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Patterns of floristic diversity in semi-natural coastal vegetation of Lebanon and implications for conservation

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Abstract. The current understanding of the status of the vegetation in Lebanon is largely derived from herbarium data and associated floristic studies produced by early 20th century field botanists. In common with other areas in the Mediterranean, the Lebanese coastline is highly threatened by unregulated development, yet current patterns of species richness along the Lebanese coastal zone are little studied. The objective of this study was to assess the floristic richness of the Lebanese coastal zone and to provide baseline information for conservation planning. For this purpose, permanent sample plots (6 m × 100 m) were established in 26 selected vegetation communities in coastal habitats. Monthly field collections of plant specimens were undertaken between October 1999 and July 2000. A total of 441 species were collected and identified. None of the recorded species are currently considered globally threatened, but two are Lebanese endemics (*Matthiola crassifolia* Boiss. & Gaill., *Origanum ehrenbergii* Boiss.). Species richness varied between communities, ranging from six species in a littoral limestone pavement community to 113 in an abandoned terrace community. The similarity between communities, based on Sorensen indices, was low and a large number of species were recorded only once. Cluster analysis showed a grouping of different communities within locations in some instances and the clustering of similar community types regardless of location in others. Species richness in riparian and littoral communities consisted mostly of habitat non-specific species. The low community similarity, patchy species distribution, and predominance of habitat non-specific species all point to the need to complement *in situ* conservation measures with *ex situ* conservation.

Introduction

Located at crossroads between Europe, Asia, and Africa, the Mediterranean Basin contains botanical elements from temperate, arid, and tropical biomes creating what is recognized as typical Mediterranean botanical habitats (Post and Dinsmore 1933; Mouterde 1970; Blondel and Aronson 1999; Blamey and Grey-Wilson 1998). The Basin has also experienced the oldest and heaviest human disturbances such as fire setting, clear-cutting, ploughing, heavy browsing and grazing. The varied land-use practices have led to a richness of annual and ephemeral plants, and to high plant

diversities in frequently and moderately disturbed sites. Today the region harbors a large percent of endemic species (50%), and is recognized as one of the 25 world hotspots for plant diversity in need of conservation support (Myers et al. 2000).

Lebanon, located on the Mediterranean littoral, presents a climatic and ecological diversity that is unique to the eastern Mediterranean region and the whole country is recognized as a centre of plant diversity (WWF and IUCN 1994). An estimated 2,600 plant species are recorded in Lebanon, of which 221 are broad endemics and 90 are narrow endemics (WWF and IUCN 1994; Khouzami et al. 1996). Among the most threatened areas in Lebanon is the coastline that has become a chaotic matrix of tourist resorts, private beaches, agricultural lands, industrial and urban development. This problem is not unique to Lebanon. The loss of native coastal vegetation due to unregulated urban and tourist development is well known in the Mediterranean Basin (Greuter 1979; Wisheu et al. 1994; King et al. 1997; Kutiel 2001). In addition, agriculture expansion, and the associated deep plowing, has destroyed many coastal communities (Gomez-Campo 1985; WWF and IUCN 1994). The main purpose of this study was to undertake a baseline investigation of the floristic composition of typical coastal communities with a view to developing practical recommendations for their conservation.

Materials and methods

Study area

Selection criteria for the sites were designed to capture the floristic richness of different semi-natural vegetation community types existing on the Lebanese coast. Lebanon lies on the eastern shores of the Mediterranean and spans over 10,452 km^2, with a coastal length of approximately 220 km. The coastal zone consists of a relatively narrow strip that is confined by a mountain range (the Lebanon Range), which reaches a maximum altitude of 3,088 m and acts as a barrier to the intrusion of steppe plants into the Mediterranean zones (Zohary 1973). Mild frost-free winters and hot dry summers lasting 6 months characterize the Lebanese coastline. The flowering season starts with a few species in February, but most are in bloom between mid March and late May. Precipitation is abundant between December and March, and ranges between 650 mm in the south of the country, increasing to 990 mm northwards. All study locations were selected from this coastal strip and included littoral plant communities as well as inner coastal communities within 5 km distance from the sea or a 500-m altitudinal limit.

