WORLD MARITIME UNIVERSITY

STAKEHOLDERS' PERSPECTIVE ON THE DEGRADATION OF SEAGRASS AND THE SIGNIFICANCE OF ITS RESTORATION TO CARBON SEQUESTRATION. A CASE STUDY OF ZANZIBAR, TANZANIA

SALAHUDEEN ABDALLAH MUSTAPHA

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): .....

(Date): 24Th September, 2023 .....

Supervised by: Dr. Johan Hollander

Supervisor's affiliation: World Maritime University

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Abstract

Title of Dissertation: **Stakeholders' Perspective on the degradation of seagrass and the significance of its restoration to carbon sequestration. A case of Zanzibar, Tanzania.**

Degree: **Master of Science**

This study investigates stakeholders' perspectives on seagrass degradation and the importance of its restoration for carbon sequestration in Chwaka and Fumba in Zanzibar - Tanzania, as well as professionals. Study participants include 66 individuals from 2 fishing communities, government officials, non-governmental organizations, and academic institutions labelled as professionals in this study.

It employs a qualitative method approach using questionnaires to seek the perceptions of community people and professionals and also to understand the drivers of seagrass degradation as perceived by local community stakeholders, including fisherfolk, seaweed farmers, gleaners, and professionals. It also explores the awareness of the community regarding the role of seagrass in carbon sequestration. 50% of the respondents from Chwaka were aware of carbon sequestration with regards to seagrass, compared to 13.3% from Fumba.

The respondents identified various impacts, like loss of fish catch, loss of invertebrate gleaning, loss of the natural beauty of the ocean, and coastal and shoreline erosion due to seagrass degradation in the study area. They attribute it to factors such as climate change, fishing activities, grazing from sea urchins, and pollution as the causes of the degradation. The chi-square test (x^2) shows that there is no significant difference from the study area in their perceptions of the impacts of seagrass degradation.

The study underscores the multifaceted benefits of seagrass restoration, reaffirming its pivotal role in marine ecosystems. These benefits encompass supporting fisheries, providing habitat, enhancing breeding grounds, and sequestering carbon, including blue carbon. The results aim to inform conservation and restoration strategies and management practices that address seagrass degradation while emphasizing the significant role seagrass restoration can play in mitigating climate change through carbon sequestration.

Understanding stakeholders' perspectives and integrating their views into conservation initiatives is crucial for the sustainable management of seagrass ecosystems in Zanzibar and beyond, ultimately contributing to global efforts to combat climate change and preserve marine biodiversity.

KEYWORDS: Seagrass, degradation, restoration, carbon sequestration, stakeholders, perceptions, blue carbon.

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List of Abbreviations

WI	Western Indian Ocean
WIOM	Western Indian Ocean Marine Science Association
MBCA	Menai Bay Conservation Area
IMS	Institute of Marine Science
NGO	Non-Governmental Organization

1.0 Introduction

Seagrass ecosystems, found in shallow coastal waters across the globe, represent a critical component of coastal ecosystems. These underwater meadows provide a wide range of ecosystem services, including habitat provision for various marine species, carbon sequestration, shoreline stabilization, and support for fisheries (Orth et al., 2006; Duarte et al., 2008; Unsworth et al., 2015). They are sustaining the livelihoods of millions of individuals globally and offering crucial ecological functions (Unsworth et al., 2019; Ambo-rappe et al., 20221). They are one of the planet's most prolific aquatic ecosystems and typically coexist with other significant primary producers like macroalgae (Duarte and Chiscano, 1999; Jones et al., 2022). Seagrass beds and meadows are found in shallow water depths of less than five meters (Aller et al., 2017; Belshe et al., 2018). Seagrass can grow to a maximum depth of up to 50m, depending on water clarity (Hemminga and Duarte, 2000; Ismail, 2021). Some of the species are found in tropical environments, while others do so in waters that are more temperate (Short et al. 2007). Fourteen species of seagrass have been discovered off the East African coast and islands of the West Indian Ocean (WIO) (Gullström et al. 2002; Ochieng and Erftemeijer 2003; Gullström et al. 2006; Duarte et al. 2012). Due to poor mapping caused by accessibility issues, it is not clear how much actual seagrass bed area exists (Esteban et al. 2018). Not only does this apply to the Western Indian Ocean region, but the actual global area covered by seagrasses is still unknown due to the lack of extensive inventories. This is probable because seagrasses grow partially submerged or submerged and the most popular mapping techniques used in vegetation assessments have limitations. Integrating coastal marine management and the welfare of seagrass meadows will be improved, which will benefit coastal communities, marine ecosystems, and everyone who enjoys the beautiful beaches in Zanzibar. Adequate monitoring of density and distribution, addressing human threats to seagrass meadows, and consulting with coastal communities on sustainable methods for maintaining seagrasses. Seagrass beds have been deteriorating and partially recovering

since the 1990s, according to a timeline analysis of their health state in Zanzibar (Nchimbi & Lyimo, 2019), although degradation brought on by anthropogenic impacts still poses a threat to their long-term health.

The meadows affect the physical environment in several ways, including reducing current flow and water energy (Fonseca and Fisher, 1986; Jones et al., 2022), increasing particle deposition and stabilising bottom sediment (Terrados and Duarte, 2000), preventing coastal erosion (Almasi et al., 1987), and influencing nutrient dynamics (Romero et al., 2006). It has been estimated that about $19,000 a year is considered the value of one hectare of seagrass, equivalent to two football fields (Reynolds, 2018).

Despite their ecological and socio-economic significance, seagrass ecosystems are facing growing threats from a range of anthropogenic pressures, including coastal development, pollution, overfishing, and climate change (Waycott et al., 2009; Short et al., 2011).

As coastal areas continue to experience rapid urbanization and industrialization, seagrass degradation has become an issue of increasing concern (Unsworth et al., 2014). The loss of seagrass meadows can result in the decline of important fisheries, increased coastal erosion, and reduced carbon sequestration capacity (Fourqurean et al., 2012; Cullen-Unsworth et al., 2014). To address these challenges, seagrass restoration has gained attention as a potential tool for mitigating seagrass loss and enhancing the resilience of these ecosystems (Van Katwijk et al., 2016). However, successful seagrass restoration is a complex endeavour, involving ecological, social, and economic dimensions. Since seagrass meadows are declining at a rapid rate and restoration is consequently necessary, there have been several seagrass restorations projects in Tanzania. A project to restore damaged seagrass habitats carried out by the University of Dar es Salam in Tanzania was supported by the Western Indian Ocean Marine Science Association (WIOMSA). The results show a very high survival rate of 49.1% for plugs with a diameter of 10 cm, compared to 40.7% for plugs with a diameter of 7 cm (Wegoro et al., 2022). Contrary to this, the global assessment of

seagrass restoration programs states that more than 30% survival is a significant achievement that makes the restoration project highly effective.

