FLORA AND HABITATS ON ALGIER'S COASTLINE (ALGERIA): STATE OF KNOWLEDGE AND CONSERVATION ISSUES

Nassima Yahi, Sofiane Ahmed-Zaid, Imen Kafi, Nassima Souyad

Abstract: Coastal ecosystems are rich in biodiversity and maintain a delicate ecological balance. They serve to preserve biodiversity, protect against erosion and stabilize sediments. Nevertheless, they are facing major challenges. Coastal dunes in particular are being affected by a combination of human and natural pressures. They require the implementation of sustainable conservation strategies. Algeria's coastline faces a number of threats, including increasing urbanization and summer overcrowding. These factors have led to the degradation of coastal dunes, threatening flora and habitats. Conservation measures are therefore urgently needed. This study contributes to the assessment of some coastal habitats in Algiers through an inventory of the flora and the monitoring of a number of emblematic species. Meanwhile, a diachronic analysis of the flora has been undertaken in order to understand the fluctuations that have occurred over time. This diagnosis of the coastal flora and the major threats to the habitats provides information on their conservation status and serves as a reference for future conservation and restoration studies.

Keywords: Dune vegetation, Coastline, Mediterranean, South shore, Monitoring.

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Introduction

Coastal dunes and lagoons are unique, fragile and dynamic ecosystems located between the sea and the land. These areas play a vital role in the coastal environment, providing a range of ecosystem services and supporting rich biodiversity. Their conservation is essential to preserve these precious habitats and to ensure their ecological functionality [12].

Coastal areas are characterized by a high level of risk because of their intrinsic vulnerability to the sea action and the high number of socio-economic activities such as artificial structures, extraction of dune sands, grazing and hotel constructions. Among coastal habitats, dunes are particularly studied and considered in conservation status assessments, especially in the Mediterranean biogeographical regions, where they represent the most vulnerable habitats in the face of human and natural pressures [1].

Along the coast of Algiers, the dune vegetation has been the subject of few phytoecological-phytosociological [16, 6, 7, 8, 9] and ecophysiological studies [14, 2]. These contribute to a better understanding of plant community structure and plant adaptation strategies to the hostile conditions of coastal dunes.

The aim of the present study is to update our knowledge of the floristic composition of Algerian coastal dunes and to carry out a diachronic analysis of the dune flora in the face of global changes affecting these fragile ecosystems.

Materials and Methods

1. Study area

In the eastern part of the Algerian coast, beaches dominate the coastline and cover most of the area, while cliffs form only a small proportion [14]. In contrast, much of the west coast of Algeria is characterized by low rocky plateaus, cliffs with varying slopes and terraces. The cliffs are interspersed with coves and bays with sand or gravel deposits. Dunes are found in limited quantities at the mouths of the Nador and Mazaffran rivers [9].

The study area is located in the coastal region of Algiers, which extends from Bou-Ismail Bay in the west to Zemmouri Bay in the east for approximately 150 km along the Mediterranean coast. The coastal plains and hills of the Algerian Sahel define the southern boundaries of the area. It is important to note that the scarcity of coastal dunes in this zone required the selection of sites. The first site was to the east of Algiers (Zemmouri) and the second to the west (Zéralda). The choice of these two sites was based on their representativeness and the presence of vegetation relevant to the study (figure 1).

The study area has a sub-humid bioclimate with warm winters. The summer dry season lasts about 4 months (Table 1).

