dalieh, Ramlat el Bayda and Saint Elie), in addition to anthropogenic patches found in street medians, pedestrian paths, and abandoned built stuctures.

1. Sampling

The sampling technique performed by Dinsdale (1997) was applied: When a vegetation community harbored the target species two quadrats were used, one quadrat was set to include the target species and the other quadrat was placed in a location where the target species did not grow. In communities that did not harbor the target species only one quadrat was used. As in Dinsdale (1996), sampling quadrats were placed in areas judged to be representative of the selected location and for the purpose of capturing the maximum observed variation; the sampling therefore, had to be deliberately biased.

Three modifications were made to the sampling technique by Dinsdale et al. (1997) to address site specific issues: 1) when the boundary of a given plant community was not clearly defined due to site disturbance, quadrats were set within assumed boundaries of plant communities to capture plant diversity, 2) in cases where species had an 'individualistic' distribution pattern adding to the difficulty in conceiving boundaries (Goldsmith, 1974), the number of quadrats was increased to capture the observed variation, and 3) communities that did not contain target species were selected to be adjacent to sampled communities that harbored the target species because the dispersal distance for the target species is not known.

2. Recruitment of target species in samples

To describe urban habitats that favor the presence of each target species, recruitment was evaluated using a 3-point ordinal scale: (1) species absent; (2) poor recruitment (not all age groups present in sampling quadrat); (3) high recruitment (all age groups of target species present in sampling quadrat).

3. Environmental Data

In each quadrat, environmental data were collected in order to describe the habitat of each target species. Data were gathered on ordinal and nominal scales. Although nominal and ordinal data are weak in explaining variability when compared to interval data, they are still useful in characterizing controlling environmental factors and in particular those variables measuring biotic pressure (Kent & Coker, 1992).

In an urbanized setting, it is conceivable that anthropogenic factors influence both the distribution of species and the environment in which they occur. Since urban sprawl is not likely to have occurred evenly in all habitats, it therefore follows that the range of certain environmental variables might be more restricted by the anthropogenic factor than others. Variables suspected to have been severely restricted were excluded from this study. These included all soil variables, aspect and slope. If steep terrains are less likely to be lost for urbanization, a target species might persist on them not because they are necessarily preferred to less inclined patches, but because those patches constitute the last remaining habitable sites.

The following variables were recorded and a standard data record form was completed for each quadrat (Table 3, 4, 5 & 6). The survey was mainly carried out during April and May 2014. Quadrats that were studied in the summer of 2014 were again surveyed for verification in April and May 2015.

For each quadrat, several microclimate and habitat environmental variables were assessed. Some of these variables were accounted for in similar studies (e.g. Dinsdale, 1996) and others were included to better describe the anthropogenic features of each sample:

- Height of dominant vegetation was first measured in centimeters. Each measurement was then transformed into 5-point ordinal scale: (1) Very low, < 3 cm; (2) Low, 3 - 10 cm; (3) Typical of dwarf shrubs, 10 - 30 cm; (4) Tall, 30-100 cm; (5) Very tall, > 100 cm. This grouping is based on Mueller-Dombois and Ellenberg (1965/1966) height classification of chamaephytes (woody plants with resting buds on or near the ground).

- Bare ground (% cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Natural hard surfaces (%cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Anthropogenic hardscape cover (%cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Persistent vegetation cover (%cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Bryophytes (%cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Litter cover (% cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Litter type (5-point ordinal scale): (1) sparse without signs of decay; sometimes dense in distinct places such as around the stems of certain perennial species and primarly formed of the plant's own dead rosette leaves; (2) intermediately dense without signs of decay - rarely burrying considerable parts of stems of taller plants; (3) Dense without peat accumulation; (4) Dense, with slight peat accumulation; (5) Significant peat accumulation (hiding parts of the stems of other species.

- Anthropogenic litter cover (%cover, 6-point Domin scale): (1) less than 1%; (2) 1-4%; (3) 5-24%; (4) 25-49%; (5) 50-74%; (6) 75-100%.
- Microtopography (5-point ordinal scale): 1 (flat), 2 (through), 3 (uneven), 4 (more uneven), 5 (deeply rutted/poached)
- Exposure to direct sunlight at the level of target species (5-point ordinal scale): (1) Open, subjected to direct sunlight all day; (2) Open (subjected to direct sunlight for most of the day or slightly sheltered by taller vegetation; (3) Partially Sheltered by taller plants and not exposed completely to direct sunlight most of the day; (4) Significantly but not completely sheltered by taller vegetation and not subject to direct sunlight for most of the day; (5) Sheltered (completely by canopy, buildingor any other structure that cpmpletely prevents exposure to direct sunlight)
- Degree of human interference (5-point ordinal scale): (1) No current anthropogenic activity; (2) Low anthropogenic activity, infrequent pedestrian activity, no recreational activity, landscaping effort such as watering plants in street median; (3) Good pedestrian activity, low recreational activity; (4) Heavy pedestrian activity, intermediate recreational activity, (5) Heavy machinery, high recreational activity.

The mean, minimum, maximum and standard deviation of each environmental variable were determined for all surveyed samples and for samples were target species existed; these are shown in Appendix V.

Table 3: Table 1 of site and quadrat recording forms for floristic and environmental survey of sites containing target species

Quadrat No.		Image file name	
Date			
Site			
Habitat Type	☐ Anthropogenic ☐ Semi-natural		
Habitat Features	☐ Sandy beach ☐ Sandy soil ☐ Sandstone formations ☐ Limestone formations	☐ Rubble ☐ Degraded Asphalt ☐ Managed	Other
Predominant Species			
Target species	Recruitment if present		
Matthiola crassifolia			
Limonium mouterdei			
Limonium postii			

Table 4: Table 2 of site and quadrat recording forms for floristic and environmental survey of sites containing target species

Microclimate and habitat variables						
Height of dominant vegetation in (cm)						
Bare ground	+	1	2	3	4	5
Bryophytes	+	1	2	3	4	5
Persistant vegetation	+	1	2	3	4	5
Litter cover	+	1	2	3	4	5
Anthropogenic litter	+	1	2	3	4	5
Hard surfaces	+	1	2	3	4	5
Anthropogenic hard surfaces	+	1	2	3	4	5
Litter type	1	2	3	4	5	
Microtopography	1 (flat)	2 (through)	3 (uneven)	4 (more uneven)	5(deeply rutted/poached)	
Exposure	1 (Open)	2	3	4	5 (sheltered)	
Degree of human interference	1	2	3	4	5	

4. Floristic investigation

Floristic investigation included identifying all species of vascular plants occurring in each sampled quadrat using Lebanese floras (Post, 1932; Mouterde, 1966-1984; Tohme & Tohme, 2014). The 1 m × 1 m sampling quadrats were placed in anthropogenic habitats, barely accessible grounds and in habitats that do not include shrubby vegetation (Kent, 2012), whereas the 2 m × 2 m sampling quadrats were used in locations where shrubs were present (Kent, 2012). Each quadrat was divided into 100 contiguous subunits to allow for a more objective estimation of cover, which was determined by eye. Subunits that were completely covered by a certain species represented a cover of 1% for that species. Estimation by eye was therefore restricted to parts of the sampling quadrats that included subunits that were partially filled. The overall percent cover for each species determined the Domin scale abundance measure for that species. In the Domin cover scale, the range 0 - 100% is partitioned into a number of classes with smaller graduations nearer to the bottom of the scale. The 11-point Domin cover scale (Kent, 2012) was used. Speed and relative accuracy of measurement justified choosing a subjective assessment approach (Causton, 1988; Kent & Coker, 1992). This aided approach aims at mitigating possible sources of bias that might be encountered when more subjective assessment methods are used (Kennedy and Addison, 1987 and Bergstedt *et al.* 2009).

Table 5: Table 3 of site and quadrat recording forms for floristic and environmental survey of sites containing target species

Species No.	Species name or Image name	Species No.	Species name or Image name
1		7	
2		8	
3		9	
4		10	
5		11	
6		12	

Table 6: Table 4 of site and quadrat recording forms for floristic and environmental survey of sites containing target species

Cover estimation by eye		
Value	Domin scale	Species No.
+	A single individual	
1	1-2 individuals	
2	Several individuals	
3	1-4% cover	
4	5-10% cover	
5	11-25% cover	
6	26-33% cover	
7	34-50% cover	
8	51-75% cover	
9	76-90% cover	
10	91-100% cover	

The native status of each of the associated plant species was reviewed in the literature and through online databases. This allowed for determining whether these species were native or alien and whether they are Plants of Conservation Interest or not (Kantsa *et al.* 2013).

5. Physiognomic investigation

Application of life-form classification involves categorizing all the plants in a study area into Raunkaier groups (Kent, 2012). Table 7 introduces the main groups of life-forms of self-supporting plants. Phanerophyes and chamaephytes describe woody plants or herbaceous evergreen perennials; hemicryptophyes and geophytes describe perennial and biennial herbaceous plants with periodic shoot reduction; therophyres describe annual plants.

Table 7: Main Raunkiaer life-form groups of self-supporting plants

Source: Ellenberg, H. & Mueller-Dombois, D. 1965/66. A key to Raunkiaer plant life forms with revised subdivisions. Ber. Geobot. Inst. Eidg. Tech. Hochsch. Stift. Rübel Zür. 37: 56-73.

Life-form group	
Phanerophytes	Plants that grow taller than 25-50 cm, or whose shoots do not die back periodically to that height limit
Chamaephytes	Plants whose shoot system is perennially sustained within 25—50 cm above ground surface, or plants that grow taller than 25-50 cm, but whose shoots periodically die back to that height limit
Hemicryptophytes	Plants characterized with periodic shoot reduction to a remnant shoot system that lies relatively flat on the ground surface
Geophytes (Cryptophytes)	Plants characterized with periodic reduction of their shoot system to storage organs imbedded in the soil
Therophytes	Plants whose shoot and root system die after seed production completing their life cycle within one year

The life-form group of each of the associated plants was described according to Mueller-Dombois and Ellenberg (1965/1966). For each target species, a life-form spectrum of all its associates is presented as a bar graph showing the percentage of species in each life-form. Abbreviations of life-form name, numeric codes and simplified descriptions of each physiognomic description are provided in Appendix I.

In case the physiognomy of a species was creeping (reptant) in a bunched shoot arrangement (caesptose) allowing for mat-formation, it was described as caespitose reptant.

6. Statistical Analysis

a. Community classification and structure

The floristic data set for each target species included an eight character name of each associate and its respective abundance measure (Domin scale) was classified using Two Way INdicator SPecies ANalysis (TWINSPAN) (Hill, 1979).

b. Life-form spectra classification

The life-forms of all associates were classified into life-form spectra using TWINSPAN (Hill, 1979). Species with the same life-form were considered as one entry.

Results of life-form classification using TWINSPAN were presented as tables showing average abundance of each life-form group. The different life-form classifications obtained were sorted by their increasing order of representation of the target species. Life-forms that were dominant in quadrat groups in which the target species was not well represented were considered as possibly incompatible with it.

C. Red-Listing Status of Target Species

Red-Listing status of each of the target species was determined using the standard criteria established by the International Union for the Conservation of Nature (IUCN, 2010). The Extent Of Occurance (EOO) for each species was estimated using GeoCAT (Bachman *et al.* 2011).

CHAPTER IV

RESULTS

A. Distribution and state of target species in Beirut

1. *Matthiola crassifolia*

a. <u>Geographic range</u>

The Beirut population of *Matthiola crassifolia* is concentrated on the southern side of the promontory (Figure 3). Lying at 1 km from the sea, Tallet El Khayat is this species' most inland site.

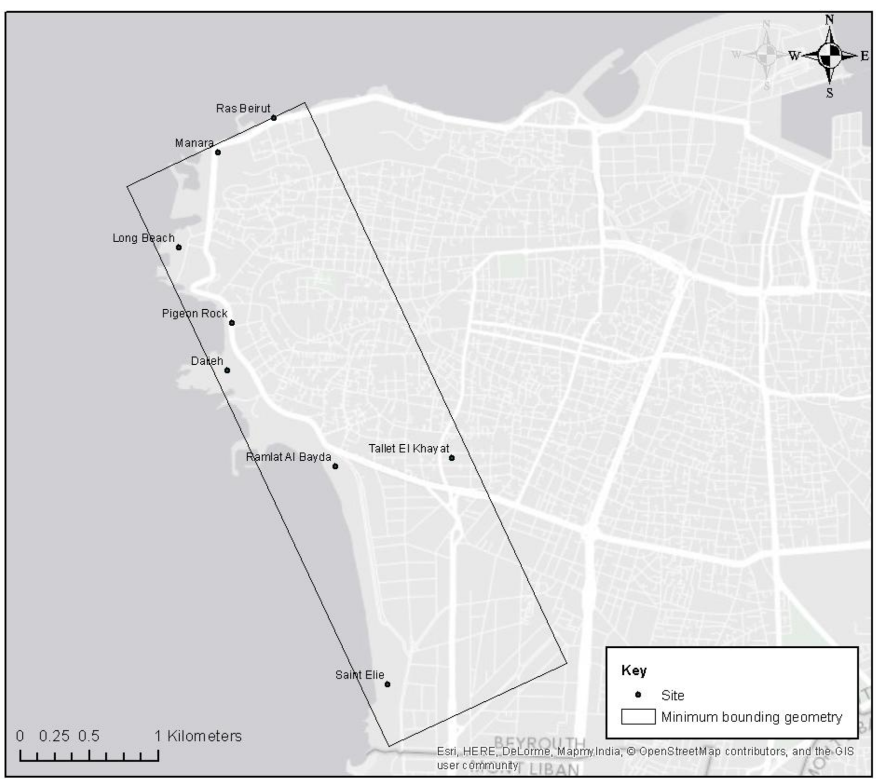

Figure 3: Minimum bounding geometry of *Matthiola crassifolia* in Beirut

Matthiola crassifolia is the most widely distributed endemic in Beirut. Field surveys identified the presence of the species in 73 patches (Figure 4).

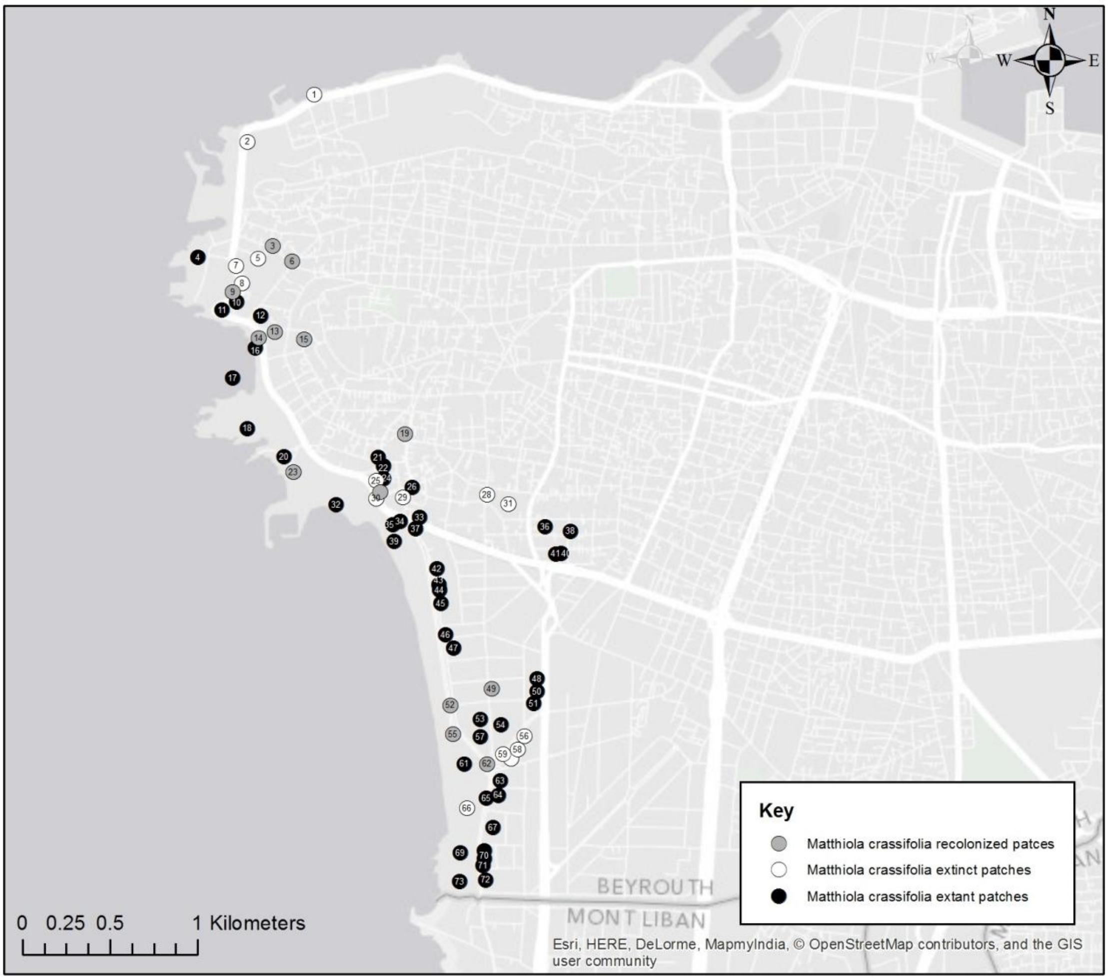

Figure 4: Distribution of *Matthiola crassifolia* sites in Beirut

Of those 73 patches, only Pigeon Rock (Patch 17) is protected by law. The limestone cliff facing Pigeon Rock (Patch 16) is almost completely inaccessible and may be considered protected. The remaining 71 patches are not protected.

The dynamic changes during the course of this study were as follows:

- Twenty patches were destroyed including the one with most clump counts (Patch 66). Only four of these were recolonized.
- New patches were recently colonized by the species.
- The extent of this species in Beirut was reduced by 800 m during the course of this study as a conserquence to the loss of Patch 1 and Patch 2. This loss accounts for decrease of 17% in the plant's range in the city over a period four years.

b. <u>Population size</u>

A clump count carried in 2012 for this species showed that a minimum of 4109 clumps of *Matthiola crassifolia* were present in Beirut. As shown in Figure 5, the clumps were unevenly distributed over 73 patches. The largest clump counts which consisted of more than 175 clumps per patch were found in only 8% of the recorded patches namely in the limestone cliff facing Pigeon Rock (Patch 16), Dalieh (Patch 20), and Saint Elie (Patch 61, 73, 69 & 66). The remaining patches included small and medium sized clump counts.

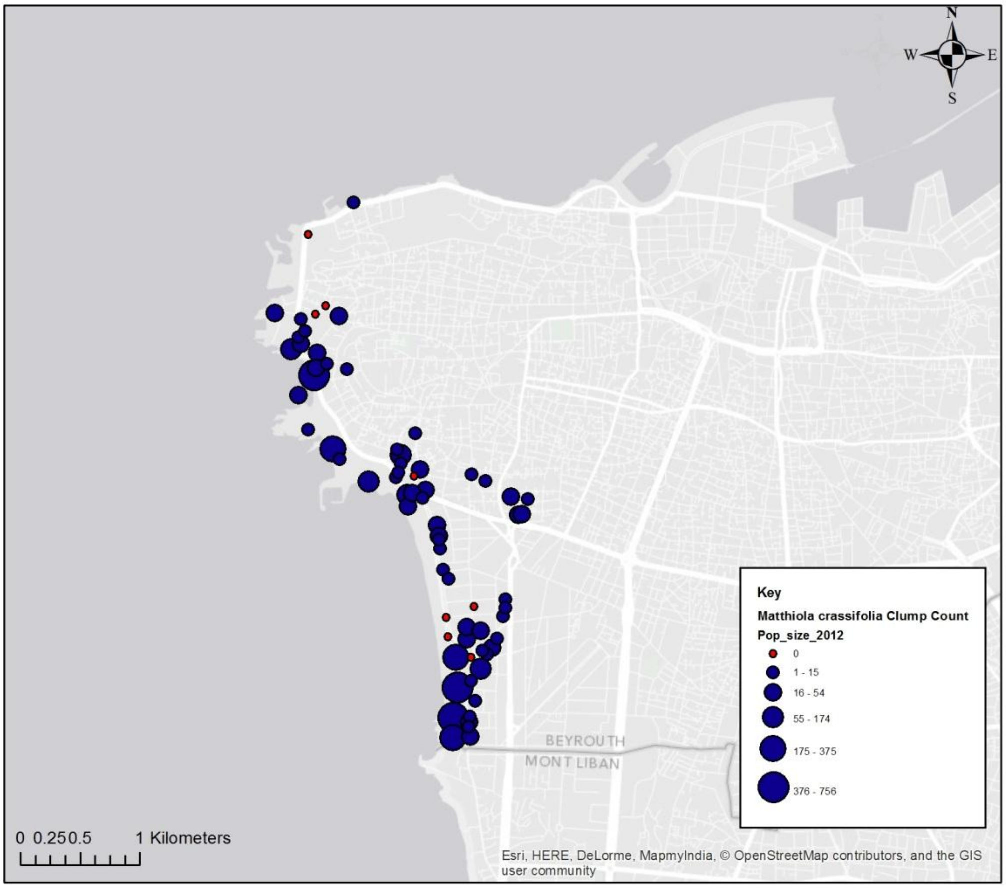

Figure 5: *Matthiola crassifolia* clump count in Beirut

The patch with the most number of clumps (756 clumps), Patch 66, went extinct in 2015. It was destroyed by the ongoing development of a new tourist attraction. The site[1] once included the only wet sandstone cliff found in Beirut. Other noteworthy large clump counts were found at its proximity in Patches 69 and 73. Patch 69 is an abandoned military base that was established on piles of rubble. Patch 73 was used as a parking lot that was established on an abandoned dump. The anthropogenic cliff

[1] As a reminiscent to this site's pristine condition, two species of orchids were encountered in it. These were *Anacamptis sancta* and *Ophrys umbilicata*.

formed by the piles of rubble and municipal waste constituted a habitat for hundreds of *M. crassifolia* plants.

c. Threats

The main threat to *M. crassifolia* was urbanization. It accounted for patch extinction of the largest patch surveyed. Secondary threats include landscaping activities which have sometimes identified this species as a weed. Its die back has often been removed and discarded despite the fact that includes the silique fruits. The racemes are often picked by pedestrians due to their ornamental value. On many occasions, dead plants were observed that were uprooted for no apparent reason.

d. Habitat

As presented in Figure 6, the *Matthiola crassifolia* patches are considerably varied in terms habitat type.

