The Plant Communities of Oman's Central Coastline: A Baseline Ecological Assessment amid Rising Threats

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Abstract

In recent decades, the botanical knowledge within the Sultanate of Oman has advanced considerably. However, the coastal vegetation is comparatively understudied with much of the country's extensive coastline still undocumented. This is despite Oman's coast being faced with a plethora of threats including development, overgrazing and the invasive species *Neltuma juliflora*. This study presents the first comprehensive botanical assessment of Oman's central coastline, a region of global importance due to the high proportion of endemic floral species. We aimed to investigate species composition, determine the main floral communities and analyse factors affecting species richness to establish a baseline for future conservation and management efforts. Thirty-three sites along the central coast, between Shannah and Sawqirah, as well as Masirah Island, were surveyed. A total of 94 plant taxa were documented, 17 of which were national Red List species. Hierarchical clustering identified six floral communities and PERMANOVAs confirmed significant differences in species composition. Indicator species analysis also determined species indicative of each community type. Species richness was significantly affected by habitat type, plant community, soil type and the presence of *N. juliflora*. Sandy gravel plains and sand/gravel/clay soils supported the highest species richness likely due to greater habitat heterogeneity. Species richness was notably high around Masirah Island, as well as sites featuring coastal escarpments which supported a higher proportion of endemic species. These results highlight priority areas for conservation. Targeted monitoring and habitat protection are urgently needed to safeguard this region's unique and threatened flora.

Keywords: Oman, Coastal vegetation, Plant community structure, Endemism, Species richness, Invasive species, Baseline floristic survey, Conservation

Introduction

At the foundation of most coastal ecosystems is the coastal vegetation, which sustains ecosystem structure, function and resilience (De Battisti, 2021). Coastal vegetation has evolved to tolerate extreme habitats and must cope with severe stressors including nutrient deficiency, high salinity, low water soils as well as constant wind and salt spray (Pessoa and Lidon, 2013, Asensi and Diez-Garretas, 2017). These harsh conditions have shaped the highly specialised floral communities which characterise coastal zones.

Despite its arid climate, the Sultanate of Oman supports a diverse flora of over 1400 species from several biogeographic regions, with 13.6% of species being endemic or range-restricted (Miller et al., 1996, Patzelt, 2015). Oman has an extensive coastline of 3000 km and features an array of coastal ecosystems such as sandy beaches, salt flats (sabkha), lagoons (khawrs) and isolated pockets of mangrove (Ghazanfar, 1999, Patzelt, 2015). Floral community composition is primarily dependent on salinity, water content and soil type, and species are usually halophytic or salt-tolerant perennials (Ghazanfar, 1999, König and Fried, 2015). The local variations in abiotic factors influence composition resulting in small-scale vegetation mosaics (Abuzinada et al., 2008). Oman's coastal vegetation also provides key ecosystem services, such as carbon sequestration, erosion prevention and shoreline stabilisation (Brown et al., 2008, Claereboudt, 2019).

Although botanical research in Oman has advanced in recent decades (Lupton et al., 2016), the coastal vegetation is comparatively understudied, and many stretches of coastline remain undocumented. One understudied area is Oman's central coastline, despite the area holding high conservation value as a local centre of plant endemism (Patzelt, 2015). Most existing research on this region is limited to the Bar al Hikman Peninsula where basic floral communities have been described. To the north of the peninsula, around Shannah, Ghazanfar (1999) described a community, dominated by *Limonium stocksii* and *Zygophyllum qatarense,* characteristic of northern Oman's coastal vegetation. On the peninsula's southern edge as well as the eastern shores of Masirah Island, an *Atriplex–Suaeda* community was described, where low seaward dunes are dominated by the halophytic shrubs *Atriplex farinosa* and *Suaeda moschata* (Ghazanfar, 1999). The peninsula also supports a community of the grasses *Halopyrum mucronatum* and *Urochondra setulosa* found on stabilised dunes, while the saline plains are dominated by *Arthrocaulon macrostachyum* and *Suaeda vermiculata* (Ghazanfar et al., 2019). In areas of shallow sand, a community dominated by *L. stocksii, Cyperus aucheri* and *Sphaerocoma aucheri* is found (Ghazanfar et al., 2019). Apart from Bar al Hikman, Ghazanfar (1999) also described a community further south at Ras Madrakah, dominated by *Limonium axillare*, *Urochondra setulosa* and *Sporobolus* spp., which is more characteristic of southern Oman's coastal vegetation (Ghazanfar, 1999). The central coastline also contains isolated populations of grey mangrove, *Avicennia marina*, in sheltered habitats like khawrs (Ghazanfar et al., 2019).

Oman's coastal vegetation faces many threats. The central coastline is experiencing some of the highest development pressures within the country, resulting in habitat degradation and destruction (Patzelt, 2014, Williams et al., 2022). The once small fishing village of Duqm is now the largest Special Economic Zone in the Middle East, and vast stretches of coastline have been converted into port, fishery and tourist infrastructure (Al-Muharrami, 2019). Overgrazing is another major threat to the coastal vegetation as livestock densities in central Oman far exceed the carrying capacity of the coastal rangelands (Ministry of Agriculture and Fisheries, 2014, Claereboudt, 2019). Road construction and off-road driving along the coast directly degrades habitats and also increases access to endemic-rich areas, formerly protected by their remoteness (Anderson et al., 2019). Other threats to coastal vegetation include the invasive species *Neltuma juliflora* (Al-Wardy et al., 2021) as well as pollution especially from discarded fishing gear (van Hoytema et al., 2020).

Rationale for Study

Existing research on Oman's coastal vegetation is largely descriptive. Therefore, fine-scale, quantitative surveys are required to accurately delineate plant communities and provide up to date information on the composition and distribution of Oman's coastal flora. As anthropogenic threats increase along the central coastline, areas of conservation value must be identified. Endemic species are especially at risk because of their smaller distributions (Patzelt, 2014, Coelho et al., 2020). Endemic-rich areas along the central coastline must be identified before they are lost, so that conservation measures can be put in place to protect these globally important habitats (Anderson et al., 2019).

Study Aims

This study provides the first comprehensive botanical assessment of Oman's central coastline. We aimed to compile a species inventory with special emphasis on the threatened or range-restricted species herein referred to as Red List species (Patzelt, 2014). Furthermore, we aimed to delineate and describe the major plant communities across the central coastline and determine key indicator species. We also aimed to map species richness and analyse some of the key factors affecting species richness across the central coastline.

Methods

Study Area

The study focused on the central coastline from Shannah to Sawqirah, as well as the coastline of Masirah Island (18-21° N, 56-59° E). The central coastline is predominately characterised by a low shoreline with flat sandy beaches but also includes geomorphic variety such as coastal sabkha, khawrs, gravel plains, and rocky outcrops (Patzelt, 2015, Hereher et al., 2020). The climate is hyper-arid: mean annual temperature ranges from 26-28°C with less than 100 mm of annual rainfall (Al-Charaabi and Al-Yahyai, 2013). Some areas of the central coastline come under the influence of occasional coastal fogs (Patzelt, 2015, Borrell et al., 2019).

Vegetation Surveys

Between February-March 2024, 33 sites along the central coastline were surveyed (Fig. 1). Sites were chosen based on accessibility as well as local knowledge. To account for the mosaic and patchy distribution of the coastal vegetation, a random sampling approach was used. At each site, the boundaries were determined based on satellite imagery and field reconnaissance to capture habitat patches. Ten 5x5 m quadrats were placed at randomly generated coordinates with a minimum distance of 10 m between them. Within each quadrat, plant species were identified and counted and local site variables (e.g., soil type) were recorded. Additional species observed outside of quadrats were also recorded at each site. Plant taxa were identified by Oman Botanic Garden (OBG) experts. Oman Red List species were identified using the Oman Plant Red Data Book (OPRDB; Patzelt, 2014), as well as current knowledge from the OBG experts.

Data Analysis and Mapping

Data was analysed in R v.4.4.1 (R Core Team, 2024) with R studio (Posit Team, 2024) with the ‘tidyverse’ packages (Wickham et al., 2019). For a small number of quadrats, species counts were uncertain (e.g., from dense cover or clonal growth) so the missing values were imputed by replacing them with the median count of that species across all other quadrats where it was observed (Legendre and Legendre, 2012). Shannon diversity index was calculated for all quadrats and total richness was calculated for each site as well as Red List species richness. Richness and diversity were mapped using the ‘sf’ (Pebesma, 2018, Pebesma and Bivand, 2023) and ‘rnaturalearth’ (Massicotte and South, 2023) packages.

Community Classification and Indicator Species Analysis

To determine communities, a Bray-Curtis dissimilarity matrix was calculated from a presence-absence dataset for the species at each site. Agglomerative hierarchical clustering was used to group sites using Ward’s minimum variance method as this gave the highest agglomerative coefficient. The optimal number of clusters was determined using cluster validity metrics: the elbow method, silhouette analysis and gap statistic. The clusters were mapped onto a two-dimensional space using principal coordinates derived from the Bray-Curtis dissimilarity matrix. The R packages: ‘cluster’ (Maechler et al., 2023), ‘vegan’ (Oksanen et al., 2025), ‘dendextend’ (Galili, 2015) and ‘factoextra’ (Kassambara and Mundt, 2017) were used for clustering.

Permutational Multivariate Analysis of Variance (PERMANOVA) was carried out with the ‘vegan’ R package (Oksanen et al., 2025) to assess whether species composition significantly differed across each community, based on the Bray-Curtis dissimilarity matrix, with 999 permutations. This was followed by PERMANOVA pairwise comparisons between each pair of communities to identify significant differences. Adjusted p-values using the ‘Bonferroni correction’ were used to reduce the likelihood of type I errors (Armstrong, 2014).

Indicator species analysis (ISA) was performed with the ‘indicspecies’ package (De Cáceres and Legendre, 2009). The indicator value index was used to assess species fidelity and exclusivity to each community. Communities were named based on the genera of the two most dominant species defined as those occurring most frequently across sites and quadrats within each community.

Generalised Linear Mixed Models

To assess the impact of environmental and anthropogenic factors on species richness, generalised linear mixed models (GLMMs) were used to account for the nested data structure, with quadrats grouped within sites (Bolker et al., 2009). The models used a Poisson distribution with a log link function and incorporated random intercepts for both sites and quadrats within sites, while treating the predictor variables as fixed effects. Models were fitted with the maximum likelihood method with Laplace approximation.

The categorical predictor variables were community type, habitat type, soil type, development proximity, litter pollution level, grazing level, lagoon adjacency and *N. juliflora* presence. To assess the effect of the predictor variable on species richness ANOVAs were used to compare the full model with a reduced model that excluded the predictor variable. The 'lme4' package was used for the GLMMs (Bates et al., 2015).