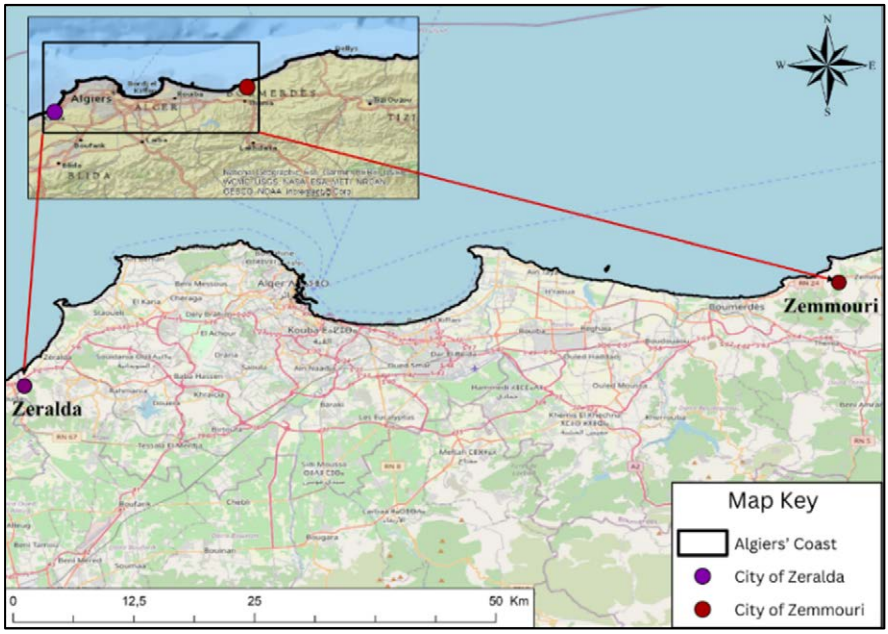

Figure 1 – Study area.

Table 1 – Climate summary for the Zemmouri and Zéralda regions for the period 1991- 2021 (Climate data, 2021).

City	Annual precipitation (mm)	Average annual temperature (°C)	M (°C)	m (°C)	Dry period	Bioclimate
Zemmouri	672	17.5	32.8	5.6	From mid-May to mid-September	Subhumid with a warm winter
Zeralda	605	18.3	30.2	8.7		

2. Vegetation sampling and analysis

Vegetation sampling was carried out in a subjective mode. Plots were selected on the basis of their homogeneity and ability to represent dune vegetation. In the first phase, transects were made in the presence areas with systematic measurements. The results of this phase are not included in this study. Subsequently, 26 floristic surveys were carried out using the sigmatist (phytosociological) method [6]. The taxa have been identified using the flora of Quezel et Santa [13]. The nomenclatural update was made on the basis of the synonymic index of Dobignard et Chatelain [4].

The content of our surveys is compared with those carried out at Zeralda and Zemmouri by other authors in 1960 [16] and 2008 [7,8,9] to support our diachronic analysis of the coastal dune flora.

Floristic surveys were analysed using R. The results were presented by means of a factorial correspondence analysis, which enabled several plant groupings to be identified. These groupings are characterized on three different levels: physiognomic, biological and phytogeographic.

Station assessments have been used as an approach to provide an overall view of the situation of the study populations. They can be applied to a single taxon, to several taxa, or to a plant community as a whole [10].

To estimate plant diversity of the regions of Zemmouri and Zeralda over three temporal intervals, the Shannon-Weiner index (H'), Simpson's diversity index (D) and Pielou's evenness index were calculated. The equations of these indices are as follow:

$$H' = -\sum[(pi)\times\ln(pi)] \quad (1)$$

where:
H': Shannon-Weiner index;
pi: ni/N (ni: number of individuals of a species, N: total number of species);
ln: natural log.

$$D = 1 - \sum (n/N)^2 \quad (2)$$

where:
D: Simpson's diversity index;
n: number of individuals of a particular species;
N: total number of individuals of all species.

$$E = H'/Hmax \quad (3)$$

where:
E: Evenness index:
H': Shannon-Weiner index;
Hmax: natural logarithm of the total number of species.

To evaluate the similarities between the both regions at different periods of time, Jaccard and Sørensen indices were calculated using the following equations:

$$S_J = a / (a + b + c) \quad (4)$$

where:
S_J: Jaccard index;
a: number of species common to list 1 and 2;
b: number of species specific to list 1;
c: number of species specific to list 2.

