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Seagrasses of West Africa: New Discoveries, Distribution Limits and Prospects for Management

Mohamed Ahmed Sidi Cheikh [1,2,*], Salomão Bandeira [2,3,*], Seydouba Soumah [4], Gnilane Diouf [4], Elisabeth Mayé Diouf [5], Omar Sanneh [6], Noelo Cardoso [7], Abubacarr Kujabie [8], Melissa Ndure [4,9], Lynette John [10], Lisdália Moreira [11], Zofia Radwan [11], Iderlindo Santos [2,12], Adam Ceesay [12], Marco Vinaccia [2] and Maria Potouroglou [13]

1 Département de SIG, Caisse de Dépôts et Développement, Nouakchott P.O. Box 4525, Mauritania
2 Project ResilienSEA, C/o GRID-Arendal, GRID-Arendal, Teaterplassen 3, N-4836 Arendal, Norway
3 Department of Biological Sciences, Eduardo Mondlane University, Maputo 1100, Mozambique
4 Instituto de Engenharia E Ciências Do Mar, Campus de Ribeira de Julião, Universidade Técnica do Atlântico Instituto (UTA), CP 163, Mindelo 2110, Cape Verde
5 University Institute of Fisheries and Aquaculture, Cheikh Anta Diop University, Fann, Dakar BP 5005, Senegal
6 Department of Parks and Wildlife Management, Abuko, The Gambia
7 Ministério das Pescas, Avenida Amilcar Cabral C.P. 102 Bissau, Guiné-Bissau, Bissau 1400, Guinea-Bissau
8 National Environment Agency, Jimpex Road, Kanifing, The Gambia
9 Environment Protection Agency, Freetown, Sierra Leone
10 Institute of Marine Biology and Oceanography (IMBO), University of Sierra Leone, Freetown, Sierra Leone
11 Direcção Nacional do Ambiente, Ministério do Ambiente, CP 332-A, Praia 7600, Cape Verde
12 Wetlands International Afrique, Dakar BP 25 581, Senegal
13 World Resources Institute, Thomas House, 84 Eccleston Square, London EC1A 1HQ, UK
* Correspondence: ouldsidicheikh@yahoo.fr (M.A.S.C.); salomao.bandeira4@gmail.com (S.B.)

Abstract: The onset of a major seagrass initiative in West Africa enabled important seagrass discoveries in several countries, in one of the least documented seagrass regions in the world. Four seagrass species occur in western Africa, *Cymodocea nodosa*, *Halodule wrightii*, *Ruppia maritima* and *Zostera noltei*. An area of about 62,108 ha of seagrasses was documented in the studied region comprising seven countries: Mauritania, Senegal, The Gambia, Guinea Bissau, Guinea, Sierra Leone and Cabo Verde. Extensive meadows of *Zostera noltei* were recorded for the first time at Saloum Delta, Senegal, which represents the new southernmost distribution limit of this species. This paper also describes the seagrass morphology for some study areas and explores the main stressors to seagrasses as well as conservation initiatives to protect these newly documented meadows in West Africa. The produced information and maps serve as a starting point for researchers and managers to monitor temporal and spatial changes in the meadows' extent, health and condition as an efficient management tool.

Keywords: seagrass distribution; monitoring; threats; southernmost limit *Zostera noltei*; West Africa

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1. Introduction

Seagrasses are one of the most valuable marine ecosystems on the planet, providing essential services and benefits to nature, societies and economies [1,2]. West Africa (herein referred to as the region from Mauritania to Sierra Leone, including Cabo Verde) has historically been one of the least studied regions on seagrasses [1], with the exception of a handful of published studies for Senegal [3] and Cabo Verde [4], while Mauritania has a long history of seagrass research outputs [5–9]. Further south, seagrass reports extend to São Tomé and Principe within the Gulf of Guinea [10]. In 2018, a seagrass conservation project was initiated in West Africa to bring capacity building through training workshops and research and management activities that prompted new discoveries of seagrasses' distribution within the seven-country-group: Cabo Verde, Mauritania, Senegal, The Gambia, Guinea Bissau, Guinea and Sierra Leone.

Comprehensive mapping initiatives and monitoring schemes help generate knowledge and new data, and raise awareness on the importance of seagrasses. To our knowledge, there have been no comprehensive distribution maps of seagrasses covering the whole coastline of West Africa (with the exception of Mauritania) [11], although seagrasses have been known to exist along parts of the coasts of Mauritania, Cabo Verde and Senegal prior to this study. Furthermore, there has been little information regarding the presence of seagrasses in deeper water (>10 m) in this region [12], although this is confirmed in other regions that share the same seagrass species (e.g., *Cymodocea nodosa* in the Mediterranean) [13].

The value of seagrass, that is qualitative or quantitative, economic, ecological or existence, is indisputable [1,14,15]. In a tropical and sub-tropical context and indeed on a global scale, seagrass plays a major role in food security [16], coastal protection [17], provision of habitat and food for charismatic and endangered species such as dugongs and sea turtles, as well as climate change mitigation through carbon sequestration and storage [1] and provision of livelihoods for coastal communities [18]. However, those critical habitats are threatened by several land- and ocean-based threats, and climate change drivers [19,20]. A key reason for seagrasses' lack of protection is the paucity of information regarding some of the most basic aspects of their distribution and health. In areas where there are available datasets, protection levels for seagrasses have increased [11]. Large- and small-scale mapping may sustain different objectives, but they can both track changes and serve as early-warning signals of anthropogenic pressures, emphasize the need to halt and reverse these, and inform seagrass restoration activities. Furthermore, the improvement of conservation and management of seagrasses requires increased knowledge of not only how seagrass meadows respond to environmental change, but also of the magnitude and scale of the benefits these ecosystems contribute to human livelihoods and wellbeing, locally, regionally and globally.

This study provides a much-needed regional dataset, therefore contributing significant knowledge about ecological processes that can inform and be embedded into a global seagrass analysis. We aim to (a) document the seagrass occurrence points and distribution limits in this region, and (b) map the seagrass extent across the seven countries of West Africa.

2. Materials and Methods

2.1. Study Area and Case Study Sites

The study area encompasses the shallow waters (up to around 5 m) in near-shore areas along the coastline of West Africa, from Mauritania in the north to the southern end of Sierra Leone, including Cabo Verde. Seven countries are covered in this study: Mauritania, Senegal, The Gambia, Guinea Bissau, Guinea, Sierra Leone and Cabo Verde. Case study sites and areas of known occurrence of seagrasses, informed either by previous studies or interviews with fishers and local managers, were chosen, totaling to 10 sites for the seven countries (Table 1).

The West African coastal zone is characterized by a circulation of water masses at the level of the continental shelf creating two systems of large currents with very different characteristics [21]. First, the Canary Current from the north is a cold permanent current, one branch of which crosses the Atlantic towards the west following the trade winds at the level of Cape Blanco (Mauritania) to form the North Equatorial Current. The other branch moves from north to south, along the coasts of Mauritania and Senegal and forms a coastal drift of a width equivalent to that of the continental shelf. Under this coastal current is a counter-current directed northward at the continental slope between Cabo Verde and Cape Blanco [22,23]. The North Equatorial Current appears from October and covers the entire continental shelf in January. The branch that moves from north to south, along the coasts of Mauritania and Senegal, occurs between November and June, forming a coastal drift of a width equivalent to that of the continental shelf. Hot, dry continental air masses originating from the high-pressure system above the Sahara Desert give rise to dusty Harmattan winds over most of West African winter, from November to February [24]. In summer, moist equatorial air masses originating over the Atlantic Ocean bring annual monsoon rains [25].

