ResilienSEA

High Level Assessment of Seagrass Ecosystem Services in West Africa – Perception of Stakeholders

MAVA
FONDATION POUR LA NATURE

Editors

Tibor VEGH	*Duke University, USA*
Maria POTOUROGLOU	*GRID-Arendal, Norway*

Technical support

Mohamed Ahmed SIDI CHEIKH	*Agence Caisse des dépôt et de développement (CDD), Mauritania*
Mallé DIAGANA	*GRID-Arendal, Norway*
Marco Vinaccia	*GRID-Arendal, Norway*
Tanya Bryan	*GRID-Arendal, Norway*

Contributing Authors

Abdou Karim SALL	*Aire marine protégée (AMP) Joal, Senegal*
Abdou SALAM KANE	*Ministère de l'Hydraulique et de l'Assainissement, Senegal*
Ahmed GUISSE	*Centre de Recherche Scientifique Conakry Rogbané (CERESCOR), Guinea*
Aissa REGALLA	*Instituto da Biodiversidade e das Áreas Protegidas (IBAP), Guinea-Bissau*
Alassane SARR	*Institut universitaire de Pêche et Aquaculture (IUPA), Senegal*
Alkaly DOUMBOUYA	*Centre National des Sciences halieutiques de Boussoura (CNSHB), Guinea*
Amadou KIDE	*Parc National du Banc d'Arguin (PNBA), Mauritanie*
Antonio PINTO	*University of Cape Verde, Cape Verde*
Colonel Boucar NDIAYE	*Direction des Aires Marines Communautaires Protégées (DAMCP), Senegal*
Corine ALMEIDA	*University of Cape Verde, Cape Verde*
Djeynaba SECK	*Centre de Suivi Ecologique (CSE), Senegal*
Djibril LY	*Parc National du Banc d'Arguin (PNBA), Mauritanie*
Ebrima NJIE	*University of Banjul, The Gambia*
Iça BARRI	*Centro de Investigação Pesqueira Aplicada (CIPA), Guinea-Bissau*
Jacque André NDIONE	*Centre de Suivi Ecologique (CSE), Senegal*
Jean-Henri SENE	*Réseau régional d'aires Marines Protégées en Afrique de l'Ouest (RAMPAO), Senegal*
Lamin KOMMA	*National Environment Agency, The Gambia*
Lemhaba YARBA	*Parc National du Banc d'Arguin (PNBA), Mauritanie*
Lisdália Moreira	*National Environment Directorate, Cape Verde*
Malick DIOUF	*Institut universitaire de Pêche et Aquaculture (IUPA), Senegal*
Marone MAMADOU	*Direction des Parcs Nationaux (DPN), Senegal*
Maurice DASYLVA	*Université Assane SECK de Ziguinchor, Senegal*
Mohamed Lamine SIDIBE	*L'Environnement Marin et côtier, Guinea*
Momar SOW	*Direction des Aires Marines Communautaires Protégées (DAMCP), Senegal*
Ousainou TOURAY	*Department of Parks and Wildlife Management (DPWM), The Gambia*
Ousmane DIANKHA	*Direction des Aires Marines Communautaires Protégées (DAMCP), Senegal*
Ousmane DIARRA	*Direction des Parcs Nationaux (DPN), Senegal*
Paul Lamin	*Environmental Protection Agency (EPA), Sierra Leone*
Ramatu Massaquoi	*Environmental Protection Agency (EPA), Sierra Leone*
Ruis FREITAS	*University of Cape Verde, Cape Verde*
Sara DIENG	*Institut des Sciences de l'Environnement (ISE), Senegal*
Taibou BA	*Centre de Suivi Ecologique (CSE), Senegal*
Tomy MELO	*Biosfera, Cape Verde*

The authors of the report wish to express the utmost gratitude to the MAVA Foundation for Nature for its financial and technical support to the ResilienSEA project.

High Level Assessment of Seagrass Ecosystem Services in West Africa - Perception of Stakeholders

Contents

Executive summary

1. Seagrasses provide valuable ecosystem services–benefits to humans–but are now being lost globally at rapid rates due mainly to anthropogenic stressors. Ecosystem services are defined as the benefits that humans derive from the environment, in this case, from seagrass ecosystems. This report provides an initial assessment of seagrass ecosystem services in seven countries of West Africa, including Mauritania, Senegal, The Gambia, Guinea Bissau, Guinea, Cape Verde and Sierra Leone.
2. Many of the ecosystem services that seagrass ecosystems *outside of* West Africa provide have values estimated over five degrees of magnitude, between USD 11 and USD 2.4 million per hectare. Only two values were published on West African seagrass species USD 136 and USD 1,226 per hectare per year, for nursery habitat and fish habitat, respectively.
3. Based on regional opinion of experts, seagrass ecosystems are widely recognized as providing valuable benefits to the local, regional, and global community. In order of perceived importance, ideal considerations for further research, the top five are: (1) biodiversity habitat, (2) fish and nursery habitat, (3) sediment stabilization, (4) climate change mitigation through carbon storage, and (5) water quality regulation.
4. The importance of seagrass ecosystem services is widely shared among regional experts. Experts recognize that local communities depend on seagrasses to a noticeable extent, and that seagrasses are threatened by multiple stressors, both anthropogenic and natural.
5. The importance of ecosystem services related to culture, art, and design, a sense of place, and general societal health and well-being have been revealed.
6. Regional experts showed an understanding of the threats seagrasses face, which as a group they listed in order of importance as (1) human disturbance and development, (2) pollution, (3) fishing related threats, (4) climate change, and (5) lack of information.
7. There is a general understanding of ineffective and poor management of seagrasses in West Africa, driven mostly by lack of financial resources and priorities in policy and legislation
8. Further research should prioritize updated seagrass maps, a complete list of seagrass ecosystem services, including social services, primary economic valuation studies, and surveys or interviews with beneficiaries that benefit from seagrass ecosystem services.
9. Economic values of ecosystem services need to be better incorporated into policy decisions, but values that currently exist in the literature should be treated with caution.

Introduction

Seagrass meadows provide valuable ecosystem services–benefits to humans–but are now being lost globally at rapid rates due mainly to anthropogenic stressors (Unsworth et al. 2014; Dewsbury et al. 2016; Nordlund et al. 2016; Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018; Nordlund, Jackson, et al. 2018). Seagrasses off the coast of West Africa belong to two geographic bioregions (Green and Short 2003; Short et al. 2007) (**Error! Reference source not found.**). The northern part of West Africa belongs to the Mediterranean bioregion, where vast deep meadows of moderate diversity and a temperate/tropical mix of seagrasses (9 species in total) grow in clear water; ii) The southern part of West Africa belongs to the Tropical Atlantic bioregion with high diversity tropical seagrasses (10 species in total).

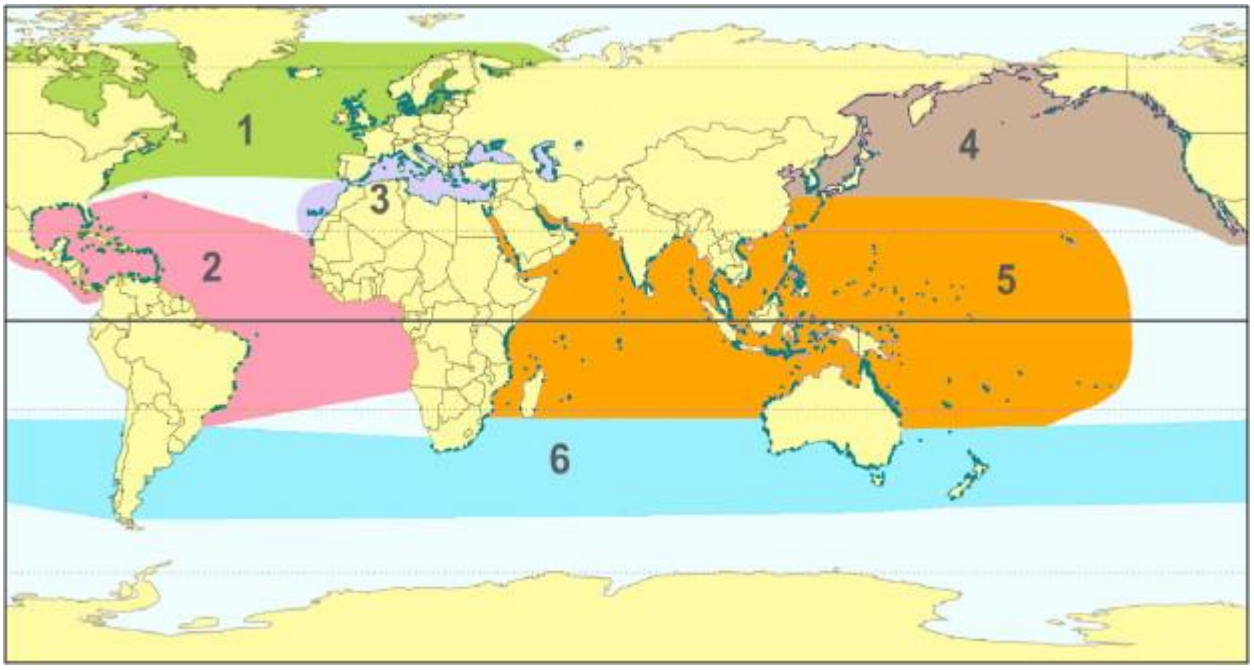


Figure 1: Global distribution of seagrasses and geographic bioregions

Source: (Short et al. 2007) based on data from (Green and Short 2003)[1].

Note: Global distribution of seagrasses (dark blue points and polygons) and geographic bioregions (colored areas); 1. Temperate North Atlantic, 2. Tropical Atlantic, 3. Mediterranean, 4. Temperate North Pacific, 5. Tropical Indo-Pacific, 6. Temperate Southern Oceans.

[1] Note: Recent updates from the United Nations Environment – World Conservation Monitoring Centre build extensively on the dataset from (Green and Short 2003) and are available here: http://data.unep-wcmc.org/datasets/7. No updates or changes have been done on West African seagrasses since the publication of the original dataset.