Understanding the perceived threats to seagrass degradation, the impacts of such degradation, and the benefits and challenges of restoration is essential for designing effective restoration strategies. Moreover, the role of stakeholders and their collaboration in restoration efforts cannot be overstated, as it directly influences the outcomes of these initiatives (Mazor et al., 2020).

Understanding the complex dynamics of seagrass ecosystems and the perceptions of their importance and threats requires a multifaceted approach. A crucial aspect of this understanding is the examination of stakeholders' perspectives, as their engagement and collaboration are instrumental in the conservation and restoration of seagrass habitats (Tallis et al., 2008). Stakeholders in seagrass ecosystems can be categorized into several groups, each with unique interests and roles, including fishers, government institutions, gleaners, seaweed farmers, and academic and research institutions. Examining how these stakeholders perceive seagrass ecosystems, their benefits, and the challenges they face in safeguarding these habitats is essential for designing effective conservation and restoration strategies. Effective conservation and management methods depend on understanding stakeholder views and the importance of seagrass restoration, particularly in terms of carbon sequestration. This study aims to investigate the stakeholders' perspective on seagrass degradation and the significance of its restoration to carbon sequestration. By analysing perceptions, challenges, and opportunities, this study seeks to contribute valuable insights into the development of sustainable seagrass management and restoration strategies.

1.1 Ecology of Seagrass Ecosystem

Seagrasses are marine angiosperms that form extensive underwater meadows in coastal regions around the world (Short et al., 2007). These ecosystems are characterized by their ability to thrive in shallow, sunlit waters, where they play a crucial role in stabilizing sediments, improving water quality, and providing essential

habitat for a diverse array of marine organisms (Orth et al., 2006). The structure of seagrass beds, composed of both below-ground and above-ground shoots rhizomes, allows them to trap and store significant amounts of carbon, making them an essential component of blue carbon ecosystems (Duarte et al., 2013).

Seagrasses are known to support a wide variety of marine life, including commercially important fish species, invertebrates, and endangered species such as sea turtles (Unsworth et al., 2015). Their intricate plant structure provides nursery grounds for juvenile fish and invertebrates, offering protection from predation. Furthermore, seagrass meadows contribute to global biodiversity and support recreational and commercial fisheries (Beck et al., 2001).

1.2 Threats to Seagrass Ecosystem

Despite their ecological importance, seagrass ecosystems face multiple threats that have led to widespread degradation and loss. Coastal development, which often results in increased nutrient runoff and sedimentation, can smother seagrass beds (Halpern et al., 2008). Pollution from agriculture, industry, and urban areas introduces contaminants and excess nutrients that can disrupt seagrass growth and water quality (Short et al., 2011). Overfishing, especially of herbivorous species that help control algal growth, can indirectly harm seagrass meadows (Hughes et al., 2018).

Climate change-related factors, such as rising sea temperatures and ocean acidification, pose additional challenges to seagrass health (Short et al., 2011). Increased sea levels and more frequent and severe storms can result in physical damage to seagrass beds and coastal erosion (Mazda et al., 2006). These cumulative stressors threaten the resilience and long-term survival of seagrass ecosystems (Waycott et al., 2009).

1.3 Seagrass Restorations and Its challenges

In response to the global decline of seagrass meadows, seagrass restoration initiatives have gained traction as a potential solution. Successful seagrass restoration efforts require a deep understanding of the ecological requirements of seagrasses, the

selection of suitable planting sites, and effective restoration techniques (Van Katwijk et al., 2016). However, seagrass restoration is not without its challenges.

Strong wave energy, technical complexities, and the need for long-term monitoring and adaptive management are some of the challenges faced by restoration practitioners (Campbell et al., 2014). Moreover, the success of restoration efforts often depends on the involvement and collaboration of various stakeholders, including local communities, scientists, and policymakers (Mazor et al., 2020). The effectiveness of restoration projects is closely tied to the engagement and support of these stakeholders.

1.4 Role of Stakeholders in Seagrass Conservations and Restoration

Stakeholder involvement is a critical factor in seagrass restoration success. Local communities who rely on seagrass for their livelihoods, as well as government agencies and non-governmental organizations (NGOs), play essential roles in restoration efforts (Mazor et al., 2020). Effective stakeholder collaboration can lead to more sustainable and community-supported restoration projects.

However, the level of stakeholder involvement, the roles they play, and their perceptions of seagrass degradation and restoration can vary significantly. Understanding these variations and the dynamics of stakeholder engagement is crucial for designing tailored restoration strategies that account for local contexts and priorities.

1.5 Seagrass in Zanzibar

The study was conducted in Zanzibar, the island of the United republic of Tanzania, East Africa. Zanzibar is located in the Indian Ocean and consists of several islands. Zanzibar is a popular tourist destination known for its stunning beaches, rich cultural heritage, and historical sites like Stone Town. Tourism is a major driver of the local economy. Other economic activities include fishing and agriculture (Moreira-Saporiti et al., 2021). Zanzibar's waters are known for their coral reefs and seagrasses, which are vital for biodiversity and protect the coastline from erosion. Zanzibar experiences significant tidal fluctuations due to its location along the Indian Ocean. The changing

tides are a unique feature and influence various activities, including fishing. Furthermore, about one-fifth of the population in Zanzibar earns a living through fishing, which generally employs low-tech, conventional methods such as wooden basket traps, seine nets, spears, and handlines (de la Torre-Castro et al., 2014; Khamis et al., 2017; Staehr et al., 2018). These technologies, together with illegal ways of fishing, affect the seagrass meadows. Seagrass-dominated areas are the preferred fishing grounds for small-scale fisheries in Zanzibar (la Torre-Castro et al., 2014; Hedberg et al., 2018)

The study was conducted specifically at Chwaka and Fumba coastal villages. Chwaka Bay is situated along the shores of Indian ocean is known for its traditional fishing (Moreira-Saporiti et al., 2021) located at the east coast of Unguja Island, Zanzibar, Tanzania (6° 6–13′ S, 39° 24–31′ E). Chwaka is a semi-enclosed tidal embayment (~50 km^2) characterised by soft sediment substrata, that are largely covered with seagrasses and macroalgae (Gullström et al., 2022). Chwaka Bay is a unique "hotspot" for seagrass diversity, with eleven species recorded. These species range in size from small, quickly growing "pioneer" species like *Thalassodendron ciliatum* and *Halophila stipulacea* to large, slowly growing "climax species" with thick and long leaves like *Enhalus acoroides* (Purvis et al., 2021). As a result, it is not unexpected that the small-scale subsistence fishery in Chwaka Bay can be considered a seagrass fishery, with the majority of the species caught being closely related to the seagrass meadows (de la Torre-Castro and Rönnbäck 2004; de la Torre-Castro 2006). The second coastal village was Fumba Peninsula, which is located on the southwest coast and relies primarily on small-scale fishing immediately off the coast. It is lying under the Menai Bay Conservation Area (MBCA) (Purvis and Jiddawi, 2023).