This particular hydrological regime favors a diversity of rare biotopes on the West African coast [26]. The coastal upwelling area off Northwest (NW) Africa is one of the four large systems of Eastern Boundary Currents (EBC) within the trade wind belts of the subtropics [27]. The West Africa Marine Ecoregion is one of the most productive and economically important fishing zones in the world [28]. Several critical habitats for marine biodiversity are protected by the network of marine protected areas (MPAs) in the West African ecoregion. More than 1000 species of fish have been recorded in the region, several of which are shared between the countries [29]. The upwelling phenomenon also occurs in the region, bringing to the surface nutrient-rich waters that lead to increased biodiversity. Off the continental coast, fishing pressure has increased markedly during the past two decades, which has led to a large decrease (by an order of magnitude) of demersal fish biomass of commercial species in particular [30,31].

Table 1. Case study sites used to primarily document seagrasses in the region (countries in alphabetical order).

Country	Case Study Site	Latitude N	Longitude W
Cabo Verde	Gamboa (Praia, Santiago Island)	14.90774°	−23.50849°
Guinea	Tristao Islands	10.7569°	−14.9417°
Guinea Bissau	Unhocomo and Unhocomozinho	11.3290°	−16.4333°
Mauritania	Banc d'Arguin National Park	19.89019°	−16.31148°
	Baie de l'Etoile	21.02287°	−17.01228°
Senegal	Delta du Saloum Biosphere Reserve	13.77027°	−16.65355°
Sierra Leone	Turtle Islands (Bumpetuk Island)	7.6578°	−13.0277°
The Gambia	Bijol Islands-Tanji, Gunjur	13.3832° 13.1500°	−16.8170° −16.7666°
	Karfaya-Kartong	13.1232°	−16.8147°

2.2. Species Distribution

In order to record the seagrass distribution in each country, a systematic and coordinated approach was followed starting with scoping missions in pre-selected areas previously mentioned by local communities, managers and fishers. Photographs were also used to ascertain the seagrasses' description by the local communities. Thorough field expeditions aiming at documenting seagrass presence were instrumental to the discoveries of the new distribution limits and records of seagrass species, especially in The Gambia, Guinea Bissau, Guinea and Sierra Leone. Furthermore, these expeditions served to further re-confirm and expand existing records of the presence of seagrasses in Senegal, Cabo Verde, and Mauritania [3,4]. Field expeditions were carried by the National Implementing Teams (NITs), comprised of multi-institutional and multi-sectoral entities within each West African country that were brought together with the role to undertake the implementation activities at the national level. Information on *Ruppia maritima* was gathered only from literature [32–34]. Seagrass species identification was carried out using standard literature protocols and handout sheets [35,36] as well as publications from the region [3,4,7]. The IUCN Red listing was also used for updated species descriptions [37].

2.3. Seagrass Mapping

Mauritania has historically benefited from extensive field investigations, mostly by European scientists. Extensive field ground-truthing was also carried out in Senegal, confirming seagrass presence over nearly the whole of the coastal zone of Senegal. Similarly, researchers in The Gambia have conducted extensive ground-truthing field trips especially after the onset of new seagrass restoration initiatives in the country, which confirmed the presence of seagrass in many areas. Field ground-truthing was limited within Guinea Bissau, Cape Verde, Guinea and Sierra Leone, due to the remoteness of the field sites.

The methods used for seagrass mapping have been previously applied in other regions [38]. The NITs conducted field surveys during which they collected data using a hand-held GPS device with 3 m of accuracy. These data were then introduced into a collective database that contains information on the identified species name, coordinates of each presence point, depth, and whether the site is subtidal or intertidal. In total, there were 1096 datapoints, collected from October 2019 to June 2022 from the case study sites of the entire study area (Cabo Verde with 15 datapoints, Mauritania with 551, Senegal 401, The Gambia 78, Guinea 5, Guinea Bissau 21 and Sierra Leone 25). This is the first attempt for mapping seagrass presence in the region using field surveys, except for Mauritania [25]. After collecting the initial information from each team, QGIS3.16 open-source software [38,39] was used for projecting the coordinates using the GCS WGS84 World Geodetic System [40].

2.4. Refining of Initial Mapping Efforts in Each Country

The members of the NITs carried out further exploration missions at the case study sites and beyond, covering in this way a substantial part of the coastal area of each country. For every new seagrass area confirmed, a GPS point was taken. The complete dataset of all GPS points was integrated into a geographic information system using QGIS. The QGIS served to integrate the geo-referenced data to the database, along with drawing tools for polygons. Data in QGIS made the visualization of the geographic location of different GPS points, and consequently the location of newly confirmed seagrass meadows. The boundaries of these new seagrass areas, as informed by the NITs, were also digitized to indicate the presence of seagrass meadows, even for those with a low coverage or shoot density. For Mauritania and Senegal, polygons were drawn based on images seen by experts, then combined with extensive ground observation and visual interpretation of the satellite imagery. We benefited by having a high resolution of satellite images, freely used as a base map in Google Earth, showing easily the intertidal meadows during low tide. Contours on seagrass area benefited from extensive datapoints obtained by local experts in each of country. For Gambia, Sierra Leone and Guinea Bissau, mapping was carried out from extensive ground-truthing (through walking in the intertidal and snorkeling in the subtidal), then polygons concluded using geo-reference points (that also include points within meadow boundaries).

2.5. Seagrass Monitoring and Threats Inventory

Seagrass monitoring was carried out in eight of the case study sites as listed in Table 1, covering Cabo Verde, Mauritania, Senegal, Sierra Leone and The Gambia, by combining groundtruthing and local fishers' knowledge [41–44]. Measurements of shoot morphometrics were conducted using field ecological methods adapted from global seagrass monitoring protocols described in SeagrassWatch [45]. Seagrass percentage cover, canopy height, shoot density, and species composition were assessed along transects, using quadrats of 0.25 m^2. Information on whether the meadows were intertidal or subtidal and replicates were documented. Systematic observations on the threats present in and around the case study sites were also conducted during the field expeditions. These included information on both natural and anthropogenic impacts such as fishing activities, human settlements, tourism activities and presence of garbage and covered Mauritania, Senegal, The Gambia and Sierra Leone.

