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A first attempt at seagrass repartitioning in the Moroccan coasts

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ABSTRACT: Seagrasses play a prominent ecological role and support the productivity on which many communities of marine animals feed and reproduce but, unlike their macroalgae and microalgae counterparts, their diversity and extent have never been rigorously documented in Moroccan coasts. In this study we compiled and analyzed the available bibliographic data (Physical and chemical requirements) relating to seagrasses, followed by determination of physico-chemical characteristics of six selected coastal environments in Moroccan coasts. Comparison between seagrass species requirements and selected coastal environment conditions allowed us to distinguish four seagrass species (*Zostera noltii*, *Zostera marina*, *Cymodocea nodosa*, *Posidonia oceanica*) which can shelter these study areas. This paper provides baseline data for further work on ecological study and long term monitoring; and a first step to create a seagrass check-list in Moroccan coasts.

KEYWORDS: Seagrass requirements, Moroccan Mediterranean Sea, Moroccan Atlantic Ocean.

1 INTRODUCTION

Seagrasses are continental flowering plants which, at the end of the Secondary (some 120 million years ago), returned to the marine environment. They constitute an ecological group formed by a small number of families and species [1]. Today, seagrasses give rise to dense formations called 'meadows', met with in practically all the coastal areas of the world [2] except Antartica [3].

Seagrass meadows rank among the most productive ecosystems on Earth [4], [5] and thus, forms an ecologically critical habitat throughout much of the world's coastal oceans [6].

All seagrasses share a set of characteristics [1], such as:

- They are able to live totally emerged (e.g. absence of stomata within the foliar tissues);
- They have an effective system for fixing themselves to the sediment;
- They are adapted to life in a salty environment;
- They have a hydrophilous pollination system (pollen transported by water);
- They are able to successfully compete with other marine vegetation (e.g. algae).

Seagrass habitats are an important component of the marine environment, acting as ecological engineers [7] and providing numerous ecological services [8], including sediment stabilization, nutrient transformation, primary production, feeding, nursery habitat for both recreationally and commercially important fish and shellfish species [9], [10].

Increased coastal development, leading to high nutrient and sediment inputs, has altered water quality, which is a critical component in supporting healthy seagrass populations [11]. Several studies have indicated that seagrass habitat is declining in over 40 locations worldwide [3], [9], [10].

It is generally acknowledged that in order for sound management of resources to exist, there needs to be an inventory and a baseline of those resources [12]. While these exist for other marine species in Moroccan coasts such as macroalgae and microalgae flora, there is currently no reliable baseline available for seagrass habitats. Hence, this paper aims to evaluate the coastal environments which are propitious for the development of seagrass species. This will provide essential baseline information for further complex ecological study.

2 METHODS

2.1 STUDY SITES

Morocco has a coast extending over 3,446 km, with a Mediterranean facade of close to 600 km and an Atlantic one of about 2,850 km (Ministère de l'Agriculture et du Développement Rural, 2003).

Owing to its position both on the Atlantic Ocean and the Mediterranean Sea, Morocco is characterized by paralic coastal environments (estuaries and lagoons mainly) that serve important biological functions to several species, including development, reproduction and feeding.

The choice of study areas is based on the ecological value of the sites (SIBE'S, Ramsar sites), the surface area, the economic value and the degree of anthropogenic pressure on the environment. Thus, six areas were selected in this study including bays and lagoons (Bay of Dakhla, lagoon of Khnifiss, Merja Zerga lagoon, Cape of Three Forks, lagoon Complex Sidi Moussa-Oualidia, lagoon of Nador) (figure 1).

Fig.1. Location map of the 6 lagoons selected for evaluating the presence of seagrasses in Moroccan coasts

2.2 LITERATURE DATA

This preliminary study of seagrass in Moroccan coasts is based essentially on literature review. Initial efforts are focused on the acquisition of a source information point, which is compiled into spreadsheets and diagrams. The following steps have been performed: 1) Identifying seagrass species in Atlantic and Mediteranean Bioregion, 2) Summarize the physico-chemical

seagrass conditions, 3) Determine the physico-chemical characteristics of study areas, and 4) Determine the regions propitious of seagrass developpement, by comparing the physico-chemical conditions of those regions and the optimum conditions required for seagrass developpement.

