Mamadou Abdoul Ba

Current information on seagrass habitats of the Banc d'Arguin National Park, Mauritania

UNIVERSIDADE DO ALGARVE

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Master in Marine Biodiversity, Fisheries and Conservation

Mestrado em Biodiversidade, Pescas e Conservação Marinhas

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UNIVERSIDADE DO ALGARVE

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Declaração de autoria de trabalho

Declaro ser autor deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da lista de referências incluída.

Declaration of Authorship of work

I declare I am the author of this work, which is original and unpublished. The sources consulted have been duly cited in the text and included in the list of references.

Déclaration de l'auteur de l'œuvre

Je déclare être l'auteur de cet ouvrage original et inédit. Les sources consultées ont été dûment citées dans le texte et incluses dans la liste de références.

Mamadou Abdoul Ba

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Summary:

Seagrass beds play an essential role in coastal ecosystems, providing critical habitat, carbon sequestration and numerous ecosystem services. The Banc d'Arguin National Park (PNBA) in Mauritania is a UNESCO World Heritage Site known for its rich marine biodiversity and unique coastal ecosystems structured by extensive marine vegetation. Seagrass meadows, in particular, are extremely important in this protected area, for supporting a multitude of ecosystem services and ecological functions. This study aims to compile and update the most recent information gathered as part of our work on seagrass habitats and their associated species in the Banc d'Arguin National Park over the last five years. The information gathered shows that three seagrass species are widespread along the coast of the PNBA, but that they are ecologically and structurally different, and that they are subject to threats that differ between species depending on their biology. A major concern for this vast protected national park is that the main threats to seagrass habitats are not local in origin and cannot therefore be easily managed and avoided by the management authorities. Conservation of seagrass habitat by the Mauritanian authorities is a priority, but local action cannot counteract global pressures, particularly climate change and invasive species.

Resumo:

As pradarias de ervas marinhas desempenham um papel essencial nos ecossistemas costeiros, proporcionando habitat crítico, sequestro de carbono e numerosos serviços ecossistémicos. O Parque Nacional do Banc d'Arguin (PNBA), na Mauritânia, é Património Mundial da UNESCO, conhecido pela sua rica biodiversidade marinha e ecossistemas costeiros únicos estruturados por extensa vegetação marinha. As pradarias de ervas marinhas, em particular, são extremamente importantes nesta área protegida, por suportarem uma multiplicidade de serviços ecossistémicos e funções ecológicas. Este estudo visa compilar e atualizar as informações mais recentes recolhidas como parte do nosso trabalho sobre habitats de ervas marinhas e suas espécies associadas no Parque Nacional do Banc d'Arguin nos últimos cinco anos. A informação recolhida mostra que três espécies de ervas marinhas estão distribuídas ao longo da costa do PNBA, mas que são ecológica e estruturalmente diferentes, e que estão sujeitas a ameaças que diferem entre espécies dependendo da sua biologia. Duas espécies temperadas, *Zostera noltei* e *Cymodocea nodosa*, aqui perto do seu limite sul de distribuição, estão muito ameaçadas pelas alterações climáticas, prevendo-se redução ou mesmo extinções locais, na sua distribuição. Cymodocea nodosa foi ainda observada frequentemente afetada por fatores bióticos como infeções por organismos endófitos (oomicetes) e cobertura por epífitos como algas filamentosas, briozoários e ascídeas coloniais. As duas espécies temperadas de ervas marinhas são as mais importantes no PNBA do ponto de vista estrutural, pois atingem as maiores dimensões e assim criam habitat de forma muito mais significativa para a biodiversidade marinha que deles depende, comparativamente à espécie de afinidade tropical, *Halodule wrightii*. Esta última, aqui no seu limite norte de distribuição, prevê-se que continue a aumentar em distribuição e abundância no PNBA, à medida que as temperaturas aumentam, o que é favorável. Esta espécie será também beneficiada com o desaparecimento da espécie maior, *Cymodocea nodosa*, que compete pela luz, sendo de maiores dimensões. Uma grande preocupação para este vasto parque nacional protegido é que as principais ameaças aos habitats de ervas marinhas não são de origem local e, portanto, não podem ser facilmente geridas e evitadas pelas autoridades de gestão. A conservação do habitat das ervas marinhas pelas autoridades mauritanas é uma prioridade, mas medidas locais não podem contrariar as pressões globais, especialmente as alterações climáticas e as espécies invasoras.

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PNBA – Bank d'Arguin National Park

1 : Introduction

Seagrass beds are essential components of coastal ecosystems, providing numerous ecological and economic benefits. They help to stabilise the coastline, improve water quality and serve as essential habitats for a wide range of marine organisms. In the Banc d'Arguin National Park (PNBA) in Mauritania, seagrass beds play an essential role in maintaining the unique biodiversity of the region and the overall health of this globally important coastal ecosystem. The seagrass species that inhabit this region, *Halodule wrightii, Cymodocea nodosa* and *Zostera noltei,* have very distinct characteristics and different ecological importance as habitat providers. In addition, their very distinct biological and ecological characteristics mean that they are differently vulnerable to threats and pressures from anthropogenic factors and natural events.

The Banc d'Arguin National Park, established in 1976, located along the west coast of Mauritania, is a UNESCO World Heritage Site and a Ramsar wetland of international importance, and spanning approximately 12,000 km2, is West Africa's largest Marine Protected Area (Araujo & Campredon 2016). It is renowned for its exceptional biodiversity, which includes a large number of bird species, marine life and numerous seagrass meadows, that are habitat for a very large population of green turtles (Catry et al. 2023). These seagrass beds not only serve as feeding and breeding grounds for various marine species, but also as carbon sinks, helping to mitigate the effects of climate change. Three seagrass species are present in the PNBA: *Zostera noltei, Cymodocea nodosa* and *Halodule wrightii* (Chefaoui et al., 2021). The intertidal seagrass area of the National Park was estimated as 67.400 ha using 518 Landsat image (Tregarot et al. 2021), and the total intertidal plus subtidal was estimated to be around 500.000 ha by Pottier et al. (2021) using Sentinel2 and Chefaoui et al. (2021) by species distribution modeling based on temperatures and depth (a proxy for light).

The seagrass meadows of the Banc d'Arguin National Park extend over large areas of the coastal zone, encompassing a vast network of interconnected channels and foreshores. These meadows can extend over vast areas, offering a rich mosaic of habitats for a wide variety of marine life. Seagrass beds are found throughout the park, but are particularly concentrated in sheltered, shallow areas. These areas offer ideal conditions for the growth and propagation of various other species associated with seagrass habitats.

This study aims to review the current state of knowledge concerning three key seagrass species on the Banc d'Arguin: *Halodule wrightii, Cymodocea nodosa* and *Zostera* noltei, based on the data we have generated over the last five years through our field surveys and information gathering. This compilation of all new information is important and useful for the management authorities and other stakeholders and co-managers, as well as for scientistis and the general public, to contribute to inform decisions, management, conservation initiatives and education.

The specific objectives of this study are to review, for the PNBA, our own data collected and produced by research initiatives over the last 5 years (2018-2023) on seagrass habitats, namely:

Spatial and vertical distribution: Understanding the horizontal and vertical spatial distribution and habitat structure of these seagrass species on the Banc d'Arguin is essential for effective conservation and management.

Biology and reproductive strategies: The ecological characteristics and life strategies of *Halodule wrightii, Cymodocea nodosa* and *Zostera noltei* determine their capacity for resilience and adaptation to changing environmental conditions. These species have a variety of biological characteristics that will be compared with what is known about the PNBA.

Threats

Physical threats: Climate change, dust storms, limitation of irradiation: Seagrass ecosystems are very vulnerable to stress factors induced by climate change and, for the PNBA, rising sea temperatures and rising sea levels are of particular concern. Desert dust storms and water turbidity are also of concern. This study reviews what is known about the potential effects of physical environmental threats on the seagrass beds of the Banc d'Arguin.

Biotic threats: Epiphytes and invasive species: Epiphytic organisms can have a significant influence on seagrass health and ecosystem dynamics and are known to cause significant seagrass die-offs worldwide. Similarly, invasive species pose a significant threat to seagrass ecosystems worldwide. This study examines the evidence for the presence of epiphytes associated with *Halodule wrightii, Cymodocea nodosa* and *Zostera noltei* and the evidence for their negative effects on seagrass meadows in the PNBA. We are also investigating the presence and impact of invasive species on these three seagrass species on the Banc d'Arguin, seeking to understand whether there are more species that are affected or sites.

This comprehensive study aims to provide valuable information on the ecology and conservation of *Halodule wrightii, Cymodocea nodosa* and *Zostera noltei* on the Banc d'Arguin, a unique and ecologically important area. By synthesising existing knowledge and identifying key research gaps, this study contributes to a better understanding of seagrass ecosystems and supports conservation efforts in the face of current environmental challenges.