Results

Plant Records

Across 33 sites and 330 quadrats, 1,133 plant records were made. Within quadrats, 78 taxa were recorded: 71 were identified to species level, four to genus level, two were unidentifiable and one, *Nanorrhinum* sp. nov., has not been described. *Heliotropium bacciferum* was treated as two taxa: one representing the commonly occurring coastal species and the other a rarer regionally endemic subspecies referred to in the OPRDB as *Heliotropium fartakense* (Patzelt, 2014). The most frequently recorded species were *L. stocksii* (found in 27.3% of quadrats), *H. mucronatum* (26.1%), and *Z. qatarense* and *Zygophyllum hamiense* (23.6% each). The most abundant species by count was *C. aucheri* with 3,461 individual plants (29% of total counts).

Additional species not included in quadrats, but encountered at each site, were recorded to give 16 additional taxa, two of which have not been described *Lindenbergia* sp. nov., and *Pycnocycla* sp. nov. This brought the total list of taxa recorded to 94 (supplementary information). The most common species found at sites were *H. bacciferum* (60.6% of sites), *C. aucheri* (57.6%), and *Z. hamiense* (51.5%). Forty-one species were exclusive to single sites, of which 21 were found within single quadrats.

Of the 94 taxa, 17 were Red List species (Table 1) all of which are range-restricted except for *A. marina*. Four species are endemic, eight are regionally endemic, and two are near endemic. None of these species have been assessed by the IUCN apart from *A. marina* which is listed as least concern (IUCN, 2025).

Community Delineation and Distribution

Hierarchical clustering identified six plant communities across the 33 sites along the central Oman coastline, as visualised in the dendrogram (Fig. 2a) with height indicating the level of dissimilarity between clusters. Sites belonging to the same community type were similar in species composition.

The clustering results, based on the Bray-Curtis dissimilarity matrix (Fig. 2b) display the distinct community compositions with minimal overlap between most groups, except for Communities 3 and 5. PERMANOVA confirmed that species composition significantly differed ($p<0.001$) among the communities, with 52.7% of the variation explained by community type. Pairwise PERMANOVA tests (Table 2) identified significant differences ($p<0.05$) between community pairs with the greatest dissimilarity between communities 1 and 3 ($R^2 = 0.582$), 2 and 6 ($R^2 = 0.498$) and 2 and 3 ($R^2 = 0.453$), suggesting high species turnover between these communities.

Each community type was spread widely across the central coastline (Fig. 2c). Community 2 is the most widespread. Communities 1, 3 and 4 are found at the northern end of the coastline whereas communities 5 and 6 are found towards the southern end of the central coastline. Community 3 is mainly restricted to Masirah Island and Community 6 is mainly found around Sawqirah Bay.

Indicator Species Analysis

ISA confirmed 24 out of the 94 taxa served as reliable indicator species for the communities (Table 3). Most indicator species are strongly associated with multiple communities. *L. stocksii* and *Z. qatarense* are each indicative of five communities. However, *A. farinosa*, *Campylanthus sedoides*, *Cistanche tubulosa*, *Echiochilon jugatum*, *Polycarpaea spicata*, *Pulicaria glutinosa*, *Pulicaria undulata* and *Zygophyllum indicum* are each indicative of only one community type. *A. farinosa*, *C. tubulosa* and *N. juliflora* are the strongest indicator species.

Community Types

Each of the six communities identified are named after the dominant species (Fig. 3) and key indicator species are also labelled.

1. *Suaeda-Limonium* Community

This community is found towards the north of the central coastline around Shannah, Bar Al Hikman, Bentoot and Ras Madrakah on sandy beaches or near khawrs. The dominant species are *S. moschata* and *L. stocksii*. The community is also strongly characterised by *A. farinosa* and *C. tubulosa* which were present on seaward dunes and are unique to this community. Other common species are *A. macrostachyum* and *U. setulosa*.

2. *Limonium-Zygophyllum* Community

This community occurs in a range of habitats and has a very wide distribution across the coastline found near Shannah, Sadab and Khahil. The two dominant species, and only indicator species, are *L. stocksii* and *Z. qatarense*. *H. mucronatum* is also commonly found. This community also occurred on coastal sabkhas. Despite being found over the most sites, this community had the lowest overall species richness with only two species unique to the community and one Red List species (Table 4).

3. *Heliotropium-Cyperus* Community

This community was mainly confined to Masirah Island on sandy dunes or sandy gravel plains. The most dominant species were *H. bacciferum* and *C. aucheri*. *N. juliflora* was the most indicative species for this community. Twelve species were unique to this community (Table 4).

4. *Suaeda-Zygophyllum* Community

This community was found on sandy beaches and sandy gravel plains around Bar Al Hikman as well as Al Khaluf and Nafun. *S. moschata* dominates this community as well as *Z. hamiense. H. mucronatum* is also commonly found.

5. *Heliotropium-Zygophyllum* Community

This community was found towards the south of the central coastline at Raz Markaz, Dharaf, Al Quwayah and Sawqirah. The community was frequently found near khawrs and dominated by *H. bacciferum* and *Z. hamiense*. *Ipomoea pes-caprae* is the most indicative and often forms dense vegetation mats across the beach. This community was by far the richest, representing 60 species across four sites with nearly half of these species being unique within this community and 13 Red List species present (Table 4).

6. Ipomoea-Neltuma Community

This community is mainly restricted to Sawqirah Bay and is found near khawrs and on sandy beaches. The community is characterised by shrubs or trees of *N. juliflora* with *I. pes-caprae* often forming vegetation mats.

Richness and Diversity Across the Central Coast

Total species richness, Red List species richness and median diversity of each site varied along the central coastline (Fig. 4). Raz Markaz (site 21) had the highest total species richness with 28 species. Red List species richness was relatively low across sites apart from Sawqirah (site 33) and Raz Markaz which had six and five Red List species respectively. The highest diversity is around Masirah Island, with Site 9 having a high median diversity index of 1.68. Areas around Bar Al Hikman are also diverse, as well as sites 25, 26 and 33.

Factors Affecting Species Richness

Community type significantly influenced species richness ($\chi^2 = 15.46$, Df = 5, $p<0.01$; Fig. 5). Community 3 had the highest mean species richness (4.99), which was significantly higher ($p<0.05$) than Communities 2, 4 and 6.

Habitat type significantly influenced species richness (χ^2 = 9.19, Df = 3, $p<0.05$). Mean species richness was highest for the sandy gravel plain habitats (5.19; Fig. 6). This habitat is significantly richer ($p<0.05$) than the khawr habitat (2.54) and sandy beach habitat (3.07).

Soil type significantly influenced species richness (χ^2 = 21.38, Df = 6, $p<0.01$). Sand/gravel/clay soils supported the highest species richness with a predicted mean of 7.42 (Fig. 7). This soil type had a significantly higher mean species richness ($p<0.05$) than the clay (2.26), sand (3.11), sand/clay (2.14) and sand/clay/salt (1.80) soil types. The model also predicted that the sand/rock soil type had a significantly higher mean species richness (4.84) than the sand/clay soil.

The presence of *N. juliflora* significantly influenced species richness (χ^2 = 12.79, Df = 2, $p<0.01$). Mean species richness is significantly higher ($p<0.05$) when *N. juliflora* was present within a quadrat (5.99) over quadrats at sites where *N. juliflora* was not present at all (2.86; Fig. 8). GLMMs found no significant effect of development proximity, litter pollution level, grazing and lagoon adjacency on species richness.

Discussion

Overview

To the best of our knowledge, this study provides the first systematic vegetation survey to cover the entire central Oman coastline. A total of 94 taxa were recorded, of which 17 were classed as Red List species (Patzelt, 2014). Areas of high species richness and diversity are concentrated around Masirah Island, Raz Markaz and Sawqirah, with the latter two sites also having a high endemic richness. Six communities were identified with unique species compositions and species richness was influenced by community type, habitat type, soil type and presence of *N. juliflora.*

Vegetation Characteristics

The coastal vegetation of the central Oman coastline is primarily composed of xeromorphic dwarf shrubland, featuring grasses and other annuals, many of which are halophytic or salt-tolerant (Patzelt, 2015). The halophytic shrub species *L. stocksii*, *Z. qatarense*, *Z. hamiense* and *H. bacciferum* and grasses *C. aucheri* and *H. mucronatum* are the most common species along the central coastline. Many halophytic species are closely related and belong to vicariant groups where environmental factors have led to species divergence within genera (e.g., *Zygophyllum* and *Cyperus*) (Ghazanfar et al., 2019). Pockets of *A. marina* are present around Shannah, Bar Al Hikman, Filim, Dharaf, Wadi Halfayn and Nafun with the largest forest on Mahout Island (Ghazanfar et al., 2019). *N. juliflora* has also invaded many areas of the central coastline and is most prevalent around Masirah Island and Sawqirah Bay. There is a high proportion of range-restricted species along the central coastline which aligns with the central desert coastal area as a local centre of endemism (Patzelt, 2015).

Plant Communities

Six communities were identified along the central coastline. Within each community, there is variation in species composition between sites due to the influence of local environmental conditions (e.g., substrate type and inundation frequency) (Ghazanfar, 1999).

Previously, Ghazanfar (1999) described the flora at Shannah as a *Limonium-Zygophyllum* community, with *L. stocksii* and *Z. qatarense* as the dominant species, which is still present (Community 2). This community is also present in sabkha habitats which is unsurprising as *L. stocksii* and *Z. qatarense* are among the most salt-tolerant halophytes within the Arabian Peninsula (Ghazanfar et al., 2019). Further investigation also revealed a *Suaeda-Limonium* community (Community 1) around Shannah and the Bar Al Hikman Peninsula. This community was dominated by the near endemic species *S. moschata*, as well as *L. stocksii*. *A. farinosa* and *C. tubulosa* are common above the high tide mark alongside *S. moschata* (Ghazanfar et al., 2019). *C. tubulosa* is a herbaceous obligate parasite and grows off of *A. farinosa* roots (Pickering and Patzelt, 2008). This community is likely the same as the *Atriplex-Suaeda* community described by Ghazanfar (1999a) around Bar Al Hikman.

The *Heliotropium-Cyperus* Community (Community 3) is found mainly on Masirah Island's coast on shallow sands where *H. bacciferum* and *C. aucheri* are the dominant species (Ghazanfar et al., 2019). *H. bacciferum* is often dominant on gravel habitats which was the main habitat type along Masirah's coast (Sherwani, 2019). This community is also heavily influenced by *N. juliflora*, which is widespread across the island and in some places has formed dense impenetrable thickets where the native vegetation has been outcompeted (Al-Wardy et al., 2021, Patzelt and Lupton, 2021).