Figure 1: The map showing the study sites at Fumba and Chwaka bay source: Orangesmile,2002

1.6 Objectives

1. To identify threats and describe the impact of seagrass degradation.
2. To evaluate seagrass restoration's economic, social and environmental benefits for blue carbon sequestration and storage.
3. To examine the role of stakeholder collaboration and partnerships in enhancing the effectiveness of seagrass restoration efforts for blue carbon.

Additionally, the aims raise additional questions that may advance to the objectives, including:

1. How do stakeholders view degradation of seagrass habitats and its impact on blue carbon?
2. To what extent do stakeholders understand the role of seagrass in blue carbon sequestration and the benefits of its restoration?
3. How can stakeholders collaborate to promote effective restoration and management of seagrass habitats for blue carbon?

2.0 Material and Methods

2.1 Sampling Design

A total of 66 individuals participated in this study, including 60 randomly selected from both fishers, gleaners and seaweed farmers from Chwaka and Fumba coastal communities whose livelihoods depend on seagrass meadows (Table 1). Others from government institutions, academic institutions, and Non-Governmental Organizations, hereby referred to as professionals by this research. Two governmental officials (the fisheries and environmental officers) from the Ministry of Blue Economy and Fisheries Zanzibar, three academia, two from the Institute of Marine Sciences and one from the secondary school, Zanzibar National Service Technical School to represent the academic institutions. Also, one respondent was interviewed from Western Indian Ocean Marine Sciences Association (WIOMSA) to represent a non-governmental organization. Again, 20 fishers, five seaweed farmers and five gleaners were interviewed from Chwaka. For Fumba, 20 fishers and 10 gleaners were interviewed since there was no seaweed farming in the community; hence no seaweed farmers available. These stakeholders were selected by considering the closer association and dependence of their livelihoods on seagrass meadows. Respondents were identified by purposive sampling techniques and with the use of a snowball approach, with recommendations for additional participants solicited from initial contacts within each stakeholder group (Owusu and Adjei, 2021; Adjei and Overa, 2019; Penney et al., 2017). All participants had understanding and clear picture of the seagrass meadows before in the community and how it has been degraded now.

Table 1: Describing number respondents for the study. (Community and Professionals)

Community:			
	Chwaka (n = 30)	Fumba (n= 30)	Total (n = 60)
Fisher	20	20	40
Gleaners	5	10	15
Seaweed farm	5	0	5
Professionals:			
		(n=6)	
Government officials	-	-	2
Academia	-	-	3
NGO	-	-	1

2.2 Data Collection

The study used qualitative methods to take stakeholders' perspective on the degradation of seagrass and the significance of its restoration to carbon sequestration. The empirical data consists of a questionnaire (appendix A&B) survey of 60 respondents from the communities and six officials from different institutions as part of the stakeholders.

The survey was conducted from 10th July – 28th July in Zanzibar. Questionnaires were used to collect the data for the study. The community questionnaire covered two broads thematic: demographic information, and perception on seagrass degradation and its significance to carbon sequestration. The demographic section screened respondents' age, gender, occupation and how long has the person been working in relation to seagrass. The questionnaire included open ended questions which allow the respondents to freely talk about knowledge and experience about seagrass, carbon sequestration and any other relevant issues concerning the project topic. The survey lasted between 20-30 mins on average per person. To assess participants' perceptions, specific questions asked included what are the main drivers of seagrass degradation in your community, what role different stakeholders (e.g.,

government, NGOs, local communities) should play in seagrass restoration (Appendix A).

Figure 2: Degraded seagrass meadows at Chwaka
Source: Salahudeen, 2023

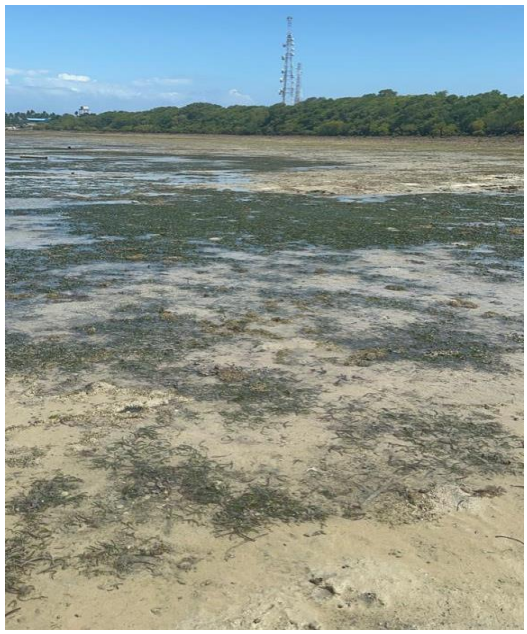

Figure 3: Degraded seagrass meadows at Fumba
Source: Salahudeen, 2023

Figure 4: Gleaners collecting invertebrates at Chwaka bay
Source: Salahudeen, 202

Figure 5: Gleaning invertebrates at Fumba
Source: Salahudeen, 2023

2.3 Data Analysis

The qualitative data from the semi structured questionnaires were analysed through content analysis, coded and organized into a short meaningful sentence. Microsoft excel was used to organized the respondents' data and the software Python (Python version 3.9) to undertake the statistical analysis and for descriptive statistics to summarize and present the results. Chi-square test was employed for independence to conduct inferential statistical analysis, examining the varying perceptions of stakeholders across different sites with respect to the significance of seagrass restoration for blue carbon. The significance level (alpha) was set at $\alpha < 0.05$ to identify statistically significant variations in stakeholder perceptions among the sites.

3.0 Results

3.1 Threats to seagrass in the study areas.

3.1.1 Threats to seagrasses

The chi-square test (χ^2) results indicate no significant association between study areas and the responses on the threats for seagrass degradation (χ^2 = [19.50], df = [0.05], p =0.24).

The perception of causes and/ or threat for seagrass degradation were almost similar for all sites. The respondents, whose livelihoods depends on seagrasses revealed a wide range of threats for seagrass degradation (Table 2). The highest percentage of respondents pinned the climate change (86.67%) and fishing activity (63.63%) as the main threats for seagrass degradation. Other threats scored a relatively lower responses including grazing from sea urchin, gleaning activities, seaweed farming and pollution. In Fumba, there was no response on pollution and gleaning; they perceived that they were not part of the threats to the degradation of seagrass (Table 2).

