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

SEAGRASS MEADOW MAPPING AND CHARACTERIZATION AT BIJOL ISLAND, THE GAMBIA

ABUBACARR KUJABIE

Master Research Program on Climate Change and Marine Sciences

São Vicente
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Abubacarr Kujabie

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 (WASCAL).

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Panel defense

President

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Examiner 1

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Examiner 2

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Dedication

I wish to dedicate this academic work to my parents, especially my late mother and my wife, Jarra Sanneh, for their encouragement and support during my studies.

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Resumo

Informações sobre a distribuição das ervas marinhas na África Ocidental é escassa, por conseguinte, a cartografia de ervas marinhas na Ilha de Bijol é um passo importante e contribuirá em muito para apoiar os gestores e decisores nas suas ações. As duas espécies de ervas marinhas encontradas neste sítio foram *Halodule wrightii* e *Cymodocea nodosa*. Neste estudo, a recolha de dados no local foi feita com o uso de GPS e quadrantes para registar a cobertura percentual de ervas marinhas e a altura do dossel. Foi utilizado um equipamento multiparamétrico para registar parâmetros ambientais, nomeadamente (Oxigénio Dissolvido, Salinidade e Temperatura) que são suscetíveis de alterar a estrutura das comunidades de ervas marinhas. A fim de avaliar o nível de conhecimentos dos interessados e a sua participação na conservação de ervas marinhas, foram aplicados questionários a pescadores e instituições com um mandato de gestão destes recursos. Foram feitos um total de vinte e sete (27) transectos, dos quais duzentos e noventa e sete (297) quadrantes foram realizados, registou-se uma maior cobertura mais próxima da linha de costa, onde era mais rasa, com um recorde quadrantes médios de 47%, enquanto a parte mais profunda tinha um registo médio de 10%. Em Tanji, o principal local de desembarque de peixe ao longo da costa da Gâmbia, apenas catorze por cento (14%) dos pescadores sabiam o que são as ervas marinhas, enquanto que, 22% dos pescadores no local de desembarque de peixe Brufut sabiam o que são as ervas marinhas. Isto é óbvio, uma vez que o inquérito indicou que apenas 1% dos inquiridos tiveram a oportunidade de ser sensibilizados sobre ervas marinhas. Os resultados mostraram que 46% das instituições interessadas nunca participaram em reuniões relacionadas com a gestão da Ilha de Bijol.

Palavras-chave: Seagrass, Bijol, *Halodule wrightii, Cymodocea nodosa*

Abstract

The information on seagrass distribution is scarce in West Africa, which is needed for proper planning and management of seagrass meadows in the region. Accurate information on their distribution and abundance is required for appropriate marine resource conservation and management of seagrass ecosystems. The two seagrass species found at this site were *Halodule wrightii* and *Cymodocea nodosa*. The study involved *in situ* data from GPS and quadrats recording seagrass percentage cover and canopy height. A multiparameter sensor was used to record environmental parameters for example (Dissolved Oxygen, Salinity, Temperature) likely to alter the structure of the seagrass communities. To gauge stakeholders' level of understanding and participation in seagrass conservation, questionnaires targeting fishermen and institutions with a mandate of managing these resources were administered.Twenty-seven (27) transects were conducted during data collection, of which two hundred and ninety-seven (297) were the number of quadrats. We recorded a higher seagrass coverage closer to the shoreline, where it was shallower, with an average quadrat record of 47%, while the more profound part had an average record of 10%. At Tanji, one of the leading fish landing sites along The Gambian coast, only fourteen per cent (14%) of the fishermen knew what seagrasses are, while 22% of fishermen at the Brufut fish landing site knew what seagrass are. The survey indicated that only 1% of the respondents were fortunate to be sensitized to seagrass importance and management measures. Results showed that 46% of the stakeholder institutions have never participated in meetings related to the management of Bijol Island. Therefore, seagrass mapping and characterization at Bijol Island was an important step and will support managers and decision-makers in their actions.

Keywords: Seagrass, Bijol, *Halodule wrightii, Cymodocea nodosa*

Abbreviations and acronyms

ANOVA	Analysis of Variance
BCC	Banjul City Council
BM	Bench Mark
BMBF	German Federal Ministry of Education and Research
Cm	Centimeter
Cn	Cymodocea nodosa
CRR	Central River Region
DO	Dissolved Oxygen
DPWM	Department of Parks and Wildlife Management
GboS	Gambia Bureau of Statistics
GDP	Gross Domestic Product
GOTG	Government of The Gambia
GPS	Global Positioning System
Hw	Halodule wrightii
KMC	Kanifing Municipal Council
LRR	Lower River Region
M	Meters
MSS	Multispectral Scanner
N	North
NARI	National Agricultural Research Institute
NBR	Nort Bank Region
NEA	National Environment Agency
NIT	National Implementing Team
NOWPAP	Northwest Pacific Action Plan
PSU	Practical Salinity Unit
Q	Quadrat
SMC	Site Management Committee
T	Transect
TBR	Tanji Bird Reserve
TM	Thematic Mapper
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change

URR	Upper River Region
USA	United States of America
USDA	United States Department of Agriculture
UTA	Universidade Técnica Do Atlântico
UTG	University of The Gambia
W	West
WASCAL	West African Science Service Center on Climate Change and Adapted Land Use
WCR	West Coast Region
WIA	Wetland International Africa

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1. Introduction

1.1 Background and Context

The coastal and marine environment is home to many valuable natural resources. The environmental changes resulting from climate change, biodiversity loss, and intensive anthropogenic exploitation of natural resources significantly impact the world's ocean ecosystems, including seagrasses (Orth et al., 2006). Seagrasses are flowering plants in shallow marine environments except in Antarctica (UNEP, 2020). The importance of the seagrass ecosystem cannot be overemphasized as they provide a unique habitat and food for other aquatic species, including fish and turtles. In addition, seagrasses help to stabilize sediments, thus, protecting the beach from coastal erosion (Orth et al., 2006). The presence of seagrass can determine ecosystem health as they are good bio-indicators by responding to the prevailing condition of the environment. Furthermore, seagrasses contribute to climate change mitigation through carbon sequestration and storage (UNEP, 2020). However, one of the main reasons for seagrasses' lack of proper protection measures is deficiency of information pertaining to some of the most basic aspects of their distribution as well as health status (Ahmed et al., 2023).

Within 81 km of The Gambia's coast, Bijol Island in Tanji was one of the areas where seagrass was discovered in 2020 (Ahmed et al., 2023). Tanji is located in Kombo North District of the Westcoast Region, a fishing community and is currently one of the busiest fish landing sites in The Gambia. The report of a training program on seagrass identification and monitoring in The Gambia from 20th to 24th January 2020 indicated random discovery of lush seagrass meadows during the field trip to Bijol Island in Tanji, Gunjur and Kartong. In The Gambia, it is discovered that Bijol island possesses the largest vegetation cover/area consisting of both *Halodule wrightii* and *Cymodocea nodosa* at coordinates N 13.38454 ^{o}, W 16.81118 ^{o} (Ahmed et al., 2023).

Globally, seagrass meadows face a high rate of disappearance largely attributed to threats from anthropogenic effects due to increased human population and related damaging activities (Orth et al., 2006). In The Gambia like most part of countries in West Africa, the coastal zone is one of the fastest growing centres, and fishing is one of the major activities (Gomez et al., 2020). Pollution from land-based sources, specifically from fisheries activities, was noticed at Bijol Island, where these seagrass species were discovered.

Apart from the destructive actions of populations living along the coast, seagrasses are not well known or considered compared to other well-known coastal ecosystems, e.g. mangroves (Lemenkova, 2011). Due to this narrow understanding of the importance of seagrasses by the locals, one would therefore consider increasing the awareness and conservation measures in The Gambia to protect seagrasses.

1.2 Problem Statement

Despite being among the most precious ecosystems in the marine environment due to its importance to human and aquatic species, global seagrass distribution is yet to be established by researchers due to a lack of data in some parts of the world, especially in West Africa (Cunha & Araújo, 2009) and The Gambia in particular. Knowledge of the local people on the availability of seagrass in The Gambia in general and at Bijol Island, in particular, is limited, coupled with an inadequate understanding of the benefits of the seagrass meadow(Ahmed et al., 2023). During the monitoring activities in The Gambia, it was observed that the seagrass coverage at Bijol Islands was identified but not mapped. Not only was the mapping incomplete or not done, but the most important environmental parameters (dissolved oxygen, pH, salinity, temperature) were never collected during monitoring activities.

1.3 Research Questions

1. How is the distribution and abundance of seagrass at Bijol Island?
2. Are stakeholders aware of seagrasses' presence at Bijol, and what are their perceptions of the seagrass ecosystems?

1.4 Relevance and Importance of the Research

There is a global knowledge gap in seagrass distribution, particularly in West Africa, which highlights the necessity to provide a more precise and reliable measure of the worldwide spatial distribution of seagrass (Mckenzie et al., 2020).

Knowledge of the global spatial distribution of seagrass meadows is needed now more than ever before. This knowledge is relevant worldwide to recognize their role in developing nature-based solutions to climate change (Mckenzie et al., 2020). As a result, there is a need to provide more precise and reliable measurements of where seagrass occurs to help quantify the ecosystem services this natural resource offers. As these resources are under threat from climate change and pollution from human factors, a robust coastal monitoring plan must be in place (Etter, 2019). Seagrass meadow mapping and characterization at Bijol will fill the gaps of knowledge about seagrass presence in the area for better-informed decision-making and conservation measures. As a result, the need for a pilot site of the seagrass meadow at Bijol Island to be mapped and documented can be upscaled to other parts of the Island.

1.5 Aim of the research

The study's main objective is to identify some areas of seagrass existence in Bijol Island and potential threats and to assess stakeholders' understanding of seagrass ecosystem services.

Specifically, it involved:

- To provide a map of seagrass distribution within Bijol Island;
- To identify species of seagrass found at Bijol Island and the environmental conditions likely to alter or drive seagrass distribution;
- To gauge stakeholders' perception of seagrass.

1.6 Structure of the work

Apart from the introduction of the work above, the next section is the literature review which deals with the main ideas of seagrass, different theories, possible gaps of knowledge in seagrass and arguments by other authors related to seagrass. Materials and methods constituted the third section which detailed approaches to collecting the required data for this thesis work. The fourth segment provided the obtained results of the study. The fifth section discussed the results obtained in the fourth section, and the final part of this work provided the study's conclusion.

2. Literature review

2.1 Overview and context

Seagrass habitats provide various ecosystem services, including providing food and shelter for many faunas, contributing to sediment trapping and stabilization of the shore, and regulating nutrient cycles and water turbidity (UNEP, 2020). In addition to the seagrass damage caused by the population living along the coast due to limited knowledge, seagrass distribution is not well documented, especially in West Africa (UNEP, 2020). (Harcourt et al., 2018) also stated that data on the global distribution of seagrass is limited to a few well-studied areas. This challenge is severe, particularly in Africa, where financial and technical resources are limited. Therefore, the global estimates of carbon storage by seagrass remain imprecise. Even though there is growing sophistication in Blue Carbon science, some elementary data remains inaccurate. Prominent among these is the regional level of seagrass habitats, which is crucial in defining seagrass carbon (C) stocks and flows (Harcourt et al., 2018).

On a global scale, seagrass conservation and management have increased considerably over the recent decade (Turner & Schwarz, 2006). Consequently, there was a need to present data specific to Bijol Island in The Gambia about seagrass as an ecosystem constituent which could be relied on to guide resource managers in informed decision-making. Thus, mapping and preserving seagrass habitats is intimately related to overall coastal ecosystem function sustainability. Quantifying the extent and resilience of seagrass habitats remains an essential component of near-shore monitoring and managing this underwater resource (Turner & Schwarz, 2006). For decades, various methods have been used for mapping and monitoring seagrass habitats in shallow coastal waters, including optical remote sensing in many locations. Traditionally this relied on the use of aerial photography and, more recently, moderate-spatial resolution multispectral satellite image data: Landsat Multispectral Scanner (MSS), Thematic Mapper (TM)/Enhanced Thematic Mapper (Lemenkova, 2011).

Simple *in situ* measurements were also used to rapidly assess and map seagrass using GPS and quadrats (McKenzie, 2003b). Among other relevant tools, scientists use in mapping seagrass is the Manual for the Scientific Monitoring of Seagrass Habitat, Worldwide edition (Short et al., 2006). Other parameters relevant for subsequent monitoring will include environmental parameters such as water temperature, salinity, water level, dissolved oxygen, etc., that help establish the baseline conditions at the time (Lirman & Cropper, 2003).

2.2 Seagrass distribution

2.2.1 Global distribution of seagrass

The earlier approximations recognized that seagrasses occur in 191 countries. It is estimated that the global seagrass spatial distribution varies significantly in all the published literature, reaching between 177,000 to 600,000 km^2 due to limited mapping efforts (Mckenzie et al., 2020). The least researched area on the globe for seagrass is the west coast of Africa, with a limited number of publications which, in most cases, cover only Mauritania (Cunha & Araújo, 2009). Experts searched seagrass beds in Senegal in 2008, where *Cymodocea nodosa* and *Halodule wrightii* were found in some parts of the protected areas of Joal. However, the southern distribution of these seagrass beds is yet to be thoroughly defined, and their presence could be on the other coast of Senegal and beyond (Cunha & Araújo, 2009).

Inadequate mapping efforts in some parts of the world and challenges to accessing other areas due to water clarity or depth make it difficult to obtain reliable data on global seagrass distribution. Australia has been recognized as the country with the highest amount of compiled seagrass area with 83 013 km^2, representing 31% of the international known seagrass area. On the other hand, Cabo Verde is the country with the lowest amount of seagrass area at 20 m^2 (Mckenzie et al., 2020). In a recent publication on seagrass of West Africa titled 'Seagrasses of West Africa: New Discoveries, Distribution Limits and Prospects for Management' (Ahmed et al., 2023) highlighted countries in West Arica with total coverage of seagrass (see table 1).

Table 1: Measured seagrass extent for each country; its confidence in the whole region (Ahmed et al., 2023)

COUNTRY	MEASURED SEAGRASS AREA (ha)
Cabo Verde	0.62
Mauritania	52,300
Senegal	8372
The Gambia	111
Guinea Bissau	881
Guinea	428
Sierra Leone	154
Total of the region	**62,108.02**

2.2.2 Seagrass environment

Seagrasses are submerged flowering plants found in marine areas with generally saline waters (Etter, 2019). Seagrass meadow distribution factors include nutrient levels, sunlight, turbidity, water level, temperature, current and wave action, and salinity. According to (Ramili et al., 2018). seagrasses can tolerate some disparity in environmental features such as salinity, temperature, substrate, light, and water movement. A study on morphometric characteristics of seagrass species conducted in North Makulu, Indonesia, in 2018 recorded some environmental parameters, including water temperatures at a range of 27.3 -29.7 ºC, salinity within the scope of 33.4 - 35.2, and pH within the range of 4.8-9.5, and dissolved oxygen (DO) within the range of 7.8-12.7 mg/l (Ramili et al., 2018). Similar environmental parameters were collected at Bijol Island.

The depth range of seagrass is most likely to be determined at its most profound edge by the accessibility of light for photosynthesis. Exposure at low tide, wave action, associated turbidity, and low salinity due to freshwater inflow regulate seagrass species' existence at the shallow edge (Duarte et al., 2008). In most cases, seagrass's ideal salinity range is from 20 to 42 (Collier et al., 2014). This preferred condition can be affected by watershed runoff resulting in hypo-saline conditions. However, the impacts from runoff are perhaps extreme in semi-enclosed bays and harbours where extra nutrients and sediments reaching seagrass areas are retained longer and accrue quicker. On the other hand, hyper-salinity can occur in shallow embayment as a result of high rates of evaporation. Salinity affects water uptake, plant water potential, and cellular ion concentrations. As a result, there are damaging consequences for cellular integrity when plants become salinity-stressed. However, the level of impact on the seagrass depends on the duration of exposure, and it is possible for seagrass to recover after a brief status of exposure to salinity stress but may fail to recover after prolonged stress (Collier et al., 2014).