The *Suaeda-Zygophyllum* Community (Community 4) was dominated by *S. moschata* and *Z. hamiense. Z. hamiense* is closely related to *Z. qatarense* but is not regionally endemic (Patzelt, 2014, Ghazanfar et al., 2019). On the southern half of the central coastline, the *Heliotropium-Zygophyllum* Community (Community 5) can be found. This community is of conservational importance as it is highly speciose with a high proportion of Red List species.

The *Ipomoea-Neltuma* Community (Community 6) is dominated by *I. pes-caprae*, a rapidly growing salt-tolerant creeper vine common in coastal areas, particularly in southern Oman (Khan et al., 2023). This community is primarily confined to Sawqirah Bay. The bay comes under the influence of the Khareef, which brings seasonal rains and coastal fogs, creating unique conditions that likely contribute to this community's restricted distribution (Borrell et al., 2019). *N. juliflora* was also the strongest indicator for this community and has invaded many areas of the coast along Sawqirah Bay (Al-Wardy et al., 2021).

Species Richness

Species richness was highest within the sandy gravel habitats. These habitats are common in or around wadi beds where the gravelly sediment is deposited from flooded wadis (Ghazanfar and Osborne, 2010). These habitats can support a rich assemblage due to the variable microhabitats (e.g., a mix of sand, gravel and small rocks), which increases niche availability and supports species characteristic of many different habitat types (Abuzinada et al., 2008, Tourenq and Launay, 2008). The sand/gravel/clay soil type also supported the highest species richness due to the increased heterogeneity of microsites provided by the different soil textures which provide varying moisture and nutrient conditions (Williams and Houseman, 2014). Gravel is an important edaphic factor and species richness has been shown to increase with gravel content in wadi beds (El-Khouly and Shawky, 2017). Khawr habitats had lower species richness which could be due to the dominance of certain species, for example, when *A. marina* is present at khawrs there is generally a less species-rich assemblage (Bellini et al., 2022).

The invasive *N. juliflora* is very problematic along Oman's coasts and is outcompeting native species (Patzelt and Lupton, 2021). However, species richness was higher in quadrats when *N. juliflora* was present. The effect of *N. juliflora* on surrounding vegetation is dependent on the density and size of the overhanging crowns with larger plants having a more negative effect (El-Keblawy and Al-Rawai, 2007). At smaller sizes, or in shrub form, *N. juliflora* can be beneficial for surrounding flora as the crown can create a favourable microclimate where soil temperature is lower and moisture is retained, alleviating the harsh desert conditions (Byalt and Korshunov, 2021, Eshetu, 2024). For this study, all *N. juliflora* specimens sampled within the quadrats were smaller specimens and were likely more beneficial for surrounding species at this stage.

Important Areas

The central coastline of Oman forms an important part of Oman's biodiversity and supports a high proportion of range-restricted species (Patzelt, 2015). However, most of the central coastline has little to no protection. Currently, the only protected area is the Al Wusta Wetland Reserve at Bar Al Hikman. The following Red List species have been listed within the reserve which contributes to its international importance: *A. marina*, *C. sedoides*, *Euphorbia riebeckii*, *Schweinfurthia imbricata*, *Stipagrostis dhofariensis*, *Stipagrostis masirahensis*, *S. moschata* and *Z. qatarense*. Our study also confirmed the presence of two additional Red List species within the reserve area: *Caroxylon omanense* and *Gymnocarpos rotundifolius* which are both listed as vulnerable (Patzelt, 2014). Legal protection is only partially implemented within this reserve and there are no management programmes for conserving the Red List plant species (Ramsar Sites Information Service, 2023).

Masirah Island is also important for conservation and has been recognised as a Key Biodiversity Area (Key Biodiversity Areas, 2025). Our study confirmed the presence of the Red List species, *C. sedoides* and *E. jugatum* on the island. Masirah also supports several more Red List species including *S. imbricata, Convolvulus oppositifolius* and *S. moschata* (Patzelt, 2014). Masirah Island is becoming an increasingly popular tourist destination and its unique coastal flora is threatened by development as well as off-road driving (Mansour et al., 2020).

Raz Markaz and Sawqirah are also species-rich areas. Both sites shared a common feature of coastal escarpments (Fig. 9) which separate the coastal plains from the inland desert (Patzelt, 2015). The rugged topography of these habitats, as well as occasional coastal fogs, provides a variety of niches within the harsh desert conditions, which supports a higher plant richness (Stein et al., 2014, Patzelt, 2015). These areas also contain a high proportion of endemic species, supporting relict taxa indicative of a historically more mesic climate (Patzelt, 2015, Borrell et al., 2019). Raz Markaz contained five range-restricted species: *C. sedoides*, *G. rotundifolius*, *Pulicaria omanensis*, *Pycnocycla* sp. nov. and *S. moschata*. Sawqirah contained six range-restricted species: *Adenosciadium arabicum*, *C. sedoides*, *Stipagrostis sokotrana*, *S. moschata*, *Wadithamnus artemisioides* and *Xerotia arabica*. Both endemic-rich sites face development pressures. Raz Markaz is only 70 km from the Duqm Special Economic Zone and is home to a crude oil storage and export terminal. The Sawqirah site was also being developed, at the time of the study, and may already be lost. This highlights the immediate risk of endemic-rich areas being developed before their ecological importance is recognised (Anderson et al., 2019).

Future Research

With a lack of protection in place, long-term monitoring is needed to track changes in the species composition of plant communities along the central Oman coastline. Special attention should be given to the Red List species and *in situ* and *ex situ* strategies are required for their effective conservation (Patzelt, 2014). Genetic analysis of the Red List species would also be useful to determine their population structure and resilience to environmental pressures (Srivastava et al., 2019). Further areas of conservation value along the coastline need to be identified before they are lost to development. Vegetation data is still scarce for Oman’s central coastline and species distribution models could be a useful technique to maximise the small data sets and predict areas of high conservation value, for example, areas with high Red List species richness (McShea, 2014).

Conclusions

The central coastline of Oman contains a variety of important ecosystems, unique floral communities and a high proportion of the country’s Red List species. Despite this, the region remains largely unprotected and development pressures threaten many areas of high conservation value. Urgent conservation efforts, including expanding and increasing protected areas, long-term monitoring, and predictive modelling are required to safeguard the central coastline's unique communities and ensure the persistence of its range-restricted and threatened species which form an invaluable part of the country's biodiversity.

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Declarations

The authors declare no competing interests.

Data Availability

The data used in this study is available from the corresponding author upon reasonable request.

References

Abuzinada, A. H., Barth, H., Krupp, F., Böer, B. & Al Abdessalaam, T. Z. 2008. *Protecting the Gulf's Marine Ecosystems from Pollution*: Springer Science & Business Media.

Al-Charaabi, Y. & Al-Yahyai, S. 2013. Projection of future changes in rainfall and temperature patterns in Oman. *Journal of Earth Science & Climatic Change*, 4(5), 154-161.

Al-Muharrami, S. 2019. Large Projects in Light of Oman's Diversification Strategy: the Case of Special Economic Zone in Duqm. *Journal Socio-Economic Analyses*, 2, 178-186.

Al-Wardy, M., Al-Rawas, G., Charabi, Y. & Choudri, B. 2021. Spatiotemporal assessment of *Prosopis juliflora* invasion: linking invasion pattern to meteorological conditions. *Tropical Ecology*, 62, 197-208.

Anderson, F., Elliot, A., Al Harthi, L., Al Hatmi, S., Al Hinai, A., Al Issai, G., Knees, S., Lupton, D. & Al Qassabi, Z. 2019. *Important Plant Areas of Oman*. Centre for Middle Eastern Plants & Oman Botanic Garden.

Armstrong, R. A. 2014. When to use the Bonferroni correction. *Ophthalmic and Physiological Optics*, 34(5), 502-508.

Asensi, A. & Diez-Garretas, B. 2017. Coastal vegetation. *In:* Loidi, J. (ed.) *The Vegetation of the Iberian Peninsula: Volume 2.* Cham, Switzerland: Springer

Bates, D., Machler, M., Bolker, B. & Walker, S. 2015. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48.

Bellini, C., Ciani, F., Pignotti, L., Baldini, R. M., Gonnelli, T. & Mariotti Lippi, M. 2022. Modern Pollen Analysis in the Estuary Habitats along the Coast of Dhofar (Sultanate of Oman). *Sustainability*, 14(17), 11038.

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H. & White, J.-S. S. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in Ecology & Evolution*, 24(3), 127-135.

Borrell, J. S., Al Issaey, G., Lupton, D. A., Starnes, T., Al Hinai, A., Al Hatmi, S., Senior, R. A., Wilkinson, T., Milborrow, J. L. & Stokes-Rees, A. 2019. Islands in the desert: environmental distribution modelling of endemic flora reveals the extent of Pleistocene tropical relict vegetation in southern Arabia. *Annals of Botany*, 124(3), 411-422.

Brown, G., Böer, B. & Sakkir, S. 2008. The coastal vegetation of the western and southern Gulf—characterisation and conservation aspects. *In:* Abuzinada, A. H., Barth, F., Krupp, F., Böer, B. & Al Abdessalaam, T. Z. (eds.) *Protecting the Gulf's marine ecosystems from pollution.* Switzerland: Birkhäuser Verlag.

Byalt, V. & Korshunov, M. 2021. Distribution of Invasive Species *Prosopis juliflora* (Mimosaceae) in Fujairah (UAE). *Russian Journal of Biological Invasions*, 12(2), 157-166.

Claereboudt, M. R. 2019. Oman. *In:* Sheppard, C. (ed.) *World Seas: an Environmental Evaluation, V. II: the Indian Ocean to the Pacific.* Amsterdam, the Netherlands: Elsevier.

Coelho, N., Gonçalves, S. & Romano, A. 2020. Endemic plant species conservation: Biotechnological approaches. *Plants*, 9(3), 345.

De Battisti, D. 2021. The resilience of coastal ecosystems: A functional trait-based perspective. *Journal of Ecology*, 109(9), 3133-3146.

De Cáceres, M. & Legendre, P. 2009. Associations between species and groups of sites: indices and statistical inference. *Ecology*, 90, 3566-3574.

El-Keblawy, A. & Al-Rawai, A. 2007. Impacts of the invasive exotic *Prosopis juliflora* (Sw.) DC on the native flora and soils of the UAE. *Plant Ecology*, 190, 23-35.

El-Khouly, A. A. & Shawky, R. A. 2017. Plant species diversity of some wadis at Red Sea Coast, Egypt. *Environment, Resource and Ecology Journal*, 1(1), 1-14.

Eshetu, A. A. 2024. A valuable or a curse resource? A systematic review on expansion, perception of local community, benefits and side effects of *Prosopis juliflora*. *Frontiers in Conservation Science*, 5, 1491618.