$S_S = 2a / (2a + b + c)$ 5

In the previous equation, (S_S) represents the Sørensen similarity index, (a) the number of species common to list 1 and 2, (b) the number of species specific to list 1 and (c) the number of species specific to list 2.

Results

1. Identification and characterisation of plant groups

The results of the multivariate analysis show that axis 1 contrasts two types of vegetation, a woody and shrubby pre-forest in its positive part belonging to the *Ephedro fragili-Pistacietum lentiscii* [5]. In its negative part, low maritime sand vegetation can be distinguished, belonging to the *Otantho maritimi-Ammophiletum australis* [5]. Axis 1 is interpreted as a structural vegetation gradient. Axis 2 contrasts two types of survey. In its positive part, surveys carried out on sites disturbed by human action and in its negative part, surveys carried out on less disturbed embryonic dunes. Axis 2 is interpreted as a gradient of anthropisation.

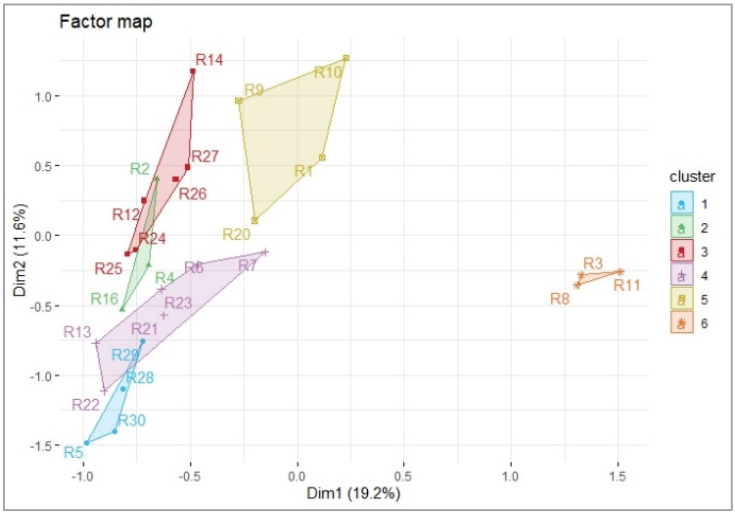

Figure 2 – Factor map of surveys.

G1: Grouping of low vegetation with patches of *Achillea maritima*;

G2: Grouping of low vegetation dominated by *Eryngium maritimum* and *Cakile maritima*. It can be considered as a pioneer grouping of maritime dunes;

G3: Low vegetation grouping dominated by *Pancratium maritimum*. In addition, significant cover values are attributed to associated species such as *Eryngium*

maritimum, Elytrigia juncea, Salsola kali, which is present at the periphery of the beach, and *Xanthium strumarium,* which is considered an invasive species;

G4: Low vegetation dominated by *Ammophila arenaria*, with a significant presence of *Pancratium maritimum*, *Cakile maritima* and *Lotus creticus*;

G5: *Lotus creticus* and *Echium sabulicola* dominate this low vegetation grouping, with the presence of *Ononis variegata and Centaurea sphaerocephala.*

G6: Pre-forest grouping almost dominated by shrubby species: *Ephedra fragilis, Phillyrea angustifolia, Pistacia lentiscus*. We note the presence of *Quercus coccifera*.

2 Biological characterisation

The dominance of a biological type (real biological spectrum) is directly linked to the physiognomically dominant species. In the low-lying vegetation groups on sea sands, we note the predominance of chamephytes (G1), therophytes (G2), geophytes (G3 and G4) and hemicryptophytes (G5). Cover in grouping 6 is dominated by phanerophytes (91 %), followed by therophytes and hemicryptophytes (3 %), chamaephytes (2 %) and finally geophytes (1 %). This grouping reveals a pre-forest environment marked by the presence of *Ephedra fragilis, Pistacia lentiscus, Phillyrea angustifolia* and *Quercus coccifera*.