2 : Methods

2.1 : Study area

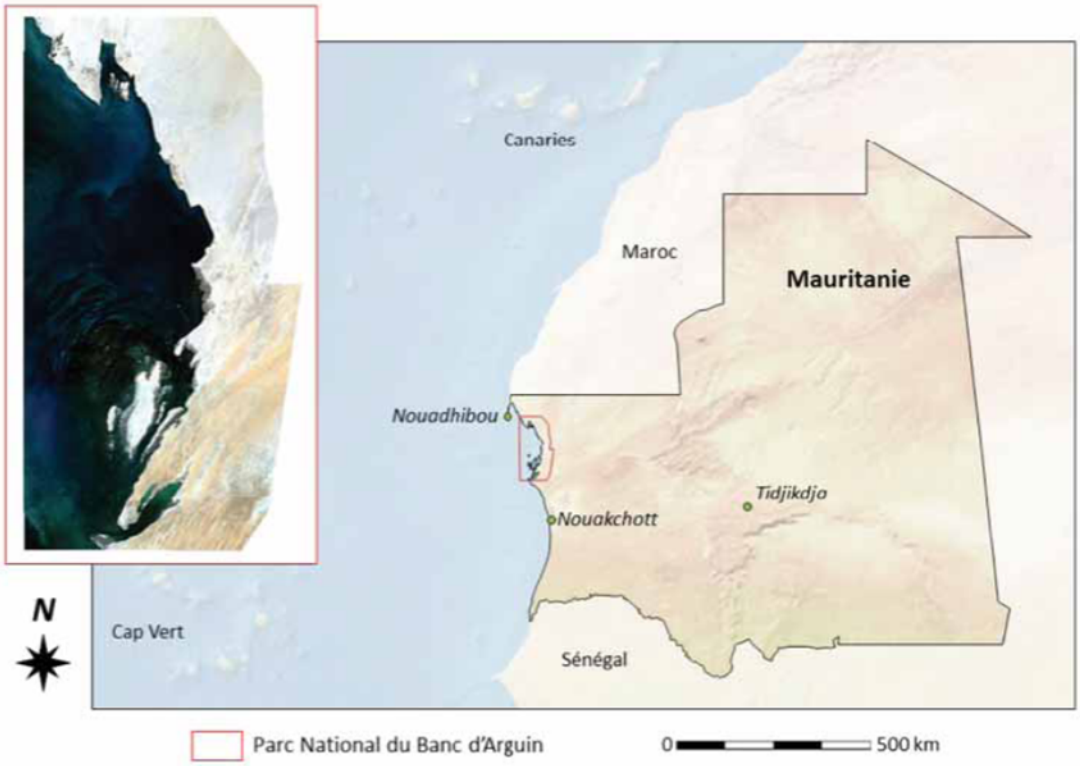

Figure A: Location and extension of the Banc d'Arguin National Park (PNBA) in Mauritania, on the Atlantic coast between the towns of Nouakchott and Nouadhibou. The zoom shows the boundaries of the PNBA as seen by the sentinel satellite (© ESA, 2018).

The Banc d'Arguin National Park (PNBA) is a nature reserve in Mauritania, founded in 1976 by decision of the President of the fledgling Islamic Republic of Mauritania, Mokhtar Ould Daddah, in consultation with the French naturalist Théodore Monod (Ould Cheikh, 2002a). Covering a third of the Mauritanian coastline, it stretches from

Pointe Minou in the north (beyond Cap d'Arguin) to the town of Mamghar in the south (beyond Cap Timiris), and also includes the islands of Arguin and Tidra. It has a surface area of 12,000 km², divided between the Atlantic Ocean and the Sahara Desert (Figure).

The PNBA is therefore one of the largest parks in West Africa, having become a Ramsar site in 1982 and a UNESCO World Heritage Site in 1989.

The Park plays a vital role in maintaining marine biodiversity and protecting the ecosystem of the Gulf of Arguin, a key element in the renewal of fisheries resources in Mauritania's EEZ (Exclusive Economic Zone) and, no doubt, on a wider sub-regional scale.

Conservation of the natural environment and sustainable development of the local population are the main objectives of the PNBA.

2.2: Data collection

2.2.1: REVIEW OF EXISTING INFORMATION:

Methods included reviewing recent (last 5 years) data and literature (since 2018), as well as collecting information from publicly available databases and unpublished data on seagrass beds in Banc d'Arguin National Park.

The review focused on all ecologically relevant data on seagrass beds in the Banc d'Arguin National Park, in particular distribution, ecology and threats. Recent data from the literature on seagrass beds in the Banc d'Arguin National Park were synthesised. Relevant data and information were extracted from the selected sources for seagrass species, including species, distribution data, ecological results and threats. Grey literature sources, including theses and technical reports relating to seagrass beds in the Banc d'Arguin National Park, were included. Experts were contacted if they had unpublished data or ideas. The result was a review of the literature and information on seagrass beds in the Banc d'Arguin National Park from publicly available databases and unpublished data sources.

2.2.2: CITIZEN SCIENCE

The study was supplemented by field surveys to develop a citizen science method, using i-naturalist, for the PNBA. A specific project in i-naturalist has been developed for this purpose:https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/

A PNBA account was created as the project administrator: pnba biodiversity.

This initiative was linked to the field surveys. Wherever possible, our field observations were photographed and added to the portal with dates and GPS coordinates.

2.2.3: LOCAL ECOLOGICAL KNOWLEDGE

Some of the data was collected by talking to fishermen about the spatial location and seasonality of seagrass beds (local ecological knowledge). Surveys were carried out with 64 Imraguen fishermen (Fig. 1a) on seagrass habitats and the feeding habits of green turtles, as well as on sites and seasons. Sites identified as important habitats for green turtles (Fig. 1a) were then visited as part of the field studies. Due to privacy concerns, as the data link fisheries practices information to specific identified humans, we do not report the full results here. The specific turtle questions asked were:

1. y-a-t-il des sites ou l'il voit frequemment des tortues de mer?
2. Y-a-t-il une saison ou il voit plus souvent les tortues de mer?
3. Que voyez-vous habituellement dans l'estomac des tortues?

Besides these, 39 other questions are available that describe their fishing practices.

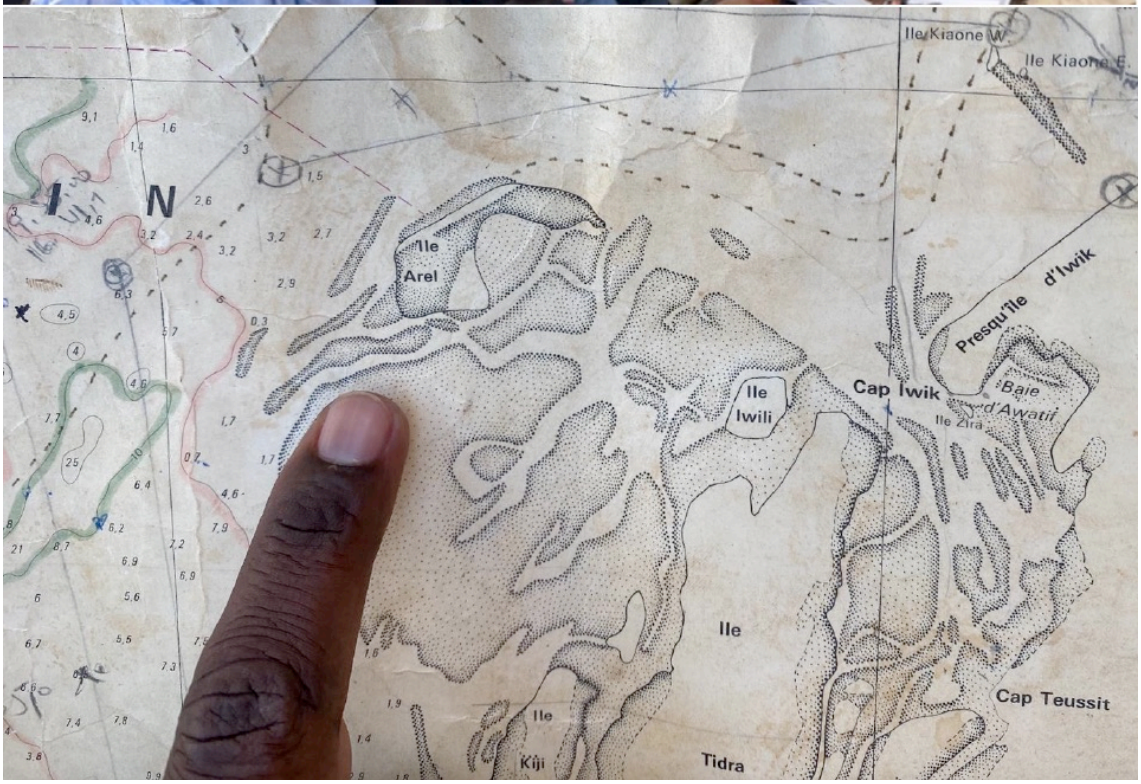

Fig. 1a Survey of local Imraguen fishermen about the location of seagrass and green turtle habitats and on the feeding habits of green turtles (image above), and indication by fishermen of an important location where most turtles spend the night.

2.2.4: FIELD SURVEYS

Essential, missing or additional information was gathered during field studies, in order to complete and verify certain information on seagrass beds (Fig. 1b). These field studies focused in part on sites indicated by fishermen as being feeding sites for green turtles. The methods used included visiting a variety of sites of high importance for marine vegetation and sampling using visual surveys at low tide, snorkelling and scuba diving (by teams of specialist divers) and "ganchorra" (a toothed dredge that collects seagrass with its rhizome, to determine whether it is attached or drifting). This made it possible to verify their presence, distribution at depth, epiphytes, associated species and diseases.