3 RESULTS AND DISCUSSION

3.1 SEAGRASS IN ATLANTIC AND MEDITERRANEAN BIOREGIONS

Seven species of seagrass have been signalled in the Mediterranean [2], [13], [14]. They are Cymodocea nodosa, Halophila stipulacea, Posidonia oceanica, Ruppia cirrhosa, Ruppia maritima, Zostera marina and Zostera noltii. Of these, Cymodocea nodosa is the most common species. The second most abundant species in this region is Posidonia oceanica, a seagrass endemic to the Mediterranean Sea. The Zostera genus (Z. marina, Z. noltii) are less common. The introduced species H. stipulacea, which essentially remains confined to the eastern part of the Mediterranean [15]. Missaoui et al., 2006 [16] have signaled the presence of H. Stipulacea in Tunisia. Finally, in certain euryhaline lagoons, we notice the development of Ruppia genus (R. cirrhosa and R. maritima), which can develop even in the estuaries and graus (RAC/SPA's report, 2000).

According to Short et al., 2007 [14] five species of seagrass have been observed in th Atlantic, *Cymodocea nodosa, Halodule wrightii, Ruppia maritima, Zostera marina* and *Zostera noltii*. Distribution studies of seagrass in this bioregion are patchy and more data needs to be collected to determine the extent of coverage and abundance of these species.

In this study, we will focus on the most frequent species in the Mediterranean and Atlantic according to Duarte (2001) [17], they are *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera marina* and *Zostera noltii*.

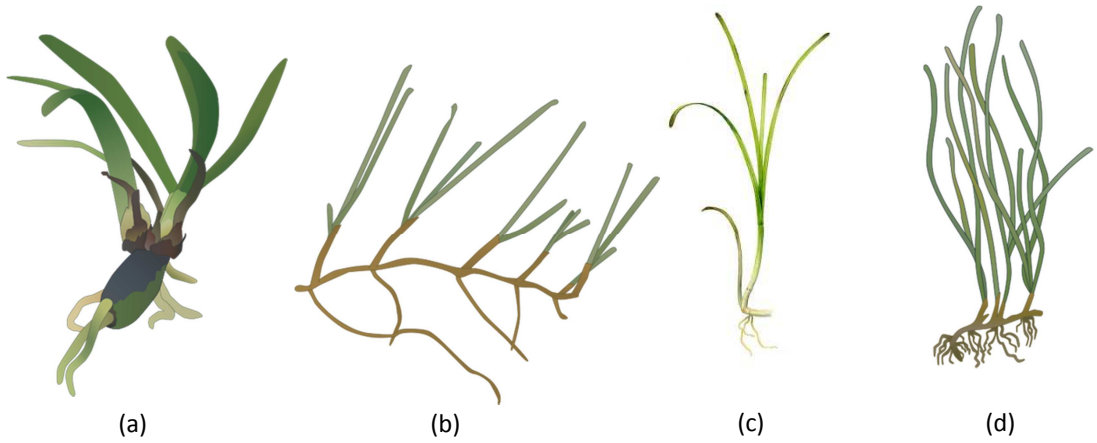

Fig. 2. Schematic illustrations of seagrass species selected: (a) Posidonia oceanica, (b) Cymodocea nodosa, (c) Zostera marina, (d) Zostera noltii (source of the single schemes: http://ian.umces.edu/symbols/).

3.2 ECOLOGICAL FEATURES OF SELECTED SEAGRASS SPECIES

Seagrass distribution along coastal areas is dependent on a number of environmental factors. They can be summarized in:

- Physical factors (substrate, temperature),
- Chemical factors (salinity),
- Hydrodynamic factors (agitation of water),
- Biotic factors (competition with other species).

Table 1. The optimum physico-chemical conditions required for the four selected seagrass species

	Seagrass species			
	Posidonia oceanica	***Cymodocea nodosa***	***Zostera marina***	***Zostera noltii***
Systems	Marine	Marine	Marine	Freshwater, marine
Conservation status UICN	Least concern (LC)[18]	Least concern (LC)[19]	Least concern (LC)[20]	Least concern (LC)[21]
Population trend	Decreasing	Stable	Decreasing	Decreasing
Abiotic factors				
Bathymetry	From shallow subtidal waters to 50-60m[22]	From shallow subtidal areas to very deep waters 50-60m[22]	Intertidal-subtidal area (3-7m in Atlantic, Up to 10m in Mediterranean) [22]	Intertidal and subtidal area Restricted (up to 4m) [22]
Physical exposure	Bear turbid water[22]	Sheltered biotopes[22]	Tolerates heavy hydrodynamic stress[22]	Tide presence, Bear relatively turbid water[22]
Substratum	Silt, fine sand, average and coarse sand, rocks[22]	Gravel, mud rich in organic matter[22]	Coarse sand to silt rich in organic matter[22]	Fairly coarse sediments rich in organic matter[22]
Temperature (°C)	9-29[22, 23]	10-30[22]	Eurythermic (0-30) [22]	Eurythermic[22]
Salinity (PSU)	Stenohaline (34-38) [22]	26-44[22]	Euryhaline (5-36) [22]	Euryhaline (9-32) [22]
Biotic factors				
Competition	*Caulerpa Taxifolia*[22]	*Z. noltii, P. oceanica*[22]	*Mytilus edulis*[22]	*Ruppia spp, Z. marina, C. nodosa*[22]
Grazing	*Sarpa salpa Paracentrotus lividus*[22]	*Paracentrotus lividus Sarpa salpa*[22]	*Cygnus olor Idotea chelipes*[22]	*Branta bernicla Anas platyrhynchos*[22]