Field sampling

Potential study locations were selected according to two basic criteria namely soil type and land use. These primary criteria were used to locate plant communities in

semi-natural environments growing on different soil types. For this purpose a digitized soil map of Lebanon was used to identify soil types prevalent in the defined coastal zone. Twenty soil types were recorded on the coastal zone and these were grouped using GIS into seven major soil types according to relatedness of parent material and degree of soil evolution. The consolidated soil map was then overlaid, using GIS, with a digitized land use map of Lebanon. This allowed the location of areas reported as semi natural, and the selection of those with distinct soil types. Field visits were then made to selected sites and the number of locations was further reduced by a secondary criterion, namely accessibility to the location. In some cases the areas were fenced and therefore access was restricted, while in others the sites were too steep and were therefore physically inaccessible. Zones in the southern areas of the country that were reported to contain landmines were naturally not visited. Eventually 11 locations were selected for the study (Figure 1). Depending on the size and heterogeneity of the location one or more community type were identified in each location. These amounted to a total of 26 vegetation communities distributed along the littoral or the inner coast (Table 1). Littoral communities included rocky beach, cliff face, limestone pavement, sandy shoreline, and littoral abandoned agricultural field. Inner coastal communities included riparian, oak/pine woodland, oak woodland, rock community, garigue (degenerate Mediterranean scrub), abandoned agricultural fields, pine woodland, maquis (thick scrubby underbush), olive grove, and abandoned hills previously cultivated as agricultural terraces.

In many of the selected locations communities were sporadic and vegetation density was sparse. The collection methodology was devised to achieve the following aims: Standardize the size of collection plots between different vegetation communities, capture the maximum vegetative cover within each community, and to complete all collection expeditions in the first 10 days of each month. Permanent collection lines, 100 m long, were thus laid out in each vegetation community and plants were collected within 3 m on both sides of the line. Collection expeditions were initiated in October 1999 and repeated on a monthly basis until July 2000. Field data recorded comprised: date of collection, location, ground coordinates using GPS (Trimble GeoExplorer II), aspect, plant reference number and name of collectors. Where field identification was possible the family and scientific name for each species was recorded, otherwise a numerical code was assigned. Specimen notes and habitat details were also recorded.

At every sampling visit all species of plants rooted within the 600 m^2 plot were recorded. Voucher specimens of every species were collected and herbarium specimens prepared. Taxonomic identification and nomenclature of the plants was based on published floras (Post and Dinsmore 1933; Mouterde 1970).

Data analysis

Species richness was measured as the total number of species per 600 m^2 plot. Species were also classified according to life form namely annuals, biennials, and