Seagrasses are recognized to be reproducing either by vegetative propagation (asexually) or sexually (Darnell et al., 2021). Since seagrasses have flowers and produce seeds, fertilizing female flowers is done through pollination in the water. On the other hand, seagrass also spreads out rhizomes that can bud new growth; as a result, a single plant could produce an entire underwater meadow (Paulo et al., 2019). However, (Creed, 1997) stated that vegetative reproduction is the core strategy for seagrasses to colonize space, consequently a critical mechanism for seagrass meadows to spread and continue. The seagrass blades extend upwards and play a vital role in capturing nutrients, sediment and sunlight from the water column, while the roots or rhizomes extend down or sideways. In most cases, flowers and fruits of seagrasses are not collected for subsequent identification. Seagrasses have fewer morphological and anatomical features for species identification than terrestrial flowering plants. Seagrass species and genera identification relies mainly on vegetative parts, including blade width, blade tips, vein numbers, fiber distributions, epidermal cells, and characteristics of the roots and rhizomes (Kuo & den Hartog, 2001). Articles on seagrass existence in West Africa are scanty or challenging to find, however, (Potouroglou & Vegh, 2018) reported that there are only three species of seagrasses identified to exist in West Africa, which include: *Cymodocea nodosa*, *Halodule wrightii*, and *Zostera noltii*. This report complemented the findings of an earlier report by (Cunha & Araújo, 2009), stating that two species of seagrass were found on the coast of Senegal and could occur much further south.

2.2.3 Natural and anthropogenic factors affecting seagrass

With growing global recognition of the importance of seagrass ecosystem services, including their role as a significant carbon sink and critical fisheries habitat, these valuable natural resources are threatened with global loss and degradation due to natural and anthropogenic factors (Mckenzie et al., 2020). In a feasibility study for assessing seagrass distribution in the Northwest Pacific Action Plan (NOWPAP) region, (Terauchi et al., 2018) highlighted the coastal areas of northeast China, Japan, Korea and the Russian Far East are parts of the World's most densely populated areas. The coastal ecosystems in this area, including seagrass beds, are threatened by anthropogenic activities. This report indicated that there had been a rapid disappearance of seagrass as a result of industrial development in the coastal regions of Japan. It has been reported that in Tampa Bay, Florida, United States of America (USA), the coastal human population has increased. In contrast, the scope of seagrass areas deteriorated by 46% between 1950 and 1980. This significant loss of seagrass coverage was due to an increase in nutrient loads, especially nitrogen, from nearby estuaries due to population growth and land-use changes (UNEP, 2020).

In addition, other main threats causing further decline in current seagrass coverage include:

- Land reclamation.
- Environmental deterioration, such as a significant change in water quality.
- An increase in water temperature and water level due to global warming.

Veettil et al., (2020), reported that seagrasses in Korea had been seriously affected by land reclamation, coastal eutrophication, aquaculture and fishing activities, and still, these threats exist. Anthropogenic nitrogen inputs from watersheds to estuaries stimulate eutrophication. As coastal eutrophication progresses, the increase in primary production results in significant changes in the dominant flora.

The algae growth can harm seagrass by overgrowing them, reducing light, or competing for resources. Therefore, an alteration in water conditions that favour the development of these pest species is potentially harmful to seagrass communities. The report further stated that global warming due to climate change appears to be a new challenge to seagrass in Korea because Korean seagrasses are cold water species (Veettil et al., 2020). (Gomez et al., 2020), stated that warming hardly acts alone without other influences. An increase in temperature might impact the plant's performance, not only directly but also by its interaction with plant acceptance mechanisms to other aspects, such as an alteration in salinity (Gomez et al., 2020). The two main environmental factors affecting seagrass performance are temperature and salinity. If these factors are changed under a future climate change scenario, this may likely be harmful to ecosystem persistence (Gomez et al., 2020). (Cunha & Araújo, 2009), stated in their study of 'New distribution limits of seagrass beds in West Africa' that human-induced habitat destructions resulted from some fishing activities, including boat anchoring, coastal net-fishing, use of beach seines, etc.. (Pottier et al., 2021), highlighted that seagrass had been gradually endangered by both natural and human pressures, particularly from pollution, overfishing, change of landscape, and climate change, all of which could harm seagrass. Pollution, mainly from fisheries activities, is one of the main impacts likely to affect seagrasses on the West African coast (Cunha & Araújo, 2009). Their results supported our findings during the data collection at Bijol Island, where observed waste, mostly from fishing gear, was observed on the Island and found a fishing net on the seagrass meadow.

The soil's physical properties affect the amount of water, air, and nutrients available for terrestrial and marine plant growth. Determining the soil's physical properties will ultimately help determine how to effectively manage a particular terrestrial or marine plant/specie effectively (Livingston et al., 1998). Soil texture is based on the relative proportion of sand**,** silt, loam and clay the soil contains and is used to name the soil, for example, sandy loam soil. Coarse-textured soils (sands, loamy sands, sandy loams) have a large particle size and do not have great water and nutrient holding capacity. As a result, they tend to be well-drained, dry out faster, and are less likely to compact. Fine-textured soils (clays, sandy clays, silty clays) have a small particle size. They can hold water and nutrients, take time to dry out, can be easily compacted when wet and often are associated with poor drainage (Livingston et al., 1998).

2.2.4 Ecosystem services of seagrass

Coastal and marine ecosystems are ecologically and socio-economically valuable globally. For example, using a method based on the economic worth of nature, services of ecological systems and the related goods provision of the whole biosphere have been estimated at a yearly value of US$33 trillion. Around 32 % of this estimated worth is from coastal ecosystems

(Ontoria, 2020). Seagrass offers a series of critically important and economically valuable ecosystem services, which include support for fisheries production, coastal protection, particle trapping and nutrient cycling. Seagrass meadows make perfect indicators for monitoring the long-term health of aquatic environments due to their quick responses to fluctuations in water quality (Biber et al., 2009). Seagrasses' role in sequestering carbon is also becoming more extensively documented in globally developing carbon markets.

Seagrasses safeguard vital hydro-ecological functions by protecting coastlines by stabilizing the sediment, protecting against coastal erosion and supporting biodiversity, in addition to being a substantial resource for local inhabitants along the coastal zone (Pottier et al., 2021). (Veettil et al., 2020), pointed out that seagrass ecosystems provide a vital role in ecosystem services and biodiversity in coastal regions. This essential role includes providing a habitat for many juvenile species, especially fish and invertebrates, as well as feeding grounds for sea turtles and improving water clarity. Another study by (Terauchi et al., 2018), reported that seagrasses had attracted considerable attention for their roles in preserving marine biodiversity and mitigating climate change.

The authors' contributions to ecosystem services of seagrasses were highlighted by (UNEP, 2020) in a report, 'The value of seagrass to the environment and people. These ecosystem services include the ability to support the global fisheries, provision of nursery habitats for aquatics species, water filtration through trapping sediments in addition to excessive nutrients from the water, reducing exposure of human and other marine species to pathogens, climate regulation, ocean acidification buffer, and coastal protection (UNEP, 2020). In a regional study on seagrass ecosystem services in West Africa, regional experts outlined ecosystem services (see table 2) as well as stated and ranked the following threats according to the level of threat potential: (1) human disturbance and development, (2) pollution, (3) fishing-related threats, (4) climate change, and (5) lack of information (Potouroglou & Vegh, 2018). A similar study by (Potouroglou et al., 2017), 'Measuring the role of seagrasses in regulating sediment surface elevation', reported that seagrass presence contributes to the elevation of the area's topography. This study noticed an average variance in surface elevation proportion of 31 mm/year, equated to adjacent unvegetated sediments.

Table 2: Ecosystem services provided by the leading West African seagrass species, based on regional expert knowledge. Two species (H. wrightii and C. nodosa) exist in The Gambia (Potouroglou, 2018).

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

3. Materials and Methods

3.1. Study area description

The coastal regions of West Africa offer numerous employment opportunities for many people, the most prominent being recreational and fisheries activities which contribute to the country's Gross Domestic Product (GDP). These lucrative jobs result in high population concentrations in these areas, and therefore, the impact on the coastal and marine environment is a significant concern for natural resource managers (Gomez et al., 2020).

The Gambia, located between 13º and 14º N and longitudes 13° 40' and 16° 50' W with a land size of 11,300 km^2, is the smallest country on the mainland African continent. The Republic of Senegal borders the country to the East, North and South while it is open to the Atlantic Ocean in the West(Lamin-wadda, 1999). The coastline of The Gambia is 81 km long from the mouth of the Allahein river in the Southern region to Buniadu Point in the North. This region has witnessed population growth due to numerous livelihood opportunities provided to a good number of both Gambians and non-Gambians through the utilization of various coastal and marine natural resources. These activities along the coast have contributed to The Gambia's socio-economic development (Lamin-wadda, 1999).

Bijol island, located 3.1 km and 3.6 km off the coast of Tanji and Brufut fish landing sites, respectively, is part of the protected area of Tanji Bird Reserve (see figures 1 & 2), established in 1993, covering 612 ha (Barnett et al., 2004). Tanji Bird Reserve was established purposely for its ornithological significance as the reserve has a total of 295 species from 61 different families, making it a hotspot for birdwatchers (Barnett et al., 2004). The Bijol island is a Marine Protected Area and an important site for biological diversity such as aquatic birds, mollusks and turtles. Department of Parks and Wildlife Management manages the island in consultation with satellite villages of Brufut, Ghana Town, Madiana and Tanji as part of a recognized co-management plan. People had never lived on this Island therefore, one of the management plans was to limit visits to the Island for fisheries and tourism activities.

Recently, Seagrass (*Halodule wrightii* and *Cymodocea nodosa*) have been reported here in January 2020 by the ResealienSEA project team (Ahmed et al., 2023), which requires better management measures by stakeholders.

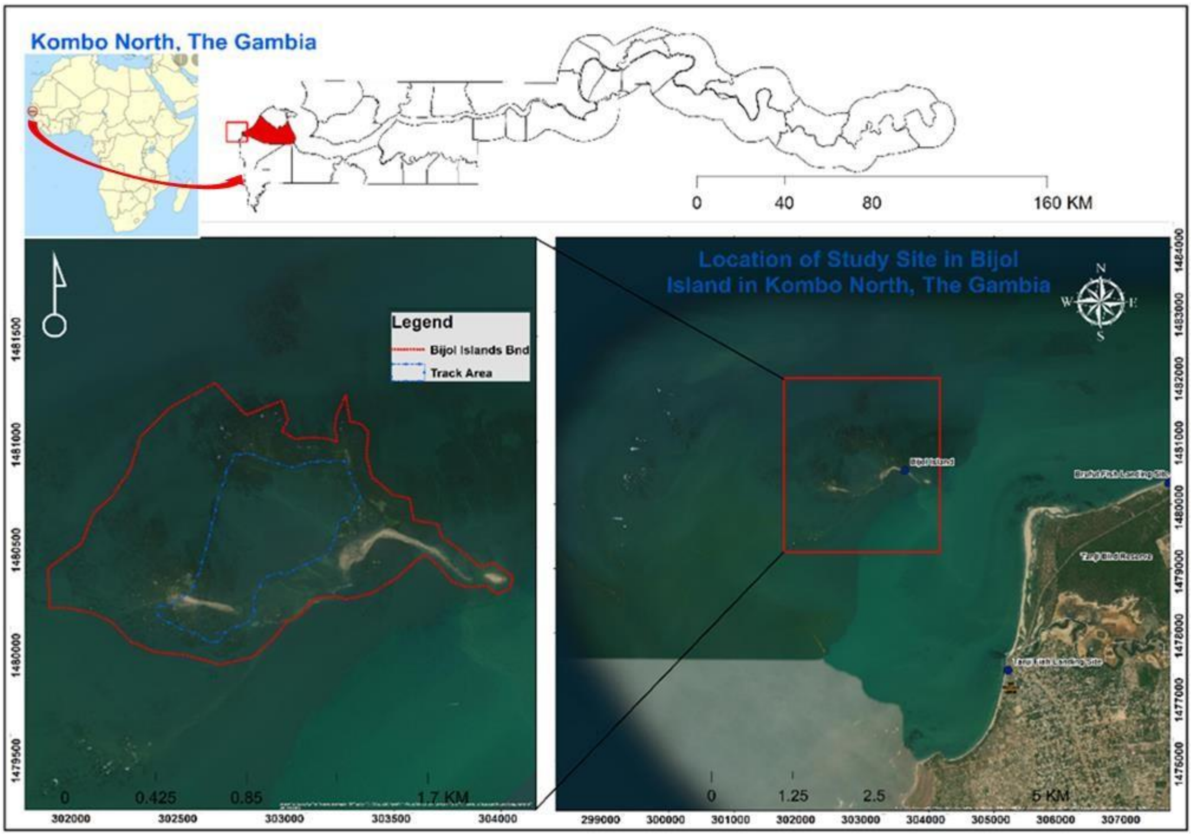

Figure 1: Map of the study area (Bijol Island) located in Kombo North District of The Gambia, West Africa (Abubacarr Kujabie 2022).


Figure 2: Image of Bijol Island visibly showing the stretch of the accreted area yet to be eroded (Source: SAS.Planet).

Climate features

The Gambia is a low-lying country, bisected by the River Gambia forming the North and South banks with tidally-inundated swamps covering about 20% of the country, which are at risk of permanent flooding by sea level rise of one meter. The low-lying topography, coupled with high dependence on subsistence rain-fed agriculture and inadequate drainage and stormwater management system in a fast expanding and unregulated urban expansion, has ranked The Gambia as one of the countries' most vulnerable to climate change (Gomez et al., 2020).

With a Sahelian climate, The Gambia has a long dry season (November to May) and a short-wet season (June to October), with average temperatures ranging from 18° to 30°C during the dry season and 23° to 33°C during the wet season. An erratic rainfall pattern has been recorded since 1960, with higher intensity storms, intra-seasonal drought and increasing average air temperatures, accompanied by periodic cold spells and heat waves. There has been a rising trend in temperature since the 1940s in the order of 0.5°C per decade. 25.8°C was the lowest mean temperature recorded in 1947, whereas 28.2°C was the highest mean temperature recorded in 2000. The current annual mean temperature will increase between 3°C and 4.5°C by 2100, demonstrating a substantial heating drift. From 1950 to 2000, there has been a decrease in the annual rainfall amounts by approximately 30%. The declined rainfall was further manifested through the extent of the rainy season and the amount recorded in August, especially between 1968 and 1985 and 2002 (Gomez et al., 2020).

Political and Socio-economic status

The Gambia is divided into seven administrative regions, which include: two municipality councils – Banjul City Council (BCC) and Kanifing Municipal Council (KMC) and five provincial administration regions – West Coast Region (WCR), North Bank Region (NBR), Lower River Region (LRR), Central River Region (CRR),) and Upper River Region (URR). The government, since 1990 has been executing a devolution policy designed to decentralize responsibilities for administration incredibly natural resource management to the regions, districts and ward levels. Banjul's administrative centre and the capital city are situated on an island.

The Gambia's economy mainly relies on agriculture, which contributed about 25% of the country's GDP from 1994-2013, and provides an activity for 70% of the labour force. The industrial sector contributed about 15% of GDP over the same period, which consists mainly of construction and agro-processing activities. Services accounted for 60% of GDP, with trade, transport, and communications being its two most significant components. Tourism is the country's primary foreign exchange earner (Komma, 2019). The 1993 population and housing census estimated the population of The Gambia at 1.0 million, the 2003 census at 1.4 million, and the 2013 census at 1.9 million, an annual growth rate of 3.3 per cent (Oh et al., 2020).

3.2. Data collection and analysis

Although seagrass mapping with satellite imagery offers data with a broad spatial scale, this entails exact geographical positions of seagrass species for the arrangements of satellite imageries and the valuation of classified bottom substrate images. As a result, it is vital to collect data on seagrass species by *in situ* field surveys (Terauchi et al., 2018). Our study was therefore based on *in-situ* data collection, applying a quantitative and qualitative methodology.

We adopted (McKenzie, 2003a) and (Lemenkova, 2011) approaches to collect the data in a specific location within Bijol Island. Among the methods and material (see figure 3) are:

- We used Satellite data from (SASPlanet/Google Earth aerial images) to identify or select the study area.
- *In-situ* measurements were conducted using 27 transects and 297 quadrats following a manual for scientific monitoring of seagrass habitat.
- We used Global Positioning System (GPS) to take coordinates of transects and the boundary of seagrass coverage.
- Measurements of environmental parameters (dissolved oxygen, salinity, sea temperature, turbidity) likely to change the structure of the seagrass communities were done on 28th January 2022 through multiparameter equipment.
- Close-ended questionnaires were administered targeting fishermen and national institutions in the fisheries and environment sector (Appendix I, II, III). Data collected in this section included the stakeholders' knowledge of seagrass availability, importance, and waste management measures. These results helped identify human-induced impacts seagrasses were subjected.
- This study selected the sample of 81 participants randomly from Tanji Fish Landing Site and 69 from Brufut Fish Landing Site.