3. Results

3.1. Seagrass Species, Distribution and Morphometrics

Four seagrass species occur in this region: *Halodule wrightii*, *Cymodocea nodosa*, *Ruppia maritima* and *Zostera noltei*. Species occurrence per country is shown in Table 2. Information on *Ruppia maritima* was drawn only from literature [32–34]. *Halodule wrightii* is widespread in western Africa, and it was found in the whole study area (across all seven countries) on eulittoral to sublittoral sandy or muddy substrates in both sheltered and exposed locations. *Cymodocea nodosa* occurs subtidally in fine sandy or muddy sediments, and was found to a depth of up to 4 m, as observed in locations in Senegal (Joal) and Mauritania. Beach cast of this species was also found in several places along the Gambian coastline, especially close to locations of known seagrass distribution (Bijol and Gunjur). *C. nodosa* may occur mixed with *H. wrightii* as observed mostly around Mauritania, Senegal (e.g., around Joal, Sangomar, Saloum Delta National Park) and parts of The Gambia (mostly Gunjur). *C. nodosa* has been observed flowering (as photographed in June 24, 2021) in Senegal. *Zostera noltei*, a temperate Atlantic species, has been previously documented in Mauritania. An extensive meadow of *Z. noltei* was recorded for the first time in the Saloum Delta of Senegal in 2019, in muddy and sheltered intertidal areas. This record constitutes the new southernmost distribution limit of the species. Although not documented as part of this study, *Ruppia maritima* also occurs in the region and has been previously observed in lagoons in Cabo Verde [32,46], which get replenished with salt water in some extreme tides or during rains. In Mauritania, *R. maritima* has been documented in sheltered bays, east of the Peninsula of Cape Blanc [34]. *R. maritima* was also documented for Senegal [33]. Seagrass presence in other western African countries, south of Sierra Leone, is expected, given similar environmental conditions and a wide occurrence of shallow areas.

Table 2. Seagrass species occurrence across the studied West Africa region. * Information drawn from previous studies [32–34].

	Cymodocea nodosa	***Halodule wrightiii***	***Zostera noltei***	***Ruppia maritima****
Mauritania	X	X	X	X
Senegal	X	X	X	X
Cabo Verde		X		X
The Gambia	X	X		
Guinea Bissau		X		
Guinea		X		
Sierra Leone		X		

The seagrass species found in Mauritania belong to two different biogeographic zones. *Z. noltei* and *C. nodosa* are of temperate affinity, while *H. wrightii* is a typically tropical species, with Banc d'Arguin representing its northernmost limit of the species distribution. Seagrasses in Banc d'Arguin appear to have remained stable in terms of distribution since the monitoring started in 2020.

Seagrasses in Senegal occur in various locations, generally in sandy-muddy substrate. *Z. noltei* in Senegal occurs in mixed meadows with *H. wrightii*, and also in small pools which maintain residual water during low spring tides.

Two seagrass species occur in The Gambia, *C. nodosa* and *H. wrightii*, in both intertidal and subtidal areas, growing in monospecific and mixed meadows. *C. nodosa* is widespread in Kartong and Gunjur, and *H. wrightii* is widespread in Bijol Islands. *C. nodosa* in Bijol Islands occurs in sandy areas, also mixed with shell debris and around rocky areas. Bijol Islands have the largest continuous seagrass area in The Gambia, with the meadows of *H. wrightii* located northwest of the islands, while those of *C. nodosa* are located southwest of the islands. The average percentage cover of seagrass meadows at Bijol Islands is about 78%, of which *H. wrightii* constitutes 80% and *C. nodosa* 20%. Generally, the seagrasses at Bijol Islands appear less impacted by anthropogenic activities, given that this is a protected area, with no people living on the islands. However, shoreline erosion has been observed in the islands and surrounding areas. At Gunjur, three meadows have been documented, but their extent is smaller than that at Bijol Islands, this last one with around 2/3 of seagrass meadows. *H. wrightii* meadows observed at Gunjur have been observed to be decreasing (from 2020 to 2022, during the beginning of the year) in density likely due to a combination of identified pressures and activities, including pollution, deposition of waste materials (old clothing, old nets, plastic bags and bottles), drag net fishing, and increased presence of macroalgae. At Karfaya-Kartong, two meadows have been documented, both of which are monospecific and consist of *C. nodosa.*

With a rather estuarine coastline, the case study sites in Guinea-Bissau are located around the islands Unhocomo and Unhocomozinho (all within the Bijagós Islands complex) where extensive seagrass meadows of *H. wrightii* have been recorded.

In Guinea, the main seagrass meadows have been documented in Tristao Islands, where *H. wrightii*'s discovery was facilitated due to the regular presence of sea turtles, for which seagrass is an important feeding habitat.

In Sierra Leone, *H. wrightii* meadows have been documented in Bumpetuk (Turtle Islands). Seagrasses are known to exist in other locations around Turtle Islands, including near Seh Island and the sacred Hoong Island. Seagrass occurrence in Hoong Island is yet to be verified, as this island cannot be visited by women, as per local tradition.

3.2. The Southernmost Limit of Zostera noltei

The southernmost limit of *Z. noltei* was documented in the Saloum Delta (Senegal) (Figure 1), in an intertidal landscape of sandy sediment similar to Banc d' Arguin (Mauritiania), occurring in small pools that maintain water at low spring tides. *Z. noltei* occurred growing in mixed meadows with *H. wrightii*, with *C. nodosa* growing on the edges of the meadows. Previously the distribution of *Z. noltei* has been documented along the coasts of the Atlantic Ocean, from the south of Norway to the south of the Mauritanian coast [47]. Figure 2 shows photographs of seagrass from the study area, including *Z. noltei* in Senegal. Flowering of seagrasses in the region has not been observed, with the exception of *C. nodosa* (Figure 2a). Figure 2b is a subtidal meadow in Cabo Verde while Figure 2e was during field assessment in Senegal. Morphometrically, for *C. nodosa* the number of leaves per shoot was 3–4 leaves; rhizome diameter was just 1 mm across samples; internodes length 0.8–2.5 cm; leaf length 12–17 cm. The intertidal *Z. noltei* forms meadows with very high density (1286.6 $\pm$ 273 shoots per m^2) in comparison to the subtidal species *H. wrightii* (376.8 $\pm$ 25.8 shoots per m^2) and *C. nodosa* (335 $\pm$ 58.3 shoots per m^2). The southernmost meadow of *Z. noltei* in Senegal had a leaf length up to 17.5 $\pm$ 1.8 cm.

3.3. Seagrass Mapping

The measured seagrass extent for each country, as well as the whole region, is shown in Table 3. These represent a combined effort of the initial mapping assessment coupled with the subsequent refining conducted by the NITs. The seagrass extent of the whole region has been estimated at 62108 ha (Table 3). With regards to individual countries, their respective estimated seagrass area is the following: Mauritania with 52,300 ha with the majority occurring inside the national park of Banc d'Arguin (Figure 3), Senegal with 8372 ha (Figure 1), The Gambia with 111 ha (Figure 4), Cabo Verde with 0.62 ha (Figure 5), Guinea Bissau with 881 ha (Figure 6), Guinea with 428 ha (Figure 7) and Sierra Leone with 15.4 ha (Figure 8). Figure 9 shows the final map of seagrass presence based on field explorations and participatory mapping with the NITs.