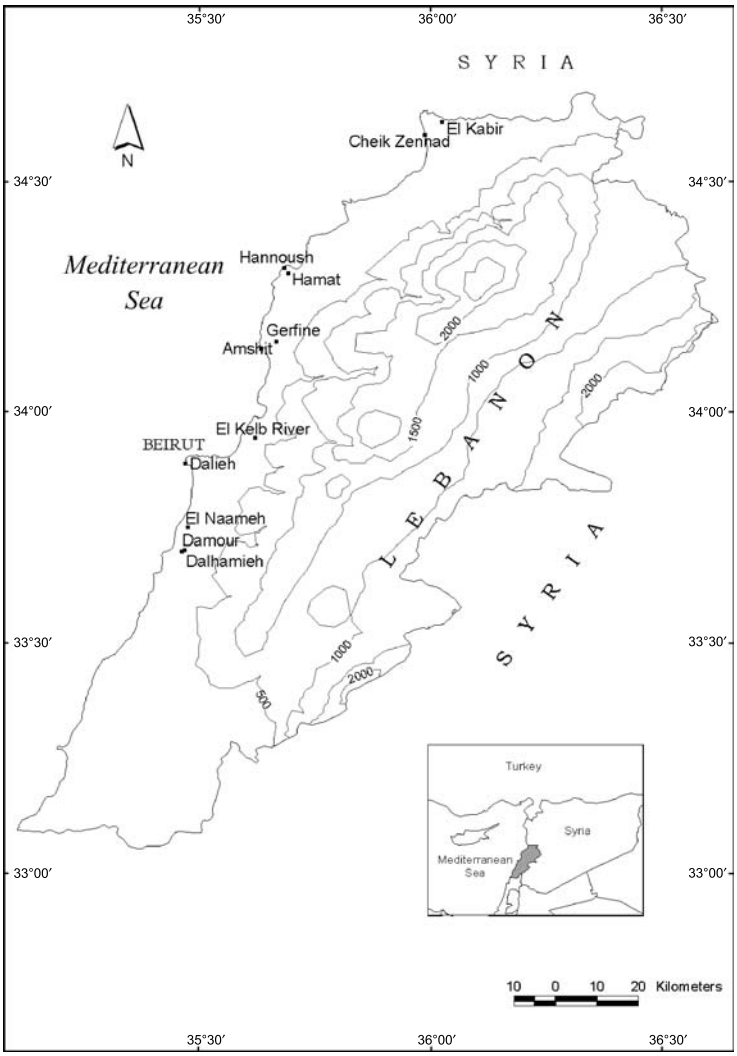

Figure 1. Distribution of study sites (semi-natural vegetation communities) along the coast of Lebanon.

perennials (Post and Dinsmore 1933; Mouterde 1970), and their frequency calculated. The Sorensen Index of Similarity ($I_{sor} = 2a/(2a + b + c)$, where $a =$ species common to two communities, $b =$ species found in one community, and $c =$ species found in the other community) was used to assess the floristic relationship between communities at the species level (Sorensen 1948). Cluster analysis was performed to separate community types based on similarity indices using SPSS software (Version 9.0, 1999). In cases where specimens could not be identified to species level, they were considered as a single species in the analyses.

Table 1. Ecogeographic description of selected plant communities on the Lebanese coast.

	Community	Location	Community code	Elevation (m)	Slope	Aspect	Soil type
Littoral	Sandy beach	Cheikh Zennad	sb-CH	2	1%	Exposed	Recent coastal sand
	Littoral abandoned field	Hannoush	laf-HAN	1	6%	West	Discontinuous red soil
	Rocky beach 1	Amshit	rb1-AM	20	7.5%	South/West	Discontinuous brown and red soil
	Rocky beach 2		rb2-AM				
	Cliff face		cl-AM				
	Limestone pavement		pav-AM				
	Rocky beach	Dalieh	rb-DA	30	1%	South/West	Discontinuous mixed soil with white limestone
	Cliff face		cl-DA				
	Limestone pavement		pav-DA				
Inner Coastal	Riparian	El Kabir River	ri-KA	10	7.5%	Exposed	Arable soils
	Abandoned field	Hamat	af-HAM	175	0%	West	Discontinuous red soils
	Rock outcrops		ro-HAM	175	4%	West/South	
	Oak woodland		ow-HAM	175	4%	West/South	
	Maquis	Gerfine	ma-GH	250	4.5%	West	Discontinuous red soils
	Garigues	El Kelb River	ga-KE	100	20%	South	Mixed soils
	Oak/pine interface		op-KE	100	22%	West/North	Discontinuous red soils
	Riparian		ri-KE	100	0%	Exposed	Sandy soils
	Oak/pine interface	El Naameh	op-NA	175	50%	West	Mixed soils on Marl with calcareous chert beds
	Pine woodland		pw-NA	175	30%	West	Mixed soils on Marl with calcareous chert beds
	Garigues		ga-NA	175	24%	North/East	Grey soils

Table 1. continued.

	Community	Location	Community code	Elevation (m)	Slope (%)	Aspect	Soil type
	Oak/pine interface	Damour	op-DAM	125	22	South/West	Mixed soils on Marl with – calcaneous chert beds
	Riparian		ri-DAM	100	0	Exposed	Alluvials
	Rock		ro-DAM	125	22	South/West	Alluvials
	Olive Groves		og-DAM	125	22	South/West	White-greyish soils
	Abandoned terraces	Dalhamieh	at-DAL	250	20	North/East	Mixed soils on Marl with calcareous chert beds
	Oak woodland		oOw-DAL	250	20	North/East	Mixed soils on Marl with calcareous chert beds

Table 2. List of main families represented in selected plant communities on the Lebanese coast (total number of collected species 441).