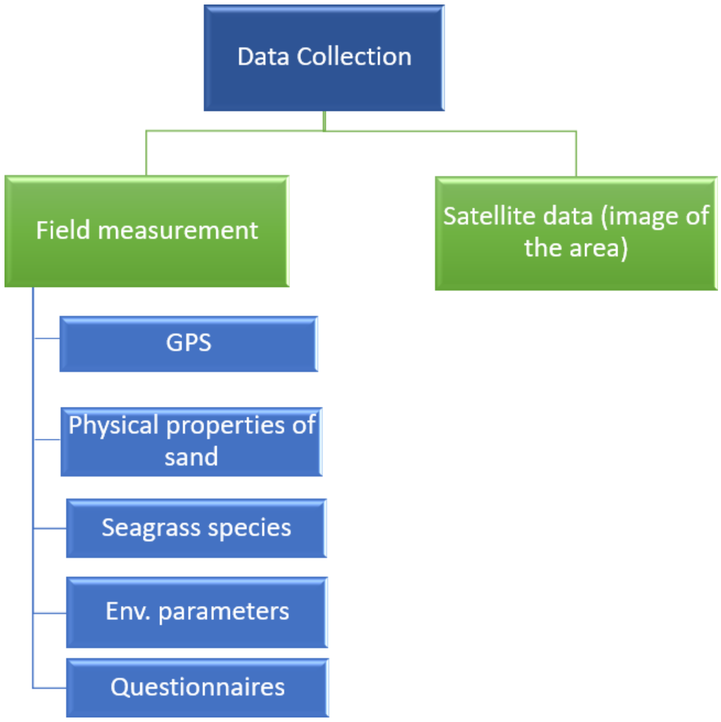

Figure 3: Methods used to collect data adapted from (Lemenkova, 2011).

- Established a sample size to administer the questionnaires on fishermen using Taro Yamane formular.
- Pearson's Chi-squared test was used to analyze data from questionnaires administered on fishermen and stakeholder institutions, to find out if significant variables are correlated or not.
- We used GPS to take coordinates of each transect and meadow boundaries, the obtained coordinates and recorded data were saved in an Excel file, converted to a shapefile, and imported to QGIS to generate a map of the study area and the extent of seagrass coverage.
- Sediments collected at 8 different transect locations and taken to the Laboratory for analysis of the physical properties using USDA system, which classifies soil textures by the fractions of sand, silt, and clay in the soil.
- The linear regression model used to generate graphs showing correlation between dependent and independent variables.
- To perform statistical analysis for different variables, we calculated the test statistic for one-way ANOVA and determined normality and homogeneity of variances in transect data to confirm whether there were significant correlations among “Average Coverage’’ as dependent variable and average water level as independent variable.

- We have divided the values of average water level in two groups or levels i.e. water level less than median water level=Low and values greater than median water level=high).
- We tested the effect of "average canopy height.cm" on "average coverage''.
- We computed Tukey HSD for doing numerous pairwise comparisons between the means of groups.
- All data analysis were performed using R programming version 4.0.3.

We measured environmental parameters (salinity, dissolved oxygen, temperature) with YSI multimeter equipment, while turbidity was taken with a turbidity column tube (see figure 4).

Figure 4: YSI Multiparameter equipment (a) and a turbidity column tube (b) for water quality reading, including salinity, dissolved oxygen, temperature; & turbidity respectively.

Assessment of seagrass coverage, canopy height and water level

At the pilot site during low tide, ranging poles were pegged to serve as benchmarks to create 27 transects of 50 m length each. Transects were laid 25 m apart parallel to the shoreline. With 11 quadrats for each transect, they totaled 297 quadrats from the 27 transects sampled (see figure 5). We obtained the per cent cover using a 50 cm x 50 cm quadrat randomly thrown along each transect around every 5 m to estimate the per cent cover using a per cent cover-photo standard sheet as the guide (Appendix V). The per cent cover was evaluated by three different people for each systematically thrown quadrat and was replicated 11 times to cover the entire single transect.

To estimate the total average per cent cover of a transect, the per cent cover of each quadrat along the 50 m long transect was summed and then divided by the number of quadrats (n = 11).

For the seagrass canopy height measurement, the dominant strap-leaf species were measured in centimeters from the sediment to the tip of the leaf of 3 shoots for each quadrat along the transect. The total number of the recorded value of the transect was divided by the number of quadrats (n = 11) to obtain each transect's average canopy height. We measured water level in centimeters for each quadrat. The total was divided by the number of quadrats (n = 11) to generate the estimated amount of average water level of each transect (see figure 6).

Pearson's Chi-squared test was used to analyze data from questionnaires administered on fishermen and stakeholder institutions. This test was meant to find out if significant variables are correlated or not where:

H0: correlation variables are independent/not related and
H1: significant variables are correlated.

We used GPS to take coordinates of each transect's starting and end points to generate a map of the study area. In addition, we took coordinates of meadow boundaries to show the extent of seagrass coverage. The obtained coordinates and recorded data were saved in an Excel file, converted to a shapefile, and imported to QGIS to generate a map of the study area showing the study area and the extent of seagrass coverage.

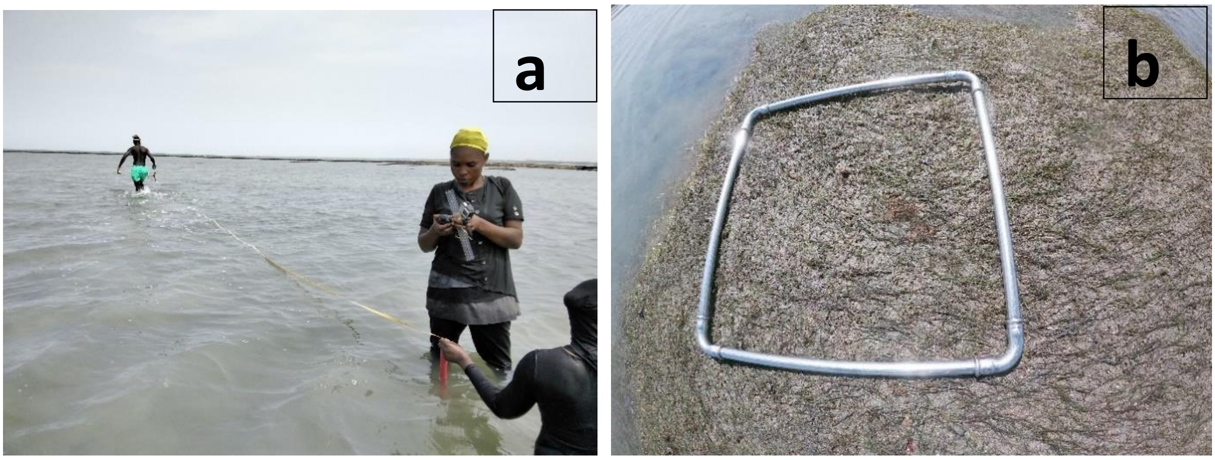

Figure 5: Setting of transect and quadrat (a and b) respectively used for H. wrightii coverage estimation, canopy height and water level at Bijol Island, Tanji.

Figure 6: Taking measurement of water level in a transect (a) and taking GPS coordinates and seagrass coverage (b) at Bijol Island in Tanji..

Identification of soil physical properties

In the field at Bijol Island, sediment was collected at 8 different transect locations (transects 1 to 8) and taken to the National Agricultural Research Institute (NARI) Laboratory for analysis of the physical properties (see figure 7). United States Department of Agriculture (USDA) system was used, which classifies soil textures by the fractions of sand, silt, and clay in the soil (Smith, 1975).

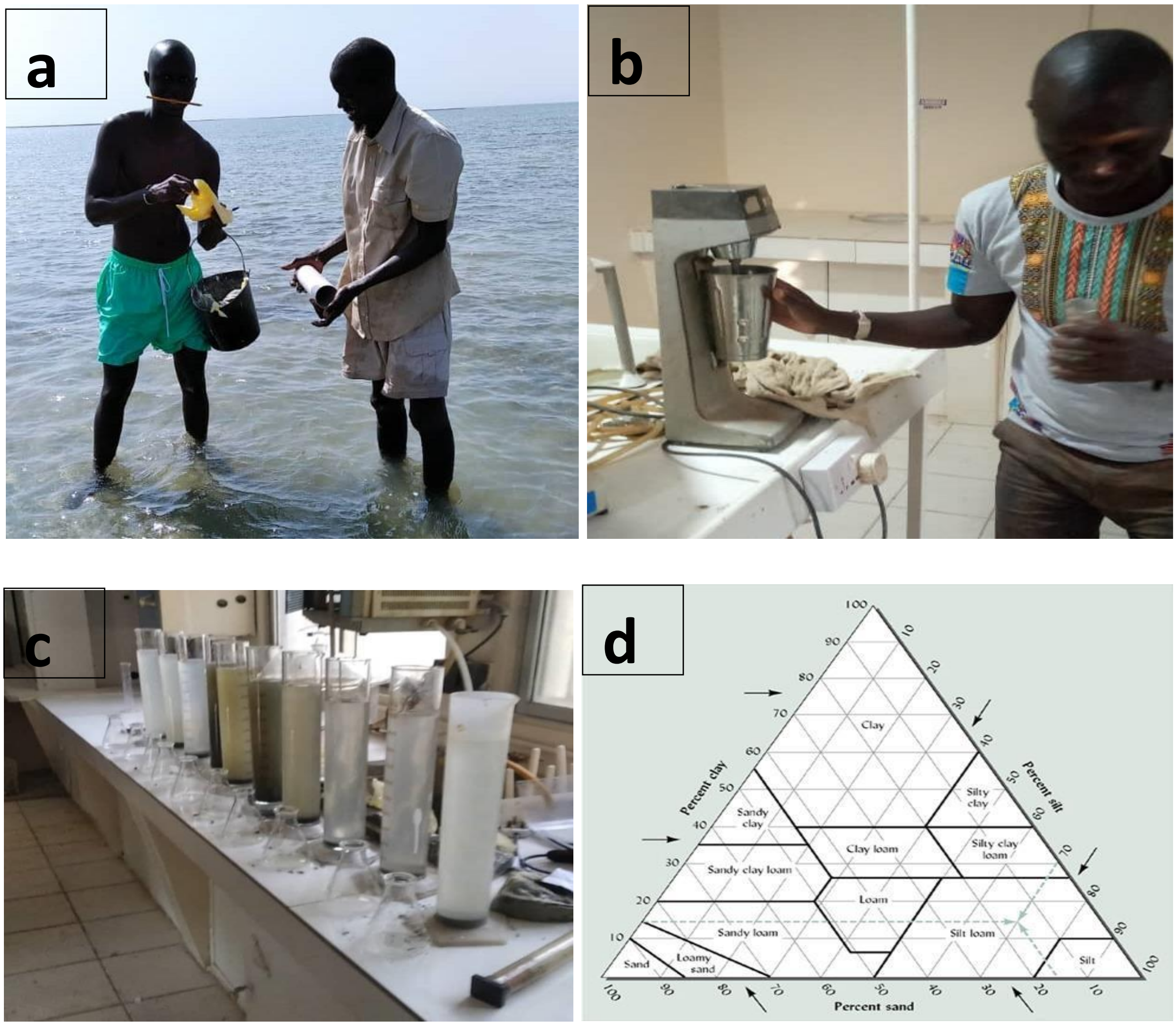

Figure 7: Process of USDA System for textural soil classification. Collection of sediment from the field for sampling (a), at the lab with an electric mixer (b), cylinders with soil samples (c) and soil texture triangle (d).

Seagrass identification

Halodule wrightii could be identified by its features of Tridentate teeth and the white rhizome. The blade tip of *Halodule wrightii* has two short horn-like points, sometimes with three horn-like points, with the median tooth generally shorter than the lateral teeth (Kuo & den Hartog, 2001). However, the leaf tip of *Cymodocea nodosa* is serrated with a pink rhizome (Potouroglou & Vegh, 2018).

Gauging stakeholders' perception about seagrass

Gauging stakeholders' perception of seagrass ecosystem services and management measures is necessary to discover opportunities for sustainable management of this aquatic resource. Awareness could change stakeholders' perception of seagrass in an environment with increased knowledge of seagrass management and the vital role seagrass play in marine environments. An increase in understanding of their importance and the necessity to be protected could lead to some behavioral change in a sense that links human activities with environmental literacy (Elggren, 2019). This study included gauging stakeholders (fishermen and natural resources managers') understanding of seagrass ecosystem services, threats and management measures. This exercise entailed administering questionnaires targeting fishermen at Tanji and Brufut fish landing sites and stakeholder institutions (Appendix I, II, III).

There was a need to establish a sample size to administer the questionnaires. From a population of 523 registered fishermen in Tanji and 240 at Brufut, we selected a sample size of 81 of the people at Tanji and 69 at Brufut with a margin of error of 10%, confidence Interval of 10 and confidence level of 95%. We derived the formula from both Creative Research Systems Sample Size Calculator (Creative Research Systems, 2012) and Taro Yamane formular as follows:

Sample size

$$ss = \frac{Z^2 * (p) * (1-p)}{C^2}$$

Where:

- Z = Z value (e.g. 1.96 for 95% confidence level)
- p = percentage picking a choice, expressed as decimal
- c = confidence interval, expressed as decimal

The above formular is similar to **Taro Yamane** formular of:

$$n = \frac{N}{1+N*(e)^2}$$

Where:

- n= sample size
- N= the population size
- e= the acceptable sampling error

From questionnaires administered at both Tanji and Brufut fish landing sites, we used Excel to calculate and generate results of the following:

- Percentage of age categories of fishermen
- Level of education

- Knowledge of seagrass
- Knowledge of seagrass ecosystem services
- Fishing within Bijol island
- Recognized issues at Bijol Island
- Knowledge of Bijol as a Marine Protected Area
- Availability of a waste management system
- Level of sensitization on seagrass

In addition, we calculated percentages of the relationship between fishing experience and knowledge of seagrass, as well as the relationship between fishing experience and knowledge of ecosystem services.

The questionnaires were meant to gauge the effectiveness of the management level of the seagrass within a protected area. Some questionnaires were administered to 13 stakeholder institutions involved in managing natural resources in The Gambia, particularly at Bijol Island, with the Department of Parks and Wildlife taking the lead. See questionnaires in Appendix I and II.

4. Results

4.1. Seagrass coverage

Results showed that more seagrass coverage was closer to the shore and decreased with water level. The p-value of the ‘average_water_level_cat’ variable was 2.5^{e-06} ($p < 0.001$), therefore it appeared that the level of ‘average_water_level_cat’ used has a real impact on the average coverage percentage. In another observation, with Tukey HSD lwr, upr: the lower and upper-end points of the confidence interval at 95 percent (default) p adj: p-value after multiple comparisons adjustment. The difference between levels of “High” and “Low” of the Variable “average_water_level” is significant, as shown by the output, with an adjusted p-value of 2.5^{e-06} or $p < 0.001$. On the other hand, we looked at ‘average_coverage’ as dependent and ‘average_canopy_height_cat’ as independent variable. The p-value of the ‘average_canopy height_cat variable’ ($p = 0.0909$) is high ($p > 0.001$); therefore, it showed that the levels of ‘average_canopy_height_cat’ used has no real impact on the average coverage percentage.

The residuals quantiles displayed against the normal distribution quantiles in the graph below with a 45-degree reference line showed that the residuals were normally distributed therefore should be about in a straight line (see figures 8, 9, 10, 11, and table 3).