The improvement of conservation and management of seagrasses, part of the broader category of coastal and marine ecosystems, requires increased knowledge not only of how seagrass meadows respond to environmental change, but also of the magnitude of the benefits these ecosystems supply to humans locally, regionally, and globally. Interpreting such benefits and values requires recognizing people as part of the socio-ecological system of interconnected human and natural systems. Ecosystem services are defined as the benefits that humans derive from the environment, and are understood within a coupled socio-ecological system (SES) framework (Ostrom 2007; McGinnis and Ostrom 2014). The SES framework consists of human and natural systems that interact in two directions. First, via human drivers where the human system influences environmental status and outcomes. Second, via ecosystem services that nature provides to human systems. In the specific case of this report, the seagrass ecosystem is considered the natural system, the local beneficiaries and stakeholders the human system, and the ecosystem service flows from seagrasses to people as the linkage between the two, as was defined in (Cullen-Unsworth et al. 2014). The ecosystem services as flows are supplied by seagrass ecosystems from the underlying natural capital stock, and can be depicted as below (Figure 2).

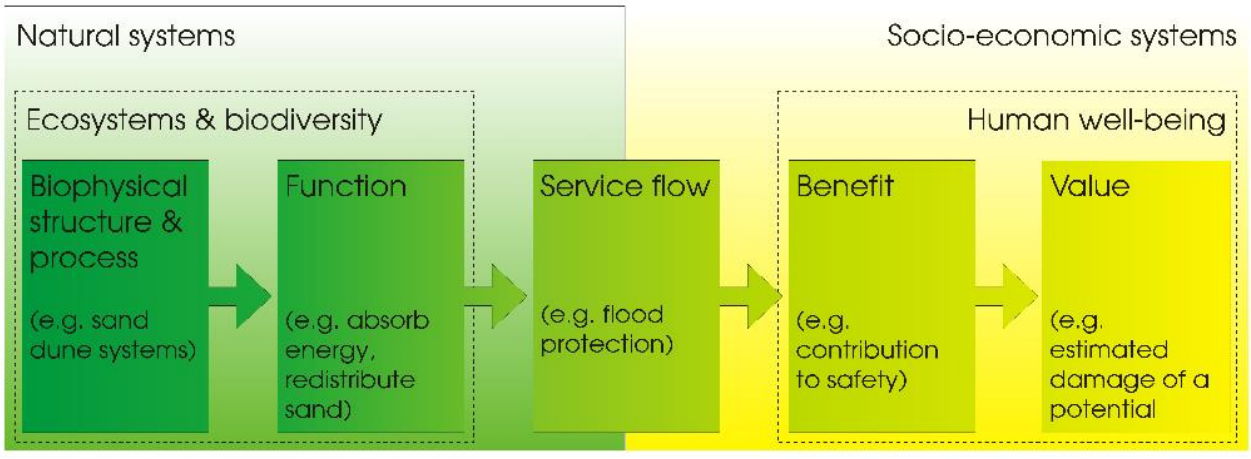


Figure 2: Ecosystem service flows from natural systems to socio-economic systems

Source: (Liquete et al. 2013)

Objectives of the report

This report provides an initial assessment of West African seagrass ecosystem services. The study area for this project is the near-shore area along the coastline of West Africa, from Mauritania south to Sierra Leone, and the islands of Cape Verde. To date, there have been no assessment of seagrass ecosystem services off the coast of West Africa, although seagrasses are known to exist along extended lengths of the West African coastline, mainly from the grey literature and local knowledge. The study area encompasses waters up to 100 meters deep, and a small amount of land along the coastline. There are three species of seagrasses known to occur in the region of interest: *Cymodocea nodosa*, *Halodule wrightii*, and *Zostera noltii*. The report synthesizes the current understanding of seagrass ecosystem services provided by the three main species found in the study area in order to better inform policy makers and stakeholders about the value that these ecosystems provide for humans living within and outside of the region.

First, the report provides a high-level overview of seagrass ecosystem services in West Africa based on published systematic reviews. Ecosystem services are assessed at a regional level, by species, taking into account the three main seagrass species that occur in the area. Where data do not exist for the region or species, the data gaps are identified. In the case of limited data availability, further research needs for seagrass ecosystem services valuation are also provided.

Second, to assess regional experts' perceptions and opinions with respect to seagrasses, data collected by a regional partner is used to identify services to be further assessed in future research. The target population are experts knowledgeable of the human-seagrass socio-ecological system in the study area. The responses shed light onto local and regional perceptions on the importance of seagrass ecosystem services, perceived threats to, and management challenges regarding seagrass ecosystems in West Africa, and key drivers of improved seagrass management in the region.

The report addresses three overarching questions: (1) What is the current state of knowledge regarding the ecosystem services and associated economic values provided by West African seagrasses? (2) What are the perceived benefits, values attributed to, threats to, and management challenges associated with West African seagrasses? (3) What are key knowledge gaps, data and research needs to inform environmental policy making in the West African context?

Methodology

Literature review

The literature review of ecosystem services provided by seagrass ecosystems in the West African context summarizes the information found in the peer reviewed and grey literatures about this ecosystem and the various services provided by it. The relevant literature was identified using Web of Science and Google Scholar searches, and resulted in a total of 47 peer reviewed publications published between 1997-2018 (see list of papers in "Literature Reviewed"). This body of literature was cross referenced with the literature reviewed in recent meta-analyses and systematic reviews on seagrass ecosystem services. As such, the initial assessment of West African seagrass ecosystem services from the literature were based on recent publications of global scope (Liquete et al. 2013; Dewsbury et al. 2016; Nordlund et al. 2016; Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018; Nordlund, Jackson, et al. 2018). None of the studies identified in the review process specifically discuss West African seagrass ecosystems in a regional context, but rather include them in a global analysis.

Synthesis of expert knowledge and perceptions on seagrass ecosystem services

The aim of the synthesis is to understand in the West African context, based on local and expert knowledge, (1) the different types of ecosystem services and benefits that seagrasses provide to various stakeholders and beneficiaries, (2) the perceived value of these ecosystem services, from the perspective of regional experts, as well as (3) the perceived threats that these ecosystems face. These benefits differ from place to place, and may include, for example, coastal protection, habitats for juvenile fish, carbon storage, water purification, tourism related, and cultural, aesthetic and or wellbeing related benefits. By synthesizing information from various experts on biology, ecology, seagrass management, and fisheries, working at local to national scales, this exercise aims to better understand seagrass uses and services, the factors that influence seagrass governance, and the variation in challenges facing seagrass ecosystems in the study area. In this way, relevant expert opinions, perceptions, and experiences of regional stakeholders and beneficiaries can be better understood in the framework of a West Africa specific socio-economic system.

Gathering expert knowledge and perceptions

The methodology comprises two parts: the development of the questionnaire to elicit answers to the perceived value of seagrass ecosystem services in the West Africa region, and that related to carrying out the data collection. The questionnaire design was based on (Schaeffer and Presser 2003; Park 2006; Gill et al. 2008; Turner 2010), and was tailored to gather data to answer the following research questions:

(1) What are the ecosystem services (i.e. benefits that humans derive from ecosystems) that seagrass ecosystems provide to humans in West Africa?

(2) What are the perceived values of seagrass ecosystem services in terms of livelihoods or other relevant measures?

(3) What is the perceived level of threat to seagrass ecosystems from the perspective of regional experts?

A regional partner gathered data on experts' knowledge and perceptions using neutral, open ended, and clearly worded questions, asked in succession from voluntary participants at seagrass ecology workshops held in late 2018. The short discussions, limited to 20 minutes each, were done by a regional partner from the West Africa region who spoke the native languages. In addition to in-person discussions, regional experts could also provide input using a web-based questionnaire. Using these two approaches, responses were recorded into a cloud-based spreadsheet for ease of storage and retrieval. Regarding the process of data gathering, respondents were assured about anonymity, and confidentiality to increase honesty and accuracy in the responses. Experts were not compensated for their time but had a good understanding of how their responses were going to be used in the future to improve seagrass management. After all the data was collected, data was analyzed by the author to identify trends and derive conclusions. The questionnaire used in the study is found in

Appendices

Appendix 1 below.

Results

Ecosystem services assessment

The ecosystem services provided by seagrasses in West Africa were assessed based on the scientific literature. The annual frequency of seagrass ecosystem service related publications has increased recently, with 2018 seeing 13 peer reviewed publications (Figure 3), showing a trend already shown in other publications such as (Ruiz-Frau et al. 2017) on seagrass ecosystem services assessment and (Himes-Cornell et al. 2018) on valuation of these services. In the literature, only one publication with data on West Africa was identified (Tuya et al. 2014).

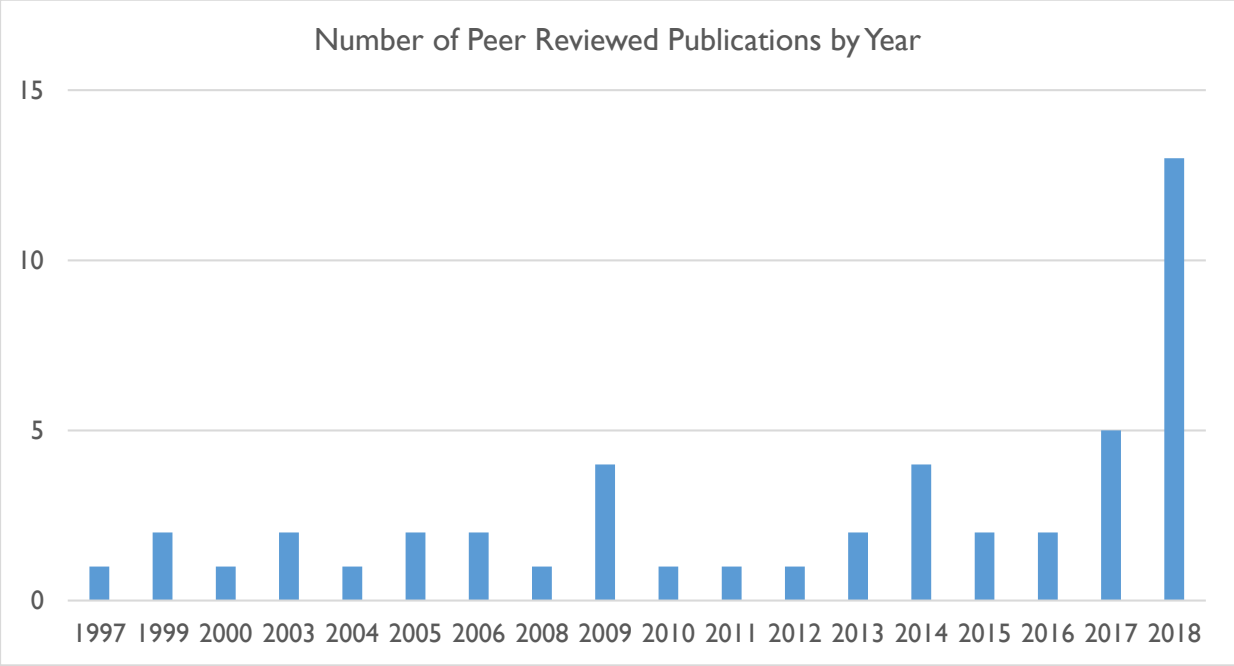


Figure 3: Number of peer-reviewed publications on seagrass ecosystem services

Note: Based on authors' literature searches using Web of Science and Google Scholar