3.3 PHYSICO-CHEMICAL CONDITIONS OF SLECTED COASTAL AREAS

To assess seagrass distribution in the Moroccan coasts, we selected six lagoonal sites: Dakhla bay, Khnifiss lagoon, Three-forks Cap, Sidi Moussa-Oualidia complex lagoon, Moulay Bouselham lagoon, Nador lagoon. All of these regions have an ecological, biological and economical role (Ramsar sites, SIBE's). Physico-chemical conditions of study zones are presented in Table 2.

3.4 STUDY AREAS PROPITIOUS OF SEAGRASS DEVELOPPEMENT

By comparing the conditions in the Moroccan coastal ecosystems and the optimal growth required by the four species treated, we can deduce: The physicochemical characteristics of the six coastal areas addressed in this study are conducive to the development of *Posidonia oceanica*, *Zostera marina*, *Zostera noltii* and *Cymodocea nodosa*. Table 3 highlights the areas likely to harbor the four species studied in the selected Moroccan coastal sites.

Posidonia oceanica: is endemic strict Mediterranean, it is a characteristic of the subtidal floor (depth of a few tens of centimeters to 30 to 40 m). This species tolerates temperature and hydrodynamics variations and prefers salinity between 36 and 39 PSU. We did not encounter it in the lagoons or the open estuaries [1].

Cymodocea nodosa: is found mainly in the Mediterranean (Three forks cap) often at the upper limit of *P.oceanica* seagrass beds in the Mediterranean marine ecosystem. Its presence is also likely in the Atlantic precisely at the Bay of Ad-Dakhla. It can be also be found associated with *Zostera noltii* to form a Joint Herbarium [1]. With an optimal salinity, temperature and an adequate average hydrodynamic low, these sites may be deemed conducive to its development.

Zostera noltii: Zostera sp are part of the estuarine vegetation. In general, the presence of *Zostera noltii*, will be conditioned by salinity and hydrodynamics since it does not tolerate areas of high tides. By cons, we can find it in the center of the Merja Zerga. It can also occur at the level of sand and mudflats of Merja. Ad-Dakhla bay is a sheltered area, and despite its significant salinity, *Zostera noltii* can be found in the eastern part. Regarding the lagoon of Nador, we can have *Zostera noltii* in the containment area which is regularly flooded. We also note at this bay, a large value of O_2 dissolved in the water fund, which may indicate the presence of dense vegetation including seagrass meadows.

Zostera marina: This species is common on the coasts of the Atlantic and uncommon in the Mediterranean (coastal lagoons, estuaries, sometimes in intermattes *Posidonia*). *Zostera marina* is a cosmopolitan species with a certain tolerance

with respect to environmental conditions. We can find it in the coastal Atlantic and Mediterranean at depths of 3-7 m respectively and 10m. Khnifiss Bay, Bay of Ad-Dakhla and the lagoon of Nador cannot shelter this case, because of the high salinity encountered in these sites. By cons, Cape three forks, the Sidi Moussa-Oualidia complex are conducive to its development.

This study is a first attempt to determine the distribution of seagrass in Morocco. Considering the large-scale loss of seagrasses (For instance, worldwide seagrass loss between the mid-1980s and mid-1990s was estimated to be 12,000 km^2 [24], the seagrass area lost cannot be quantified in Morocco due to lack of a reliable baseline information. Therefore, an evaluation of the distribution of seagrasses and evaluation of their health in the Moroccan coastal ecosystems are warranted. Further investigations are needed to address their status in more depth.