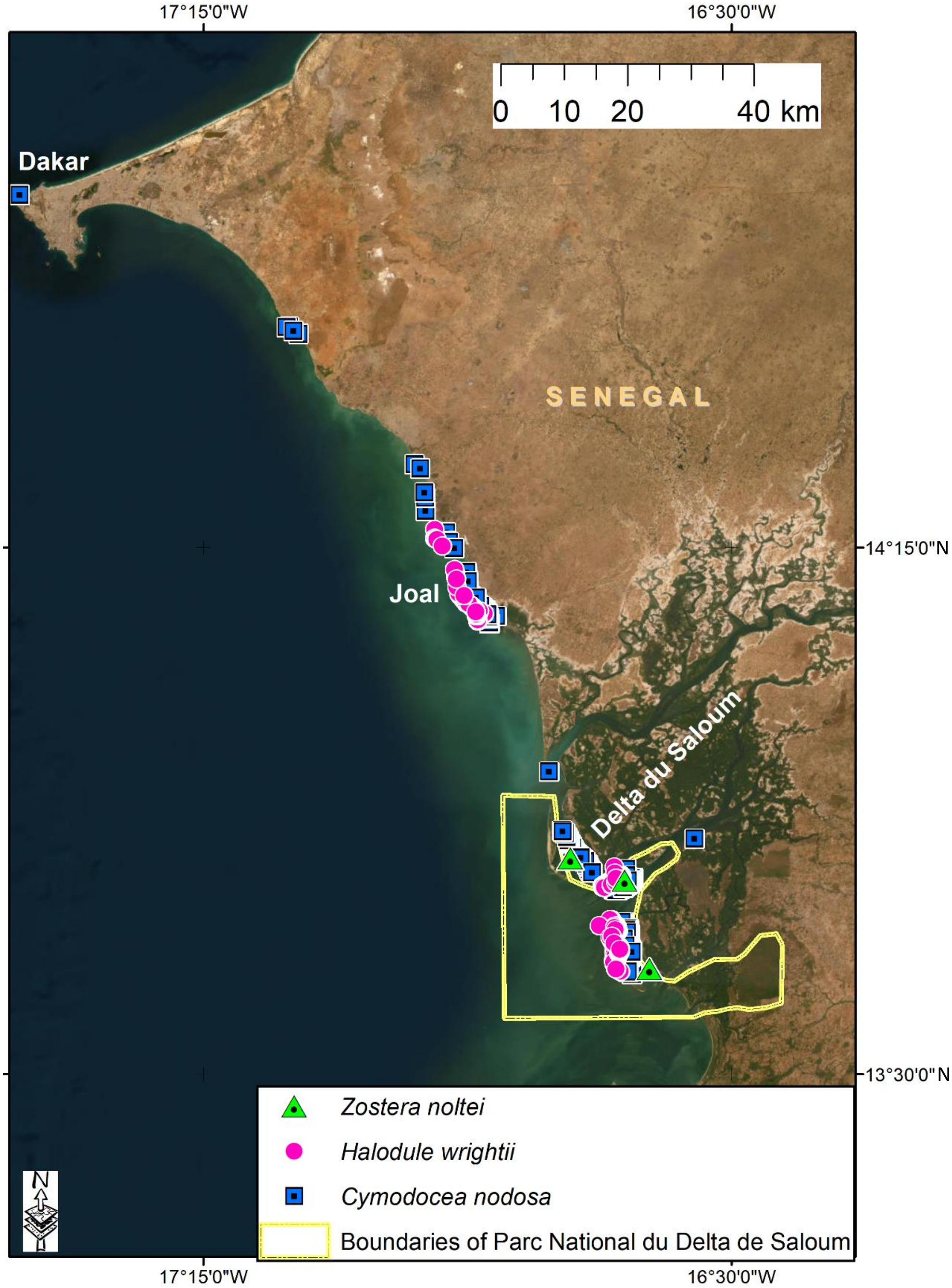

Figure 1. Seagrass distribution in Senegal. The southernmost limit of *Z. noltei* is indicated by the green symbol within the areas of Saloum Delta National Park.

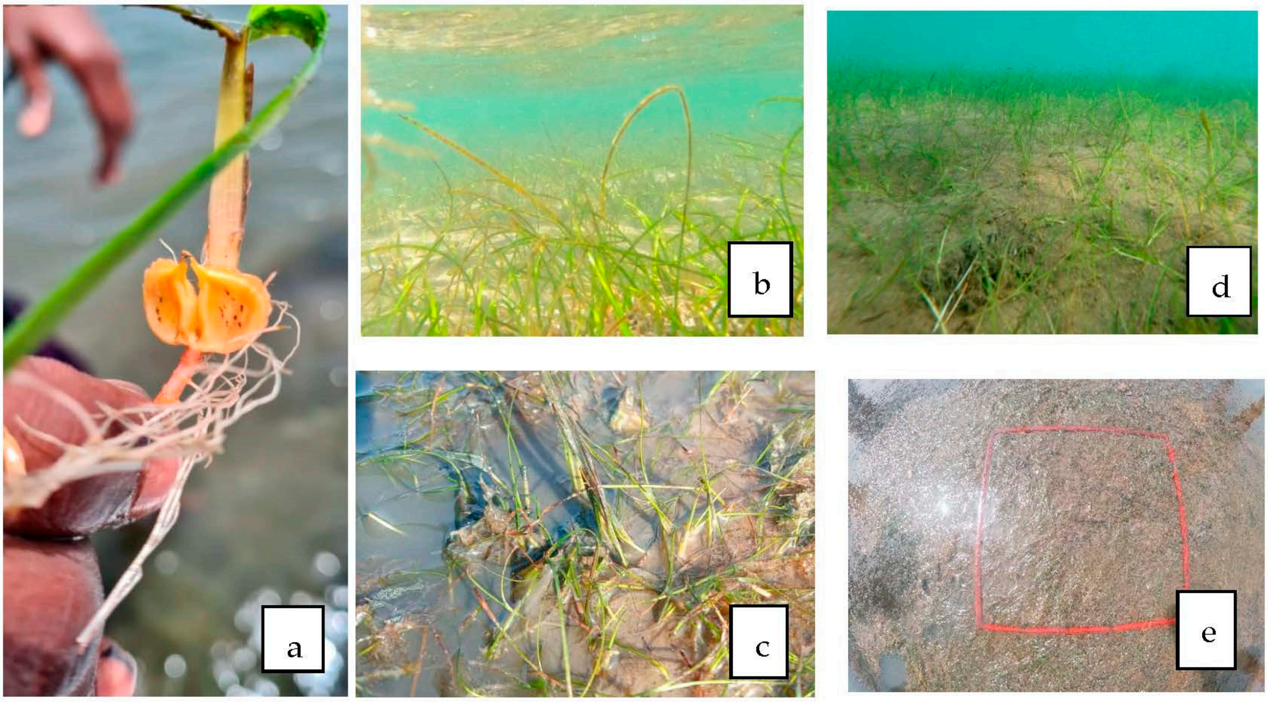

Figure 2. (**a**) Gernimating fruit of *Cymodocea nodosa* (Senegal, E.M.Diof 24 June 2021); (**b**) *C. nodosa* (Gambia 2022, S.Bandeira); (**c**) *Zostera noltei* (Senegal, 2022, E.M. Diof); (**d**) *Halodule wrightii*, (Cabo Verde 2020, S.Bandeira), (**e**) mixed *H. wrightii* and *Z. noltei* meadow (Senegal, S. Cheick).

Table 3. Measured seagrass extent for each country; its confidence in the whole region.