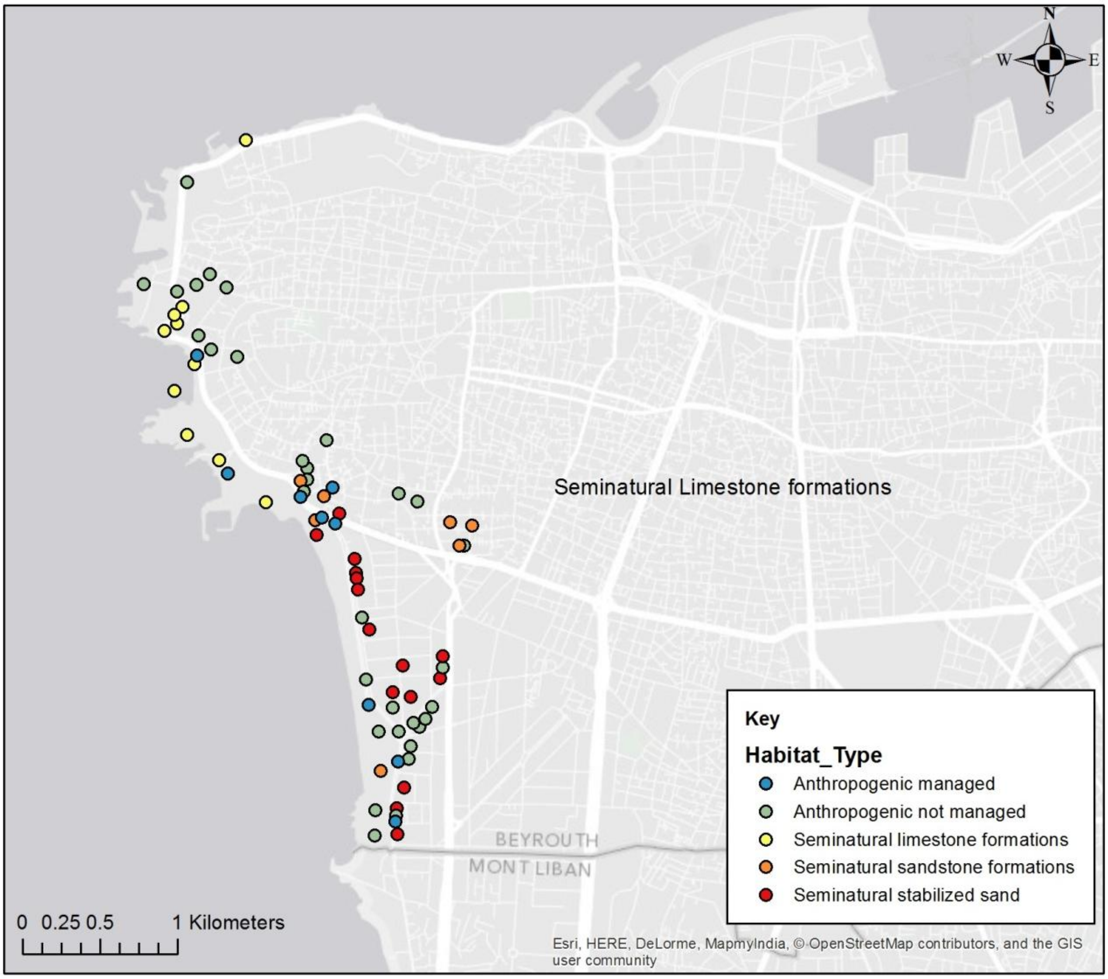

Figure 6: Habitat types of *Matthiola crassifolia* encountered in Beirut

• Seven semi-natural patches were characterized by sandstone formations. Three of these patches were lost during this study period, including the only known extant wet sandstone cliff in Beirut. One of these patches (Patch 35) included all three target species; the rest only included *M. crassifolia.*

• Ten semi-natural patches were characterized by limestone formations. Three of these patches were destroyed during the study period, while one was lost and recolonized. Only one of these patches, Dalieh (Patch 18), included both *L. postii* and

M. crassifolia; the rest only included *M. crassifolia.* It is worth noting that *L. postii* went extinct in Dalieh in 2014. It is also noteworthy that Dalieh is of cultural significance and may qualify for protection in the near future.

- Fifteen semi-natural patches were characterized by stabilized sands (without any major visible outcrop). None of these patches were lost during the study period. Only one was recently colonized. Of all target species, these patches only hosted *M. crassifolia.*

- Thirty two patches offered unmanaged anthropogenic habitat for the target species. Nine were lost during the study period and not recolonized; two were lost and recolonized; six were recently colonized. Of all target species, these patches only hosted *M. crassifolia.*

- Nine patches offered managed anthropogenic habitat, where the patched were watered, weeded, pruned, *et cetera*. Seven were publicly owned. Existence of colonized patches on private property might have been underrepresented as access was not granted on many occasions. Patches 23 and 55 were privately owned. Of all target species, these patches only hosted *M. crassifolia.*

2. *Limonium mouterdei*

a. <u>Geographic range</u>

Limonium mouterdei is restricted to a single patch (Patch 35) in Beirut (Figure 7).

Figure 7: Distribution of *Limonium mouterdei* in Beirut

This species is locally extinct in its type locality (St. Elie, Beirut) and is currently extant in only one site along the coast of Beirut. This has been confirmed through extensive field surveys conducted for the purpose of this work. The ‘Area Of Occupancy’ (AOO) of the species is estimated at 4 km² (based on a 2x2 km² grid overlay on the range map). The ‘Extent Of Occurance’ (EOO) for the species is however no more than 1000 m² (based on total area within a minimum convex polygon around all known individuals).

b. Population size

Limonium mouterdei is extremely rare. A total of 146 clumps were counted in 2014.

Between 2009 and 2014, the only remaining site containing this species was surveyed along with the plant's entire historic range. Not a single specimen was found in any other site. This may be attributed to the plant's limited ability to disperse and/or its high specific microhabitat requirements.

The only extant population is declining in the wild. Habitat loss appears to pose a serious threat. In the summer of 2014 for instance, at least three clumps were lost due to landscaping activities by an adjacent cafe and eight highly threatened adult plants were salvaged.

Quantifying decline in population size over ten years or three generations is not possible, particularly that clonal colonies are likely, given that this species can reproduce asexually through apomyxis (Palop *et al.*, 2000). Furthermore, the generation length is not yet known for this species.

It is noteworthy that most plants in the population are adults. More research is needed to investigate causes for the observed poor recruitment of individuals.

c. Threats

The major threat affecting this species is extensive habitat alteration and loss. This is caused by urban expansion and development of touristic attractions and residential areas. Areas adjacent to the only extant locality are undergoing major development eliminating suitable natural habitat for reintroduction. Since the population is close to recreation facilities, landscaping activities are also a threat. Three clumps were lost in 2015 due to installing and supporting a large olive tree.

d. Habitat

The entire species is now restricted to a remnant coastal sandstone cliff (Figure 8); however, the species may have occurred on other strata in the past, specifically that its type locality is different from the only locality in which it is extant. The reason for its restrictedness was attributed to destruction of its natural habitat due to urbanization.

Figure 8: The remanant sandstone cliff harboring the last remaining individuals of *Limonium mouterdei*

3. ***Limonium postii***

a. Geographic range

The entire species in Beirut is now restricted to less than four square meters of the remnant coastal sandstone cliff (Patch 35), the same site where *Limonium mouterdei* also finds refuge (Figure 9).

Figure 9: Distribution of *Limonium postii* sites in Beirut

The species was observed to also grow on limestone formations, but the only clump observed in such habitat was destroyed in 2014. The reason for its restrictedness was attributed to destruction of its natural habitat due to urbanization.

b. Population size

The only extant patch in Beirut (Patch 35) includes ten clumps. In 2011, one clump of *L. postii* was located in Dalieh (Patch 18). This clump was lost in 2014 during demolition works that took place in that area.

Quantifying decline in population size over ten years or three generations is not possible, particularly that clonal colonies are likely, given that this species can reproduce asexually through apomyxis (Palop *et al.*, 2000). Furthermore, the generation length is not yet known for this species.

Although no adult plants were lost in Patch 35 during the period of the study, the observed poor recruitment of the species in potentially favorable spots nearby demands further investigation.

c. Threats

As the case with *Limonium* mouterdei, the major threat affecting this species is extensive habitat alteration and loss. This is caused by urban expansion and activities associated with it.

d. Habitat

The entire species is now restricted to no more than 4 m^2 of a remnant coastal sandstone cliff; however, the species have occurred on other strata in the recent past, specifically that it was observed on limestone formations of Dalieh (Patch 18). The reason for its restrictedness was attributed to destruction of its natural habitat due to urbanization.

B. Floristic, Physiognomic and Environmental Analyses of the target species in Beirut

1. *Matthiola crassifolia*

a. Habitat features in sampled quadrats

Further *Matthiola crassifolia* habitat description was based on data collected from quadrats in 12 patches that presented either the largest clump counts or distinct anthropogenic characters. As listed in Table 8, *M. crassifolia* occupied a wide variety of habitats. In remnant semi-natural patches it was found growing on both sandstone and limestone formations and on stabilized sands and sandy soils. In anthropogenic patches it was found growing on sides of open sewers, abandoned dump sites, cracks in concrete walls, heaps of gravel, street medians and on two occasions, out of the trunks of date palm. The species' tendency to utilize modified habitats reflects its behavior as a ruderal.

Table 8: Habitat features characterizing quadrats (80 quadrats) sampled in patches chosen for for detailed study of *Matthiola crassifolia*

Site	Quadrat no.	Habitat type	Habitat features
Ayn Tina (Patch 26)	1	Anthropogenic	Spare vegetation composed of evergreen ornamentals and ruderals growing on a mostly bare sandy soil mixed with gravel in a managed street median
	2	Anthropogenic	Sparse spontaneous vegetation growing on sandy soil and gravel in street median
	3	Anthropogenic	Sandysoil of a street median completely covered with the evergreen ornamental Carissa macrocarpa
	4	Anthropogenic	A street medium in which a damaged Pittosporum tobira shrub growing as an ornamental
	5	Anthropogenic	Hedge of *Pittosporum tobira* in garden of a residential building
	6	Anthropogenic	Part of a garden of a residential building in which Lantana camara is used as an accent
Dalieh (Patch 18 & 32)	7	Seminatural	Sandy soil mainly covered with grasses
	8	Anthropogenic	Ruderals colonizing excavated limestone rubble
	9	Anthropogenic	Bare ground where heavy machinery was operating
	10	Seminatural	Limestone formation dominated with *Sarcopoterium spinosum*
	11	Anthropogenic	Part of landscaped street median dominated with *Sphagneticola*

			trilobata
	12	Seminatural	Limestone formation dominated with Thymbra capitata
	13	Seminatural	Limestone formation dominated with *Limbarda crithmoides*
	14	Seminatural	Sandy soil and degraded limestone formation dominated with *Oxalis pes-caprae*
Long Beach (Patch 4)	15, 16, 17, 18, 19	Anhropogenic	Vegetation coloizing cracks in concrete
	20	Anthropogenic	Annuals growing on a shallow layer of sandy soil that has accumulated on degrading asphalt
	21	Anthropogenic	Vegetation growing through cracks of concrete along degrading asphalt
Ramlet Al Bayda (Patch 34, 35 & 39)	22, 23, 24, 25, 26	Anthropogenic	Landscaped street median
	27	Seminatural	Sandstone formation at very close proximity to the sea on which *Matthiola crassifolia* is growing
	Sample28	Seminatural	Sandstone formation seltered by a large bolder at the edge of a steep incline
	29, 30, 31, 32	Seminatural	Mostly bare ground of sandstone formation and concerete of a destroyed structure occupied by sparse vegetation
	33	Seminatural	Stabilized sands and degraded sandstone formation predominated with dense creeping grasses
	34, 35, 37, 41, 42, 43	Seminatural	Mostly bare ground of sandstone formation occupied by sparse

			vegetation
	36	Seminatural	Sandstone formation predominated by the evergreen desert shrub with scale-like leaves, Thymelaea hirsuta
	38, 40	Seminatural	Stabilized sands and degraded sandstone formation predominated with dense creeping grasses
	39	Seminatural	Crack in concrete through which few perennial species grow
	43	Seminatural	Mostly bare ground of sandstone formation occupied by sparse vegetation
	44	Seminatural	A bolder protruding from a sandstone cliff allowing for both *Limonium mouterdei and Matthiola crassifolia* to grow on it
	45	Seminatural	Stabilized sands and degraded sandstone formation predominated by herbaceous perennials and annuals
	46, 47, 48, 49	Seminatural	Vegetation growing on slightly stabilized sands of a sandy beach
	50, 51	Anthropogenic	Meeting line of sandstone formation with pedestrian path
Raoche (Patch 14)	52, 53	Anthropogenic	Landscaped street median
Saint Elie (Patch 65, 66, 69 & 73)	54	Seminatural	Sandy soil ground covered with some sandstone pebels and a thick layer of *Polygonum equisetiforme* among which majorly annuals are growing

	55, 56	Seminatural	Sandy soil with sandstone pebels and rubble fragmets dominated with the invasive *Carpobrotus edulis* and a few other perennials and annuals
	57	Seminatural	Part of a sandstone cliff with minimal soil and dominated with *Thymbra capitata*
	58, 59	Seminatural	Mostly bare ground on wet sandstone cliff occupied by sparse vegetation
	60	Seminatural	Sandy soil with small rock fragments dominated with *Dittrichia viscosa*
	61	Seminatural	Sandy soil with small rock fragments dominated with Crithmum maritimum
	62, 63, 64, 65, 66	Seminatural	Part of steep sandstone cliff dominated with *Galium canum*
	67	Seminatural	Sandy soil with small rock fragments dominated with Echium angustifolium
	68	Seminatural	Sandy soil with small rock fragments and cement dominated with Arundo donax
	69	Seminatural	Sandysoil with sandstone pebels
	70, 71	Anthropogenic	Sparse vegetation growing on sandy soil of pedestrian path
	72	Seminatural	Vegetation dominated by *Thymaleae hirsuta* on sandy soil
	73, 74	Anthropogenic	Anbandoned dump, currently constituting sandy soil and naylon, resembling a coastal cliff colonized by annuals and *Matthiola crassifolia*
	75, 80	Seminatural	Sandysoil with sandstone rock fragments majorly covered with *Convulvulus secundus*, among other

			perennials and annuals
	76	Seminatural	The understory of *Ficus carica* growing as shrubs along an open sewage
	77	Anthropogenic	Sidewalk street planter in which a *Washingtonia* palm has been installed
	78	Anthropogenic	Sandy soil and rubble under a canopy of *Ficus microcarpa*
	79	Seminatural	Sandy soil dominated with *Echium angustifolium*, a few other perennials and many annuals

A description of environmental parameters from the species' immediate environment is presented in Table 23, in Appendix V. It is based on the analysis of 80 quadrats collected from *M. crassifolia* sites. Of these samples, 56 contained the target species and 45 were characterized by high recruitment. The highest recruitment for *M. crassiofolia* was observed in quadrats that were on average 35% bare, with percent bare ground in quadrats varying between 0% to over 75%. The same variability was observed for percent hard surfaces and percent litter cover. Litter, however, was almost always dry and sparse. *Matthiola crassifolia* was observed growing very vigorously on piles of anthropogenic litter, namely degrading municipal waste. Average persistant vegetation accounted for one quarter to one half of samples, but was highly variable. The average vegetation height in these samples was that of tall to very tall dwarf-shrubs, but a mimum height typical of typical dwarf-shrubs was also observed. Human interference was mostly absent in sites with high recruitment. The plants did grow in areas were the landscape was managed and in areas with some pedestrian activity without having people directly stepping on the plants. The sites had a good exposure to direct sunlight for most of the day. In a few samples characterized with high recruitment, *M. crassifolia* was observed growing partly sheltered by taller vegetation or not subject to direct sunlight for most of the day. The microtopography of the sites ranged from being uneven to deeply rutted.

b. Floristics

The 78 quadrats collected from the *Matthiola crassifolia* sites contained 124 plant species associated with *M. crassifolia* (Table 9). Among all associates, 16% were not native.

Table 9: Associates of *Matthiola crassifolia* in Beirut

Aegilops geniculata Roth	*Epilobium tetragonum* L.	*Phleum subulatum* (Savi) Asch. & Graebn.
Agave americana L.	*Erigeron bonariensis* L.	*Phyla nodiflora* (L.) Greene
Agave attenuata Salm-Dyck	*Erigeron canadensis* L.	*Picris rhagadioloides* (L.) Desf.
Alcea setosa (Boiss.) Alef.	*Euphorbia terracina* L.	*Piptatherum miliaceum* (L.) Coss.
Alyssum strigosum Banks & Sol.	*Ficus carica* L.	*Pittosporum tobira* (Thunb.) W. T. Aiton
Amaranthus hybridus L.	*Ficus microcarpa* L.f.	*Plantago coronopus* L.
Ambrosia maritima L.	*Galium canum* DC.	*Plantago lagopus* L.
Anacamptis sancta (L.) R. M. Bateman	*Galium murale* (L.) All.	*Polycarpon tetraphyllum* (L.) L.

Anagallis arvensis L.	*Glebionis coronaria* (L.) Spach	*Polygonum equisetiforme* Sm.
Anchusa hybrida Ten.	*Hedypnois rhagadioloides* (L.) F. W. Schmidt	*Ricinus communis* L.
Anisantha rigida (Roth) Hyl.	*Helichrysum stoechas* (L.) Moench	*Rostraria smyrnacea* (Trin.) H. Scholz
Anisantha tectorum (L.) Nevski	*Heliotropium hirsutissimum* Grauer	*Rumex conglomeratus* Murray
Arundo donax L.	*Hordeum vulgare* L.	*Sagina apetala* Ard.
Asteriscus aquaticus (L.) Less.	*Hormuzakia aggregata* (Lehm.) Guşul.	*Sagina maritima* Don
Avena sterilis L.	*Hymenocarpos circinnatus* (L.) Savi	*Salvia viridis* L.
Cakile maritima Scop.	*Hyoscyamus albus* L.	*Sarcopoterium spinosum* (L.) Spach
Campanula stellaris Boiss.	*Lagurus ovatus* L.	*Senecio × berythaeus* A.Camus & Gomb.
Capparis sicula Veill.	*Lantana camara* L.	*Sideritis romana* L.
Cardopatium corymbosum (L.) Pers.	*Leucaena leucocephala* (Lam.) de Wit	*Silene aegyptiaca* (L.) L.
Carissa macrocarpa (Eckl.) A.DC.	*Limbarda crithmoides* (L.) Dumort.	*Silene colorata* Poir.
Carpobrotus edulis (L.) N.E.Br.	*Limonium mouterdei* Domina, Erben & Raimondo	*Silybum Marianum* (L.) Gaertn.
Carthamus tenuis (Boiss. & C. I. Blanche) Bornm.	*Limonium postii* Domina, Erben & Raimondo	*Sisymbrium officinale* (L.) Scop.
Centaurea procurrens Spreng.	*Limonium virgatum* (Willd.) Fourr.	*Sonchus oleraceus* L.
Cerastium glomeratum Thuill.	*Lotus angustissimus* L.	*Sphagneticola trilobata* (L.) Pruski
Cichorium pumilum Jacq.	*Lotus cytisoides* L.	Sporobolus pungens (Schreb.) Kunth
Convolvulus secundus Desr.	*Lotus halophilus* Boiss. & Spruner	*Strelitzia reginae* Banks

Cota palaestina Kotschy	*Lotus edulis* L.	*Thymbra capitata* (L.) Cav.
Crepis aculeata (DC.) Boiss.	*Lycopersicon esculentum* Mill.	*Thymelaea hirsuta* (L.) Endl.
Crepis palaestina (Boiss.) Bornm.	*Malva oxyloba* Boiss.	*Tordylium trachycarpum* (Boiss.) Al-Eisawi
Crithmum maritimum L.	*Malva* sp.	*Tragopogon porrifolius L.*
Crucianella aegyptiaca L.	*Medicago littoralis* Loisel.	*Trifolium glanduliferum Boiss.*
Cuscuta epithymum (L.) L.	*Mercurialis annua* L.	*Trifolium purpureum* Loisel.
Cyclamen persicum Mill.	*Ochlopoa annua* (L.) H. Scholz	*Trifolium resupinatum* L.
Cynodon dactylon (L.) Pers.	*Onobrychis crista-galli* (L.) Lam.	*Trifolium scabrum* L.
Cyperus rotundus L.	*Orobanche nana* (Reut.) Beck	*Umbilicus intermedius* Boiss.
Dactyloctenium aegyptium (L.) Willd.	*Oxalis pes-caprae* L.	*Urospermum picroides* (L.) F. W. Schmidt
Daucus carota L.	*Pancratium maritimum* L.	*Valantia muralis* L.
Delosperma cooperi (Hook.f.) L.Bolus	*Parapholis incurva* (L.) C. E. Hubb.	*Verbascum sinuatum* L.
Digitaria sanguinalis (L.) Scop.	*Parietaria judaica* L.	*Veronica cymbalaria* Bodard
Dittrichia viscosa (L.) Greuter	*Paronychia argentea* Lam.	*Washingtonia* sp.
Echium angustifolium Mill.	*Phagnalon rupestre* (L.) DC.	*Yucca gigantea* Lem.
Elytrigia juncea (L.) Nevski		

Floristic data analysis with TWINSPAN of quadrats collected from the *Matthiola crassifolia* sites are presented in Table 10. The seventy eight quadrats were clustered into twenty one groups (A to U). *Matthiola crassifolia* had the highest constancy and abundance in quadrat groups A, B, C, D, E, G, I, L, M and O. In contrast quadrat groups N, P, Q, R, S, T, H and U completely excluded this species while in quadrat groups F, J, K and M, *M. crassifolia* was less represented either in terms of constancy or abudance.

It is worth noting that quadrat grouping defined by TWINSPAN analysis did not all necessarily represent communities in our study. For example, C and G both harbored high representation of *Matthiola crassifolia* and yet consisted of highly distinct vegetation communities and habitats (semi natural cliff vs street median) with *Matthiola crassifolia* and a few other ruderals recorded as the only common species.

There was a high floristic variability between different sites which resulted in a majority of quadrat groups being site specific regardless of whether they included *Matthiola crassifolia.* Quadrat groups that were site specific were: B, D, E, F, H, I, J, K, L, N, O, P, Q, S and U. Quadrat group B for instace is particular to street medians encountered in Ramlat Al Bayda area. There, *Matthiola crassifolia* is shown to be associated with several ornamental species used in the landscaping of the city; these include *Agave americana, Agave attenuata and Delosperma cooperi.* Quadrat group D is particular only to a wet sandstone cliff in Saint Elie. In it, *Parietaria Judaica, Helichrysum stoechas* and the target species were common.

The other defined quadrat groups were not location specific because they included common ruderal species characteristic of certain habitat types. In group T, which excluded the target species, the graminoids *Cyperus rotundus* and *Cynodon dactylon* were often present in gardens and street medians under and around evergreen ornamentals such the shrub *Pittosporum tobira* and the creeping herbaceous forb

Sphagneticola trilobata. A detailed description of the communities defined for *M. crassifolia* is presented in Appendix III.

Table 10: Species composition of the community types defined by TWINSPAN for *Matthiola crassifolia* floristic data.

