UNIVERSIDADE TÉCNICA DO ATLÂNTICO
INSTITUTO DE ENGENHARIA E CIÊNCIAS DO MAR

WEST AFRICAN SCIENCE SERVICE CENTRE ON CLIMATE CHANGE AND ADAPTED LAND USE

Master Thesis

AN ASSESSMENT OF SEAGRASS MEADOWS AND ECOSYSTEM SERVICES IN TURTLE ISLANDS, SIERRA LEONE

CASE STUDY: BUMPETUK

Melissa Ekua Ndure

Master Research Program on Climate Change and Marine Sciences

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An assessment of seagrass meadows and ecosystem services in Turtle Islands, Sierra Leone

Case study: Bumpetuk

Master's thesis presented to obtain the master's degree in Climate Change and Marine Sciences, by the Institute of Engineering and Marine Sciences, Atlantic Technical University, in the framework of the West African Science Service Centre on Climate Change and Adapted Land Use.

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Panel defence

President

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Examiner 1

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Examiner 2

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Dedication

To my late grandmother, Dr. Marcella Ekua Gwendolyn Davies, you will always be loved and missed.

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Resumo

As ervas marinhas são plantas aquáticas únicas que fornecem vários serviços vitais do ecossistema, incluindo a mitigação da erosão, habitat para a pesca, e sequestro de carbono. Apesar do papel significativo destas plantas no ambiente marinho, elas são ameaçadas principalmente por actividades humanas. A África Ocidental está entre as áreas menos estudadas de ervas marinhas a nível mundial. Contudo, através do projecto ResilienSEA de ervas marinhas, a região dispõe agora de mais dados sobre as ervas marinhas. A Serra Leoa registou oficialmente a erupção de ervas marinhas em 2019. Vários exercícios de monitorização foram empreendidos após a descoberta para aprender mais sobre as espécies de ervas marinhas e aumentar a sensibilização. Esta investigação procura acrescentar-se aos estudos em curso na região. Avalia três objectivos específicos - i. ecologia das ervas marinhas, ii. serviços ecossistémicos, e iii. a percepção que as pessoas têm das ervas marinhas. A avaliação ecológica incluiu a cobertura percentual de ervas marinhas, altura do dossel, tipo de sedimento e profundidade da água. O resultado mostrou uma baixa cobertura percentual de ervas marinhas, e a altura do dossel variava entre 3-10 cm. O sedimento é essencialmente arenoso. Os objectivos dois e três foram avaliados com o kit de dados aberto (ODK). Os participantes indicaram que a erva marinha na área apoia o abastecimento, regulamentação e manutenção, e serviços culturais. Também manifestaram grande interesse em aprender mais sobre a erva marinha e em conservá-la.

Palavras-chave: Seagrass, serviço ecossistémico, ResilienSEA, conservação

Abstract

Seagrasses are unique aquatic plants that provide several vital ecosystem services, including erosion mitigation, habitat for fisheries, and carbon sequestration. Despite these plants' significant role in the marine environment, they are threatened mainly by human activities. West Africa is amongst the least studied areas of seagrass globally. However, through the ResilienSEA seagrass project, the region now has more data on seagrass. Sierra Leone officially recorded seagrass in 2019. Several monitoring exercises have been undertaken following the discovery to learn more about the seagrass species and raise awareness. This research seeks to add to the ongoing studies in the area. It assesses three specific objectives – i. seagrass ecology, ii. ecosystem services, and iii. people's perception of seagrass. The ecological assessment included seagrass percentage cover, canopy height, sediment type, and water depth. The result showed low seagrass percentage cover, and the canopy height ranged between 3–10 cm. The sediment is primarily sandy. The open data kit (ODK) assessed objectives two and three. Participants indicated that seagrass in the area supports provisioning, regulatory and maintenance, and cultural services. They were also keen interest in learning more about seagrass and conserving it.

Keywords: Seagrass, ecosystem services, ResilienSEA, conservation

Abbreviations and acronyms

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem services
EPA	Environment Protection Agency
GPS	Global Positioning System
IUCN	International Union for the Conservation of Nature
MPA	Marine Protected Area
MFMR	Ministry of Fisheries and Marine Resources
NDC	Nationally Determined Contributions
NIT	National Implementation Team
NPAA	National Protected Area Authority
ODK	Open Data Kit
SRE	Sherbro River Estuary
SSL	Statistics Sierra Leone
UNEP	United Nations Environmental Programme

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1. Introduction

1.1 Background and Context

Seagrasses are marine flowering plants of terrestrial origin (GRID - Arendal, 2022) found in shallow subtidal and intertidal coastal waters on all continents except Antarctica (Nordlund et al., 2016). These plants are monocotyledons, grouped based on their ecological habitat rather than a common ancestry taxon (Kuo & Hartog, 2006). Seagrasses are critical in the coastal and marine environment, delivering numerous ecosystem services and benefits (Spalding et al., 2001), including improving marine biodiversity and human well-being (Short et al., 2016).

Despite the critical roles of seagrass in the coastal environment, seagrass beds are rapidly declining globally (McKenzie et al., 2020). Recent research suggests that seagrass loss has increased almost tenfold over the last 40 years (Orth et al., 2006). This loss is often due to coastal development, over-exploitation, climate change, and nutrient and sediment pollution (Orth et al., 2006). Furthermore, the lack of awareness of the presence and importance of seagrass makes its effective management and conservation (Unsworth et al., 2018) quite tricky. To enhance the understanding of seagrass in West Africa, in 2018, the ResilienSEA project started. The project's primary goal was to support seagrass research and capacity building in seven countries (ResilienSEA, 2018). Through the project, countries have documented species diversity patterns, conducted monitoring activities, and raised awareness of the importance of seagrass beds and the need to conserve them. Three seagrass species have been identified in the region: *Cymodocea nodosa, Halodule wrightii* (Figure 1), and *Zostera noltii* (ResilienSEA, 2021).

1.2 Problem Statement

The conservation of seagrass meadows is a new domain in West Africa, especially in Sierra Leone. While some baseline studies have been conducted through the ResilienSEA project, there is still room for further baseline research. Additionally, seagrass is still undocumented in most parts of the country. The National Implementation Team (NIT) of the ResilienSEA project has assessed the health of the seagrass beds, specie present, and seagrass percentage cover (NIT, ResilienSEA project, 2020). The result of the monitoring indicated the presence of the seagrass species *Halodule wrightii* in the Sherbro River Estuary (SRE), close to Bumpetuk, Turtle Islands (NIT, ResilienSEA project, 2020). The monitoring also revealed that the seagrass beds were healthy despite being distributed in patches. Community awareness programs were also conducted in the communities close to the seagrass beds (NIT, ResilienSEA project, 2020).

Although the NIT has conducted a few scientific and social studies in the area, a holistic evaluation of the local awareness (the social aspect) of seagrass and its ecosystem functions has not been conducted. The lack of data on local knowledge and ecosystem services supported by the seagrass beds along the SRE might be a setback to its conservation. According to Unsworth et al. (2018), conservation and restoration are difficult because humans have little knowledge of seagrass ecosystems. Therefore, as Sierra Leone continues to research seagrass and incorporate seagrass conservation into national policies and action plans, research on local knowledge and ecosystem services is critical.

1.3 Research Questions

1. What is the ecological (seagrass percentage cover, canopy height, sediment type, and water depth) status of seagrass meadows in Bumpetuk?
2. What is the level of local knowledge of seagrass? What are the current ecosystem services provided by the seagrass meadows? Do locals understand the link between these ecosystem services and the presence of seagrass?
3. What information will most benefit local communities to enhance their knowledge of seagrass and its ecosystem services?
4. Are there any existing local seagrass conservation activities? If yes, what are the most valuable initiatives?

1.4 Relevance and Importance of the Research

This study will complement the ongoing research on seagrass in Sierra Leone by providing further information for seagrass management and conservation. It will also help assess the impact of the ResilienSEA project in the communities close to the seagrass beds and highlight some achievements. Additionally, this research will be a tool to inform policies for seagrass conservation and, ultimately, the advancement of the United Nations Sustainable Development Goal (SDG) 14 (Life under water), particularly target 14.2, which is "sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts."

1.5 Objectives of the work

This research aims to assess seagrass ecology and ecosystem services using the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2012) and the local perspectives on seagrass in Bumpetuk village, Turtle Islands. Specifically, the research will evaluate the following:

1. The ecological (percentage cover, canopy height, sediment type, and depth) status of seagrasses in Bumpetuk.
2. The ecosystem services supported by seagrass meadows in Bumpetuk village.
3. Local knowledge of seagrass, possible threats, and local management practices.

1.6 Structure of the work

The research is divided into six parts. Chapter 1 gives a broad overview of the thesis, including the aim of the study and its justification. Chapter 2 covers a literature review of relevant research done locally and globally. The methodology for the assessment used is presented in Chapter 3. The research results are presented in Chapter 4, and the discussions are in Chapter 5. Chapter 6 gives a summary of the thesis and recommendations for future work.

2. Literature review

2.1 Seagrass and its distribution pattern

Seagrasses are a group of plants that grow submerged in shallow coastal and estuarine water (Orth et al., 2006). These monocotyledon plants with leaves, roots and rhizomes can produce seeds and flowers (Reynolds, 2018) just like terrestrial plants. The plant leaves are upright, allowing the plants to receive sunlight, while the roots and rhizomes are embedded in the sediment, absorbing and storing nutrients and anchoring the plant (Hartog & Kuo, 2006). They mainly grow on soft sediment types such as muddy, sandy, clay, and, in some cases, rocky areas up to about a depth of 1-3 meters (Reynolds, 2018). *Halophila decipiens,* found predominantly in tropical regions (Indian River Lagoon Species Inventory, n.d.), can grow to a maximum depth of approximately 50 meters (Short et al., 2007).

There are seventy-two (72) known seagrass species, classified within four families (Reynolds, 2018); i.) Zosteraceae; ii) Cymodoceaceae; iii) Hydrocharitaceae; and iv) Posidoriaceae (Hartog & Kuo, 2006). The global spatial distribution and abundance of seagrass are approximately 177,000 and 600,000 km2, respectively (McKenzie et al., 2020). Seagrass distribution and diversity are divided into six using the bioregion model based on the climate, oceans, and species diversity (Short et al., 2007). Seagrass is divided into– Tropical North Atlantic (Bioregion 1), Tropical Atlantic (Bioregion 2), Mediterranean (Bioregion 3), Temperate North Pacific (Bioregion 4), Tropical Indo-Pacific (Bioregion 5) and Temperate Southern Oceans (Bioregion 6) (Short et al., 2007). Figure 1 shows the global distribution of seagrass across all six bioregions. Short et al. (2007) indicated the Temperate North Atlantic (North Carolina, USA to Portugal) has the least seagrass species diversity (5 species), and the Tropical Indo-Pacific bioregion has the highest recorded number of seagrass species, with 24 identified species.

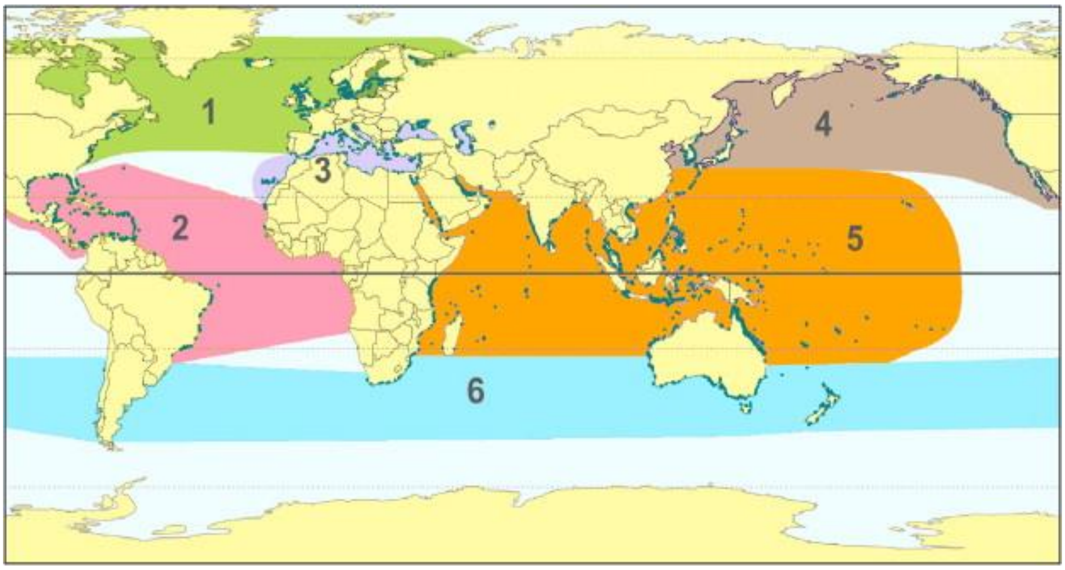


Figure 1: Global seagrass distribution and diversity map. Source: Short et al. (2007)

The Tropical Atlantic bioregion (Australia, West Africa, and South America) has clear water with a high diversity of seagrasses on reefs and shallow banks (Short et al., 2018). Ten seagrass species have been identified in the region, but it is dominated by three– *Testuinum*, *Syringodium filiforme*, and *Halodule wrightii* (Short et al., 2007). Seagrass growth and distribution are also restricted within this high-temperature area (Green et al., 2003). It is also interesting to note that this region supports grazers, including sea turtles, dugongs, and manatees (Short et al., 2007).

West Africa has previously been one of the least researched areas worldwide (UNEP 2020). However, recent research has shown that seagrass plays a significant role in the West African marine ecosystem because they offer nutrient-rich habitats for various animals (GRID-Arendal, 2022). Seagrasses in the region grow within different coastal habitats, with most meadows found predominately close to coastlines and estuaries (GRID-Arendal, 2022). Furthermore, because of the high turbidity and little light intake, seagrass in these areas grows in shallower waters (GRID-Arendal, 2022). *H. wrightii* has been identified in all seven ResilienSEA seagrass pilot countries (GRID-Arendal, 2022).