Fig. 1b: Collection of seagrass samples in the PNBA to determine density and leaf length.

2.2.5: Mapping subtidal meadows

Mapping subtidal seagrass beds in the PNBA, during this mission we aimed to combine side-scan sonar and a single-beam echo sounder with an underwater camera and tide gauges to map the subtidal seagrass beds on the Banc d'Arguin. Data collection was carried out on pre-identified transects (Fig. 2), focusing on relatively shallow areas (< 10 m) as seagrass beds are less likely to develop in deeper areas (Fig. 2).

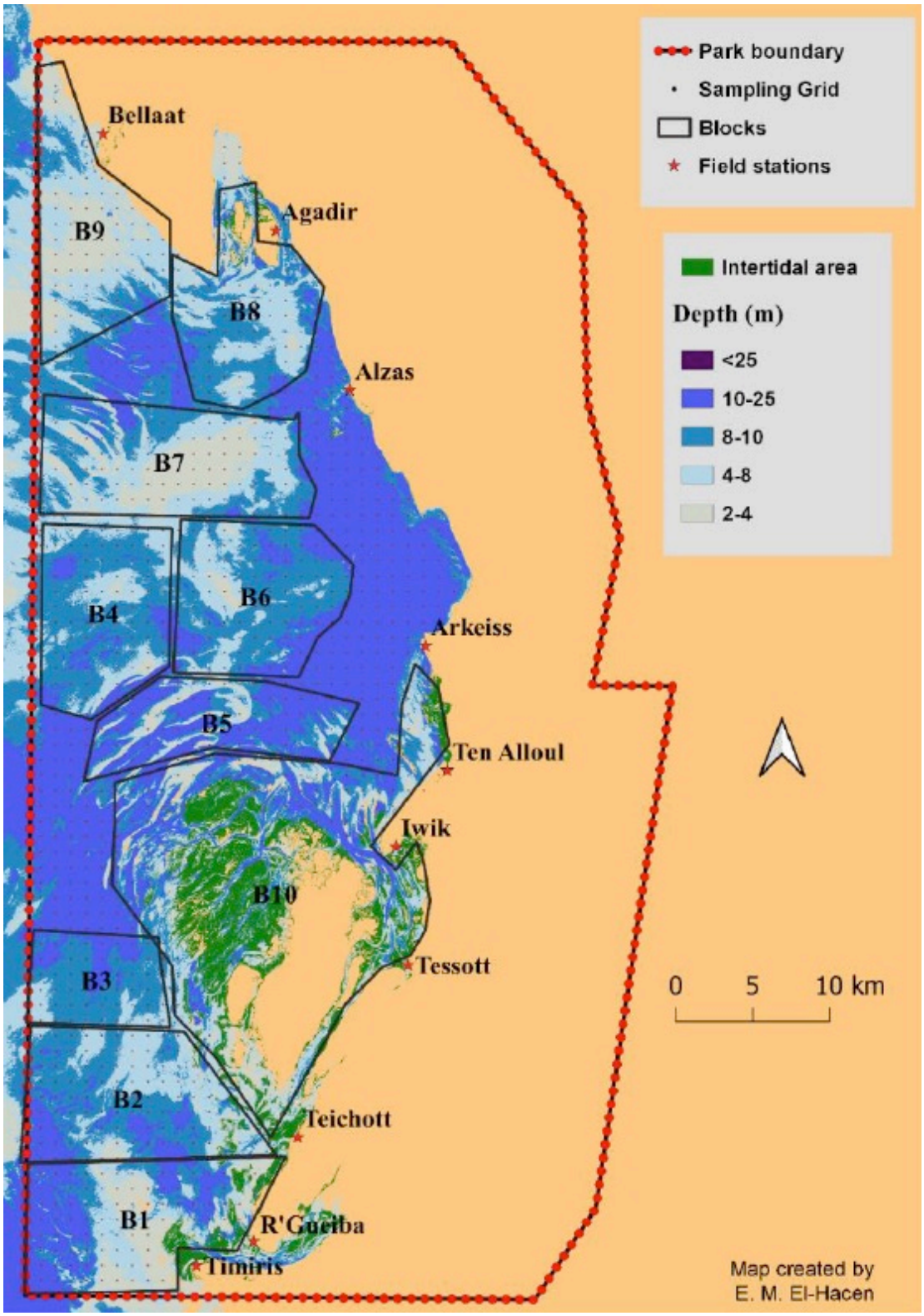

Figure 2. Map showing the area targeted for mapping subtidal seagrass beds. The area has been divided into different blocks that can be approached from the different field stations. The map also shows an approximation of depth, which was used to target the most likely areas for subtidal seagrass beds (< 10 m depth).

3 : Results and discussion

3.1: SPATIAL DISTRIBUTION:

3.1. a: LOCAL ECOLOGICAL KNOWLEDGE:

Spatial locations: Local fishermen indicated several names and locations of sites in the Banc d'Arguin National Park where many green turtles come to feed (Fig. 3). These sites were surveyed, generally indicating the presence of abundant seagrass or red algae, as reported by the fishermen. Mojd Dakhna was identified by all fishermen as the most important site for green turtles, while the other sites indicated were named by some fishermen, but not all unanimously. The Idess site was studied with fishermen from Imraguen, who indicated that it was full of red algae, and this was indeed the case.

Feeding: fishermen also indicated that most green turtles feed on sea grass or red algae.

Seasonality: fishermen have indicated that green turtles and red algae are more abundant in summer, during the warmer months such as July and August, and that they become rare during the colder months such as January.

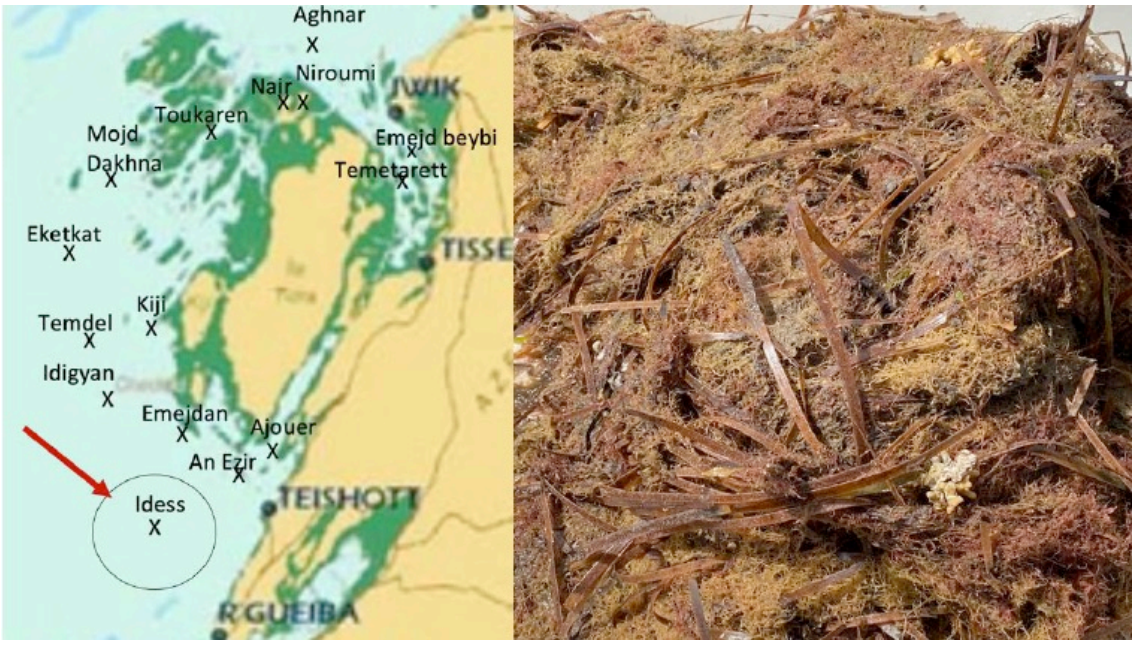

Fig. 3 Left: Names of sites mentioned by Imraguen fishermen as having many turtles in summer because of the abundance of sea grass or red algae. The most important site for green turtles is Mojd Dakhna. Right: sample taken from the Idess site, which fishermen described as having an abundance of red algae. This was confirmed by sampling.

3.1.b : PHOTOGRAPHIC RECORDS OF MARINE BIODIVERSITY

The project created in i-naturalist to record species distributions within the PNBA (https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/, consulted in September 2023) currently has 1901 species distribution records, for 282 species (Fig. 4, 5).