Table 2: Perceived response on the threats for seagrass degradation in the study areas for non-professionals

Seagrass threats	% Response			Chi-square test for association
	Chwaka bay (n = 30)	Fumba (n= 30)	Mean (n = 60)	
Climate change	80.00	93.33	86.67	$\chi2$ = 19.50
Fishing activity	63.33	63.33	63.33	p = 0.24
Pollution	6.67	0.00	3.33	
Grazing from sea urchin	56.67	3.33	30.00	
Gleaning	3.33	0.00	1.67	
Seaweed farming	3.33	13.33	8.33	

Participants from the professionals, perceive threats to seagrass degradation with little difference from those of the community. The threats were almost the same, but as the community people prioritizes climate change as the main threat, the professionals feel that illegal fishing activities are the highest threat, followed by

seaweed farming. Other threats were also mentioned, like boating and anchoring, strong waves, and grazing by sea urchins, as major threats. Some threats also scored relatively low, like pollution and tourism (Figure 6).

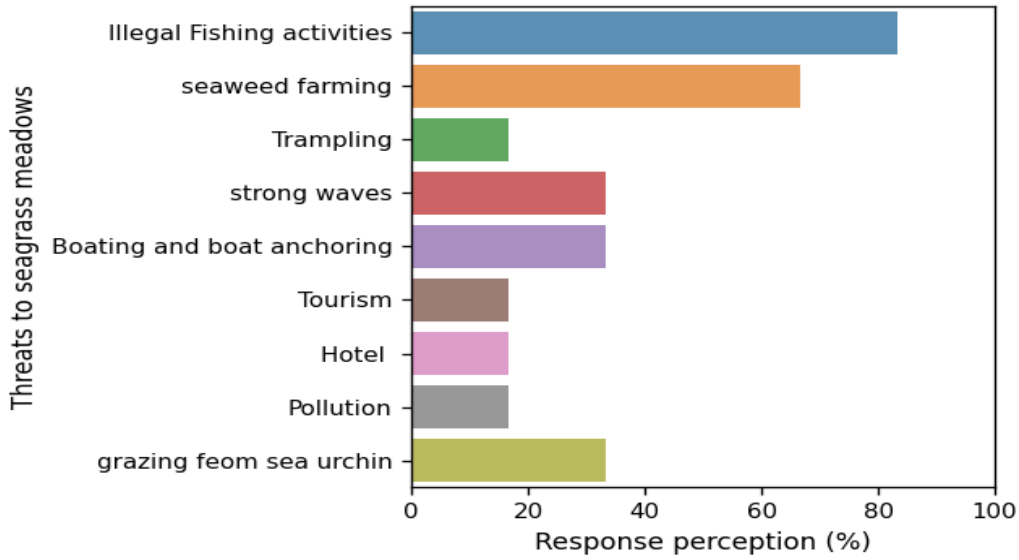

Figure 6: Multiple response analysis on the threats to seagrass meadows by the study professionals

3.1.2 Impacts of Seagrass degradation

Furthermore, the respondents identified various impacts that had been arising due to seagrass degradation in the study areas. The chi-square test ($\chi 2$) showed that the perception of respondents from Chwaka and Fumba was not significant different ($\chi 2$= 24, $p>0.05$). Generally, loss of fish catch (43.30%) and loss of invertebrate gleaning (21.70%) were perceived as the main impacts of seagrass degradation (Table 3). Loss of the natural beauty of the ocean, coastal and shoreline erosion, poverty and sandbar formation were identified with less scores. The loss of invertebrate diversity scored the highest perceived impact at Fumba, while the decline in fish stocks scored the highest in Chwaka.

Table 3: Perceived response on the impact of seagrass degradation in the study areas

Effect of seagrass degradation	% Response			Chi-square test for association
	Chwaka bay (n = 30)	Fumba (n= 30)	Overall (n = 60)	
Loss of fish catch	53.3	33.3	43.3	$\chi 2 = 24.00$
Loss of the natural beauty of the ocean	16.7	16.7	16.7	p = 0.24
Coastal erosion	13.3	10.0	11.7	
Poverty	3.3	6.7	5.0	
Loss of invertebrate gleaning	13.3	30.0	21.7	
Sandbar's formation	0.0	3.3	1.7	

The professionals identify loss of ocean beauty as the main effect of seagrass degradation, followed by loss of fish catch. Other effects such accelerating poverty, loss of revenue and discouraging tourism got similar and lowest scores (Figure 7).

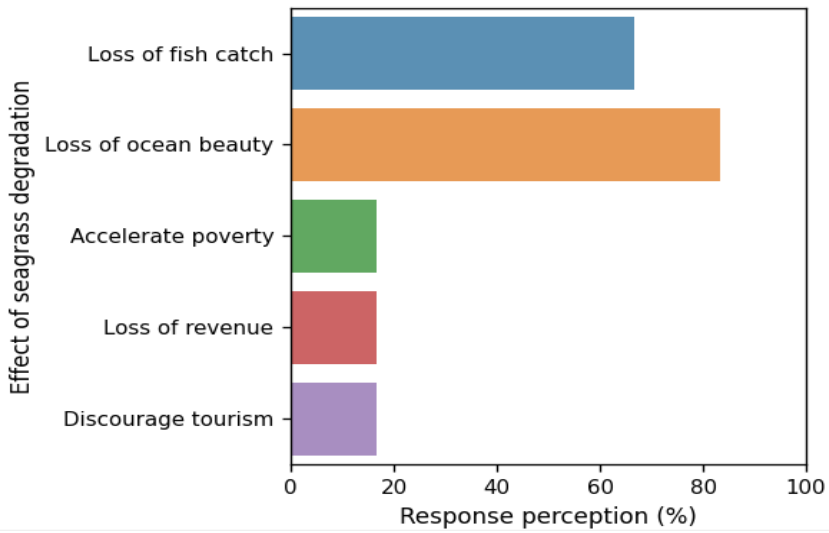

Figure 7: Multiple response analysis on the impacts of seagrass degradation by the professionals

3.2 Economic, social and environmental benefits of seagrass for blue carbon sequestration and storage

3.2.1 Challenges for seagrass restoration

Generally, the respondent identified several factors that might hinder seagrass restoration. Strong wave energy has given highest response as major challenge or factor hinder seagrass restoration programme (40 %) where by the highest score being recorded at Fumba. The challenge was protecting the restored plots, funding, fishing activity, fishers themselves, threats, technicality. On the other hand, 15% and 6.7% of the respondents had no ideas and no challenge, respectively (Figure 4). Furthermore, the Chi square ($\chi 2$) indicated no significance association between study areas and perception responses ($\chi 2 = 30$, $p > 0.05$) (Table 4).