Country	Measured Seagrass Area (ha)
Cabo Verde	0.62
Mauritania	52,300
Senegal	8372
The Gambia	111
Guinea Bissau	881
Guinea	428
Sierra Leone	15.4
Total of the region	**62,108.02**

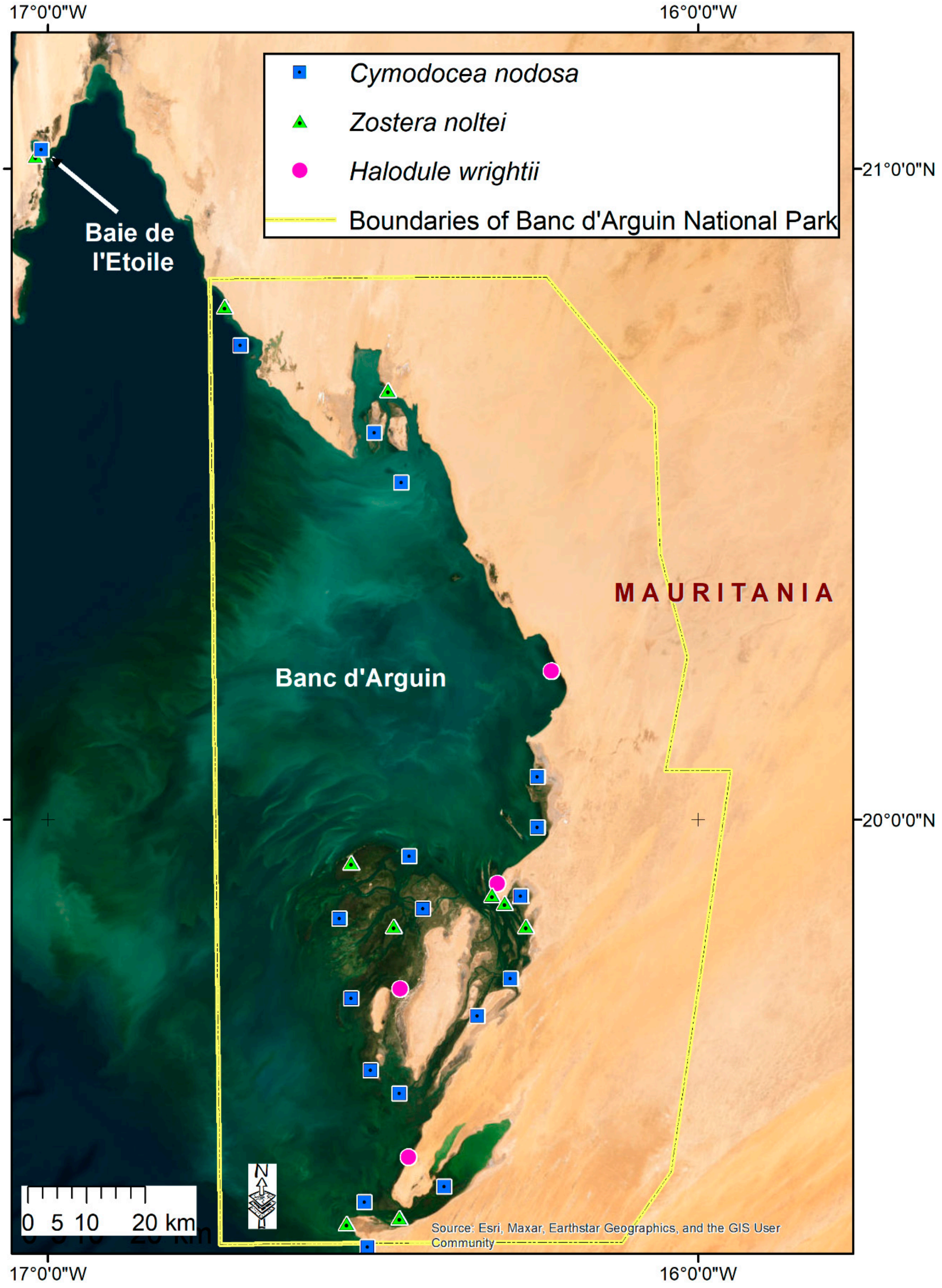

Figure 3. Seagrass distribution in Mauritania.

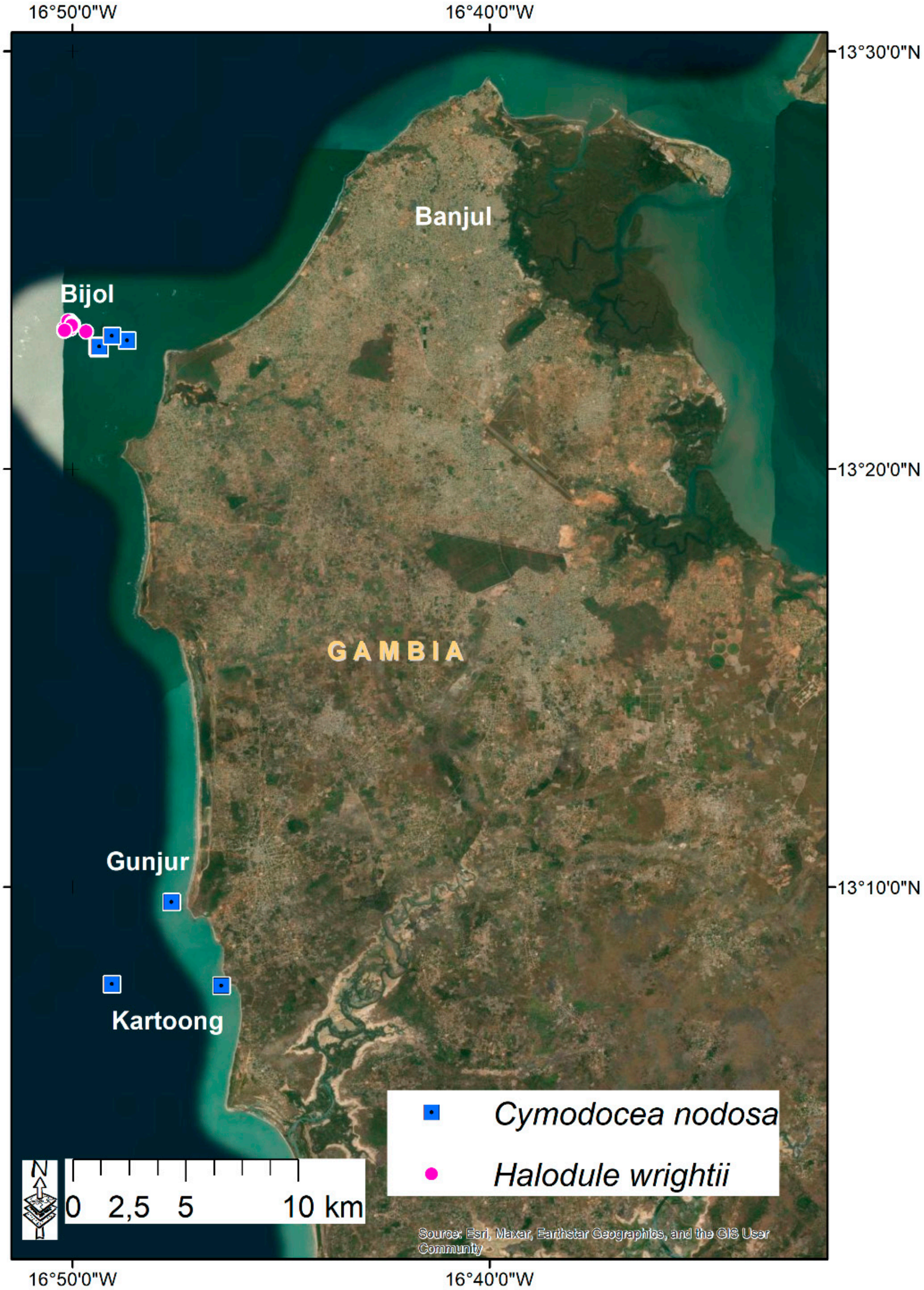

Figure 4. Seagrass distribution in The Gambia.