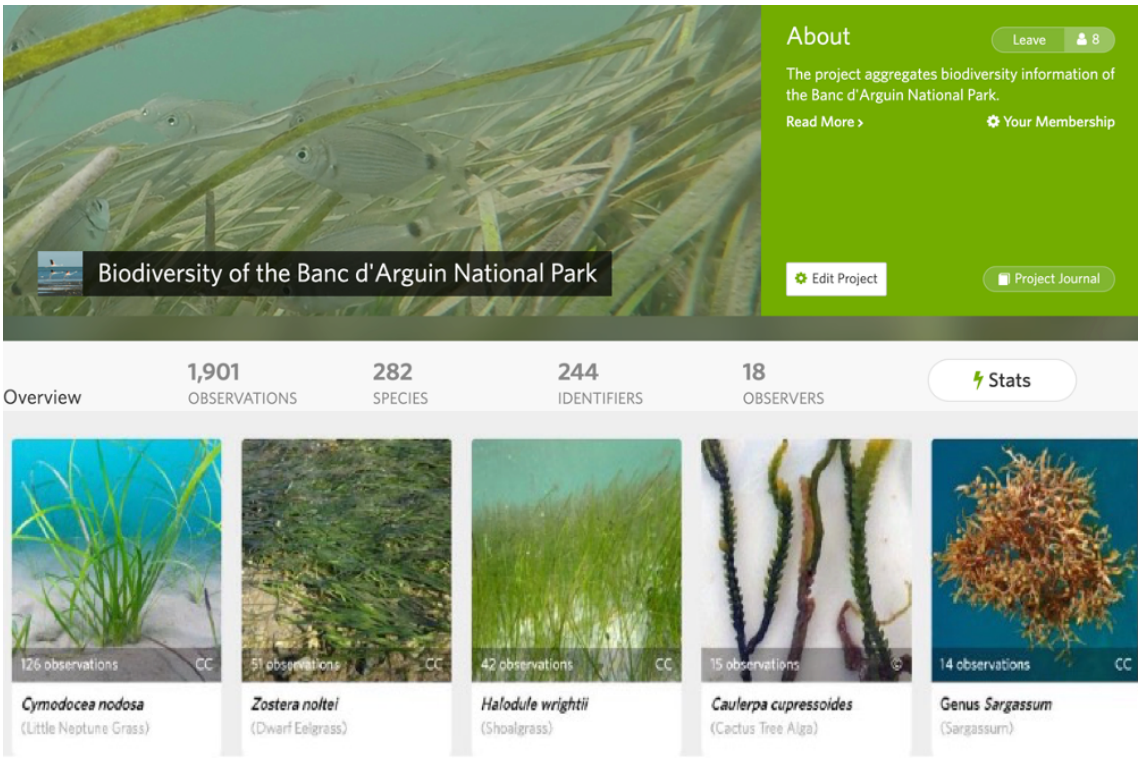

Fig. 4. i-naturalist project for recording photos of the biodiversity of the PNBA https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ , consulted in September 2023. The images show the most frequently recorded species, which coincide with the main species forming the habitat: three species of seagrass, green algae of the *Caulerpa* genus and brown algae of the *Sargassum* genus.

Fig. 5 Spatial distribution of the photographic records of biodiversity in the PNBA. From https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ , consulted in September 2023.

3.1.c : THE PNBA BIODIVERSITY PORTAL

Photograph-based records from the naturalist portal, added to all the other information compiled, and made available in the newly created PNBA biodiversity portal (Fig. 6): https://www.marafrica.net/records/ , consulted in September 2023, resulted in a total of 3011 records of PNBA species, for 394 species, compiled from observations over the last 45 years.

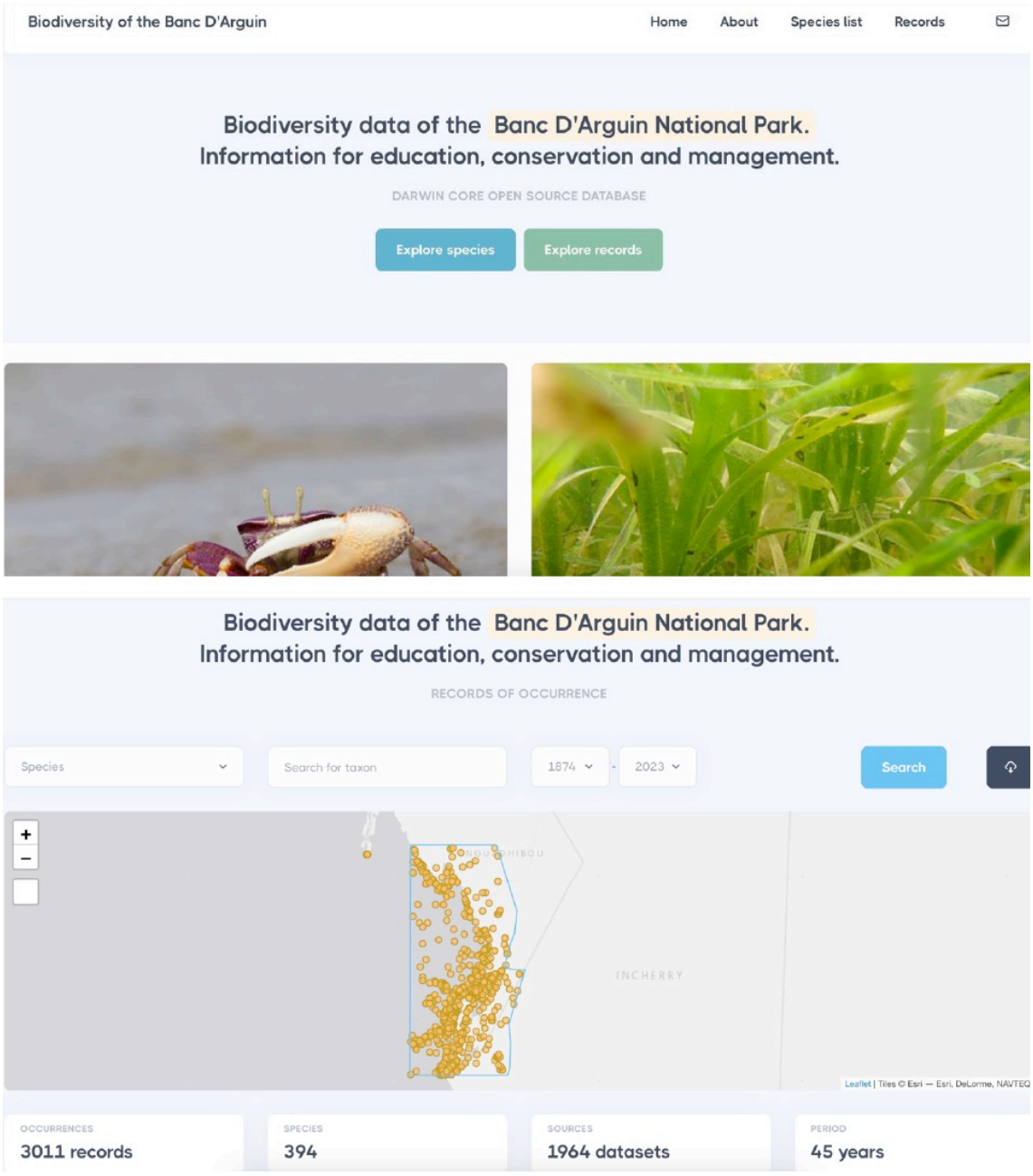

Fig.6. Bioportal of the PNBA's biodiversity: https://www.marafrica.net/records/, consulted in September 2023, including 3011 records of species in the PNBA to date, for 394 species, compiled from observations over the last 45 years.

3.1.d : Mapping subtidal meadows

In this field mission, which took place between 8 January and 15 February 2023, we covered most of the shallow zone (< 10 m depth) (Fig. 4) and made 341 ground-truthing points on small transects. Our preliminary observations indicate that, in general, seagrass beds dominate the subtidal seabed between 0 and 3.5 m, but can be found down to 6.5 m in clear water. The seabed between 3.5 and 5.5 m is characterised by the coexistence of seagrass beds and different species of algae, with the dominance of seagrass diminishing as turbidity increases. Overall, at a depth of less than 6 m, algae dominate in sheltered areas, and the seabed is mainly bare in areas with strong currents. Two species of subtidal seagrass were observed in the park: *Cymodocea nodosa* is the most common species north of Tidra, particularly in muddy areas, while *Halodule wrightii* was very common in the south (e.g. Baie de Saint-Jean) and seems to grow well on sandy substrates. Numerous species of algae have been identified in the park, including some green macroalgae (*Acetabularia* sp.), brown algae (*Gongolaria nodicaulis, Sargassum* sp.) and red algae (*Laurencia* sp., *Gelidium* sp., *Dasya corymbifera*, *Jania* sp., *Plocamium cartilagineum, Hypnea musciformis*). This information is still preliminary, pending completion of the analysis of the data collected by a private consultancy.

3.2 : Spatial distribution of *Cymodocea nodosa*

The portal has photographic records of 171 sites with *Cymodocea nodosa*, indicating its presence along the coasts of the entire PNBA (Fig. 7, 8).