Galili, T. 2015. dendextend: an R package for visualizing, adjusting and comparing trees of hierarchical clustering. *Bioinformatics*, 31(22), 3718-3720.

Ghazanfar, S. 1999. Coastal vegetation of Oman. *Estuarine, Coastal and Shelf Science*, 49, 21-27.

Ghazanfar, S. A., Böer, B., Al Khulaidi, A. W., El-Keblawy, A. & Alateeqi, S. 2019. Plants of Sabkha ecosystems of the Arabian Peninsula. *In:* Gul, B., Boer, B., Khan, M. A., ClusenerGodt, M. & Hameed, A. (eds.) *Sabkha Ecosystems: Volume VI: Asia/Pacific.* Cham, Switzerland: Springer.

Ghazanfar, S. A. & Osborne, J. 2010. Conservation through restoration: study of a degraded gravel plain in South Eastern Arabia. *Pakistan Journal of Botany*, 42, 193-204.

Hereher, M., Al-Awadhi, T., Al-Hatrushi, S., Charabi, Y., Mansour, S., Al-Nasiri, N., Sherief, Y. & El-Kenawy, A. 2020. Assessment of the coastal vulnerability to sea level rise: Sultanate of Oman. *Environmental Earth Sciences*, 79, 1-12.

IUCN. 2025. *IUCN Red List* [Online]. Available: https://www.iucnredlist.org [Accessed 21 July 2025].

Kassambara, A. & Mundt, F. 2017. Package ‘factoextra’. *Extract and visualize the results of multivariate data analyses*, 76(2), 10.18637.

Key Biodiversity Areas. 2025. *Masirah island (8231) Oman, Middle East* [Online]. Available:
https://www.keybiodiversityareas.org/site/factsheet/8231#:~:text=Additional%

20biodiversity%3A%20See%20box%20for,and%20Pandion%20haliaetus%20(58). [Accessed 18 February 2025].

Khan, S. A., Al Faraji, S. R. S., Almukhaini, M. S. H., Mohd, A., Jamal, F. & Verma, S. S. P. P. 2023. In Vitro Establishment, Hydroponic, Salt Tolerance, Antifungal and Phytochemical Investigations in Important Sand Binder Medicinal Plant *Ipomoea pes-caprae*. *Traditional Medicine*, 4(1), 1-0.

König, P. & Fried, O. 2015. Plant communities on the NE coast of Oman and their site conditions. *Phytocoenologia*, 45(3), 269-290.

Legendre, P. & Legendre, L. 2012. Complex ecological data sets. *Developments in environmental modelling.* Elsevier.

Lupton, D., Al Moqbali, H., Al Rahaili, B., Al Qassabi, Z., Al Hajri, B., Anderson, A. & Patzelt, A. 2016. The Oman Botanic Garden (3): a Review of Progress (2010–2016) with Emphasis on Herbarium and Seed Bank Collections, Propagation Challenges and Garden Design Principles. *Sibbaldia: the International Journal of Botanic Garden Horticulture*, 14, 119-132.

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M. & Hornik, K. 2023. cluster: Cluster Analysis Basics and Extensions. https://CRAN.R-project.org/package=cluster

Mansour, S., Al-Awhadi, T. & Al-Hatrushi, S. 2020. Geospatial based multi-criteria analysis for ecotourism land suitability using GIS & AHP: a case study of Masirah Island, Oman. *Journal of Ecotourism*, 19(2), 148-167.

Massicotte, P. & South, A. 2023. rnaturalearth: World Map Data from Natural Earth.

McShea, W. J. 2014. What are the roles of species distribution models in conservation planning? *Environmental Conservation*, 41(2), 93-96.

Miller, A. G., Cope, T. A. & Nyberg, J. 1996. *Flora of the Arabian Peninsula and Socotra,* Edinburgh, UK: Edinburgh University Press.

Ministry of Agriculture and Fisheries. 2014. *Second Country Report on the State of Farm Animal Genetic Resources*. Oman: Ministry of Agriculture and Fisheries.

Oksanen, J., Simpson, G. L., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'Hara, R. B., Solymos, P., Stevens, M. H. H., Szoecs, E., Wagner, H., Barbour, M., Bedward, M., Bolker, B., Borcard, D., Carvalho, G., Chirico, M., De Caceres, M., Durand, S., Evangelista, H. B. A., FitzJohn, R., Friendly, M., Furneaux, B., Hannigan, G., Hill, M. O., Lahti, L., McGlinn, D., Ouellette, M.-H., Ribeiro Cunha, E., Smith, T., Stier, A., Ter Braak, C. J. F. & Weedon, J. 2025. vegan: Community Ecology Package. https://CRAN.R-project.org/package=vegan

Patzelt, A. 2014. *Oman Plant Red Data Book,* Oman: Diwan of Royal Court, Oman Botanic Garden.

Patzelt, A. 2015. Synopsis of the flora and vegetation of Oman, with special emphasis on patterns of plant endemism. *Abhandlungen der Braunschweigischen Wissenschaftlichen Gesellschaft*, 282, 317.

Patzelt, A. & Lupton, D. A. 2021. Invasive alien species of Oman. *Invasive Alien Species: Observations and Issues from Around the World*, 2, 184-206.

Pebesma, E. & Bivand, R. 2023. *Spatial data science: With applications in R,* Boca Raton: Chapman and Hall.

Pebesma, E. J. 2018. Simple features for R: standardized support for spatial vector data. *The R Journal*, 10(1), 439.

Pessoa, M. F. & Lidon, F. C. 2013. Impact of human activities on coastal vegetation-a review. *Emirates Journal of Food and Agriculture*, 926-944.

Pickering, H. & Patzelt, A. 2008. *Field guide to the wild plants of Oman,* Richmond, Surrey: Royal Botanical Gardens, Kew.

Posit Team 2024. RStudio: Integrated Development Environment for R. Boston, MA: Posit Software, PBC. http://www.posit.co/.

R Core Team 2024. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Ramsar Sites Information Service. 2023. *Wetlands Reserve in Al Wusta Governorate*.

Sherwani, N. 2019. Flora, life-forms and biological spectrum of Muscat Governorate. *Sultan Qaboos University Journal for Science* 24(2), 95-108.

Srivastava, V., Lafond, V. & Griess, V. C. 2019. Species distribution models (SDM): applications, benefits and challenges in invasive species management. *CABI Reviews*, 14, 1-13.

Stein, A., Gerstner, K. & Kreft, H. 2014. Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecology Letters*, 17(7), 866-880.

Tourenq, C. & Launay, F. 2008. Challenges facing biodiversity in the United Arab Emirates. *Management of Environmental Quality: An International Journal*, 19(3), 283-304.

van Hoytema, N., Bullimore, R. D., Al Adhoobi, A. S., Al-Khanbashi, M. H., Whomersley, P. & Le Quesne, W. J. 2020. Fishing gear dominates marine litter in the Wetlands Reserve in Al Wusta Governorate, Oman. *Marine Pollution Bulletin*, 159, 111503.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D. A., François, R., Grolemund, G., Hayes, A., Henry, L. & Hester, J. 2019. Welcome to the Tidyverse. *Journal of Open Source Software*, 4(43), 1686.

Williams, B. A., Watson, J. E., Beyer, H. L., Klein, C. J., Montgomery, J., Runting, R. K., Roberson, L. A., Halpern, B. S., Grantham, H. S. & Kuempel, C. D. 2022. Global rarity of intact coastal regions. *Conservation Biology*, 36(4), e13874.

Williams, B. M. & Houseman, G. R. 2014. Experimental evidence that soil heterogeneity enhances plant diversity during community assembly. *Journal of Plant Ecology*, 7(5), 461-469.

Figures

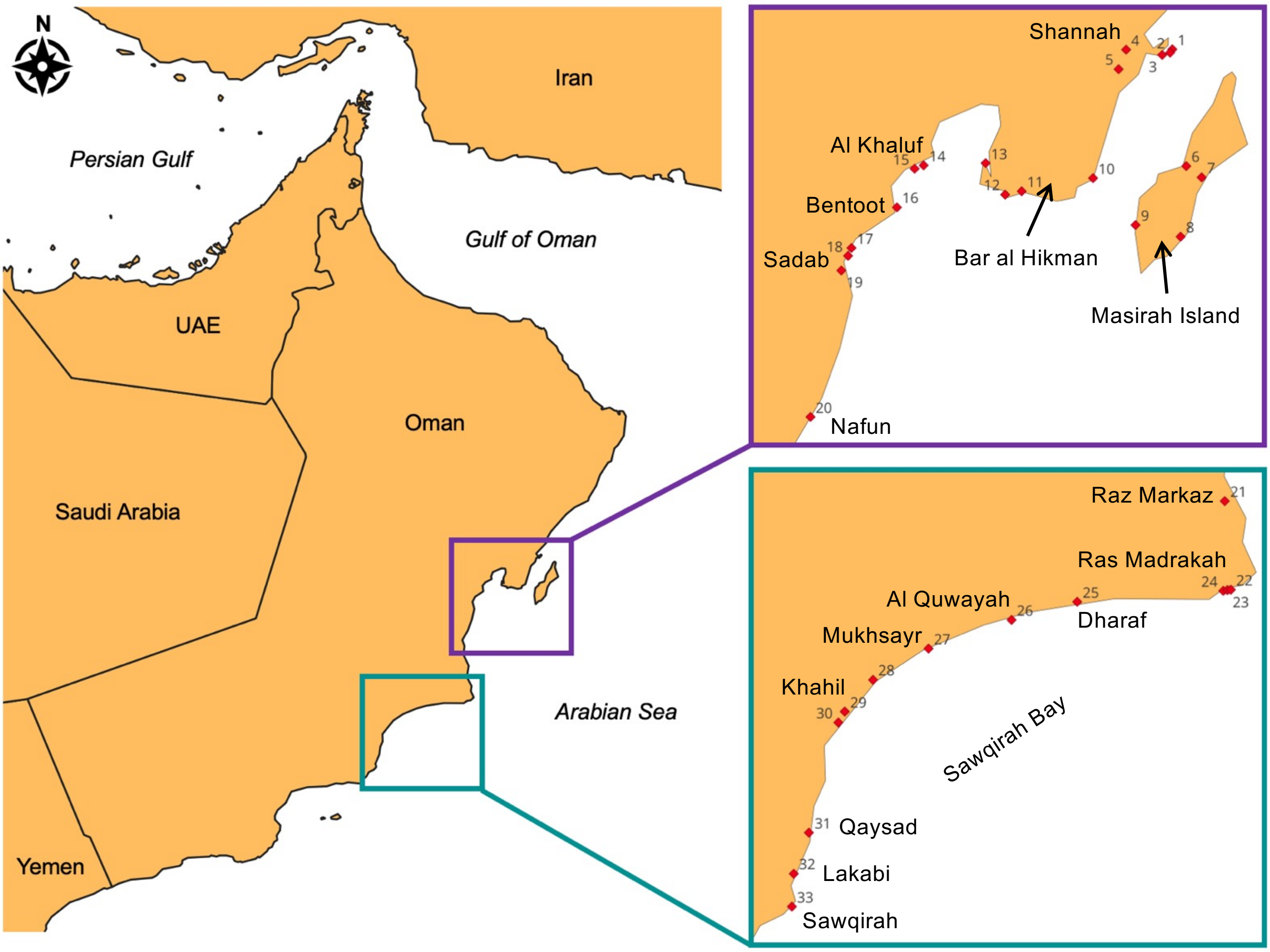


Figure 1. The 33 sites surveyed across Oman's central coastline. The sites are numbered from 1-33 with sites 1-20 in the purple box and sites 21-33 within the teal box. Key locations around each site are labelled.