	Twinspan groups																					
Species	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	Species
Yuccgiga		II 3																				Yuccgiga
Agavamer		III 3																				Agavamer
Agavatte		III 3																				Agavatte
Washsp00	VI 3																					Washsp00
Streregi	III 3	II 3																				Streregi
Galicanu			III 3																			Galicanu
Delocoop	V 4	V 3																				Delocoop
Parijuda			III 2	VI 3	VI 2	II 3		VI 3														Parijuda
Erigcana	V 2				VI 2																	Erigcana
Umbiinte			III 2																			Umbiinte
Ochlannu	III 1																					Ochlannu
Digisang		II 1																				Digisang
Campstel				VI 2																		Campstel
Hyosalbu			II 3																			Hyosalbu
Erigbona	V 2	VI 2																				Erigbona
Limbcrit	III 2		II 2										III 3									Limbcrit
Critmari	V 2						II 3					VI 3										Critmari
Leucleuc							II 1															Leucleuc
Ficucari								VI 4														Ficucari

Recicomm						VI 3						Recicomm
Echiangu					II 3							Echiangu
Carpedul					II 4							Carpedul
Phylnodi			VI 2	VI 3								Phylnodi
Epiltetr					II 1							Epiltetr
Rumecong				II 2								Rumecong
Paraincu				V 2								Paraincu
Trifresu					II 2							Trifresu
Dactaegy			VI 2	IV 3								Dactaegy
Sagimari		VI 2		III 2	IV 2							Sagimari
Trifglan					II 2							Trifglan
Anistect			VI 2	IV 2	II 2							Anistect
Hordvulg					II 2							Hordvulg
Lycoescu					II 1							Lycoescu
Amarhybr					II 1							Amarhybr
Plancoro	II 2			III 2	V 2							Plancoro
Rostsmyr				IV 2	IV 2			V 2			III 2	Rostsmyr
Trifscab					II 2						III 1	Trifscab
Galimura				III 2	III 2	VI 2	III 3	III 2				Galimura
Lotuangu					II 2					VI 3		Lotuangu
Medilitt					II 2					VI 2		Medilitt
Planlago				III 3				III 2				Planlago

Crepacul							VI 3		V 2	IV 2	II 2				Crepacul
Urospicr	III 2	IV 2				V 2	III 2			IV 3	III 2				Urospicr
Arundona			II 3							III 4					Arundona
Lotucyti						III 2	II 3		VI 2				IV 2		Lotucyti
Cappsicu				IV 2							II 2				Cappsicu
Tragporr		III 2								IV 2					Tragporr
Valamura				VI 2			III 2			IV 2	IV 2				Valamura
Creppala		II 2		IV 2	VI 3	III 3				V 2	III 2	VI 2	III 2		Creppala
Malvsp00			II 1		VI 2						III 2				Malvsp00
Helistoe			II 3	IV 3						V 3			III 4		Helistoe
Limopost			II 3								III 3				Limopost
Verbsinu			II 2	IV 2					III 3	IV 3	II 2				Verbsinu
Silecolo						II 2					III 2				Silecolo
Anisrigi							II 2			IV 2		VI 2			Anisrigi
Senebery							III 2		III 2	III 2	V 2				Senebery
Glebcoro	III 2		II 2						III 2	III 2	IV 2		III 2		Glebcoro
Thymcapi			II 3								III 2		VI 3		Thymcapi
Sarcspin													III 3		Sarcspin
Limovirg													IV 3		Limovirg
Elytjunc			II 2		VI 3					III 2			V 2	VI 2	Elytjunc
Cardcory													III 2		Cardcory
Silymari														VI 2	Silymari

Dauccaro						VI 2	Dauccaro
Cyclpers					III 2		Cyclpers
Hymecirc						VI 3	Hymecirc
Trifpurp					III 2	VI 1	Trifpurp
Salvviri					III 3		Salvviri
Crucaegy					III 2		Crucaegy
Aegigeni						VI 2	Aegigeni
Asteaqua	II 2				IV 3		Asteaqua
Cichpumi					IV 1		Cichpumi
Hedyrhag					III 2		Hedyrhag
Picrrhag					IV 2		Picrrhag
Helihirs					III 1		Helihirs
Carttenu			III 2	II 2	IV 3	VI 2	Carttenu
Cuscepit					III 1		Cuscepit
Thymhirs			III 4	III 2			Thymhirs
Phagrupe			III 3				Phagrupe
Convsecu		V 4					Convsecu
Ambrmari			III 1				Ambrmari
Centproc			III 2				Centproc
Paroarge			IV 2				Paroarge
Polyequi			III 4				Polyequi
Alceseto		VI 2	III 3	III 3		VI 3	Alceseto

Anchhybr									V 2	III 3	V 2										Anchhybr
Anacsanc										III 3											Anacsanc
Phlesubu									III 2												Phlesubu
Alysstri										III 2											Alysstri
Ceraglom									III 2	III 2											Ceraglom
Sagiapet										III 2											Sagiapet
Onobcris										IV 2											Onobcris
Laguovat										III 2											Laguovat
Euphterr										III 1											Euphterr
Tordtrac			II 1	IV 2			II 2		III 3	VI 3											Tordtrac
Sisyoffi		II 2								IV 2	IV 2		III 2								Sisyoffi
Orobnana										III 1											Orobnana
Mattcras	**VI 3**	**VI 3**	**VI 3**	**VI 3**	**VI 3**	**IV 3**	**VI 3**		**VI 3**	**V 3**	**V 2**	**VI 3**	**IV 3**		**VI 3**	**V 2**					**Mattcras**
Cyperotu		IV 2				III 2	II 2													IV 3	Cyperotu
Soncoler		IV 2					III 2			III 2	II 1					III 1					Soncoler
Pitttobi							II 3													IV 4	Pitttobi
Polytetr	III 2	III 2				III 2	VI 2	VI 2	VI 2	V 2	III 2	VI 2								VI 2	Polytetr
Lotuhalo							III 2			III 2	V 3	VI 2				V 2					Lotuhalo
Avenster							II 2				III 1	VI 2	III 2	VI 4					VI 1		Avenster
Anagarve							III 2			V 2	III 2			VI 2				III 2			Anagarve
Cotapala					VI 2	III 2	II 2				V 2	VI 2	III 2			III 2					Cotapala
Lotuedul											IV 2					V 2					Lotuedul

Carimacr																	VI 4			Carimacr
Lantcama									II 2							III 4				Lantcama
Dittvisc		IV 2					III 3	III 3					IV 3	V 3						Dittvisc
Sphatril					II 2													IV 4		Sphatril
Sporpung									II 2							III 4				Sporpung
Cynodact									III 1		IV 2		VI 2		VI 3	VI 3	VI 3	VI 3		Cynodact
Oxalpesc		VI 2						III 3							VI 3					Oxalpesc
Cakimari										VI 2			IV 3							Cakimari
Sileaegy														III 2						Sileaegy
Mercannu	II 2				II 1		VI 3	V 2	III 2					V 2	VI 3	VI 3				Mercannu
Sideroma														III 1						Sideroma
Verocymb								III 3							VI 3	V 2				Verocymb
Hormaggr										VI 2	III 1		IV 3							Hormaggr
Malvoxyl					II 1			III 2						III 2						Malvoxyl
Limomout	II 3								V 3					VI 3		III 3				Limomout
Pancmari									II 2				IV 2							Pancmari
Piptmili															VI 3				VI 2	Piptmili
Ficumicr																			VI 4	Ficumicr

The Roman number corresponds to species constancy within each TWINSPAN group (I = 5% or less; II = 6 – 20%; III = 21 – 40%; IV = 41 – 60%; V = 61 – 80%; VI = 81 – 100%). The Arabic number indicates average species abundance for each group on the domin scale.

c. Physiognomy

The physiognomic description of associates of *Matthiola crassifolia* based on Ellenberg and Mueller-Dombois (1965/1966) amended to include bunched shoot arrangement in reptant species yielded 57 different life-forms. These are represented in Table 11 and are fully described in Appendix I.

Table 11: Life-form of associates of *Matthiola crassifolia*

Life-form eight digit name	Abbreviated life-form category	Numeric code	Species eight digit name	No. of species
Phaner01	Mes P scap	1.113.101.230	Ficumicr	1
Phaner02	Mes aP scap	1.113.213.435	Leucleuc	1
Phaner03	N P caesp	1.121.101.520	Carimacr	1
Phaner04	N P caesp	1.121.101.530	Pitttobi	1
Phaner05	N P caesp	1.121.106.511	Thymhirs	1
Phaner06	N P caesp	1.121.106.520	Lantcama	1
Phaner07	Mi aP caesp	1.122.211.530	Ficucari	1
Phaner08	N P ros	1.211.500.000	Agavamer, Agavatte, Yuccgiga	3
Phaner09	Mes P ros	1.213.300.000	Washsp	1
Phaner10	N P herb	1.511.210.000	Streregi	1
Phaner11	N P herb	1.521.212.530	Recicomm	1
Phaner12	Mi P gram	1.522.110.000	Arundona	1

Chamae01	Ch frut	2.111.30	Thymcapi	1
Chamae02	Ch frut pulv	2.131.40	Sarcspin	1
Chamae03	Ch suff	2.211.30	Galicanu, Limomout	2
Chamae04	Ch suff	2.211.40	Critmari, Dittvisc, Helistoe, Limbcrit, Limopost, Limovirg, Phagrupe	7
Chamae05	Ch suff	2.212.40	Echiangu	1
Chamae06	t Ch suff rept	2.222.20	Convsecu, Lotucyti	2
Chamae07	t Ch suff rept	2.222.40	Cappsicu	1
Chamae08	Ch suff	2.241.40	Mattcras	1
Chamae09	t Ch suff scap	2.242.40	Ambrmari, Centproc	2
Chamae10	Ch herb	2.311.50	Piptmili	1
Chamae11	Ch herb rept	2.321.30	Sporpung, Cynodact	2
Chamae12	Ch herb rept (caesp)	2.321.30	Sporpung, Cynodact	2
Chamae13	Ch herb rept	2.321.40	Sphatril	1
Chamae14	Ch herb rept (caesp)	2.321.40	Sphatril	1
Chamae15	Ch l succ (rept)	2.421.22	Delocoop	1
Chamae16	Ch l succ (rept)	2.421.32	Carpedul	1
Hemicr01	c H caesp	3.102.4	Elytjunc	1
Hemicr02	c H rept	3.202.1	Paroarge	1

Hemicr03	e H rept	3.203.2	Phylnodi	1
Hemicr04	e H rept	3.203.2	Phylnodi	1
Hemicr05	e H rept	3.203.3	Polyequi	1
Hemicr06	e H rept (caesp)	3.203.3	Polyequi	1
Hemicr07	c H scap	3.302.4	Epiltetr	1
Hemicr08	c H scap	3.302.5	Alceseto	1
Hemicr09	c H ros	3.312.4	Verbsinu	1
Hemicr10	c H sem	3.322.3	Cardcory	1
Hemicr11	c H sem	3.322.4	Anchhybr, Parijuda, Rumecong, Silymari, Tragporr	5
Hemicr12	c H sem	3.322.5	Dauccaro, Erigcana	2
Geophy01	c G bulb	4.232.2	Cyclpers	1
Geophy02	c G bulb	4.232.3	Anacsanc, Oxalpesc, Umbiinte	3
Geophy03	G bulb	4.242.4	Pancmari	1
Geophy04	c G rhiz	4.332.4	Cyperotu	1
Therop01	met T caesp	5.104.3	Ochlannu, Paraincu, Phlesubu	3
Therop02	met T rept	5.204.2	Rostsmyr	1
Therop03	met T rept	5.204.3	Dactaegy, Digisang, Trifresu, Trifscab	4
Therop04	met T scap	5.304.2	Alysstri, Campstel, Ceraglom, Galimura, Polytetr, Sagiapet, Sagimari, Valamura	8
Therop05	met T scap	5.304.3	Cakimari, Crucaegy, Hymecirc, Laguovat,	17

			Lotuangu, Lotuedul, Lotuhalo, Medilitt, Mercannu, Onobcris, Salvviri, Sideroma, Sileaegy, Silecolo, Trifglan, Trifpurp, Verocymb	
Therop06	met T scap	5.304.4	Aegigeni, Anagarve, Anisrigi, Anistect, Avenster, Euphterr, Hordvulg, Hyosalbu, Lycoescu	9
Therop07	met T scap	5.304.5	Amarhybr	1
Therop08	met T ros	5.314.3	Plancoro, Planlago	2
Therop09	met T sem	5.324.2	Asteaqua, Cichpumi	2
Therop10	met T sem	5.324.3	Cotapala, Crepacul, Hedyrhag, Picrrhag, Senebery	5
Therop11	met T sem	5.324.4	Carttenu, Creppala, Erigbona, Glebcoro, Helihirs, Hormaggr, Malvoxyl, Malvsp00, Sisyoffi, Soncoler, Tordtrach, Urospicr	12
VasPar01	vp	20.1	Cuscepit	1
VasPar02	vp)	20.2	Orobnana	1

Amendments added in parantheses to abbreviation of life-form category.

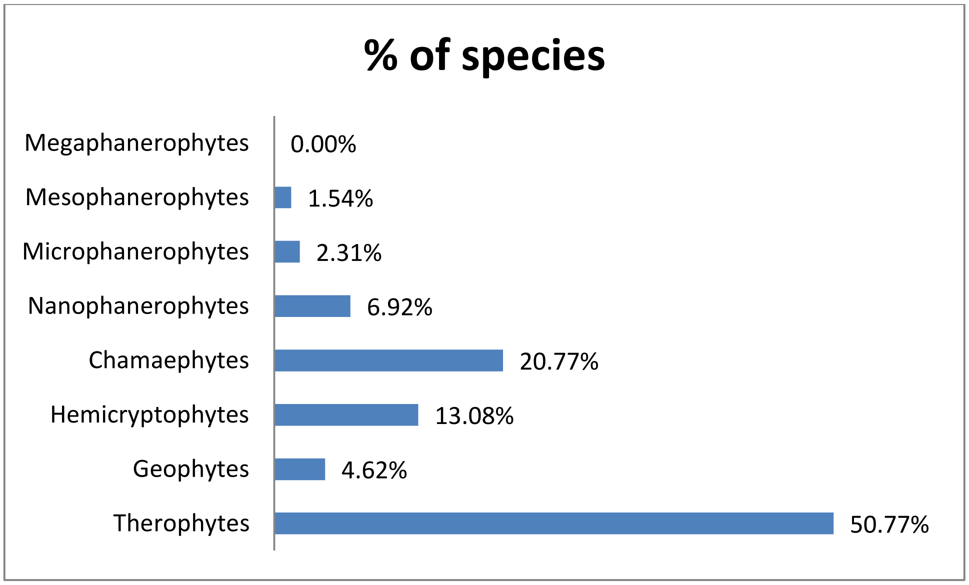

Figure 10: Raunkiaer life-form spectrum of vegetation in *Matthiola crassifolia* habitat

Figure 10 presents the Raunkiaer spectrum of *M. crassifolia* habitat. Chamaephytes constituted the most prominent perennial life-form of the vegetation. They were represented by 24 species. Over half of all chamaephytes were either regional or national endemics and only three were not native. Phanerophytes were represented by 14 species, 10 of which were not native. Perennials characterized by a periodic shoot reduction were represented 15 hemicryptophytes and six geophytes. Annuals were represented by 64 autotrophic therophytes species and two heterotrophic vascular parasites.

TWINSPAN analysis of physiognomic data for associates of *M. crassifolia* in Beirut resulted in 14 quadrat groups (A to N), representing the life-form spectra of the studied vegetation (Table 12). The different groups of quadrats are listed in decreasing order of represention of the target species. Life-form spectra with the highest representation of target species were represented by quadrat groups C, D, E, I. Quadrat groups defining life-form spectra with intermediate average representation of target species were G, H and K.

Table 12: Life-form composition of the life-form spectra defined by TWINSPAN for *Matthiola crassifolia* detailed physiognomic data.

Representation of target species VI3								
Twinspan group	Life-forms		Twinspan group	Life-forms		Twinspan group	Life-forms	
C	Phaner08	IV 3	D	**Chamae08**	**VI 3**	E	Phaner05	II 4
	Phaner10	II 3		Chamae06	IV 2		Phaner12	II 4
	Phaner09	II 2		Chamae02	II 3		Phaner04	II 3
	Chamae08	**VI 3**		Chamae04	II 3		Phaner02	II 1
	Chamae15	V 3		Chamae01	II 2		**Chamae08**	**VI 3**
	Chamae04	II 1		Hemicr03	V 3		Chamae16	II 4
	Hemicr05	III 2		Hemicr11	IV 2		Chamae01	II 3
	Hemicr12	II 2		Hemicr01	III 3		Chamae05	II 3
	Geophy04	IV 2		Hemicr10	II 2		Chamae04	II 2
	Therop11	VI 2		Hemicr12	II 2		Chamae13	II 2
	Therop04	IV 2		Geophy04	III 2		Chamae09	II 2
	Therop01	II 1		Geophy01	II 2		Hemicr08	II 3

	Therop03	II 1	Therop11	VI 3	Hemicr01	II 2
	Therop05	II 1	Therop03	VI 2	Hemicr05	II 2
			Therop06	V 2	Hemicr09	II 2
			Therop04	IV 3	Hemicr07	II 1
			Therop08	IV 3	Geophy02	II 3
			Therop01	IV 2	Geophy04	II 2
			Therop02	IV 2	Therop10	V 3
			Therop10	IV 2	Therop04	V 2
			Therop05	III 3	Therop06	V 2
			Therop09	III 2	Therop02	IV 2
					Therop05	IV 2
					Therop08	IV 2
					Therop11	IV 2
					Therop03	II 2
					Therop07	II 2

							VasPar02	II 1
Representation of target species VI3			Representation of target species V3			Representation of target species IV 2		
Twinspan group	Life-form		Twinspan group	Life-forms		Twinspan group	Life-forms	
I	Phaner05	II 3	G	Phaner05	II 2	H	Phaner09	II 3
	Phaner09	II 3		Phaner06	II 2		Phaner10	II 3
	Chamae08	VI 3		Chamae08	V 3		Chamae04	VI 3
	Chamae03	IV 3		Chamae04	IV 3		Chamae01	IV 3
	Chamae04	III 2		Chamae03	III 3		Chamae08	IV 2
	Chamae01	II 3		Chamae06	II 3		Chamae11	IV 1
	Hemicr11	III 2		Chamae13	II 2		Chamae03	III 3
	Hemicr01	II 2		Chamae07	II 2		Chamae06	III 2
	Hemicr09	II 2		Chamae11	II 2		Chamae15	II 4
	Geophy02	III 2		Chamae01	II 1		Hemicr01	III 2
	Therop11	III 2		Hemicr11	VI 2		Hemicr12	II 2
	Therop05	II 2		Hemicr08	III 3		Therop11	V 2

				Hemicr09	III 3		Therop10	IV 2
				Hemicr06	II 4		Therop09	III 2
				Hemicr01	II 2		Therop02	II 2
				Hemicr02	II 2		Therop04	II 2
				Hemicr12	II 2		Therop05	II 2
				Geophy02	II 2		VasPar01	II 1
				Geophy03	II 2			
				Therop05	VI 3			
				Therop04	VI 2			
				Therop10	VI 2			
				Therop11	VI 2			
				Therop06	IV 2			
Representation of target species III 3			Representation of target species -			Representation of target species -		
Twinspan group	Life-form		Twinspan group	Life-forms		Twinspan group	Life-forms	
K	Phaner06	II 4	A	Hemicr04	VI 4	B	Chamae12	VI 3

	Chamae11	V 3		Therop01	VI 2		Therop04	VI 2
	Chamae04	III 4						
	Chamae08	**III 3**						
	Chamae10	II 3						
	Hemicr06	II 4						
	Geophy02	II 3						
	Geophy03	II 2						
	Therop05	VI 3						
Representation of target species -			Representation of target species -			Representation of target species -		
Twinspan group	Life-forms		Twinspan group	Life-forms		Twinspan group	Life-forms	
F	Phaner07	VI 4	J	Phaner03	VI 4	L	Chamae12	VI 4
	Phaner11	VI 3		Chamae11	VI 3		Chamae03	III 3
	Hemicr11	VI 3		Therop06	VI 1		Chamae07	III 2
	Therop04	VI 2					Chamae11	III 2
							Therop05	VI 3

						Therop06	III 2
Representation of target species -			Representation of target species -				
Twinspan group	Life-forms		Twinspan group	Life-forms			
M	Phaner04	VI 4	N	Phaner01	VI 4		
	Chamae11	VI 2		Chamae10	VI 2		
	Therop04	VI 2					

The Roman number corresponds to species constancy within each TWINSPAN group (I = 5% or less; II = 6 – 20%; III = 21 – 40%; IV = 41 – 60%; V = 61 – 80%; VI = 81 – 100%). The Arabic number indicates average species abundance for each group on the domin scale. Life-form of target species is presented in bold.

In some quadrat groups that included that highest representation of *Matthiola* crassifolia, unbranched dwarf trees (< 2 m) with semi-succulent leaves having a circular arrangement at a similar height of the trunk (Phaner08), typical and tall evergreen dwarf-shrubs (Chamae03 & Chamae04), low reptant evergreen low succulent (Chamae15), tall (30 – 100 cm) drought-deciduous hemicryptophytes with a bunched or circular shoot arrangement (Hemicr01) and small (3 – 10 cm) reptant, not with bunched shoot arrangement, sparingly evergreen hemicryptophytes (Hemicr03) were common. Ornamental examples of these life-forms include *Agave* and *Yucca* species for Phaner08, cultivated Sea Lavender species for Chamae03 and Chamae04, *Delosperma cooperi* as ground cover for Chamae15, Little Bluestem, *Schizachyrium scoparium*, for Hemicr01 and *Phyla nodiflora*, when not mat-forming, for Hemicr03.

These quadrat groups were sometimes dominated with nanophyllous (usually less than 1 cm^2) normal-sized evergreen shrub with irregular crown extending to near their base (Phaner05), tall graminoid variously lignified shrub (Phaner12) and typical reptant evergreen low succulants (Chamae16). Ornamental examples of these life-forms include tamarisk species for Phaner05, various cane species and *Carpobrotus edulis* for Chamae16.

Quadrat groups that completely excluded the target species were mostly dominated with phanerophytes. These were mesophyllous (leaves usually more than 5 cm^2 and less than 100 cm^2) large evergreen trees with spherical crown restricted to their upper half (Phaner01), mesophyllous normal-sized evergreen shrubs with spherical crown extending to near their base (Phaner04), microphyllous (usually less than 5 cm^2) normal-sized evergreen shrubs (< 2 m) with spherical crown extending to near their base (Phaner03), and mesophyllous tall (2 – 5 m) deciduous shrub with spherical crown extending to near the base of the shrub (Phaner07). Ornamental examples of these life-forms include various shade trees for Phaner01, shrubs used as hedges such as *Pittosporum tobira* for Phaner04 and Phaner03.

Other quadrat groups that completely excluded the target species were dominated with typical evergreen herbaceous chamaephyte along the ground in a bunched and spreading shoot arrangement (Chamae12). Ornamental plant species belonging to Chamae12 and similar life-forms include turfgrass species and the Singapore Daisy, *Sphagneticola trilobata*.

A detailed description of the life-form spectra defined by TWINSPAN for *M. crassifolia* is presented in Appendix IV.

2. *Limonium mouterdei*

a. Habitat features in sampled quadrats

Further *Limonium mouterdei* habitat description was based on data collected from quadrats in the only extant patch. Table 13 includes a description of the habitat types and features observed in each sampling quadrat.

Table 13: Habitat features in sampled quadrats for *Limonium mouterdei* in the species's only extant patch

Location	Sample number	Habitat type	Habitat features
Ramlet Al Bayda (Patch 35)	29, 30, 31, 32	Seminatural	Mostly bare ground of sandstone formation and concerete of a destroyed structure occupied by sparse vegetation
	33	Seminatural	Stabilized sands and degraded sandstone formation predominated with dense creeping grasses
	34, 35, 37, 41, 42, 43	Seminatural	Mostly bare ground of sandstone formation occupied by sparse vegetation
	36	Seminatural	Sandstone formation predominated by the evergreen desert shrub with scale-like leaves, Thymelaea hirsute
	38, 40	Seminatural	Stabilized sands and degraded sandstone formation predominated with dense creeping grasses
	39	Anthropogenic	Crack in concrete through which few perennial species grow
	44	Seminatural	A bolder protruding from a sandstone cliff allowing for both *Limonium mouterdei and Matthiola crassifolia* to grow on it
	45	Seminatural	Stabilized sands and degraded sandstone formation predominated by herbaceous perennials and annuals

A description of environmental parameters from the species' immediate environment is presented in Table 24 in Appendix V. It is based on the analysis of 18 quadrats collected from the *L. mouterdei* site. Ten quadrats contained the target species, of which five were characterized by high recruitment.