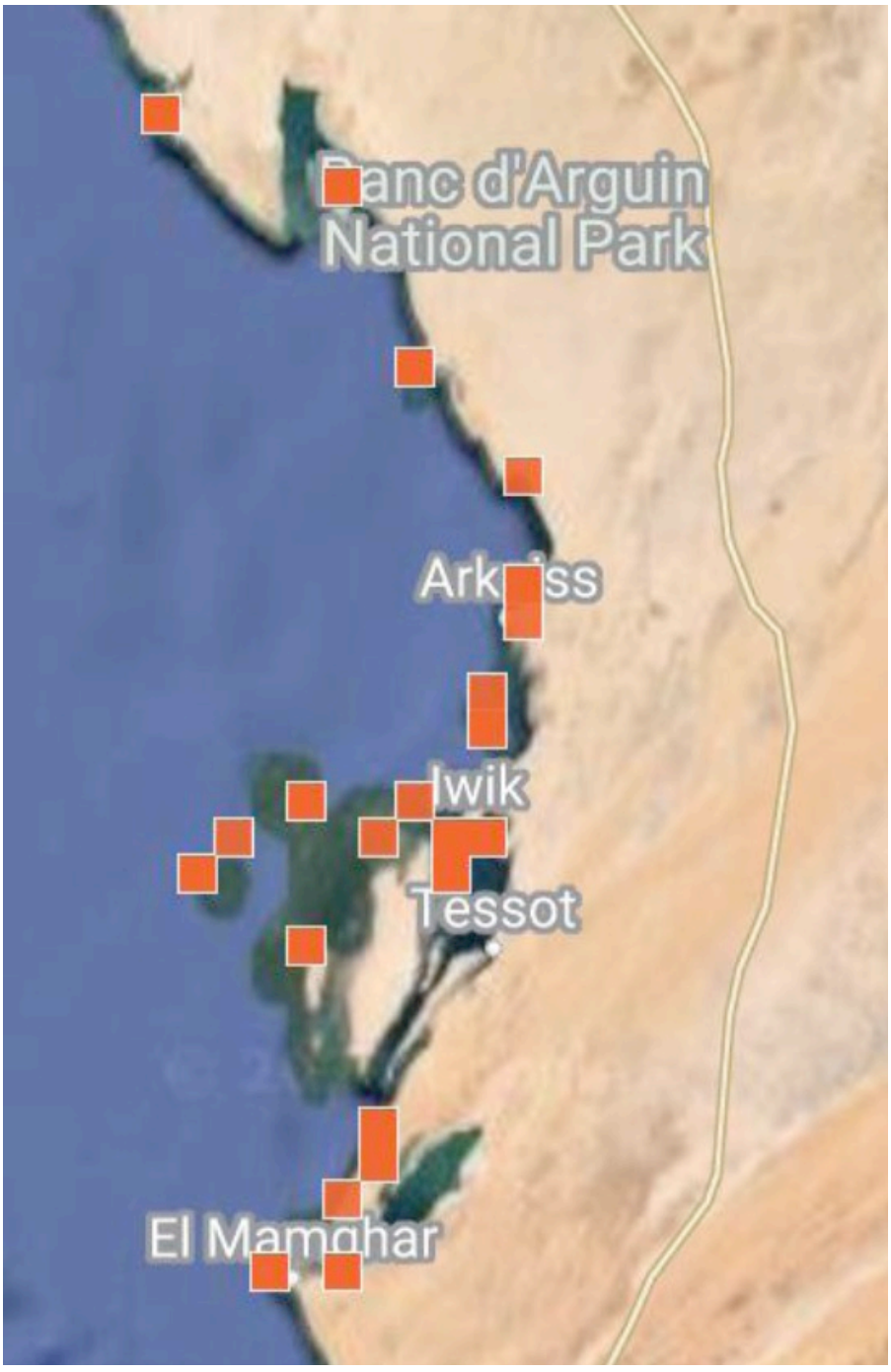

Fig 7: Photographic records in the PNBA-inaturalist portal showing where the *Cymodocea nodosa* seagrass has been recorded. From https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ , accessed September 2023.

Fig.8: Examples of photographic records of *Cymodocea nodosa* in the PNBA. From https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ , consulted in September 2023.

3.3 : Spatial distribution of *Halodule wrightii*

The 81 localities recorded containing Halodule wrightii indicate its presence everywhere along the subtidal meadows of the PNBA except at its northern limit (Fig 9). The most northerly records so far in the portal are at Cap Tagarit. In general, records of H. wrightii were

subtidal and almost always mixed with Cymodocea nodosa, or if they are intertidal, they are found in humid areas where the leaves of the herbarium do not dry (Fig.10).

Fig: 9 Photographic records in the PNBA-inaturalist citizen-science portal showing where the alga *Halodule wrightii* has been recorded. From https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ , accessed September 2023.

Fig. 10. Examples of photographs of *Halodule wrightii* in the PNBA, in very shallow (left) and deeper (right) waters, illustrating how it is commonly mixed with *Cymodocea nodosa* in subtidal zones. According to https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ consulted in September 2023.

3.4 : Spatial distribution of *Zostera noltei*

The 72 recorded locations of *Zostera noltei*, compared to the surveyed sites where *Zostera noltei* could have been recorded but was not present, indicate that it is widespread along the intertidal zones of all regions of the PNBA (Fig. 11), from north to south and both inshore and offshore. However, it is more common in sheltered areas or in the more protected parts of islands that are areas of sediment accumulation, and less common on open coasts with higher hydrodynamic exposure, where the substrate is sandier.

Fig 11: Photographic records in the PNBA-inaturalist citizen-science portal showing where the *Zostera noltei* herbarium has been recorded using photographs in i-naturalist. Taken from https://www.inaturalist.org/projects/biodiversity-of-the-banc-d-arguin-national-park/ , consulted in September 2023.

3.4.5: LEAF CHARACTERISTICS

Leaf length and density are specific characteristics of seagrass beds in the PNBA and can vary depending on the seagrass species. Different species have distinct morphological characteristics, including leaf length and traits, in order to adapt to local environmental conditions.

In the PNBA, the different seagrasses have very distinct characteristics (Fig. 12), which has strong implications for ecosystem benefits and functions. However, these characteristics vary spatially from the south to the north and from the east to the west of the PNBA.

Leaf size: In general, *Cymodocea nodosa* has larger, longer leaves, reaching > 50 cm in suitable conditions, and wider (2- 6 mm), and is therefore the flagship species of subtidal habitats. Fishermen report that it is the main food of green turtles in the PNBA, which may be associated with its size. There is high variability in leaf length among sites in the PNBA (Fig. 12), showing that the habitat conditions vary and strongly affect the state of the seagrass meadows, in ways that differ among species and among habitats. On the other hand, the thinnest leaves in general are those of *Halodule wrightii* (0.5-0.6 mm), the tropical species, which is the species expected to become more and more predominant in a warmer future (see climate change effects) (Chefaoui et al. 2021).

Shoot density: In general, the seagrass that is capable of achieving the greatest shoot density is *Zostera noltei*. This is related to their growth angles, creating a different more closed growth geometry of the rhizomes inside patches, which increases the number of shotts per unit area (density). Once again, there is high variability in leaf length among sites in the PNBA (Fig. 12), showing that also for density, like for length, the habitat conditions vary and strongly affect the state of the seagrass meadows, in ways that differ among species and among habitats.

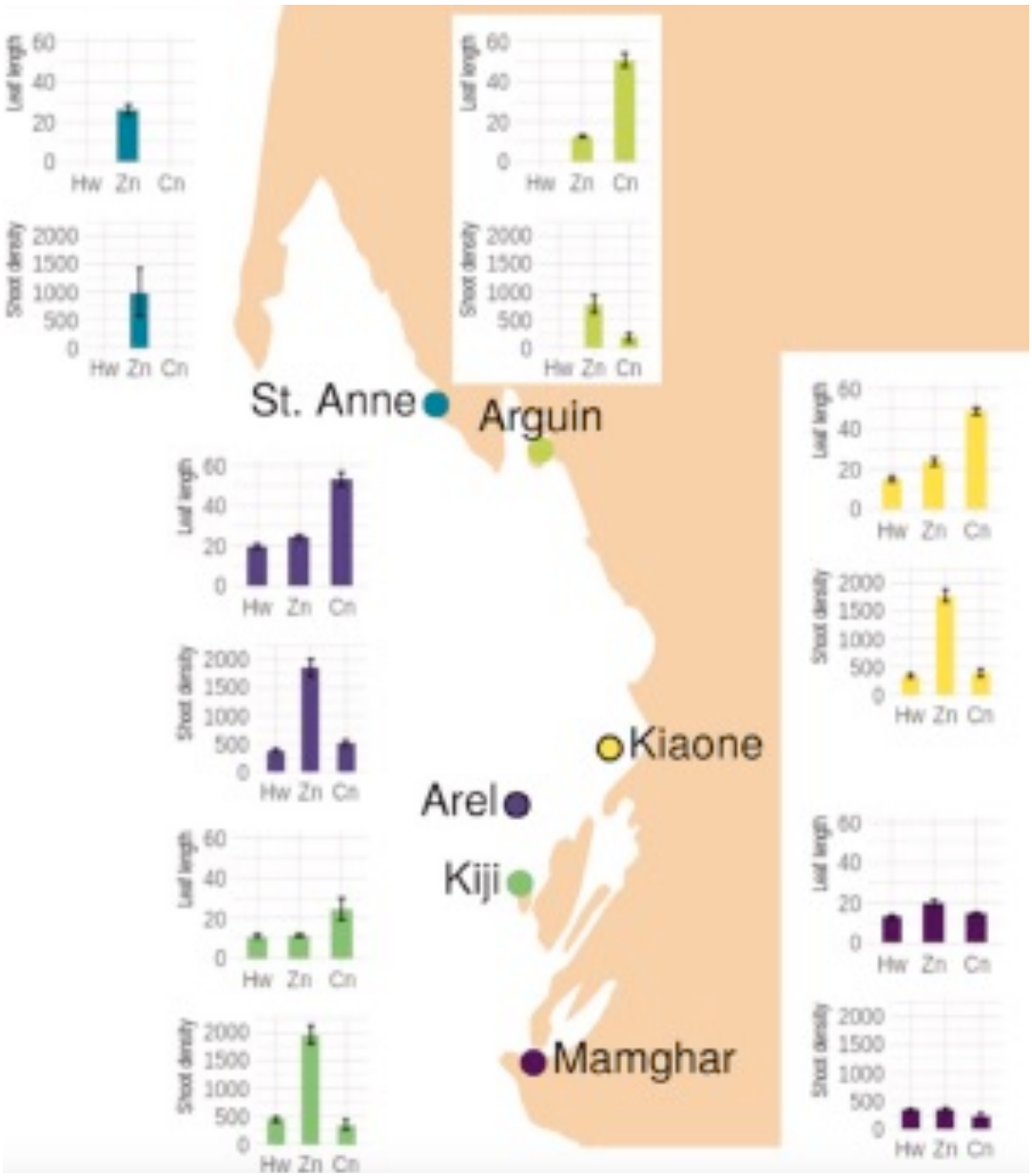

Fig 12- Shoot density and leaf characteristics recorded by our field surveys at various sites in the PNBA (our publication Chefaoui et al. 2021).