Ecosystem services that were evaluated were based on those identified in a recent review paper (Nordlund et al. 2016), to date the most comprehensive assessment of seagrass ecosystem services based on expert elicitation. Seagrass ecosystem services provided by the three main West African species, *Cymodocea nodosa*, *Halodule wrightii*, and *Zostera noltii*, were extracted from the paper and subsequently cross-checked for completeness with other reviews that did not have regional presence and absence breakdowns, including (Dewsbury et al. 2016; Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018). The relevant ecosystem services included services such as fish

habitat, vertebrate and invertebrate habitat, food, nursery, pharmaceuticals, raw material, carbon sequestration, coastal protection, sediment accretion or stabilization, mariculture substrate, water purification, bequest value, cultural and spiritual values, and tourism (Figure 4).

Ecosystem service	***Cymodocea nodosa***	***Halodule wrightii***	***Zostera noltii***
Fish habitat	X	X	X
Nursery habitat	X	X	X
Sediment stabilization	X	X	X
Water purification	X	X	X
Tourism	?	X	?
Bequest value	X	?	X
Carbon sequestration	X	?	X
Compost fertilizer	?	X	?
Education	X	?	X
Food (assoc. spp)	X	X	X
Invertebrate habitat	X	?	X
Recreation	?	X	?
Research	X	X	X
Sediment accretion	X	?	X
Vertebrate habitat	?	X	?

Figure 4: Ecosystem services provided by the main West African seagrass species, based on regional expert knowledge

Source: (Nordlund et al. 2016)

Fish habitat is considered as one of the most important ecosystem service provided by seagrasses, due to the straightforward connection to either livelihoods in the case of small scale or artisanal fisheries, or to regional or global markets of fish or other marine products (Dewsbury et al. 2016; Nordlund, Unsworth, et al. 2018). The nursery habitat ecosystem service also connects seagrass ecosystems to wider livelihoods implications or fisheries markets. Several species of juvenile fish and other valuable or important vertebrate or invertebrate species often use seagrass beds in

early stages of their lifecycles. As an illustration of the fish or nursery habitat functions, consider that seagrass-associated species in the Mediterranean were estimated to contribute 30%–40% to the value of commercial fisheries landings and approximately 29% to recreational fisheries expenditure (Jackson et al. 2015). Sediment stabilization is an ecosystem service provided by seagrasses that has gotten more attention in recent years due to increased concerns with sea level rise and increases in storm intensities worldwide (Paul 2018). A recent study, encompassing both intertidal and subtidal, and tropical and temperate seagrass ecosystems showed that presence of seagrass resulted in an average difference in surface elevation rate of 31 mm/year, compared to adjacent unvegetated sediments (Potouroglou et al. 2017). Essentially, the presence of seagrasses has been shown to result in coastal seabeds and shorelines less susceptible to erosion. Water purification, the ability of seagrasses to function as filters of seawater for the benefit of marine organisms, has been studied and known for more than 30 years (Short and Short 1984). With increased pollution levels in global oceans, water purification is ever more important and valued.

Economic value of seagrass ecosystem services

Until recently, economic valuations of seagrass ecosystem services have been sparse, often relying on proxy measures of value, and not keeping up with the widening breadth of ecological knowledge generated about these systems (Dewsbury et al. 2016). In addition, most studies to date have relied on measures of consumptive value and have not evaluated non-consumptive use values, existence or bequeath values, or cultural and social values. This existing limitation in the valuation literature has been linked to, or even contributed to the continued degradation of these ecosystems, because the full economic value of loss is systematically underestimated.

By far the most widely used approaches to value seagrass ecosystem services are market price and benefit transfer (Himes-Cornell et al. 2018). Market price approaches estimate the economic value of an ecosystem service, such as fisheries contributions, by generating estimates of what the supported fish biomass would have been sold on the market. Benefit transfer approaches refer to a certain type of valuation methods that use existing measures of economic value from the literature and adopt them to a local context. Both approaches share relatively low resource cost to apply them because they do not require primary data collection, explaining their wide

adoption. Also, indirect-use and non-use values of ecosystem services, such as cultural or spiritual values, have not been widely estimated.

The current state of the seagrass ecosystem valuation literature, with it's over reliance on benefit transfer, continues to risk recycling old value estimates from the literature (Himes-Cornell et al. 2018). The seagrass valuation literature contains relatively old estimates that are often five years older than the date of publication, making the values estimated in a 2014 publication a decade old in 2019. Therefore, more recent valuation studies using a breadth of methodologies have been recommended. A geographic coverage gap has also been shown in the valuation literature (Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018). Specifically, seagrass valuation studies are almost nonexistent in Africa, as well as in North America, and Island nations.

To evaluate the present status of the seagrass ecosystem valuation literature as of 2018, a literature database from a recent review on coastal marine ecosystem services identified 101 peer reviewed publications, serving as a starting point for this assessment (Himes-Cornell et al. 2018). Of the 32 publications on seagrass ecosystem services, only one was conducted in West Africa in species found in the study area, and yielded two value estimates (Table 1). The literature review of (Himes-Cornell et al. 2018) did not report economic value estimates in monetary terms for any of the ecosystems covered.

Published estimates of seagrass ecosystem service values range over several orders of magnitude. For example the average ecosystem service value for the fisheries nursery function is USD 618,505 per hectare per year, with a range of USD 84 to 2.47 million per hectare per year (Dewsbury et al. 2016). In the same study, the average economic value of the nutrient cycling ecosystem service is estimated at USD 23,237, indicating a very large range in the published values. Another recent literature review on seagrass ecosystem services show no seagrass ecosystem service valuation studies from West Africa, only one on the entire continent of Africa, and just three studies from the Mediterranean (Ruiz-Frau et al. 2017). Similar to (Himes-Cornell et al. 2018), this analysis did not report even one seagrass ecosystem service economic value estimate.

To update or complement, if necessary, the literature identified in (Dewsbury et al. 2016; Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018), we used the valuation database from the Marine Ecosystem Services Partnership (MESP) database[2]. MESP is virtual center for information and communication on the human uses of marine ecosystem services around the world, and was used to provide other illustrative seagrass ecosystem service values not found in recent reviews of the valuation literature (Table 1).

Table 1: Illustrative economic values of seagrass ecosystem services in West Africa (top) and selected values from outside the region

Country / Region	**Species studied**	**Ecosystem service**	**Economic value (2018 USD)**	**Method of value estimation**	**Citation**
West Africa					
Spain – Canary Islands, Eastern Atlantic	*Cymodocea nodosa*	Fish habitat	1,226 /ha /yr	Market price	(Tuya et al. 2014)
Spain – Canary Islands, Eastern Atlantic	*Cymodocea nodosa*	Nursery habitat	136 /ha /yr	Market price	(Tuya et al. 2014)
Non West Africa					
United States – State of Virginia	*Zostera marina*	Habitat (blue crab)	3.9m-5.21m /yr	Production function	(Anderson 1989)
Australia	*Zostera capricorni, Halodule pinifolia*	Habitat, Biodiversity support	2,497 /ha /yr	Production function	(Spurgeon 1999)
Indonesia	*Thalassia hemprichii, Enhalus acoroides, Syringodium isoetifolium, Halophila ovalis*	Fish habitat	28-120 /ha /yr	Production function	(Unsworth et al. 2014)
Australia	*Zostera capricorni, Halodule pinifolia*	Fish habitat	1.5m-5.4m /yr	Production function	(Watson et al. 1993)

[2] http://map.marineecosystemservices.org/

Australia	*Zostera capricorni, Halodule pinifolia*	Habitat, Biodiversity support	3,477 /ha /yr	Production function	(Watson et al. 1993)
Philippines	*Cymodocea rotundata, Enhalus acoroides, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium, Thalassia hemprichii*	Fish habitat	83 /ha /yr	Production function	(Stuip et al. 2002)
Philippines	*Cymodocea rotundata, Enhalus acoroides, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium, Thalassia hemprichii*	Raw materials, Food, Medicine	7,905 /ha /yr	Production function	(White et al. 2000)
Philippines	*Cymodocea rotundata, Enhalus acoroides, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium, Thalassia hemprichii*	Raw materials, Food, Medicine	15,255 /ha /yr	Market price	(White et al. 2000)

The table above provides indicative values identified in the literature. Other values, such as one as high as USD 32,087 per hectare per year for nutrient cycling in *Posidonia oceanica* species, have been estimated using benefit transfer for the Catalonia region of the Mediterranean in Spain (Costanza et al. 1997; Brenner et al. 2010). Another recent study in the Mediterranean on the same species estimated ecosystem service values of USD 11-325, 38-49, 85, and 266 per hectare per year for carbon sequestration, fisheries support, water purification, and coastal protection due to wave attenuation, respectively (Campagne et al. 2015). When including all seagrass ecosystem services, the authors estimated USD 401-726 per hectare per year of total economic

value provided by *Posidonia oceanica* species. On the high end of the economic value range, the ecosystem services provided by *Posidonia oceanica* in the Mediterranean were valued at USD 2.4 million per hectare per year, a value composed almost entirely of sediment retention (Vassallo et al. 2013).

The data identified in the literature was deemed insufficient in terms of number of observations, and in terms of how recent the values are. Approaches to adopt some the values from the literature using meta-analysis or benefit transfer approaches were therefore not supported by the existing literature. Nonetheless this review provides a range of values that could be used or referenced in management or policy discussions with the appropriate caveats regarding time of publication or methods used and not used.