Figure 5. Seagrass distribution in Cabo Verde.

Figure 6. Seagrass distribution in Guinea Bissau.

Figure 7. Seagrass distribution in Guinea.

Figure 8. Seagrass distribution in Sierra Leone.

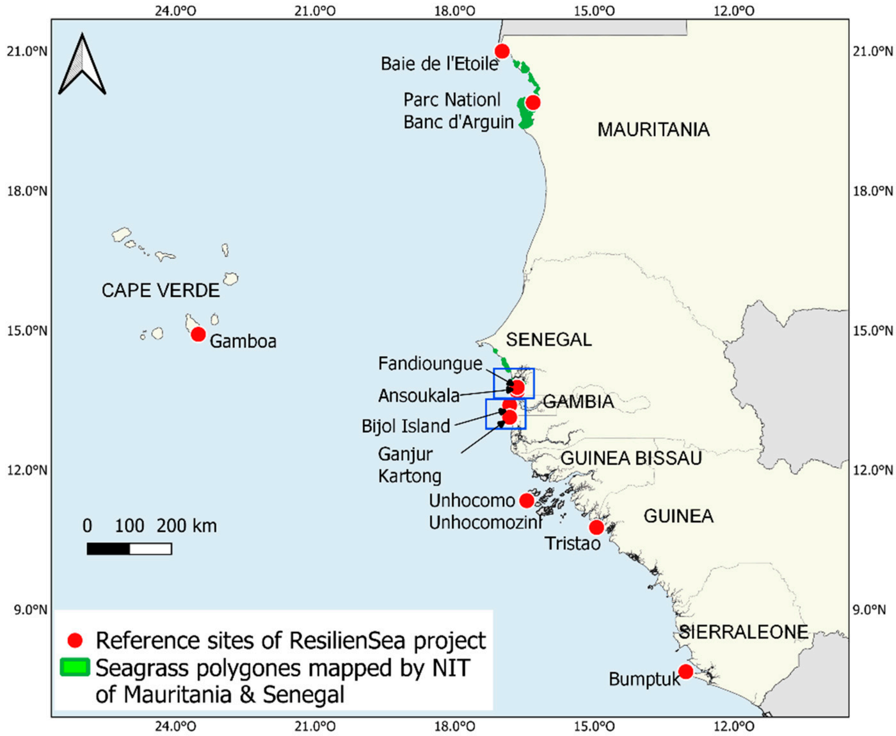

Figure 9. Seagrass distribution and extent in the whole study area.

3.4. Threats to Seagrasses in West Africa

Systematic observations during the field missions conducted by the NITs indicate that the seagrass in the study region appears to be threatened by a number of pressures, natural and anthropogenic. Seagrasses in Praia (Cabo Verde) are threatened from increasing coastal development within Gamboa and nearby areas. These include tourism infrastructure, surrounding multistory buildings and a bridge to Santa Maria Islet, disturbing the northern border of a small seagrass meadow. Furthermore, the port nearby and downtown Praia as well as effluents may bring pollution to this seagrass meadow. While seagrass in the case study site in Senegal might occur within a marine protected area, fishing-related activities such as boating and trampling, as well as eutrophication, might negatively impact seagrasses around Joal (near Dakar). The main threats to seagrass meadows in Senegal are of anthropogenic nature such as inappropriate fishing gear, including the use of nets and trawling, that uproots seagrass shoots, in addition to pollution from motorized boats and plastic waste.

Erosion has affected several areas in The Gambia, in addition to port development and trampling around Gunjur. Sea turtles are common in Gunjur, with possible increased grazing intensity occurring in seagrasses. Bijol Islands appear to be less impacted by direct human activities, however with some obstructive materials such as old nets, old clothing and other objects being observed on the shoreline of the islands. The meadows in Kartong appear to have little or no impact by human activities. Seagrass meadows in Bijagos Islands, Guinea Bissau, are potentially impacted by beach scene dragging nets. In Sierra Leone, the main pressures to seagrasses are destructive fishing practices, such as bottom trawling, that cause part or full removal of seagrasses. Seagrass meadows in Seh Island in Sierra Leone are highly threatened by boating, trampling and trash pollution.

In Mauritania, seagrass meadows face local pressures from overfishing and illegal fishing within Banc d'Arguin, land and sea pollution, and uncontrolled coastal development that leaves the meadows weakened and vulnerable. Given the richness of the fish in the waters of Banc d'Arguin, many fishermen from outside the geographical area of the park enter illegally, often in search of large catches. This pressure, which is often difficult to control despite the monitoring efforts carried out by the authorities in collaboration with the Mauritanian Coast Guard, constitutes a serious risk for the seagrass meadows due to the use of unregulated fishing gear that is prohibited and destructive because it can tear off seagrass rhizomes, and thus any possibility of regeneration may be limited.

Seagrass references in local African languages or creole may indicate some degree of a socio-cultural interaction with these critical habitats. Senegalese call seagrasses with the names 'djakha-djakha', 'samba gnagna', 'dat' in "Serer" African language; the names "waag" (sometime referred as alga) and "nianthj" are of "Lebou" language origin. Seagrasses in Guinea Bissau are locally known as *Emidja* and within the Bijagós Archipelago is in majority either stable or increasing. Nonetheless, anthropogenic activities are perceived as being the ones that mostly impact and reduce seagrasses.

Bumpetuk and Seh Island (Figure 10) have contrasting appearances (Table 4), indicating diversity of seagrass meadows, as well as the need for the development and implementation of management measures especially at Seh Island, due to increased boat activity and observed pollution in the area.

Figure 10. High and low density of seagrass meadow at Seh (**left**) and Bumpetuk (**right**), Photo: SB.

Table 4. Overview of the seagrass meadows in Sierra Leone.

Item	Bumpetuk	Seh
First discovered	13 December 2019	24 March 2022
Area estimate in 2022	Up to 10,000 m^2 (1 ha)	Up to 1000 m^2
Coordinates	N 07°38.973′, W 013°02.733	N 07° 37.971′, W 012°59.841′
Seagrass % cover	Less that 5%	up to 95–99%
Shoot density	<150 shoots per m^2	At least 1000 shoots per m^2
Canopy height	7–12 cm	9–11 cm
Impact/threats	Sedimentation	Boat activity, trampling, plastic and other pollution

4. Discussion

4.1. Seagrass Distribution

Knowledge of seagrass occurrence was limited to Senegal and Mauritania in the past decade and more recently seagrass was described for the first time in Cabo Verde [47]. After the development of a major seagrass initiative and new institutional approach in seven countries in West Africa, seagrasses were subsequently discovered in the Gambia, Guinea Bissau, Sierra Leone and Guinea, and in several locations across the whole study region. Beyond these seven countries, the presence of seagrass has also been reported in Angola, Benin, Gabon, Ghana, Togo, Nigeria, and São Tomé and Príncipe Islands [10,48]. *Zostera capensis*, a rather temperate and subtropical species, also occurs in the west coast (Atlantic) of South Africa, just north of Cape Town within Langebaan Lagoon, outskirt of Saldanha Bay [49]. *Zostera capensis* has a rather wider distribution across the east coast of Africa [50]. Our study enhances the knowledge of seagrass distribution and extent in West Africa, a region that has been historically lacking primary data, with previous modelling attempts predicting suitable habitats for seagrass occurrence without follow-up validation [38].