3.5.a : RANGE OF DEPTHS AND THREATS

The depth of seagrass beds in the PNBA varies slightly depending on biotic and abiotic factors, but generalisable patterns can be described on the basis of our studies (Fig 13). In general, their distribution tends to be limited by sufficient light penetration to support photosynthesis. In addition, hydrodynamic exposure seems to influence the presence of meadows, via sediment stability, as we generally observed that meadows were present in areas of sediment accumulation.

The intertidal zone can be locally extensive and contains exclusively Zostera noltei. Although the upper limits of subtidal species can sometimes be exposed to the air for short periods without drying out, they do not survive otherwise. The vertical extension of seagrass beds in the intertidal zone can reach hundreds of metres, depending on the amplitude of the tide at the location in question.

Subtidal zone: the subtidal seagrasses of the PNBA include a mixture of *Cymodocea nodosa* and *Halodule wrightii* at shallower depths. *Halodule wrightii* has a very narrow vertical reach (around 50 cm) when mixed with *Cymodocea nodosa*, which shades it out. In the absence of *Cymodocea nodosa*, we observed deeper *Halodule wrightii* at Mojd Dakhna, where the sea water is less turbid. Its depth can vary according to specific local light conditions, and our observations suggest that it is particularly influenced by competition with *Cymodocea nodosa*.

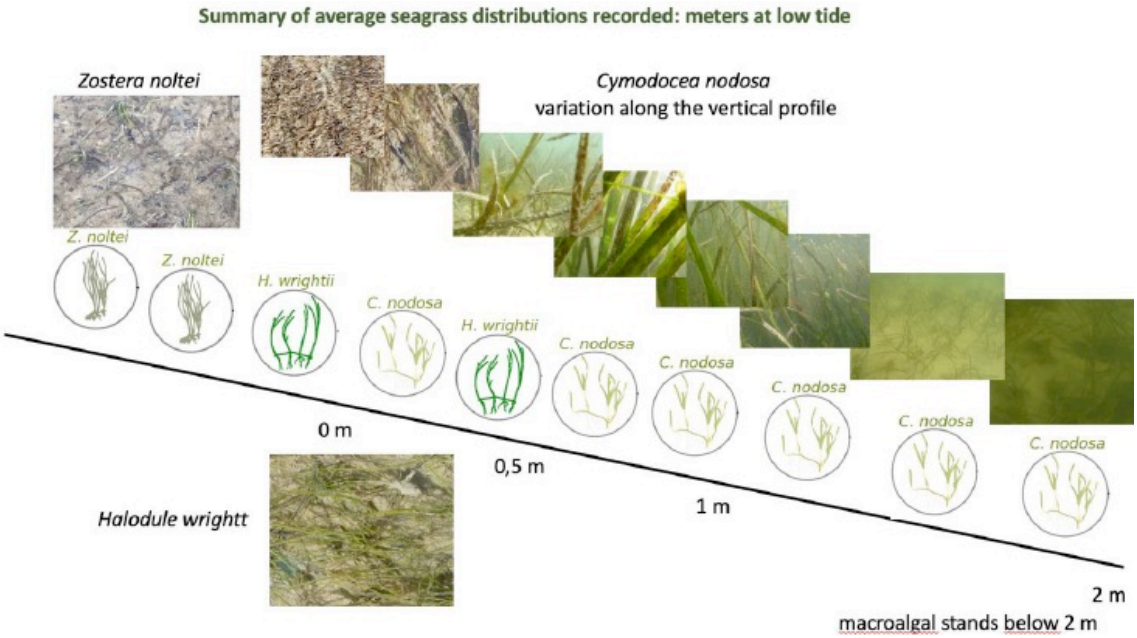

Fig. 13. Depth profile showing a diagram of the predominant vertical distribution of the three seagrass species within the PNBA, based on our field observations and sampling.

The maximum depth of *Cymodocea nodosa*, that we observed both during snorkelling surveys by swimming to the last living leaves, and during sampling from the boat with ganchorra, was always greater than for *Halodule wrightii* when the two species occurred together. In general, *C. nodosa* has only been observed in areas of the PNBA with depths greater than 4 m at low tide (at high tide this is approximately 6 m), often even less, only above 2 m at low tide (corresponding to approximately 4 m at high tide) (Fig. 14), but it does not tolerate immersion in warm conditions either (Fig. 15).

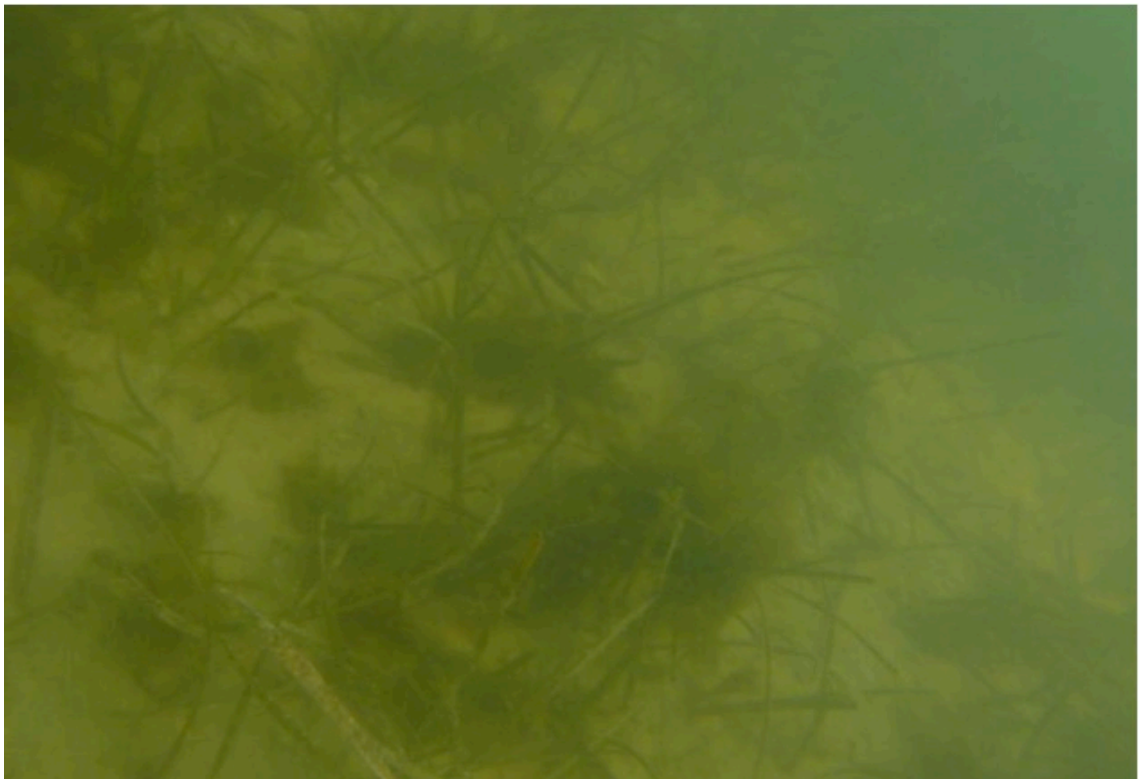

Fig 14. The depth limit of *Cymodocea nodosa*, here close to 2.5 m at low tide, probably limited by light.

Fig 15. Dead *Cymodocea nodosa* near Mamghar in December 2020, in the intertidal zone. Factors acting at shallow depths, such as exposure to heat and/or desiccation

and/or dust burial, could have caused this mortality, as the deeper populations remained healthy.

3.5. b: EPIPHYTES

The photographs available and our studies show different states of the herbarium. In some records, it is possible to see the leaves infected by pathogens (such as oomycetes) or covered by epiphytic invertebrates (ascidians and bryozoans) or filamentous algae (see Figs. 16, 17). The latter reduce access to light and nutrients.

Botrylloides diegensis is an invasive ascidian species covering the leaves of *Cymodocea.* It is a new record in Mauritania. It was very common on *Cymodocea* at all the stations in the PNBA.