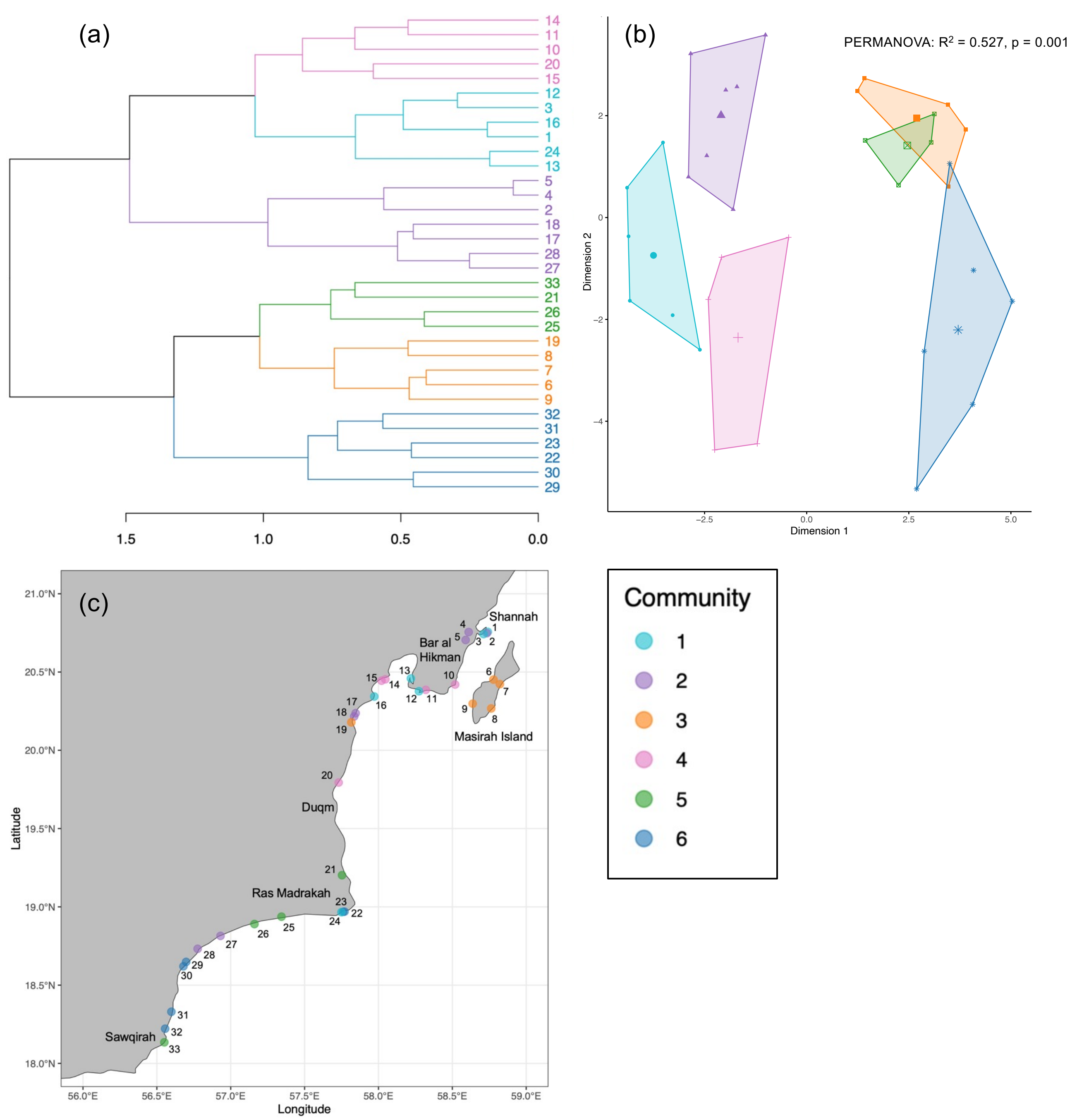
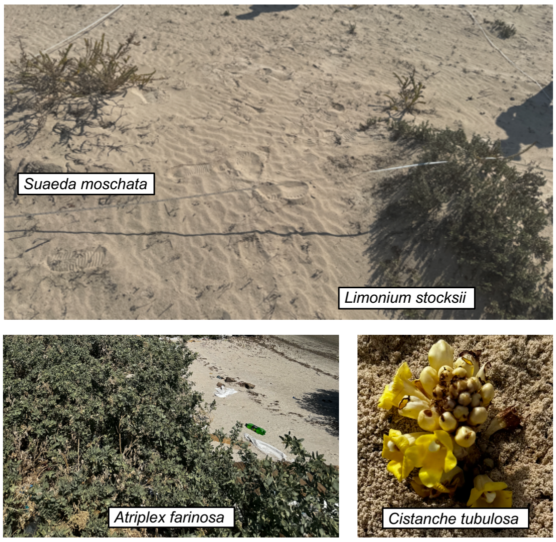
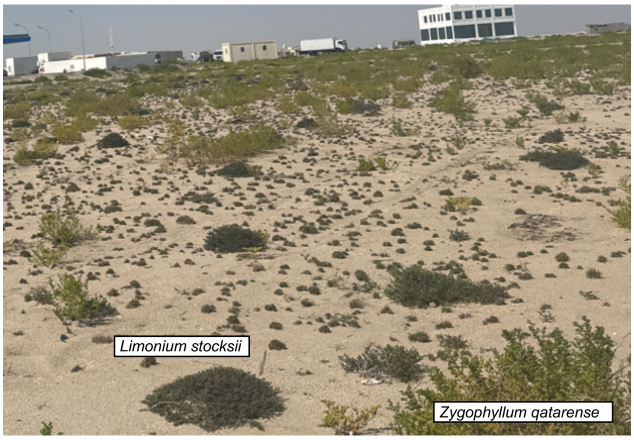


Figure 2. Results of the community analysis, the legend for community colours is included bottom right. (a) Dendrogram showing six distinct plant communities based on hierarchical clustering of species composition across sites. (b) Ordination plot based on the Bray-Curtis dissimilarity. Convex hulls indicate the spread of each community, and the large symbols indicate the centroids of each cluster. The PERMANOVA results indicate significant differences among communities. (c) The 33 study sites along the central Oman coastline and their community type.

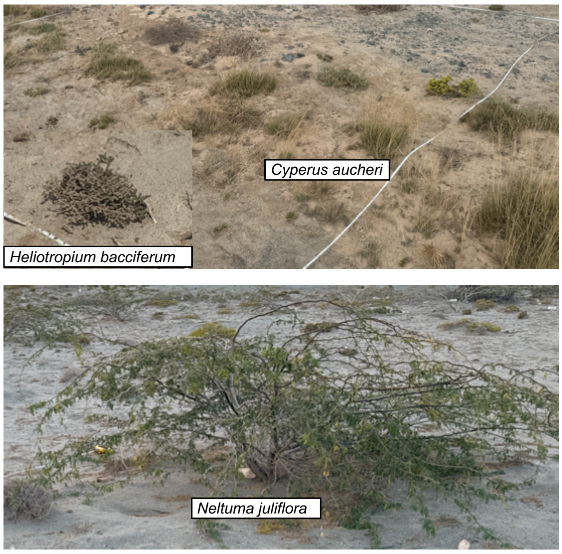
1: *Suaeda – Limonium* Community



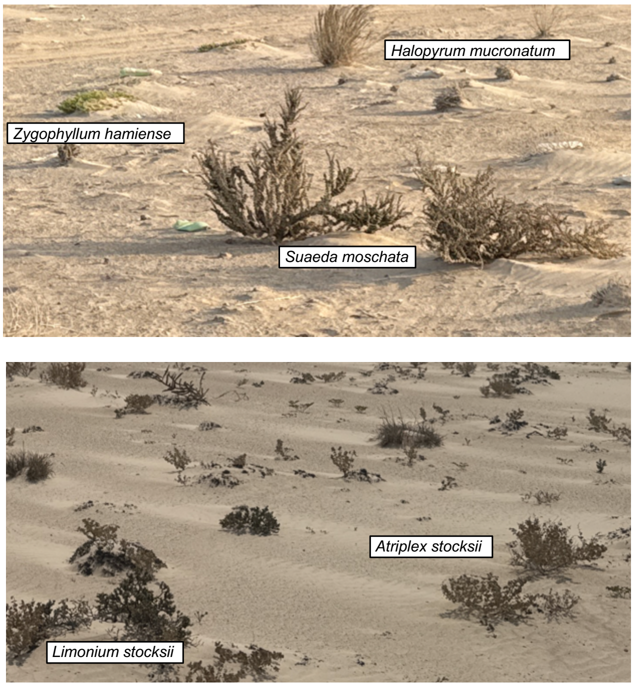
2: *Limonium - Zygophyllum* Community



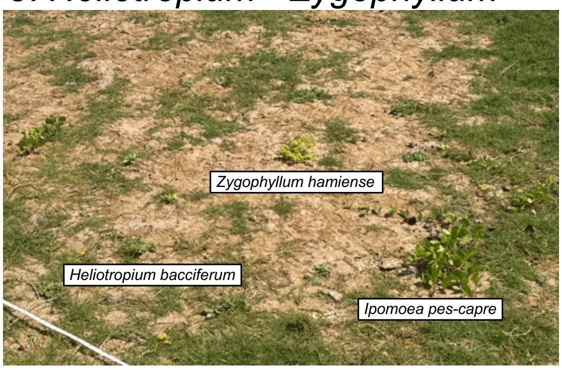
3: *Heliotropium - Cyperus* Community



4: *Suaeda - Zygophyllum* Community



5: *Heliotropium - Zygophyllum*



6: *Ipomoea - Neltuma* Community

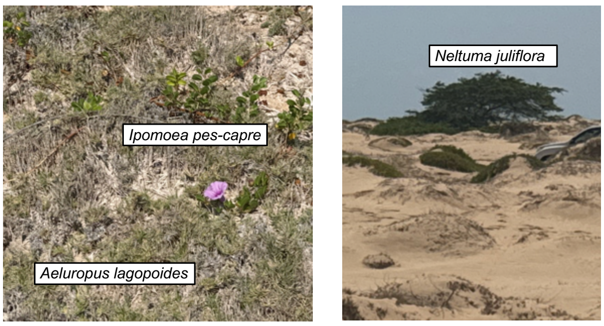


Figure 3. Example photographs of each community type present along the central Oman coastline. The dominant species and key indicator species are labelled.