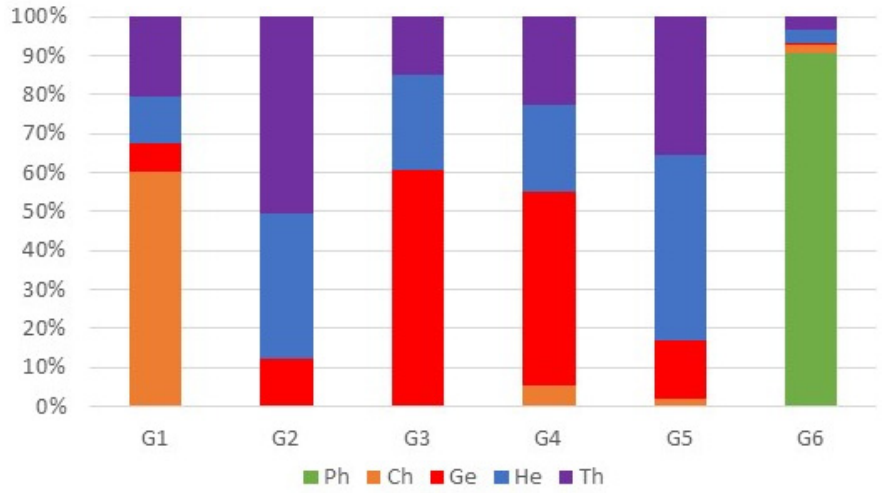

Figure 3 – Biological spectrum (Ph: phanerophytes, Ch: chamaephytes, Ge: geophytes, He: hemicryptophytes, Th: therophytes).

The flora studied shows that the Mediterranean and wide distribution dominate globally in the 6 grouping (Figure 4).

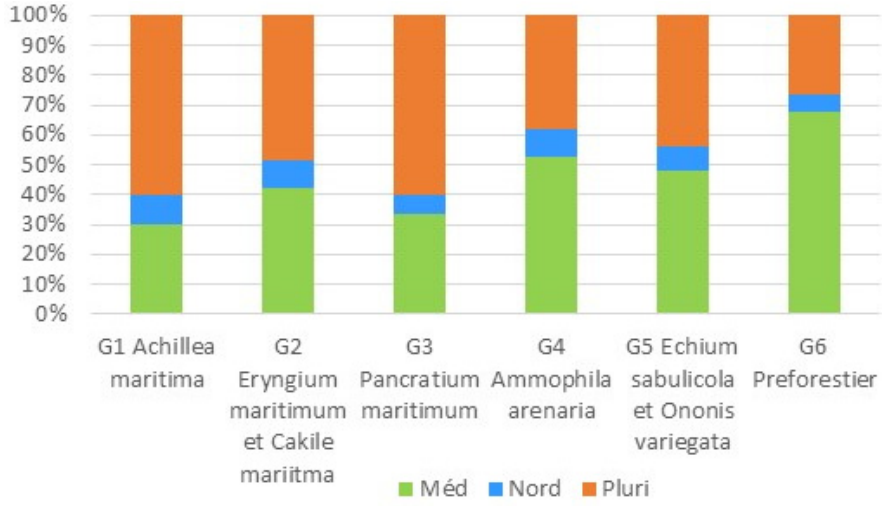

Figure 4 – Biogeographic spectrum.

3. Station assessments

As part of our study, we carried out station assessments for some emblematic species on the coast of Algiers: *Achillea maritima*, *Ammophila arenaria* and *Pancratium maritimum*. The aim was to analyse their chorology and phytoecology, and to identify the main threats facing their populations along the coast.

At the Zéralda site, *Pancratium maritimum* (Figure 5) is threatened mainly by over-visitation during the summer period and sand stripping to build car parks, transport routes and tourist complexes.