Family	Number of collected species	percentage of collected species
Asteraceae	61	14
Fabaceae	50	11
Poaceae	47	11
Lamiaceae	26	6
Apiaceae	25	6
Brassicaceae	18	4
Liliaceae	13	3
Boraginaceae	11	2
65 families	Less than 10 sp.	43

Results

Floristic composition

The recorded floral richness in all selected coastal communities totaled 441 species from 287 genera and 73 families (Dardas 2000; Dagher 2001). This represented approximately 28% of the total reported coastal flora (Post and Dinsmore 1933; Mouterde 1970). Some of these species are of conservation significance. Two species are endemic to Lebanon, *Matthiola crassifolia* Boiss. & Gaill. (Brassicaceae) and *Origanum ehrenbergii* Boiss. (Lamiaceae). Three species are listed as threatened in the Lebanese Biodiversity Study, although none have yet been formally assessed using the IUCN Red List categories (NBSAP 1998), 39 species are reported as medicinal plants, and one is a wild-collected commercial flower (*Narcissus tazetta* L., Amaryllidaceae). Eight families contributed 57% of the floristic structure of the selected communities. These were Asteraceae, Fabaceae, Poaceae, Lamiaceae, Apiaceae, Brassicaceae, Liliaceae, and Boraginaceae (Table 2).

Alpha diversity

Mean richness of the entire sampled communities was 38 and 54 species 600 m^2 for littoral and inner coastal communities respectively (Table 3), and a large degree of variation between sites was noted. Among littoral communities, rocky beaches (rb1-AM, rb2-AM) were the richest (61 and 62 species, respectively), while the poorest community (six species) was found on limestone pavement (pav-DA) (Table 3). Among inner coastal communities, the abandoned terrace community (at-DAL) was the richest (113 species), while the poorest was the oak woodland (ow-HAM) (19 species) (Table 3).

Table 3. Species richness and percent annual and perennial species in selected coastal Lebanese plant communities.

	Community type	Community	Species richness	% annuals	% perennials
Littoral	Sandy Beach	sb-CH	38	61	29
	Littoral abandoned field	laf-HAN	47	49	43
	Rocky beach	rb1-AM	61	64	31
		rb2-AM	62	63	31
		rb-DA	38	45	50
	Pavement	pav-AM	14	57	36
		pav-DA	6	17	83
	Cliff face	cl-AM	44	59	32
		cl-DA	33	33	61
Inner Coast	Riparian	ri-KA	53	55	43
		ri-KE	96	56	39
		ri-DAM	81	54	38
	Oak/pine Interface	op-KE	23	18	73
		op-NA	26	15	81
		op-DAM	32	3	97
	Pine woodland	pw-NA	31	52	43
	Oak woodland	ow-HAM	19	37	58
		ow-DAL	47	43	53
	Olive groves	og-DAM	46	49	45
	Garigues	ga-NA	63	52	41
		ga-KE	46	40	57
	Rock outcrop	ro-DAM	56	43	55
		ro-HAM	26	58	39
	Maquis	ma-GH	60	57	40
	Abandoned field	af-HAM	92	53	41
	Abandoned terraces	at-DAL	113	56	41

Community structure and species distribution

Annual plants constituted more than 50% of the total recorded species in 6 out of 26 communities (Table 3). More than a third of the collected species were found in only one of the 26 communities and none were recorded in all communities (Figure 2). In contrast, much of the species richness in the different coastal communities resulted from a large number of species occurring at low frequency where the number of species found in more than one community decreased with increasing number of communities visited.

Similarity indices and cluster analysis

Similarity indices of pair-wise comparisons were low ranging from 0 to 0.563 for I_{sor}, at the species level and cluster analysis divided the selected communities into three main groups sharing very little similarity (Figure 3).