2.2 The seagrass species *Halodule wrightii*

H. wrightii is one of the seventy-two (72) identified seagrass species worldwide. It is widely distributed in five seagrass bioregions (Short et al., 2007). This specie of seagrass belongs to the family Cymodoceaceae and is commonly known as "shoal grass" or "shoalweed" (Wikipedia contributors, 2022). *H. wrightii* is a short-lived herbaceous plant with simple structures (Tussenbroek, 2010). It has a concave leaf tip with usually a darker central nerve at the tip (GRID-Arendal, 2022). Each plant stem has two to four leaves with a maximum length of 30 cm, and the rhizomes range in colour from pale to white (Sidi Cheikh et al., 2023). *Halodule wrightii* occurs in estuarine waters of the Gulf of Mexico, the Atlantic Ocean, and the Caribbean (J & Nordman, 2007) in mixed seagrass plant communities or monospecific seagrass beds that can mix with other submerged coastal vegetation (Riveria-Guzman et al., 2017). This specie can grow on sandy and muddy coasts in sheltered to moderately sheltered areas to a depth of approximately 3 meters (Riveria-Guzman et al., 2017). *H. wrightii* is a highly tolerant plant that can survive various environmental conditions, including varying temperatures, sediment accumulation, water currents, waves, and eutrophication (Fourqurean et al., 2012). *Halodule wrightii* has a high growth and associated mortality rate (Short et al., 2007). Rivera-Guzman et al. (2017) identified a difference in seasonal growth in *H. wrightii* during spring and summer. In Brazil, the seagrass is dormant during winter, starts regrowth in spring and summer, and reaches its maximum biomass variation between August – and September (Short et al., 2007).

2.3 Ecosystem services

The ecosystem services concept has been studied since the late 1970s (Vihervaara et al., 2010) because ecosystems are a fundamental part of nature. Article 2 of the Convention on Biological Diversity (CBD) defines an ecosystem as "*a dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit."* (Morgera et al., 2015). Ecosystems provide both direct and indirect services to humans, termed ecosystem services (Costanza et al., 1997). These services, such as food, pollination and climate regulation, can be local, regional, or global (Millennium Ecosystem Assessment, 2005). Ecosystem services have also been defined differently by various researchers. Ostrom (2007) defines ecosystem services as the possible services humans can derive from the environment. Other definitions include:

> "*The contributions that ecosystems make to human well-being, and distinct from the goods and benefits that people subsequently derive from them*" (Haines-Young & Potschin, 2012).

> "*Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human population derive, directly or indirectly, from ecosystem functions*" (Costanza et al. 1997).

"*The conditions and processes through which natural ecosystems, and the species that them up, sustain and fulfil human life*" (Postel et al. 2012).

In 2012, the European Environment Agency published the Common International Classification of Ecosystem Services (CICES) version 4. This paper was developed to assist in harmonising the various viewpoints on the concepts of ecosystem services and to allow information sharing (Haines-Young & Potshin, 2013). The CICES scheme divides ecosystem services into provisioning, regulation and maintenance, and cultural services. These sections can be further subdivided into "Divisions," "Groups," and "Classes" (Haines-Young & Potschin, 2013), as shown in Table 1.

Table 1: CICES v 4.3 "three-digit level" classification. Source: Haines-Young & and Potschin (2013)

Section	Division	Group
Provisioning	Nutrition	Biomass
		Water
	Materials	Biomass, Fibre
		Water
	Energy	Biomass-based energy sources
		Mechanical energy
Regulation & Maintenance	Mediation of waste, toxins, and other nuisances	Mediation by biota
		Mediation by ecosystems
	Mediation of flows	Mass flows
		Liquid flows
		Gaseous/air flows
	Maintenance of physical, chemical, and biological conditions	Lifecycle maintenance, habitat, and gene pool protection
		Pest and disease control
		Soil formation and composition
		Water conditions
		Atmospheric composition and climate regulation
Cultural	Physical and intellectual interactions with ecosystems and land-/seascapes (ecosystem settings)	Physical and experimental interactions
		Intellectual and representational interactions
	Spiritual, symbolic, and other interactions with ecosystems and landscape-/seascapes (ecosystem settings)	Spiritual and or emblematic
		Other cultural outputs

1. **Provisioning service** covers the ecosystem's nutritional, material, and energetic outputs (Haines-Young & Potschin, 2012).
2. **Regulating and maintenance** service covers how living organisms can influence the ambient environment that affects human performance. It also covers the degradation of wastes and toxic substances and the flow of solids, liquids, and gases that affect human well-being and performance (Haines-Young & Potschin, 2013).
3. **Cultural service** covers all the non-material and normally non-consumptive outputs of ecosystems that affect people's physical and mental states (Haines-Young & Potschin, 2013).

Studies estimate that the ocean and coastal ecosystems contribute more than 60% of the economic value of the biosphere (Ruiz-Frau et al., 2017; Costanza, 1999; Martinez et al., 2007; Costanza et al., 2014). Seagrasses are a vital part of the sea. Some scientists refer to them as the sea's "lungs" and "ecosystem engineers" (United Nations Environmental Programme, 2020). They are areas of high socio-economic and environmental importance in coastal marine environments across the globe (Short et al., 2016). The ecosystem services provided by seagrass beds may vary depending on the type of species, size, and productivity of the seagrass bed (Nordlund et al., 2019).

In some areas, seagrass beds support fisheries production (Nordlund, 2018) by providing nursery habitats and space for juvenile fishes (United Nations Environmental Programme, 2020), purifying water of excess nutrients and contaminants by filtration (Short et al., 2016; United Nations Environmental Programme, 2020). These ecosystems also support diverse biodiversity, including sea horses, turtles, manatees, and dugongs (United Nations Environmental Programme, 2020). New studies show that seagrass beds have the potential to control diseases by removing pathogens from the water (United Nations Environmental Programme, 2020). They also help to reduce climate change by sequestering carbon (Fourqurean et al., 2012). Carbon sequestration and storage in mangroves, salt marshes, and seagrass meadows are essential coastal 'blue carbon' ecosystem services for climate change mitigation. These unique plants can bury carbon 35 times faster than rainforests per unit area (Sogin et al., 2022). A study by Bryan et al. (2020), shows that seagrass dominates the blue carbon coverage in West Africa, with Guinea and Guinea-Bissau accounting for 60% of the projected total seagrass area (Bryan et al., 2020). According to this study, an estimated 4.8 million hectares of seagrass in West Africa store 673 million metric tons of carbon. In addition, seagrasses also play a significant role in certain cultural beliefs or practices. These include tourism, recreation, and religious links (De la Torre-Castro and Rönnbäck 2004).

However, seagrass ecosystems are under threat, and the rate of decline is accelerating (ResilienSEA, 2018). Over the years, seagrass has decreased globally due to pressures from coastal developments, boating activities, pollution, and anthropogenic and natural activities (Unsworth et al., 2018). Based on the current trend, global seagrass is estimated to decline by 30% to 40% (Bryan et al., 2020). The International Union for Conservation of Nature (IUCN) red list has identified fifteen (15) vulnerable or near-threatened seagrass species, accounting for 24% of all seagrass species (Short et al., 2011). Three seagrass species are already threatened; *Phyllospadix japonicus, Zostera chilensis,* and *Zostera geojeensiz* (Short et al., 2011). Hence, if seagrass beds are not conserved, numerous important marine ecosystems will be left unprotected or lost. The destruction will severely affect the human population that depends on its resources and ecosystem services (Short et al., 2011).

Seagrass ecosystem services research suffers from three main biases; i. geographical bias; ii. service research bias (provisioning and regulating services have received more attention while cultural services are understudied), iii. discipline bias (research has been done on seagrass ecology, but limited studies have been documented on the social and economic aspects) (Ruiz-Frau et al., 2017). Furthermore, little literature still describes traditional awareness of seagrass (Unsworth et al. 2018). Local communities must understand the importance of seagrass ecosystems and their threats from a local, regional, and global level (Unsworth et al. 2018). The traditional perception of ecosystems is vital for developing effective conservation strategies and policies. A broad understanding of the habitat of local coastal communities will considerably impact how people interact with seagrass and seagrass ecosystems (Unsworth et al., 2018).

2.4 ResilienSEA project

The ResilienSEA project is a MAVA Foundation, funded project implemented in seven West African countries. The project implementing countries are Cabo Verde, Guinea Bissau, Guinea, Gambia, Mauritania, Senegal, and Sierra Leone (ResilienSEA Project, 2021). The project aims to improve seagrass data in the region project while enhancing capacity building, sensitisation, research, and policy advocacy (GRID-Arendal, 2022). Since the project’s inception, data on the region’s seagrass distribution, ecology, and threats have increased significantly (GRID-Arendal, 2022). However, research on seagrass in the region is very low and their only a few published articles from Mauritania, Cabo Verde and Senegal.

All seven countries have mapped and monitored seagrass (GRID-Arendal, 2022). So far, the extent of seagrass mapped in the region is estimated at 62,108 ha (Sidi Cheikh et al., 2023). Implementing countries have also identified the main threats to seagrass beds in their countries.

Furthermore, seagrass awareness is improving, and communities are taking strides to learn more about this critical ecosystem and implement conservation and restoration mechanisms (GRID-Arendal, 2022).

2.5 Seagrass in Sierra Leone

In December 2019, Sierra Leone officially recorded seagrass in the Sherbro River Estuary (NIT, ResilienSEA project, 2020). It is unclear whether this was the country's first sighting of seagrass. However, no formal record or publication on seagrass beds was available before this discovery. Since the sighting of seagrass close to Bumpetuk Island along the Sherbro River Estuary, the NIT has mapped the pilot site and conducted four monitoring exercises and awareness-raising programs. In 2022, the NIT discovered seagrass near two other areas along the Sherbro River Estuary – Sei and Mania community (close to Bumpetuk) (NIT, ResilienSEA project, 2022). These islands, known as Turtle Islands, are located in the southern province of Sierra Leone and are home to the Sherbro people. According to the Environment Protection Agency (2019), the Turtle Islands are low-lying islands threatened by coastal erosion.

For a country like Sierra Leone, national and community awareness of seagrass is just beginning. This limited awareness implies that actions to conserve seagrass beds are still in their infancy. According to the NIT, the pillars to enhance and promote effective seagrass conservation are either being developed or under review (NIT, ResilienSEA project, 2020).

2.6 Coastal and Marine conservation in Sierra Leone

A Marine Protected Area (MPA) is defined as a spatially delimited area(s) of the marine environment that are managed in part or in whole to conserve biodiversity (Edgar et al., 2007). MPAs in Sierra Leone include the Scarcies River Estuary (the great and little Scarcies), the Sierra Leone River Estuary, the Sherbro River Estuary, and the Yawri Bay. These MPAs were established by the Ministry of Fisheries and Marine Resources (MFMR) in 2012 and are managed by the MFMR and the National Protected area Authority (NPAA). The MPAs were declared protected because of their value to fisheries. It seeks to protect endangered species such as sharks, manatees, sea turtles, and dolphins (Ministry of Fisheries and Marine Resource Gazette, 2012). Although these areas have been declared protected, the government still struggles to regulate coastal and marine activities.

The NPAA, in partnership with West Africa Biodiversity and Climate Change (WA BiCC) in November 2020, developed a co-management plan for the Sherbro river Estuary (USAID/West

Africa Biodiversity and Climate Change (WA BiCC), 2020). This plan provides a framework for conserving coastal and marine biodiversity in the SRE by the government and local communities. However, the existing co-management plan does not cover seagrass because seagrass awareness was limited while developing the project. Communities are aware of critical ecosystems such as mangroves and take a community-based approach to manage them, but this is not true for seagrass.

Nonetheless, with the growing knowledge of seagrasses and their vital ecosystem, Sierra Leone is reviewing some national conservation strategies (NIT, ResilienSEA project, 2020). Similarly, a significant milestone for Sierra Leone is the inclusion of mangroves and seagrass conservation in the country's updated Nationally Determined Contributions (NDC) 2021. In addition, the NIT for Sierra Leone conducted a stakeholder's power map to identify the level of influence of key stakeholders in seagrass protection (National Implementation Team, Sierra Leone, 2021). This survey will help the government understand the roles of the relevant players in decision-making for managing the seagrass and policy-making process. Also, community participation, according to them, has been a significant part of the project implementation.

3. Materials and Methods

3.1 Study Area

The coastline of Sierra Leone is 460 km long, with 190 km of sheltered coast that is dominated by extensive mangroves and mudflats (Johnson, 2006). The country is rich in marine biodiversity, with several small Islands, some of which are uninhabited. One such Island is the Turtle Islands - a chain of eight islands located in Dema chiefdom, Bonthe district, in the southern region of Sierra Leone. These Islands sit at the mouth of the Sherbro River Estuary (Anthony, 2004), which is approximately 80 km long and receives discharges from the Jong, Kittam, and Wanje Rivers (WA BiCC, 2019). Figure 2 is a map showing the location of all the Islands that make up the Turtle Islands: Moot, Bumpetuk, Nyangei, Seh, Baki, Yele, Chepo, and Hoong.

The Sherbro River Estuary (SRE) is a designated Marine Protected Area with a total area of 283.54 km^2 (WA BiCC, 2019). The estuary comprises vast deposits of sandy-muddy sediments and extensive mangrove forests with semidiurnal tides (Anthony, 2004). The most important vegetation of the SRE is the mangrove. The estuary holds the most extensive pristine mangrove forests in Sierra Leone, accounting for about 54% of the country's mangrove resources (USAID/West Africa Biodiversity and Climate Change, 2020). Sierra Leone River Estuary is a significant habitat for fishing, spawning, and nursery ground for marine turtles and fish (Anthony, 2004). Furthermore, the estuary is an important stop-over along the East-Atlantic Flyway for migratory waterbirds (USAID/West Africa Biodiversity and Climate Change, 2020).

Turtle Islands have a low population density (Anthony, 2004). The estimated population of Dema chiefdom based on the 2015 national census was 7,411 (Statistics Sierra Leone (SSL), 2017). The Sherbro and Mende people inhabit the islands, and their primary source of income is fishing. These people are artisanal fishermen, with a few being farmers, traders, and transporters. However, trawlers sometimes operate illegally in the area, causing damage to local fishing gear and the marine environment (Environmental Justice Foundation, 2009). Trawling and tourism are other activities on the Island, but they are not regular and are done mainly by tourists.

Bumpetuk community (7˚39' 21" N 13˚01' 24" W) is the largest of the eight Turtle Islands and the primary data site for the ResilienSEA project (Figure 2). The Island is located west of Bonthe

Island and shares a landmass with two other communities—Mania and Moot. According to the village head, Mr Chalobah, the estimated population of the Bumpetuk community is 1,500. As indicated earlier, this Island is the country's primary site of the ResilienSEA project (National Implementation Team (NIT) Report, 2020).