Table 4: Perceived response on the challenges for seagrass restoration in the study areas

Seagrass restoration challenges	% Response			Chi-square test for association
	Chwaka bay (n = 30)	Fumba (n= 30)	Overall (n = 60)	
Strong wave	23.3	56.7	40.0	$\chi 2 = 30.0$
Funding	10.0	0.0	5.0	$p = 0.222$
Fishing activity	23.3	6.7	15.0	
Fishers	6.7	6.7	6.7	
Technicality	26.7	6.7	16.7	
Protection	10.0	20.0	15.0	
Threats	10.0	0.0	5.0	
No idea	16.7	13.3	15.0	
No challenge	3.3	10.0	6.7	

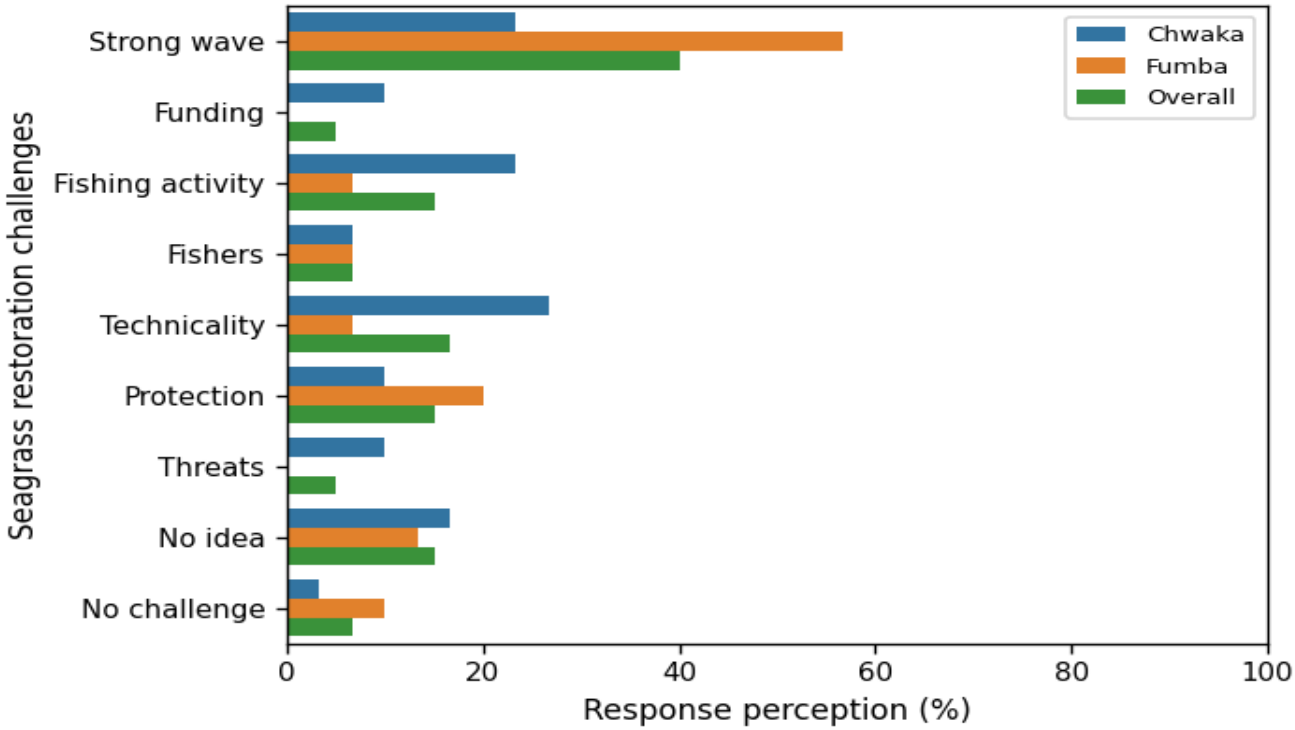

Figure 8: Multiple response analysis on the challenges on seagrass restoration in the study areas

3.2.2 Stakeholders' knowledge on seagrass carbon sequestration

For Fumba, majority of responded had no idea on seagrass carbon sequestration (86.7%) which means they do not have any idea or knowledge about carbon sequestration, similar to 46.7% respondents from Chwaka. 50% of the respondents from Chwaka says yes, they have knowledge of what carbon sequestration is as compare to only 10% from Fumba (Figure 9).

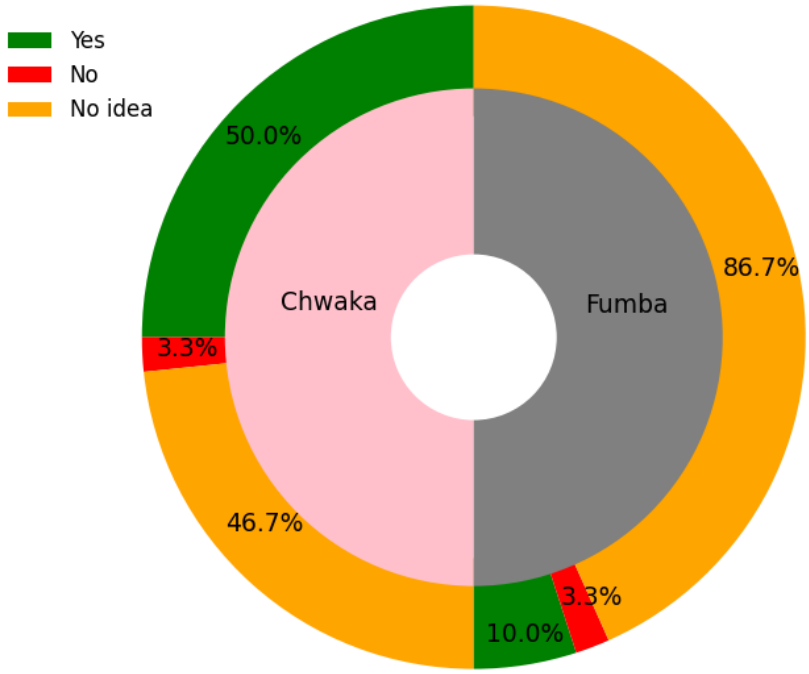

Figure 9: The donut pie chart for response on knowledge analysis on carbon sequestration in the study areas

3.2.3 Perceptions on social economic and environmental benefits of Seagrass restoration

With regard to the perceived on social economic and environmental benefits of seagrass restoration, in general, the respondents had identified numerous benefits offered by seagrass restorations. Such benefits include, support fisheries (90%), habitat provision (85%) and increases breeding grounds for both fish and invertebrates (41.7%). Other benefits are to stabilize seafloor, serves as feeding ground for some aquatic species, increase wave buffering capacity and also serves as feeds for some species. However, there was no significant association ($p > 0.05$) between study areas and responses on benefits provide by seagrass restoration (Table 5).