Gaps and challenges with integration into policy

Lack of information has been cited in the literature as one of the key barriers to overcome in the management of coastal marine ecosystems, including seagrasses (Dewsbury et al. 2016; Ruiz-Frau et al. 2017). Challenges with integration of ecosystem service valuation information into policy have been shown to exist due to multiple factors. These include insufficient, old, or possibly poor quality data, as well as the almost complete lack of understanding of the social aspects and non-use values of seagrass ecosystem services (Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018). The benefits that humans derive from seagrasses will not be fully recognized until the social aspects, and cultural values, are assessed.

Assessing regional experts' perceptions to seagrasses

There were a total of 18 experts the provided data for the study. All of the countries in the study area were represented in the responses with the largest number of experts from Mauritania and Senegal, followed by Guinea (Figure 5). With respect sectors of employment, 50% were governmental agency or department employees, 41% researchers or academics, with the rest equally divided between people employed in non-governmental or non-profit organizations, and sub-national level government (Appendix 2). The experts are engaged multiple areas of work. In order, 23% are in research, 22% in natural resource management, 18% in conservation, 14% in fishing, with the rest 23% in public engagement, site management, and tourism (Appendix 3).

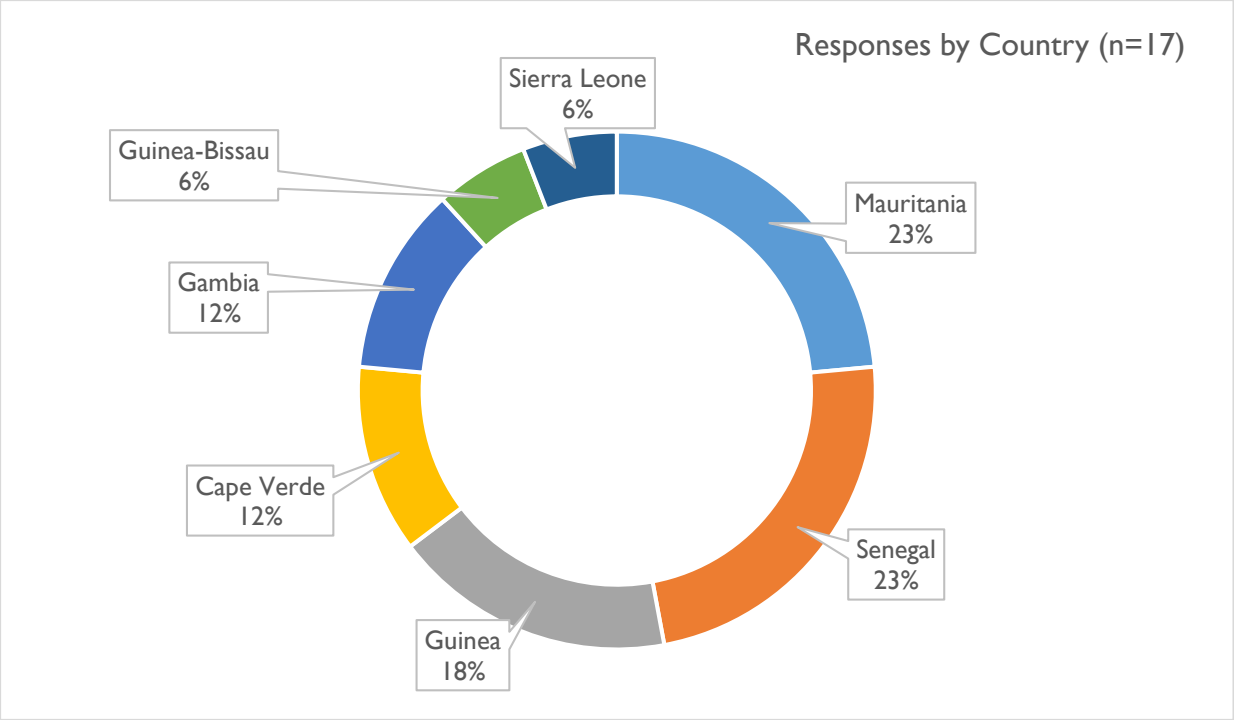


Figure 5: Responses by country

The majority of respondents that are users of seagrass ecosystems are minimally dependent on seagrasses for their livelihoods. Specifically, 61% of seagrass users either do not depend on seagrasses for livelihoods, or report up to 25% dependency (Appendix 4). Similarly, 78% of those that engage with seagrasses due to their work, only work on seagrass ecosystems for up to half of their time (

Appendix 5). Regardless of their work relationship or livelihoods derived from seagrasses, half of all respondents rated seagrass management as not effective, with 28% as somewhat effective, and 22% as effective (Appendix 6). Policy and legislation and financial resources are cited as the main drivers of seagrass management, with 48% and 35% of respondents, respectively. Following these drivers are lack of capacity or information, and tradition, both cited by 9% of respondents (Appendix 7).

All respondents realized the ecosystem services that seagrasses provide and named at least five different services in each of their responses. In total, 13 different ecosystem services were listed. Ordered by prevalence, these are provision of habitat for natural biodiversity and protected species, fish nursery habitats, coastal protection and sediment stabilization, climate regulation

through carbon storage, water quality regulation, raw material, recreation, sense of place and cultural connections, spiritual value, benefits related to mariculture, breeding site for fish and, provision of traditional medicines (Appendix 8). The majority of respondents agreed or strongly agreed with the importance of seagrass ecosystem services, including sense of place, culture, art, and design, and societal health and well-being (Figure 6).

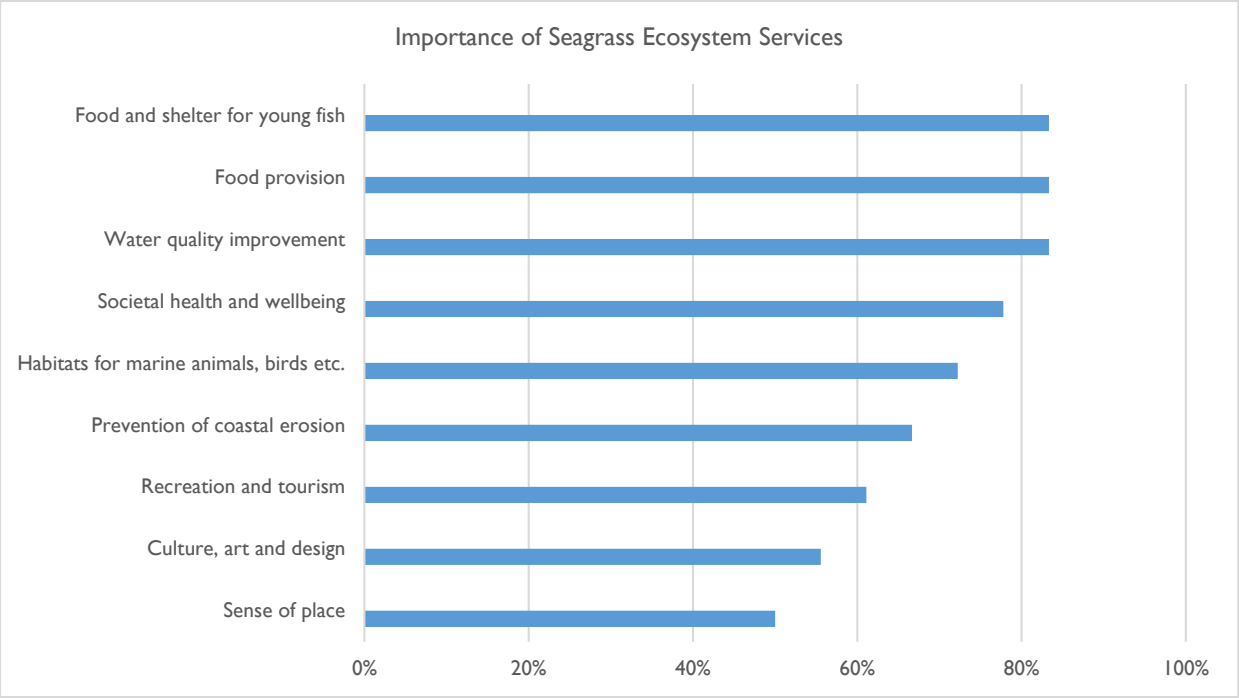


Figure 6: Percentage of expert respondents that agree or strongly agree with the importance of select seagrass ecosystem services

Respondents listed the top five perceived threats to seagrass ecosystems in the region, in order, as human disturbance and development, pollution, unregulated or destructive fishing, climate change, and lack of knowledge or information (Appendix 9). Other threats listed include offshore oil exploration, coastal erosion, invasive species, silting, and ocean acidification. When asked to rank threats to seagrass ecosystems in the region as believed to be perceived by policymakers, respondents cited lack of knowledge, prioritization, and unregulated or destructive fishing as the most important challenges (**Error! Reference source not found.**).