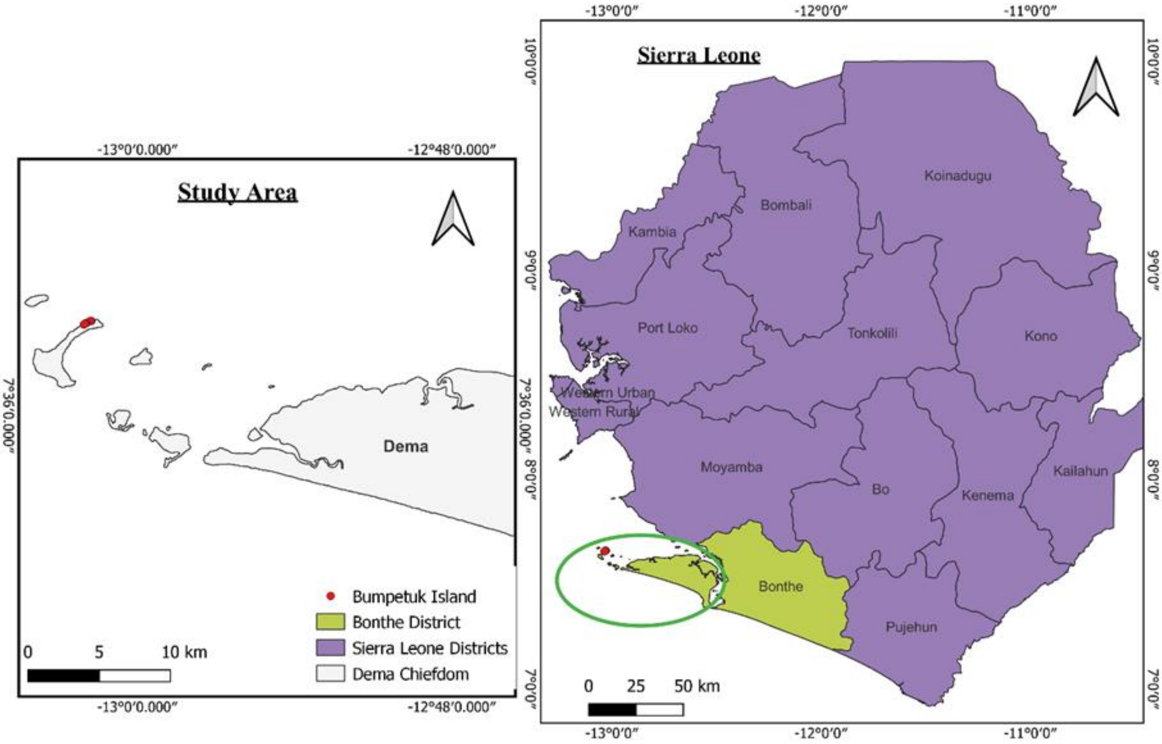


Figure 2: Map showing seagrass location at Bumpetuk, Turtle Islands, Dema Chiefdom

3.2 The climate of the area

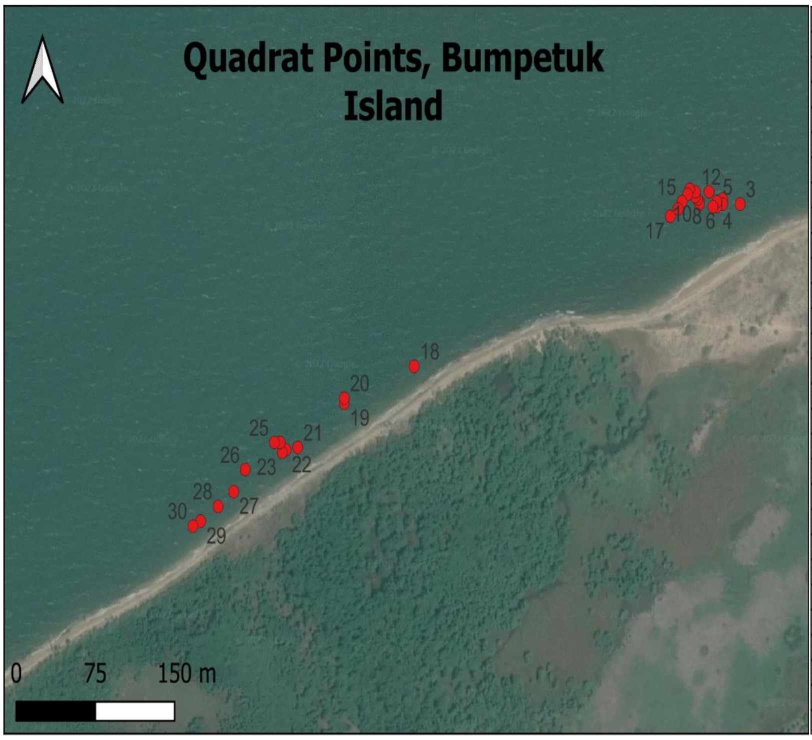
According to the National Meteorological Agency's 3rd national climate communication report, Sierra Leone has an annual average rainfall of 2,746 mm (Government of the Republic of Sierra Leone, 2017). The coastal districts of Sierra Leone had the heaviest rain; the average rainfall in the Bonthe district was 3,659 mm (Government of the Republic of Sierra Leone, 2017). Climate change and sea-level rise have harmed low-lying coastal settlements and small islands in Sierra Leone, including Turtle Islands (Sankoh et al., 2015).

3.3 Sample design

The assessment was conducted between January 27th to 30th, 2022, during low tides. Before the study commenced, an ethical clearance was sought from the NIT representatives and the chief of the Bumpetuk community. The survey of the seagrass beds was carried out on foot because the seagrass beds were easy to access during low tides. The ecological study followed the methods described by McKenzie for rapid assessment of and monitoring of seagrass in the tropics (McKenzie, 2003).

3.3.1 Ecological assessment

The ecological assessment covered seagrass canopy height, water depth, and sediment analysis. A 50 x 50 cm quadrat was laid at random points along a transect, and data was collected at thirty points during the transect. The GPS points of each quadrat are shown in Figure 3.



Quadrat no	Latitude	Longitude
1	7.660183333	-13.02951667
2	7.66015	-13.02951667
3	7.66015	-13.02936667
4	7.660133333	-13.02956667
5	7.660166667	-13.02956667
6	7.660133333	-13.0296
7	7.660233333	-13.02963333
8	7.660166667	-13.02971667
9	7.66015	-13.02971667
10	7.660183333	-13.02973333
11	7.6602	-13.02975
12	7.660233333	-13.02975
13	7.66025	-13.0298
14	7.660216667	-13.02981667
15	7.660166667	-13.02986667
16	7.660116667	-13.0299
17	7.660066667	-13.02996667
18	7.65905	-13.03216667
19	7.6588	-13.03276667
20	7.658833333	-13.03276667
21	7.6585	-13.03316667
22	7.658483333	-13.03326667
23	7.658466667	-13.0333
24	7.658533333	-13.03331667
25	7.658533333	-13.03336667
28	7.6581	-13.03385
29	7.658	-13.034
30	7.657966667	-13.03406667

Figure 3: Quadrat GPS points in Bumpetuk

The canopy height of the plant was determined by extending the plant's leaf to maximum length and measured using a 15 cm ruler. The leaves were measured from the tip to the rhizome just above the sediment, as shown in Figure 4. Three leaves were measured in each quadrat, and the mean canopy height for each was calculated and multiplied by 80% (Duarte & Kirkman, 2001). The tallest 20% of leaves were ignored and measured from the remaining 80% in each quadrat (Duarte & Kirkman, 2001). This choice better represents canopy height using the mean and reduces the number of probable inaccuracies (Duarte & Kirkman, 2001). In addition, the water depth was measured using a 100-meter tape at various points. The tape was lowered into the water and held just above the sediment, and that depth was recorded. A tape was used instead of a Secchi disk because the latter was unavailable.

Figure 4: Canopy height measurement at Bumpetuk using a 15 cm ruler.

For sediment analysis, sediment samples were collected within each quadrat to determine the sediment type in the pilot area. A total of thirty (30) sediment samples were collected from thirty quadrat points and separated into two (1-16 and 17 – 30). The samples collected were analysed using the BA 200N shaker at the Universidade Técnica do Atlântico (UTA) laboratory. The main advantage of this method is that it differentiates sediment into different sizes and decreases the time required to perform sieve analysis.

3.3.2 Local knowledge Survey

A structured questionnaire was administered to determine the perception of coastal communities, especially Bumpetuk, on seagrass and the ecosystem services it supports. The questionnaire was developed using the XLS Form syntax based on the study's objectives and deployed on GSP-enabled smartphones using the Open Data Kit (ODK) Collect App. The application can collect and aggregate spatial (or location-based) data and its attributes, including unique IDs, labels, date and time stamps, photos, audio and video recordings, and notes. In this study, the backend aggregate server used was Google Drive. Before the assessment, the sample size was estimated using Equation 1. The participation eligibility criteria required individuals to be eighteen years old or above.

$$Sample\ size = \frac{(Z - score)^2 \times stdDev \times (1 - stdDev)}{(Margin\ of\ error)^2} \quad (1)$$

The approximate population of Bumpetuk is 1500, according to the local chief. The chief stated that the population is primarily made up of young children under eighteen (18). Considering this, the survey's estimated population size (i.e., sample frame) was 700 people, excluding all residents under 18. Thus, assuming a 90% confidence level, a standard deviation of 0.5 and a margin error of $\pm$ 5% (Scott and Gerald, 2010), the estimated sample size for the survey is 249 respondents. The questionnaire was delivered during a town hall meeting at Bumpetuk and through personal interviews in other islands and areas. A short introductory meeting was held with community stakeholders on January 27th 2022. A town hall consultation was held at the village square following this meeting. Figure 5 is a cross-section of the respondents.

Figure 5: Town hall meeting with stakeholders and residents at Bumpetuk

As shown in Appendix 1, the survey questionnaire began with a brief description, followed by consent to participate. Twenty- six questions were asked under six sections.

1. *Demography* - Age, occupation, gender, and educational level.
2. *Seagrass identification* included questions designed to test residents' knowledge of seagrass. Pictures were shown to the participants, and they were asked to identify seagrass.
3. *Ecosystem services*- This section had questions about provisioning, regulating and maintenance, and cultural services. It also covered the fauna associated with the seagrass ecosystem in the area.
4. *Threats and conservation*- this section covered threats to seagrass ecosystems and whether the locals know the threats to the seagrass beds.
5. *People and seagrass*- this section sought to identify the relevant information locals will require on seagrass and strategies to communicate the information to them.
6. *Reflection* - participants were asked their opinion of the survey and whether it had changed their perception of seagrass.

3.5 Data Analyses

3.5.1 Soil analysis

Grain size analysis- dry method (Geotechnical Test Method, 2015) was used to determine the different grain size distributions of the sediments collected at Bumpetuk. This analysis gives the quantitative proportion of soil grains in a dry soil sample. It is carried out using the sieve analysis for coarse-grained soil (sand, gravel) (Shkisha, 2013). Five sieves were used with aperture sizes: 63µm, 125µm, 250µm, 500µm, and 2.0 mm. Each sieve was cleaned, weighed, and their weights recorded. Afterwards, the sieves were arranged in the BA 200N shaker in ascending order. The soil sample was placed at the top (largest sieve opening), covered, stacked on a mechanical shaker, and shaken. The BA 200N shaker ran for 10 minutes, after which the sieves were reweighed, and the weight was recorded (Figure 6).

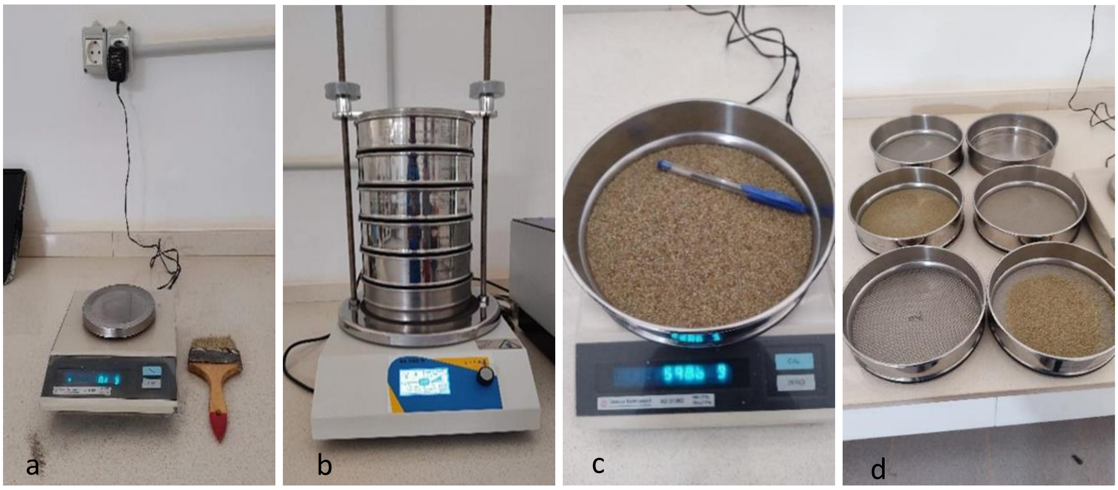


Figure 6: Grain size analysis; a) weighing equipment and brush used to clean sieve before working, b) Mechanical shaker, c) weighing after shaking, d) the five sieves and pan after shaking for 10 minutes.

By subtracting the empty weight of the sieve from the sieve weight with soil, the weight of soil retained in the sieves was estimated. The weight maintained is then divided by the original weight of the soil sample to calculate the percentage of soil retained (Geotechnical Test Method, 2015). The total passing from each sieve was determined by subtracting the cumulative percentage kept in each sieve from the total above it.

$$Soil\ retained\ (g) = (weight\ of\ seive + soil\ retained) - weight\ of\ empty\ seive \quad (2)$$

$$percent\ retained\ (g) = \frac{soil\ retained}{total\ weight} * 100 \qquad (3)$$

Response recorded in the ODK Collect app was transmitted to Google Drive for aggregation into a single Google Sheet. Subsequently, the Google Sheet containing the data was downloaded in Excel for further analysis. It resulted in extraction in the form of basic statistics on the desktop using Microsoft Excel. In addition, the variables were subjected to a chi-square test using the STATA software. The chi-square analysis is a tool for determining if categorical variables are related.

4. Results

This chapter provides the data collected for this research. The data are organised following the objectives indicated in chapter one. The social survey is presented following the questions in the questionnaire.