High recruitment for *L. mouterdei* was observed in quadrats that were mostly bare, with plenty of hard surfaces. Persistant vegetation accounted for an average cover of about 25%. The average vegetation height in these samples was typical of dwarf-shrub dominated communities, but it ranged between low to very tall. These sites were characterized by little sparse and dry litter. Barely any anthropogenic litter was present. Human interference was minimal. The sites had a good exposure to direct sunlight for most of the day. The microtopography of the site ranged from through to deeply rutted.

b. <u>Floristics</u>

The 18 quadrats collected from the *L. mouterdei* site contained 36 plant species besides *L. mouterdei* (Table 14). The target species was present in 12 quadrats. Among all associates, only *Lantana camara* was not native and is described in the literature as potentially invasive (Cronk & Fuller, 1995).

Table 14: Associates of *Limonium mouterdei* in Beirut

Alcea setosa (Boiss.) Alef.	*Hormuzakia aggregata* (Lehm.) Guşul.	*Sideritis romana* L.
Anagallis arvensis L.	*Lantana camara* L.	*Silene aegyptiaca* (L.) L.
Anchusa hybrida Ten.	*Limonium postii* Domina, Erben & Raimondo	*Silene colorata* Poir.
Avena sterilis L.	*Lotus edulis* L.	*Sisymbrium officinale* (L.) Scop.
Capparis sicula Veill.	*Lotus halophilus* Boiss. & Spruner	*Sonchus oleraceus* L.
Carthamus tenuis (Boiss. & C. I. Blanche) Bornm.	*Malva oxyloba* Boiss.	Sporobolus pungens (Schreb.) Kunth
Cota palaestina Kotschy	*Malva* sp.	*Thymbra capitata* (L.) Cav.
Crepis aculeata (DC.) Boiss.	*Matthiola crassifolia* Boiss. & Gaill.	*Thymelaea hirsuta* (L.) Endl.
Crepis palaestina (Boiss.) Bornm.	*Mercurialis annua* L.	*Urospermum picroides* (L.) F. W. Schmidt
Cynodon dactylon (L.) Pers.	*Pancratium maritimum* L.	*Valantia muralis* L.
Dittrichia viscosa (L.) Greuter	*Polycarpon tetraphyllum* (L.) L.	*Verbascum sinuatum* L.
Glebionis coronaria (L.) Spach	*Senecio × berythaeus* A.Camus & Gomb.	*Veronica cymbalaria* Bodard

The classification groups resulting from the TWINSPAN analysis of the floristic data of *L. mouterdei* are presented in Table 15. Five quadrat groups (A to E) were defined; none of which excluded the target species.

Table 15: Species composition of the community types defined by TWINSPAN for *Limonium mouterdei* floristic data.

	Twinspan group					
Species	A	B	C	D	E	Species
Verocymb					V 3	Verocymb
Mercannu		IV 2	III 2	IV 2	VI 3	Mercannu
Cynodact	III 2		IV 1	III 2	VI 3	Cynodact
Sporpung				III 2	III 4	Sporpung
Anagarve				V 2	III 2	Anagarve
Hormaggr	III 3					Hormaggr
Mattcras	VI 3	V 2	V 2	IV 2		Mattcras
Limopost	III 3		V 3			Limopost
Malvoxyl		III 2				Malvoxyl
Soncoler		III 1	III 1			Soncoler
Sideroma		III 1				Sideroma
Sileaegy		III 2				Sileaegy
Dittvisc		IV 3				Dittvisc
Thymhirs		III 3	III 1	III 3		Thymhirs
Lotuedul		IV 2	III 2	VI 3		Lotuedul
Cotapala		III 2	V 2	VI 2		Cotapala
Lotuhalo		IV 2	V 2	VI 3		Lotuhalo
Malvsp00			IV 2			Malvsp00

Carttenu			III 2			Carttenu
Glebcoro			VI 2	III 2		Glebcoro
Silecolo			IV 2			Silecolo
Polytetr			V 2			Polytetr
Thymcapi			III 3	III 1		Thymcapi
Sisyoffi			IV 2	IV 2		Sisyoffi
Urospicr			III 2	III 2		Urospicr
Senebery			VI 2	V 2		Senebery
Valamura			V 2	IV 2		Valamura
Anchhybr			IV 2	VI 3		Anchhybr
Creppala				V 2		Creppala
Crepacul				III 2		Crepacul
Avenster				IV 1		Avenster
Pancmari				III 2		Pancmari
Verbsinu				III 2		Verbsinu
Alceseto				IV 3		Alceseto
Cappsicu				III 2		Cappsicu
Lantcama				III 2		Lantcama
Limomout	**III 3**	**VI 3**	**V 3**	**V 3**	**III 3**	**Limomout**

The Roman number corresponds to species constancy within each TWINSPAN group (I = 5% or less; II = 6 – 20%; III = 21 – 40%; IV = 41 – 60%; V = 61 – 80%; VI = 81 – 100%). The Arabic number indicates average species abundance for each group on the domin scale.

The community analysis shows that *Limonium mouterdei* is primarly a species of a coastal rupestral dwarf-shrub community, currently also dominated by *Matthiola crassifolia* and *L. postii*; and in which *Dittrichia viscosa, Thymbra capitata,* among other species, are common. The target species was also associated to communities dominated by grasses and other herbaceous species. The representation of the target species in all communities indicates that *L. mouterdei* was behaving as a preferential species in the area in which it is present. Such a species is often present with variable abundance in some communities, but is especially abundant in just one. The species' absence in other suitable areas is likely primarily due to limitations in dispersal. A detailed description of the communities defined for *L. mouterdei* is presented in Appendix III.

c. Physiognomy

The physiognomic description of associates of *L. mouterdei* based on Ellenberg and Mueller-Dombois (1965/1966) amended to include bunched shoot arrangement for reptant species, yielded 18 different life-forms represented in Table 16 and are fully described in Appendix I.

Table 16: Life-forms of associates of *Limonium mouterdei*

Life-form eight digit name	Abbreviated life-form category	Numeric code	Species eight digit name	Number of species
Phaner05	N P caesp	1.121.106.511	Thymhirs	1
Phaner06	N P caesp	1.121.106.520	Lantcama	1
Chamae01	Ch frut	2.111.30	Thymcapi	1
Chamae03	Ch suff	2.211.30	Limomout	1
Chamae04	Ch suff	2.211.40	Dittvisc, Limopost	2
Chamae07	t Ch suff rept	2.222.40	Cappsicu	1
Chamae08	Ch suff	2.241.40	Mattcras	1
Chamae11	Ch herb rept	2.321.30	Sporpung, Cynodact	2
Chamae12	Ch herb rept (caesp)	2.321.30	Sporpung, Cynodact	2
Hemicr08	c H scap	3.302.5	Alceseto	1
Hemicr09	c H ros	3.312.4	Verbsinu	1
Hemicr11	c H sem	3.322.4	Anchhybr	1

Geophy03	G bulb	4.242.4	Pancmari	1
Therop04	met T scap	5.304.2	Valamura, polytetr	2
Therop05	met T scap	5.304.3	Verocymb, Lotuedul, Lotuhalo, Mercannu, Sideroma, Sileaegy, Silecolo	7
Therop06	met T scap	5.304.4	Avenster, Anagarve	2
Therop10	met T sem	5.324.3	Cotapala, Crepacul, Senebery	3
Therop11	met T sem	5.324.4	Carttenu, Creppala, Glebcoro, Urospicr, Hormaggr, Malvoxyl, Malvsp00, Sisyoffi, Soncoler	9

Amendments added in parantheses to abbreviation of life-form category.

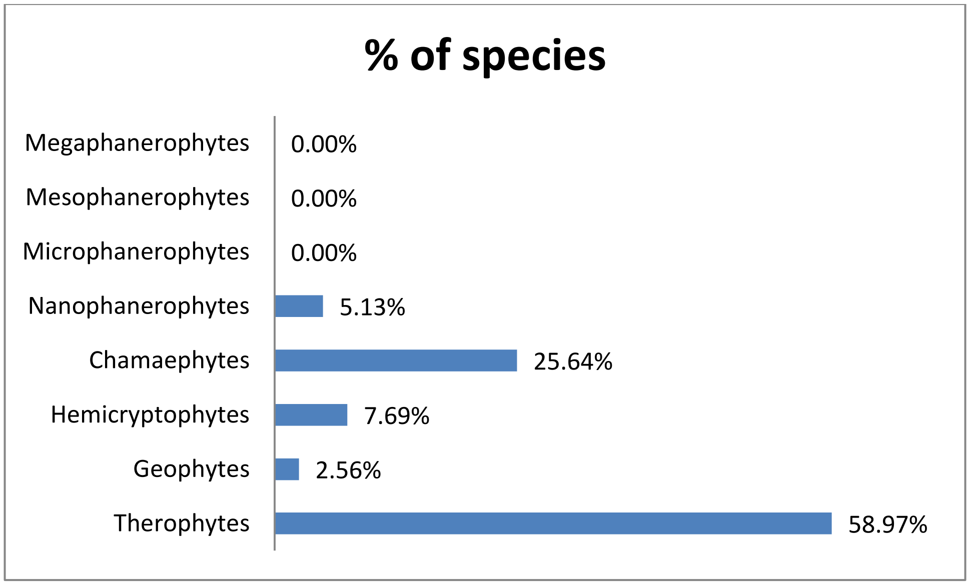

Figure 11: Raunkiaer life-form spectrum of vegetation in *Limonium mouterdei* habitat

Chamaephytes constituted the most prominent perennial life-form of the vegetation (Figure 11). They were represented by eight species, of which were the coastal endemics being investigated in this study. Phanerophytes were represented by two species of which one is potentially invasive (*Lantana camara*). Perennials with periodic shoot reductions were represented by three hemicryptophytes and a single geophyte. Annuals were represented by 23 species.

TWINSPAN analysis of physiognomic data for associates of *L.mouterdei* in Beirut resulted in six quadrat groups (A-F), representing the life-form spectra of the studied vegetation (Table 17). The different groups of quadrats are listed in decreasing order of representation of the target species. Quadrat groups A, B, D, C and F included the target species, while quadrat group E excluded it.

Table 17: Life-form composition of the life-form spectra defined by TWINSPAN for *Limonium mouterdei* detailed physiognomic data.

Representation of target species VI3			**Representation of target species VI3**			**Representation of target species VI3**		
Twinspan group	Life-forms		Twinspan group	Life-forms		Twinspan group	Life-forms	
A	Phaner05	III 3	B	Phaner05	III 1	D	Phaner05	III 3
	Chamae03	**VI 3**		**Chamae03**	**VI 3**		Phaner06	III 2
	Chamae08	VI 2		Chamae04	V 3		**Chamae03**	**VI 3**
				Chamae01	III 3		Chamae08	V 2
				Chamae08	III 2		Chamae07	III 2
				Chamae11	III 1		Chamae01	III 1
				Therop04	V 2		Hemicr11	VI 2
				Therop10	VI 2		Hemicr08	III 2
				Therop05	V 2		Geophy03	II 2
				Therop11	V 2		Therop05	VI 3
							Therop06	VI 2
							Therop10	VI 2

							Therop11	VI 2
							Therop04	V 2
Representation of target species IV 2			Representation of target species III 3			Representation of target species -		
Twinspan groups	Life-forms		Twinspan groups	Life-forms		Twinspan group	Life-forms	
C	Chamae04	VI 3	F	Chamae12	V 4	E	Chamae11	VI 2
	Chamae08	VI 2		**Chamae03**	**III 3**		Hemicr08	VI 3
	Chamae03	**IV 2**		Chamae08	III 3		Hemicr11	VI 3
	Chamae11	III 2		Chamae11	IV 2		Hemicr09	VI 2
	Hemicr11	IV 2		Chamae07	III 2		Therop05	VI 3
	Therop11	VI 2		Therop05	VI 3		Therop11	VI 3
	Therop05	V 2		Therop06	III 2		Therop06	VI 2
	Therop04	IV 2					Therop10	VI 2
	Therop10	IV 2						

The Roman number corresponds to species constancy within each TWINSPAN group (I = 5% or less; II = 6 – 20%; III = 21 – 40%; IV = 41 – 60%; V = 61 – 80%; VI = 81 – 100%). The Arabic number indicates average species abundance for each group on the domin scale. Life-form of target species is presented in bold.

Quadrat groups that included the target species were dominated by Chamae03 Chamae04 and. Nanophyllous (of leaves usually less than 1 cm^2) normal-sized evergreen shrub with irregular crown extending to near the base (Phaner05) and tall evergreen semi-woody dwaf-shrub (Chamae08) were common in several quadrat groups that included the target species. Ornamental plant species belonging to these life-forms and similar ones include various species of cultivated Sea Lavender species for Chamae03 and Chamae04, the hoary stock *Matthiola incana* for Chamae08 and tamarisk species for Phaner05.

In single quadrat group that included the target species, typical evergreen herbaceous chamaephytes creeping along the ground in a bunched and spreading shoot arrangement (Chamae12) dominated, albeit there the target species had a compromised representation. Ornamental plant species belonging to Chamae12 and similar life-forms include turfgrass species and the Singapore Daisy, *Sphagneticola trilobata*.

The quadrat group that excluded the target species was almost completely dominated by life-forms characterized with periodic shoot reduction. These were very tall and tall drought-deciduous hemicryptophytes, Hemicr08 and Hemicr11, and the medium-sized and tall annuals, Therop05 and Therop11. Ornamental plant species belonging to similar life-forms include all species that periodically shed their vegetative parts such as hollyhocks, *Alcea rosea.*

A detailed description of the life-form spectra defined by TWINSPAN for *L. mouterdei* is presented in Appendix IV.

3. *Limonium postii*

a. Habitat features in sampled quadrats

Further *Limonium postii* habitat description was based on data collected from quadrats in its last remaining patch in Beirut. Table 18 includes description of the habitat types and features observed in each sampling quadrat.

Table 18: Habitat features in sampled quadrats for *Limonium postii* in the species' last remaining patch in Beirut

Location	Sample number	Habitat type	Habitat features
Ramlet Al Bayda (Patch 35)	28	Seminatural	Sandstone formation sheltered by a large bolder at the edge of a steep incline
	29, 30, 31, 32	Seminatural	Mostly bare ground of sandstone formation and concerete of a destroyed structure occupied by sparse vegetation
	33	Seminatural	Stabilized sands and degraded dandstone formation predominated with dense creeping grasses
	51	Anthropogenic	Meeting line of sandstone formation with pedestrian path

A description of environmental parameters from the species' immediate environment is presented in Table 25, Appendix V. It is based on the analysis of seven quadrats collected from the *L. postii* site. Four of these contained the target species and were characterized by high recruitment.

The highest recruitment for *L. postii* was observed in quadrats that were on average 25 to 49% bare with plenty of hard surfaces. Average persistant vegetation accounted about one third of the area. The average vegetation height in these samples was mostly typical of dwarf-shrub dominated communities. These sites were characterized by little sparse and dry litter. Barely any anthropogenic litter was present. Human interference was almost absent. The sites had a good exposure to direct sunlight for most of the day. The microtopography of the site ranged from being uneven to deeply rutted.

b. Floristics

The seven quadrats collected from the remnant *L. postii* site contained 23 plant species besides *L. postii* (Table 19). Four of the seven quadrats contained all ten *L. postii* clumps still present in Beirut. None of the associates was non-native.

Table 19: Associates of Limonium postii in Beirut

Anchusa hybrida Ten.	*Lotus edulis* L.	*Sonchus oleraceus* L.
Carthamus tenuis (Boiss. & C. I. Blanche) Bornm.	*Malva* sp.	Sporobolus pungens (Schreb.) Kunth
Cota palaestina Kotschy	*Matthiola crassifolia* Boiss. & Gaill.	*Thymbra capitata* (L.) Cav.
Cynodon dactylon (L.) Pers.	*Mercurialis annua* L.	*Thymelaea hirsuta* (L.) Endl.
Glebionis coronaria (L.) Spach	*Polycarpon tetraphyllum* (L.) L.	*Urospermum picroides* (L.) F. W. Schmidt
Hyoscyamus albus L.	*Senecio × berythaeus* A.Camus & Gomb.	*Valantia muralis* L.

Limonium mouterdei Domina, Erben & Raimondo	*Silene colorata* Poir.	*Veronica cymbalaria* Bodard
Lotus halophilus Boiss. & Spruner	*Sisymbrium officinale* (L.) Scop.	

The classification groups resulting from the TWINSPAN analysis of the floristic data of *L. postii* are presented in Table 20. Three quadrat groups (A-C) were defined. Quadrat groups A and B included the target species, while quadrat group C excluded it.

Table 20: Species composition of the community types defined by TWINSPAN for *Limonium postii* floristic data.

	Twinspan groups			
Species	A	B	C	Species
Verocymb			VI 2	Verocymb
Mercannu		III 2	VI 3	Mercannu
Cynodact		IV 1	VI 2	Cynodact
Sporpung			VI 4	Sporpung
Hyosalbu	IV 2			Hyosalbu
Mattcras	VI 3	V 2		Mattcras
Limopost	IV 3	V 3		**Limopost**
Malvsp00		IV 2		Malvsp00
Sisyoffi		IV 2		Sisyoffi
Urospicr		III 2		Urospicr
Soncoler		III 1		Soncoler
Carttenu		III 2		Carttenu

Glebcoro	VI 2	Glebcoro
Senebery	VI 1	Senebery
Cotapala	V 2	Cotapala
Lotuedul	III 2	Lotuedul
Lotuhalo	V 2	Lotuhalo
Silecolo	IV 2	Silecolo
Valamura	V 2	Valamura
Polytetr	V 2	Polytetr
Anchhybr	IV 2	Anchhybr
Limomout	V 3	Limomout
Thymcapi	III 3	Thymcapi
Thymhirs	III 1	Thymhirs

The Roman number corresponds to species constancy within each TWINSPAN group (I = 5% or less; II = 6 – 20%; III = 21 – 40%; IV = 41 – 60%; V = 61 – 80%; VI = 81 – 100%). The Arabic number indicates average species abundance for each group on the domin scale.

The community analysis shows that *Limonium postii* is a species of a coastal rupestral dwarf-shrub community, currently also dominated by *L. mouterdei, Matthiola crassifolia* and *Thymbra capitata. Limonium postii* was observed to grow mostly as a chasmophyte. The natural degradation of outcrop may have facilitated the establishment of sacaton grass, *Sporobolus pungens*, and bermudagrass, *Cynodon dactylon*, dominated communities that have excluded the species. A detailed description of the communities defined for *L. postii* is presented in Appendix III.

c. Physiognomy

The physiognomic description of associates of *L. postii* based on Ellenberg and Mueller-Dombois (1965/1966) amended to include bunched shoot arrangement in reptant species yielded 13 different life-forms represented in Table 21 and are fully described in Appendix I.

Table 21: Life-forms of associates of *Limonium postii*

Life-form eight digit name	Abbreviated life-form category	Numeric code	Species eight digit name	No. of species
Phaner05	N P caesp	1.121.106.511	Thymhirs	1
Chamae01	Ch frut	2.111.30	Thymcapi	1
Chamae03	Ch suff	2.211.30	Limomout	1
Chamae04	Ch suff	2.211.40	Limopost	**1**
Chamae08	Ch suff	2.241.40	Mattcras	1
Chamae11	Ch herb rept	2.321.30	Sporpung, Cynodact	2
Chamae12	Ch herb rept (caesp)	2.321.30	Sporpung	1
Hemicr11	c H sem	3.322.4	Anchhybr	1
Therop04	met T scap	5.304.2	Valamura, Polytetr	2
Therop05	met T scap	5.304.3	Verocymb, Lotuedul, Lotuhalo, Mercannu, Silecolo	5
Therop06	met T scap	5.304.4	Hyosalbu	1
Therop10	met T sem	5.324.3	Senebery, Cotapala	2
Therop11	met T sem	5.324.4	Malvsp00, Sisyoffi, Urospicr,	6

			Soncoler, Carttenu, Glebcoro	

Amendments added in parantheses to abbreviation of life-form category.

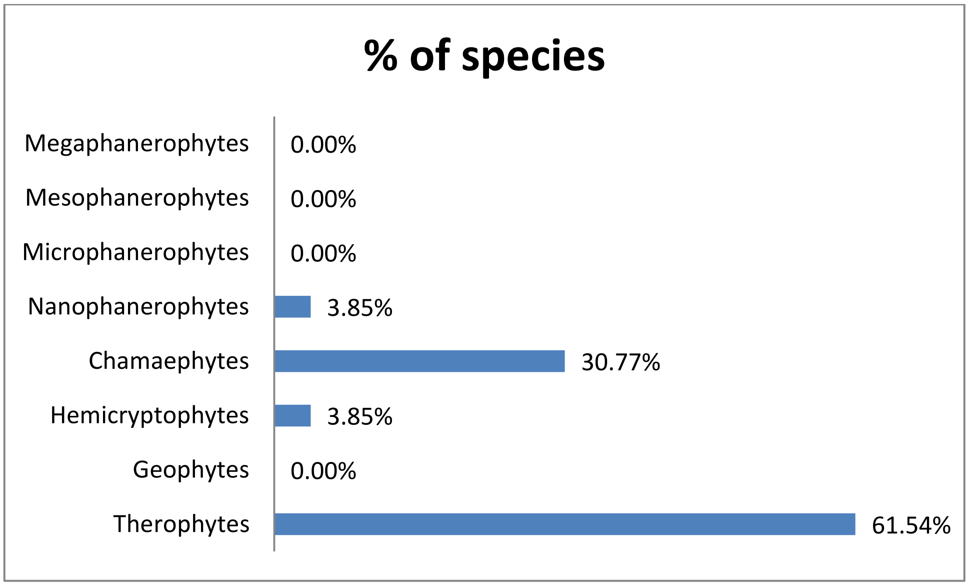

Figure 12: Raunkiaer life-form spectrum of vegetation in *Limonium postii* habitat

Chamaephytes constituted the most prominent perennial life-form of the vegetation (Figure 12). They were represented by six species, or which were the the coastal endemics being investigated in this study. Phanerophytes were represented by single species. Therophytes were represented by 16 species.

TWINSPAN analysis of physiognomic data for associates of *L. postii* in Beirut resulted in four quadrat groups (A-D), representing the life-form spectra of the studied vegetation (Table 22). The different groups of quadrats are listed in decreasing order of representation of the target species. Quadrat groups B and C included the target species, while quadrat groups A and D excluded it.

Table 22: Life-form composition of the life-form spectra defined by TWINSPAN for Limonium postii detailed physiognomic data.

Representation of target species VI3			**Representation of target species IV 2**			**Representation of target species -**		
Twinspan group	Life-forms		Twinspan group	Life-forms		Twinspan group	Life-forms	
B	**Chamae04**	**VI 3**	C	Phaner05	IV 2	A	Chamae08	VI 3
	Chamae08	VI 2		Chamae03	VI 3		Therop06	VI 2
	Chamae03	III 3		Chamae01	IV 3			
	Chamae11	III 1		**Chamae04**	**IV 2**			
	Hemicr11	V 2		Chamae08	IV 2			
	Therop05	V 3		Chamae11	IV 1			
	Therop10	V 2		Therop04	VI 2			
	Therop04	V 2		Therop10	VI 2			
	Therop11	VI 2		Therop11	VI 2			
				Therop05	IV 2			

Representation of target species -		
	Twinspan group	Life-forms
D	Chamae12	VI 4
	Chamae11	VI 2
	Therop05	VI 3

The Roman number corresponds to species constancy within each TWINSPAN group (I = 5% or less; II = 6 – 20%; III = 21 – 40%; IV = 41 – 60%; V = 61 – 80%; VI = 81 – 100%). The Arabic number indicates average species abundance for each group on the domin scale. Life-form of target species is presented in bold.