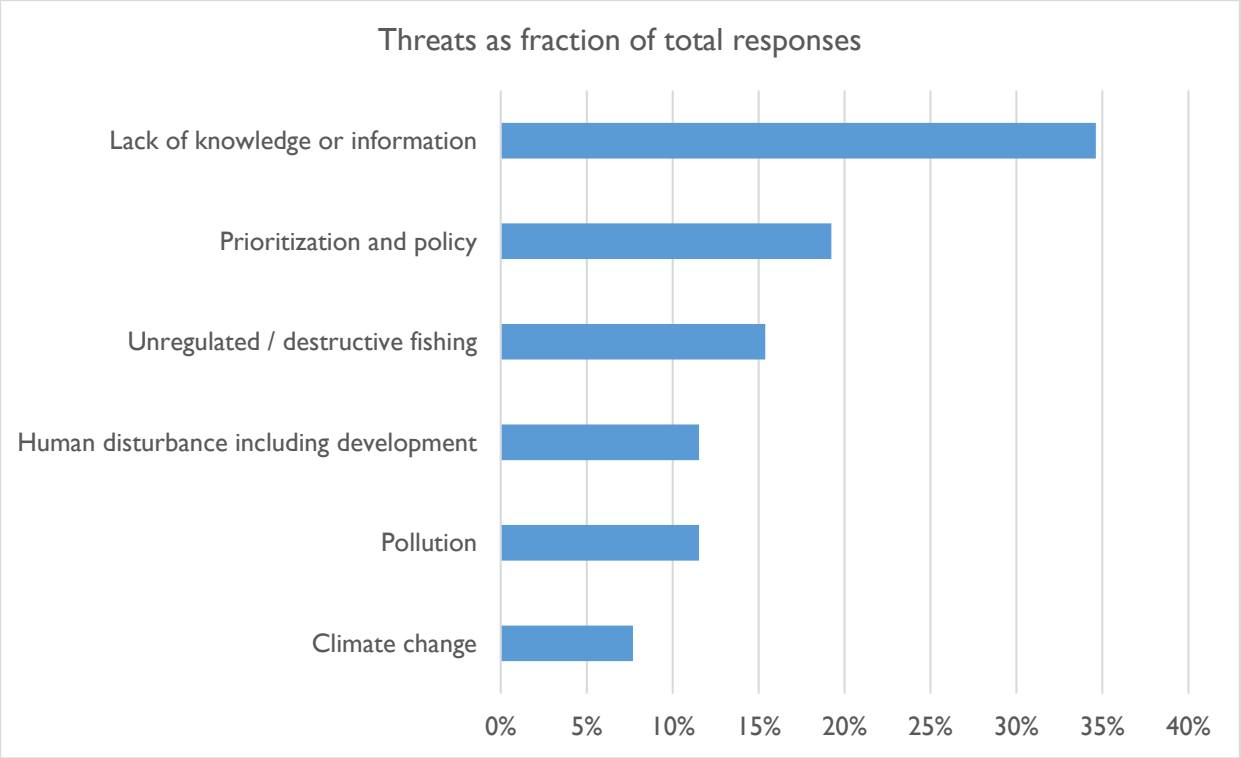


Figure 7: Threats to seagrass ecosystems and management challenges believed to be perceived by policymakers

Conclusion

The literature review and regional expert responses of the countries, organizations, and areas of expertise provide a solid basis to understand the scientific understanding of the global community and the perceptions of the regional community with respect to seagrass ecosystems in West Africa. To date, with the exception of a handful of global reviews, the literature on West Africa seagrass ecosystem services is inadequate. Despite this gap in the literature, the top priority ecosystem services–fisheries, nursery function, sediment stabilization, to name a few–require increased attention and further research and evaluation in a regionally specific manner.

First, better maps on current extent and coverage loss rates are needed because the current data is outdated. Second, a thorough review of the literature indicates that while the ecosystem services provided by West African seagrass species are assessed in the literature, this body of literature contains few if any locally estimated economic values of these services(Dewsbury et al. 2016; Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018). For more efficient policy making, there is a need for local seagrass ecosystem service assessments and valuations. To date, the valuation literature misses groups of services, such as cultural, spiritual, indirect use, and non-use values. Additionally, a wide range of primary valuation methods–not only market price and benefit transfer approaches–are recommended to avoid cycling through potentially inaccurate and biased values. Furthermore, new studies are needed that incorporate more recent economic conditions, or personal preferences and provide up-to-date economic value estimated.

The assessment of regional expert knowledge on seagrasses indicated a wide recognition of the breadth and importance of seagrass ecosystem services across the region, professions, and levels of involvement with the ecosystem. Key ecosystem services recognized include biodiversity habitat, fisheries and nursery habitat, coastal sediment stabilization, climate regulation through carbon storage, and water quality regulation. The importance of less commonly recognized, locally-derived, and more socially relevant and appreciated ecosystem services is revealed. These include the value of seagrasses in culture, art, design, their importance as a sense of place, and their contribution to wider societal health and well-being.

Regional seagrass experts showed a thorough understanding of the threats seagrasses face. As a group, they ranked threats according to level of threat potential as (1) human disturbance and development, (2) pollution, (3) fishing related threats, (4) climate change, and (5) lack of information. A more complete assessment and valuation of seagrass ecosystem services, especially of social aspect for better policy integration, will lead to their better integration into policy making and seagrass management in the region.

Literature reviewed

Aller EA, Gullström M, Maarse FKE, Gren M, Nordlund LM, Jiddawi N, Eklöf JS. 2014. Single and joint effects of regional-and local-scale variables on tropical seagrass fish assemblages. Marine biology. 161(10):2395–2405.

Barbier EB, Hacker SD, Kennedy C, Koch EW, Stier AC, Silliman BR. 2011. The value of estuarine and coastal ecosystem services. Ecological monographs. 81(2):169–193.

Barbier EB, Koch EW, Silliman BR, Hacker SD, Wolanski E, Primavera J, Granek EF, Polasky S, Aswani S, Cramer LA. 2008. Coastal ecosystem-based management with nonlinear ecological functions and values. science. 319(5861):321–323.

Brenner J, Jimenez JA, Sarda R, Garola A. 2010. An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain. Ocean & Coastal Management. 53(1):27–38.

Brooke K, Stacey M. 2017. Host-pathogen dynamics of seagrass diseases under future global change. Marine Pollution Bulletin.

Campagne CS, Salles J-M, Boissery P, Deter J. 2015. The seagrass Posidonia oceanica: ecosystem services identification and economic evaluation of goods and benefits. Marine pollution bulletin. 97(1–2):391–400.

Connolly RM, Smith TM, Maxwell PS, Olds AD, Macreadie PI, Sherman CD. 2018. Highly disturbed populations of seagrass show increased resilience but lower genotypic diversity. Frontiers in plant science. 9:894.

Costanza R, d'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'neill RV, Paruelo J. 1997. The value of the world's ecosystem services and natural capital. nature. 387(6630):253.

Cullen-Unsworth L, Unsworth R. 2013. Seagrass meadows, ecosystem services, and sustainability. Environment: Science and Policy for Sustainable Development. 55(3):14–28.

Cullen-Unsworth LC, Nordlund LM, Paddock J, Baker S, McKenzie LJ, Unsworth RK. 2014. Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing. Marine Pollution Bulletin. 83(2):387–397.

Cullen-Unsworth LC, Unsworth R. 2018. A call for seagrass protection. Science. 361(6401):446–448.

Daily GC, Polasky S, Goldstein J, Kareiva PM, Mooney HA, Pejchar L, Ricketts TH, Salzman J, Shallenberger R. 2009. Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment. 7(1):21–28.

Dewsbury BM, Bhat M, Fourqurean JW. 2016. A review of seagrass economic valuations: gaps and progress in valuation approaches. Ecosystem Services. 18:68–77.

Duarte CM. 2000. Marine biodiversity and ecosystem services: an elusive link. Journal of experimental marine Biology and Ecology. 250(1–2):117–131.

Fisher B, Turner RK, Morling P. 2009. Defining and classifying ecosystem services for decision making. Ecological economics. 68(3):643–653.

Green EP, Short FT. 2003. World atlas of seagrasses. Univ of California Press.

Heck Jr KL, Hays G, Orth RJ. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. Marine Ecology Progress Series. 253:123–136.

Himes-Cornell A, Pendleton L, Atiyah P. 2018. Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. Ecosystem services. 30:36–48.

Holmlund CM, Hammer M. 1999. Ecosystem services generated by fish populations. Ecological economics. 29(2):253–268.

Hughes AR, Stachowicz JJ. 2004. Genetic diversity enhances the resistance of a seagrass ecosystem to disturbance. Proceedings of the National Academy of Sciences. 101(24):8998–9002.

Jackson EL, Rees SE, Wilding C, Attrill MJ. 2015. Use of a seagrass residency index to apportion commercial fishery landing values and recreation fisheries expenditure to seagrass habitat service. Conservation Biology. 29(3):899–909.

Just W, Pere R. 2018. Effects of small-scale, shading-induced seagrass loss on blue carbon storage: Implications for management of degraded seagrass ecosystems. Journal of applied ecology.

Keulen MV, Nordlund LM, Cullen-Unsworth LC. 2018. Towards recognition of seagrasses, and their sustainable management. Marine pollution bulletin. 134:1.

Koch EW, Barbier EB, Silliman BR, Reed DJ, Perillo GM, Hacker SD, Granek EF, Primavera JH, Muthiga N, Polasky S. 2009. Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. Frontiers in Ecology and the Environment. 7(1):29–37.

Kremen C. 2005. Managing ecosystem services: what do we need to know about their ecology? Ecology letters. 8(5):468–479.

Lamb JB, van de Water JA, Bourne DG, Altier C, Hein MY, Fiorenza EA, Abu N, Jompa J, Harvell CD. 2017. Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. Science. 355(6326):731–733.

Liquete C, Piroddi C, Drakou EG, Gurney L, Katsanevakis S, Charef A, Egoh B. 2013. Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PloS one. 8(7):e67737.

Martin L, Maria S, Elisabeth E, Anders L, Salomão K, Mtwana BL, Mats N. 2018. Blue Carbon Storage in Tropical Seagrass Meadows Relates to Carbonate Stock Dynamics, Plant–Sediment Processes, and Landscape Context: Insights from the Western Indian Ocean. Ecosystems.

Maxwell PS, Eklöf JS, van Katwijk MM, O'brien KR, de la Torre-Castro M, Boström C, Bouma TJ, Krause-Jensen D, Unsworth RK, van Tussenbroek BI. 2017. The fundamental role of ecological feedback mechanisms for the adaptive management of seagrass ecosystems–a review. Biological Reviews. 92(3):1521–1538.

Moberg F, Rönnbäck P. 2003. Ecosystem services of the tropical seascape: interactions, substitutions and restoration. Ocean & Coastal Management. 46(1–2):27–46.

Nordlund LM, Jackson EL, Nakaoka M, Samper-Villarreal J, Beca-Carretero P, Creed JC. 2018. Seagrass ecosystem services–What's next? Marine pollution bulletin. 134:145–151.

Nordlund LM, Koch EW, Barbier EB, Creed JC. 2016. Seagrass ecosystem services and their variability across genera and geographical regions. PLoS One. 11(10):e0163091.

Nordlund LM, Koch EW, Barbier EB, Creed JC. 2017. Correction: Seagrass ecosystem services and their variability across genera and geographical regions. PloS one. 12(1):e0169942.