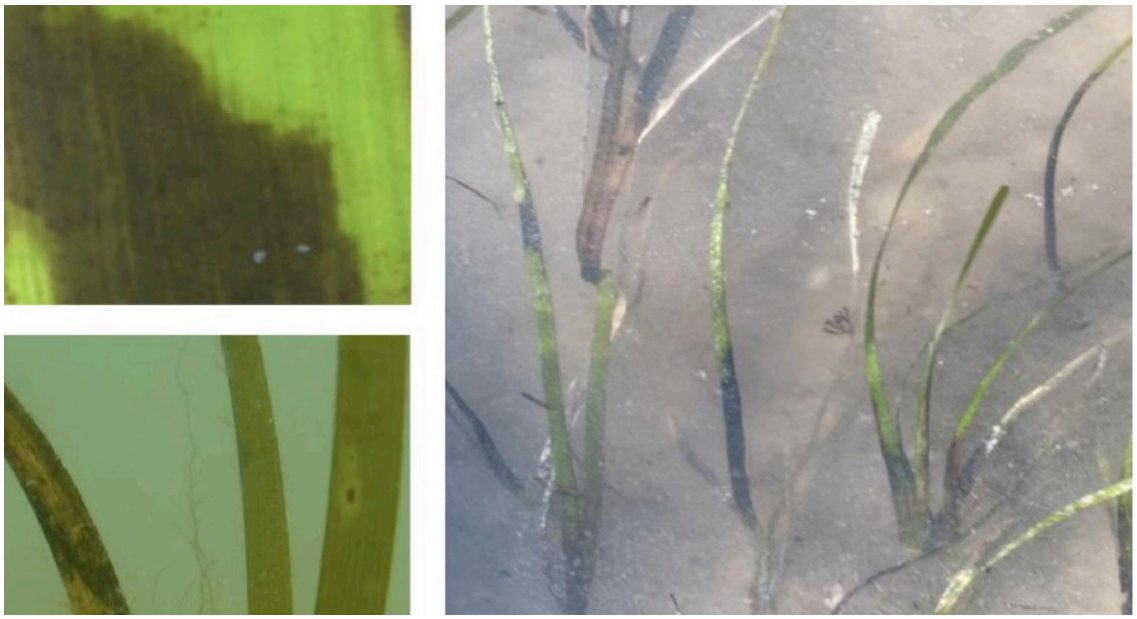

Fig. 16 Infected leaves of *Cymodocea nodosa*, with black spots of endophytic oomycetes, namely *Halophytophtora* spp.

Fig. 17. Epiphytic animals covering the leaves of *Cymodocea nodosa*. Top left: Bryozoa, bottom right: *Botrylloides diegensis*, an invasive ascidian.

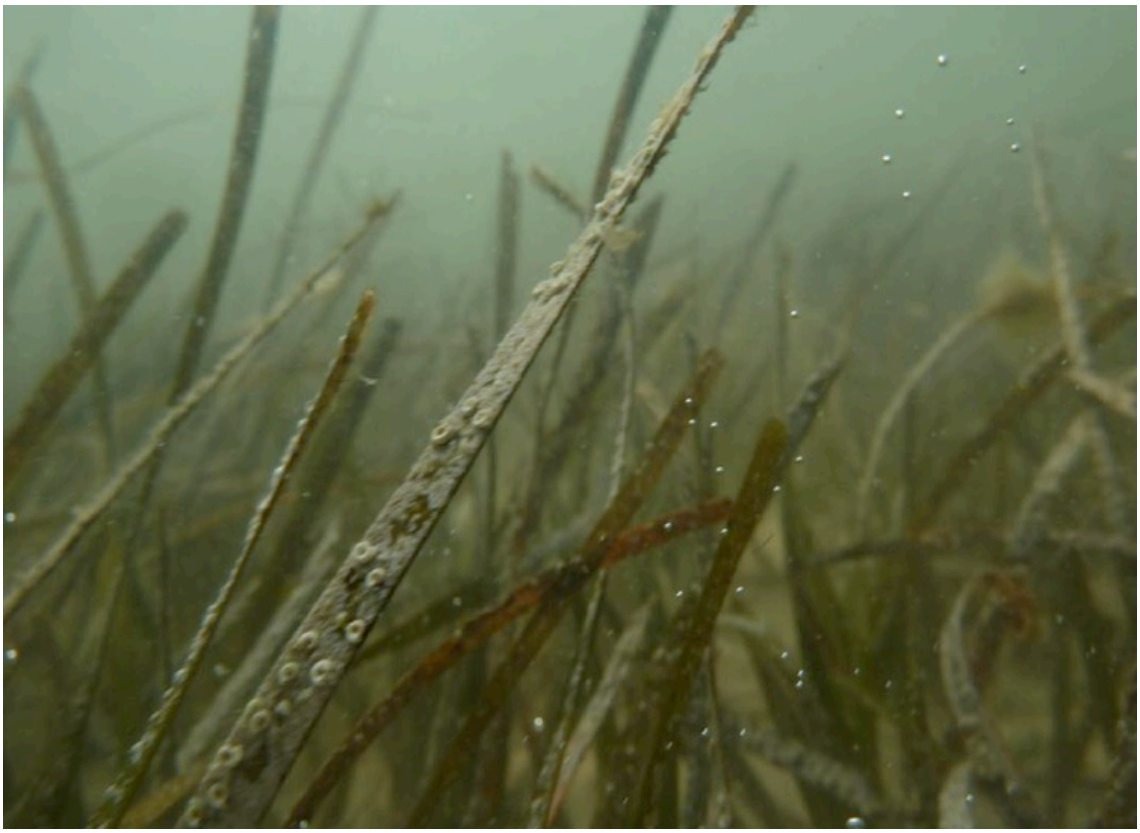

Fig. 18. Epiphytic algae: certain sites and certain seasons were conducive to the growth of microscopic or macroscopic algae, particularly on the leaves of seagrass beds. These were mainly brown filamentous algae.

The presence and composition of epiphytic algae (Fig.18) on seagrass beds can be important indicators of degraded seagrass ecosystem health.

Research and monitoring efforts in the PNBA should continue to focus on identifying and studying the epiphytic species present and their interactions with seagrass hosts in order to assess the overall health of seagrass ecosystems and their role in supporting coastal biodiversity.

3.5.c : OTHER THREATS

Locally, we have observed massive mortality, the causes of which are unclear. The total loss of Zostera noltei leaves in autumn 2020 could hypothetically be linked to dust loads causing burial and temporarily preventing access to light (Fig. 19). Dust particles on the Banc d'Arguin increased and had a massive load in 2020 (unpublished data).

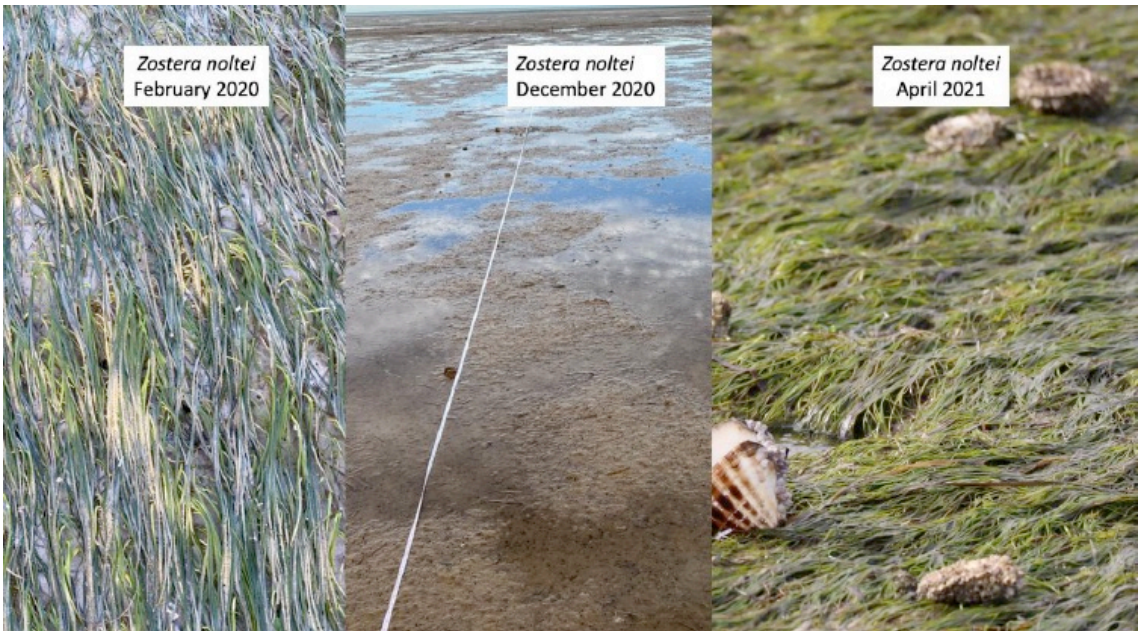

Fig. 19: Major mortality observed in *Zostera noltei* in the PNBA in autumn 2020.

The meadows in the PNBA are under serious threat from global warming (Fig. 20, 21) due to changes in seawater temperature and sea level , as we have described in our predictive study in (Chefaoui et al. 2021).