Quadrat groups that included the target species were dominated by typical and tall evergreen dwarf-shrubs (Chamae01, Chamae03 and Chamae04). These comprised most of the persistant vegetation associated with *L. postii*. None of these completely covered the any of the collected samples, effectively mainaining plenty of bare ground. Also present were several therophytic life-forms, but these were hardly common in the quadrat groups that included the target species.

Quadrat groups that excluded the target species were either dominated by typical evergreen herbaceous chamaephytes creeping along the ground in a bunched and spreading shoot arrangement (sometimes allowing for mat-formation and peat accumulation) (Chamae12) or by tall evergreen semi-woody dwaf-shrubs (Chamae08). It is noteworthy however that Chamae08 probably did not itself exclude the target species as the quadrat group in which it dominated (quadrat group A) was comprised of a single sample collected from a nearby pedestrian path. Ornamental plant species belonging to Chamae12 and similar life-forms include turfgrass species and the Singapore Daisy, *Sphagneticola trilobata*.

A detailed description of the life-form spectra defined by TWINSPAN for *L. postii* is presented in Appendix IV.

C. Red-listing status of target species

Building on the current geographic range for each target species and a more thorough understanding of their current-day status in Beirut, the three target species were Red-Listed as follows:

- *Matthiola crassifolia* is is now present in Khaldeh, Beirut and Byblos. Its EOO was estimated with the aid of GeoCAT (Bachman *et al.* 2011) to be less than 5,000 km^2. The species is present in less than five locations and its EOO, quality of habitat and number of locations or subpopulations are in continuous decline. The species is listed as Endangered: EN B1ab(i, iii, v)

- *Limonium mouterdei* is a range-restricted species, currently known from only a single location in Beirut and extinct in its type locality, Saint Elie (Southern Beirut). Its Area Of Occupancy (AOO) was estimated using a cell width of 2 km at 4 km^2. Its Extent Of Occurrence (EOO) was estimated in the field at 1000 m^2 as the total area within a minimum convex polygon around all known individuals. The sandstone cliff on which it persists has and is still being degraded by urban expansion. These threats are likely to continue as the area is favorable for tourism and there is no current protection for this species' habitat. Landscaping activities in and near the last remaining refuge of the species are leading to a decline in EOO; AOO; area, extent and quality of habitat; number of locations; and number of mature individuals. Therefore, the species is Red-Listed as Critically Endangered: CR B1+2ab (i, ii, iii, iv, v); B1+2ab (i, ii, iii, iv, v); C2a(ii).

- *Limonium postii* was still present in its southern-most locality, Beirut, in which it is almost extinct in the wild. Its northern-most limit was the Palm Island reserve. Its EOO was estimated with the aid of GeoCAT (Bachman *et al.* 2011) to currently be less than 5,000 km^2. The species is present in less than five locations and its EOO, quality of habitat and number of locations or subpopulations are in continuous decline. The species is listed as Endangered: EN B1ab(i, iii, v)

CHAPTER V

DISCUSSION

The red-listing status of each endemic species investigated in this study, their restrictedness to a highly urbanized region and the lack of *in situ* conservation sites signifies the urgency of resorting to integrating these rare natives in the urban matrix of the city. Critically endangered and known to persist on no other site but a single remnant sandstone cliff in Beirut, a single development project can lead to the extinction of *Limonium mouterdei* in the wild. The other two species are more widespread, but nevertheless, they are restricted to a highly urbanized region and each has already been lost at at least one of their historic localities in the past century. Despite not being critically engangered, rising land value poses a real threat of indiscriminantly destroying their habitat in Lebanon (Makhzoumi, 2012).

For this reason, understanding the requirements of these species is crucial and ecological investigations employing vegetation description need to be conducted in the highly urbanized region in which they persist. Applying vegetation description techniques in highly disturbed areas with the aim of contributing to planting design strategies that lead to plant conservation and in identifying suitable sites for introduction of these species was the central goal of this study.

A. Implications on vegetation description in urbanized settings

For the purpose of mitigating the problem posed by the over-representation of ruderals in disturbed areas (Kent, 2012) and to better conceptualize requirements of species of conservation interest, in this study, TIWNSPAN was used to classify detailed physiognomic data into life-form spectra instead of its traditional use of classifying floristic data into communities. Since the resulting classsifications were subsequently sorted by decreasing representation of target species, this approach utilizes both physiognomic and floristic data. In the last decade, other researchers have also sought to simultaneously utilize physiognomic and floristic vegetation description methods in their studies. Vestergaard (2006) generated quadrat groups based on floristic data through TWINSPAN and then described the life-form spectra in each; and a new vegetation classification approach that relies on both physiognomy and floristics and functions over large areas was published in 2014 under the name EcoVeg (Faber-Langendoen *et al.*, 2014). Our approach however differs from EcoVeg in that it is meant to classify vegetation over small areas in urbanscapes and differs from the approach applied by Vestergaard (2006) in that it first mathematically classifies physiognomic data and later sorts the classifications by a specific floristic trend (such as the representation of a target species).

Given that certain mechanisms of competition such as growth form, shading effects and deposition of litter are directly related to physiognomy (Kent, 2012) and given that other competition mechanisms such as allelopathic potential and differences in reproductive strategy were recently found to be indirectly related to it, the description of life-form spectra along with their representation of a target species is likely to be highly useful at understanding requirements of persistence of a rare species (Nelis, 2012; Meiners, 2014). The conventional way of representing physiognomic data is through bargraphs showing the % species of each life-form (Kent, 2012). This approach cannot be used to classify quadrats into quadrat groups as the percent of species within each life-form category does not inform about the abundance measure of that life-form. In our study percent cover of each life form was determined allowing for classification of data into life form spectra defined by abundance measures. When used to classify physiognomic data, TWINSPAN defined groups of quadrats that were similar in physiognomy. Instead of the customary % species, it provided each life-form an average abundance measure on the Domin scale.

A comparison between TWINSPAN classification of floristic vs physiognomic data revealed less quadrat grouping in the latter; when analyzing data collected for *Matthiola crassifolia*, a target species behaving as a ruderal, the classification of the detailed physiognomic data using TWINSPAN resulted in 33% less quadrat groups than the classification based on floristic data. Furthermore, the floristic classification grouped quadrats that do not have any species in common except ruderal species. For example quadrat groups C and G included, each, sets of quadrats that do not have almost any species in common except the ruderal *Matthiola crassifolia*.

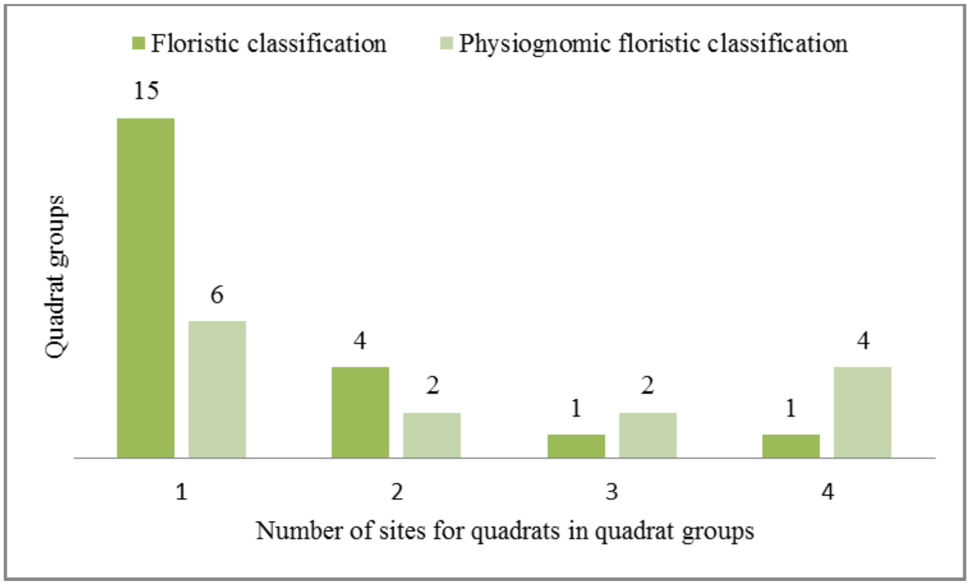

Figure 13: No. of quadrat groups defined by TWINSPAN versus number of sites for quadrats in each

Over 70% of the quadrat groups defined based on floristic data included quadrats collected from a single site (Figure 13). This location dependence clustering may be due to differences in the distribution of ruderals among sites. The presence and diversity of ruderals in urban contexts are themselves site-dependent and this can affect interpretation of floristic data when classified mathematically. In contrast classifying the quadrats based on physiognomic characters of the vegetation was not site dependent except in cases where quadrat groups consisted of a single quadrat. As illustrated through the analyses of *Matthiola crassifolia* vegetation description data, detailed physiognomic data can aid in revealing vegetation patterns accompanying different abundance measures of a rare species throughout its range by being less site dependent in defining associations between sampled quadrats.

For target species that were not ruderal and that were restricted to the interior of remnant semi-natural patches, relying of physiognomic data also proved useful. The method distinguished, despite the limited number of samples, between quadrat groups that included the target species and those that excluded it. In contrast, the floristic investigation of *L. mouterdei* failed to segregate plant communities according to the presence of absence of the target species. This could be attributed to the fact that the target species seemed to behave as a preferential species in that it is present in all communities with no apparent community excluding it.

With respect to *L. postii*, which is extremely limited in its distribution in the study area (4 m^2), TWINSPAN's ability to segregate between quadrat groups that excluded the target species from those that include it was also demonstrated to be better when detailed physiognomic data was used in comparison to floristic data.

B. Potential applications of life-form spectra defined by life-form abundance

Provided appropriate conservation targets, Gaston (2005) proposes that urban ecology can have success stories emerge even in cities. By understanding the physiognomy and structure and environmental conditions in which a species occur, green areas can either be designed to suit the requirements of a target species or already established areas can be efficiently surveyed for candidate sites suited for introduction.

Life-form spectra have often been presented by the percentage of their constituent species (Kent, 2012). Describing life-form spectra based on the abundance measures of their constituent life-forms instead can allow them to function as blueprints for planting designs. This allows landscape architects to design green areas with very detailed ecological considerations and without restricting them to specific species of plants or native only policies. This may also simultaneously help them achieve desired environmental, sociobehavioral and aesthetic outcomes.

Given the rate of expansion of urban landscapes (McDonnell and Pickett, 1990; Pickett *et al.* 1997; Alberti *et al.*, 2001; Marzluff *et al.*, 2001), increasing species' patch area in a city could soon become highly desired (Rosenzweig, 2003). This could be achieved by basing landscape design on life-form spectra describing the physiognomy of vegetation in which species of conservation interest have been found to be most abundant or, at least, from which they were not observed to be excluded.

By sorting quadrat groups by their representation of target species, conclusions could be derived on what prevailing life-forms either exclude the target species or not and which life-form spectra could be emulated to increase patch area.

In quadrat groups where target species were highly represented, life-forms that had a limited representation and very high abundance were considered compatible with the target species. When species belonging to such life-forms are used as the dominant vegetation in urban habitats, provided suitable environmental conditions and horticultural practices, the target species is expected to be successfully integrated in them.

C. Increasing species patch area in an urbanized setting

In an urbanized setting, patch area of a species of conservation interest can be increased by integrating it in sites well-matched with its needs, provided a suitable growing medium and horticultural practices that can sustain the species. Doing rapid assessments of the physiognomy of green areas in a city can lead to the identification of suitable sites for introduction requiring no modification.

Because knowledge of species' preferred physiognomies encompasses an understanding of its position in the vertical stratification of its ecological community (Kent 2012), such an assessment would lead to the identification of inconspicuous areas suited for introduction. *Matthiola crassifolia*, for instance, was observed to thrive as part of the shrub layer under taller nanophyllous shrubs like the Shaggy sparrow-wort, *Thymalea hirsuta*, and the understory of tuft-trees like the fan palm, *Washingtonia robusta*, and groves of the giant reed, *Arundo donax*. Species belonging to these life-forms or similar ones dominate many patches within the planted street medians of Beirut. Many of these small landscape elements may be compatible with the target species. Below are illustrations of parts of street medians and sidewalks in w hich *M. crassifolia* was observed growing during this study (Figure 14, 15 & 16).

Figure 14: Planted street median at the Ramlat Al Bayda site

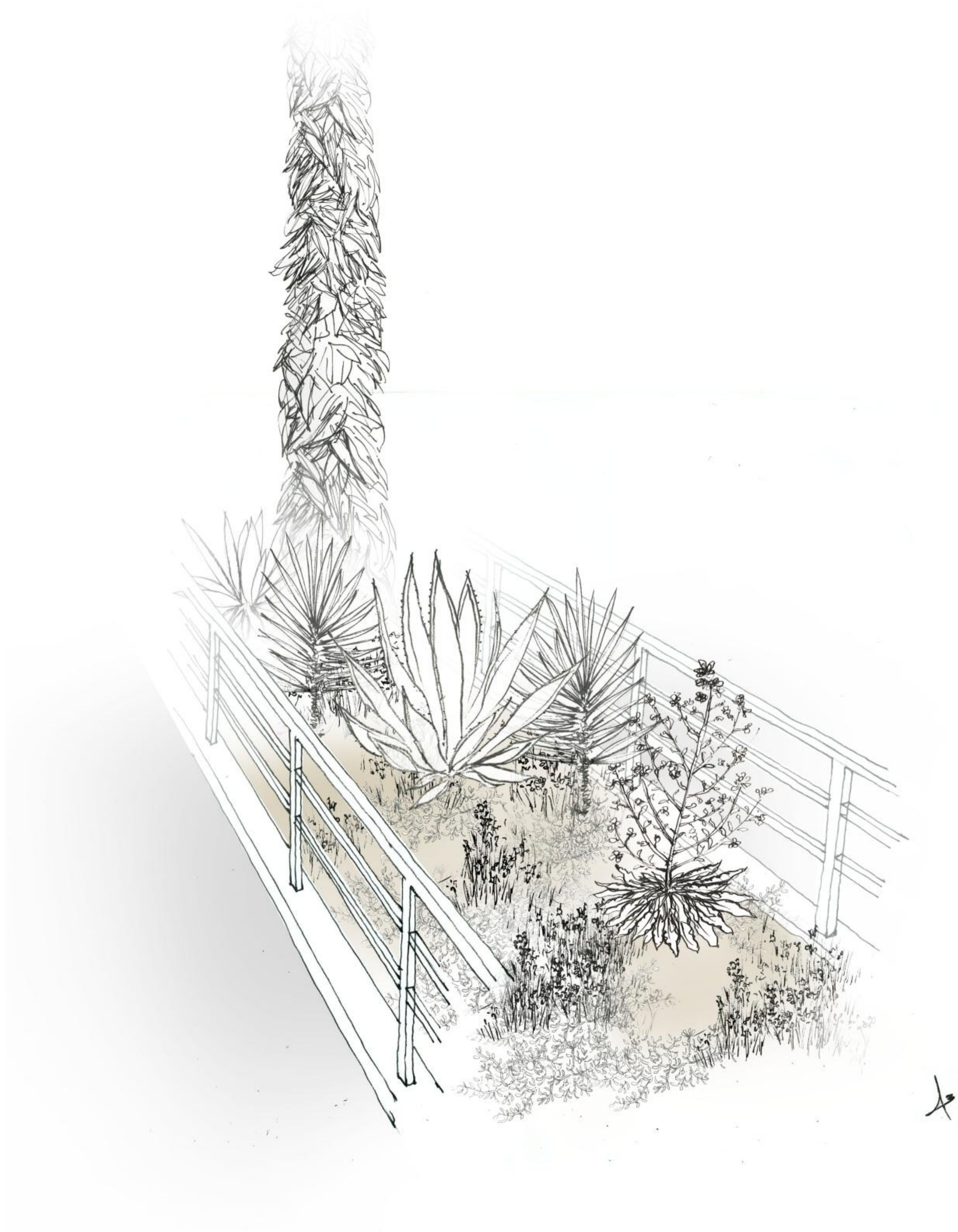

Figure 15: Planted street median at Saint Elie

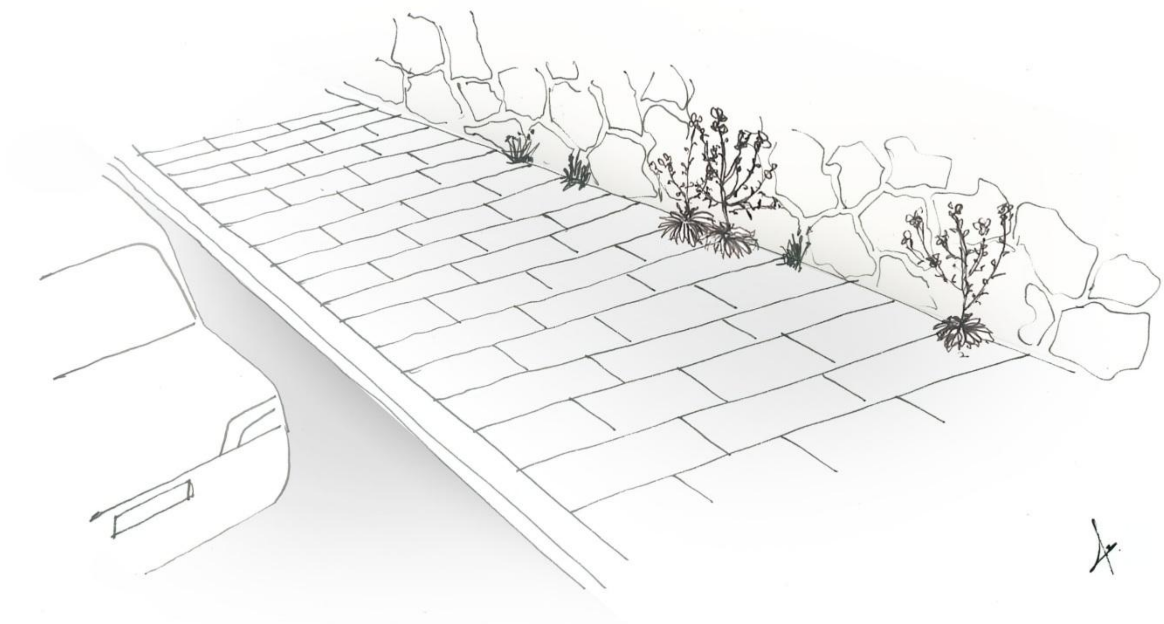

Figure 16: *Matthiola crassifolia* growing througjh cracks of concrete on sidewalk in Ramlat Al Bayda

Modification of green areas not suitable for a target species due to physiognomy of vegetation needs only to exclude species of incompatible life-forms or at least restrict their abundance. If possible, such species can also be trained to allow for the presence of the target species among them. Pruning canopy for instance would allow for the coexistence of shade intolerant shrub species.

Privately owned small landscape elements, such as balconies and rooftop decks, are uniquitous in cities. Community-based conservation can effectively increase patch area of a species of conservation interest by introducing it to such locations (Francis & Lorimer, 2011). Below are illustrations of potted *L. mouterdei*, *L. postii* and *M. crassifolia* (Figure 17, 18 & 19).

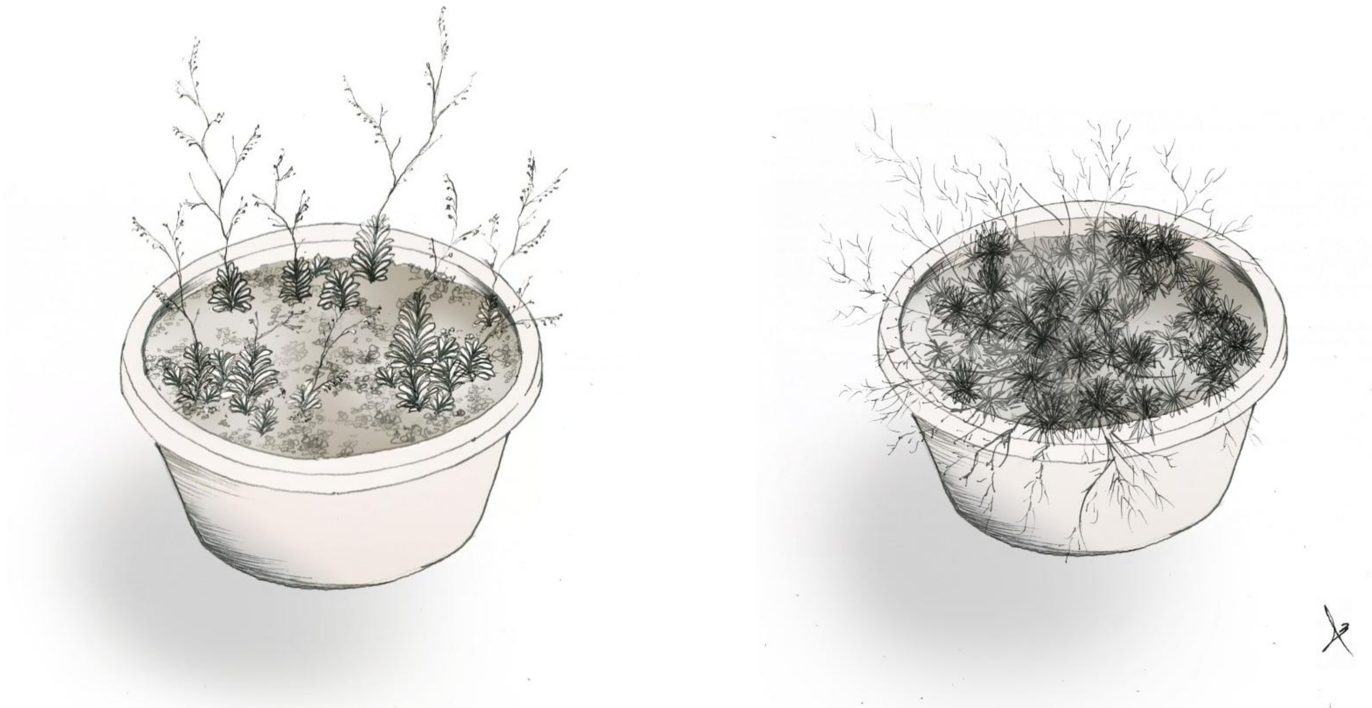

Figure 17: Potted *Limonium postii* grown from cuttings (left) and Salvaged *Limonium mouterdei* sustained in a pot (right)