4.1 Ecological survey

4.1.1 Percentage cover

Seagrass percentage cover at the time of the assessment was low. The percentage cover mainly ranged between 20% and 35%. Figure 7 shows pictures of some of the quadrats at different points during the transect. In some areas, the seagrass percentage cover was less than 5%.

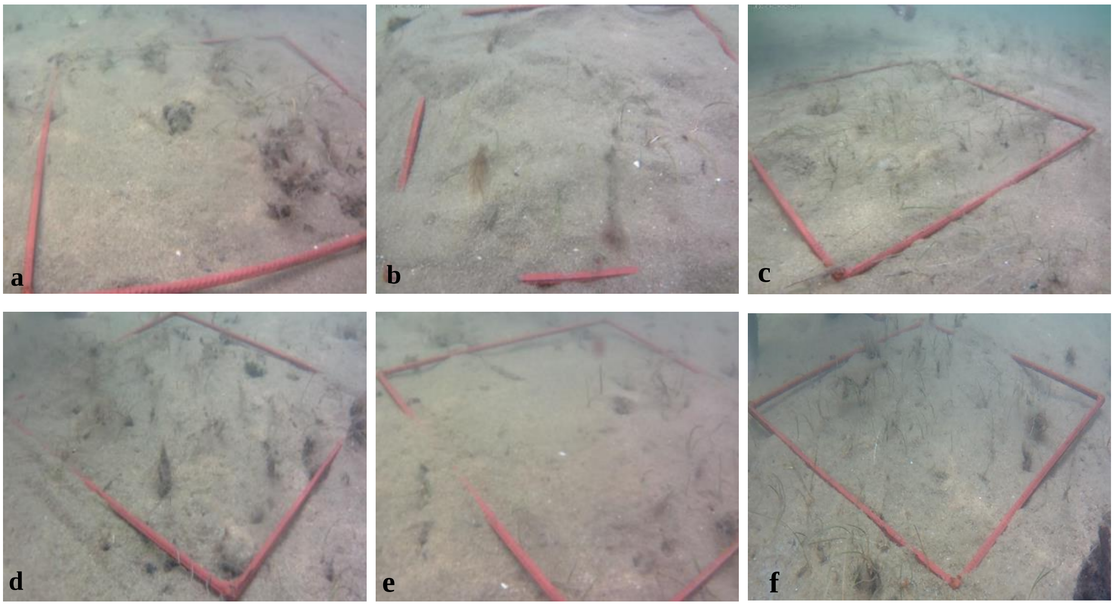


Figure 7: Visual percentage cover of seagrass at different points during the transect.

4.1.2 Canopy height

Table 2 presents the results obtained from the leaves measured. The leaves varied in length with the canopy height, ranging from 4 to 10 cm in most areas.

Table 2: Canopy height Analysis showing the mean and standard deviation as described by Duarte & Kirkman (2001)

Quadrat ID	Canopy Height (cm)			Canopy Height (cm)	Mean *80
1	8.5	8	6.8	7.77	6.21
2	7	7	6.8	6.93	5.55
3	7	6.5	6.5	6.67	5.33
4	9	8.8	9	8.93	7.15
5	5	5	5.1	5.03	4.03
6	10	10.3	9.8	10.03	8.03
7	4.5	3.8	4.1	4.13	3.31
8	3.8	3	4.2	3.67	2.93
9	4.7	4.5	4.5	4.57	3.65
10	4.3	4	4.3	4.20	3.36
11	10.3	10.2	8.3	9.60	7.68
12	6	6.1	5.8	5.97	4.77
13	10	10	8	9.33	7.47
14	7.2	7	7	7.07	5.65
15	7	7	7	7.00	5.60
16	6	7	7	6.67	5.33
17	5	4.3	4.5	4.60	3.68
18	10	10.3	10.1	10.13	8.11
19	4.7	3	3.4	3.70	2.96
20	7.8	6.9	7	7.23	5.79
21	4.2	4	6	4.73	3.79
22	4.5	4.3	5	4.60	3.68
23	4.3	4	4.3	4.20	3.36
24	7	6.8	7.3	7.03	5.63
25	9.6	10	10.3	9.97	7.97
26	0	0	0	0.00	0.00
27	10	9.6	10.3	9.97	7.97
28	10.2	10	10.2	10.13	8.11
29	9.3	9.5	7.3	8.70	6.96
30	0	0	0	0.00	0.00

4.2.3 Sediment type

The soil collected in each quadrat was divided into two based on visual evaluation. Based on the similarity in the sediment texture, the sand from quadrants 1–17 and 18–30 was combined. The grain analysis showed that the sediment consists of gravel, sand, and fines. Tables 3 and 4 show a breakdown of the results for the soil samples collected in quadrats 1- 17. The highest grain size percentage at 97.5% is sand. Also, it can be seen from Tables 5 and 6 that the predominant grain size is also sand – 97.5%.

Also, it is interesting to note that there was a high amount of sediment around Bumpetuk, which made it difficult to assess and see the seagrass. Interviews were conducted with local fishermen to understand if this was a regular occurrence or was due to human actions. According to the locals, a high amount of sand is normal at certain times of the year because the islands sit at the mouth of the SRE and receive sediments from other major rivers. However, the seagrass beds in Bumpetuk are the only areas affected by sand accumulation. Then again, according to the NIT representative, during the previous monitoring exercise conducted in December 2020, the deposit around the area was far less, and it was easy to identify and monitor the seagrass beds.

Table 3:Sediment sample 1 (combined quadrats 1 – 17)

Sieve No.	Diameter (mm)	Weight of empty sieve (g)	Weight of sieve + soil retained	Soil retained (g)	Accumulative retain (gm)	Mass retained (%)	Percentage passing
1	2	511.2	511.6	0.4	0.4	0.14	99.8077
2	0.5	429.1	592.7	163.6	164	56.05	21.1538
3	0.25	397.4	434.4	37	201	12.68	3.3654
4	0.125	408.6	499.2	90.6	202.8	31.04	2.5000
5	0.063	381.8	382	0.2	203	0.07	2.4038
6	Pan	475.4	475.5	0.1	203.1		
			Total soil retained =	**291.9**			

Table 4: Grain percentage for quadrat 1-17

Soil type	Percentage
% Gravel	0.14
% Sand	97.5
% Fines	2.4

Table 5: Sediment sample 2 (quadrat 18 – 30)

Sieve No.	Diameter (mm)	Weight of Empty sieve (g)	Weight of sieve + soil retained (g)	Soil retained (g)	Accumulative retain (gm)	Mass retained (%)	Percentage passing
1	2	511.2	512.5	1.3	1.3	0.67	99.3300
2	0.5	429.1	511.8	82.7	84	42.65	57.3491
3	0.25	397.4	486.3	88.9	172.9	45.84	54.1516
4	0.125	408.6	427	18.4	191.3	9.48	90.5105
5	0.063	381.8	384.3	2.5	193.8	1.2893	98.7106
6	pan	475.4	475.5	0.1	0	0.0516	
			Total soil retained =	**193.9**			

Table 6: Grain percentage for quadrat 18-30

Soil Type	Percentage
% Gravel	0.2
% Sand	97.5
% Fines	2.3

4.2 Local knowledge survey

The respondents' overall perception of seagrass beds is presented in the following subsections. One hundred and thirty-three (n=133) people participated in the survey. Table 7 shows a breakdown of the participants and their locations. Most of the survey participants are from Bumpetuk and other Turtle Islands. The other participants are migratory fishermen or businessmen.

Table 7: Location of respondents

No.	Island/ Community	No. of respondents
1	Bumpetuk	63
2	Nyangai	8
3	Mania	5
4	Moot	5
5	Freetown	6
7	Yelibuya	1
8	Yilleh	1
9	Sei	2
10	Other (Between islands)	42
Total		**133**

4.2.1 Demographics

This section of the questionnaire required respondents to give information on age, gender, occupation, and education to create a baseline for interpreting the results. Of the study population, 15.79 % (n=21) were women, and 84.21 % (n=122) were men. From the data in Figure 8, it is apparent that a high number of respondents do not know their age. Fifty-nine respondents, 36% of men (n=48) and 8% of women (n=11), selected "do not know". More men were represented in all age groups.

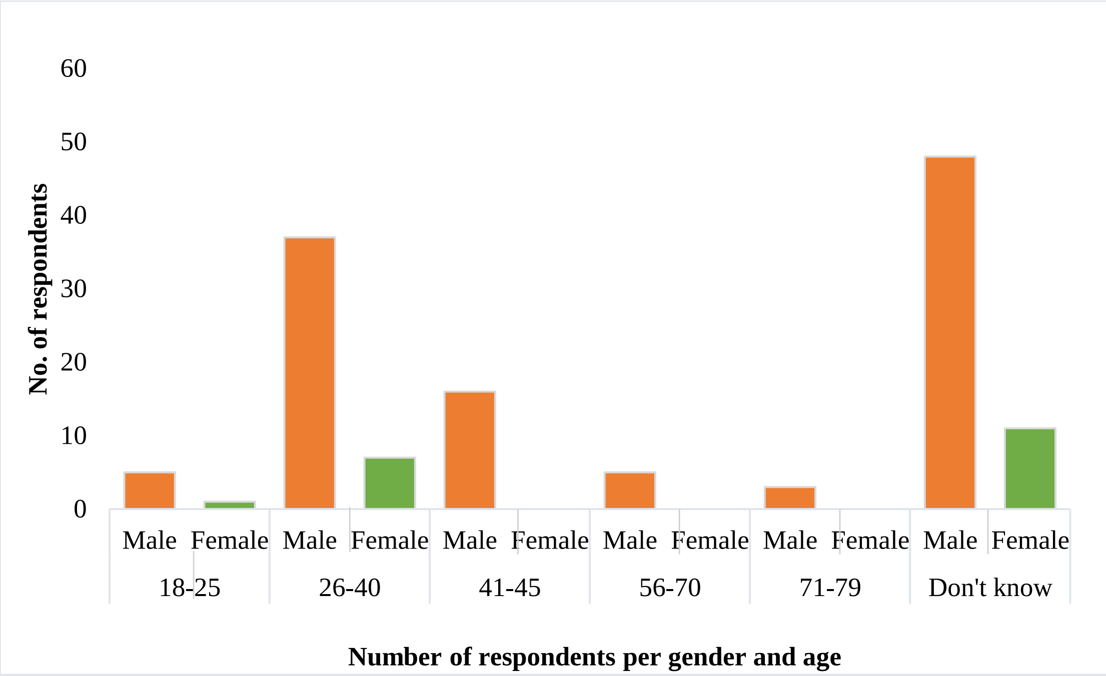


Figure 8: Gender and age of respondents

It can be seen from the data in Table 8 that 57.14% (n=76) of the survey respondents had no educational background, and 31.58 % (n=42) had basic primary school education. Most respondents were self-employed, 66% (n=88) were fishermen, and 1.5% (n=2) were unemployed. The women were fishmongers or petty traders; see figure 9 below.

Table 8: Educational background

Education	Frequency	Percentage (%)	Cumulative
None	76	57.14	57.14
Primary	42	31.58	88.72
Secondary	12	9.02	97.74
Tertiary	2	1.50	99.25
other	1	0.75	100.00
Total	**133**	**100.00**	

Figure 9: Occupation of respondents

The respondents were divided into six groups depending on how long they lived on Bumpetuk. Table 9 below shows the length of stay for participants. 22.6% of respondents had spent over a decade on the Island, while 0.8% (n=l) had never been there. The part-time visitors 30.83% (n=30) include migratory fishermen and men married to women on the Island. Other 21.80 (n=29) include those who only fish within the area or work in the area.

Table 9: Length of years in Bumpetuk

Length of stay	Frequency	Percentage (%)	Cumulative
0 - 2 years	13	9.77	9.77
2 - 10 years	19	14.29	24.06
Holidays	1	0.75	24.81
More than 15 years	30	22.56	47.37
Part-time	41	30.83	78.20
other	29	21.80	100.00
Total	**133**	**100.00**	

4.2.2 Local awareness of the project

The second section of the questionnaire was to determine the local perception of seagrass. Most of the questions in this section were not compulsory. Firstly, participants were asked about the ResilienSEA project and the project site. While the NIT team had conducted several awareness-raising and monitoring programs in Bumpetuk, the survey revealed that 69% (n=92) of respondents had never heard of the ResilienSEA project before the study, and 7% were uncertain about the project in Bumpetuk or Turtle Islands; see Figure 10 below.

Figure 10: Results show the awareness of the ResilienSEA project among respondents.

For the pilot site identification, the data in Figure 11 shows that 15.78% (n=21) can identify the pilot area. Many respondents who could locate the site lived in Bumpetuk or fished around there. However, 75% (n=101) of the participants did not answer the question.

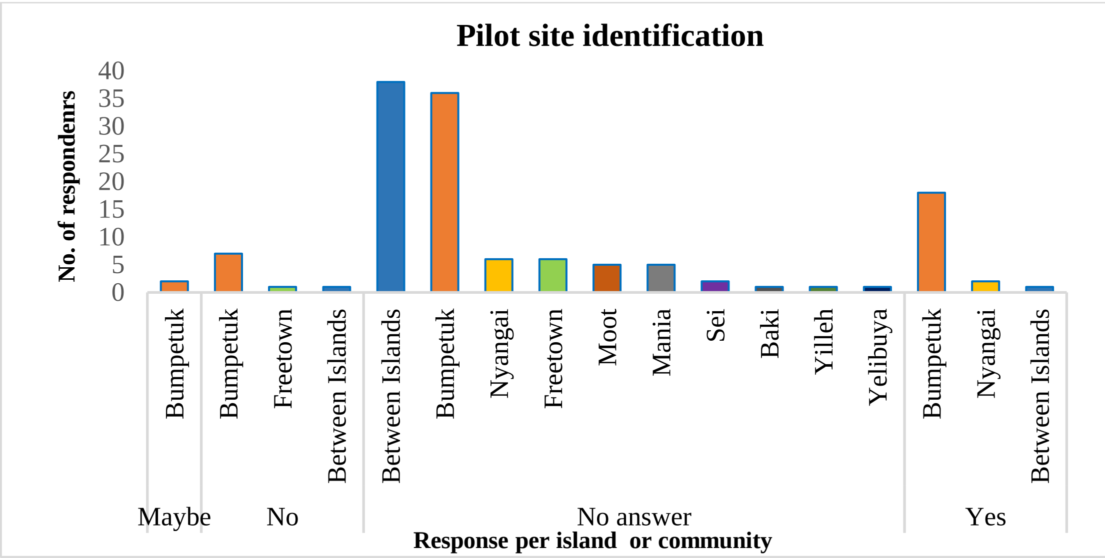


Figure 11: Identification of the ResilienSEA pilot site in Bumpetuk based on the respondents' locations

4.2.3 Seagrass Identification

The initial question required respondents to describe seagrass in their own words. This question was asked to determine if there is a distinction between being informed and being able to recognise it. When the respondents were asked if they knew what seagrass was without pictures, 45.11 % (n=60) indicated "no", and 36.84% (n=49) chose "yes", as presented in Table 10. Interestingly, the men were more aware of seagrass than the women. As a follow-up question, participants described seagrass in their own words. Many respondents indicated that seagrass is a type of grass or plant found close to the sea.