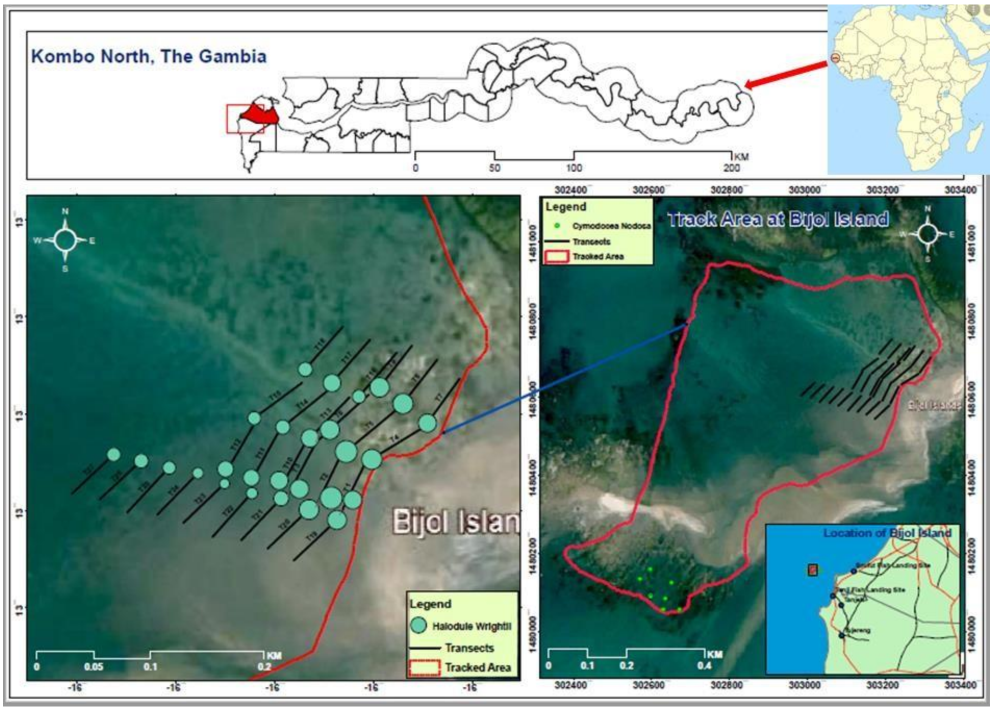

Figure 8: Map of the study area (Bijol Island) located in Kombo North District of The Gambia, West Africa. Legend of percentage coverage corresponding to the size of the dots.

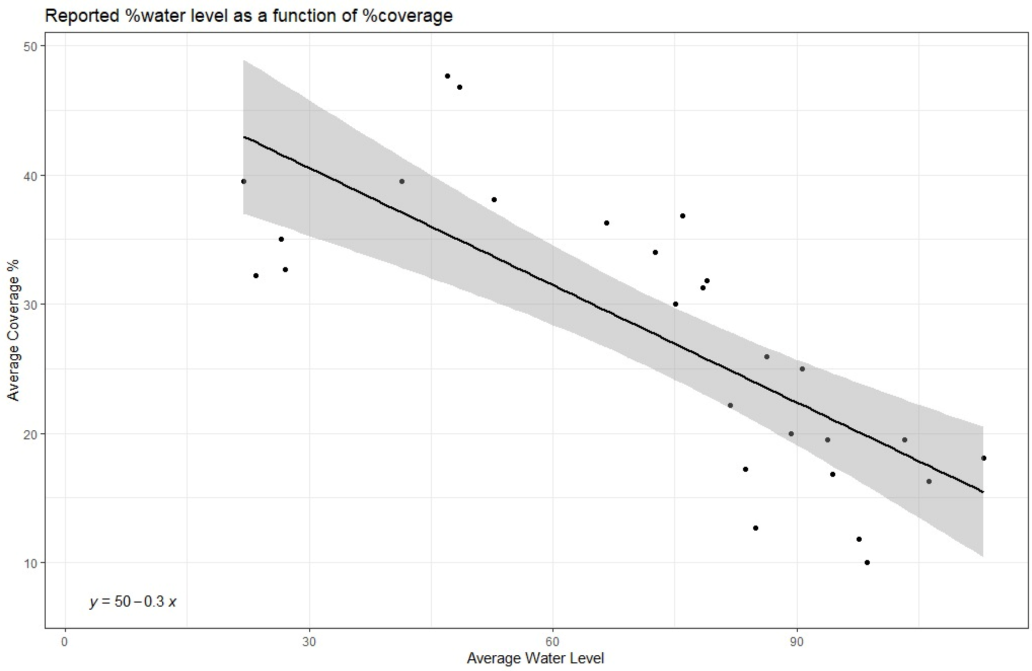

Figure 9: The linear regression model's graph showed correlation between dependent and independent variables. The water level increased, and average coverage decreased.

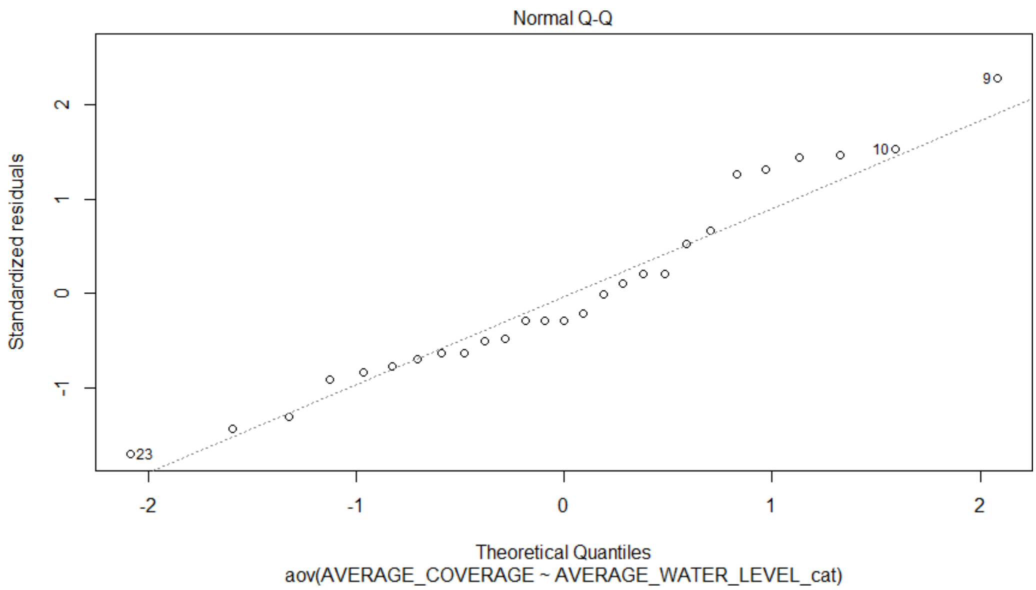

Figure 10: Normal QQ plot to test the normality assumption of one-way ANOVA. We can infer normality because all of the points lie roughly along this reference line.

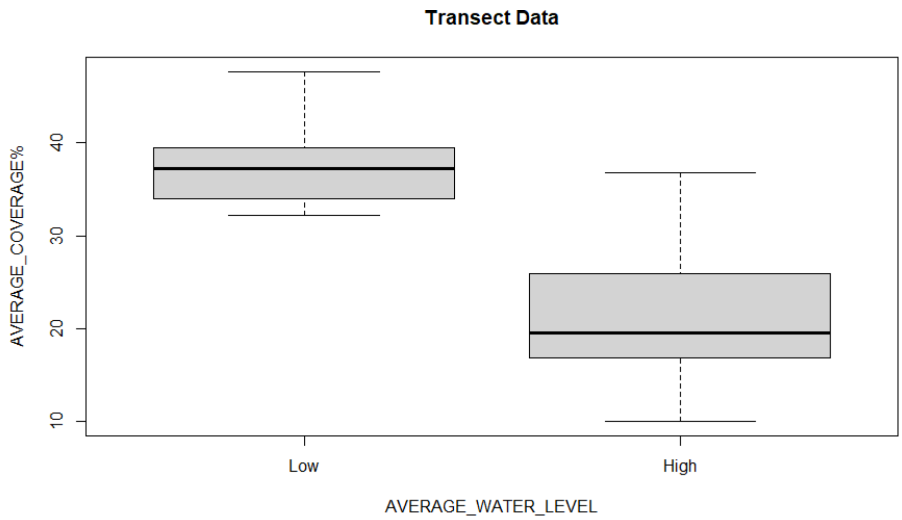

Figure 11: *Boxplots showing the distribution of categorized average water level.*

However, we marked GPS coordinates of the presence of *Cymodocea nodosa* specie in a sub-tidal area without setting any transect meant for the subsequent recording of per cent cover and canopy height. Transects could not be established here due to the water level that prevented us from establishing similar transects and quadrats where these species were in a subtidal environment. Furthermore, we could not map the complete coverage of the species due to limited capacity.

Table 3: Statistical analysis of coverage, canopy height and water level for the 27 transects shows a variation in coverage with water level.

T. No.	AV. COVERAGE%	MAX.	MIN.	SD. ±	AV. CANOPY HEIGHT (cm)	MAX.	MIN.	SD.±	AV. WATER LEVEL (cm)	MAX.	MIN.	SD.±
1	32.7	65.0	0.0	19.7	9.8	14.5	0.0	3.89	27.1	43.0	16.0	8.75
2	47.7	80.0	25.0	22.2	12.6	20.0	9.0	3.46	47.0	58.0	36.0	7.46
3	34.0	80.0	0.0	29.5	10.2	14.9	0.0	3.96	72.6	85.0	51.0	13.2
4	39.5	80.0	0.0	32.7	11.9	19.9	0.0	5.22	22.0	32.0	15.0	5.63
5	46.8	80.0	25.0	25.4	16.1	22.5	11.0	4.32	48.5	55.0	40.0	5.42
6	36.3	80.0	0.0	30.0	9.9	15.0	0.0	4.57	66.6	88.0	35.0	19.0
7	32.2	65.0	0.0	25.5	10.9	16.0	0.0	4.62	23.5	36.0	19.0	4.56
8	39.5	65.0	5.0	24.5	11.6	20.0	6.0	3.92	41.4	56.0	19.0	10.8
9	36.8	80.0	5.0	28.5	13.5	20.0	8.1	3.56	75.9	92.0	60.0	9.93
10	31.8	65.0	0.0	22.3	8.0	14.0	0.0	3.53	79.0	110.0	62.0	15.0
11	25.9	65.0	5.0	24.7	9.1	12.0	5.0	2.35	86.3	100.0	70.0	12.1
12	25.0	40.0	5.0	7.69	8.7	14.0	5.0	2.85	90.7	116.0	82.0	9.84
13	31.3	65.0	0.0	23.1	8.2	12.6	0.0	3.31	78.5	105.0	54.0	15.0
14	20.0	55.0	5.0	15.7	8.3	12.0	6.0	1.88	89.3	104.0	69.0	9.43
15	16.8	30.0	5.0	10.9	8.6	14.0	6.0	1.91	94.4	113.0	75.0	13.6
16	17.2	40.0	0.0	12.9	8.8	12.0	0.0	3.24	83.7	100.0	72.0	6.59
17	30.0	65.0	5.0	24.0	10.9	14.2	7.0	1.96	75.1	88.0	60.0	9.84
18	19.5	65.0	5.0	18.9	9.7	13.0	7.0	2.31	93.8	112.0	74.0	14.0
19	35.0	80.0	0.0	20.6	9.6	15.0	0.0	3.98	26.5	52.0	8.0	11.8
20	38.1	65.0	0.0	28.3	8.1	13.0	0.0	3.26	52.8	62.0	50.0	3.3
21	22.2	80.0	0.0	29.5	9.4	12.4	0.0	3.54	81.8	90.0	69.0	6.07
22	12.7	30.0	5.0	10.3	8.6	12.0	6.0	2.17	84.9	92.0	72.0	6.63
23	10.0	25.0	0.0	9.29	9.6	14.0	0.0	3.6	98.6	108.0	84.0	7.54
24	11.8	25.0	0.0	10.1	8.5	13.0	0.0	3.24	97.6	119.0	80.0	13.4
25	16.3	30.0	5.0	10.5	9.3	13.0	6.0	2.08	106.2	111.0	95.0	4.94
26	19.5	30.0	5.0	11.2	9.3	12.5	7.0	1.51	103.3	110.0	97.0	5.31
27	18.1	30.0	5.0	10.1	9.7	14.0	6.4	2.24	113.0	116.0	110.0	1.86

4.2. Environmental parameters

The results of environmental parameters collected included salinity with readings between 29.4 to 34; water temperature between 23.6 to 24.2°C; dissolved oxygen within 8.5-12.2mg/l; turbidity between 5.00-12.00 FTU (see table 4).

Table 4: Results of baseline environmental parameters collected from 9 different positions within the study area at Bijol Island.

No.	Sample location	Temperature (°C)	Salinity (PSU)	Turbidity (FTU)	Dissolve Oxygen (mg/L)
1.	T1	23.7	29.7	11.00	8.7
2.	II	24.1	29.4	11.50	8.9
3.	III	24.2	29.5	11.00	8.5
4.	T2	23.6	30.2	5.00	9.0
5.	II	23.7	30.1	8.00	12.2
6.	III	23.7	30.1	12.00	9.3
7.	T3	23.8	29.5	11.00	8.5
8.	II	23.8	30.2	10.00	8.9
9.	III	23.9	34.0	8.00	9.1

The results of the transects where the soil samples were collected showed that the most significant percentage of soil composition was sand, followed by silt and clay. This composition of percentages from 3 different soil fractions classified the soil type as sandy-loam. The USDA textural soil classification based on the soil's fraction of sand, silt, and clay are shown for the different transects (see table 5).

Table 5: Sediment collected from 8 locations within the study area (Bijol Island). Results of the analysis of soil physical properties at NARI soil and plant lab conducted on 3rd February 2022 with sediment type being sandy loam.

SAMPLE ID.	% Sand	% Clay	%Silt	Final result
T1	63.1	5.24	31.6	Sandyloam
T2	63.1	9.24	27.6	Sandyloam
T3	63.1	7.24	29.6	Sandyloam
T4	53.1	9.24	37.6	Sandyloam
T5	53.1	7.24	39.6	Sandyloam
T6	63.1	7.24	29.6	Sandyloam
T7	53.1	9.24	37.6	Sandyloam
T8	73.1	9.24	17.6	Sandyloam

Seagrass identification

In The Gambia, two species (*Cymodocea nodosa* and *Halodule wrightii)* were reported to have existed mainly on Bijol Island (Ahmed et al., 2023). During data collection, using a magnifier, *Halodule wrightii* at Bijol Island was identified by its features of Tridentate teeth and the white rhizome. (Kuo & den Hartog, 2001) further highlighted that the blade tip of *Halodule* *wrightii* has two short horn-like points, sometimes with three horn-like points, with the median tooth generally shorter than the lateral teeth. (Phillips, 1967) stated that leaves of *Halodule wrightii* have three veins or vascular bundles, one central and two laterals. Each vein may produce an extension at the leaf tip in the form of a tooth. If all three veins have extensions, the leaf apex is tridentate; if only the two lateral veins are extended, then the leaf is bidentate. Therefore, the median dentation is the most variable vein in length (see figure 12).

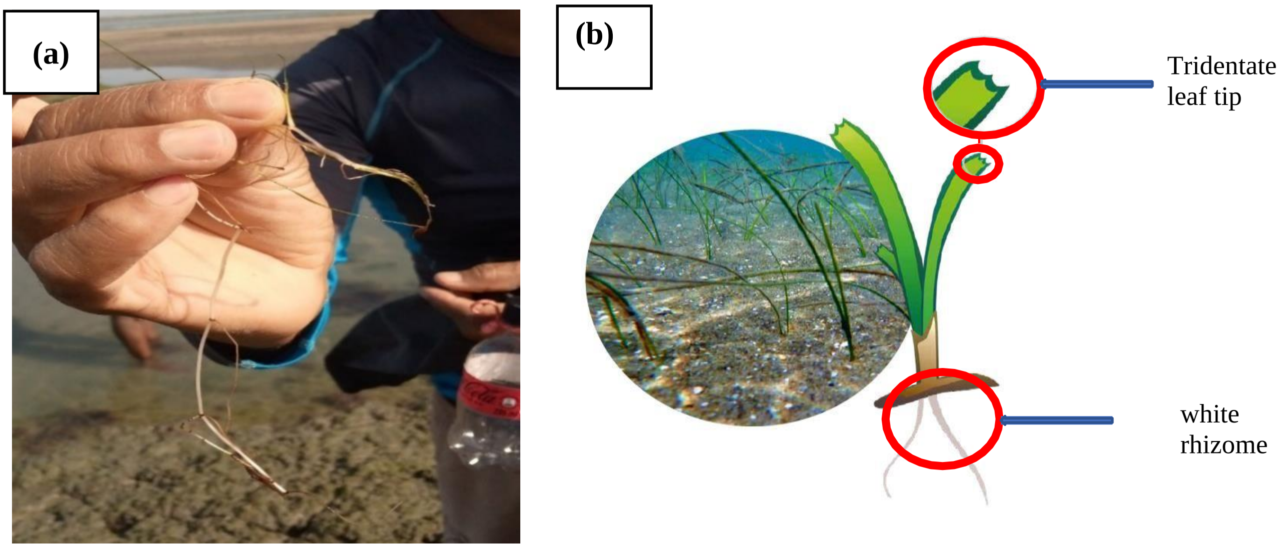

Figure 12: Seagrass species identification in the field through characteristics of leaf tip and rhizome of H. wrightii (GRID-Arendal, 2022).