At the Zemmouri site, *Ammophila arenaria* (figure 6) is threatened by over-grazing, over-tourism, sand stripping just a few metres from its habitat, pollution and vehicle traffic on the dunes.

Initial monitoring of *Achillea maritima* populations in its potential range at Zemmouri shows that it has not managed to colonise the upper reaches of the beaches and is confined to small patches (Figure 7) scattered on embryonic dunes or at the transition to white dunes. These areas are currently very threatened by the passage of vehicles and heavy machinery. They deserve to be protected.

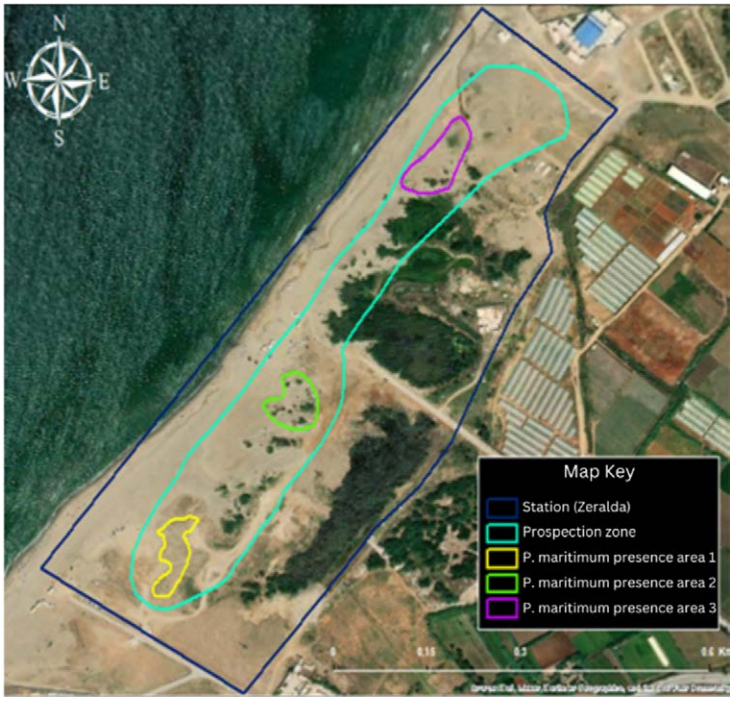

Figure 5 –. Areas of occurrence of *Pancratium maritimum* in the sampled site of Zeralda.

Figure 6 – Areas of occurrence of *Ammophila arenaria* in the sampled site of Zemmouri.

Figure 7 – Areas of occurrence of *Achillea maritima* in the sampled site of Zemmouri

4 Plant biodiversity

The evaluation of alpha diversity in plant communities across two regions of coastal dunes in Algiers and during three periods of time (1960, 2008 and 2023) revealed significant patterns when measured using Shannon-Weiner, Simpson and Pielou indices (Table 2). Overall, the values of Shannon-Weiver index ranged between 1.81 and 2.32, which means that the diversity of these two regions across the three periods of time is moderate. The same observations were made for Simpson's index where the diversity was mainly moderate, while for the Evenness index, it indicated that the two regions across the three periods were generally unstable with some exceptions.

In Zemmouri region, the Shannon index, which measures diversity of species within a community, indicated a moderate stable diversity over time, with values around 2. The Simpson index, which also accounts for species diversity, showed a significant decrease of diversity and this in 2023 compared to the two previous periods (1960 and 2008), where the Simpson index was around 0.65, suggesting a more uneven distribution due to the dominance of a few species. The Pielou's index, reflecting species evenness, corroborated these findings by demonstrating unstable communities across time.

Table 2 – Summary of the values of Shannon, Simpson and Evenness indices in both regions of Zemmouri and Zeralda.