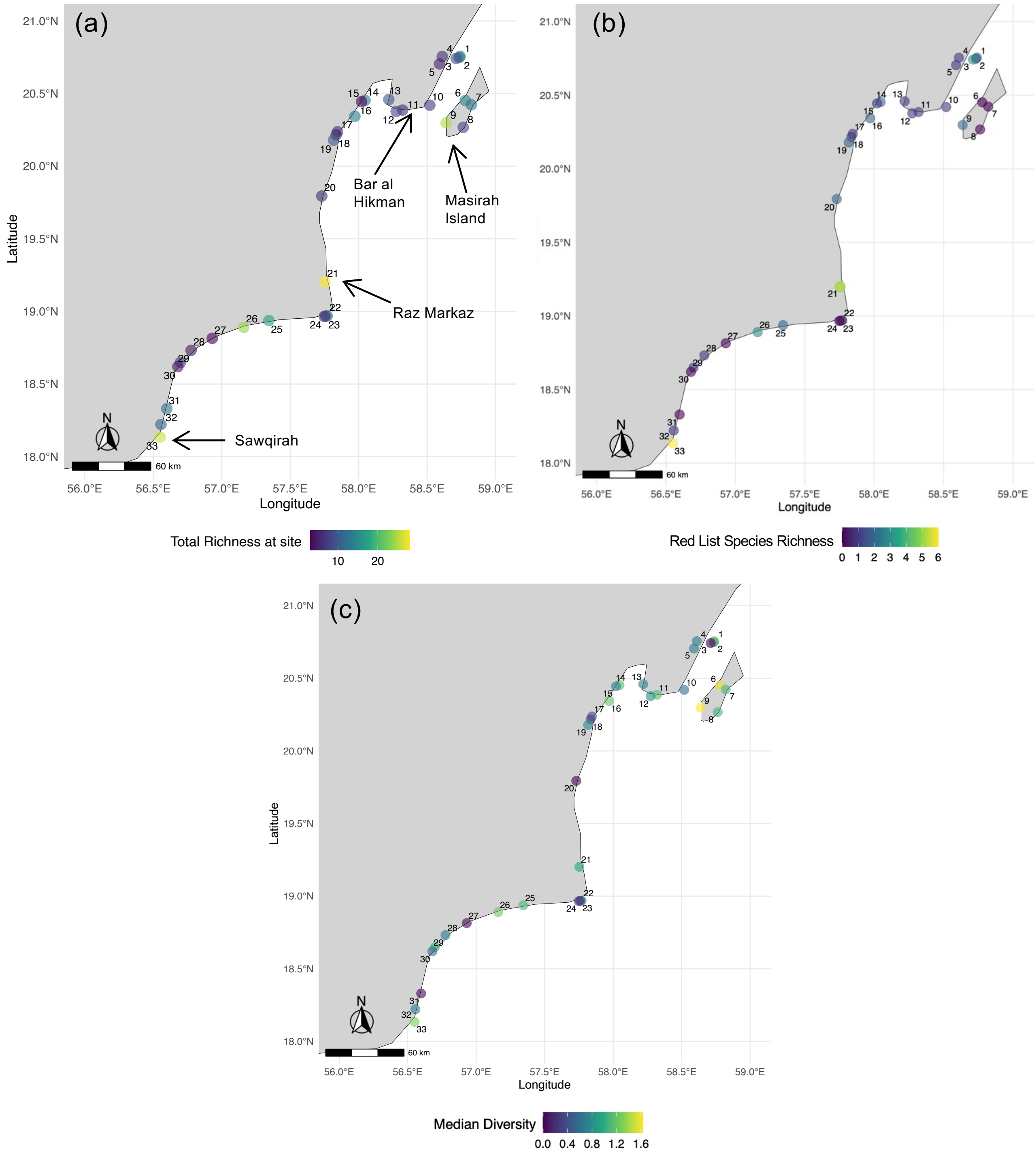


Figure 4. Maps of each site across the central coastline displaying (a) total species richness, (b) Red List species richness and (c) median diversity within quadrats for each site.

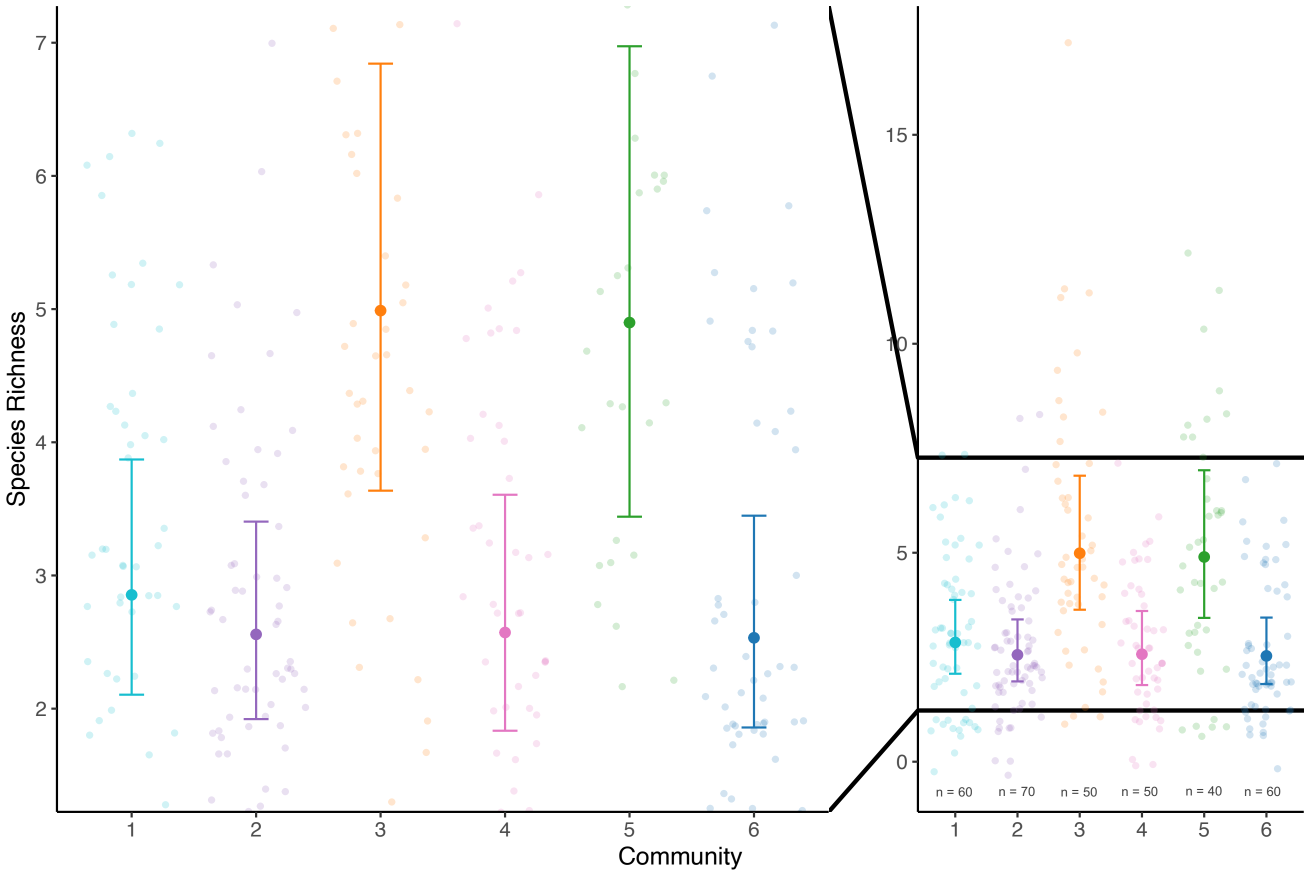


Figure 5. Generalised linear mixed model predictions of species richness by community type. Large points indicate the predicted mean species richness with 95% confidence intervals shown by the range bars. Jittered points are the observed values for individual quadrats. Sample sizes (n) are shown above the x-axis. A section of the plot is enlarged for better visualisation.