For *Cymodocea nodosa*, the tip of the leaf is serrated with a pink rhizome (see figure 13) (Potouroglou & Vegh, 2018). However, (Kuo & den Hartog, 2001)stated that other methods that one could use to identify species include electron microscopy, isozyme analysis, physiology, biochemistry and molecular genetics.

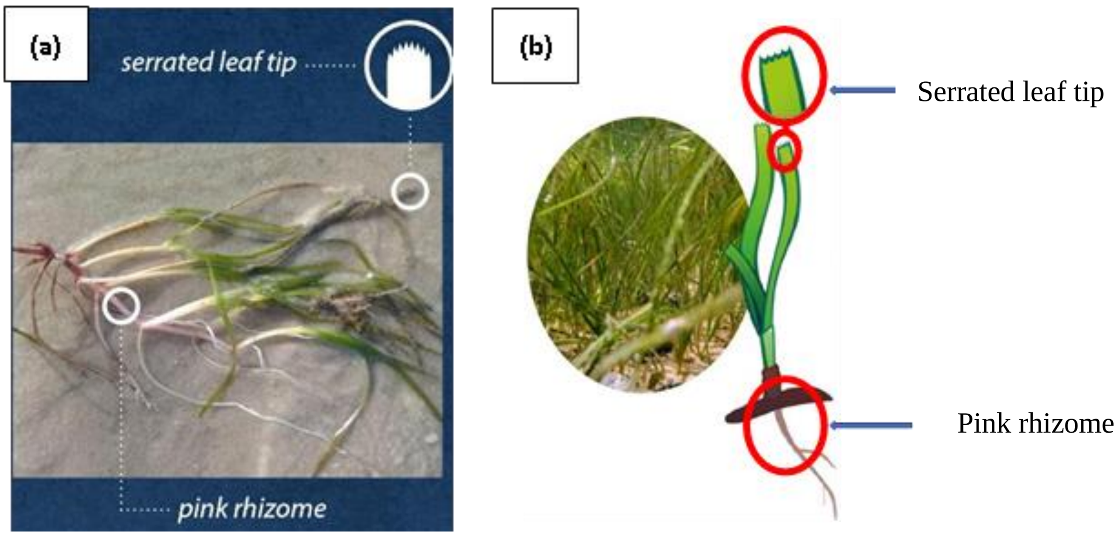

Figure 13: Characteristics of leaf tip and rhizome of C. nodosa specie (a) and (b) (Mohamed Ahmed Sidi Cheikh and GRID-Arendal, 2022 respectively).

4.3. Interviews

At Tanji fish landing site, the majority of fishermen interviewed were within the age category of 34-40 years old, the least was the youngest with the age category between 18-25 years old, while other age brackets were within 26-33 years, 41-48 years, 49-56 years, and 57 years and above (see figure 14). However, their highest level of formal education attained was secondary level, with few achieving that level. Most of them stopped at an elementary level of education (see figure 15).

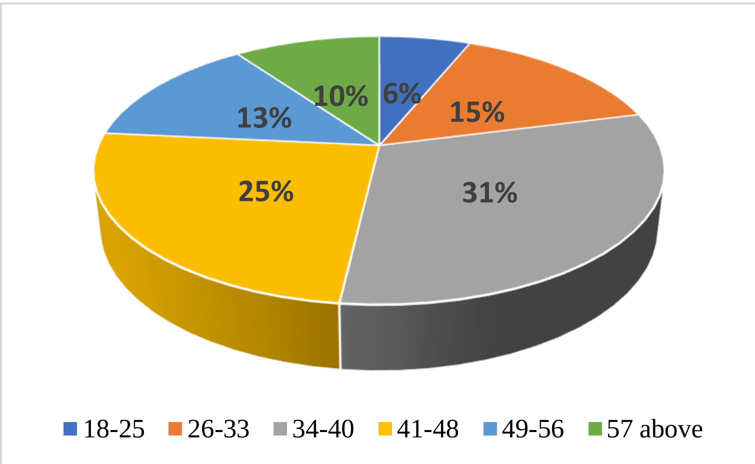

Figure 14: Tanji fishermen's age category, with most fishermen under the age category between 34-40 and least under the age category 18-25.

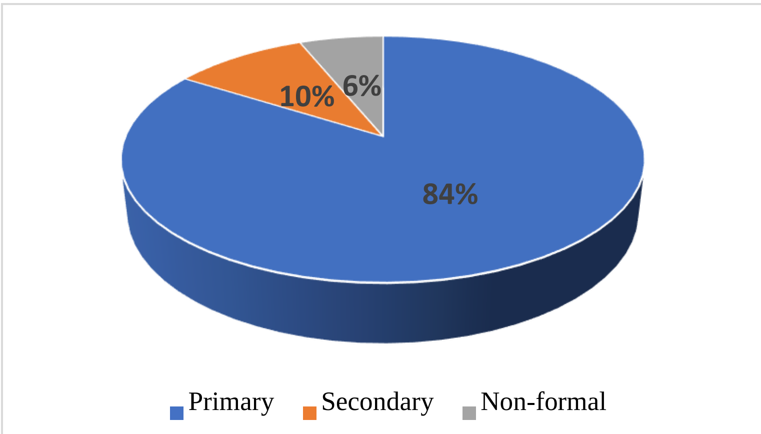

Figure 15: Tanji fishermen's level of education, with most attaining primary education and few with secondary education.

The fishing experience of the fishermen interviewed indicated that most had 20 years and above experience in fishing, with only a few with 5 years of fishing experience (see figure 16). On the other hand, we gauged their knowledge of identifying seagrass without showing them photos of seagrass. In the process of identification, most of them indicated that they knew and could identify what seagrasses were and few confessed not knowing (see figure 17). When we showed them seagrass specimens with other species (seaweed and algae) in a picture form for identification, only a few got it right, and the most significant percentage could not identify seagrass (see figure 18).

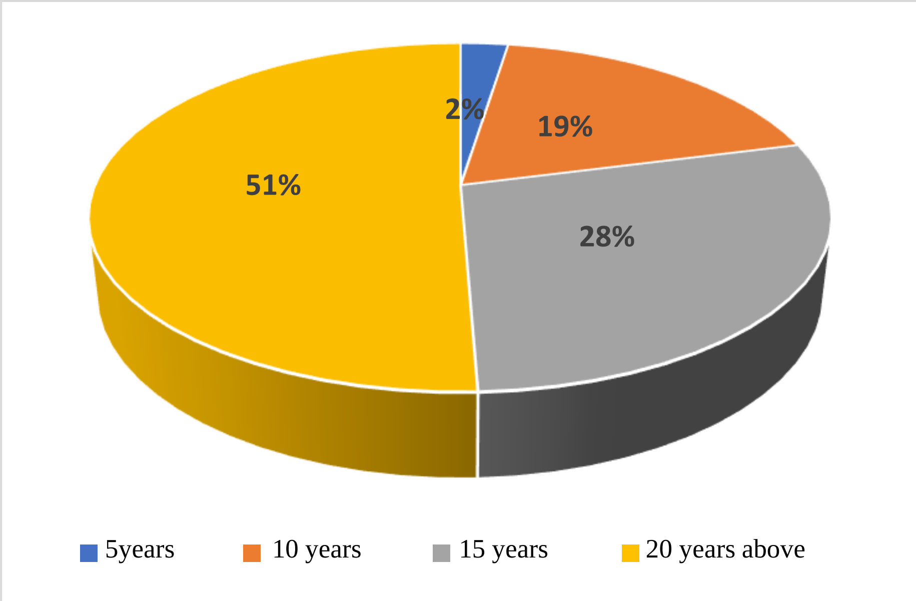

Figure 16: Tanji fishermen's fishing experience, with most of them having 20 years and more fishing experience and few with 5 years of fishing experience.

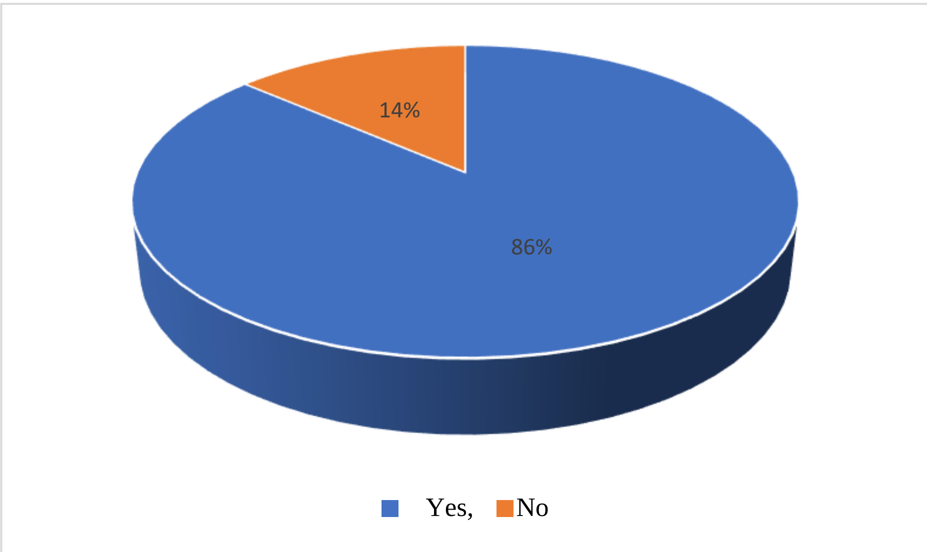

Figure 17: Tanji fishermen's attempted answers on knowledge of seagrass, with most of them stating that they knew what seagrasses were.

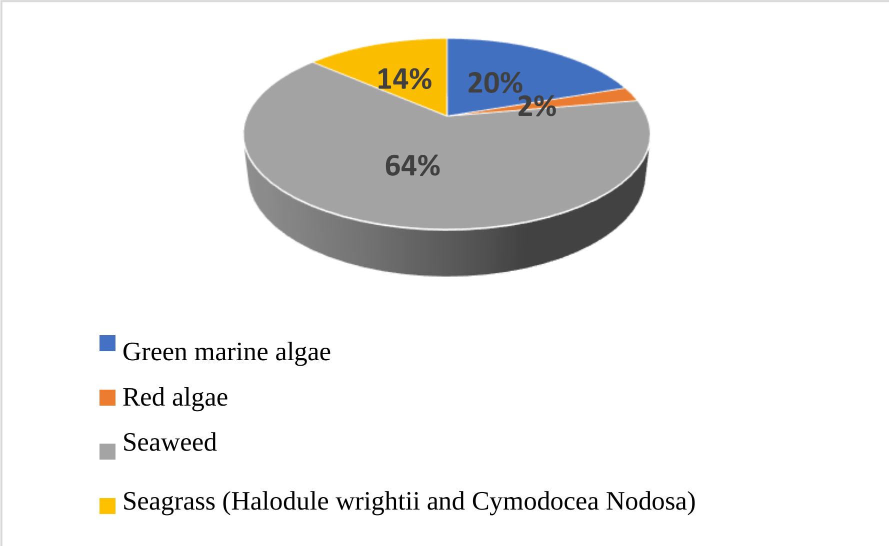

Figure 18: Tanji fishermen's actual knowledge of seagrass. Most of them referred to seaweed as seagrass, and few correctly identified seagrass.

Fishermen were asked about the ecosystem services that seagrass offer. Most of them (48%) responded that seagrass provides shelter for juvenile aquatic species; 1% of the respondent stated that it helps in storing carbon and reduces climate change; 21% indicated that it increases fish catch; 5% mentioned that it holds bottom sediment and stabilizes the beach. None said, not knowing seagrasses' ecosystem services (Appendix III).

Fishermen were asked whether they do fish close to Bijol Island or not. 84% of the respondents said they fish close to Bijol Island, and only 16% mentioned not fishing close to Bijol Island. However, during data collection on two different occasions, we found fishing nets on the Island where seagrass meadows were present (see figure 19). In a similar question, they were asked to state issues affecting Bijol Island. 65% of the respondents indicated that waste and erosion were the main issues the Island faced, 10% mentioned only waste, 19% mentioned erosion, and 6% said they didn't know about any environmental issue on the Island (Appendix VI). Regarding the protection nature of Bijol Island, 62% of fishermen in Tanji were aware of Bijol being a Marine Protected Area, 11% said Bijol was not a Marine Protected Area, whereas 8% confessed not knowing if Bijol was a Marine Protected Area or not (Appendix VI).

Figure 19: Waste and illegal fishing were some of the threats in the study area. We found the Waste category mostly from fishing gears (a) and evidence of fishing on the island as a fishing net found set on the seagrass meadow (b).

Waste management has been a problem along major fish landing sites of The Gambia. At Tanji, 72% of fishermen interviewed said there was a waste management system, 22% said there was no, and 6% stated not knowing if there was a waste management system (Appendix VI).

We did a statistical correlation to measure the relationship between different parameters including fishing experience and knowledge of seagrass for the fishermen in Tanji (see table 6). The correlation coefficient showed no correlation (X-squared = 7.099, df = 6, p-value = 0.3118). However, education and knowledge of seagrass; education and knowledge of ecosystem services; age and knowledge of seagrass; and age and knowledge of eco-system services for the fishermen in Tanji were related with X-squared = 31.43, df = 6, p-value = 2.098e-05; X-squared = 33.398, df = 8, p-value = 5.22e-05; X-squared = 52.73, df = 15, p-value = 4.275e-06; and X-squared = 40.113, df = 20, p-value = 0.004834 respectively.

Table 6: Relationship between fishing experience and knowledge of seagrass of fishermen in Tanji. Most respondents correctly identified seagrass as fishermen with a fishing experience of 20 years and above. A good number of them with the same fishing experience could not identify seagrass.

Specimen	**Respondents/% of total**	**5 years**	**10 years**	**15 years**	**20 years above**	**Total**
Green marine algae	Respondents	1.0	5.0	2.0	8.0	16
	Percentage (%) of total	1.2	6.2	2.5	9.9	19.8
Red algae	Respondents	0.0	1.0	0.0	1.0	2.0
	Percentage (%) of total	0.0	1.2	0.0	1.2	2.5
Seaweed	Respondents	1.0	8.0	18	25	52
	Percentage (%) of total	1.2	9.9	22.2	30.9	64.2
Seagrass (*Halodule wrightii* and *Cymodocea nodosa*)	Respondents	0.0	1.0	3.0	7.0	11
	Percentage (%) of total	0.0	1.2	3.7	8.6	13.6
TOTAL	**Respondents**	**2.0**	**15**	**23**	**41**	**81**
	Percentage (%) of total	**2.5**	**18.5**	**28.4**	**50.6**	**100.0**

Not many respondents were with the knowledge that seagrass stores carbon and reduces climate change (see table 7). There was another statistical correlation between fishing experience and knowledge of ecosystem services for the fishermen in Tanji. The correlation coefficient showed no correlation with (X-squared = 5.453, df = 8, p-value = 0.7082).

Table 7: Relationship between fishermen's fishing experience in Tanji and ESS knowledge. Most of the respondents stated that it provides shelter for juvenile aquatic species, while only one respondent said that it stores carbon and reduces climate change.

Specimen	Respondents/% of total	5 years	10 years	15 years	20 years above	Total
Increase fish catch	Respondents	0	6	3	8	17
	Percentage (%) of total	0.0	7.4	3.7	9.9	21.0
Hold bottom sediment and stabilize the beach	Respondents	0	0	1	3	4
	Percentage (%) of total	0.0	0.0	1.2	3.7	4.9
Provide shelter for juvenile aquatic species	Respondents	1	7	12	19	39
	Percentage (%) of total	1.2	8.6	14.8	23.5	48.1
Provide food for turtles and other marine species	Respondents	1	2	7	10	20
	Percentage (%) of total	1.2	2.5	8.6	12.3	24.7
Stores carbon and reduces climate change	Respondents	0	0	0	1	1
	Percentage (%) of total	0.0	0.0	0.0	1.2	1.2
Don't know	Respondents	0	0	0	0	0
	Percentage (%) of total	0.0	0.0	0.0	0.0	0.0
TOTAL	**Respondents**	**2**	**15**	**23**	**41**	**81**
	Percentage (%) of total	**2.5**	**18.5**	**28.4**	**50.6**	**100.0**

At the Brufut fish landing site, the percentages of age categories were 45% for fishermen between 34-40 years; 23% between 41-48 years; 9% between 49-56 years; 4% between 18-25; 12% between 26-33 years; and 7% above 57 years (Appendix VI). With regards to their level of education, 91% of the respondents attained primary education, 6% attained secondary education, and 3% had non-formal education. This result clearly showed that the literacy rate among fishermen was very low. Regarding fishing experience in terms of years, 46% had 20 years and above; 41% had 15 years of fishing experience; 12% had 10 years, and 1% had 5 years of fishing experience. Probing their ability to identify seagrass, 91% of the respondents stated that they could identify seagrass from other similar marine species, while 9% confessed that they could not identify seagrass. After displaying several similar marine species in an A4 size paper for identification of seagrass among the specimen, 71% took seaweed to be seagrass; 6% for green marine algae, 1% for red algae; while only 22% properly identified seagrass. The fishermen's knowledge of seagrass was very low, which was further justified by the number of fishermen who benefited from an awareness program on seagrass. Of the respondents, only 6% stated that they had attended an awareness program on seagrass, and 94% never attended such an awareness program.