Table 10: Knowledge of seagrass

Seagrass Knowledge	Frequency	Percentage (%)	Cumulative
No	60	45.11	45.11
Not sure	24	18.05	63.16
Yes	49	36.84	100.00
Total	**133**	**100.00**	

Participants then identified seagrass from three pictures of underwater vegetation. The question was mandatory to one answer. The participant's responses to the question are presented in Table 11 below. The pictures in the survey, in order, are shown in Figure 12.

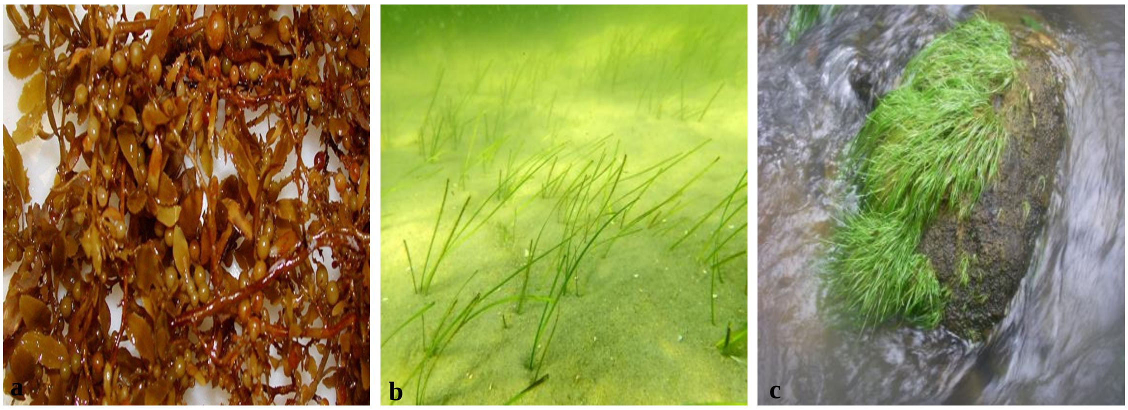


Figure 12: Seagrass identification; a.) Picture 1- Sargassum polycystin (source: Vincent K. Wangsaputra); b.) Picture 2- Seagrass (Halodule wrightii) (source: Alex Bjak); c) Picture 3 - Green Algae

While the participants could not correctly describe seagrass before, the majority identified it from the pictures. Approximately 53% of the participants identified it correctly.

Table 11: Response for identifying seagrass from an image

Seagrass identification	Gender		
	Female	**Male**	**Total**
Sargassum polycystin	14.29	13.39	13.53
Halodule wrightii	61.90	51.79	53.38
Green Algae	23.81	34.82	33.08
Total	**100.00**	**100.00**	**100.00**

After the visual question, the participants stated how difficult it was to differentiate the pictures. More than half, 73.68% (n=98) of the participants found it difficult to distinguish the different plants, and 5% (n=6) were not sure, so they answered "maybe". Respondents indicated that the photographs were small, making it difficult for most of them to see satisfactorily (see Table 12).

Table 12: Response to whether it was challenging to identify seagrass from the pictures shown to them.

Seagrass identification difficulty	Gender		
	Female	**Male**	**Total**
Maybe	0.00	5.36	4.51
No	28.57	20.54	21.80
Yes	71.43	74.11	73.68
Total	**100.00**	**100.00**	**100.00**

4.2.4 Threats to seagrass

This section focused on what the sea means to the daily lives of the responders and the potential threats that may affect the seagrass beds around Turtle Islands. Also, in this section, the respondents were educated on seagrass identification.

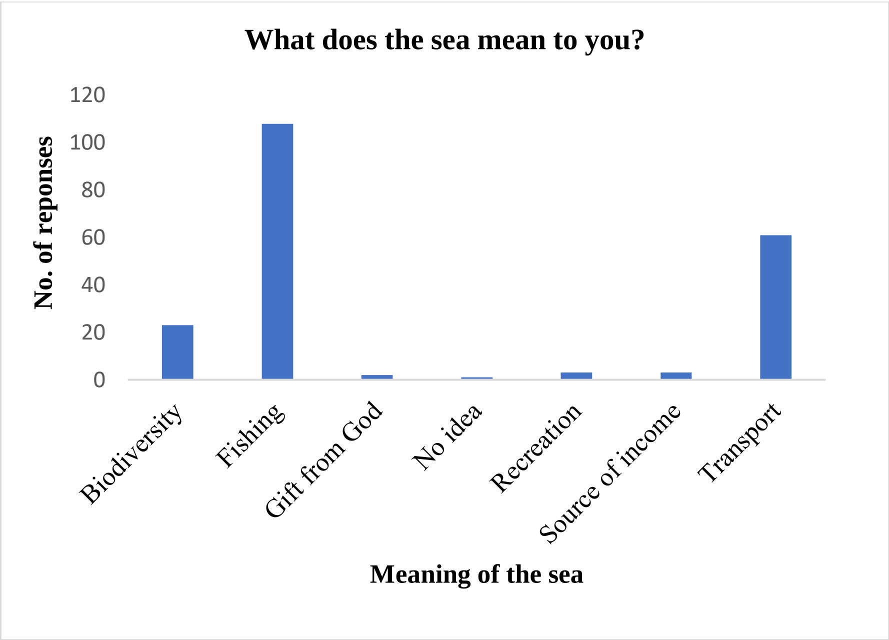


Figure 13: Response to what the sea means to the different responders.

The question on what the sea meant to the respondent was mandatory. Results in Figure 13 show that 81% (n=108) associate the sea with fishing (an essential source of their livelihood), 46% (n=61) associate the sea with transport, and 5% indicated other meanings of the sea, including "a gift from God" and no idea.

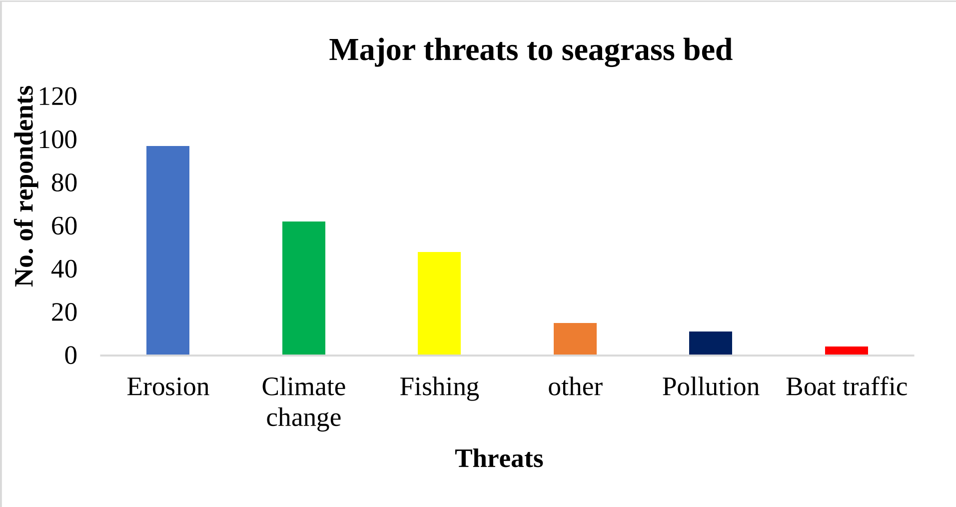


Figure 14: Local perception of main threats to seagrasses

A list of threats was listed for respondents to select the current or potential threats to seagrass. The threats listed as presented in Figure 14 were: a) erosion, b) pollution, c) climate change, d) fishing, e) boat traffic, and f) others (any other possible threats). Based on the results, coastal erosion is the main threat to seagrass in Bumpetuk. Other threats include mangrove deforestation, sand accumulation, and mining. They suggested that the pollution threat is due to poor waste management practices within the islands and land-based wastes from other areas, specifically Freetown.

4.2.5 Seagrass ecosystem services

Here, participants were asked about the direct or indirect ecosystem services provided by the seagrass. The question was framed based on the various ecosystem services supported by other marine ecosystems along the Sherbro River Estuary. Figure 15 shows the answers under each category of ecosystem service. Under provision services, 95% (n=127) of respondents indicated that seagrass is an essential habitat for numerous marine animals, especially fishes, turtles, manatees and crustaceans. A few also believed that seagrass could be used as fertiliser for farming. They also firmly believed that the seagrass beds are important nursery grounds because many of them have noticed a considerable number of fingerlings in the area. For cultural provisions supported by seagrass, 93% (n=124) responded that the site would be necessary for educational studies.

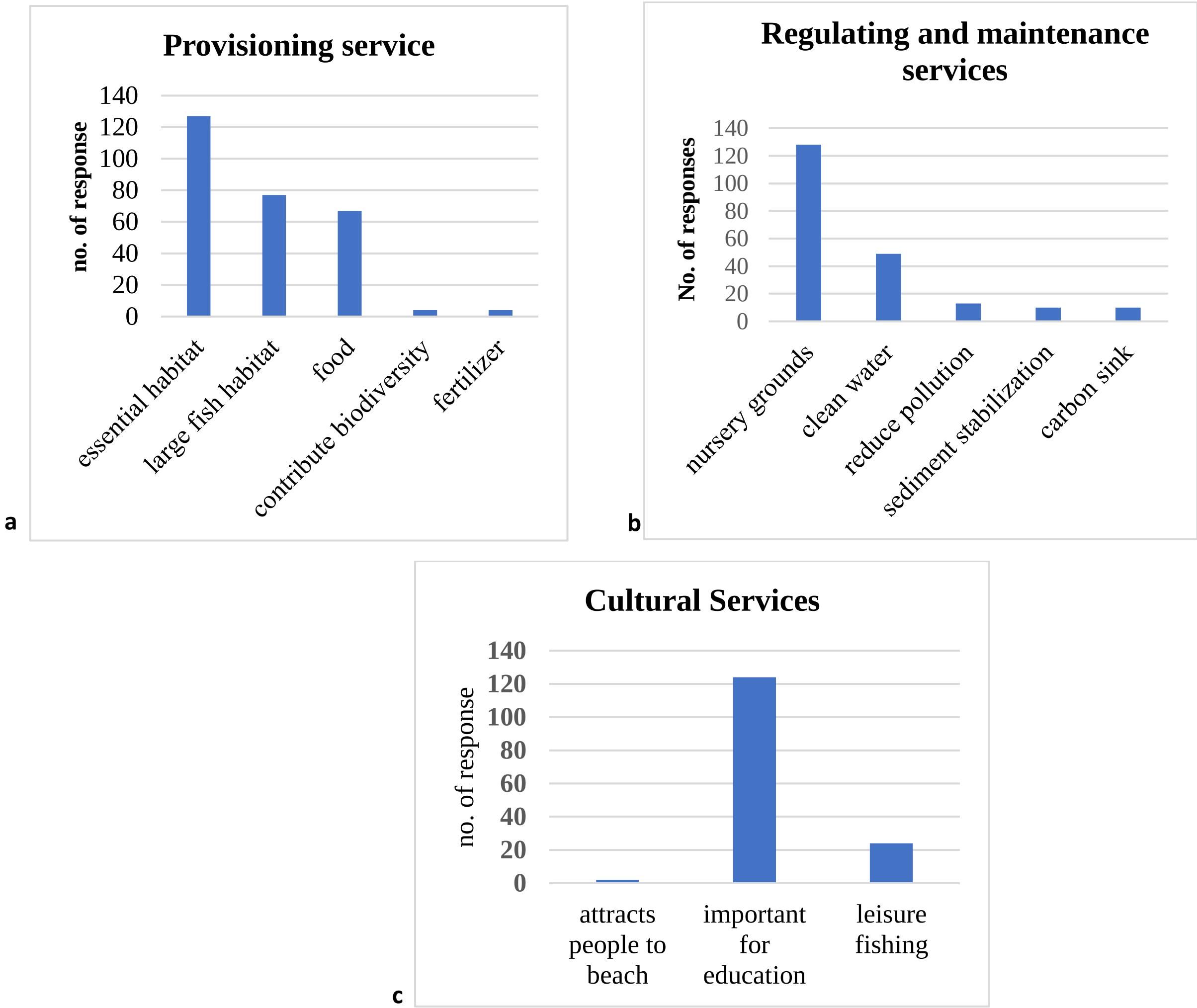


Figure 15: Ecosystem services supported by the seagrass beds; (a) Provisioning, (b) Regulating and maintenance, and (c) cultural services.

4.2.6 Seagrass Conservation

For conservation, the questions focused on the need for communities to conserve and manage the seagrass beds. The section also evaluated the desire of participants to continue learning about seagrass and local conservation strategies. The first question was a base to analyse how the locals connect their different actions to increasing pressure on ecosystem services which can lead to a decline in seagrass. The answer alternatives are categorised into three rating scales - Yes, No, or Maybe. Data from Table 13 indicates that 42% (n=56) are unsure whether their actions directly impact ecosystem decline, and 26% (n=35) believe they harmed the seagrass bed and ecosystem services. They indicated that seagrass is like terrestrial grass that grows back regardless of how often they destroy it.

Table 13: Responses to determine if locals know that their daily activities can destroy the seagrass beds.

Seagrass destruction	Gender		
	Female	Male	Total
Maybe	11	45	56
No	6	29	35
Yes	4	38	42
Total	**21**	**112**	**133**

From the chart in Figure 16, 46% (n= 62) of respondents agreed that seagrass beds should be protected, and interestingly 46% (n= 62) were hesitant about their position on seagrass conservation. According to them, seagrass will constantly grow regardless of human activities.