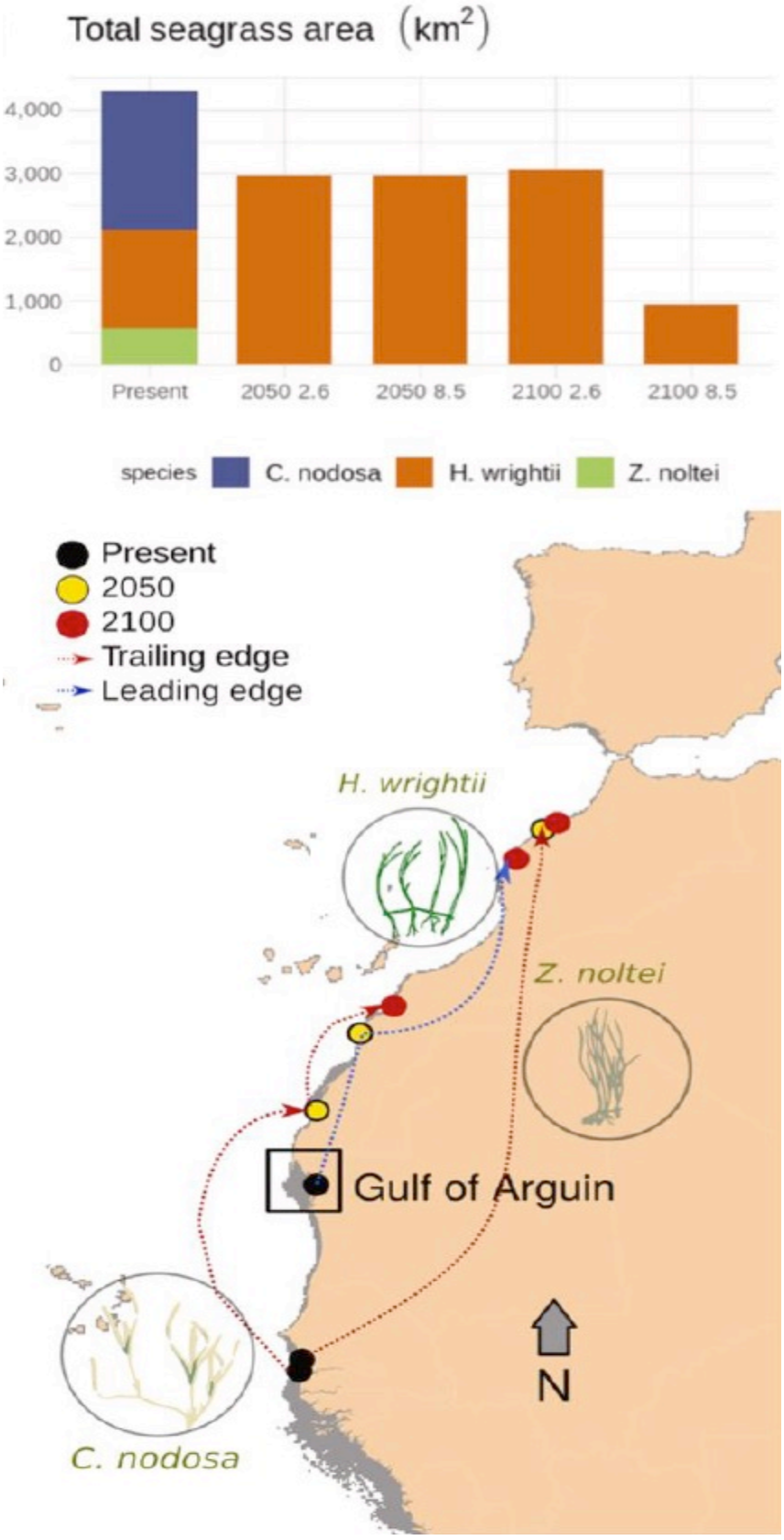

Fig.20 Top: Global change in the extent of seagrass beds, taking into account both sea level rise and future thermal conditions. Bottom: predicted shifts in species range. Modified from our paper Chefaoui et al. 2021.

Fig. 21. *Halodule wrightii,* in December 2020, thriving healthy among dead *Cymodocea nodosa.* The factor that caused the mortality of the shallow temperate *Cymodocea nodosa* did not affect *Halodule wrightii,* the tropical species, suggesting that it was a temperature effect.

In summary, seagrass conservation in the PNBA faces a number of significant threats, many of which are common to seagrass ecosystems worldwide. These threats can have detrimental effects on the health and sustainability of seagrass meadows and the wider coastal ecosystem, but many of them have a global reach, like climate change, that cannot be managed merely locally.

3.5.d : ECOLOGICAL FUNCTION AS A HABITAT

The beds create a habitat and favourable conditions for other species. Very small guitarfish are common on seagrass beds and in our samples (Fig 22). This is a critically endangered species, listed under CITES - juveniles do not migrate, so turtle habitats are nurseries for elasmobranchs. Juveniles do not migrate, so turtle habitats are nurseries for elasmobranchs.

There are more fish species and more fish in the vegetated habitats than in the non-vegetated habitats of the PNBA (Fig. 23). Several bird species use seagrass leaves for nesting in the PNBA, where there is little terrestrial vegetation (Fig. 24). These are examples of the important functions of marine vegetation in the PNBA.

Fig. 22. Very small guitarfishes, observed in our fishing samples (left picture) and swimming along the seagrass (right picture).

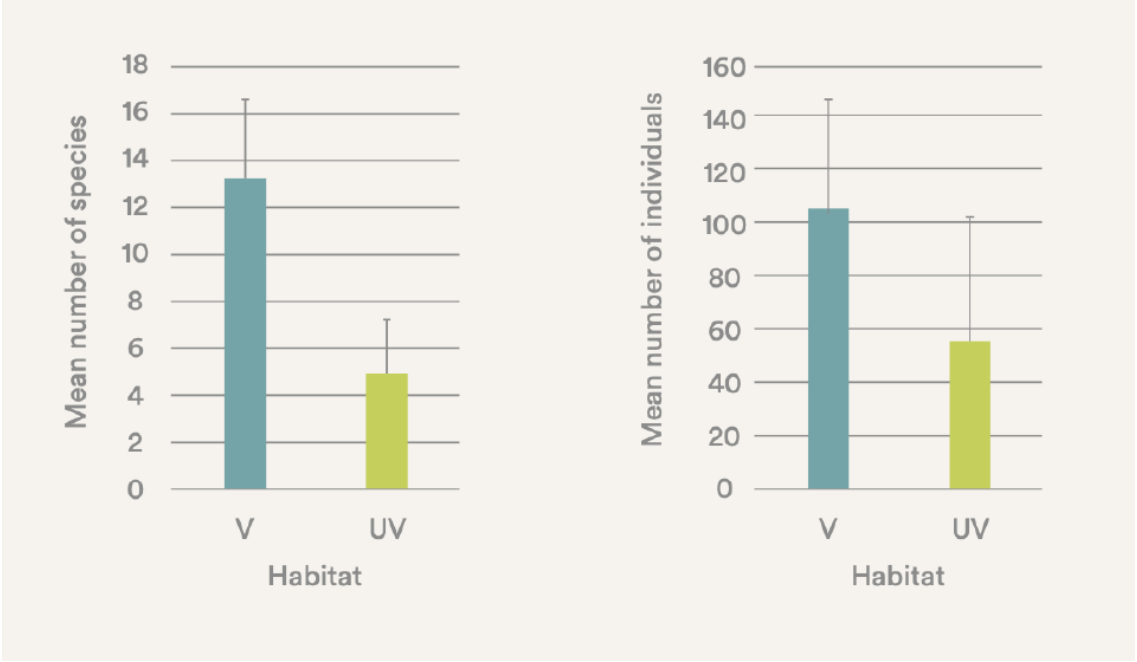

Fig. 23. Example of fisheries support from seagrass beds in the PNBA: A) average number of fish species and B) average number of individuals in vegetated (V, seagrass beds) and non-vegetated (UV, bare sediment) areas of the Banc d'Arguin National Park. Data collected during our sampling efforts, as illustrated in Fig. 22, and figure adapted from Compain (2021).

Fig.24 Several bird species use seagrass leaves for nesting in the PNBA, where terrestrial vegetation is scarce. Bird species that use seagrass leaves to build their nests: A) *Thalasseus maximus* (Zira), B) *Platalea leucorodia balsacii (*Arel), C) *Croicocephalus cirrocephalus* (Nair*), D) Onychoprion anaethetus* (Arel). Bird species that use the meadows as feeding areas: E) *Calidris alpina* (Nair). Data and images collected during our field missions, also used previously in Santos et al. 2023.

4 : Conclusion

The seagrasses of the PNBA are very vulnerable to threats, but threats are mainly not local and cannot be tackled by local management. However, research and monitoring are essential for understanding the specific threats and trends and dynamics affecting seagrass ecosystems for the future of this unique and extremely important coastal region.

The information here provided about the distribution and biological traits of seagrass beds in the Banc d'Arguin National Park is useful for conservation, management and education. These seagrass beds not only contribute significantly to the ecological diversity of the park, but also support the livelihoods of local communities and the wider marine ecosystem, all influenced by their ecological functions. Their conservation is therefore vital to maintaining the ecological balance of the park and ensuring the long-term sustainability of this unique coastal environment.

This study contributes valuable insights into the status of seagrasses in Banc d'Arguin National Park and compiles information to educate and inform management and

conservation actions. It underscores the importance of seagrass ecosystems in maintaining the biodiversity and ecological balance of the region, while also addressing the challenges they face in the context of a changing environment.

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