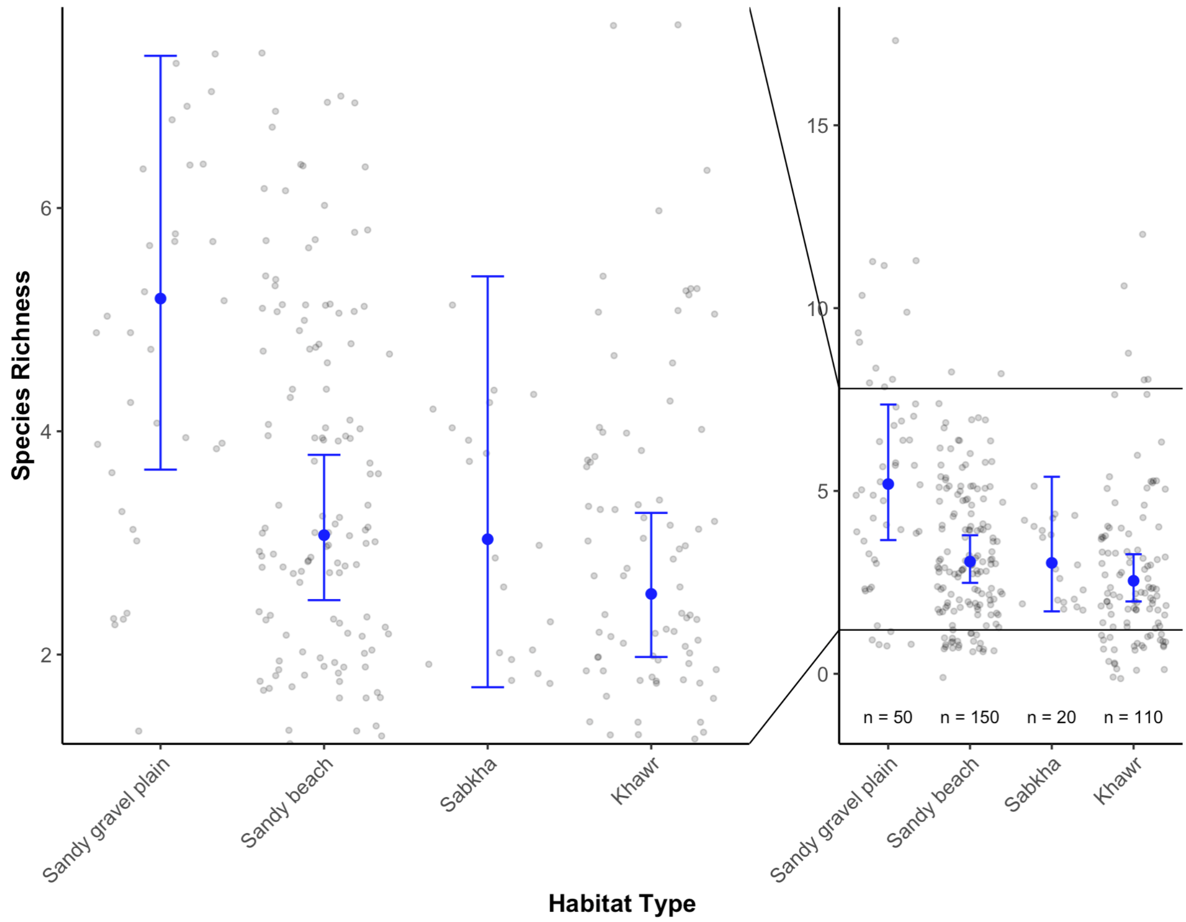


Figure 6. Generalised linear mixed model predictions of species richness by habitat type. Large points indicate the predicted mean species richness with 95% confidence intervals shown by the range bars. Jittered points are the observed values for individual quadrats. Sample sizes (n) are shown above the x-axis. A section of the plot is enlarged for better visualisation.

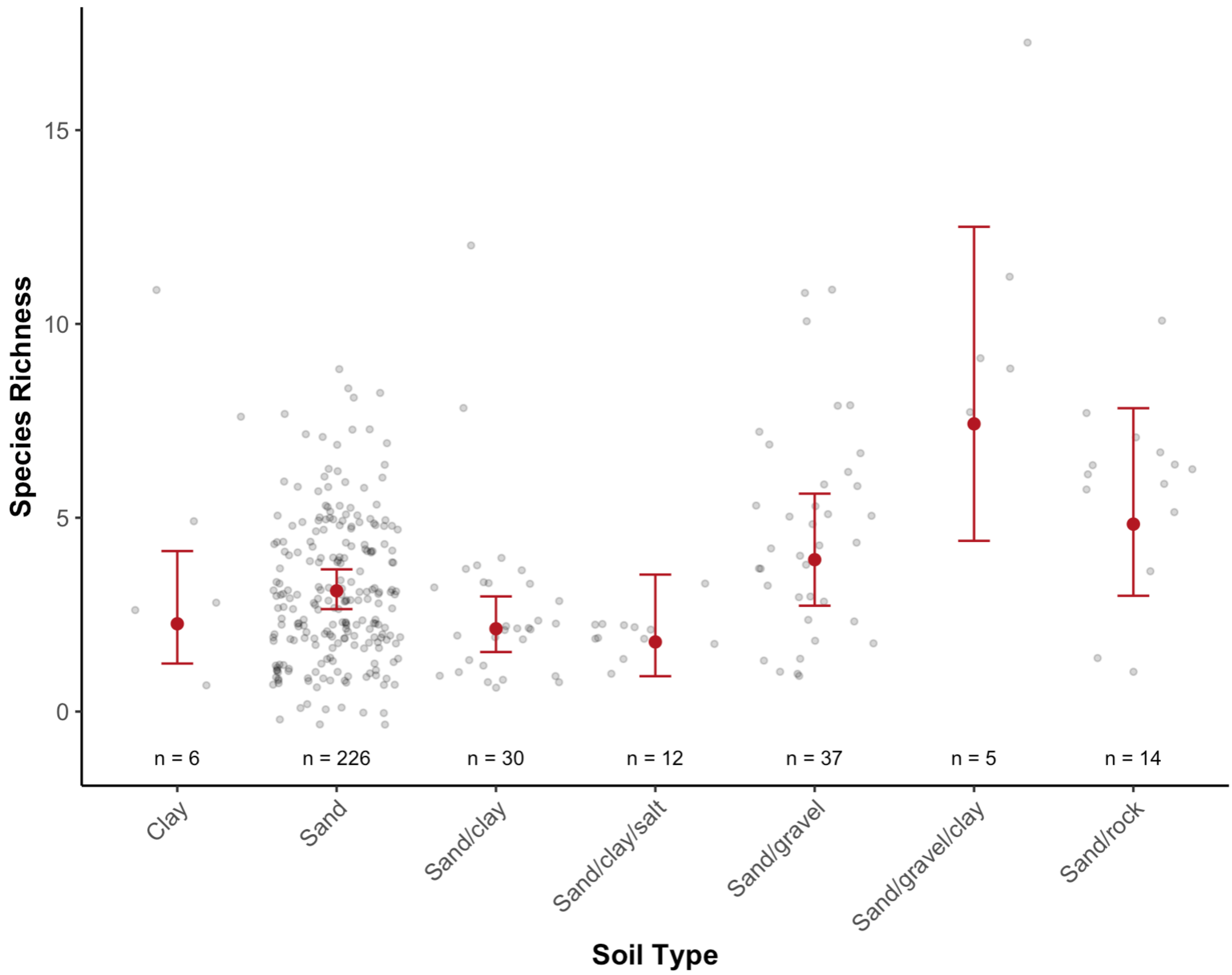


Figure 7. Generalised linear mixed model predictions of species richness by soil type. Large points indicate the predicted mean species richness with 95% confidence intervals shown by the range bars. Jittered points are the observed values for individual quadrats. Sample sizes (n) are shown above the x-axis.

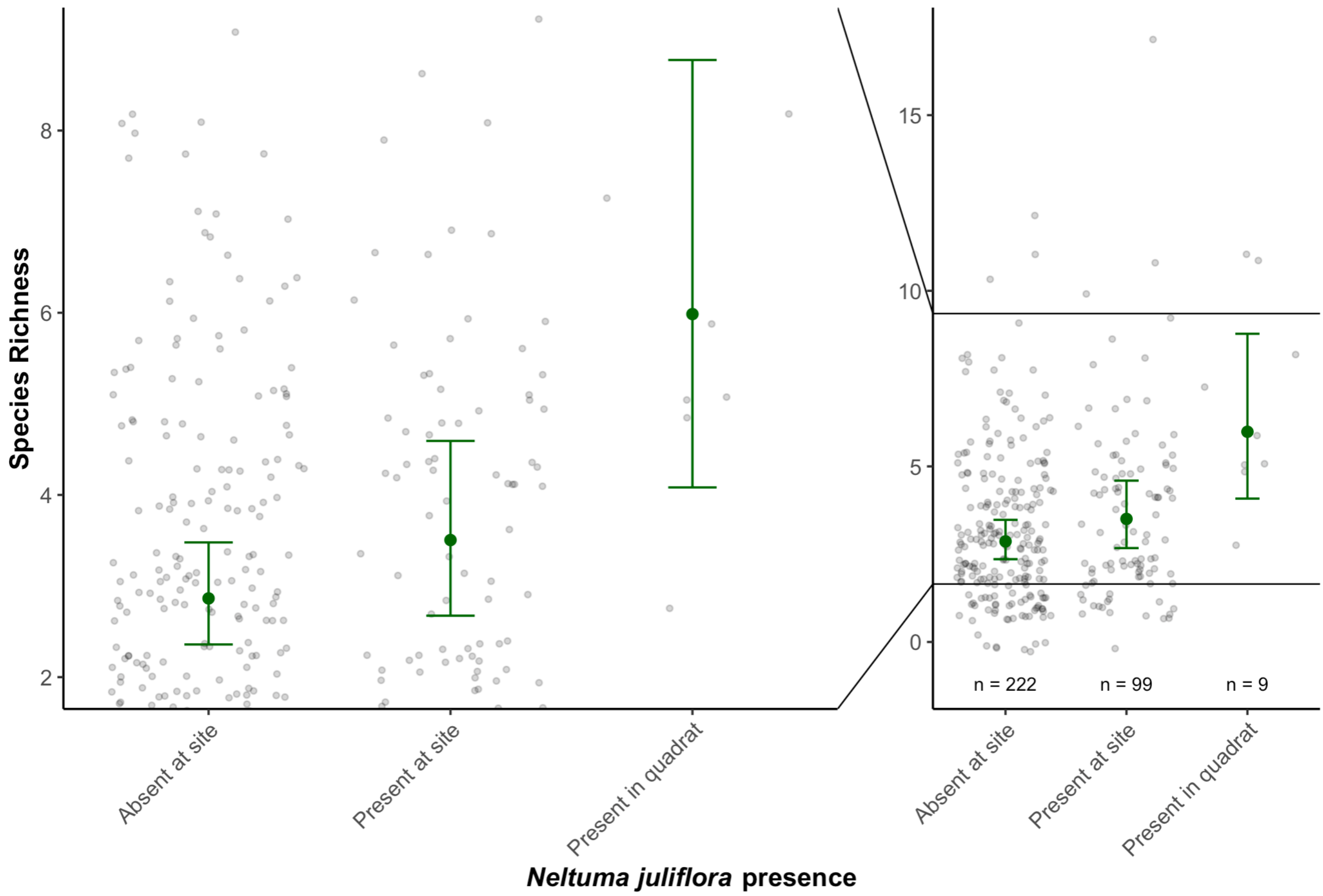


Figure 8. Generalised linear mixed model predictions of species richness by *Neltuma juliflora* presence. Large points indicate the predicted mean species richness with 95% confidence intervals shown by the range bars. Jittered points are the observed values for individual quadrats. Sample sizes (n) are shown above the x-axis.