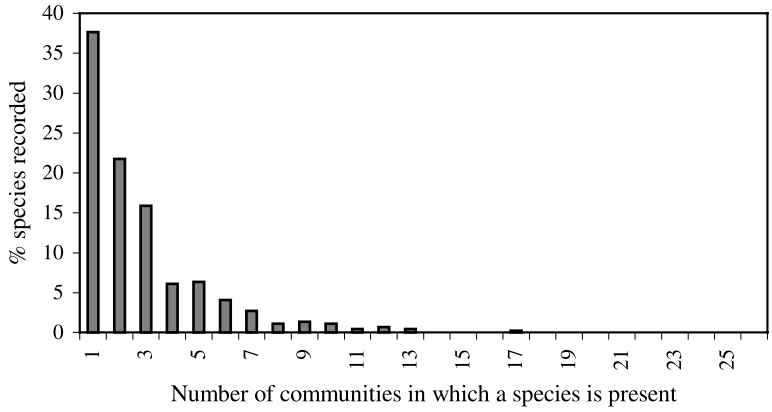

Figure 2. Frequency distribution of plant species in selected communities of the Lebanese coast.

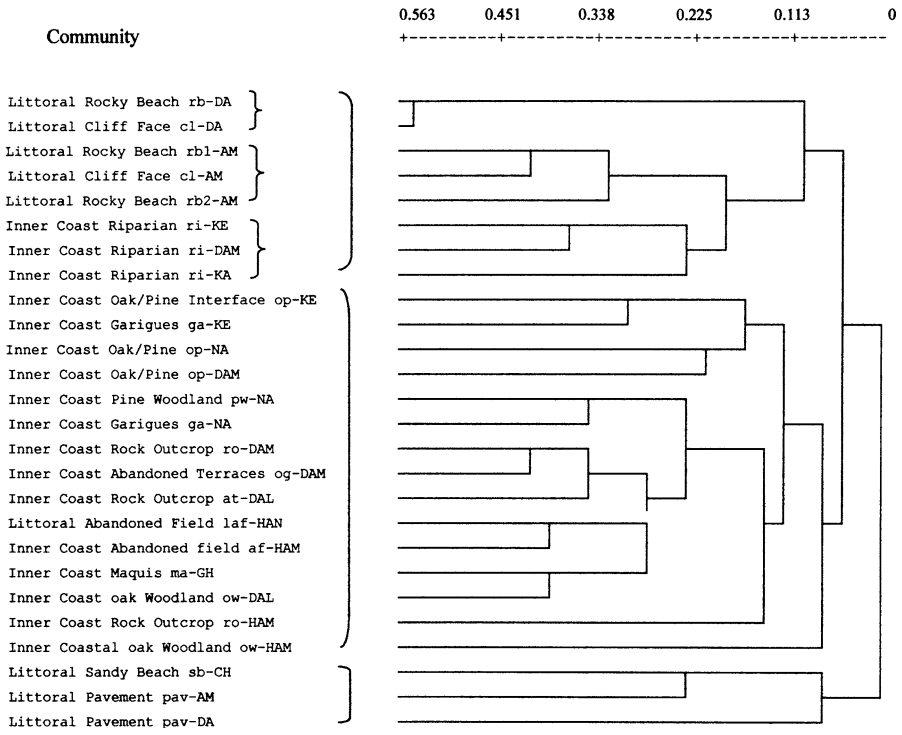

Figure 3. Dendogram of 26 selected coastal plant communities based on the Sorensen Index of similarity at the species level.

The first division separated the sandy beach community (sb-CH) and limestone pavement communities (pav-DA, pav-AM) from all others indicating no similarity ($I_{sor} = 0$) between these communities and the remaining coastal ones. The second

split ($I_{sor} = 0.056$) grouped all rocky beach, cliff face, and riparian communities into one cluster and all remaining inner coastal communities in another. This cluster was further divided into three groups: two groups that included different vegetation communities from the same location (rb-DA/cl-DA and rb1-AM/cl-AM/rb2-AM) and one that included all riparian communities (ri-KE/ri-DAM/ri-KA) from different locations. The third main cluster included all inner coastal communities (except riparian ones) and was further divided into several groups which did not seem to aggregate based on vegetation type or location proximity.