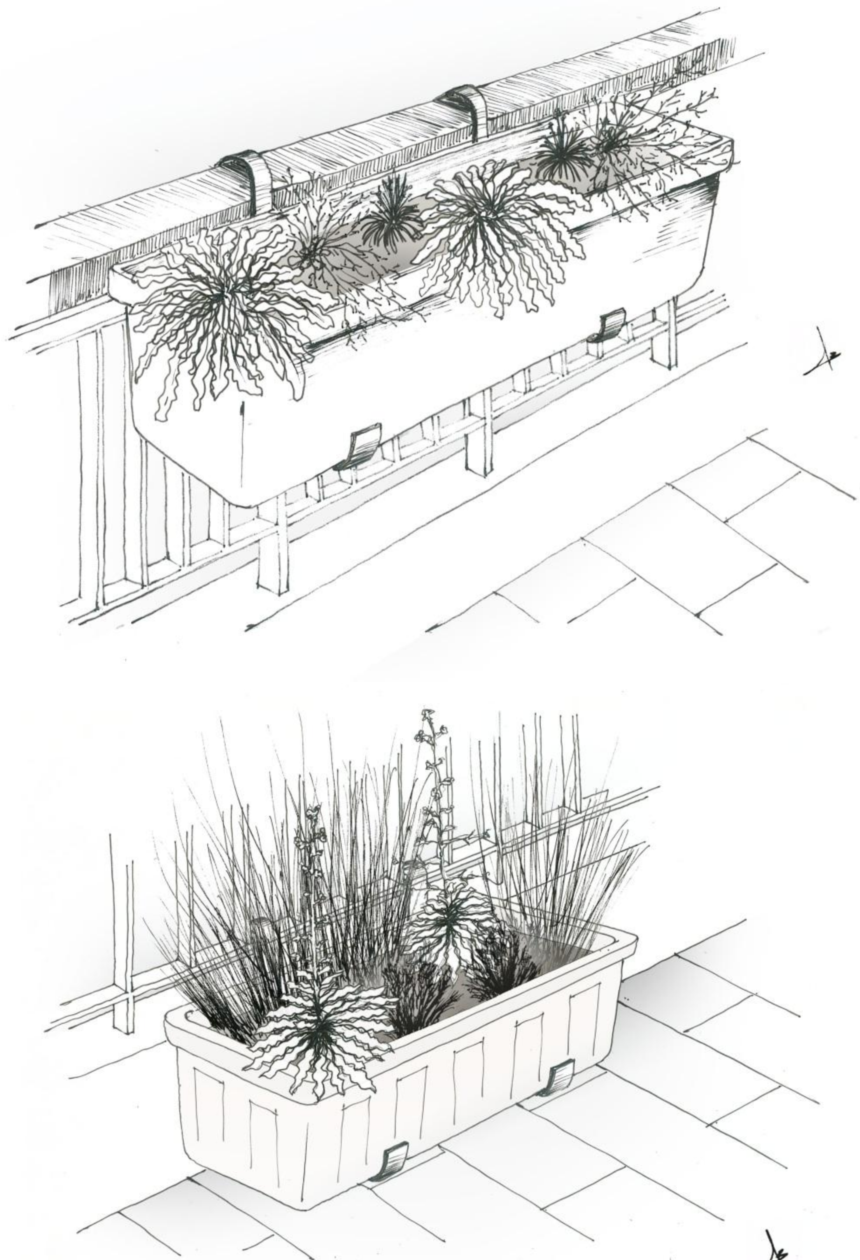

Figure 18: Balcony hanging planters in whioch combinations of native species, such as *Plantago coronopus* L. and J*uncus acutus* L., were included along some of the target species

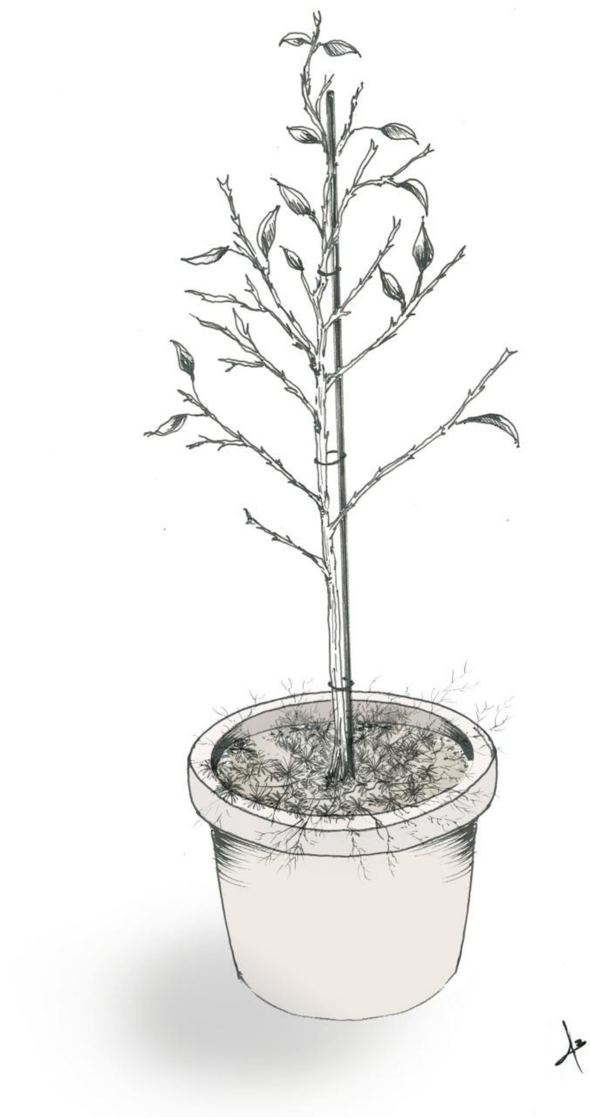

Figure 19: Potted *Limonium mouterdei* under Kumquat tree

D. On the Management of Weeds and Invasive Species

In the aftermath of invasion, the removal of invasive plant species is the first step towards restoring an ecosystem (Blackwood *et al.*, 2010). This work showed that the type of invasive species to be removed first should be determined based on its impact on endemic and rare vegetation present in a given region. Eradicating invasive species that are competing with endemics should be prioritized. Huenneke and Thomson (1995) suggest criteria for determining whether such species pose problems for specific rare native taxa. The possibility that such species could be beneficial to endemics should not be disregarded.

Not every invasive species identified in this study was found to negatively impact the target species. On the contrary, one invasive might have helped increase an endemic's patch area. Both in Khaldeh and Beirut, *M. crassifolia* was observed growing in sites dominated by the potentially invasive *Carpobrotus edulis.* This assemblage occurred at proximity to pedestrian paths where the target species was hardly present. Pedestrians were avoiding to step on it possibly due to their appreciation of *C. edulis* as an evergreen ground cover. This is in line with Misgav (2000) who has shown that public preference is greatest for evergreen vegetation. The plant's large and conspicuous size may have played a role either in increasing its perceived value or in making it more uninviting to step on. Simultaneously, *C. edulis* did not exclude the rare endemic from the site. This community is illustrated in Figure 20.

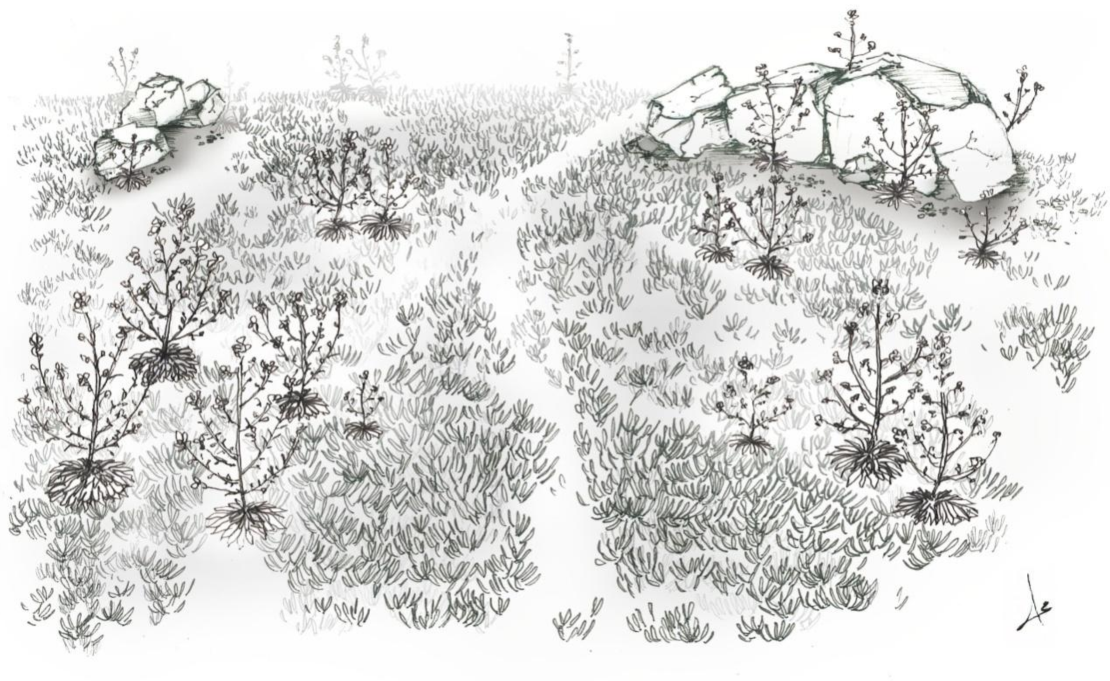

Figure 20: *Matthiola crassifolia* growing as accent through a ground cover of the potentially invasive *Carpobrotus edulis*

Landscape weeds–wildflower competition has been shown to be heightened by substrate fertility (Morris, 2003). Poor soils that could be present in microenvironments of urban areas can favor nonweedy native plants by excluding highly competitive weeds (Benventuni, 2004). Target species could be introduced to gardens among other vegetation that is tolerant of poor soils. Figure 21 illustrates a landscaped garden that includes the target species among vegetation tolerant of poor soils.

Figure 21: *Matthiola crassifolia* spontaneously growing in a garden near a sidewalk at the Ramlat Al Bayda area

CHAPTER VI

RECOMMENDATIONS AND CONCLUSION

A. Recommendations for the Conservation of Rare Species Restricted to Urban Areas

For species restricted to urban areas, it is often assumed that a bulk of its habitat has been irreversibly transformed. Furthermore, due to urbanization, extant remnant patches in urban areas are also very likely to be lost. It is therefore concluded that *in situ* conservation in such a setting is not a viable conservation approach on its own.

Recent literature has put forth several suggestion of intermediate conservation approaches.

'*Circa situm* conservation' refers to conserving plants within their geographical range but outside their natural habitat (Boshier *et al.*, 2004). Also referred to as 'conservation through use', this approach is especially applicable in case plant species restricted to urban areas possesses horticultural value that makes it appealing to people. In case species possess such values or are found to be charismatic (as a flagship species), undertsanding its requirements is key to integrate it in an urban landscape.

Below is an illustrated example of a *circa citum* conservation intevention that has been implemented for two of the target species of this study through using them as ornamentals in a concrete balcony planter (Figure 22). At this planter's inaccessible side, xerophitic cacti were planted due to their minimal requirements of watering. *Limonium* *mouterdei* was placed in the middle because it is more tolerant of drought than *M. crassifolia*.

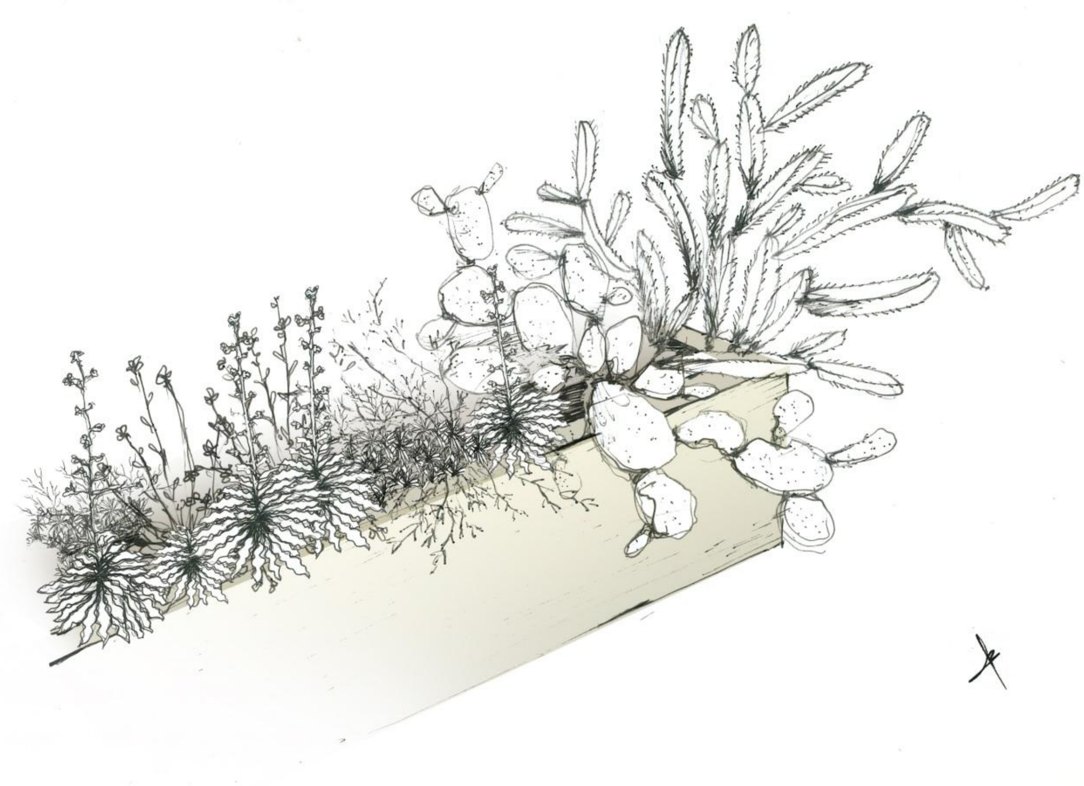

Figure 22: *Limonium mouterdei* and *Matthiola crassifolia* grown in a concrete balcony planter in Koraytem area, Beirut

Volis *et al.* (2009) and Volis and Blecher (2010a, 2010b) suggest 'quasi *in situ* conservation' as a means to bridge the gap between *in situ* and *ex situ* conservation. This is achieved through maintaining *ex situ* collections of plants and plant material, sustaining them in natural and seminatural habitat and focusing on preserving genetic variation. This approach would be essential if species restricted to urban area is at risk of losing genetic variation; this is especially the case if populations are too small or are assessed as inviable.

Plant Micro-Reserves (PMRs) are the modern alternative to inapplicable large sized nature reserves. This approach emphasizes the conservation of vegetation fragments that can function as refuge for rare species of plants. If PMRs are to be applied along the Lebanese coast, sites to be protected should include habitat types and features that host the largest number of species restricted to urbanized areas. In the case of the Lebanese coast, the remnant sandstone cliff at Ramlat Al Bayda area is one candidate. It is the only site in this region that currently includes all three endemic species. PMRs may also be established for species of conservation interest not necessarily at the level of the country.

Figure 23 presents a recommended process of choosing convenient conservation approaches depending on possible scenarios that could face researchers investigating the conservation of rare species of plants restricted to urban areas. The high demand on land for development in urban areas prioritizes the consevation of taxa restricted to them in contrast to taxa that are more widely distributed. The ownership and cultural significance of sites where a taxon exists determines whether *in situ* conservation is an option or not. Privided that in an urban area patches are often small and fragmented which lowers the viability of some species, *ex situ* measures are essential to add for the chances of success of conservation measures.

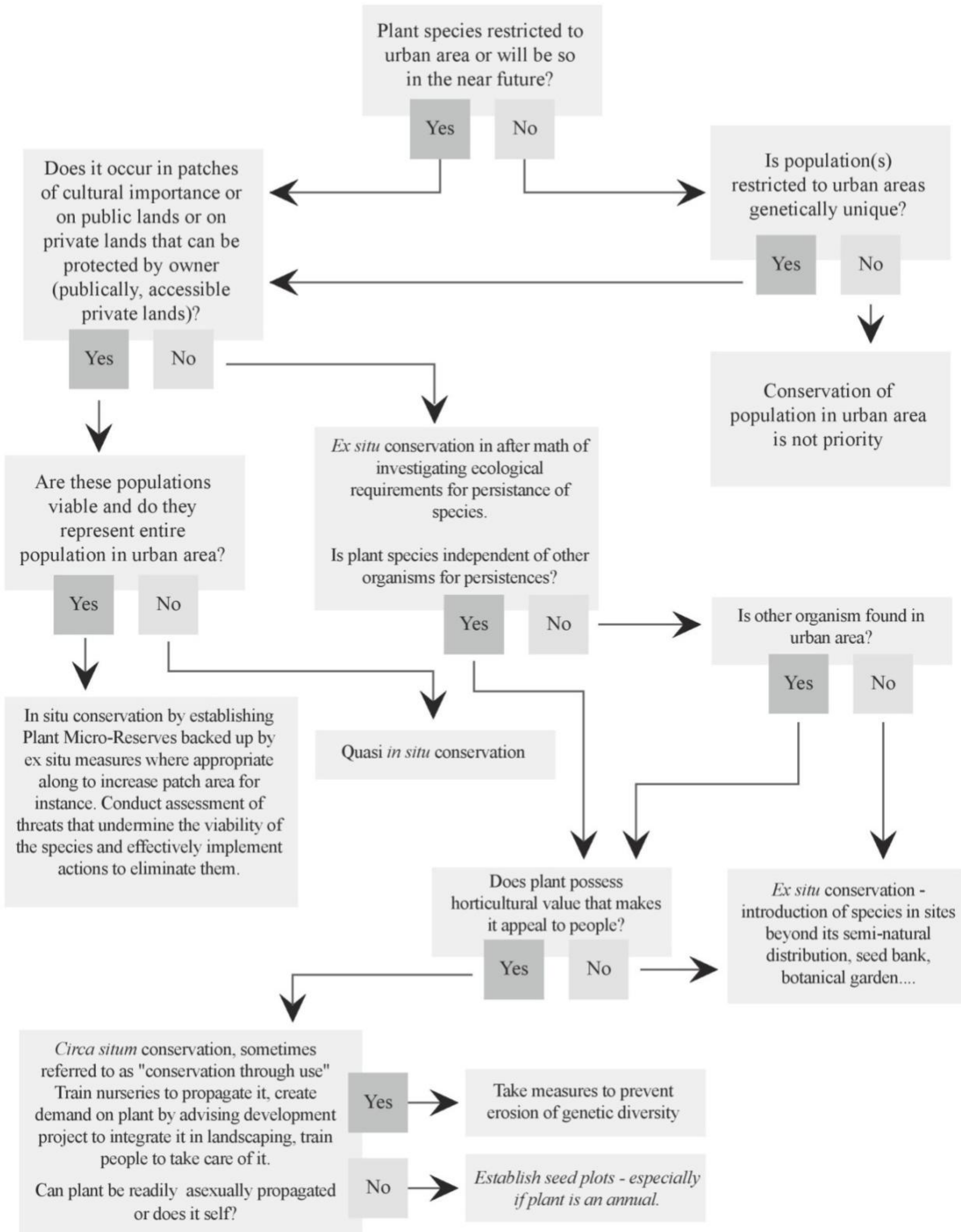

Figure 23: Flowchart aiding in selecting proper conservation approach in an urban area

B. Recommendations for Future Research

Cultural significance of ecologically important areas and the role they play for favoring conservation efforts is relevant here. Also relevant is the possibility that distinct populations could possess taxonomic differences worthy of consideration. Integrating rare species into the urban settings raises the question of how pollinators would continue to interact with plants and whether such a change in the immediate environment reflects on the genetic diversity of the population.

• The sites where the three species occur might not be of much concern to the general public. An investigation on the cultural significance of remnant patches and the implications of cultural significance on biodiversity conservation in urban habitats in Lebanon is needed. Culturally significant habitats may not necessarily be the most ecologically important. In this study, it is proposed that the number of endemic species represented in remnant patches in Beirut ought to be used as a primary criterion.

• Different populations of *Limonium postii* and *Matthiola crassifolia* display morphological differences among individuals of different populations. Such differences may be of significance ad needs further investigation.

• Plant insect interactions within urban areas should be studied and contrasted to how such interactions occur in semi-natural remnant habitat patches. Questions that need to be answered include: are floral parts that possess certain morphological variation equally attractive to pollinators in both anthropogenic and semi-natural habitat patches? If such asymmetry is found to exist for a certain species, measures should be taken to mitigate possible loss of genetic diversity for species with increasing restrictedness to anthropogenic habitats.

C. Limitations

- Demographic monitoring in the field, although essential for this kind of study (e.g. Dinsdale, 1996), was considered not applicable in Beirut. Several challenges faced during the preliminary stages of this study emphasized the futility of attempting such an investigation. These include removal of tags by municipality workers, destruction of entire remnant patches overnight and without prior notice for the purpose of controlling flying insects, deliberate destruction of plants to prevent researchers from returning to site, application of pesticides by municipality workers that damaged target species, setting remnant patches on fire to control vegetation for security concerns, trimming the die back which includes the fruits of a target species by municipality workers and uprooting monitored plants or picking their flowers by pedestrians. For species that were not studied before they were restricted to urbanized areas, attempts to grow them under different conditions are likely to provide researchers with reliable information on their environmental requirements. This is especially the case if the species only persists in very few patches that are not representative of its historic distribution.
- For species with very limited distribution, such as *Limonium mouterdei* and *L. postii*, studying the vegetation in which they are present may not be enough to fully understand all potential settings in which they can be integrated. Both species were only

present in a single site that was dominated with subshrubs and majorly characterized with bare ground. It is possible that these plants may thrive in other conditions that have not been observed in what remains of their habitat in Beirut.