	Shannon index			Simpson index			Evenness index		
	1960	2008	2023	1960	2008	2023	1960	2008	2023
Zemmouri	2.07	2.03	2.08	0.85	0.85	0.65	0.72	0.67	0.65
Zeralda	1.99	2.32	1.81	0.70	0.88	0.78	0.84	0.77	0.62

The second region, Zeralda, displayed an increase in both Shannon and Simpson indices during the period of 2008, and then declined in 2023, reaching the values of 1.81 and 0.88 for Shannon and Simpson indices, respectively. The stability of the dune ecosystems, evaluated by the Evenness index, showed in an important decline in plant community stability in this region between 1960 and 2023.

The analysis of plant composition using Jaccard and Sørensen similarity indices showed significant temporal variations across the three distinct periods in both Zemmouri and Zeralda regions (Table 3). The highest similarity in plant composition was recorded between 2008 and 2023 in the region of Zemmouri, whereas in Zeralda region, it was observed between 1960 and 2008. On the other hand, the lowest similarity was noticed between 1960 and 2023 in Zemmouri region and 2008 and 2023 in Zeralda region.

Table 3 - Summary of similarity indices (in %) between the three periods of time in the regions of Zemmouri and Zeralda.

	Zemmouri		Zeralda	
Pair comparisons	Jaccard	Sørensen	Jaccard	Sørensen
1960/2008	30	46	35	52
1960/2023	25	41	30	47
2008/2023	35	52	25	40

5 Threats Assessment on the dune ecosystem

Coastal dune ecosystems are unique habitats that harbour remarkable biodiversity and provide essential ecosystem services to coastal communities. However, these ecosystems face numerous threats that we have identified in the field (figure 8) as:

- An increasing urbanisation and infrastructure expansion;
- Sea defences and sand extraction;
- Over-visiting by tourists and leisure activities.
- Agricultural and pastoral over-exploitation: presence of goats on the dunes.

The over-exploitation of sand from coastal dunes and beaches upsets the already fragile balance of the coastline and exposes it to the aggressive action of the sea.

Figure 8 – Human activities on sand dunes.

Discussion

Coastal ecosystems in Algeria, as well as those of the Mediterranean region, have witnessed substantial changes in plant communities over time [15]. These environments face considerable degradation leading mostly to their fragmentation and destruction, affecting severely the plant communities of these ecosystems. The loss of plant diversity in coastal ecosystems is due to several factors, mainly the anthropogenic pressure such as urbanization, tourism, pollution and introduction of invasive species [3]. Climate change has also affected these ecosystems negatively. Extreme weather events like the increase in temperatures and the prolonged periods of drought exacerbates the pressure, posing further risks to coastal biodiversity [3]. Understanding the factors affecting the coastal ecosystems is of paramount importance in order to predict and manage changes in plant diversity and composition over time.

Our results indicated that the dune ecosystems in the Algiers region is experiencing a significant reduction in plant diversity, and also suggested that this loss was not a recent trend but started before 1960 and has worsened in recent years.

Conclusion

The Algiers coastline currently faces a number of significant threats, with the western side (Zeralda) more affected than the eastern side (Zemmouri). These threats include uncontrolled urbanisation, the passage of vehicles and heavy machinery over the dunes, excessive grazing, over-visiting by tourists, and sand removal. In order to stop the alarming deterioration of dune habitats and ensure their long-term survival, it is essential to consolidate the work already undertaken by ensuring the spatio-temporal monitoring of dune vegetation (station assessments). There is also an urgent need to continue the inventory of existing vegetation, monitor its demographic evolution, analyse its chorology and assess the threats to dune plant communities. In view of the worrying situation, it is essential to implement a concerted action in collaboration with the conservation structures of Algiers and the National Coastal Commissariat. Targeted conservation and restoration measures must be taken to preserve these particularly fragile habitats. It is also alarming to note that *Ammophila arenaria*, which plays a key role in fixing the dunes, is dwindling *in situ*. This species is used in dune restoration projects [10]. Therefore, in order to contribute to the conservation and restoration of the threatened dune ecosystems of the Algiers coast, it is necessary to consider reintroduction efforts.

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