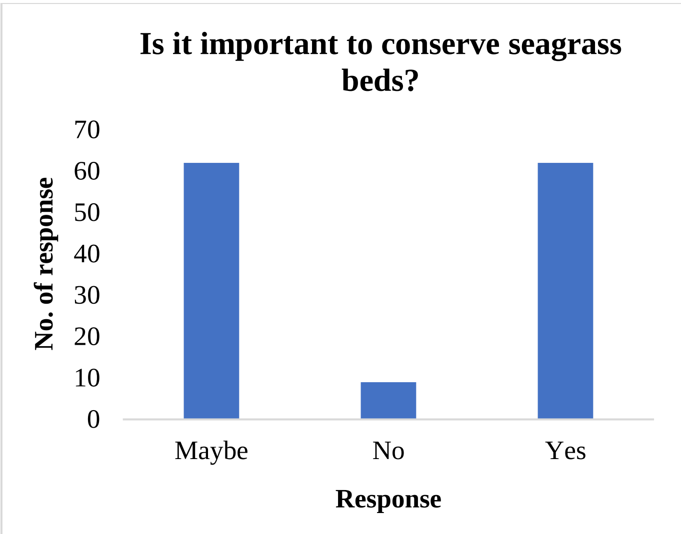


Figure 16: Response to whether it is essential to conserve seagrass beds

The level of importance of conservation was assessed using a ranking scale from 1 to 5, with one being “very important” and five “not important.” This question was not mandatory; about 53% (n=71) of participants did not answer the question, 7.52% (n=22) participants ranked seagrass protection as “not important,” and 8% (n=10) ranked it “very important” (Table 14).

Table 14: Response to the protection of seagrass

Rank	Frequency	Percentage
No response	71	53.38
1	10	7.52
2	2	1.50
3	13	9.77
4	15	11.28
5	22	16.54
Total	**133**	**100.00**

Although most participants did not consider seagrass protection important, they provided recommendations to protect the seagrass bed in the Sherbro River Estuary, as shown in figure 17. 18, 27% (n=36) of respondents highlighted monitoring as an important tool for conserving the seagrass beds. Many think that the monitoring could be done by the Bumpetuk community alone, while a few suggested that joint monitoring with other communities along the SRE would be most effective. The development of by-laws is another strong suggestion for seagrass conservation. The law will be adopted at the district level and implemented alongside national conservation policies and legislation.

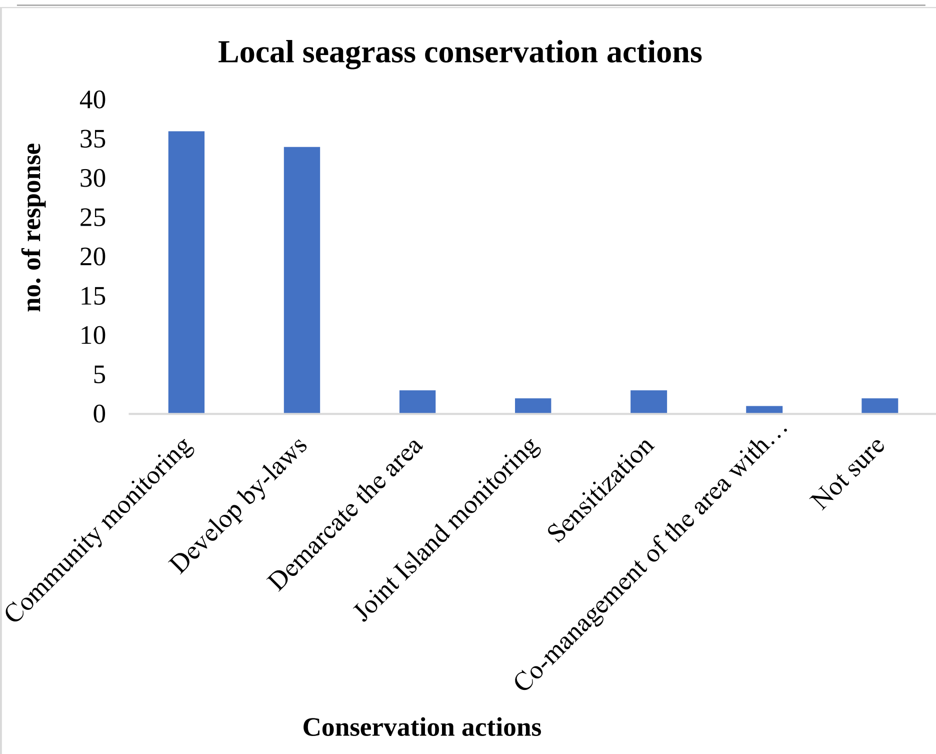


Figure 17: Actions for seagrass conservation in Bumpetuk

4.2.7 Participant Opinion of the Survey

In this final section, participants reflected on the seagrass and the survey. The participants provided multiple options for how they would prefer to receive communication information about seagrass. Various modes of communication were listed. Figure 19 provides the list of strategies presented to each participant. Most participants indicated that community engagements such as town hall meetings and radio programs are the best ways to teach them about seagrass. More people can be reached through those mediums.

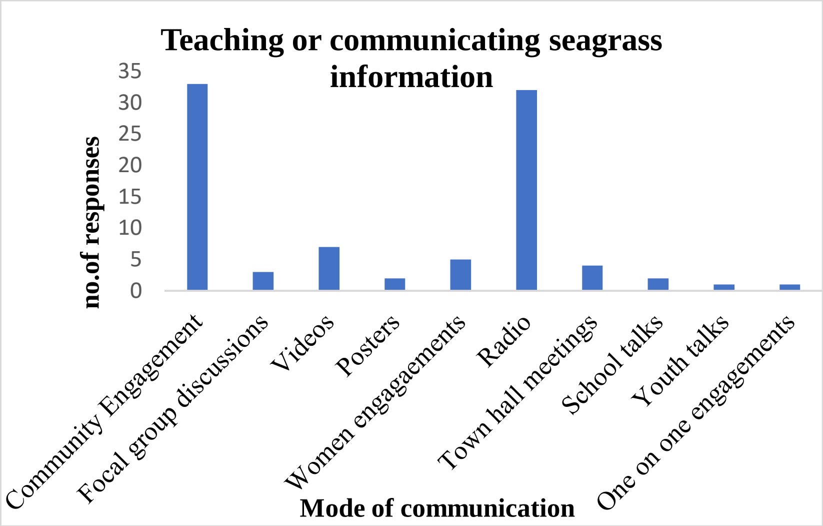


Figure 18: Strategies to educate communities on seagrass.

The female participants suggested gender and age-specific focus group discussions at the community level.

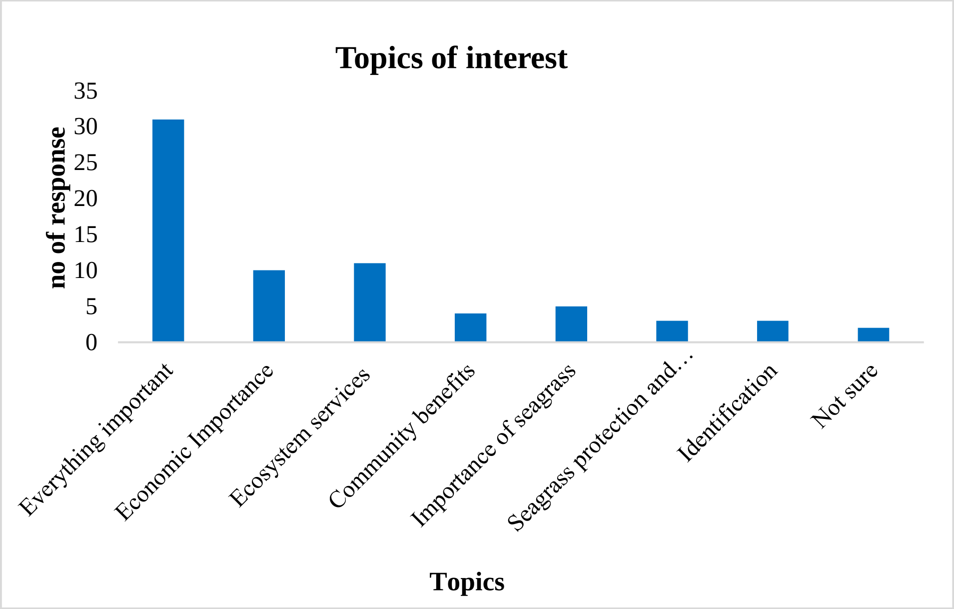


Figure 19: Topic of interest to the local communities

Only thirty-one (31) respondents wanted to learn everything necessary about seagrass, ten (10) wanted more information on its economic importance or value to their daily lives, and others wanted to know about seagrass ecosystem services, identification, and community benefits. Two (2) respondents were uncertain of the topic but indicated they would keep an open mind (see Figure 19). The respondents want to enhance their knowledge of seagrass, and with a growing understanding, they may learn to value these marine plants more.

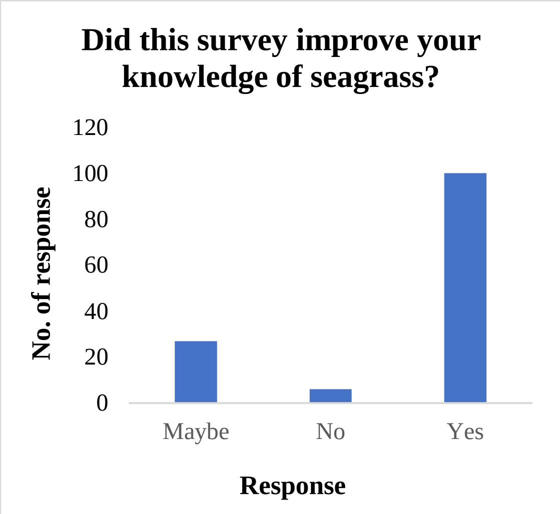


Figure 20: Response to assess if participants learned anything new from the survey

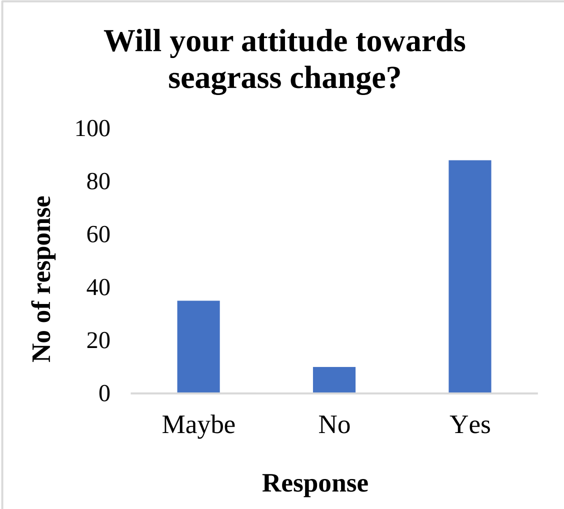


Figure 21: Response to assess if the respondents will see seagrass differently

In Figure 20, 75% (n=100) of the participants felt they learned something new from the survey, and 5% indicated they did not learn anything new. Results on attitude change after the survey, 66% (n=83) of the responders feel that their attitude towards seagrass will change moving forward, 26% (n= 35) of the responders said: "maybe," and 8% said "no" (see Figure 21). Nonetheless, most indicated they are willing to change their attitude toward seagrass.

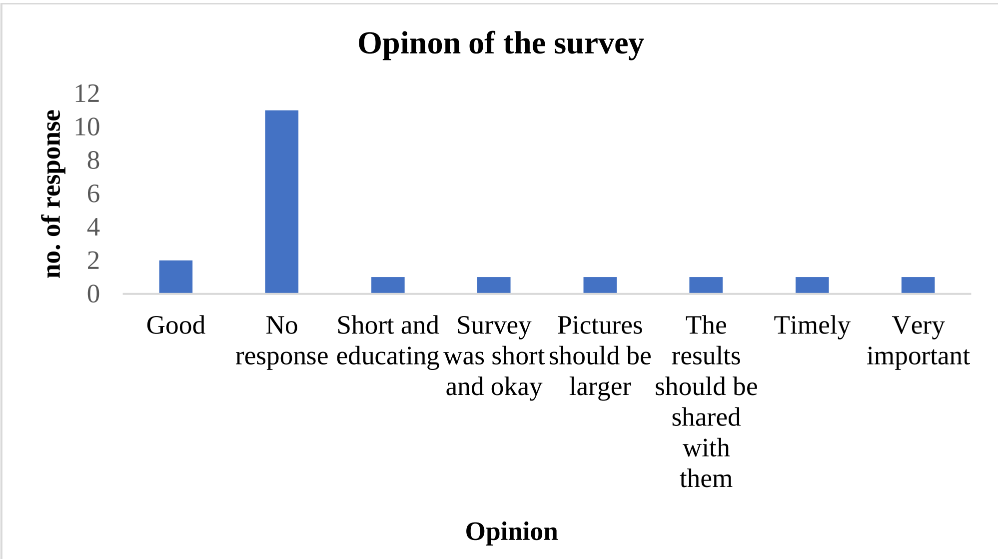


Figure 22: Responses on the opinion of the survey

Most respondents skipped this section or did not respond—figure 22 shows the responses from those participants who provided an answer to the question.

4.3 Summary of key findings from the survey

The main findings from the survey indicate the following:

1. The length of seagrass ranged between 3.8 to 10 cm, with an abundance between 20 and 35%. Furthermore, the soil type in the area is predominantly sandy, with a small proportion of gravel.
2. One hundred thirty-three (n= 133) people participated in the survey, most of whom were men.
3. Respondents from Bumpetuk and Mania could identify seagrass and could identify the location of the seagrass beds.
4. The identified threats to the seagrass beds are erosion, pollution from upstream, fishing, boating (transport) and climate change.
5. The seagrass beds in Bumpetuk provide provisioning, regulating, maintenance, and cultural services. These beds support fisheries, control erosion, filter water, and provide areas for research and tourism.
6. The ResilienSEA project in Bumpetuk is known to residents living in Bumpetuk. They are aware of the project and can identify the location of the seagrass.
7. Women do not play an active role in marine activities, although some own boats. They are mainly into fish processing and petty trading.
8. Locals are willing to enhance their capacity on seagrass conservation and are interested in learning about the ecosystem services it provides, its economic value, and anything necessary.
9. Many locals believe that the seagrass can be conserved at the local level and suggested possible conservation actions, including monitoring, developing by-laws, community monitoring, and coordination with relevant national institutions.

5. Discussion

The outcome of this research has provided insight into the status of seagrass in Bumpetuk, the local perception of it, and its related ecosystem services. However, given the limitations of this study, the findings should be evaluated with care.