Discussion

The results of this study constitute the basis for further inventorying and subsequent decision-making regarding conservation plans for the Lebanese coastal zone. Some of the findings have important implications when planning conservation strategies. These include the noted large variation in species richness between communities, the fact that most recorded species were found in only one of the 26 communities, and that communities within close proximity of each other were not consistently similar in terms of floristic composition. In addition most semi-natural coastal communities occupied relatively small areas that were typically interspersed within urban, industrial, and agriculture landscapes. The conservation of these communities is further complicated by the fact that national environmental organizations perceive these habitats as insignificant landscapes and have focused instead on the conservation of vegetation communities with a culturally built in value (such as Cedar and Pine forests), or with a regional significance (such as wetlands).

A step involving the identification of coastal lands where the conservation of semi-natural communities would be considered has been initiated and 25 sites have been proposed. Ten of these sites were characterized as potential nature reserves requiring protection, eight as degraded areas requiring protection, and seven as degraded areas requiring rehabilitation (SOER 2001). The protection of these and other sites, however, might not be easily implemented given the high real estate value on the coastline, which constitutes only 13% of the total area of the country yet harbors more than half the Lebanese population estimated at 4.3 million (SOER 2001). In fact, urban expansion on the Lebanese coast constitutes the highest threat to biodiversity. Evidence of this threat was clearly felt during the course of this study (10 months) in which two out of the 26 study plots were destroyed by urban expansion, thus giving an idea of the rate at which loss of semi-natural habitats is occurring.

The study also revealed that cliff face communities shared similarity to nearby rocky beach communities and may therefore play an important role in conservation as inaccessible plant refuges. Rocky beaches had the highest species richness but these habitats are highly threatened. Rocky beaches are usually destroyed because the landscape is generally not appreciated as a natural asset, instead beach users commonly conceive it as unfriendly space. As such, developers tend to remove the rocks and replace them, or fill them with structural material or sand/soil to create a flat usable space, a more desirable artificial sandy beach, or a lawn area.

The recommendation to establish *ex situ* facilities in addition to *in situ* measures has been proposed (NBASP 1998). Today, however, such a recommendation may not constitute a viable option for coastal vegetation; given the current national socio-economic situation, the establishment of an *ex situ* facility, such as a botanic garden, for the coastal flora is unlikely to compete with more visible flora at higher altitudes where the vegetation is more attractive and therefore more conducive to awareness campaigns and conservation activities. An *ex situ* facility on the coast is clearly at a disadvantage in this respect and is unlikely to rank high in national priorities. In this context, given the limited national resources which prohibit the creation and maintenance of botanic gardens, and the difficulty the country is already experiencing to sustain the protection and management of declared protected areas, alternative venues need to be examined for conservation. The authors propose to investigate options for exploring lands, with specified uses, that have not conventionally been considered as potential conservation refuges. For instance, open spaces on the Lebanese coast that are relatively 'protected' from urban and agricultural encroachment include archeological and historic sites, religious holdings, and university campuses. These might become the only options in the near future for *in situ*/*ex situ* conservation of coastal vegetation. An investigation is needed to assess the economic, socio-cultural, and biological feasibility of establishing and maintaining plant species and vegetation communities in these sites, and develop mechanisms to sustain this proposed multifaceted land use. Meanwhile, attempts should be made to identify species with a relatively restricted coastal distribution and target their habitats for conservation.