APPENDIX I

LIFE-FORMS

No.	Life-form eight digit name	Abbreviation of life-form category	Numeric code	Simplified description of life-form
1	Phaner01	Mes P scap	1.113.101.230	Mesophyllous (leaves usually more than 5 cm ^{2} and less than 100 cm^2) evergreen large tree (5 – 50 m) with spherical crown restricted to upper half of tree
2	Phaner02	Mes aP scap	1.113.213.435	Mesophyllous feathery leaved deciduous large tree with cylindrical crown extending down to more than half of tree
3	Phaner03	N P caesp	1.121.101.520	Microphyllous (usually less than 5 cm^2) normal-sized evergreen shrub (< 2 m) with spherical crown extending to near the base shrub
4	Phaner04	N P caesp	1.121.101.530	Mesophyllous normal-sized evergreen shrub with spherical crown extending to near the base of the shrub
5	Phaner05	N P caesp	1.121.106.511	Nanophyllous (usually less than 1 cm^2) normal-sized evergreen shrub with irregular crown extending to near the base of the shrub

6	Phaner06	N P caesp	1.121.106.520	Microphyllous normal-sized evergreen shrub with irregular crown extending to near the base of the shrub
7	Phaner07	Mes aP caesp	1.122.211.530	Mesophyllous tall (2 – 5 m) deciduous shrub with spherical crown extending to near the base of the shrub
8	Phaner08	N P ros	1.211.500.000	Unbranched dwarf tree (< 2 m) with semi-succulent leaves having a circular arrangement at a similar height of the trunk
9	Phaner09	Mes P ros	1.213.300.000	Unbranched large tree with fan shaped leaves having a circular arrangement at a similar height of the trunk
10	Phaner10	N P herb	1.511.210.000	Normal-sized non-graminoid evergreen herb with large leaf fronds
11	Phaner11	N P herb	1.521.212.530	Mesophyllous normal-sized evergreen shrubby non-graminoid herb with normal branches and leaves and crown extending to near the base of the shrub
12	Phaner12	Mi P gram	1.522.110.000	Tall graminoid variously lignified shrub
13	Chamae01	Ch frut	2.111.30	Typical (10 – 30 cm) woody evergreen dwarf-shrub
14	Chamae02	Ch frut pulv	2.131.40	Tall (30 – 100 cm) woody evergreen dwarf-shrub
15	Chamae03	Ch suff	2.211.30	Typical semi-woody evergreen dwarf-shrub
16	Chamae04	Ch suff	2.211.40	Tall evergreen semi-woody dwarf-shrub

17	Chamae05	Ch suff	2.212.40	Tall deciduous semi-woody dwarf-shrub
18	Chamae06	t Ch suff rept	2.222.20	Low (3 – 10 cm) deciduous semi-woody dwarf-shrub creeping along the ground
19	Chamae07	t Ch suff rept	2.222.40	Tall deciduous semi-woody dwarf-shrub creeping along the ground
20	Chamae08	Ch suff	2.241.40	Tall evergreen semi-woody dwaf-shrub
21	Chamae09	t Ch suff scap	2.242.40	Tall deciduous dwarf-shrub
22	Chamae10	Ch herb	2.311.50	Tall evergreen herbaceous chamaephyte growing in clusters or tufts
23	Chamae11	Ch herb rept	2.321.30	Typical evergreen herbaceous chamaephyte (grass) creeping along the ground
24	Chamae12	Ch herb rept (caesp)	2.321.30	Typical evergreen herbaceous chamaephyte (grass) along the ground in a bunched and spreading shoot arrangement (sometimes allowing for mat-formation and peat accumulation)
25	Chamae13	Ch herb rept	2 .321.40	Typical evergreen herbaceous chamaephyte (forb) creeping along the ground
26	Chamae14	Ch herb rept (caesp)	2 .321.40	Typical evergreen herbaceous chamaephyte (forb) creeping along the ground with a bunched and spreading shoot arrangement (sometimes allowing for peat accumulation and mat-formation)
27	Chamae15	Ch l succ (rept)	2.421.22	Low reptant evergreen low succulent
28	Chamae16	Ch l succ (rept)	2.421.32	Typical reptant evergreen low succulant

29	Hemicr01	c H caesp	3.102.4	Tall (30 – 100 cm) drought-deciduous hemicryptophyte with a bunched or circular shoot arrangement
30	Hemicr02	c H rept	3.202.1	Very low (< 3 cm) reptant drought-deciduous hemicryptophyte
31	Hemicr03	e H rept	3.203.2	Small (3 – 10 cm) reptant sparingly evergreen hemicryptophyte
32	Hemicr04	e H rept	3.203.2	Small reptant with a bunched and spreading shoot arrangement (sometimes allowing for peat accumulation and mat-formation) sparingly evergreen hemicryptophyte
33	Hemicr05	e H rept	3.203.3	Medium-sized (10 – 30 cm) reptant sparingly evergreen hemicryptophyte
34	Hemicr06	e H rept	3.203.3	Medium-sized reptant with a bunched and spreading shoot arrangement (sometimes allowing for peat accumulation and mat-formation)sparingly evergreen hemicryptophyte
35	Hemicr07	c H scap	3.302.4	Tall drought-deciduous hemicryptophyte with a leafless stalk growing directly from the ground
36	Hemicr08	c H scap	3.302.5	Very tall (> 100 cm) drought-deciduous hemicryptophyte with a leafless stalk growing directly from the ground
37	Hemicr09	c H ros	3.312.4	Tall drought-deciduous hemicryptophyte with a stalk growing directly from the ground having a circular arrangement of leaves at its base

38	Hemicr10	c H sem	3.322.3	Medium-sized drought-deciduous hemicryptophyte with a leaved stalk growing directly from the ground
39	Hemicr11	c H sem	3.322.4	Tall drought-deciduous hemicryptophyte with a leaved stalk growing directly from the ground
40	Hemicr12	c H sem	3.322.5	Very tall drought-deciduous hemicryptophyte with a leaved stalk growing directly from the ground
41	Geophy01	c G bulb	4.232.2	Small (3 – 10 cm) bulbous geophyte with stalk growing directly from the ground
42	Geophy02	c G bulb	4.232.3	Medium-sized (10 – 30 cm) bulbous geophyte with a stalk growing directly from the ground
43	Geophy03	G bulb	4.242.4	Tall (30 – 100 cm) sparignly evergreen bulbous geophyte with a stalk growing directly from the ground
44	Geophy04	c G rhiz	4.332.4	Tall rhizome geophyte with a stalk growing directly from the ground
45	Therop01	met T caesp	5.104.3	Medium-sized (10 – 30 cm) annual growing in clusters or tufts
46	Therop02	met T rept	5.204.2	Small (3 – 10 cm) annual without a circular arrangement of leaves at a similar height of the stalk creeping along the ground
47	Therop03	met T rept	5.204.3	Medium-sized annual without a circular arrangement of leaves at a similar

				height of the stalk creeping along the ground
48	Therop04	met T scap	5.304.2	Small annual with a leafless stalk growing directly from the ground
49	Therop05	met T scap	5.304.3	Medium-sized annual with a leafless stalk growing directly from the ground
50	Therop06	met T scap	5.304.4	Tall (30 – 100 cm) annual with a leafless stalk growing directly from the ground
51	Therop07	met T scap	5.304.5	Very tall (1 – 3 m) annual with a leafless stalk growing directly from the ground
52	Therop08	met T ros	5.314.3	Medium-sized annual with a circular arrangement of leaves at a similar height of the stalk growing directly from the ground
53	Therop09	met T sem	5.324.2	Small annual with leaves on stalk growing directly from the ground
54	Therop10	met T sem	5.324.3	Medium-sized annual with leaves on stalk growing directly from the ground
55	Therop11	met T sem	5.324.4	Tall annual with leaves on stalk growing directly from the ground
56	VasPar01	-	-	Small annual vascular parasite that grows on other plants as a total stem parasite
57	VasPar02	-	-	Small annual vascular parasite that grows on other plants as a total root parasite

Amendments added in parantheses to abbreviation of life-form category.

APPENDIX II

SPECIES

Species eight digit name	Species name	Family	Status	Life-form eight digit name
Ficumicr	Moraceae	*Ficus microcarpa* L.f.	I	*Phaner01*
Leucleuc	Mimosaceae	*Leucaena leucocephala* (Lam.) de Wit	I	Phaner02
Carimacr	Apocynaceae	*Carissa macrocarpa* (Eckl.) A.DC.	I	Phaner03
Pitttobi	Pittosporaceae	*Pittosporum tobira* (Thunb.) W. T. Aiton	I	*Phaner04*
Thymhirs	Thymelaeaceae	*Thymelaea hirsuta* (L.) Endl.	RE	Phaner05
Lantcama	Verbenaceae	*Lantana camara* L.	I	*Phaner06*
Ficucari	Moraceae	*Ficus carica* L.		Phaner07
Yuccgiga	Asparagaceae	*Yucca gigantea Lem.*	I	Phaner08
Agavamer	Asparagaceae	*Agave americana* L.	I	Phaner08
Agavatte	Asparagaceae	*Agave attenuata* Salm-Dyck	I	Phaner08

Washsp	Arecaceae	*Washingtonia* sp.	I	Phaner09
Streregi	Strelitziaceae	*Strelitzia reginae* Banks	I	Phaner10
Recicomm	Euphorbeaceae	*Ricinus communis* L.		Phaner11
Arundona	Poaceae	*Arundo donax* L.		Phaner12
Thymcapi	Lamiaceae	*Thymbra capitata* (L.) Cav.		Chamae01
Sarcspin	Rosaceae	*Sarcopoterium spinosum* (L.) Spach	RE	Chamae02
Galicanu	Rubiaceae	*Galium canum* DC.	RE	Chamae03
Limomout	Plumbaginaceae	*Limonium mouterdei* Domina, Erben & Raimondo	NE	Chamae03
Helistoe	Asteraceae	*Helichrysum stoechas* subsp. *barrelieri* (Ten.) Nyman		Chamae04
Limbcrit	Asteraceae	*Limbarda crithmoides* (L.) Dumort.	RE	Chamae04
Phagrupe	Asteraceae	*Phagnalon rupestre* (L.) DC.		Chamae04
Limopost	Plumbaginaceae	*Limonium postii* Domina, Erben & Raimondo	NE	Chamae04
Critmari	Apiaceae	*Crithmum maritimum* L.	RE	Chamae04
Dittvisc	Asteraceae	*Dittrichia viscosa* (L.) Greuter	RE	Chamae04
Limovirg	Plumbaginaceae	*Limonium virgatum* (Willd.) Fourr.	RE	Chamae04

Echiangu	Boraginaceae	*Echium angustifolium* Mill.	RE	Chamae05
Convsecu	Convolvulaceae	*Convolvulus secundus* Desr.		Chamae06
Lotucyti	Fabaceae	*Lotus cytisoides* L.		Chamae06
Cappsicu	Capparidaceae	*Capparis sicula* Veill.		Chamae07
Mattcras	Brassicaceae	*Matthiola crassifolia* Boiss. & Gaill.	NE	Chamae08
Ambrmari	Asteraceae	*Ambrosia maritima* L.		Chamae09
Centproc	Asteraceae	*Centaurea procurrens* Spreng.	RE	Chamae09
Piptmili	Poaceae	*Piptatherum miliaceum* (L.) Coss.	RE	Chamae10
Sporpung	Poaceae	*Sporobolus pungens* (Schreb.) Kunth	RE	Chamae11 & Chamae12
Cynodact	Poaceae	*Cynodon dactylon* (L.) Pers.		Chamae11 & Chamae12
Sphatril	Asteraceae	*Sphagneticola trilobata* (L.) Pruski	I	Chamae13 & Chamae14
Delocoop	Aizoaceae	*Delosperma cooperi* (Hook.f.) L.Bolus	I	Chamae15
Carpedul	Aizoaceae	*Carpobrotus edulis* (L.) N.E.Br.	I	Chamae16
Elytjunc	Poaceae	*Elytrigia juncea* (L.) Nevski	RE	Hemicr01
Paroarge	Caryophyllaceae	*Paronychia argentea* Lam.	RE	Hemicr02

Phylnodi	Verbenaceae	*Phyla nodiflora* (L.) Greene	I	Hemicr03 & Hemicr04
Polyequi	Polygonaceae	*Polygonum equisetiforme* Sm.		Hemicr05 & Hemicr06
Epiltetr	Onagraceae	*Epilobium tetragonum* L.		Hemicr07
Alceseto	Malvaceae	*Alcea setosa* (Boiss.) Alef.		Hemicr08
Verbsinu	Scrophulariaceae	*Verbascum sinuatum* L.		Hemicr09
Cardcory	Asteraceae	*Cardopatium corymbosum* (L.) Pers.	RE	Hemicr10
Silymari	Asteraceae	*Silybum Marianum* (L.) Gaertn.		Hemicr11
Tragporr	Asteraceae	*Tragopogon porrifolius* subsp. *longirostris* (Sch. Bip.) Greuter		Hemicr11
Anchhybr	Boraginaceae	*Anchusa hybrida* Ten.	RE	Hemicr11
Rumecong	Polygonaceae	*Rumex conglomeratus* Murray		Hemicr11
Parijuda	Urticaceae	*Parietaria judaica* L.		Hemicr11
Dauccaro	Apiaceae	*Daucus carota* L.		Hemicr12
Erigcana	Asteraceae	*Erigeron canadensis* L.	I	Hemicr12
Cyclpers	Primulaceae	*Cyclamen persicum* Mill.	RE	Geophy01
Anacsanc	Orchidaceae	*Anacamptis sancta* (L.) R. M. Bateman		Geophy02

Oxalpesc	Oxalidaceae	*Oxalis pes-caprae* L.	I	Geophy02
Umbiinte	Crassulaceae	*Umbilicus intermedius* Boiss.		Geophy02
Pancmari	Amaryllidaceae	*Pancratium maritimum* L.		Geophy03
Cyperotu	Cyperaceae	*Cyperus rotundus* L.		Geophy04
Ochlannu	Poaceae	*Ochlopoa annua* (L.) H. Scholz		Therop01
Paraincu	Poaceae	*Parapholis incurva* (L.) C. E. Hubb.		Therop01
Phlesubu	Poaceae	*Phleum subulatum* (Savi) Asch. & Graebn.		Therop01
Rostsmyr	Poaceae	*Rostraria smyrnacea* (Trin.) H. Scholz		Therop02
Trifscab	Fabaceae	*Trifolium scabrum* L.		Therop03
Trifresu	Fabaceae	*Trifolium resupinatum* L.		Therop03
Dactaegy	Poaceae	*Dactyloctenium aegyptium* (L.) Willd.		Therop03
Digisang	Poaceae	*Digitaria sanguinalis* (L.) Scop.		Therop03
Alysstri	Brassicaceae	*Alyssum strigosum* Banks & Sol.	RE	Therop04
Campstel	Campanulaceae	*Campanula stellaris* Boiss.	RE	Therop04
Ceraglom	Caryophyllaceae	*Cerastium glomeratum* Thuill.	RE	Therop04

Polytetr	Caryophyllaceae	*Polycarpon tetraphyllum* L. (L.)		Therop04
Sagiapet	Caryophyllaceae	*Sagina apetala* Ard.	RE	Therop04
Sagimari	Caryophyllaceae	*Sagina maritima* Don		Therop04
Galimura	Rubiaceae	*Galium murale* (L.) All.	RE	Therop04
Valamura	Rubiaceae	*Valantia muralis* L.	RE	Therop04
Cakimari	Brassicaceae	*Cakile maritima* Scop.		Therop05
Sileaegy	Caryophyllaceae	*Silene aegyptiaca* (L.) L.	RE	Therop05
Silecolo	Caryophyllaceae	*Silene colorata* Poir.	RE	Therop05
Mercannu	Euphorbeaceae	*Mercurialis annua* L.		Therop05
Hymecirc	Fabaceae	*Hymenocarpos circinnatus* (L.) Savi		Therop05
Lotuangu	Fabaceae	*Lotus angustissimus* L.		Therop05
Lotuhalo	Fabaceae	*Lotus halophilus* Boiss. & Spruner, in Boiss.		Therop05
Lotuedul	Fabaceae	*Lotus edulis* L.		Therop05
Medilitt	Fabaceae	*Medicago littoralis* Loisel.		Therop05
Onobcris	Fabaceae	*Onobrychis crista-galli* (L.) Lam.		Therop05

Trifglan	Fabaceae	*Trifolium glanduliferum* var. *nervulosum* (Boiss. & Heldr.) Zohary		Therop05
Trifpurp	Fabaceae	*Trifolium purpureum* Loisel.		Therop05
Salvviri	Lamiaceae	*Salvia viridis* L.		Therop05
Sideroma	Lamiaceae	*Sideritis romana* subsp. *curvidens* (Stapf) Holmboe		Therop05
Verocymb	Plantaginaceae	*Veronica cymbalaria* Bodard	RE	Therop05
Laguovat	Poaceae	*Lagurus ovatus* L.		Therop05
Crucaegy	Rubiaceae	*Crucianella aegyptiaca* L.	RE	Therop05
Euphterr	Euphorbeaceae	*Euphorbia terracina L.*		Therop06
Aegigeni	Poaceae	*Aegilops geniculata* Roth		Therop06
Anistect	Poaceae	*Anisantha tectorum* (L.) Nevski		Therop06
Anisrigi	Poaceae	*Anisantha rigida* (Roth) Hyl.		Therop06
Avenster	Poaceae	*Avena sterilis* L.		Therop06
Hordvulg	Poaceae	*Hordeum vulgare* L.		Therop06
Hyosalbu	Solanaceae	*Hyoscyamus albus* L.		Therop06
Anagarve	Primulaceae	*Anagallis arvensis* L.	RE	Therop06

Lycoescu	Solanaceae	*Lycopersicon esculentum* Mill.	I	Therop06
Amarhybr	Amaranthaceae	*Amaranthus hybridus* L.	I	Therop07
Plancoro	Plantaginaceae	*Plantago coronopus* L.		Therop08
Planlago	Plantaginaceae	*Plantago lagopus* L.	RE	Therop08
Asteaqua	Asteraceae	*Asteriscus aquaticus* (L.) Less.	RE	Therop09
Cichpumi	Asteraceae	*Cichorium pumilum* Jacq.		Therop09
Cotapalae	Asteraceae	*Cota palaestina* Kotschy, in Unger & Kotschy		Therop10
Crepacul	Asteraceae	*Crepis aculeata* (DC.) Boiss.	RE	Therop10
Hedyrhag	Asteraceae	*Hedypnois rhagadioloides* subsp. *tubaeformis* (Ten.) Hayek		Therop10
Picrrhag	Asteraceae	*Picris rhagadioloides (L.) Desf.*	RE	Therop10
Senebery	Asteraceae	*Senecio* × *berythaeus* A.Camus & Gomb.		Therop10
Creppala	Asteraceae	*Crepis palaestina* (Boiss.) Bornm.	RE	Therop11
Erigbona	Asteraceae	*Erigeron bonariensis* L.	I	Therop11
Glebcoro	Asteraceae	*Glebionis coronaria* (L.) Spach		Therop11
Helihirs	Boraginaceae	*Heliotropium hirsutissimum* Grauer	RE	Therop11

Hormaggr	Boraginaceae	*Hormuzakia aggregata* (Lehm.) Guşul.	RE	Therop11
Tordtrach	Apiaceae	*Tordylium trachycarpum* (Boiss.) Al-Eisawi		Therop11
Carttenu	Asteraceae	*Carthamus tenuis* (Boiss. & C. I. Blanche) Bornm.	RE	Therop11
Soncoler	Asteraceae	*Sonchus oleraceus* L.		Therop11
Urospicr	Asteraceae	*Urospermum picroides* (L.) F. W. Schmidt	RE	Therop11
Sisyoffi	Brassicaceae	*Sisymbrium officinale* (L.) Scop.		Therop11
Malvsp00	Malvaceae	*Malva* sp.		Therop11
Malvoxyl	Malvaceae	*Malva oxyloba* Boiss.	RE	Therop11
Cuscepit	Convolvulaceae	*Cuscuta epithymum* var. *rubella* (Engelm.) Trab.		VasPar01
Orobnana	Orobanchaceae	*Orobanche nana* (Reut.) Beck		VasPar02

APPENDIX III

DESCRIPTION OF COMMUNITIES DEFINED BY TWINSPAN

A. Communities defined for *Matthiola crassifolia* floristic data

Matthiola crassifolia had highest representation in quadrat groups A, B, C, D, E, G, I, L, M and O. With the exception of quadrat groups C and G, all others seem to represent distinct communities. Groups A and B represented part of the vegetation of the street medians that run along the waterfront of Beirut. In group A, *Washingtonia* sp., *Strelitzia reginae* and *Delosperma cooperi* were common. Quadrats belonging to this group were collected from the street medians of the corniche at the Raoche area and a sidewalk planter at Saint Elie. In group B, *Agave americana*, *Agave attenuata* and *Delosperma cooperi* were common. Quadrats belonging to this group were collected from the street median of the corniche at Ramlet Al Bayda area. Group D was particular to a wet coastal sandstone cliff located in Saint Elie. *Parietaria judaica, Helichrysum stoechas* and *M. crassifolia* were common. Other associated species included *Campanula stellaris*, *Valantia muralis, Oxalis pes-caprae* and *Sagina maritime.* Group E is constituted of a single quadrat that was collected at the Long Beach area. Its vegetation was growing out of cracks in concrete. Besides *M. crassifolia*, *Elytrigia juncea* and *Crepis palaestina* were common. Group I was a group quadrats collected from Saint Elie sites featuring vegetation growing on sandy soil with rock fragments on the surface. *Dittrichia viscosa*, *Convolvulus secundus*, *Verbascum sinuatum* were key indicator perennials. *Galium murale, Tordylium trachycarpum* and

Mercurialis annua were common annual species. Group L was made of a single quadrat that was collected from sandy beach of Ramlat Al Bayda. *Crithmum maritimum* was the predominant perennial species, while both *Lotus angustissimus* and *Anisantha rigida* were common annuals. Group O also had *Dittrichia viscosa,* as an indicator perennial, but it also had elements of coastal sands, Cakile *maritima* and *Hormuzakia aggregate,* common.

Quadrat groups C and G do not seem to represent distinct plant communities found in the city, instead they might be representing overlapping communities that have a high representation of ruderals. The target species in this investigation seems to behave as a ruderal itself. Group C included quadrats from both unmanaged anthropogenic habitat and seminatural sandstone formations from Ramlet Al Bayda and Saint Elie. Unmanaged anthropogenic habitat included abandoned dump sites, cracks in concrete, pedestrian paths and rubble. With the exception of *Matthiola crassifolia* and *Galium canum,* all other species were poorly represented. As was the case with group C, group G also included quadrats from both anthropogenic and semi-natural habitat. Habitat features in these quadrats primarily included sandy soils in street medians, pedestrian paths and the semi-natural environment. *Crepis aculeata*, *M. crassifolia*, *Crithmum maritimum*, *Echium angustifolium*, *Carpobrotus edulis*, *Lotus cytisoides*, *Pittosporum tobira* highly represented in some quadrats but were not very common. Besides *Crepis aculeata* and *M. crassifolia,* species behaving as ruderals in this group of quadrats include *Polycarpon tetraphyllum* and *Sagina maritima*. These two species were very ubiquitous in the quadrats of group G, but each was characterized by a modest abundance measures.

In quadrat groups F, J, K and M, *M. crassifolia* was less represented. With the exception of quadrat group F, the compromised representation of the target species in these quadrat groups could be partly attributed to the high representation of other dwarf-shrub species. In group F, the sparingly herbaceous evergreen *Phyla nodiflora* was a key indicator species along with the annuals *Dactyloctenium aegyptium* and *Plantago lagopus.* Group J was characteristic of habitat in Saint Elie area where degraded sandstone and sandy soil were prominent. *Arundo donax*, *Thymelaea hirsuta*, *Helichrysum stoechas*, *Verbascum sinuatum*, *Dittrichia viscosa, Phagnalon rupestre*, *Polygonum equisetiforme*, *Alcea setosa*, *Anchusa hybrida*, *Anacamptis sancta*, *Oxalis pes-caprae, Urospermum picroides, Tordylium trachycarpum*, *Veronica cymbalaria* were common. In group K, all three endemic dwarf-shrubs were key indicators along with the herbaceous perennial *Alcea setosa* and the annual *Lotus halophilus*. This community was characteristic to some sandstone formations in Ramlet Al Bayda area. Group M[2], typified the community very prevalent on the limestone formations of Dalieh. In it, *Limbarda crithmoides*, *Helichrysum stoechas*, *Thymbra capitata*, *Sarcopoterium spinosum*, *Limonium virgatum, Salvia viridis, Asteriscus aquaticus*, and *Carthamus tenuis* were common.

Quadrat groups N, P, Q, R, S, T, H and U completely excluded *M. crassifolia*. In group N, the herbaceous perennial *Alcea setosa* and the graminoid annual *Avena sterilis* were common. In group P, *Limonium mouterdei* and *Dittrichia viscosa* were common

[2] This community possibly once included *Limonium postii* before it went extinct in that locality in 2014.

dwarf-shrubs, while *Mercurialis annua* was a common annual. In group Q, the graminoid *Cynodon dactylon* and *Piptatherum miliaceum* were dominant, along with the bulbous and invasive *Oxalis pes-caprae* and the annual *Mercurialis annua* which was observed to thrive in shady places. Group R was characterized by the endemic *L. mouterdei*, *Mercurialis annua*, the graminoids *Cynodon dactylon* and *Sporobolus pungens.* The invasive shrub, *Lantana camara*, was also present. Quadrat groups S and T were very similar in that they had evergreen ornamental perennials as key indicator species along with graminoid ruderals. In group S, the evergreen ornamental shrub *Carissa macrocarpa* was a key indicator along with the graminoid ruderal *Cynodon dactylon*. In group T, the graminoids *Cyperus rotundus* and *Cynodon dactylon* were often present in gardens and street medians under and around evergreen ornamentals such the shrub *Pittosporum tobira* and the creeping herbaceous forb *Sphagneticola trilobata.* In group H, *Ficus carica* that had probably escaped cultivation in the area of study and adopted a shrubby appearance was associated with the herbaceous *Parietaria judaica* and *Ricinus communis*. This community predominated on the sides of open sewers in Saint Elie. In group U, the tropical evergreen *Ficus microcarpa* almost excluded all other vegetation from its understory with the exception *Piptatherum miliaceum.*

B. Communities defined for *Limonium mouterdei* floristic data

The highest representation of *L. mouterdei* appeared in group B. In this group, *Dittrichia viscosa* and *Thymelaea hirsuta* were common.