The newly discovered *Z. noltei* meadows in Senegal (world's southernmost limit) exhibit similar features with the meadows in Mauritania [6]: occurring in a seascape described (at low spring tides) as with retained water in pools, with the species occurring in rather dry areas and the pools mostly occupied by *C. nodosa.* Previously, the distribution of *Z. noltei* has been ascertained along the coasts of the Atlantic Ocean, from the south of Norway to the south of the Mauritanian coast only [47]. *C. nodosa* in the region is mostly found subtidally [51], often growing in mixed meadows with *H. wrightii*. *C. nodosa*'s presence in Senegal had been documented prior to this study [3] and its presence in The Gambia was documented for the first time in 2018 as part of the present study.

The distribution of *Ruppia maritima* in the wider western Africa region is poorly known. In Angola, *R. maritima* was first recorded in 1857 at Salinas do Dungo [52]. The species has also been reported growing in inland saline wetlands in Mwashya, Democratic Republic of the Congo [53] as well as in coastal lagoons in Ghana [54,55], Senegal [33] and Mauritania (in Nouadhibou) [34]. Further south, in Atlantic Africa, *R. maritima* appears common in brackish pools along the Namibian coastline [56]. Though, the species was not included in our study, there is a need for future sampling and registration of known locations.

4.2. Threats to Seagrasses

While seagrass discoveries are rather new in this region, the threats from anthropegenic activities have probably occurred for a long time. A series of studies modeling species distribution in the tropical Atlantic coupled with climate change scenarios suggested an accentuated decrease in distribution of *C. nodosa*, endangering its present distribution especially in Banc d'Arguin, Mauritania [12] and the current southermost limit of the species in Senegal. According to [12], a decrease in intertidal *Zostera noltei* areas is predicted to reach 14% in 2050 and 72% area reduction in 2100. By 2050, the dominant seagrass species would become the tropical *H. wrightii* (being then thinner and sparser); however, this could double in extent and, as stated, due also to its fast-growing ability can actually benefit from some disturbance [57]. This regime shift is expected to have a huge impact on local fishing communities, the biodiversity associated with seagrass meadows and their ecosystem services [12]. Banc d'Arguin National Park is the northernmost limit of the tropical seagrass *H. wrightii* as well as the mangrove of *Avicenia germinas* [40,58]. An increase in seagrass cover over the last three decades is probably linked to a decrease in dust storm events [59,60].

Seagrass meadows, tidal marshes and mangrove forests belong to the so-called coastal blue carbon habitats [61,62]. By sequestering and storing significant amounts of carbon from the atmosphere and the ocean, blue carbon ecosystems help mitigate climate change [1]. If these natural habitats of seagrass in the Banc d'Arguin were disturbed, millions of tons of CO_2 and other greenhouse gases, such as methane, could be released into the atmosphere. The park was designated in 2020 as the third most important global site in terms of carbon storage among UNESCO marine World Heritage sites [63]. The UNESCO Global Program has recently estimated that the overall contribution of the park to blue carbon stores is at 100,000,000 Mg C, which places Banc d'Arguin third globally after The Great Barrier Reef in Australia and Everglades National Park in the United States. According to [64], the share of CO_2 sequestered over the period 2020–2030 by the marine ecosystems of the Banc d'Arguin could reach 7.3 Mt CO2eq or 22% of the cumulative avoided GHG emissions targeted in the Paris Agreement. With a total area of 674 km^2, the economic value of the carbon sequestration service provided by the seagrass meadows in Banc d'Arguin is estimated at 89,394,214 USD per year [65]. Cabo Verde and Sierra Leone are the only countries from West Africa, and out of 16 countries across the globe, that have recognized and included their seagrass meadows within their nationally determined contributions [1], being among the few countries to set such a strategic role for seagrasses.

According to recent studies in West Africa, and particularly in Mauritania, physical stressors drive or impact on seagrass growth and coverage seasonally such as dust load events and air temperature from heat waves [66,67]. Dust at short term prompts a decay of the leaves, and therefore has a negative impact on seagrasses. At a long term, Sahara dusts bring minerals (such as iron and phosphorus), which might have a positive effect on marine life including seagrasses. Heat waves have been documented destroying the seagrass leaves [67]. The dust events can be divided in two kinds: the first one is related to a wind known as Harmattan that flows from the Northeast, brings a lot of coarse sediment [66], and can lead to suffocating seagrass. The second kind of dust storm occurs generally during rainy season in the Sahel region that starts from June to September [68,69]. The fine sediments can transport particles in the high atmosphere with a westerly direction to the Caribbean, passing by islands in the Atlantic, including Cape Verde [69].

4.3. Mapping

For future studies, the classification should be run with each country as a study area, as the seven countries exhibit significant differences especially in geomorphology, size and species assemblages [70,71]. It is desired to move one step further to incorporate seagrass mapping prediction for the entire region. Mauritania and especially the PNBA has been a subject of many seagrass studies related to ecology and mapping of seagrass distribution [5–9]. The last known seagrass prediction for the entire country is around 80,000 hectares, placing the PNBA third in terms of carbon stock among UNESCO marine sites [63].

To fill the gaps in mapping seagrass distribution, polygon data may be better for classification than datapoints, as they provide a larger area for the training process to classify different habitats [71]. Other satellite imagery composites with much finer resolution (as low as 30 cm) can also be acquired, which can be used during the training process in Google Earth Engine followed by the same classification process. It is noteworthy that substantial effort is required to download the commercial imagery, e.g., for Planet (even if this is free under a research license), and re-upload the images into the Google Earth Engine (GEE). On the other hand, the Sentinel-2 and Landsat archives are already in the cloud-native archive. Better future connectivity of GEE and the Planet API could enable high-resolution seagrass mapping. [39] performed the new SAV method of mapping using drone images to enhance classification accuracy. However, this method is still sensitive to water quality disturbed by suspended sediment and other organic material. In West Africa, seagrass is not expected to go very deep if compared with, e.g., the Mediterranean [13]. We find it in shallow areas and those areas tend to have suspended material and mud. Turbidity is the factor that hinders satellites' capacity to detect subtidal seagrass, even in relatively shallow water. The matter is water clarity, not bathymetry.

4.4. Seagrass Monitoring and Application to Conservation Efforts

While some seagrass meadows are located within marine protected areas [7], yet temporal and spatial dynamics, including events of seagrass dieback, are poorly understood. Examples of the most pressing seagrass degradation in West Africa are those in Gamboa (Praia, Cabo Verde) and Seh Island in Sierra Leone, due to coastal development, unregulated boating and persisting pollution.

The decrease in the seagrass abundance between February and July, especially in Mauritania is linked to the accumulation of sand on the leaves of eelgrass causing burial of plants under the coarse sand, which can even create anaerobic conditions in the roots of eelgrass [61]. Nevertheless, [72] pointed out that *Zostera noltei* is tolerant to the relatively anoxic conditions typical of the rich organic sediments as in Banc d'Arguin. However, [73] reported that the critical level of accretion or erosion tolerated by this species is extremely low due to its small size and the presence of short vertical rhizomes. [72] pointed out the possibility of a light threshold for rhizome branching could explain the seasonality of shoot recruitment, as well as the observed decrease in shoot density along depth (or light) gradients in seagrass meadows. The low seagrass abundance around summer can likely be attributed to dust effects combined with desiccation caused by the increase of the air temperature that can reach 45 °C, with a strong eastern wind that increases the potential of evapotranspiration. This stressor was discussed by [67], who unraveled the mechanisms of breakdown of mutualism between eelgrass and bivalves due to desiccation. The desiccation would be even more harmful for seagrasses when it coincides with a low tide, exposing the low-lying meadows to high temperatures.