Table 5: Perceived responses on social economic and environmental benefits of Seagrass restoration

Seagrass restoration benefits	% Response			Chi-square test for association
	Chwaka bay (n = 30)	Fumba (n= 30)	Overall (n = 60)	
Support fisheries	80.0	100.0	90.0	$\chi 2 = 26.67$
Habitat provision	73.3	96.7	85.0	$p = 0.37$
Increase breeding grounds	26.7	56.7	41.7	
Increase feeding grounds	20.0	10.0	15.0	
Feeds	10.0	10.0	10.0	
Stabilize seafloor	26.7	26.7	26.7	
Ocean beautification				
Increase wave buffer capacity	3.3	10.0	6.7	

The professionals identify many benefits that are derived from restoring the degraded seagrass meadows and are not much different from what the respondents from the communities also identify: that it provides support in fisheries and habitat provision, as the majority of the respondents from the professionals' stated that it provides nursery grounds as part of supporting fisheries and also stabilizes the sea floor, providing habitat and feeding grounds for some species. They perceived that seagrass restoration would support tourism and also increase carbon sequestration (Figure 10).

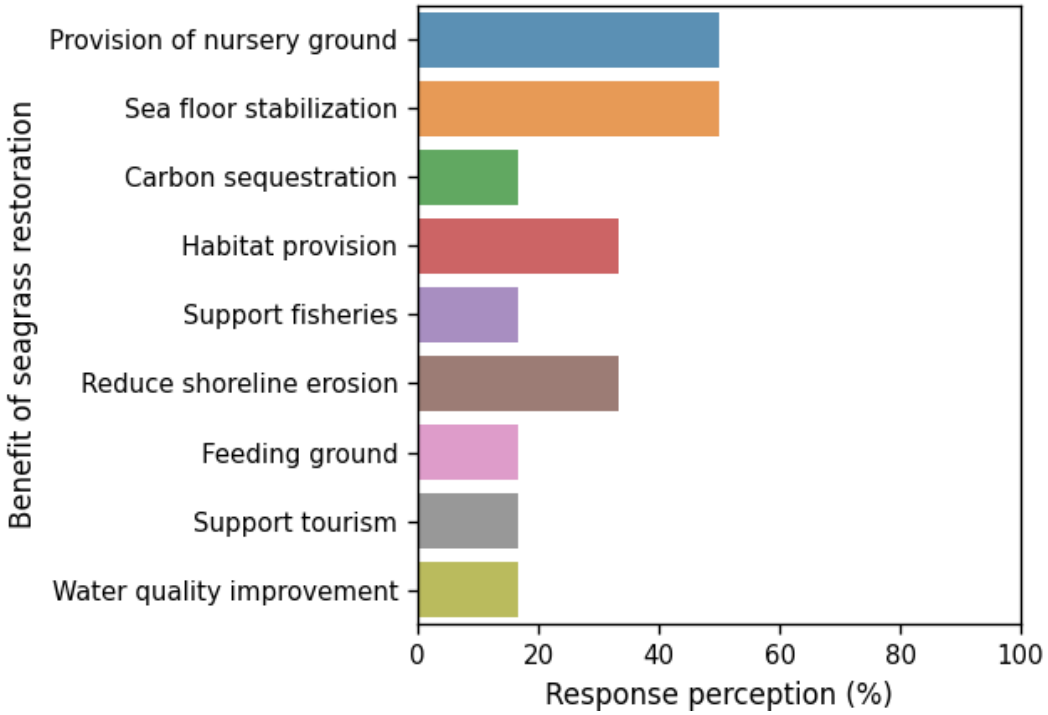

Figure 10: Multiple response analysis on social economic and environmental benefits of Seagrass restoration by the professionals.

3.3 The role of stakeholder collaboration and partnerships in enhancing seagrass restoration efforts for blue carbon

Figure 11 presents perceived response by survey respondents on the role of stakeholders on seagrasses restoration efforts in the study sites. Overall, 73.3% and 26.7 % of the respondents reported conservation and protection, respectively as a major role of stakeholders towards effective and sustainable seagrass restoration project. On the other hand, respondents highlight other roles including awareness rising (education (6.7%)), collaboration at every step of seagrass restoration effort (6.7%), forming association as for easing implementation of restoration project (1.7%) as well as to implement zoning and restricts any human activities at the designated seagrass restoration sites (1.7%).

Again, the respondents identified that they are poorly involved by the government to seagrass related projects. Generally, 98.7% of the surveyed respondents had never

been invited nor involved in any seagrass's restoration project either by the government or non-governmental agencies. The chi-square test ($\chi 2$) results indicate similar perception between Fumba and Chwaka ($p > 0.05$) (Table 6).

Furthermore, respondents highly indicated that the management structure for sustainable and effective seagrass restoration must involve both participatory and technocratic approach (58.3%). However, few respondents suggested the Participatory (Bottom-top approach) and Technocratic (Top-Down approach) as required management structure for effective and sustainable seagrass restoration.

The chi-square test (x^2) results indicate significant associations ($p = 0.037$) between the study areas and the management structure, whose significance level is less than 0.05. This means that the probability of observing such a level by random chance alone is less than 5%. So, the choice of management structures between the study areas is not uniform or the same. There is a likelihood that there are some reasons that influence the difference. Each site prioritizes its management structure differently (Table 7).

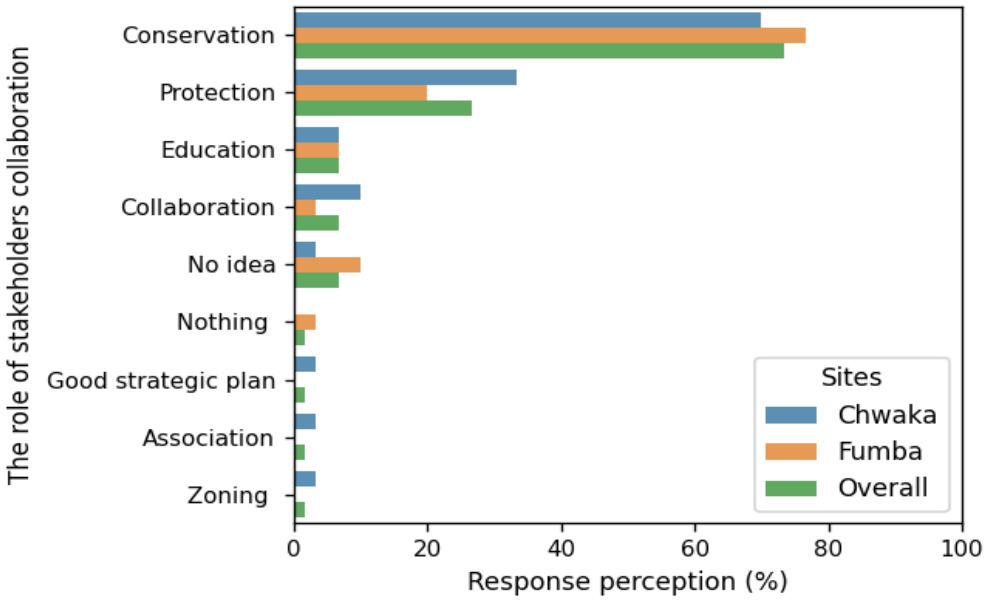

Figure 11: Multiple response analysis on role of stakeholders' collaboration and partnership on seagrasses restoration