We measured fishermen's knowledge of the ecosystem services of seagrass. 41% of the respondents mentioned that it provides shelter for juvenile aquatic species; 25% stated that it gives food for turtles and other marine species; 33% indicated that it increases fish catch; 1 % mentioned that it holds bottom sediment and stabilizes the beach.

Regarding encroaching on Bijol Island in their fishing activities, 39% confirmed that they fish on Bijol Island, while 61% said they don't fish close to Bijol Island. Fishermen reported other issues to have been experienced on the island. Of the respondents, 51% reported both waste and erosion, 30% for erosion only, 17% for waste only, and only 2% said they did not realise any issue on the island. On whether there was a waste management system at the fish landing site, 68% reported that they didn't know if there was a waste management system; 20% said there was no waste management system, and 12% reported that there was a waste management system.

We gauged fishermen's knowledge of whether Bijol was a Marine Protected area. Of the respondents, 61% were aware that Bijol was a Marine Protected Area; 22% reported that Bijol was not a Marine Protected Area, and 17% stated not knowing if the Island was a Marine Protected Area or not.

A correlation was conducted from data in the table below to measure the relationship between fishing experience and knowledge of seagrass for the fishermen in the Brufut Fish Landing Site (see table 8). The correlation coefficient showed a statistically significant correlation (X-squared = 22.187, df = 6, p-value = 0.00112).

Table 8: Table showing relationship between fishing experience and knowledge of seagrass of fishermen in Brufut. However, most of the respondents mistook seaweed to be seagrass.

Specimen	**Respondents/% of total**	**5 years**	**10 years**	**15 years**	**20 years above**	**Total**
Green marine algae	Number of respondents	1	2	1	0	4
	Percentage (%) of total	1.4	2.9	1.4	0.0	5.8
red algae	Number of respondents	0	1	0	0	1
	Percentage (%) of total	0.0	1.4	0.0	0.0	1.4
seaweed	Number of respondents	0	4	21	24	49
	Percentage (%) of total	0.0	5.8	30.4	34.8	71.0
seagrass (*Halodule wrightii* and *Cymodocea nodosa*)	Number of respondents	0	1	6	8	15
	Percentage (%) of total	0.0	1.4	8.7	11.6	21.7
TOTAL	**Number of respondents**	**1**	**8**	**28**	**32**	**69**
	Percentage (%) of total	**1.4**	**11.6**	**40.6**	**46.4**	**100.0**

We correlated to determine the relationship between different variables including fishing experience and knowledge of ecosystem services for the fishermen in Brufut (see table 9). The correlation coefficient showed a statistically significant correlation (X-squared = 25.507, df = 6, p-value = 0.000275). Additionally, there were correlations between education and knowledge of seagrass; education and knowledge of eco-system services; and age and knowledge of seagrass with X-squared = 58.961, df = 6, p-value = 7.318e-11; X-squared = 20.511, df = 6, p- value = 0.002245; and X-squared = 76.087, df = 15, p-value = 3.601e-10 respectively.

Table 9: Table showing relationship between fishing experience of fishermen in Brufut and knowledge of ESS. Most respondents stated that it provides shelter for juvenile aquatic species.

Specimen	Respondents/% of total	5 years	10 years	15 years	20 years above	Total
Increase fish catch	Number of respondents	0	1	3	19	23
	Percentage (%) of total	0.0	1.4	4.3	27.5	33.3
Hold bottom sediment and stabilize the beach	Number of respondents	0	0	1	0	1
	Percentage (%) of total	0.0	0.0	1.4	0.0	1.4
Provide shelter for juvenile aquatic species	Number of respondents	1	5	18	4	28
	Percentage (%) of total	1.4	7.2	26.1	5.8	40.6
Provide food for turtles and other marine species	Number of respondents	0	2	6	9	17
	Percentage (%) of total	0.0	2.9	8.7	13.0	24.6
Stores carbon and reduces climate change	Number of respondents	0	0	0	0	0
	Percentage (%) of total	0.0	0.0	0.0	0.0	0.0
Don't know	Number of respondents	0	0	0	0	0
	Percentage (%) of total	0.0	0.0	0.0	0.0	0.0
TOTAL	**Number of respondents**	**1**	**8**	**28**	**32**	**69**
	Percentage (%) of total	**1.4**	**11.6**	**40.6**	**46.4**	**100.0**

The proper management of natural resources requires a stakeholder approach. Questionnaires were developed geared toward understanding stakeholder institutions' involvement in the management of Bijol Island. From the administered questionnaires where focal persons of 13 institutions participated, the result showed that most focal persons attained certificate/diplomat; few with Bachelors and Masters; and none with PhD (see figure 20). The results showed that the most significant percentage of the focal persons responsible for managing Bijol Island and its natural resources were without a bachelor's degree. We asked about their participation in meetings related to Bijol Island and a good number of them reported that they participated in quarterly meetings. Also, a good number of others said they never attended any discussion about Bijol Island's management. At the same time, few reported that they attended meetings related to Bijol Island every year (see figure 21).

Stakeholder institutions' focal persons also reported issues affecting Bijol Island. With their responses, 31% reported only erosion; 15% reported only waste issues; 46% reported both waste and erosion, and 8% said they did not know. We asked stakeholders regarding their knowledge of the protection status of Bijol Islan. 85% confirmed knowing that Bijol Island was a Marine Protected Area; 15% stated not knowing if Bijol Island was a Marine Protected Area, and none mentioned Bijol was not a Marine Protected Area.

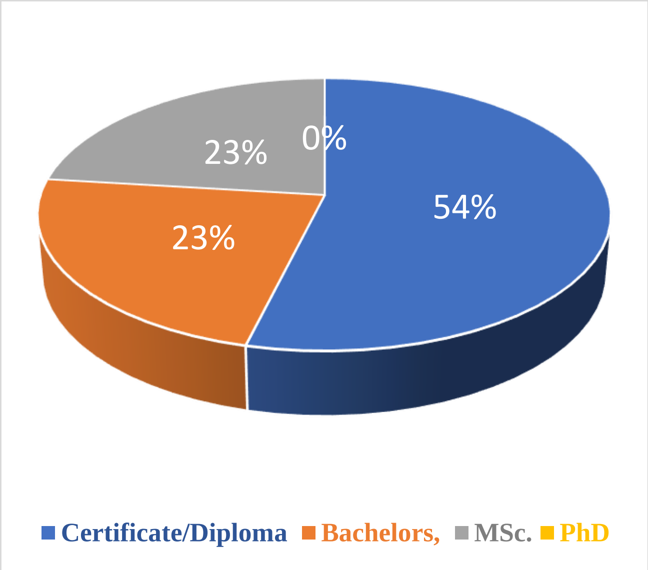

Figure 20: Level of education for stakeholder institutions' focal persons.

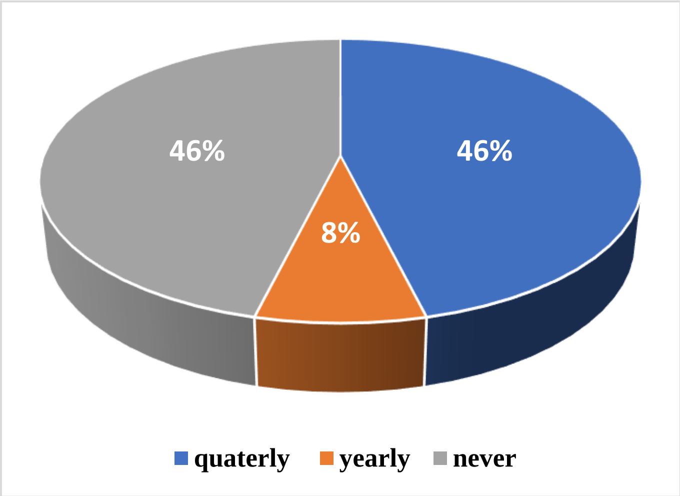

Figure 21: Stakeholder institutions' participation in meetings.

We tested different variables to confirm correlations or not. These included relationship between number of meetings and knowledge of a management plan for Bijol; relationship between number of meetings of stakeholder institutions and knowledge of seagrass; relationship between education of focal persons of stakeholder institutions and knowledge of seagrass; and relationship between education of focal persons of stakeholder institutions and knowledge of Eco-system Services resulting in X-squared = 3.8458, df = 2, p-value = 0.1462; X-squared = 2.8287, df = 2, p-value = 0.2431; X-squared = 2.7169, df = 2, p-value = 0.2571; and X-squared = 11.693, df = 6, p-value = 0.06918 respectively. These showed no significant relationship between the tested variables.

5. Discussion

The yearly accessible energy that seagrasses can use is one of the primary environmental aspects influencing photosynthesis, growth, productivity, and depth distribution. Our Maps show the percentage distribution of *Halodule wrightii* with more coverage on the shore and lesser coverage offshore. The report further stated that most seagrasses were limited to depths of less than 20 m, which is almost 11% of the surface irradiance. This depth implies more energy is available closer to the shore than in the deeper waters, and seagrass growth and productivity are higher in shallow areas. However, in some cases, light penetration in coastal waters is much lower than in deeper clear ocean water due to higher turbidity along the coast. The results limit photosynthesis in high turbid areas irrespective of the depth (Turner & Schwarz, 2006).

Not only did the coverage decline towards the deeper parts, but also areas with more coverage tend to have elevated ground compared to other areas with lesser coverage within the same transect. We noticed this elevation while recording a water level of 11 quadrats for each transect. Quadrats with higher coverage percentages recorded a shallower water level than other quadrats with lesser or no coverage within the same transect. Our result was similar to that of (Potouroglou et al., 2017). They found out in a report 'Measuring the role of seagrasses in regulating sediment surface elevation' that seagrass presence caused an average variation in surface elevation rate of 31 mm/year compared to adjacent unvegetated sediments. (Ruiz-Frau et al., 2019) reported that seagrass presence reduces bed erosion thresholds and improves water clarity. Seagrasses' role in stabilizing the shoreline by trapping sand was further confirmed from our results of fishermen's knowledge of seagrass ecosystem services, as some fishermen did mention similar results.

The results of environmental parameters collected included salinity with readings between 29.4 to 34; water temperature between 23.6-24.2ºC; dissolved oxygen within 8.5-12.2 mg/l; turbidity between 5.00-12.00 FTU. Apart from the direct water from the rains, there were no apparent means of changing this water to hypo-saline conditions through run-off as there was no evidence of run-off close to the Bijol Islands. A study on morphometric characteristics of seagrass species in North Makulu, Indonesia, in 2018 showed similar results, with water temperatures between the range of 27.3 -29.7ºC, salinity at the range of 33.4 - 35.2, pH within the scope of 4.8-9.5, and dissolved oxygen (DO) within the range of 7.8-12.7 mg/l (Ramili et al., 2018). Seagrass rely heavily on sediment for nutrients and anchorage; as a result, their distribution is to a large extent related to sediment type (Turner & Schwarz, 2006). The soil's physical properties at Bijol Island were sandy-loam soil type. A soil type of which sand dominated silt and clay, which is considered an ideal substrate for seagrass beds (Etter, 2019). (Turner & Schwarz, 2006) stated that, generally, seagrass occurs in a relatively homogeneous, soft-sediment environment. Altering the environmental settings such as hydrodynamics, change in soil chemistry, and nutrient enrichment, among others, could result in changes related to ecosystem functioning, including seagrass (Nordlund et al., 2018). The fundamental hypothesis is that if water quality is maintained or improved, the seagrass habitat will continue to flourish (Turner & Schwarz, 2006).

Our results showed that two seagrass species, *Cymodocea nodosa* and *Halodule wrightii* existed at Bijol Island in The Gambia. *Halodule wrightii* was identified through its features of tridentate teeth and white rhizome. (Kuo & den Hartog, 2001)stated that the blade tip of *Halodule wrightii* has two short horn-like points, occasionally with three horn-like points, with the median tooth generally shorter than the lateral teeth. (Phillips, 1967) mentioned that leaves of *Halodule wrightii* have three veins or vascular bundles, one central and two laterals. According to this author, each vein may produce extension at the leaf tip in the form of a tooth. The author further highlighted that if all three veins have extensions, the leaf apex is tridentate; if only the two lateral veins are extended, then the leaf is bidentate. Therefore, the most variable vein in length is the median dentation (Phillips, 1967).

Seagrass meadows are sensitive to the impacts associated with human activities, which could result in a substantial decline in a seagrass meadow. Pollution mainly from fisheries activities was noticed and reported at Bijol island and could contribute to deteriorating the required environment for seagrass to strive. (Turner & Schwarz, 2006) said that pollution could lead to substantial water and sediment quality changes, which can influence seagrass beds.

Stakeholders' ability to identify seagrass and their perception of seagrass and their management were essential to plan or recommend a proper management measure based on facts on the ground. Our results from the questionnaires showed that most stakeholders were unaware of seagrass because a good number of them could not distinguish seagrass from other similar marine species. Most of them referred to seaweed and algae as seagrass. However, those who knew seagrass at Brufut fish landing site were fishermen with 20 years and above of fishing experience. In another study in 2021 on 'assessing the role of seagrasses as a socio-ecological system' at Gamboa Bay in Cabo Verde, the study obtained similar results from questionnaires administered as a good number of fishermen misidentified marine algae and seaweed to be

Seagrass (Seydouba, 2021). (Elggren, 2019) stated that the need for stakeholders' knowledge of threats to marine species and the relationship with their behaviour towards the resources could determine the level of management required. Therefore, the management is a significant issue, especially when accurate data on their distribution is either inadequate or lacking (Umamaheswari et al., 2009).

The results showed that most respondents understood the ecosystem services that seagrass provides. The answers provided included that seagrass offers shelter for juvenile aquatic species, increases fish catch; holds bottom sediment and stabilizes beach; the least states that it helps store carbon and reduces climate change. These results are comparable with those of (Rasheed et al., 2014); (Ramili et al., 2018); and (Veettil et al., 2020) reported that seagrass provides vital services, including fisheries production, coastal protection through trapping sand particles, as well as sequestering carbon (Seydouba, 2021). Similar results were stated by (Pottier et al., 2021)in their mapping of the coastal marine ecosystem of the National Park of Banc d'Arguin in Mauritania.

6. Conclusions

6.1 Conclusions of the work

The findings from the map generated from a selected section of seagrass distribution indicated more coverage of *Halodule wrightii* closer to the shore, and the coverage declined towards deeper waters. There were fluctuations in the elevation of the floor in areas where seagrass coverage was higher compared to areas with lesser coverage within the same transect. While *Halodule wrightii* specie exists in an intertidal zone, *Cymodocea nodosa* exists in the subtidal site, and transects could not be conducted due to the water level where *Cymodocea nodosa* exist. However, we mapped the presence of the specie in some areas.

Environmental conditions that are likely to alter or drive seagrass distribution were recorded with salinity between 29.4 to 34 with no evidence of a possible run-off as one of the conditions to change the present state of salinity level; water temperature was at 23.6-24.2ºC; dissolved oxygen within 8.5-12.2 mg/l; turbidity between 5.00-12.00 FTU. The soil's physical properties collected from 8 different transects at the site showed a sandy-loam soil type.

Stakeholders' perceptions about seagrass and their management at Tanji Fish Landing Site showed 64% mistaken seaweed for seagrass, 2% mistaken red algae for seagrass, 20% mistook green marine algae for seagrass, and only 14% could correctly identify seagrass. However, the most significant percentage of those correctly identified seagrass were fishermen with 20 years and above of fishing experience. At Brufut Fish Landing Site, 71% mistook seaweed as seagrass, 6% mistook green marine algae for seagrass, 1% mistook red marine algae, and 22% correctly identified seagrass. This result showed a low percentage of fishermen at both fish landing sites with knowledge of seagrass.