Table 2. Localisation and physico-chemical conditions of study sites: Dakhla bay (DB), Khnifiss lagoon (KL), Oualidia lagoon (OL), Sidi Moussa lagoon (SML), Moulay Bouselham lagoon (MBL), Three-forks Cap (TFC), Nador lagoon (NL).

	Atlantic Ocean					Mediterranean Sea	
	DB	***KL***	***OL***	***SML***	**MBL**	**TFC**	**NL**
Localisation	23°45'N, 15°50'W	28°03'N, 12°15'W	32°46'N, 09°01'W	33°01'N, 08°44'W	34°51'N, 06°16'W	35°26'N, 02°59'W	35°10'N, 02°57'W
Morphology							
Surface area (Km^2)	400 [27]	65 [28]	3,5 [31]	4,2 [37]	30 [38]	5.000 (ha) [40]	115 [41]
Length (km)	37 [27]	20 [28]	7 [32]	5,5 [37]	9 [38]		24 [41]
Width (km)	14 [27]	0,1 [28]	0,5 [32]	0,5 [37]	5 [38]		7,5 [41]
Inlets	1 [27]	1 [28]	2 [32]	2 [37]	1 [38]	Limited [40]	1 [41]
Depth (max) (m)	20 [27]	6 [28]	6 [32]	6 [37]	5 [38]	6 [40]	8 [42]
Substratum	Sandy/muddy, covered with carpet of algae and salt steppes[27]	sandy, muddy sand and sandy mud[29]	Sand, mud, muddy sand, sandy mud[33]	Sand, mud, muddy sand, sandy mud [32]	Muddy, sandy silt, sandy clay, soft sandstone[38]	Sand [40]	Sand, clay-sand, clay-silt-sand [42]
Freshwater supply	No permanent supply[27]	Absent[29]	Supply in downstream area[34]	Freshwater input along mainland shore [32]	Canal de Nador et de l'oued Drader et Canal du Nador[38]	-	River (Oued Selouane and Oued Bouareg), urban waste water [42]
Hydrology							
Temperature (°C)	15-22 [27]	16,1-24,4 [30]	16-25 [35, 36]	13-24 [32]	13-28 [39]	-	11,8- 27,5 [42]
Salinity (PSU)	36-40 [27]	34-44,1 [30]	5-40 [34]	22,5-35,9 [32]	Up to 35 [39]	-	37-42,7 [43]

Table 3. Study areas propitious of seagrass developpement: Dakhla bay (DB), Khnifiss lagoon (KL), Oualidia lagoon (OL), Sidi Moussa lagoon (SML), Moulay Bouselham lagoon (MBL), Three- forks Cap (TFC), Nador lagoon (NL).

	Atlantic Ocean					Mediterranean Sea	
	DB	***KL***	***OL***	***SML***	**MBL**	**TFC**	**NL**
Posidonia oceanica	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Zostera noltii	Present	Absent	Absent	Absent	Present	Present	Present
Zostera marina	Absent	Absent	Present	Present	?	Present	Absent
Cymodocea nodosa	Present	Absent	Absent	Absent	?	Present	Absent

4 CONCLUSION

Seagrass beds are among the most valuable ecosystems in the world [8]. They produce a variety of goods (finfish and shellfish) and provide ecological services (maintenance of marine biodiversity, regulation of the quality of coastal waters, protection of the coast line) which are directly used by or are beneficial to humans and condition the economic development of coastal zones. In addition seagrasses are indicators of the status of the coastal zone which can be used in coastal management strategies aiming at preserving or improving the environmental quality of the coastal zone.

The growth and distribution of seagrasses are controlled by the physical, chemical and biological properties of the environment they live in. Sufficient light, nutrients and inorganic carbon are basic needs for photosynthesis, but also a suitable substratum, moderate exposure, temperature and various biological factors affect the distribution of seagrasses.

In Morocco, seagrasses are relatively unknown and underappreciated. During the last two decades hydrobiological research has multiplied, and algae have occupied a primary importance, both in terms of biodiversity [25], [26] and water quality, regardless of seagrasses, which also play several roles and reflect the ecological health of an entire ecosystem. There is no actual scientific research on the exact location or the geographical extent and composition of seagrasses meadows. Some reports and scientific studies are limited to indicating the presence of seagrasses without any inventory of species of seagrasses.

This study is a first attempt at seagrass repartitioning in the Moroccan coasts and according to our results we can deduce that the physicochemical characteristics of the six coastal areas addressed in this study are conducive to the development of *Posidonia oceanica*, *Zostera marina*, *Zostera noltii* and *Cymodocea nodosa*.

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