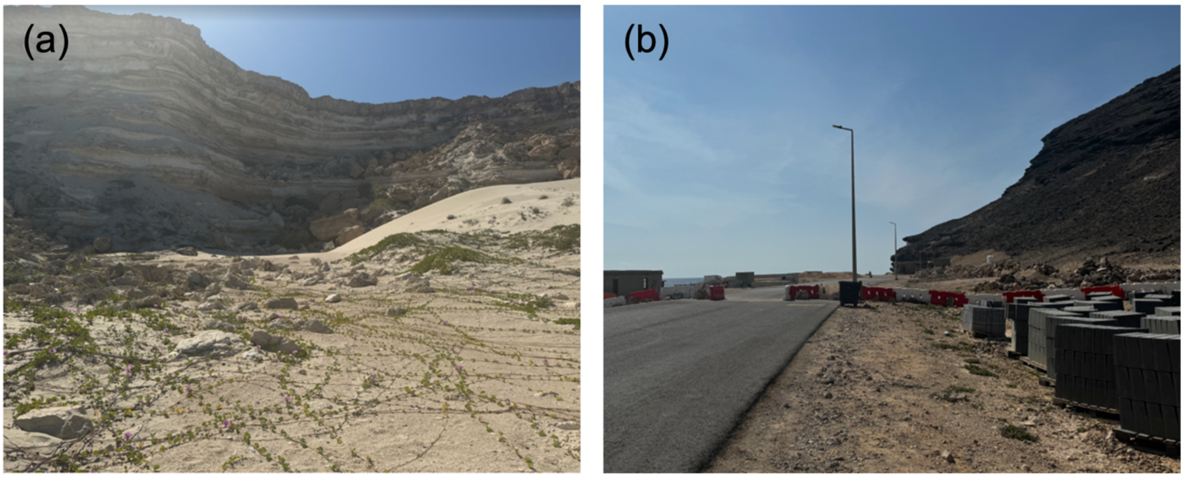


Figure 9. The coastal escarpment habitats of (a) Raz Markaz and (b) Sawqirah. The site at Sawqirah was actively undergoing development.

Tables

Table 1. The Red List species surveyed along the central Oman coastline. The threat status is either Least Concern (LC), Near Threatened (NT) or vulnerable (VU) and endemism status is either endemic (E), near endemic (NE) or regionally endemic (RE).

Species	Threat Category	Endemism
Adenosciadium arabicum	LC	RE
Avicennia marina	NT	Not endemic
Campylanthus sedoides	NT	E
Caroxylon omanense	VU	E
Convolvulus oppositifolius	NT	E
Echiochilon jugatum	LC	RE
Gymnocarpos rotundifolius	VU	NE

Heliotropium fartakense	LC	RE
Herniaria maskatensis	LC	RE
Pulicaria omanensis	LC	RE
Pulicaria pulvinata	NT	E
Pycnocycla sp. nov.	Unknown	E
Stipagrostis sokotrana	LC	RE
Suaeda moschata	NT	NE
Wadithamnus artemisioides subsp. *batharitica*	VU	E
Xerotia arabica	VU	RE
Zygophyllum qatarense	LC	RE

Table 2: Pairwise PERMANOVA results for each significant comparison. The F-statistic reflects differences in species composition, while R^2 indicates the variance explained. Adjusted p-values account for multiple testing.

Comparison	F	R^2	Adjusted p-value
1-2	6.96	0.388	0.030
1-3	12.53	0.582	0.045
2-3	8.28	0.453	0.030
2-4	4.98	0.333	0.015
2-6	10.89	0.498	0.015
4-6	5.31	0.371	0.045

Table 3. Indicator species associated with each community. A value of 1 means the species is an indicator for that community type and a 0 means it is not. The indicator

value represents the strength of association between the species and its community or communities, and the p-value indicates the statistical significance.

Species	Community Type						Indicator Value	P value
	1	2	3	4	5	6		
Atriplex farinosa	1	0	0	0	0	0	1	0.001
Atriplex stocksii	0	0	0	1	1	0	0.680	0.017
Campylanthus sedoides	0	0	0	0	1	0	0.750	0.009
Cistanche tubulosa	1	0	0	0	0	0	1	0.001
Cleome brachycarpa	0	0	1	0	1	0	0.667	0.023
Crotalaria persica	0	0	1	0	1	1	0.632	0.045
Dactyloctenium aegyptium	0	0	0	0	1	0	0.707	0.013
Echiochilon jugatum	0	0	1	0	0	0	0.775	0.006
Indigofera oblongifolia	0	0	0	0	1	0	0.707	0.015
Ipomoea pes-caprae	0	0	0	0	1	1	0.894	0.001
Launaea intybacea	0	0	0	0	1	0	0.707	0.014
Limonium stocksii	1	1	1	1	1	0	0.861	0.004
Neltuma juliflora	0	0	1	0	0	1	1	0.001
Phoenix dactylifera	0	0	0	0	1	1	0.632	0.034
Polycarpaea spicata	0	0	0	0	1	0	0.671	0.033
Pulicaria glutinosa	0	0	1	0	0	0	0.775	0.004
Pulicaria undulata	0	0	0	0	1	0	0.707	0.014
Sphaerocoma hookeri	0	0	1	0	1	0	0.770	0.011
Suaeda moschata	1	0	0	1	1	0	0.859	0.002
Taverniera lappacea	0	0	0	0	1	1	0.707	0.012

Tephrosia purpurea	0	0	1	0	1	0	0.707	0.013
Zygophyllum hamiense	1	0	1	1	1	1	0.832	0.013
Zygophyllum indicum	0	0	1	0	0	0	0.775	0.004
Zygophyllum qatarense	1	1	0	0	0	0	0.721	0.046

Table 4. Comparison of the six communities based on the total number of species, species unique to the community, and number of Red List species.

Community Number	Community Name	Number of Sites	Total Species	Species unique to Community	Oman Plant Red List Species
1	*Suaeda – Limonium*	6	19	2	4
2	*Limonium - Zygophyllum*	7	16	2	1
3	*Heliotropium - Cyperus*	5	34	12	3
4	*Suaeda- Zygophyllum*	5	20	4	4
5	*Heliotropium - Zygophyllum*	4	60	28	13
6	*Ipomoea - Neltuma*	6	31	6	3

Supplementary Information

The total list of plant species from the survey of the central Oman coastline.

1. *Adenosciadium arabicum* H. Wolff
2. *Aeluropus lagopoides* (L.) Thwaites
3. *Aerva javanica* (Burm.f.) Juss. ex Schult.
4. *Aizoon canariense* L.
5. *Aristida* sp.
6. Arthrocaulon *macrostachyum* (Moric.) Piirainen & G.Kadereit
7. *Astragalus eremophilus* subsp. *Eremophilus*
8. *Atriplex farinosa* Forssk.
9. *Atriplex stocksii* (Wight) Boiss.
10. *Avicennia marina* (Forssk.) Vierh.

11. *Blepharis ciliaris* (L.) B.L.Burtt
12. *Campylanthus sedoides* A.G.Mill.
13. *Capparis cartilaginea* Decne.
14. *Caroxylon omanense* (Boulos) Freitag & G.Kadereit
15. *Centaurea pseudosinaica* subsp. *pseudosinaica*
16. *Chrozophora oblongifolia* (Delile) A.Juss. ex Spreng.
17. *Cistanche tubulosa* (Schenk) Wight ex Hook.f.
18. *Cleome brachycarpa* Vahl ex DC.
19. *Cleome pallida* Kotschy
20. *Commicarpus helenae* (Roem. & Schult.) Meikle
21. *Cometes abyssinica* R.Br. ex Wall.
22. *Convolvulus hystrix* subsp. *hystrix*
23. *Convolvulus oppositifolius* Alfarhan
24. *Convolvulus prostratus* Forssk.
25. *Convolvulus virgatus* Boiss
26. *Corchorus depressus* (L.) Peterm.
27. *Cressa cretica* L.
28. *Crotalaria persica* (Burm.f.) Merr.
29. *Cucumis prophetarum* L.
30. *Cynomorium coccineum* L.
31. *Cyperus aucheri* Jaub. & Spach
32. *Cyperus conglomeratus* Rottb.
33. *Cyperus* sp.
34. *Dactyloctenium aegyptium* (L.) Willd.
35. *Echiochilon jugatum* I.M. Johnst.
36. *Eragrostis* sp.
37. *Euphorbia granulata* Forssk.
38. *Gymnocarpos rotundifolius* Petruss. & Thulin
39. *Halopeplis perfoliata* (Forssk.) Bunge ex Ung.-Sternb.
40. *Halopyrum mucronatum* (L.) Stapf
41. *Heliotropium bacciferum* Forssk.
42. *Heliotropium bacciferum subsp. bacciferum*
43. *Herniaria maskatensis* Bornm.
44. *Indigofera arabica* Jaub. & Spach
45. *Indigofera oblongifolia* Forssk.
46. *Indigofera semitrijuga* Forssk.
47. *Indigofera* sp.
48. *Ipomoea pes-caprae* (L.) R.Br.
49. *Kohautia retrorsa* (Boiss.) Bremek.
50. *Launaea capitata* (Spreng.) Dandy
51. *Launaea bornmuelleri* (Hausskn. ex Bornm.) Bornm.
52. *Launaea intybacea* (Jacq.) Beauverd
53. *Limonium stocksii* (Boiss.) Kuntze
54. *Lindenbergia* sp. nov.
55. *Lotus garcinia* Ser.
56. *Lycium shawii* Roem. & Schult.
57. *Nanorrhinum* sp. nov.
58. *Neltuma juliflora (Sw.) Raf.*
59. *Pergularia tomentosa* L.
60. *Periploca aphylla* Decne

61. *Phoenix dactylifera* L
62. *Pluchea arabica* (Boiss.) Qaiser & Lack
63. *Polycarpaea spicata* Wight ex Arn.
64. *Polycarpon succulentum* J. Gay
65. *Polygala erioptera* DC.
66. *Prosopis cineraria* (L.) Druce
67. *Pulicaria glutinosa* (Boiss.) Jaub. & Spach subsp. glutinosa
68. *Pulicaria omanensis* E.Gamal-Eldin
69. *Pulicaria pulvinata E.Gamal-Eldin*
70. *Pulicaria undulata* (L.) C.A.Mey.
71. *Pycnocycla* sp. nov.
72. *Salvadora persica* L.
73. *Schweinfurthia papilionacea* (L.) Boiss.
74. *Senna italica* Mill.
75. *Sphaerocoma hookeri* subsp. *Aucheri* (Boiss.) Kool & Thulin
76. *Sporobolus virginicus* (L.) Kunth
77. *Stipagrostis sokotrana* (Vierh.) De Winter
78. *Suaeda aegyptiaca* (Hasselq.) Zohary
79. *Suaeda moschata* A.J. Scott
80. *Suaeda vermiculata* Forssk. ex J.F. Gmel.
81. *Tamarix mascatensis* Bunge
82. *Taverniera spartea* DC.
83. *Taverniera lappacea* (Forssk.) DC.
84. *Tephrosia purpurea* (L.) Pers.
85. Unidentified grass
86. Unidentified shrub
87. *Urochondra setulosa* (Trin.) C.E.Hubb.
88. *Vachellia tortilis* (Forssk.) Galasso & Banfi
89. *Wadithamnus artemisioides subsp. batharitica*
90. *Xerotia arabica* Oliv.
91. *Zygophyllum hamiense* Schweinf.
92. *Zygophyllum indicum* (Burm.f.) Christenh. & Byng
93. *Zygophyllum qatarense* Hadidi
94. *Zygophyllum simplex* L.