From the two fishing communities of Tanji and Brufut, a more significant percentage of fishermen could state the ecosystem services that seagrasses provide, which include providing shelter for juvenile aquatic species, increasing fish catch, holding bottom sediment and stabilizing the beach. The least percentage mentioned storing carbon and reducing climate change. At stakeholder institutions, a more significant percentage of focal persons' highest level of attained education was at diploma level and few with BSc. and MSc. However, stakeholders' participation in the management of Bijol Island was very low, with 46% stating that they never participated in meetings related to the management of Bijol Island in general and seagrasses in particular. Other issues reported on the island by fishermen and representatives of stakeholder institutions were mainly waste and erosion of the island. Although, illegal fishing was reported and observed to occur on the island as evidence of a fishing net corroborated with fishermen's responses that they fish close to Bijol Island.

6.2 Main contributions

This study contributes to filling the knowledge gap on the availability, characteristics and distribution of seagrass at Bijol Island in The Gambia, in particular, the region and the globe at large. Stakeholders' perception and engagement in managing seagrass, specifically in Bijol Island, is generally established.

The limitations during this piece of work included inadequate financial and technical resources. The data collection was also done within two weeks when the area to be mapped was large, coupled with a series of questionnaires to be administered. Most fishermen also refused to give their names even though they accepted to be interviewed.

6.3 Recommendations and future work

From the findings of this work, to properly manage seagrass at Bijol Island, experts must sensitize fishermen and stakeholders in natural resource management and the presence of seagrass in the area and their importance in terms of ecosystem services provision. The sensitization must include stakeholders understanding environmental parameters likely to change seagrass performance and health status.

Fishing activities on the island must be prohibited to avoid disturbance in the seagrass meadow. To achieve this objective in Bijol, national actors must include all other stakeholders in the management of Bijol Island through regular monitoring, meetings and enforcement of policies related to the management of protected areas, especially Marine Protected Areas. These stakeholders should include but are not limited to: Department of Parks and Wildlife Management; National Environment Agency; Department of Forestry; Department of Water Resources; Fisheries Department; Gambia Maritime Administration; Gambia Navy; Gambia Fire and Rescue Services; Gambia Tourism Board; Gambia Bird Watchers Association; The Communities of Tanji, Brufut, and Madiyana.

There should be a well-established and recognized waste management system at both Fish Landing Sites of Tanji and Brufut to curtail the amount of waste reaching Bijol Island. In addition, there is a need for continued research to document more results related to the seagrass ecosystem. Stakeholders can initiate this research through co-opting research institutions, e.g. University of The Gambia (UTG), into the management committee of Bijol Island.

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Appendix

Appendix I

Questionnaires of fishermen’s knowledge on seagrass

This study will keep the ethical consideration in mind during administering these questionnaires. All the interviewees will be informed about the nature of the study and a consent will be obtained from respondents who agreed to take part in the study. All information attained from respondents will be confidential and will only be used for the research purpose. Respondents will be informed that their contribution in the study is deliberate and no names will be attached to the final report.

1. What is your name (optional)?
2. Age?
    a) 18-25,
    b) 26-33,
    c) 34-40,
    d) 41-48,
    e) 49-56,
    f) 57 above
3. What is your level of education?
    a) Primary,
    b) Secondary,
    c) Non-formal
4. Fishing experience?
    a) 5years,
    b) 10 years,
    c) 15 years,

d) 20 years above

5. Do you know what seagrasses are?

a) Yes,

b) No

6. Can you identify which of these pictures is seagrass? (pictures to be printed)

a) Green marine algae,

b) red algae,

c) seaweed,

d) seagrass (*Halodule wrightii* and *Cymodocea nodosa*)

7. What are the ecosystem services that seagrass can provide?

a) Increase fish catch,

b) hold bottom sediment and stabilize the beach,

c) provide shelter for juvenile aquatic species,

d) provide food for turtles and other marine species,

e) stores carbon and reduces climate change

f) don’t know,

8. Do you fish close to Bijol Island?

a) Yes

b) No

9. What are some of the issues you noticed at Bijol Island?

a) waste issues

b) erosion

c) both waste and erosion

d) don't know

10. Do you know if Bijol Island is a Marine Protected Area?

a) Yes

b) No

c) Don't know

11. Do you have a waste management system at the landing site?

a) Yes

b) No

c) Don't know

12. Have you ever been sensitized on seagrass?

a) Yes,

b) No

13. Would you participate if invited in a sensitization program on the importance and conservation of seagrass?

a) Yes

b) No

14. If no, why?

Appendix II

Questionnaires for stakeholder institutions on the management of Bijol island

This study will keep the ethical consideration in mind during administering these questionnaires. All the interviewees will be informed about the nature of the study and a consent will be obtained from respondents who agreed to take part in the study. All information attained from respondents will be confidential and will only be used for the research purpose. Respondents will be informed that their contribution in the study is deliberate and no names will be attached to the final report.

1 What is your name (optional)?

2 What is your level of education?

a) Certificate/diplomat,

b) Bachelors,

c) MSc.

d) PhD

3 Name of institution?

4 Position held?

5 Length of service in the institution?

a) 5years,

b) 10 years,

c) 15 years,

d) 20 years above

6 Do you know Bijol Island?

a) Yes

b) No

7 How often does your institution attend meetings related to Bijol Island?

a) quarterly

b) yearly

c) never

8 Do you know stakeholder institutions in the management of Bijol Island?

a) Yes

b) No

9 What are some of the issues you noticed or have been informed at Bijol Island?

a) waste issues

b) erosion

c) both waste and erosion

d) don't know

10 Do you know if Bijol Island is a Marine Protected Area?

a) Yes

b) No

c) Don’t know

11 Is there a management plan for Bijol Island?

a) Yes

b) No

c) Don’t know

12 Is there a waste management system at Tanji/Brufut landing site?

a) Yes

b) No

c) Don’t know

13 Do you know what seagrasses are?

a) Yes,

b) No

14 What are the ecosystem services that seagrass can provide?

a) Increase fish catch,

b) hold bottom sediment and stabilize the beach,

c) provide shelter for juvenile aquatic species,

d) provide food for turtles and other marine species,

e) stores carbon and reduces climate change,

f) don’t know,

15 Has your institution ever participated in a meeting/sensitized on seagrass?

a) Yes,

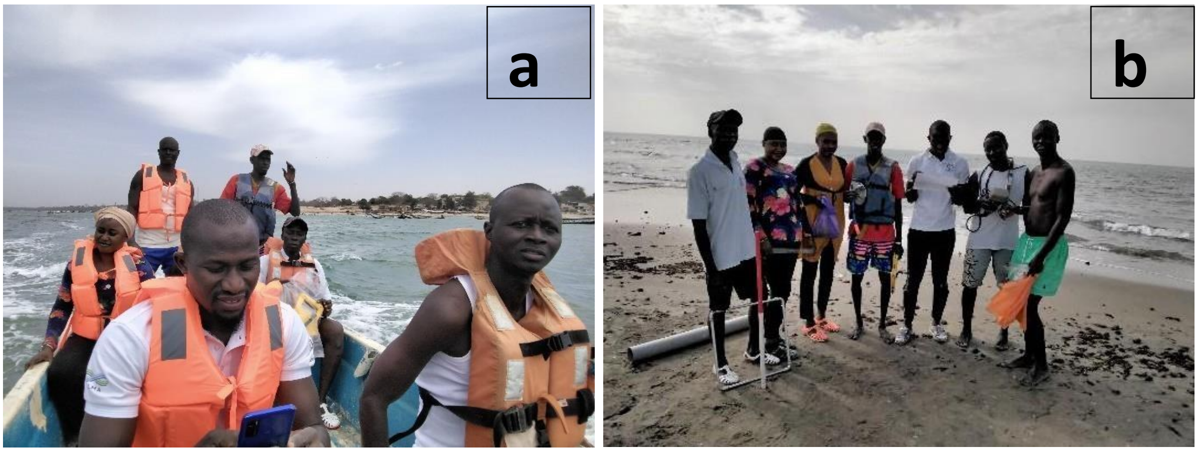
b) No

16 Would you participate if invited in a sensitization program on the importance and conservation of seagrass?

a) Yes

b) No

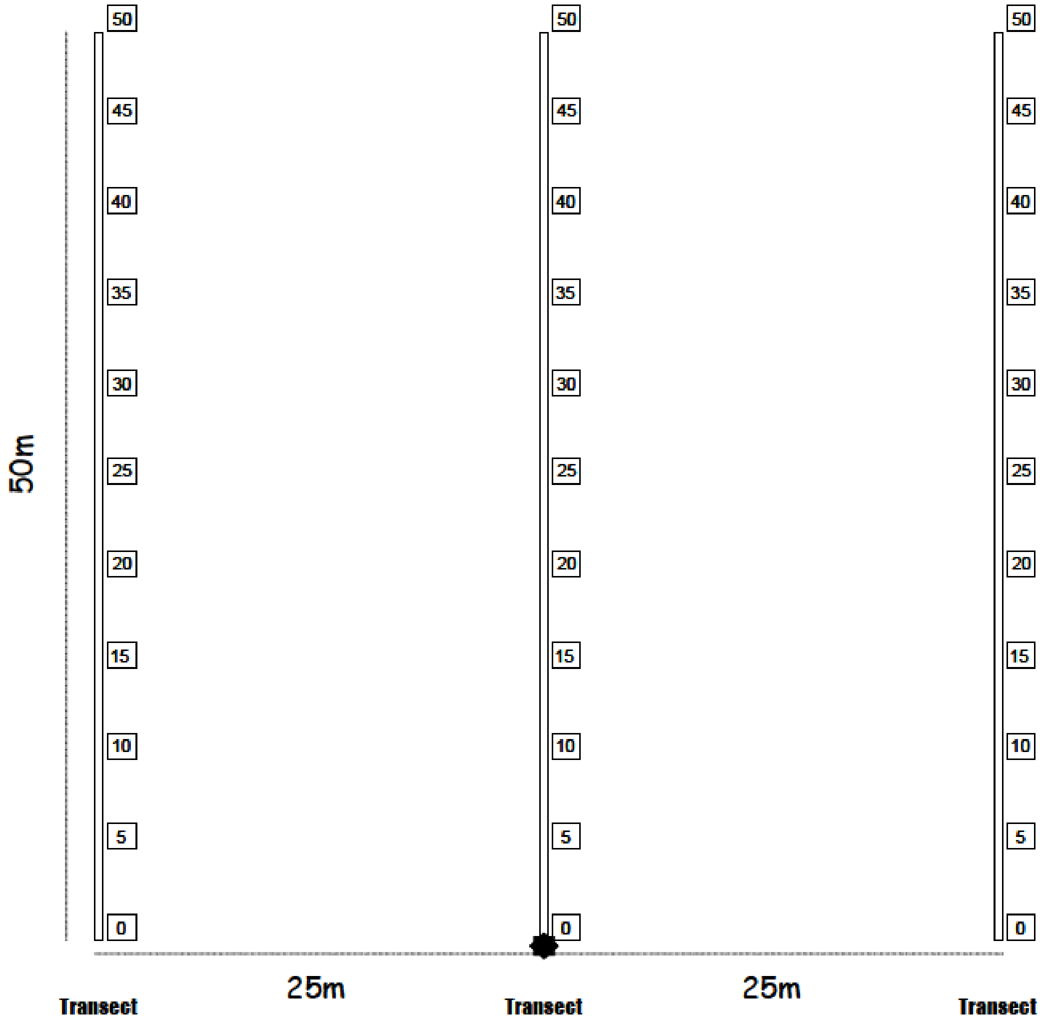
17 If no, why?



Appendix III:

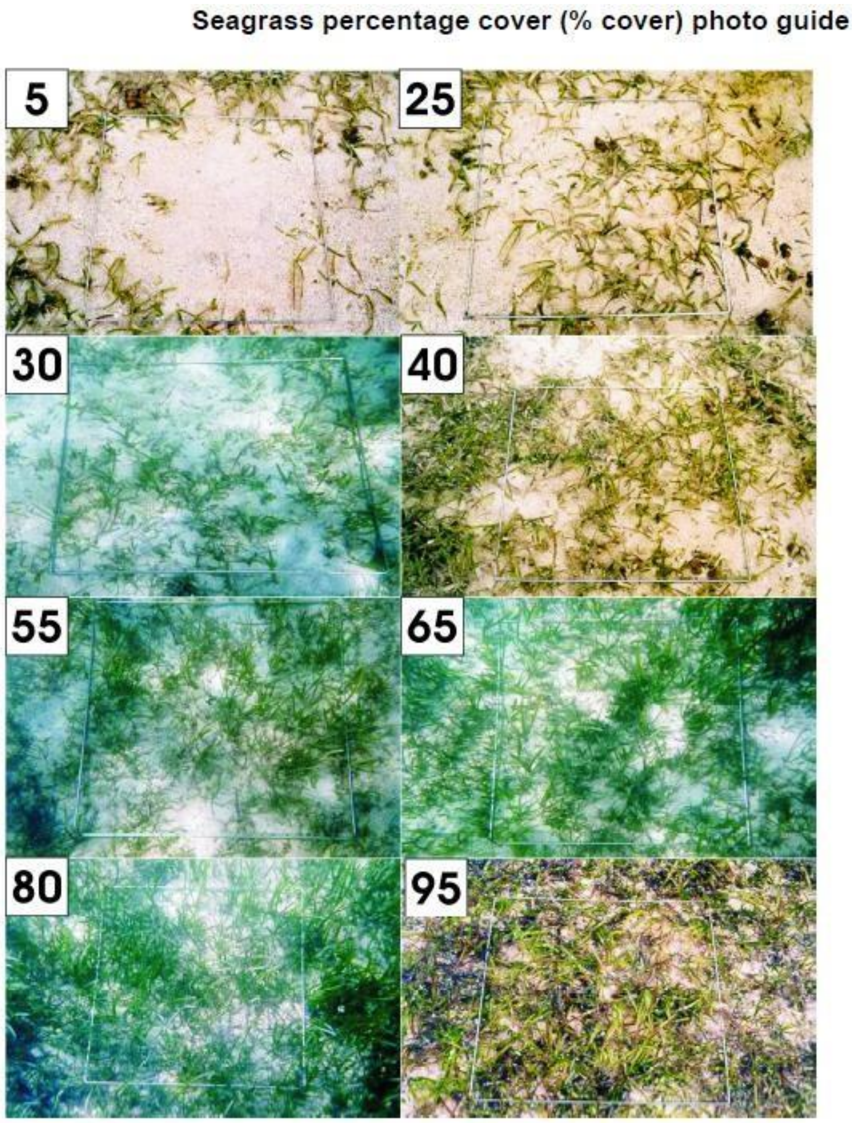
With NIT heading to the study site (a) and at the study site (b) for data collection at Bijol Island in Tanji.

Site layout



Appendix IV:

Example of site Layout with transects of 50 m length and quadrats in positions of 5 m between each and 25 m apart between transects.