Groups C and D had a similar representation of the target species. In Group D, *Thymelaea hirsuta* was again a key indicator along with a marked representation of the annuals *Lotus edulis* and *Lotus halophilus* and the herbaceous perennials *Anchusa hybrida* and *Alcea setosa.* Group C was dominated by the target species, the endemic *Limonium postii* and the regional endemic *Thymbra capitata.*

The groups with the least representation of the target species were quadrat groups A and E. The other two target species, *Limonium postii* and *Matthiola crassifolia*, were most represented in group A. This group of quadrats had the least representation of *L. mouterdei*. The tall annual *Hormuzakia aggregata* was also common. Group E constituted a community dominated by the grasses *Cynodon dactylon* and *Sporobolus pungens.* Also common were the medium-sized annuals *Veronica cymbalaria* and *Mercurialis annua*.

C. Communities defined for *Limonium postii* floristic data

L. postii was well included in groups A and B. Group B[3] exemplified the community in which *L. postii* occurred in Beirut. All three coastal endemic species were represented in this group. In it, *L. mouterdei* and *Thymbra capitata* were dominant. A large number of other associated species occurred; most notably were *Senecio × berythaeus*, *Glebionis coronaria*, *M. crassifolia*, *Cota palaestina*, *Lotus halophilus*, *Valantia muralis* and *Polycarpon tetraphyllum*. These species were almost ubiquitous in this group. Group A was strictly constituted of chasmophytic and rupestral vegetation. It

[3] This community was also represented by the Twinspan quadrat group C for *L. mouterdei*

was a small group of quadrats that were species poor. In this group, two of its three species were endemic to Lebanon. The endemic *Matthiola crassifolia* was an important dwarf-shrub.

L. postii was excluded from group C. This group was represented by a single quadrat that was dominated by *Sporobolus pungens* and *Merculialis annua.*

APPENDIX IV

DESCRIPTION OF LIFE-FORM SPECTRA CLASSIFIED BY TWINSPAN

A. Life-form spectra defined for *Matthiola crassifolia detailed physiognomic data*

Life-form spectra with the highest representation of target species were represented by quadrat groups C, D, E, I. In all these quadrat groups, the life-form describing tall evergreen semi-woody dwarf-shrubs (Chamae08) was a key indicator. In quadrat group C, unbranched dwarf trees with semi-succulent leaves having a circular arrangement at a similar height of the trunk (Phaner08) and normal-sized non-graminoid evergreen herbs with large leaf fronds (Phaner10) were common life-forms used as accent in the landscaping of the street median at the seafront. Low reptant evergreen succulent (Chamae15) were used as ground cover. Quadrat groups D and E exemplified some of the physiognomies of the dwarf-shrub dominated vegetation of rocky formations in Beirut. Besides the scapose dwarf-shrub representing the target species (Chamae08), quadrat group D also included tall woody evergreen dwarf-shrubs (Chamae02) and tall evergreen semi-woody dwarf-shrubs (Chamae04). Herbaceous perennials were also common and these were represented by small reptant sparingly evergreen hemicryptophytes (Hemicr03) and tall drought-deciduous hemicryptophytes with a bunched or circular shoot arrangement (Hemicr01). Several annual life-forms were common. These included tall annuals with leaves on stalk that grows directly from the ground (Therop11), small annuals with a leafless stalks growing directly from the ground (Therop04), medium-sized annuals with a circular arrangement of leaves at a similar height of the stalk growing directly from the ground (Therop08) and medium-sized annuals with leafless stalks growing directly from the ground (Therop05). In quadrat group I, nanophyllous normal-sized evergreen shrubs with irregular crown extending to near the base of the shrub (Phaner05) were the dominant panerophytes or unbranched large trees with fan shaped leaves having a circular arrangement at a similar height of the trunk (Phaner09). With varying prevalence, chamaephytes were also common in this quadrat group group. These included tall evergreen semi-woody dwaf-shrub (Chamae08), typical semi-woody evergreen dwarf-shrub (Chamae03), and typical ever-green woody dwarf-shrubs (Chamae01).

Quadrat group E was unique in that it included quadrats in which a single life-form dominated at times and was not present in others; meanwhile life-forms of herbaceious species were more ubiquitous. Life-forms that dominated in certain quadrats were:

- Nanophyllous normal-sized evergreen shrub with irregular crown extending to near the base of the shrub (Phaner05)
- Tall graminoid variously lignified shrub (Phaner12)
- Typical reptant evergreen low succulant (Chamae16)

- Mesophyllous normal-sized evergreen shrub with spherical crown extending to near the base of the shrub (Phaner04)[4]

Woody and semi-woody perennial life-forms that were common in this quadrat group, but were not highly abundant, included typical ever-green woody dwarf-shrubs (Chamae01) and tall deciduous semi-woody dwarf-shrubs (Chamae05). Very tall drought-deciduous hemicryptophytes with a leafless stalk growing directly from the ground (Hemicr08) and medium-sized bulbous geophytes with stalks growing directly from the ground were common herbaceous perennial life-forms. Other common herbaceous life-forms included medium-sized annuals with leaves on stalks that growing directly from the ground (Therop10).

Quadrat groups defining life-form spectra with intermediate average representation of target species were G, H and K. In quadrat G, the life-form of the target species was still the most represented one. Other common dwarf-shrubs included tall evergreen semi-woody dwarf-shrub (Chamae04) and typical semi-woody evergreen dwarf-shrub (Chamae03). Low deciduous semi-woody dwarf-shrub creeping along the ground (Chamae06) was sometimes common. Herbacious perennials common in this quadrat group were very tall drought-deciduous hemicryptophyte with a leafless stalk growing directly from the ground (Hemicr08), tall drought-deciduous hemicryptophyte with a stalk growing directly from the ground having a circular arrangement of leaves at its base

[4] This life-form was dominant in its sample, but it had a restricted abundance compared to the other life-forms listed. In sites were it was prevalent, *Matthiola crassifolia* was excluded. Refer to quadrat group M.

(Hemicr09). Medium-sized therophytes with leafless stalks growing directly from the ground (Therop05) were common annuals. An irregularity in this quadrat group was medium-sized reptant sparingly evergreen hemicryptophyte with bunched and spreading shoot arrangements (Hemicr06). This life-form was only highly represented in a single quadrat in which the target species was not represented. This life-form – along with the pronounced representation of herbaceous species - is suspected of compromising the representation of the life-form of the target species in this quadrat group. Quadrat group H illustrated how in an anthropogenic area high representation of life-forms describing ruderal species lays down the architecture of the physiognomy of admixed vegetation. Tall evergreen semi-woody dwarf-shrubs (Chamae04) were the key indicator life-form of this group. Other common dwarf shrubs in this group were typical ever-green woody dwarf-shrubs (Chamae01) and typical semi-woody evergreen dwarf-shrub (Chamae03) III 3. Three evergreen life-forms representing ornamental vegetation were sometimes present and each characterized by high abundance. These were unbranched large trees with fan shaped leaves having a circular arrangement at a similar height of the trunk (Phaner09), normal-sized non-graminoid evergreen herbs with large leaf fronds (Phaner10), and low reptant evergreen low succulant (Chamae15). This quadrat group represented physiognomies of vegetation in not well maintained gardens from which weeds were not removed and physiognomies in vegetation were ornamental extotics have escaped cultivation. The life-form spectrum defined by quadrat group K described the physiognomy of vegetation occurring on sandy soils in wich reptant herbaceous perennials predominated. Typical evergreen herbaceous chamaephyte (grass) creeping along the ground (Chamae11) and medium-sized reptant with a bunched and spreading shoot arrangement sparingly evergreen hemicryptophyte (Hemicr06) gave this vegetation its major character. This herbaceous cover was sometimes perforated by tall evergreen semi-woody dwarf-shrub (Chamae04), tall evergreen semi-woody dwaf-shrub (Chamae08), tall evergreen herbaceous chamaephyte growing in clusters or tufts (Chamae10), Medium-sized bulbous geophyte with a stalk growing directly from the ground (Geophy02) II 3. Microphyllous normal-sized evergreen shrubs with irregular crown extending to near the base of the shrub (Phaner06) were sometimes abundantly present. Medium-sized annuals with leafless stalks growing directly from the ground (Therop05) were very common.

Quadrat groups A, B. F, J, M, N, Life-form spectra with no representation of target species. Quadrat groups A and B were dominated by vegetation that allowed for mat-formation and peat accumulation. Quadrat group A was dominated by small reptant sparingly evergreen hemicryptophytes with a bunched and spreading shoot arrangement (Hemicr04) while quadrat group B was dominated with typical evergreen herbaceous chamaephyte grass creeping along the ground in a bunched and spreading shoot arrangement (Chamae12). In quadrat group F, mesophyllous tall deciduous shrub with spherical crown extending to near the base of the shrub (Phaner07) almost completely prevented sunlight from penetrating. Also common were mesophyllous normal-sized evergreen shrubby non-graminoid herb with normal branches and leaves and crown extending to near the base of the shrub (Phaner11), as well as tall drought-deciduous hemicryptophytes with leaved stalks growing directly from the ground (Hemicr11). The life-form spectrum defined to quadrat group J was dominated by microphyllous normal-sized evergreen shrubs with spherical crowns extending to near their base (Phaner03). The typical evergreen herbaceous chamaephyte (grass) creeping along the ground (Chamae11) was well represented. Quadrat group L was predominated by typical evergreen herbaceous chamaephyte creeping along the ground in a bunched and spreading shoot arrangement (Chamae12). Such an arrangement of shoots woud allow for mat-formation and peat accumulation. Less common in this vegetation assemblage were the typical semi-woody evergreen dwarf-shrubs (Chamae03). Medium-sized annual with a leafless stalk growing directly from the ground (Therop05) were also common. Quadrats groups M and N both had a single life-form almost exclusively dominating their vegetation. Quadrat group M was exclusively dominated by a mesophyllous normal-sized evergreen shrub life-form with spherical crown extending to near the base of the shrub (Phaner04) while quadrat group N was exclusively dominated by a mesophyllous evergreen large tree life-form with spherical crown restricted to the upper half of tree (Phaner01).

B. Life-form spectra defined for *Limonium mouterdei detailed physiognomic data*

Life-form spectra with highest representation of *Limonium mouterdei* were quadrat groups A, B and D. Both quadrat groups A and D were characterized by having nanophyllous normal-sized evergreen shrubs with irregular crown extending almost to the base (Phaner05) and typical semi-woody evergreen dwarf-shrubs (Chamae03), but quadrat group D also had a significant abundance of medium-sized annual species with leafless stalks growing directly from the ground (Therop05). In quadrat group B, evergreen dwarf-shrubs were most common. These were typical evergreen woody dwarf-shrubs (Chamae01), typical semi-woody evergreen dwarf-shrubs (Chamae03) and tall semi-woody evergreen dwarf-shrubs (Chamae04).

Life-form spectra defined by quadrat groups C and F had an intermediate representation of target species. Quadrat group C was characterized a by a pronounced abundance of tall evergreen semi-woody dwarf-shrubs (Chamae04). Other dwarf-shrubs were also represented, but they weren't as common (Chamae03, Chamae8). Quadrat F was dominated by typical evergreen herbaceous chamaephytes that creep along the ground in a bunched and spreading shoot arrangement (Chamae12). Such an arrangement would allow for mat-formation and peat accumulation. Typical semi-woody evergreen dwarf-shrubs (Chamae03), tall evergreen semi-woody dwaf-shrubs (Chamae08) and medium-sized annuals with leafless stalks growing directly from the ground (Therop05) were also common.

Quadrat group E was the only life-form spectrum without representation of the target species. All life-forms common in this quadrat group were either herbaceous perennials or annuals. These were very tall drought-deciduous hemicryptophytes with a leafless stalk growing directly from the ground (Hemicr08), tall drought-deciduous hemicryptophytes with a leaved stalk growing directly from the ground (Hemicr11), medium-sized annuals with a leafless stalk growing directly from the ground (Therop05) and tall annuals with leaves on a stalk growing directly from the ground (Therop11).

C. Life-form spectra defined for *Limonium postii detailed physiognomic data*

Life-form spectra with the highest representation of *Limonium postii* were quadrat groups B and C. Quadrat group B was characterized by a dominance of typical semi-woody evergreen dwarf-shrubs (Chamae03) and tall evergreen semi-woody dwarf-shrubs (Chamae04). Medium-sized annuals with leafless stalk growing directly from the ground were also common. Quadrat group C was dominated with typical semi-woody evergreen dwarf-shrubs (Chamae03), typical woody evergreen dwarf-shrubs (Chamae01) and tall semi-woody evergreen dwarf-shrubs**.** This group of quadrats less commonly included nanophyllous normal-sized evergreen shrubs with irregular crowns extending to near their base (Phaner05). In both quadrat groups B and C, annuals consistantly had a fair representation; small to medium sized annuals with leafless stalks growing directly from the ground (Therop04 and Therop05) as well as medium-sized and tall annuals with leaved stalks growing directly from the ground were most common.

Quadrat groups A and D had no representation of the target species. Quadrat group A represented a single quadrat collected from a nearby pedestrian path. It was dominated by tall evergreen semi-woody dwaf-shrub (Chamae08). Quadrat group D represented a quadrat collected from a relatively large adjacent area characterized by a dominance of typical evergreen herbaceous chamaephyte creeping along the ground in a bunched and spreading shoot arrangement (Chamae12). This arrangement of reptant shoots allowed for both mat-formation and peat accumulation. Puncturing through the reptant graminoid shoots were tall scapose annuals (Therop05).

Life-forms of dominant perennial vegetation occurring in samples with highest representation of target species include the life-form of the target species itself and typical semi-woody evergreen dwarf-shrubs (Chamae03).

The only life-form of dominant perennial vegetation strictly occurring in samples with no representation of target species is Chamae12. It describes typical evergreen herbaceous chamaephyte creeping along the ground in a bunched and spreading shoot arrangement (allowing for mat-formation and peat accumulation).

Life-forms of vegetation suspected of compromising abundance of target species when abundant are the following three life-forms: Tall evergreen semi-woody dwaf-shrubs (Chamae08), typical woody evergreen dwarf-shrub (Chamae01) , typical semi-woody evergreen dwarf-shrub (Chamae03).

All three life-forms belong to the other three chamaephytes that define the species communities in this habitat. Although shown by Wilson (2007) to be unlikely, since all four species have similar physiognomies, it is possible that these species are competing for space. Another possibility is that these species might be competing for a scarse resource such as water in summer.

APPENDIX V

ENVIRONMENTAL DATA

A. Environmental data collected for *Matthiola crassifolia*

Table 23: Means, standard deviations, maxima and minima of the 12 variables measured in the survey of *Matthiola* crassifolia sites in Beirut

Environmental Variable			Sampled quadrats 1	2	3
1	Vegetation height				
		Mean	4.225	4.304	4.533
		Max	6.000	6.000	6.000
		Min	1.000	2.000	3.000
		S.D.	1.147	0.971	0.869
2	Bare ground (see text)				
		Mean	3.444	3.696	3.533
		Max	6.000	6.000	6.000
		Min	1.000	1.000	1.000
		S.D.	1.700	1.413	1.424
3	Hard surfaces (see text)				
		Mean	3.844	3.643	3.267
		Max	6.000	6.000	6.000
		Min	1.000	1.000	1.000
		S.D.	2.011	1.813	1.802
4	Anthropogenic hardscape cover (see text)				

	Mean	1.933	1.679	1.622
	Max	6.000	6.000	6.000
	Min	1.000	1.000	1.000
	S.D.	1.514	1.403	1.419
5	Persistant vegetation cover (see text)			
	Mean	4.000	4.000	4.111
	Max	6.000	6.000	6.000
	Min	1.000	2.000	2.000
	S.D.	1.477	0.991	0.935
6	Bryophytes(see text)			
	Mean	1.000	1.161	1.200
	Max	1.000	4.000	4.000
	Min	1.000	1.000	1.000
	S.D.	0.000	0.596	0.661
7	Litter cover (see text)			
	Mean	3.356	3.339	3.467
	Max	6.000	6.000	6.000
	Min	1.000	1.000	1.000
	S.D.	1.401	1.325	1.408
8	Litter type (see text)			
	Mean	1.378	1.071	1.089
	Max	5.000	2.000	2.000
	Min	1.000	1.000	1.000
	S.D.	0.912	0.260	0.288

9	Anthropogenic litter cover (see text)			
	Mean	1.533	1.768	1.756
	Max	3.000	6.000	6.000
	Min	1.000	1.000	1.000
	S.D.	0.548	0.991	1.090
10	Microtopography (see text)			
	Mean	2.932	3.054	2.844
	Max	5.000	5.000	5.000
	Min	1.000	1.000	1.000
	S.D.	1.591	1.381	1.364
11	Exposure to direct sunlight at the level of target species (see text)			
	Mean	2.068	1.893	1.889
	Max	5.000	4.000	4.000
	Min	1.000	1.000	1.000
	S.D.	0.974	0.888	0.959
12	Degree of human interference (see text)			
	Mean	1.556	1.411	1.378
	Max	5.000	3.000	3.000
	Min	1.000	1.000	1.000
	S.D.	0.755	0.565	0.535

The first column corresponds to all sampled quadrats for target species. The second column corresponds to sampled quadrats where target species was present. The third column indicates corresponds to sampled quadrats where presence of target species was characterized by high recruitment.

B. Environmental data collected for *Limonium mouterdei*

Table 24: Means, standard deviations, maxima and minima of the 12 riables measured in the survey of *L. mouterdei* at its last remaining site in Beirut

Environmental Variable		Sampled quadrats 1	2	3
1	Vegetation height (see text)			
	Mean	3.944	3.750	3.500
	Max	5.000	5.000	5.000
	Min	2.000	2.000	2.000
	S.D.	1.056	1.138	1.080
2	Bare ground (see text)			
	Mean	3.889	4.333	4.800
	Max	6.000	6.000	6.000
	Min	1.000	1.000	3.000
	S.D.	1.844	1.371	0.789
3	Hard surfaces (see text)			
	Mean	4.611	5.083	5.400
	Max	6.000	6.000	6.000
	Min	1.000	2.000	4.000
	S.D.	1.685	1.165	0.699
4	Anthropogenic hardscape cover (see text)			
	Mean	1.667	1.417	1.500
	Max	6.000	3.000	3.000
	Min	1.000	1.000	1.000
	S.D.	1.328	0.793	0.850

5	Persistant vegetation cover (see text)			
	Mean	3.778	3.833	3.400
	Max	6.000	6.000	4.000
	Min	1.000	2.000	2.000
	S.D.	1.437	1.193	0.699
6	Bryophytes (see text)			
	Mean	1.000	1.000	1.000
	Max	1.000	1.000	1.000
	Min	1.000	1.000	1.000
	S.D.	0.000	0.000	0.000
7	Litter cover (see text)			
	Mean	3.444	3.167	2.800
	Max	6.000	6.000	4.000
	Min	2.000	2.000	2.000
	S.D.	1.423	1.115	0.632
8	Litter type (see text)			
	Mean	1.389	1.167	1.000
	Max	3.000	3.000	1.000
	Min	1.000	1.000	1.000
	S.D.	0.778	0.577	0.000
9	Anthropogenic litter cover (see text)			
	Mean	1.500	1.333	1.200
	Max	2.000	2.000	2.000
	Min	1.000	1.000	1.000

	S.D.	0.514	0.492	0.422
10	Microtopography (see text)			
	Mean	3.944	4.250	4.300
	Max	5.000	5.000	5.000
	Min	2.000	2.000	2.000
	S.D.	1.211	0.965	0.949
11	Exposure to direct sunlight at the level of target species (see text)			
	Mean	2.056	2.083	2.100
	Max	3.000	3.000	3.000
	Min	2.000	2.000	2.000
	S.D.	0.236	0.289	0.316
12	Degree of human interference (see text)			
	Mean	1.056	1.000	1.000
	Max	2.000	1.000	1.000
	Min	1.000	1.000	1.000
	S.D.	0.236	0.000	0.000

The first column corresponds to all sampled quadrats for target species. The second column corresponds to sampled quadrats where target species was present. The third column indicates corresponds to sampled quadrats where presence of target species was characterized by high recruitment.

C. Environmental data collected for *Limonium postii*

Table 25: Means, standard deviations, maxima and minima of the NN variables measured in the survey of L. postii at its last remaining site in Beirut

Environmental Variable			Sampled quadrats 1	2	3
1	Vegetation height (see text)				
		Mean	3.429	2.750	2.750
		Max	5.000	3.000	3.000
		Min	2.000	2.000	2.000
		S.D.	1.134	0.500	0.500
2	Bare ground (see text)				
		Mean	4.143	4.000	4.000
		Max	6.000	5.000	5.000
		Min	1.000	3.000	3.000
		S.D.	1.864	1.155	1.155
3	Hard surfaces (see text)				
		Mean	5.000	5.250	5.250
		Max	6.000	6.000	6.000
		Min	2.000	5.000	5.000
		S.D.	1.414	0.500	0.500
4	Anthropogenic hardscape cover (see text)				
		Mean	2.000	2.250	2.250
		Max	3.000	3.000	3.000
		Min	1.000	1.000	1.000
		S.D.	1.000	0.957	0.957

5	Persistant vegetation cover (see text)				
		Mean	3.571	3.500	3.500
		Max	6.000	5.000	5.000
		Min	2.000	3.000	3.000
		S.D.	1.397	1.000	1.000
6	Bryophytes (see text)				
		Mean	1.000	1.000	1.000
		Max	1.000	1.000	1.000
		Min	1.000	1.000	1.000
		S.D.	0.000	0.000	0.000
7	Litter cover (see text)				
		Mean	2.714	2.000	2.000
		Max	6.000	2.000	2.000
		Min	2.000	2.000	2.000
		S.D.	1.496	0.000	0.000
8	Litter type (see text)				
		Mean	1.286	1.000	1.000
		Max	3.000	1.000	1.000
		Min	1.000	1.000	1.000
		S.D.	0.756	0.000	0.000
9	Anthropogenic litter cover (see text)				
		Mean	1.286	1.250	1.250
		Max	2.000	2.000	2.000
		Min	1.000	1.000	1.000

		S.D.	0.488	0.500	0.500
10	Microtopography (see text)				
		Mean	3.714	4.250	4.250
		Max	5.000	5.000	5.000
		Min	2.000	3.000	3.000
		S.D.	1.380	0.957	0.957
11	Exposure to direct sunlight at the level of target species (see text)				
		Mean	2.143	2.000	2.000
		Max	3.000	2.000	2.000
		Min	2.000	2.000	2.000
		S.D.	0.378	0.000	0.000
12	Degree of human interference (see text)				
		Mean	1.143	1.250	1.250
		Max	2.000	2.000	2.000
		Min	1.000	1.000	1.000
		S.D.	0.378	0.500	0.500

The first column corresponds to all sampled quadrats for target species. The second column corresponds to sampled quadrats where target species was present. The third column indicates corresponds to sampled quadrats where presence of target species was characterized by high recruitment.

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