Nordlund LM, Unsworth RK, Gullström M, Cullen-Unsworth LC. 2018. Global significance of seagrass fishery activity. Fish and Fisheries. 19(3):399–412.

O'Brien KR, Waycott M, Maxwell P, Kendrick GA, Udy JW, Ferguson AJ, Kilminster K, Scanes P, McKenzie LJ, McMahon K. 2018. Seagrass ecosystem trajectory depends on the relative timescales of resistance, recovery and disturbance. Marine pollution bulletin. 134:166–176.

Olson A, Hessing-Lewis M, Juanes F. 2018. Seagrass nursery function enhanced by habitat connectivity.

Orth RJ, Carruthers TJ, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S. 2006. A global crisis for seagrass ecosystems. Bioscience. 56(12):987–996.

Reynolds LK, McGlathery KJ, Waycott M. 2012. Genetic diversity enhances restoration success by augmenting ecosystem services. PloS one. 7(6):e38397.

Ruiz-Frau A, Gelcich S, Hendriks IE, Duarte CM, Marbà N. 2017. Current state of seagrass ecosystem services: research and policy integration. Ocean & Coastal Management. 149:107–115.

Short F, Carruthers T, Dennison W, Waycott M. 2007. Global seagrass distribution and diversity: a bioregional model. Journal of Experimental Marine Biology and Ecology. 350(1–2):3–20.

Skilleter GA, Olds A, Loneragan NR, Zharikov Y. 2005. The value of patches of intertidal seagrass to prawns depends on their proximity to mangroves. Marine Biology. 147(2):353–365.

Snelgrove PV. 1999. Getting to the bottom of marine biodiversity: sedimentary habitats: ocean bottoms are the most widespread habitat on earth and support high biodiversity and key ecosystem services. BioScience. 49(2):129–138.

Traganos D, Reinartz P. 2018a. Interannual Change Detection of Mediterranean Seagrasses Using RapidEye Image Time Series. Frontiers in plant science. 9:96.

Traganos D, Reinartz P. 2018b. Mapping Mediterranean seagrasses with Sentinel-2 imagery. Marine pollution bulletin. 134:197–209.

Tuya F, Haroun R, Espino F. 2014. Economic assessment of ecosystem services: monetary value of seagrass meadows for coastal fisheries. Ocean & coastal management. 96:181–187.

Unsworth RK, van Keulen M, Coles RG. 2014. Seagrass meadows in a globally changing environment. Marine Pollution Bulletin. 83(2):383–386.

Unsworth RK, Nordlund LM, Cullen-Unsworth LC. 2018. Seagrass meadows support global fisheries production. Conservation Letters.:e12566.

Vassallo P, Paoli C, Rovere A, Montefalcone M, Morri C, Bianchi CN. 2013. The value of the seagrass Posidonia oceanica: A natural capital assessment. Marine pollution bulletin. 75(1–2):157–167.

Waycott M, Duarte CM, Carruthers TJ, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes AR. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences. 106(30):12377–12381.

Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JB, Lotze HK, Micheli F, Palumbi SR. 2006. Impacts of biodiversity loss on ocean ecosystem services. science. 314(5800):787–790.

Literature cited

Anderson EE. 1989. Economic Benefits of Habitat Restoration: Seagrass and the Virginia Hard-Shell Blue Crab Fishery. North Am J Fish Manag. 9(2):140–149.

Brenner J, Jimenez JA, Sarda R, Garola A. 2010. An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain. Ocean Coast Manag. 53(1):27–38.

Campagne CS, Salles J-M, Boissery P, Deter J. 2015. The seagrass Posidonia oceanica: ecosystem services identification and economic evaluation of goods and benefits. Mar Pollut Bull. 97(1–2):391–400.

Costanza R, d'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'neill RV, Paruelo J. 1997. The value of the world's ecosystem services and natural capital. nature. 387(6630):253.

Cullen-Unsworth LC, Nordlund LM, Paddock J, Baker S, McKenzie LJ, Unsworth RK. 2014. Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing. Mar Pollut Bull. 83(2):387–397.

Dewsbury BM, Bhat M, Fourqurean JW. 2016. A review of seagrass economic valuations: gaps and progress in valuation approaches. Ecosyst Serv. 18:68–77.

Gill P, Stewart K, Treasure E, Chadwick B. 2008. Methods of data collection in qualitative research: interviews and focus groups. Br Dent J. 204(6):291–295. doi:10.1038/bdj.2008.192.

Green EP, Short FT. 2003. World atlas of seagrasses. Univ of California Press.

Himes-Cornell A, Pendleton L, Atiyah P. 2018. Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. Ecosyst Serv. 30:36–48.

Jackson EL, Rees SE, Wilding C, Attrill MJ. 2015. Use of a seagrass residency index to apportion commercial fishery landing values and recreation fisheries expenditure to seagrass habitat service. Conserv Biol. 29(3):899–909.

Liquete C, Piroddi C, Drakou EG, Gurney L, Katsanevakis S, Charef A, Egoh B. 2013. Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PloS One. 8(7):e67737.

McGinnis M, Ostrom E. 2014. Social-ecological system framework: initial changes and continuing challenges. Ecol Soc. 19(2).

Nordlund LM, Jackson EL, Nakaoka M, Samper-Villarreal J, Beca-Carretero P, Creed JC. 2018. Seagrass ecosystem services–What's next? Mar Pollut Bull. 134:145–151.

Nordlund LM, Koch EW, Barbier EB, Creed JC. 2016. Seagrass ecosystem services and their variability across genera and geographical regions. PLoS One. 11(10):e0163091.

Nordlund LM, Unsworth RK, Gullström M, Cullen-Unsworth LC. 2018. Global significance of seagrass fishery activity. Fish Fish. 19(3):399–412.

Ostrom E. 2007. A diagnostic approach for going beyond panaceas. Proc Natl Acad Sci. 104(39):15181–15187.

Park A. 2006. Surveys and Secondary Data Sources: Using Survey Data in Social Science Research in Developing Countries. In: Perecman E, Curran H, editors. A Handbook for Social Science Field Research: Essays and Bibliographic Sources on Research Design and Methods. Thousand Oaks, CA: Sage.

Paul M. 2018. The protection of sandy shores–Can we afford to ignore the contribution of seagrass? Mar Pollut Bull. 134:152–159.

Potouroglou M, Bull JC, Krauss KW, Kennedy HA, Fusi M, Daffonchio D, Mangora MM, Githaiga MN, Diele K, Huxham M. 2017. Measuring the role of seagrasses in regulating sediment surface elevation. Sci Rep. 7(1):11917.

Ruiz-Frau A, Gelcich S, Hendriks IE, Duarte CM, Marbà N. 2017. Current state of seagrass ecosystem services: research and policy integration. Ocean Coast Manag. 149:107–115.

Schaeffer NC, Presser S. 2003. The science of asking questions. Annu Rev Sociol. 29:65–88.

Short F, Carruthers T, Dennison W, Waycott M. 2007. Global seagrass distribution and diversity: a bioregional model. J Exp Mar Biol Ecol. 350(1–2):3–20.

Short FT, Short CA. 1984. The seagrass filter: purification of estuarine and coastal waters. In: The estuary as a filter. Elsevier. p. 395–413.

Spurgeon J. 1999. The socio-economic costs and benefits of coastal habitat rehabilitation and creation. Mar Pollut Bull. 37(8–12):373–382.

Stuip MAM, Baker CJ, Oosterberg W. 2002. The socio-economics of wetlands. The Netherlands: Wetlands International and RIZA.

Turner DW. 2010. Qualitative interview design: A practical guide for novice investigators. Qual Rep. 15(3):754–760.

Tuya F, Haroun R, Espino F. 2014. Economic assessment of ecosystem services: monetary value of seagrass meadows for coastal fisheries. Ocean Coast Manag. 96:181–187.

Unsworth RK, van Keulen M, Coles RG. 2014. Seagrass meadows in a globally changing environment. Mar Pollut Bull. 83(2):383–386.

Vassallo P, Paoli C, Rovere A, Montefalcone M, Morri C, Bianchi CN. 2013. The value of the seagrass Posidonia oceanica: A natural capital assessment. Mar Pollut Bull. 75(1–2):157–167.

Watson RA, Coles RG, Long WL. 1993. Simulation estimates of annual yield and landed value for commercial penaeid prawns from a tropical seagrass habitat, northern Queensland, Australia. Mar Freshw Res. 44(1):211–219.

White AT, Ross M, Flores M. 2000. Benefits and costs of coral reef and wetland management, Olango Island, Philippines. Collect Essays Econ Coral Reefs.:215–227.

Appendices

Appendix 1: Questionnaire used to assess regional expert knowledge and perceptions regarding the value of seagrass ecosystem services in West Africa

Section 1: Background

1. What type of organisation do you work for?

Government agency/department, Sub-national level of government (e.g. local authority, municipality etc.), Private sector, Research institution, Academia, Non-governmental organisation, Non-profit organisation, Other (please specify)

2. Please select which category best describes your area of work relating to seagrasses (please tick all that apply)

Conservation, Natural Resource Management, Fishing, Public engagement, education and outreach, Research, Site management e.g. national park officer, Tourism, Other (please specify)

3. How much of your research/work relates to seagrasses?

Less than 25%, More than 25% but less than 50%, More than 50% but less than 75%, More than 75%, Other (please provide an estimate)

4. In relation to your seagrass-related work, please complete the following in as much detail as possible. If you work in multiple regions, please indicate:

Country:

Site:

Multiple locations:

Section 2: Seagrasses and their benefits

1. What services and benefits are provided by seagrasses in your region? Please select all that apply.

Climate regulation/carbon storage, Raw material, Benefits related to mariculture, Fisheries/ Fish nursery habitats, Recreation e.g. recreational fishing, diving, photography, Provision of habitat for natural biodiversity and protected species, Coastal protection/sediment stabilization, Water quality regulation (e.g. diseases, nutrient cycling), Sense of place and cultural connections, Spiritual value, Other (please specify)

2. How much of your livelihood depends on seagrass ecosystems?

Less than 25%, More than 25% but less than 50%, More than 50% but less than 75%, More than 75%, Other (please provide an estimate)

3. Please indicate how much you agree with the following statements about the benefits that seagrasses in your region provide to you:

Strongly disagree Disagree Neither agree or disagree Agree Strongly Agree Unsure

- Seagrasses are important for food provision.
- Seagrasses provide food and shelter for young fish.
- Seagrasses can help prevent coastal erosion.
- Seagrasses provide important habitats for marine animals etc.
- Seagrasses improve water quality.
- Seagrasses are important for societal health and wellbeing.
- Seagrasses are a valuable environment for recreation and tourism
- Seagrasses are important to inspire culture, art and design.
- Seagrasses are important for a sense of place.