The seagrass bed in Bumpetuk is mono-specie and patchy. An important finding of this study shows that the percentage cover of seagrass in January is lower than in the previous monitoring exercise conducted by the national team in February 2020, which indicated that seagrass coverage was greater than 50% (NIT, ResilienSEA project, 2020). The low abundance observed might be due to seasonal change, as Rivera-Guzman et al. (2017) suggested, or it may be due to other factors, including sand accumulation or seagrass degradation from climate change.

The results from grain size analysis showed that sand is the predominant grain in the pilot site, consistent with Anthony (2004). Remarkably, the sand around the pilot site was far more than in other areas around the Island. This discovery was surprising because, according to the NIT, the Turtle Islands were experiencing increased coastal erosion. The sand accumulation may have resulted from sediment deposits from nearby rivers or erosion of other islands. The accumulation of sand in the area may account for the low percentage of cover observed. These findings support the suggestion by Fourqurean et al. (2012) that *H. wrightii* can survive in extreme environmental conditions, including sediment accumulation.

Surprisingly the canopy height was higher than anticipated. Previous monitoring reports indicated that the seagrass canopy height was mainly between 4 and 7 cm (NIT, ResilienSEA project, 2020); the data collected ranged from 4 to 10 cm. A possible explanation might be a mixture of young and mature shoots in the same area.

A significant limitation of the ecological survey is the frequent tidal changes in the area and the limited time required to complete the evaluation, making it challenging to assess the site extensively. Furthermore, the assessment was conducted in one season (dry season); thus, further studies must be undertaken to develop a seasonal trend for seagrass in Sierra Leone.

Studies show that seagrass, unlike coral reefs and mangrove forests, is understudied, and many coastal communities close to seagrass beds are unaware of its presence (Cullen-Unsworth & Unsworth, 2013). This is the case for the seagrass beds in Turtle Islands. The responses from the assessment show that through the ResilienSEA project, the locals, especially those in

Bumpetuk and Mania, are more aware of seagrass and its significance. Nonetheless, many participants could not identify the specie or the pilot site in Bumpetuk. This finding is encouraging and implies that the NIT has been enhancing local knowledge of seagrass in Bumpetuk. Participants from other areas could not distinguish between seagrass and seaweed, which may affect the management and protection of seagrass. Also, relevant government institutions do not have adequate knowledge of seagrass conservation. It is encouraging to note that the Environment Protection Agency – Sierra Leone (EPA-SL), other government institutions and local representatives are updating the Sherbro River Estuary Co-management plan to incorporate seagrass conservation. This plan will enhance seagrass awareness and protection at national and local levels.

By letting the participants identify the ecosystem services seagrass provides, the survey tried to determine if they understood the concept of ecosystem services. There was more considerable overall uncertainty in their responses. The seagrass beds, like the mangroves along the SRE, support provisioning, regulatory and maintenance, and cultural services like the mangroves (Environment Protection Agency, 2019). Respondents indicated that seagrass is a habitat for primary production because it is a habitat for young fish, crustaceans, and molluscs and a food source for turtles and manatees. This might be one of the reasons why the Sherbro River estuary is rich in marine biodiversity, including a high population of turtles and manatees. Most of the responses under maintenance and regulation services are under the division of maintenance of physical, chemical, and biological conditions (Haines-Young & Potschin, 2012). These services include sediment stabilisation, water filtration, nursery ground, and carbon sequestration. Bryan et al. (2020) estimates that the total seagrass area in Sierra Leone is approximately 4445.62 km^2 and can store 0.613 Mt of carbon. Using this estimation, it is safe for the country to cite seagrass as a significant element in the fight against climate change. Also, respondents indicated that seagrasses might minimise the effect of erosion. According to them, the erosion rate around the pilot area is slower than in other locations on the Island. Figure 23 shows eroded locations in other parts of the Island. However, this study could not confirm this fact, although an unusually high amount of sand was noticed in the pilot site. Locals could not directly associate seagrass with cultural services primarily because they do not use it for traditional practices. They, however, proposed that the seagrass beds would be necessary for tourism and education, especially research.

Erosion, fishing, pollution, and climate change are the main threats to seagrass. From observation, fishing is the primary threat to seagrass around Turtle Islands. Currently, fishing activities are not conducted around the Bumpetuk pilot site, but if the fishing system is changed, it will potentially threaten the seagrass bed in that area. Erosion was also an observed threat; however, an earlier study by the EPA-SL (2019) showed that the erosion rate in Bumpetuk since 2005 has been low at -2.23 m/year. Other threats include sea level rise and mangrove deforestation (WABiCC, 2019; Environment Protection Agency, 2019). Massive mangrove deforestation exists in some areas along the SRE (WABiCC, 2019). Improving the knowledge about seagrass will reduce potential human threats to the sites and promote conservation.

Figure 23: Pictures (a and b) show evidence of coastal erosion in some parts of Bumpetuk

Local communities play a crucial role in conservation, so it is, therefore, essential that they be included in developing and implementing conservation actions. Therefore, it is vital that the NIT should continue to engage stakeholder groups in managing natural resources such as seagrass. Several participants suggested improving awareness through continued engagement and experience sharing around Turtle Islands and through national programs. These could be shared on the radio –using plays or educational talk shows. Focus group discussion will be most helpful in educating women on seagrass management because, even though many women own boats and nets, it is uncommon for women to participate actively in group meetings when men are around. In some cases, women are not invited to be part of the meetings.

According to Orth et al. (2006), efforts to conserve seagrasses will be unsuccessful without significant local support. The survey findings strongly support local participation in the management of these sites. The participants indicated that the Bumpetuk community was not protecting the seagrass beds at the time. Still, some youths had taken up the responsibility of monitoring the area occasionally. They have also tried to identify possible areas where seagrass could grow. Nordlund et al. (2018) highlighted that it is essential for locals to understand the value of seagrasses if countries want sustainable seagrass conservation. This statement is true; some are enthusiastic about developing proper strategies to protect the seagrass and associated ecosystems. These actions show that the community can manage the pilot site with logistical and technical support from relevant institutions. They suggested developing by-laws that would be implemented alongside national laws. Also, locals proposed demarcating the area and putting signs and fines prohibiting illegal fishing practices around or near the seagrass.

6. **Conclusions and Recommendations**

6.1 Conclusions

The study has established a possible trend of seasonal change in seagrass and the environment in Bumpetuk. This can be seen in the low abundance and canopy height recorded during the survey. Notwithstanding, the seagrass bed in Bumpetuk is thriving.

The sea is a significant piece of the people along the Sherbro River Estuary, including the Turtle Islands. The link between the sea and the participants was quite evident during the research. The participants clearly explained the connection between the sea and their daily activities (fishing and transportation). However, they do not fully understand the impact of some of their actions on ecosystems living close to or in the sea. Conservation efforts may be slow along the SRE because they believe these resources are "God-given" and cannot be exhausted or destroyed. In addition, value is placed on particular coastal ecosystems, like mangroves, while others, such as seagrasses, have been neglected.

Seagrass conservation is critical now because of its significance in the fight against climate change and its support for biodiversity and livelihoods. The lack of awareness of its importance by coastal communities can significantly derail government efforts to conserve these plants. The Bumpetuk community has been educated on seagrass, and the youths are interested and ready to learn about the plant. Participants, especially from Bumpetuk, can now identify seagrass. Locals from other Turtle Islands and other areas are also interested in learning about the benefits of this plant in the marine environment. Women also expressed an interest in learning more despite the patriarchal limits. At a national level, Sierra Leone has done considerable work identifying the location of seagrass beds and is now working on integrating seagrass conservation into national policies and plans. Also, the NIT in Sierra Leone has drawn national attention to the value of seagrass in climate change mitigation, which is a huge stride.

Still, there is much more work to be done. Over the years, these islands may develop and grow in population, inevitably leading to more pressure on the coastal ecosystems. Also, some of these areas will possibly be significantly affected by climate change and erosion (already evident), affecting seagrass beds and other marine habitats along the area. Therefore, seagrass awareness and education must continue even after the project's life, as this will enhance the capacity of locals to tackle and manage emerging environmental issues.

6.2 Recommendation

This study is far from exhausted and could be improved or refined. The time available for data collection was limited. This notwithstanding, some recommendations based on the results are provided below.

i. The NIT should conduct regular monitoring exercises to establish an ecological and seasonal seagrass growth, abundance, and canopy height trend. The information can be used to develop a framework for seagrass conservation, monitoring, and restoration.
ii. The NIT should conduct outreach awareness programs in all the communities along the SRE. This will enhance their capacity to conserve the pilot site and any other new site discovered in the estuary. The NIT should also train local stakeholders on various seagrass-related topics and ensure that these trainees conduct educational sessions in their communities. Empowering different stakeholder groups to participate actively in the process can increase participation.
iii. More research should be conducted on physical parameters, including temperature, water composition, flora and fauna. This will enable researchers and the government to understand the imminent threats and gaps in policies and conservation actions at the local and national levels enhancing effective conservation.
iv. NIT should work with the locals to develop by-laws and properly demarcate the seagrass pilot site in Bumpetuk and the other seagrass beds in the SRE. These laws should be aligned with national policies, management plans, and strategies.
v. Informational signs with maps and pictures of the seagrass should be installed in communities with seagrass beds. These boards should contain small information about the species and how they contribute to the environment. This information will promote awareness and conservation for locals and visitors.
vi. Communities should be tasked with monitoring and managing the area with little supervision from the NIT. This will promote the long-term management of seagrass beds.
vii. Restoration is another critical component not considered in this study but must be considered in future studies. Communities should be educated on restoration procedures in case of degradation.

References

Anthony, E. J. (2004). The Turtle Bank, Sherbro Bay, West Africa: Estuarine-modified inner self shoal? *Marine Sand ware and River Dune Dynamics, 1 & 2*.

Barbier, E. B., Hacker, S. D., Kennedy, C. J., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The Value of Estuarine and Coastal Ecosystem Services. *Ecological Monographs, 81*(2), 169-193. Retrieved September 2019, from https://ssrn.com/abstract=1868308

CBD. (1992, April 5th). *United Nations Convention on Biological Diversity.* Retrieved from http://www.cbd.int/doc/legal/cbd-en-pdf

Clarito, Q. Y., Suerte, N. O., Bonita, E. C., & Clarito, I. M. (2020). Determining seagrasses community using Braun-Blanquet technique in the intertidal zones of Islas de Gigantes, Philippines. *Journal of Environment and Sustainability, 4*(1), 1-15. doi:DOI: 10.22515/sustinere.jes.v4i1.96

Costanza, R. &. (1997). The Value of the World's Ecosystem Services and Natural Capital. *Nature.* (387), 253-260. doi:10.1016/S0921-8009(98)00020-2.

Cullen-Unsworth, L., & Unsworth, R. (2013). Seagrass Meadows, Ecosystem Services, and Sustainability. *Environment: Science and Policy for Sustainable Development, 55*(3), 14-28. doi:https://doi.org/10.1080/00139157.2013.785864

Duarte, C. M., & Kirkman, H. (2001). Methods for the measurement of seagrass abundance and depth distribution. In *Global seagrass research methods* (pp. 141-153). Elsevier Science B.V.

Duarte, C., Borum, J., & Short, F. W. (2008). Seagrass ecosystems: Their global status and prospects. *Aquatic Ecosystems*, 281-294. doi:10.1017/CBO9780511751790.025

Duarte, C., Middelburg, J., & Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences, 2*, 1-8. doi:10.5194/bg-2-1-2005, 2005.

Edgar, G., Russ, G., & Babcock, R. (2007). Marine protected areas. *Marine Ecology*, 533-555.

Environment Protection Agency. (2019). *Adapting to Climate Change Induced Coastal Risk Management in Sierra Leone; Report on coastal vulnerability Assessment- Lakka, Hamilton, Conakridee, Tombo, Shenge and Turtle Island.*

Environmental Justice Foundation. (2009). *The Governance of Artisanal Fisheries in the Sherbro River Area of Sierra Leone.* Sierra Leone.

Fourqurean, J. W., Carlos, D. M., Kennedy, H., Marbà, N., Holmer, M., Mateo, M. A., . . . Serrano, O. (2012). Seagrass ecosystems as a globally significant carbon stock. *Nature Geoscience, 5*(7), 505-509. DOI:doi:10.1038/ngeo1477

Geotechnical Test Method. (2015). Test Method and Discussion for the Particle Size Analysis of Soils by Hydrometer Method. *Geotechnical Engineering Bureau. Department of Transportation*. Retrieved from https://www.geoengineer.org/education/laboratory-testing/step-by-step-guide-for-grain-size-analysis

Google. (2022). *ODK Collect and ODK Aggregate to store and mand your data*. Retrieved from Google Earth Outreach: https://www.google.com/earth/outreach/learn/odk-collect-and-odk-aggregate-to-store-and-manage-your-data/

Green, G. P., Short, F., & UNEP-WCMC. (2003). *World Atlas of Seagrasses* (Vol. 2003). UNEP-WCMC.

Grid-Arendal. (2022). *ResilenSEA - Resilient Seagrasses*. Retrieved from Grid- Arendal- a UNEP partner: https://www.grida.no/activities/430

GRID-Arendal. (2022). *Meadows of knowledge: Putting West Africa on the global seagrass map.* ResilienSEA (GRID-Arendal/RAMPAO/WIACO).

Haines-Yong, R., & Potschin, M. (2012). *CICES Version 4: Response to Consultation.* University of Nottingham: Centre for Environmental Management.

Haines-Young, R., & and Potschin, M. (2013). *Common International Classification of Ecosystem Services (CICES): Consultation on Version 4.* United Kingdom: EEA Framework Contract No EEA/IEA/09/003.

Hartog, C., & Kuo, J. (2006). *Taxonomy and Biogeography of Seagrasses.* Netherlands: Springer.

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W. and Borriello, G., (2010), December. Open data kit: tools to build information services for developing regions. In *Proceedings of the 4th ACM/IEEE international conference on Information and communication technologies and development* (pp. 1-12).

Hind-Ozan, E. J., & Jones, B. L. (2017). Seagrass Science is growing: A report of the 12th International Seagrass Biology Workshop. *Marine Pollution Bulletin*. doi: http://dx.doi.org/10.1016/j.marpolbul.2017.08.017

Jennifer C. R. Hasen, M. A. (2012). Wave and tidally driven flows in eelgrass beds and their effect on sediment suspension. *Marine Ecology Progress Series*, 271-287. doi: https://doi.org/10.3354/meps09225

J, T., & Nordman, C. (10 de 2 de 2007). *Halodule wrightii Aquatic Vegetation*. Fonte: Natureserve Explorer: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.689519/Halodule_wrightii._Aquatic_Vegetation

Environment Protection Agency. (2019). *Adapting to Climate Change Induced Coastal Risk Management in Sierra Leone; Report on coastal vulnerability Assessment- Lakka, Hamilton, Conakridee, Tombo, Shenge and Turtle Island.*

GRID-Arendal. (2022). *Meadows of knowledge: Putting West Africa on the global seagrass map.* ResilienSEA (GRID-Arendal/RAMPAO/WIACO).