Attempts were initiated in this study to identify species with a distribution restricted to two most threatened coastal habitats, namely those thriving on the littoral and riverbanks by further analyzing the data to estimate the number of species restricted to these habitats. For this purpose substractive analysis was performed to identify those species whose presence was restricted to vegetation communities of the littoral and riverbanks from those generally distributed throughout the coast. The analysis revealed that only a third (34%) of the species recorded in littoral habitats were littoral-specific while the remaining 178 species were found in various plant communities along the coast. These littoral specific species belonged to 27 families, however, only five families contributed 50% of the littoral specific species and these were Asteraceae, Poaceae, Fabaceae, Brassicaceae, and Boraginaceae. In addition, communities with high floristic richness (more than 50 species/600 m^2) included a lower percentage of littoral specific species (25%) (Figure 4). In contrast, species poor communities, such as those thriving on pavements, had the lowest absolute number of species (15 and 6 species/600 m^2 for pavement vegetation of Amshit and Dalieh respectively) but the highest percentage of littoral specific species (more than 50%).

The study also revealed that the noted high floristic richness along riverbanks was not attributed to the large number of riparian specific species rather by a large number of habitat non-specific ones (Figure 5). To identify species specific to riparian habitats the substractive analysis was performed between all species recorded on the coast and those recorded in the three selected riverbank communities. The

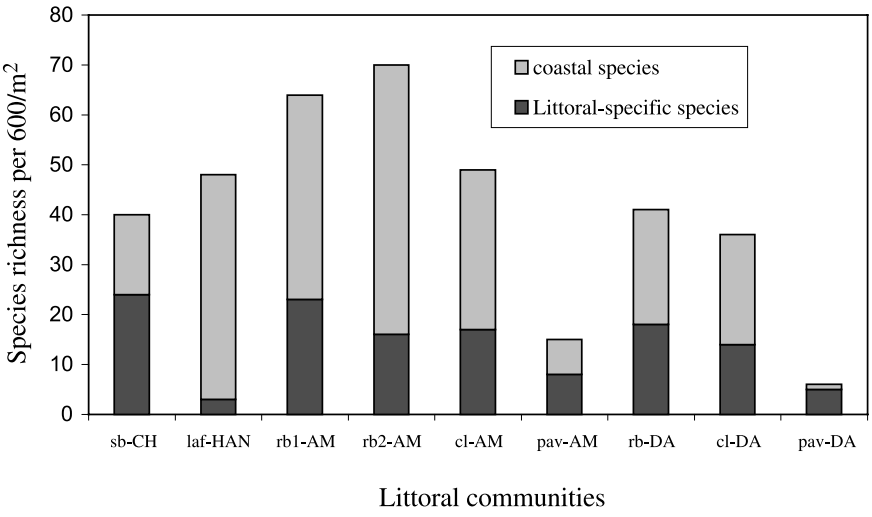

Figure 4. Relative number of littoral specific species in selected semi-natural vegetation communities on the coast of Lebanon.

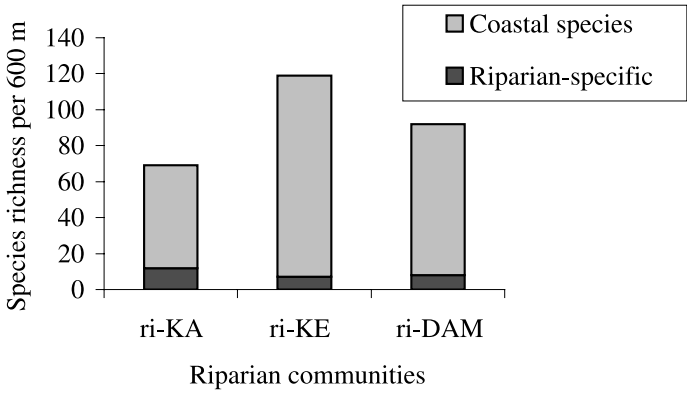

Figure 5. Relative number of riparian specific species in selected semi-natural vegetation communities on the coast of Lebanon.

resulting list was further compared with published information on agricultural weeds commonly found in Lebanon (Edgecombe 1970) and older records listing species that are restricted to riparian areas (Mouterde 1970). These results indicated that conservation measures in such areas will entail active management strategies to sustain a balance between species with a relatively broad national distribution range that have receded from dry environments and are competing with riparian specific species and those that are specific to riparian habitats.

Species identified in this study as habitat specific could constitute a component of the monitoring strategy as they might be used as plant indicators for these habitats.

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