4. Are there other services or benefits provided by seagrasses that have not been mentioned? If yes, please provide details below and give an indication of their importance using the same scale used in the previous question.

Section 3: Seagrasses and their management

1. In your opinion, what do you think are the main threats and/ or challenges to the sustainable use of seagrasses? Please rank them.

2. What do you think are the main threats and/ or challenges to the sustainable use of seagrasses from the perspective of policymakers? Please rank them.

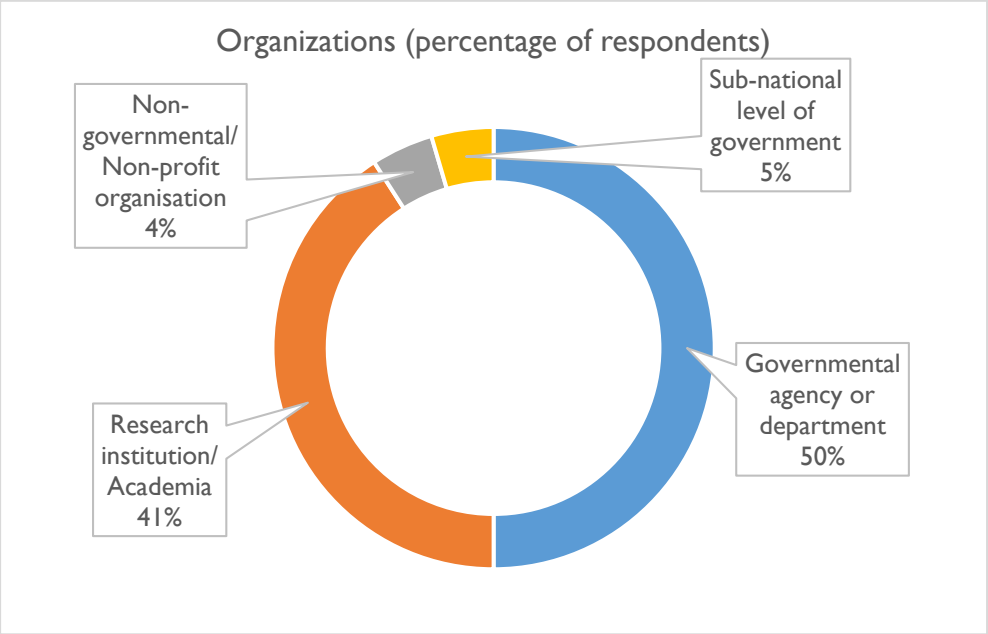
3. What are the main drivers influencing seagrass management in your region? For example, tradition, policy, financial resources

4. Overall, how would you rate the effectiveness of seagrass management in your region?

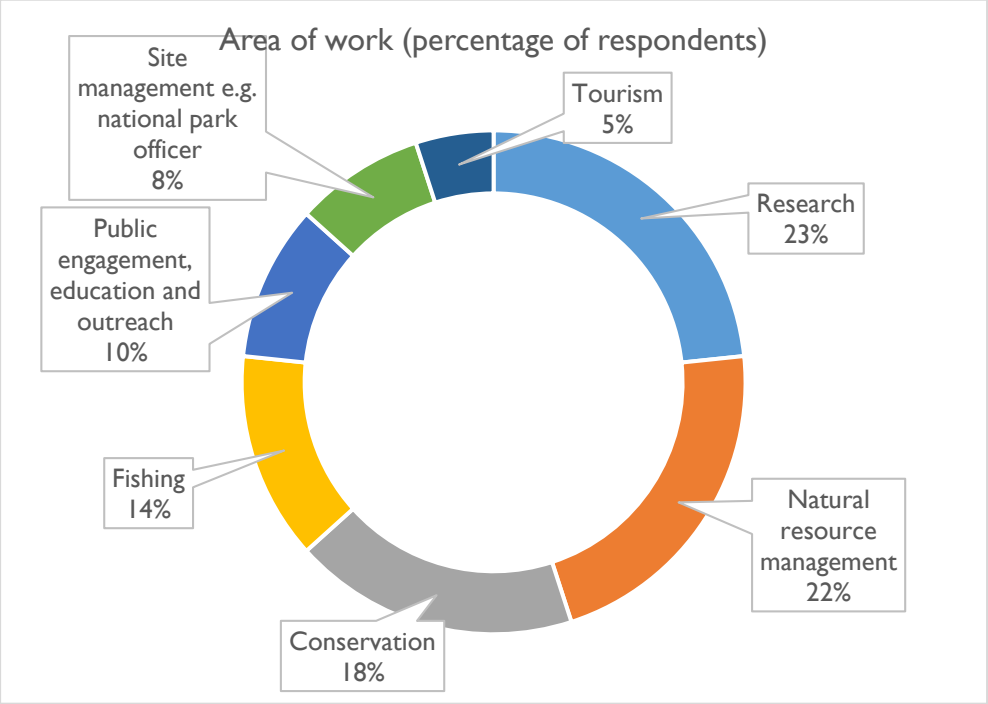
Not Effective, Somewhat Effective, Neither Effective nor ineffective, Effective, Very Effective

Please explain your answer:

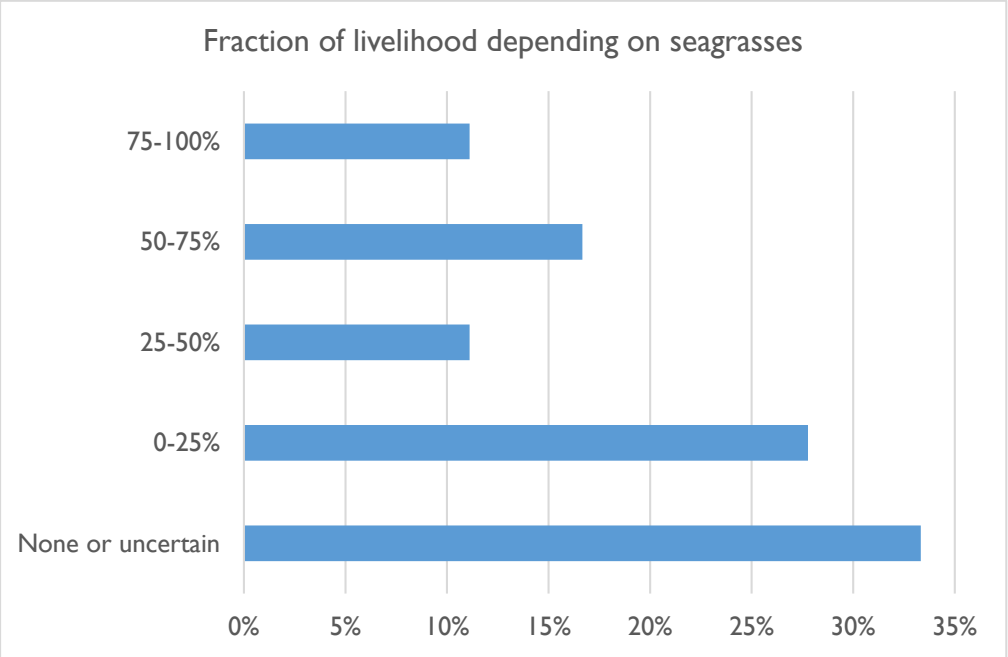
Appendix 2: Respondents by organization



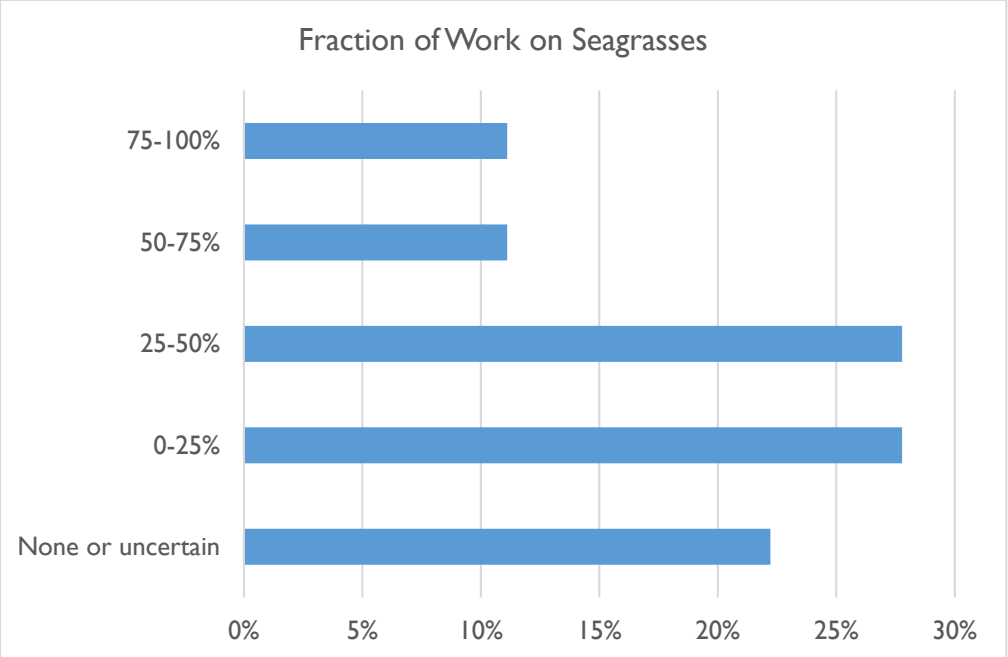
Appendix 3: Respondents by area of work



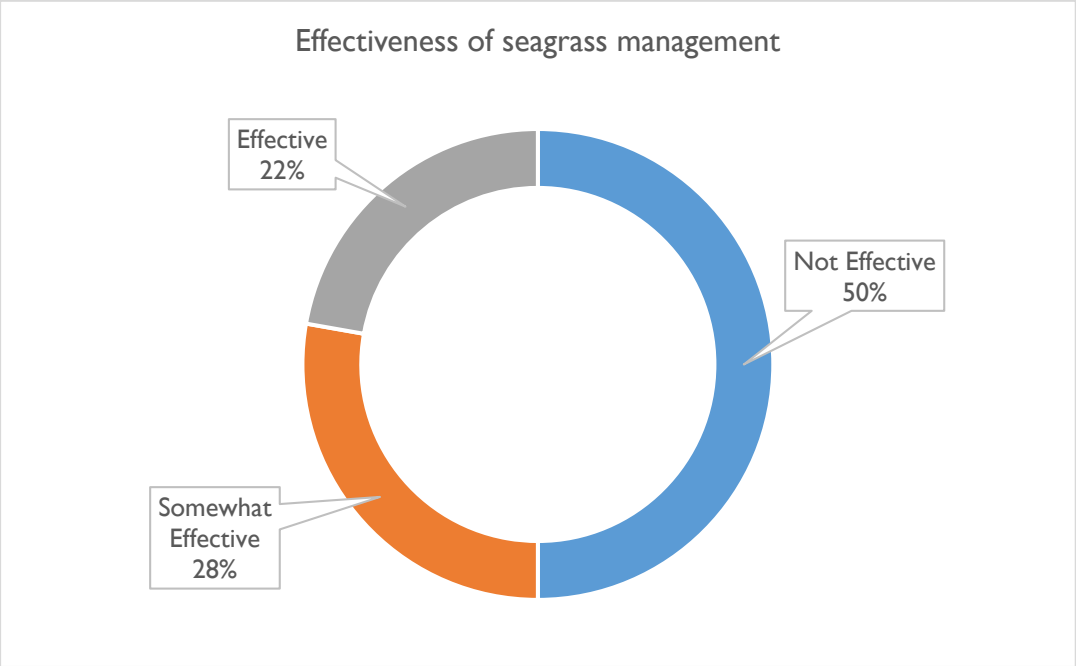
Appendix 4: Respondents by fraction of livelihood depending on seagrasses, where applicable



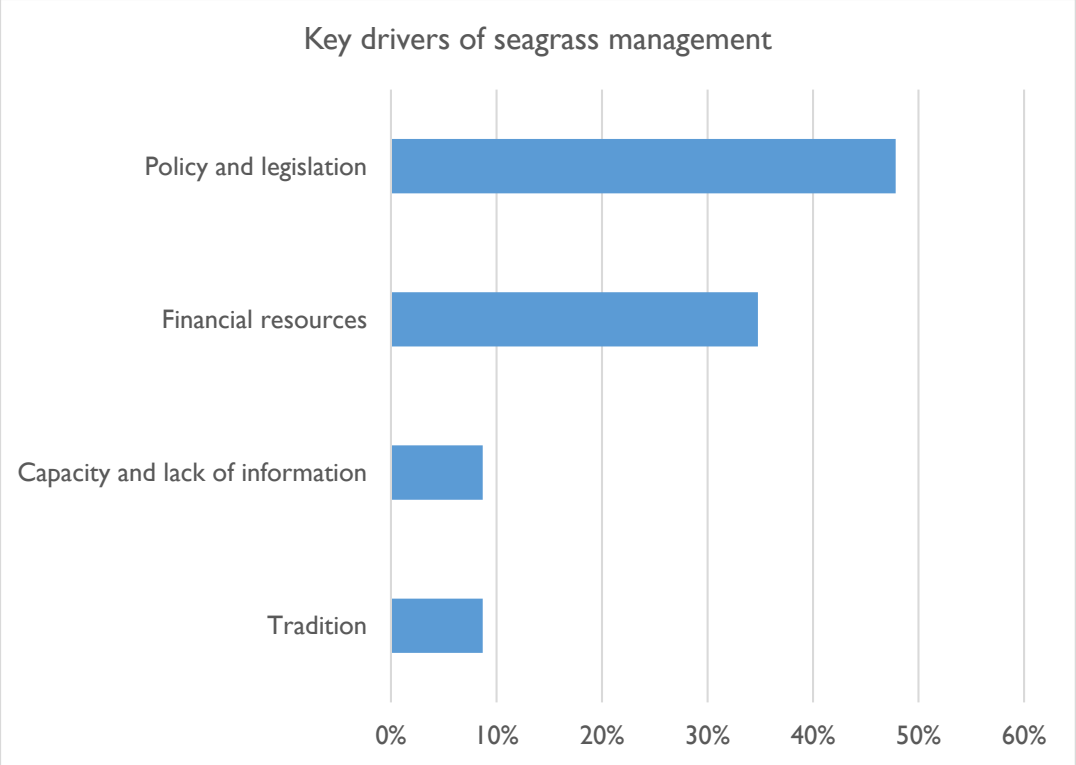
Appendix 5: Respondents by fraction of total work on seagrasses, where applicable



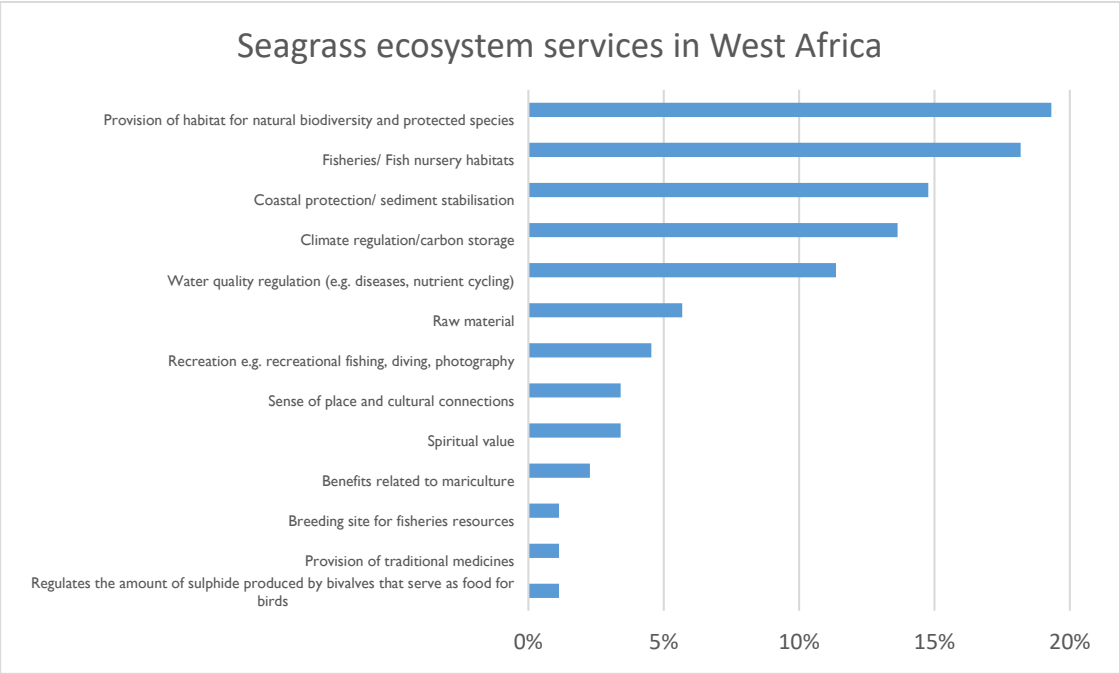
Appendix 6: Respondents' perceived effectiveness of seagrass management



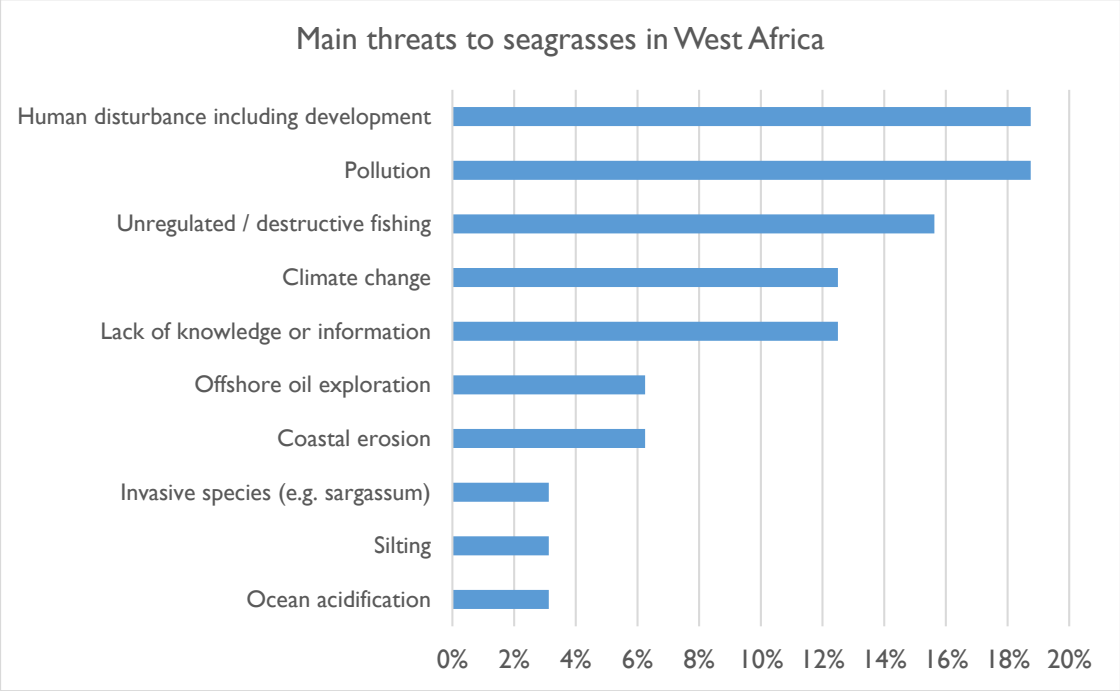
Appendix 7: Main drivers of seagrass management as perceived by regional seagrass experts



Appendix 8: Ecosystem services provided by seagrasses in West Africa according to regional seagrass experts



Appendix 9: Main threats to seagrasses or challenges to seagrass management in West Africa, as perceived by regional seagrass experts



MAVA
FONDATION POUR LA NATURE

G·R·I·D ARENDAL

UNEP

ABIDJAN CONVENTION
CONVENTION D'ABIDJAN

Wetlands
INTERNATIONAL

http://resiliensea.org