Table 6: Perceived responses of stakeholders on invitation and involvement in seagrass project by the governmental agency

Involvement in seagrass project	% Response			Chi-square test for association
	Chwaka(n=30)	Fumba (n = 30)	Overall (n = 60)	
Yes	0.0	3.33	1.7	$\chi 2 = 1.65$
No	100	96.67	98.7	$p = 0.19$

Table 7: Perceived responses on the management structure of seagrass restoration projects

Seagrass management structure	% Response			Chi-square test for association
	Chwaka (n= 30)	Fumba (n = 30)	Overall (n = 60)	
Participatory (Bottom-top)	30	23.3	26.7	$\chi 2 = 6.56$
Technocratic (Top-Down)	20	10.0	15.0	$p = 0.037$
Both (Participatory/ Technocratic)	50	66.7	58.3	

The respondents from the professionals mentioned the need for stakeholders' collaboration as a major key to implementing any seagrass restoration project. About 90% of them perceived that collaborating makes people, especially the community members, feel a sense of ownership over the project, so they need to take very good care of it. Protection is the second highest, and they indicate the need to build capacity and create awareness to increase people's knowledge, and collaboration also helps because of knowledge diversity. The community people have traditional knowledge, which helps when it comes to implementation and protecting the seagrass meadows (figure 12).

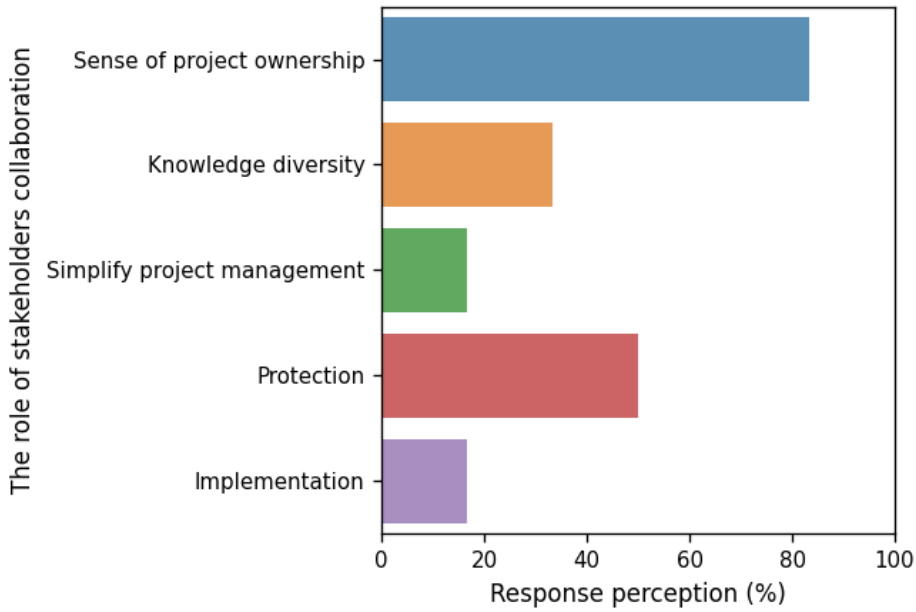

Figure 12: Multiple response analysis on role of stakeholders' collaboration and partnership on seagrasses restoration by the professionals.

4.0 Discussion

This study is the first to seek the perception of stakeholders on the degradation of seagrass meadows and the significance of restoring the meadows towards blue carbon in Zanzibar, Tanzania. The coastal sites around Zanzibar have seen a decrease in seagrass cover over time (Aller et al., 2019; Nchimbi and Lyimo, 2019). This research was carried out simultaneously with other research projects that also studied the perspectives of stakeholders on the degradation and restoration of mangrove towards blue carbon in Jozani, Zanzibar as well as stakeholder awareness, importance, and significance of seagrass towards blue carbon in Wasini, Kenya. The local stakeholders in Kenya, like in Fumba and Chwaka, are aware of the importance of the seagrass ecosystem and the significance of restoring degraded seagrass meadows. This is due to earlier restoration and some ongoing projects that were carried out in Wasini, Kenya, which increased community awareness. In the Jozani community, Zanzibar, as in Wasini in Kenya, the majority of the community people were aware of blue carbon and carbon sequestration because of many restoration projects on mangrove and on carbon sink trade, so the level of awareness on carbon sequestration is high unlike in Chwaka and Fumba where majority were not really aware of carbon sequestration.

4.1 Perceived Threats for Seagrass Degradation

The study's results indicate that climate change and fishing activity are perceived as the primary threats to seagrass degradation across the surveyed study areas. This aligns with the growing recognition in scientific literature that climate change, including rising sea temperatures and ocean acidification, can have adverse effects on seagrass ecosystems. Similarly, fishing activity, particularly destructive or unsustainable practices, has been well-documented as a significant threat to seagrass meadows.

These findings are consistent with previous research conducted by Mazarrasa et al. (2015) and Waycott et al. (2009), which also identified climate change and fishing activity as key threats to seagrass ecosystems. Moreover, Short et al. (2014) and Orth et al. (2006) have highlighted the detrimental effects of climate change on seagrass

habitats, emphasizing rising sea temperatures and ocean acidification as major contributors.

Notably, the study found that pollution and gleaning were not considered significant threats in Fumba, suggesting potential variations in local perceptions or environmental conditions. This finding is in line with the work of Björk et al. (2008), which emphasized the importance of site-specific factors in understanding threat perceptions. However, I found in the test results, indicating no significant association between study areas and threat responses, suggest that perceptions of climate change and fishing as primary threats are relatively consistent across different surveyed sites. According to findings from a different study by Mazarrasa et al. (2008), blue carbon and the environmental restrictions on seagrass habitats are both impacted by climate change. This is confirmed once more in this study, as local stakeholders in the research area identified climate change as the main concern.

This implies a broad consensus among the surveyed communities about the most pressing threats to seagrass ecosystems, similar to the results reported by Unsworth et al. (2019, 2018) and Fonseca et al. (2014).