In Gamboa, Cabo Verde, the *H. wrightii* meadow has increased in total cover, biomass, rhizome length and canopy height, and decreased in shoot density compared to a study conducted in 2015 by [4]. A seagrass extent assessment in this case study site revealed an increase in the total area from 2690 m^2 in 2015 to 6243 m^2 in 2021. Recent documentation of seagrass, other than Gamboa, includes the one from Sal Island, at Salinas de Pedra de Lume.

Table 5 below summarizes and compares previous published data [4] with this study's assessment.

Table 5. Summary of *H. wrightii* morphometrics in Gamboa Bay, Cabo Verde from previous publication [4] and this study.

Structural Parameters	From Literature [3]	This Study
Area	20 m^{-2}	6243 m^{-2}
Seagrass Cover	Not available	Around 60%
Shoot density	5998 shoots m^{-2}	989.6 shoots m^{-2}
Canopy height	8.3 cm	9.5 cm
Total biomass	120 g m^{-2}	311.9 g m^{-2}
Above ground biomass	22.98 g m^{-2}	117.7 g m^{-2}
Below ground biomass	101.25 g m^{-2}	194.3 g m^{-2}

In order to protect seagrasses and address the multiple threats that they face, legislation and policies at the domestic and regional levels are required [74]. West Africa is not an exception, and the need to improve governance systems for the protection and sustainable management of seagrasses is needed [75–77].

Several case study sites could benefit from protection frameworks that were originally devised for the conservation of other ecosystems and species such as marine turtles, fishes or birds. Bijol Islands, in The Gambia, have a protected status for turtles and therefore, indirectly, for seagrass meadows. In addition, seagrass conservation has been integrated into national legislation such as the Wildlife Act of 2020 and the Tanji Bird Sanctuary Management Plans. The Tristao Islands in Guinea have been listed in the Ramsar Convention on Wetlands since 1992. Since 2013, the site has been granted a Community Marine Protected Area status, which aims to preserve and enhance the biological, social, and cultural diversity of the site. The areas around Unhocomo and Unhocomozinho Islands in Guinea Bissau have been reported as a site for juvenile green turtles and as a mating ground for nesting adults; however, these areas have not been included yet in any formal status of protection. At present, there is an ongoing process to revise the artisanal fisheries regulations to incorporate the protection of seagrass meadows into national legislation. The revision has been approved by the Council of Ministers and is awaiting to be officially adopted. The National Park of Banc d'Arguin is a World Heritage Site and has the status of marine protected area with a specific regulation adopted in 2000 through the law 2000/2024 and its application decrees. The site is globally known for its high importance for biodiversity, including its vast seagrass meadows. In Senegal, the largest documented seagrass meadows to date are located in the Saloum Delta National Park and in the marine protected area of Joal-Fadiouth. Binding regulations are included in the 2015 Maritime Fishing Code and its 2016 Decree, which defines a maritime fringe, extending from 0 to 6 nautical miles from the baseline, where the use of bottom trawls is prohibited. Despite the protection status of both sites and extended binding regulations, bottom trawling and unregulated anchoring of fishing boats still pose a major threat to the health of seagrasses. The Turtle Islands in Sierra Leone are located in the South-eastern Province of Sierra Leone, and they are part of the Bonthe-Sherbo Estuary Marine Protected Area. The environment is characterized by extensive mangrove forests, mudflats, and sandbanks, with the recent recorded presence of seagrass meadows adding to the richness of habitats and biodiversity in this MPA.

Although some of the seagrass meadows in the region are located inside MPAs, their management plans do not always include targeted measures for the protection of these habitats, such as zoning that might restrict damaging activities, or plans for rehabilitation. Seagrass meadows can follow regional platforms such as the UN Environment Programme Regional Seas-related initiatives. Banc d'Arguin, in Mauritania is a World Heritage Site) and the Tristao Islands in Guinea are part of the Ramsar Convention (Tristao Islands, in Guinea). Within the framework of the Paris Agreement and nationally determined contributions, there is also potential to catalyze the protection and restoration of seagrass meadows and forests in the context of blue carbon and nature-based solutions for climate change mitigation and adaptation, such as in the case of Cabo Verde and Sierra Leone. Seagrass restoration could also provide all countries in the region with opportunities to achieve their pledges as part of the recently initiated United Nations Decade on Ecosystem Restoration (2021–2030) [74–78].

5. Conclusions

The year 2018 marked a new era in seagrass knowledge and management in West Africa. The creation of multi-stakeholder initiatives, National Implementing Teams (NITs), and financial and technical support enabled the discoveries of new seagrass meadows. Seagrass research and conservation in West Africa has yielded rich information, enabled comparisons between countries, recorded the world's southernmost limit of *Zostera noltei* (Delta de Saloum, Senegal) and identified new areas of interventions. This study presents new seagrass discoveries in four West African countries: The Gambia, Guinea Bissau, Guinea and Sierra Leone. Four seagrass species occur in the region with *Halodule wrightii* found in all seven countries, potentially withstanding environmental variability. With the combination of remote sensing techniques and ground-truthing, the seagrass extent over the entire West Africa region has been estimated at 62,108 hectares and its full extension will require mapping modelization. Threats to seagrass ecosystems in the region are human disturbance from coastal development, pollution, unregulated or destructive fishing, climate change [61], and lack of knowledge or information about their presence or importance. More specifically, seagrasses in Gamboa (Cabo Verde) are threatened from increasing coastal development. Fishing-related activities such as boating and trampling are rather intense in areas near Dakar, Senegal´s capital. Seagrass meadows in Seh Island in Sierra Leone are highly threatened by boating and trampling. Seagrass meadows in Mauritania face local pressures from overfishing and climate-related pressures. Regarding management and conservation of seagrasses, Guinea Bissau, Sierra Leone, Senegal and Mauritania have significant seagrass meadows in their MPAs. As an example, Senegal, a large area hosting seagrass beds is included within the boundaries of the Saloum Delta National Park and in the Marine Protected Area of Joal-Fadiouth. The Parc National du Banc d'Arguin is a World Heritage Site and has the status of Marine Protected Area. The Turtle Islands, Sierra Leone is part of the Bonthe-Sherbo Estuary Marine Protected Area. Cabo Verde and Sierra Leone listed its threatened seagrass meadows within NDCs, strategizing their governance. The Tristao Islands in Guinea have been listed in the Ramsar Convention on Wetlands and, since 2013, the site has been granted a Community Marine Protected Area status. In Guinea Bissau, the areas around Unhocomo-Unhocomozinho Islands is part of Bijagos Biosphere Reserve. This great development in seagrass knowledge in West Africa can attract more resources for both seagrass and related critical habitats, such as mangrove forests, as well as help initiate, replicate or upscale similar initiatives in other areas across the vast region of western Africa.

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