J, T., & Nordman, C. (10 de 2 de 2007). *Halodule wrightii Aquatic Vegetation*. Fonte: Natureserve Explorer: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.689519/Halodule_wrightii_Aquatic_Vegetation

Joel C. Creed, A. H. (2016). First record of seagrass in Cape Verde, Eastern Atlantic. *Marine Biodiversity Records*.

Ruiz-Frau, A., Gelcich, S., Hendricks, I., Duarte, C., & Marba, N. (2017). Current state of seagrass ecosystem services: Research and policy integration. *Ocean & Coastal Management*, 107-115.

Short, F. T., Short, C. A., & Novak, A. B. (2018). Seagrasses. Em M. C. Finlayson, R. G. Milton, C. R. Prentice, & N. C. Davidson (Eds.), *The Wetland Book. II: Distribution, Description, and Conservation* (pp. 73-91). Springer Dordrecht. doi:https://doi.org/10.1007/978-94-007-4001-3.

Sidi Cheikh, M., Bandeira, S., Soumah, S., Diouf, G., Diouf, E., Sanneh, O., . . . al., e. (2023). Seagrasses of West Africa: New Discoveries, Distribution Limits and Prospects for Management. *Diversity, 15*(5). Fonte: https://doi.org/10.3390/d15010005

Kuo, J., & Hartog, C. (2001). *Global Seagrass Research Methods.* Retrieved 4 22, 2022

Lee Long, J. W., & Thom, M. R. (2001). Improving seagrass habitat quality. In T. F. Short, & G. R. Coles, *Global Seagrass Research Methods* (pp. 410-421). Elsevier Science B.V.

McKenzie, L. J. (2003). Guidelines for rapid assessment of seagrass habitats in the Western Pacific. *Seagrass Watch*, 43.

McKenzie, L. J. (2003). Guidelines for the rapid assessment of seagrass habitats in the western Pacific. *The State of Queensland*, *July* 40. http://www.seagrasswatch.org/Methods/Manuals/SeagrassWatch_Rapid_Assessment_Manual.pdf.

McKenzie, L. J., Jones, B. L., Cullen-Unsworth, L. C., Roelfsema, C., & Unsworth, R. K. (2020). The global distribution of seagrass meadows. *Environmental Research Letters*(15). doi:https://doi.org/10.10881/1748-9326/ab7d06

Mellors, J. E. (1991). An evaluation of a rapid visual technique for estimating seagrass biomass. *Aquatic Botany*, 67-73.

Millenium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Opportunities and Challenges for Business and Industry.* Washington, DC: World Resources Insitute.

Ministry of Fisheries and Marine Resource. (2012). *Establish of Marine Protected area*. Government of Sierra Leone.

National Implementing Team (NIT) Report. (2020). *ResilienSEA National Report (Sierra Leone).* Freetown.

NIT, ResilienSEA project. (2020). *Monitoring report.*

National Implementation Team. (2021). Protection and Conservation of Seagrass Beds in Sherbro River Estuary, Sierra Leone. Report on the power mapping survey.

Nordlund, L. M., Koch, E. W., Barbier, E., & Creed, J. C. (2016). Seagrass Ecosystem Services and Their Variability across Genera and Geographical Regions. *PLoS ONE, 12*(1). doi:http://dx.doi.org/10.1371/journal.pone.0163091

Nordlund, M. L., Jackson, E. L.-V.-C., & Creed, J. C. (2018). Seagrass ecosystem services - What's next? *Marine Pollution Bulletin*, 145-151. doi:https://doi.org/10.1016/j.marpolbul.2017.09.014.

Orth, R. J., Carruthers, T. J., Dennison, W. C., Duarte, C. M., Fourqurean, J. W., Heck, K. L., Hughes, A. R., Kendrick, G. A., Kenworthy, W. J., Olyarnik, S., Short, F. T., Waycott, M., & Williams, S. L. (2006). A Global Crisis for Seagrass Ecosystems. *BioScience, 56*(12), 987-996. https://doi.org/10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2

Postel, S. B., K., K. L., Peterson, C. H., Carpenter, S. T., & Reichert, J. (2012). *Nature's services: Societal dependence on natural ecosystems.* Island Press.

ResilienSEA. (2018). Initial Assessment of the Ecosystem Services Provided by seagrass ecosystems in West Africa.

ResilienSEA Project. (2021). *Enhancing scientific expertise and building capacity in seven West African countries to improve seagrass protection.* Grid-Arendal.

Reynolds, P. L. (2018). Seagrass and Seagrass beds. *Smithsonian Ocean Portal*. Retrieved from https://ocean.si.edu/ocean-life/plants-algae/seagrass-and-seagrass-beds

Rivera-Guzmán, N. &.-C.-H., & Lorena & Rodríguez-Medina, K. &. (2017). The Biological Flora of Coastal Dunes and Wetlands: Halodule wrightii Ascherson. *Journal of Coastal Research, 33*, 938-948. doi:10.2112/JCOASTRES-D-14-00162.1.

Ruiz-Frau, A., Gelcich, S., Hendricks, I., Duarte, C., & Marba, N. (2017). Current state of seagrass ecosystem services: Research and policy integration. *Ocean & Coastal Management*, 107-115.

Sankoh, S.K., Mamie C. J.; Sankoh, Z. A.; Kamara, A.B. (2015). Integrated coastal zone management plan for Sierra Leone, 2015.

Shkisha, K. (2013). *Lesson 3. Index Properties of Soil.* Retrieved from Soil Mechanics 3 (2+1): http://ecoursesonline.iasri.res.in/mod/page/view.php?id=274

Short, F. T., Polidoro, B., Livingstone, S. R., Carpenter, K. E., Bandeira, S., Bujang, J. S., . . . Freeman. (2011). Extinction risk assessment of the world's seagrass species. *Biological Conservation, 144*(17). doi: https://doi.org/10.1016/j.biocon.2011.04.010

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. https://doi.org/10.1016/j.jembe.2007.06.012

Short, F., Short, C. A., & B, N. A. (2016). Seagrasses. In *The Wetlands book.* doi:10.1007/978-94-007-6173-5_262-1

Sidi Cheikh, M., Bandeira, S., Soumah, S., Diouf, G., Diouf, E., Sanneh, O., . . . al., e. (2023). Seagrasses of West Africa: New Discoveries, Distribution Limits and Prospects for Management. *Diversity, 15*(5). Fonte: https://doi.org/10.3390/d15010005

Spalding, M. D., Taylor, M. L., Martins, S., Green, E. P., & Edwards, M. (2001). The Global distribution and status of seagrass ecosystems. *UNEP-WCMC Global Seagrass Workshop.* St Pete Beach.

Statistics Sierra Leone (SSL). (2017). *Sierra Leone 2015 Population and Housing Census. Thematic report on population structure and population distribution.* Freetown: Statistics Sierra Leone.

Tussenbroek, B. &.-S.-G.-G. (2010). Pollen limitation in a dioecious seagrass: Evidence from a field experiment. *Marine Ecology Progress Series*, *419*, 283-288. doi:10.3354/meps08870

UNEP/GRID-Arendal. (2020, February 14th). *Hunting for seagrass in Sierra Leone.* Retrieved September 2021, from https://news.grida.no/hunting-for-seagrass-in-sierra-leone

United Nations Environment Programme. (2020). *Out of the blue: The value of seagrasses to the environment and to people.* Nairobi: UNEP.

Unsworth, R. K., McKenzie, L. J., Collier, C. J., Cullen-Unsworth, L. C., Duarte, C. M., Johan S. Eklof, J. S., . . . Nordlund, L. M. (2019). Global challenges for seagrass conservation. *Perspective*, 801-815.

Unsworth, R. K., Van Keulen, M., & al, e. (2014). Seagrass meadows in a globally changing environment. *Marine Pollution Bulletin* (83).

USAID/West Africa Biodivesity and Climate Change (WA BiCC). (2020). Co-management Plan for the Sherbro River Estuary, Sierra Leone. Commissioned by WA BiCC and National Protected Areas Authority, Sierra Leone. 2nd Labone Link, North Labone, Accra, Ghana. 117 p.

Valentine, J. &. (1999). Seagrass herbivory: Evidence for the continued grazing of marine grasses. *Marine Ecology-progress Series - MAR ECOL-PROGR SER*, 291-302. doi:10.3354/meps176291

Vihervaara, P., Ronka, M., & & Walls, M. (2010). Trends in ecosystem service research: early steps and current drivers. *Ambio*, *39*(4), 314-324. doi:10.1007/s13280-010-0048-x

WABiCC, W. A. (2019). *The Bonthe-Sherbro River Estuary.* Freetown: WABiCC.

Wikipedia. (n.d.).

Wikipedia contributors. (2022, February 17th). *Halodule wrightii.* Retrieved from In Wikipedia, The Free Encyclopedia.: https://en.wikipedia.org/w/index.php?title=Halodule_wrightii&oldid=1072458540

Wikipedia, C. (2021, August 30th). *Turtle Islands, Sierra Leone.* Retrieved November 11th, 2021, from Wikipedia, The Free Encyclopedia: https://en.wikipedia.org/w/index.php?title=Special:CiteThisPage&page=Turtle_Islands%2C_Sierra_Leone&id=1041505642&wpFormIdentifier=titleform#APA_style

Appendix

Survey questionnaire

This survey on seagrass and ecosystem services will be used in a Master's thesis. The research is done under the Atlantic Technical University, Cabo Verde, and the ResilienSEA project. The information obtained from this survey may also be published as a scientific publication and part of the ResilienSEA project reports. To answer this survey, you should be over 18 years and live or spend much time on Bumpetuk. All answers are completely anonymous.

Personal Background (compulsory):

1. I give permission for my answers to be used in this survey: ☐Yes ☐ No

2. Sex: ☐ Female ☐Male

3. Age:

☐ 18-25 ☐26-40 ☐ 41-55 ☐56-70 ☐71-79 ☐ Do not know

4. Education level

☐ Primary ☐ Secondary ☐ Tertiary ☐ None ☐ Others

5. What is your occupation:

☐ Fisher (Self-employed) ☐ Petty Trader ☐ Fishmonger ☐ Student ☐ Retired ☐ Unemployed ☐ Others (Specify)………………………………

6. How long have you lived on Bumpetuke island?

☐ 0-2 years ☐ 2-10 years ☐ More than 15 years ☐ Part-time / Move between the Islands

☐ Holiday ☐ Other (Specify)………………………………

ResilienSEA Project:

7. Have you heard of the ResilieSEA Seagrass Project in Bumpetuk? ☐ Yes ☐ No

8. If yes, can you identify the seagrass pilot site? ☐ Yes ☐ No

Identification of Seagrass:

8. Have you heard of seagrass? ☐ Yes ☐ Maybe ☐ No

9. In your opinion, what is seagrass?

………………………………………………………………………………………………

10. Please identify seagrass.

a)

b)

c)

11. Was it easy to identify the different plants using the pictures?

☐ Yes ☐ No, it was not easy ☐ Unsure about all ☐ Othe

Threats to Seagrass:

12. What does the sea mean to you?

☐ Recreation/leisure ☐ Fishing ☐ Transport route ☐ Area for marine biodiversity ☐ Other (specify)…………………………….

13. What do you think is/are the main threats to the coastal marine environment along with Turtle Islands. (Please indicate a scale of 1-5 for every threat; where five means very high threat and one means low threat)

i. Water quality/ Pollution

ii. Coastal Erosion

iii. Fishing

iv. Boat traffic

v. Climate Change

14. Do you see any other threat to the coastal marine environment on Turtle Islands?

____

____

Seagrasses marine plants that live on the seabed of saline marine environments. It has roots, rhizomes, sheaths and leaves. It can grow as a community or meadows.

15. Have you seen seagrass on the seabed around the Island?

16. In your opinion; (Yes, - Maybe, - No, - Do not know)

Tick all that applies. Do you think that seagrasses;

Provisioning Services

- Seagrass can be used as fertiliser.
- Seagrass is essential habitat for sea turtles, fish, and other marine animals
- Seagrass is a source of food for marine animals
- Larger fish and shellfish live in seagrass beds
- Seagrass meadows also contribute to biodiversity above the sea surface as seabirds.
-

Regulating and Maintenace Services

- Seagrass beds are an important nursery for small fish and other animals
- Seagrasses can clean the water of harmful substances
- Seagrass is a good carbon sink; This means that seagrasses can reduce the quantity of carbon dioxide in the atmosphere, minimising climate change.
- Seagrass binds filters the seawater, reducing pollution
- Seagrass roots stabilise marine sediments and can reduce erosion

Cultural Services

- Seagrass makes people not want to be on the beach
- Seagrasses are important for education
- Seagrass meadows are suitable for leisure fishing and swimming

Please list some of the marine animals in the seagrass meadows:

1.
2.
3.
4.
5.

People and Seagrass:

17. Do you think humans can destroy seagrass meadows? If yes, in what way? If no, why not?

…………………………………………………………………………………………………….

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Seagrasses meadows benefit many ecosystem services, including fishing, reduction of erosion, food for marine animals, cleaning or filtering the seawater and can help in regulating climate change.

18. Do you think it is essential for these marine plants to be protected for future generations?

☐ Yes ☐ No

19. How vital?

☐Very important ☐Somewhat important ☐ Not important ☐ Don’t know

20. Would you like to learn more about seagrass and the ecosystem services it supports around the Turtle Islands?

☐ Yes ☐ No

21. What would you want to know?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

22. How best do you think seagrass information can be channelled to the community?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

23. Do you think the Turtle Islands communities can protect the seagrass meadows?

☐ Yes ☐ No

24. If yes, how?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

23. Did you learn anything about seagrass and seagrass ecosystem services meadows from this survey? ☐Yes ☐ No

Will your attitude towards seagrass change?

☐ No ☐Yes ☐ Maybe

26. Please share your opinion on the survey.

…………………………………………………………………………………………………

……………………………………………………………………………………………….....

Appendix 2

Percentage cover standards: Coastal Low