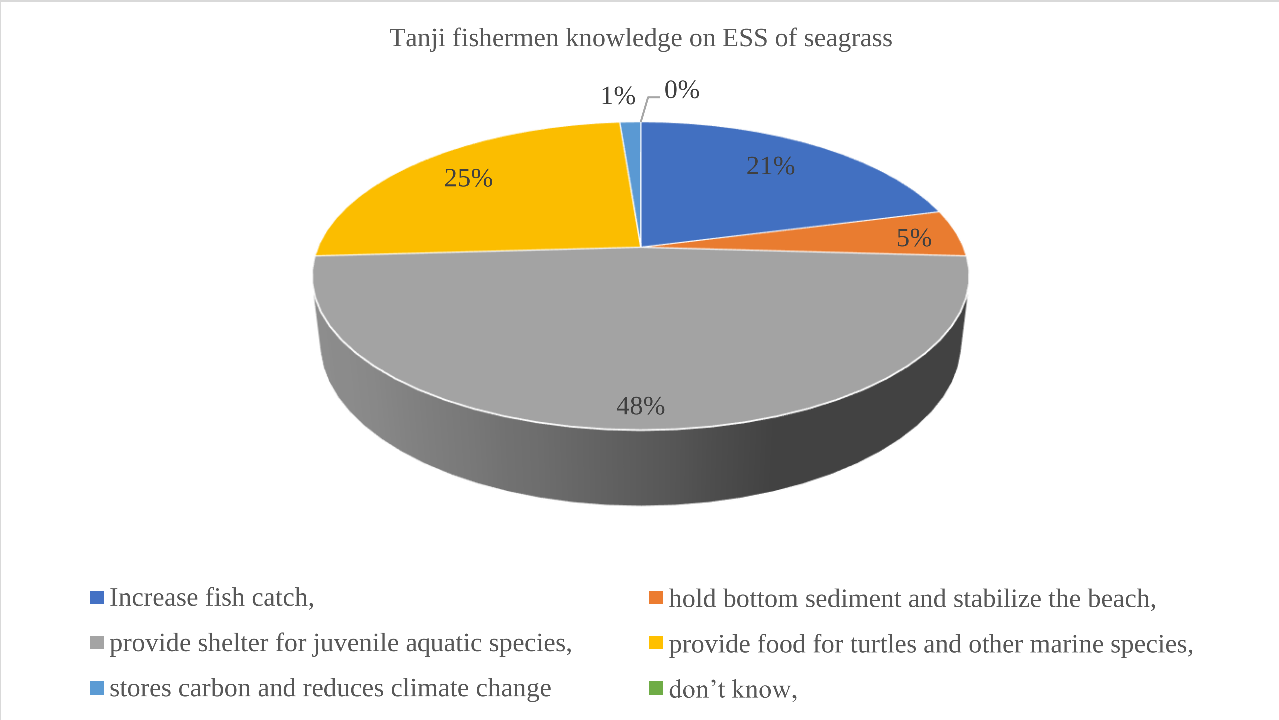


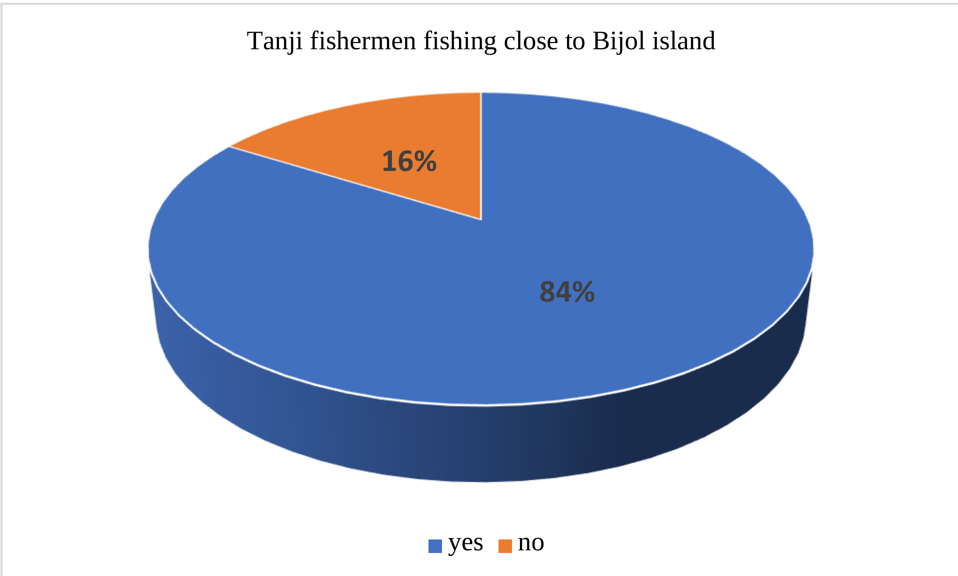
Appendix V:

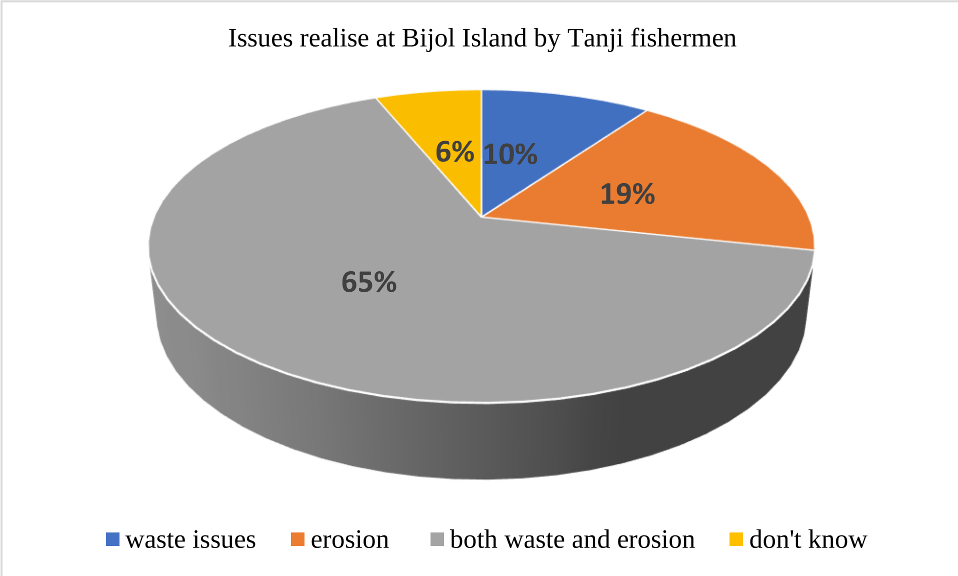
Seagrass percent cover photo guide for estimation of coverage.

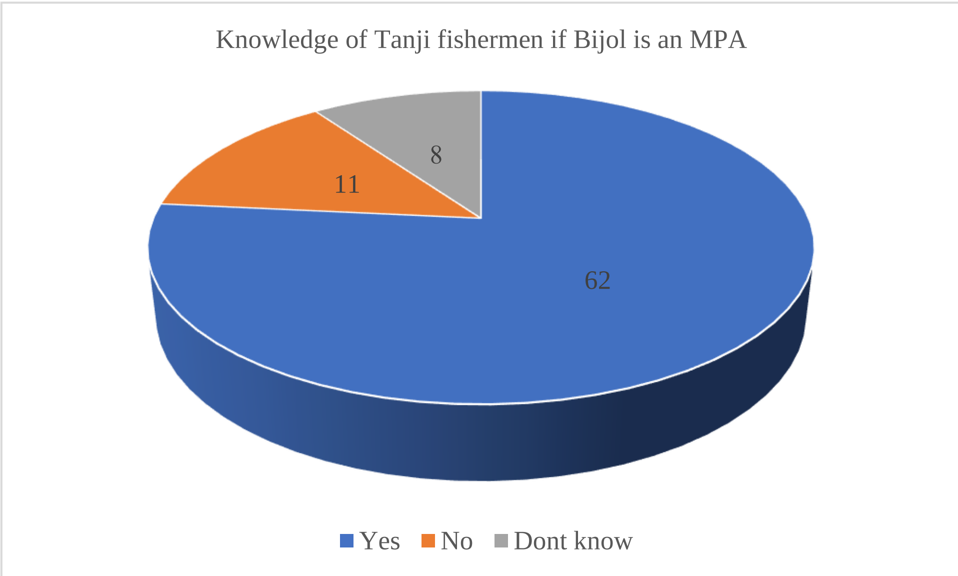
Appendix VI:

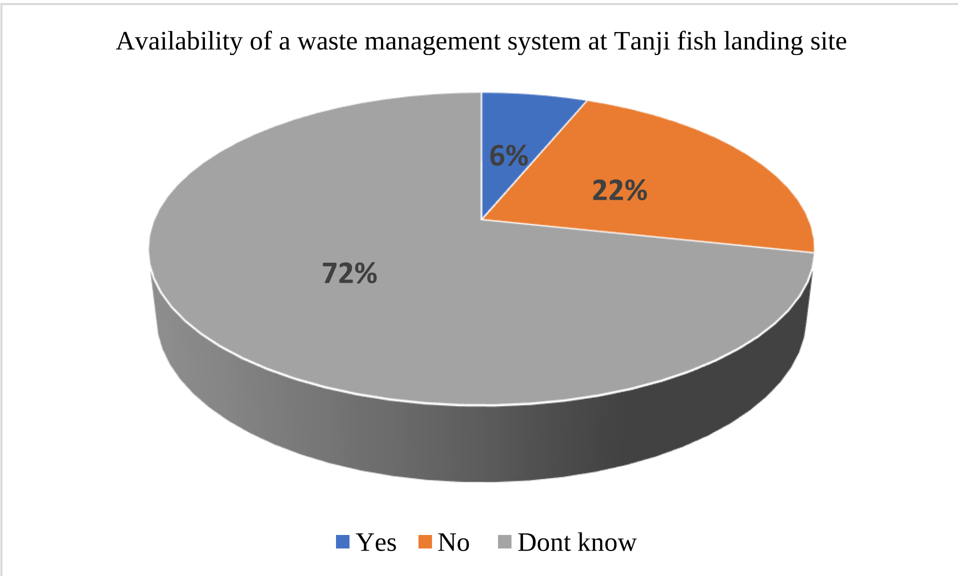
Some results from the administered questionnaires.

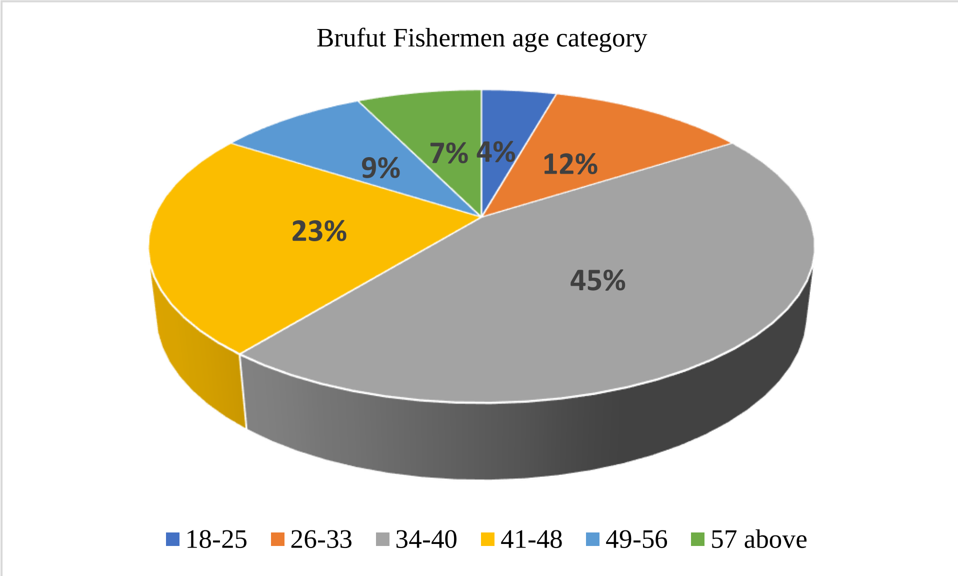


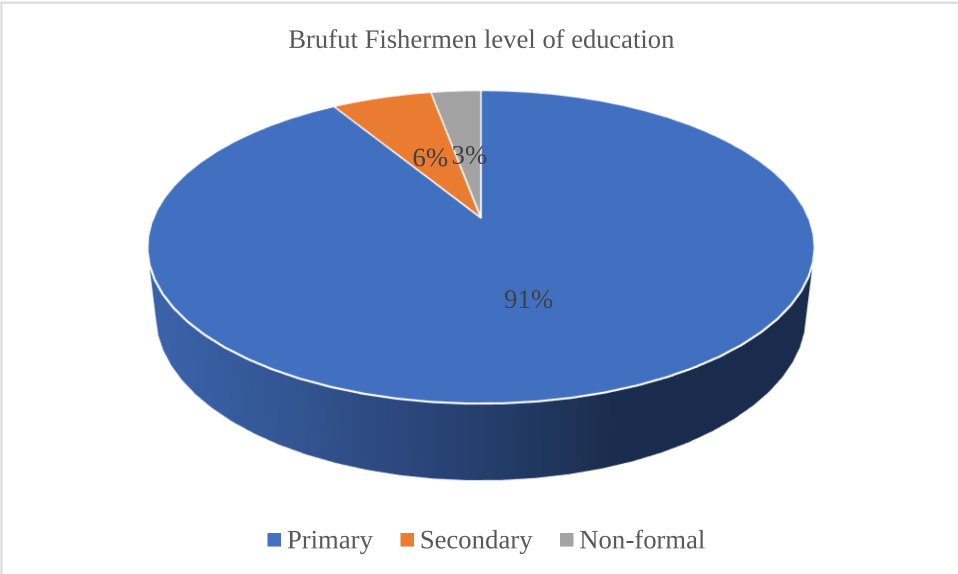


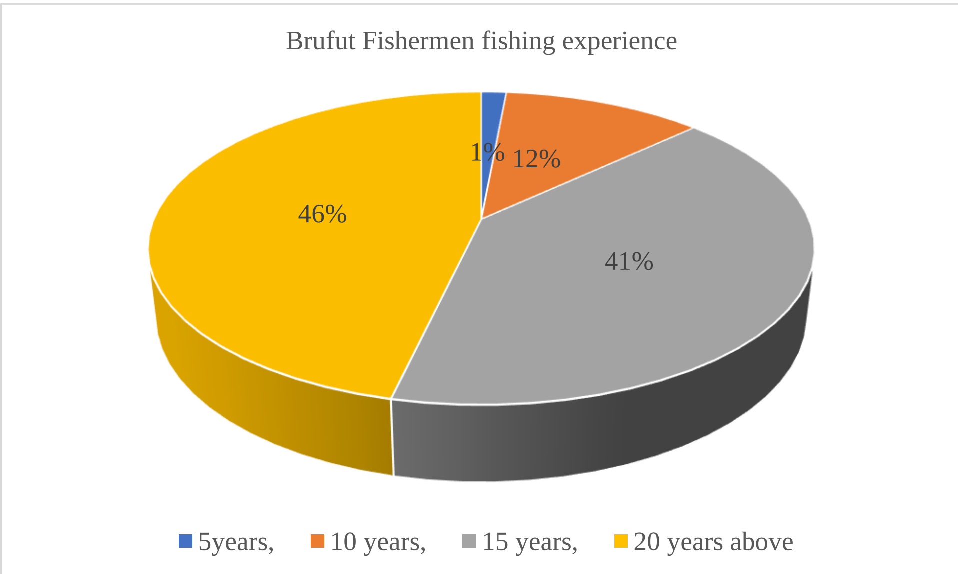

Issues realise at Bijol Island by Tanji fishermen
6%
10%
19%
65%
waste issues
erosion
both waste and erosion
don't know

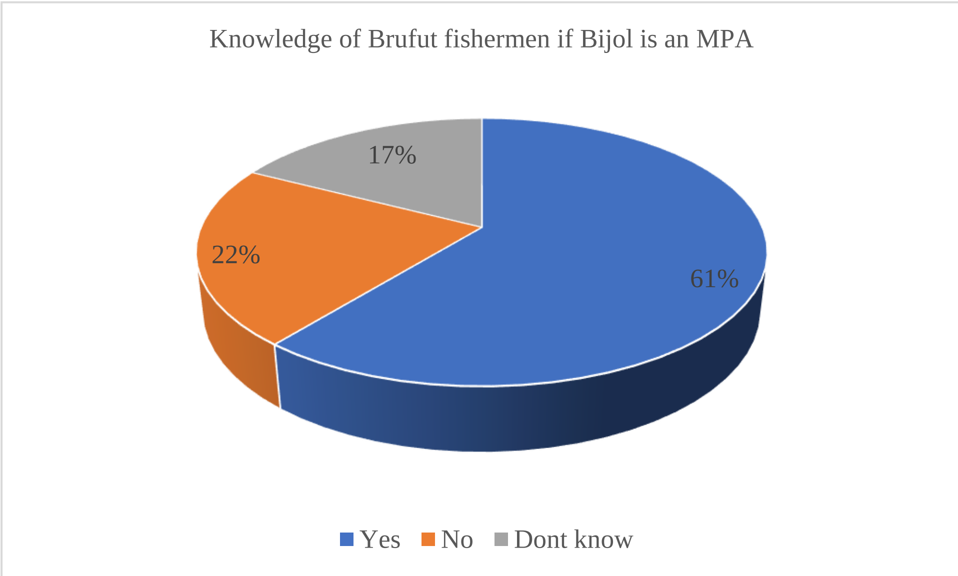

Knowledge of Tanji fishermen if Bijol is an MPA
8
11
62
Yes
No
Dont know


Availability of a waste management system at Tanji fish landing site
6%
22%
72%
Yes
No
Dont know


Brufut Fishermen age category
7%
4%
12%
9%
23%
45%
18-25
26-33
34-40
41-48
49-56
57 above


Brufut Fishermen level of education
6%
3%
91%
Primary
Secondary
Non-formal


Brufut Fishermen fishing experience
1%
12%
46%
41%
5years,
10 years,
15 years,
20 years above


Knowledge of Brufut fishermen if Bijol is an MPA
17%
22%
61%
Yes
No
Dont know