4.2 Impacts of Seagrass Degradation

Respondents identified loss of fish catch and loss of invertebrate gleaning as the primary impacts of seagrass degradation, this is no difference to a study done by Unsworth et al, (2018) in Indonesia as declining state of the fisheries resources that seagrass meadows support is as a result of seagrass declining. These findings align with previous research indicating that seagrass meadows provide essential nursery and feeding grounds for many commercially and ecologically valuable species of fish and invertebrates (Unsworth et al., 2019; Beck et al., 2001). The loss of these habitats can have cascading effects on local fisheries and biodiversity (Jackson et al., 2017). Apart from the socio-economic benefits of seagrass, it has environmental benefits, of which beautifying the ocean is one of it. When the seagrass is degraded, it reduces the beauty in a way that reduces tourism activities in that particular area and eventually reduces

revenue. Also, the effects of seagrass degradation reduce fish catch and accelerate poverty, according to the responses from the professionals

Interestingly, there is a difference in perception between professionals and community members. Professionals tend to focus more on the impact on ocean beauty and fish catch (Heck et al., 2003). This divergence in perception may stem from the professionals' broader perspective, considering economic and environmental factors, while community members may be more attuned to direct livelihood impacts (Díaz et al., 2019) and echoes the findings of Heck et al. (2003) which underscores the importance of bridging the gap in perception to develop comprehensive conservation strategies.

Furthermore, the finding from this study indicated similar perceptions across different areas and a significant difference between professionals and community members underscore the importance of involving diverse stakeholders in seagrass conservation efforts to ensure a comprehensive understanding of the impacts (Pendleton et al., 2012).

4.3 Seagrass Restoration's Benefits and Challenges

The study underscores the multifaceted benefits of seagrass restoration, reaffirming its pivotal role in marine ecosystems. These benefits encompass supporting fisheries, providing critical habitat, enhancing breeding grounds, and sequestering carbon, including blue carbon. These findings align seamlessly with the broader ecosystem services offered by seagrass meadows, as emphasized by Fourqurean et al. (2012) and Lavery et al. (2013). The significance of these ecosystem services extends beyond ecological considerations, encompassing socioeconomic and climate change mitigation aspects.

Seagrass restoration, like many ecological restoration efforts, is not without its challenges. Our study identified hurdles such as strong wave energy and technical complexities, which are commonly encountered in similar restoration projects. These challenges echo the broader obstacles discussed in the field of ecological restoration, as explored by Campbell et al. (2007) and Govers et al. (2014). These difficulties

underscore the need for innovative engineering solutions and robust collaborations among scientists, policymakers, and local communities. Such interdisciplinary approaches, as advocated by van Katwijk et al. (2016) and Boström et al. (2018), are vital for overcoming these challenges and ensuring the success of seagrass restoration efforts.

Again, the results indicate that study areas do not significantly influence perceptions of the benefits and challenges associated with seagrass restoration. This finding suggests that the recognition of these benefits and challenges is relatively consistent across different geographical locations. This consistency is reflective of the universal nature of the issues surrounding seagrass restoration, as highlighted by Paling et al. (2019). It further underscores the importance of a standardized and adaptable approach to seagrass restoration, one that can be applied effectively across diverse marine environments.

4.4 Stakeholders' knowledge on seagrass carbon sequestration

The local community members, who were involved in this research as stakeholders and included fishermen, seaweed farmers, and gleaners, had very little knowledge about seagrass's capacity to store carbon. In contrast to Chwaka, where only a small percentage of respondents were knowledgeable of carbon sequestration in relation to seagrass, the Fumba respondents had a greater understanding of the topic. The variation may be as a result of a seagrass restoration awareness project carried out in the Fumba community by the Indo-Pacific Seagrass Network and Western Indian Ocean Marine Science Association, which gave them the chance to raise awareness about carbon sequestration. In accordance with the findings of the Orth et al. (2006) study that concluded that in order to optimize the potential for seagrass restoration to carbon sequestration, it was necessary to re-connect it with public knowledge and understanding.

4.5 Stakeholder Collaboration and Partnerships

This study underscores the critical role played by various stakeholders in seagrass restoration efforts. The identified stakeholders include fishers, seaweed farmers, gleaners, fisheries officials, environmental officials, non-governmental organization, and academics, each contributing their unique perspectives and expertise to the restoration process. This multi-level engagement approach aligns with the recommendations of Ehlers et al. (2021) and Beck et al. (2011), who emphasize the importance of involving diverse stakeholders in seagrass restoration projects. This inclusivity ensures a more holistic and effective restoration strategy, as it draws upon a wide range of knowledge and experiences.

One noteworthy finding of this study is the limited involvement of stakeholders in government or NGO-led seagrass restoration initiatives. This highlights a significant opportunity for improving stakeholder engagement strategies, particularly in ensuring that local communities have a meaningful voice and a sense of ownership in restoration efforts. This observation echoes the sentiments expressed by Tallis et al. (2008), who stress the importance of community involvement and empowerment in conservation and restoration projects. Empowering local communities to actively participate in decision-making processes not only enhances the sustainability of restoration efforts but also fosters a sense of responsibility and stewardship among community members. But unfortunately, there is no ongoing restoration program currently going on at the study sites.

Furthermore, the results indicated similar perceptions between different geographical areas, and the consistent emphasis on collaboration and protection by professionals, further underscore the significance of building strong partnerships in seagrass restoration initiatives. These partnerships bridge the gap between scientific expertise and on-the-ground implementation, facilitating the translation of research findings into effective conservation and restoration actions. Trevathan-Tackett et al. (2015) provide support for this approach, emphasizing the importance of collaborative efforts in seagrass ecosystem management.

This study identifies various stakeholders, including fishers, seaweed farmers, gleaners, fisheries officials, environmental officials, and academics, as playing key roles in seagrass restoration efforts. These findings align with the importance of multi-level engagement in seagrass restoration efforts, as emphasized by Ehlers et al. (2021) and Beck et al. (2011).

The study's finding regarding the lack of involvement in government or NGO-led projects highlights opportunities for enhancing stakeholder engagement strategies, ensuring that local communities have a voice and ownership in restoration efforts, echoing the sentiments of Tallis et al. (2008). I found the results indicating similar perceptions between different areas and the emphasis on collaboration and protection by professionals underscore the significance of building strong partnerships in seagrass restoration initiatives, as supported by Trevathan-Tackett et al. (2015).

4.6 Knowledge Gap and Restoration Efforts

The acknowledgment of knowledge gaps in seagrass restoration is a critical aspect of our study, and it aligns with the dynamic and evolving nature of ecological restoration science. Ecological restoration is an interdisciplinary field that continually evolves as new research findings emerge and as we gain a deeper understanding of complex ecosystem dynamics. Seagrass restoration, like other ecological restoration efforts, faces ongoing challenges and uncertainties that necessitate adaptive and research-based strategies.

One of the fundamental takeaways from this study is the recognition that seagrass restoration initiatives must be adaptable and based on empirical evidence. The influence of various factors on restoration outcomes, including environmental conditions, local ecological interactions, and the specific species composition of seagrass meadows, highlights the need for a nuanced and context-specific approach. The evolving nature of ecological restoration science underscores the importance of continuous research and monitoring to refine and improve restoration techniques.

Furthermore, our study underscores the importance of collaboration and community involvement in successful seagrass restoration efforts. While scientific expertise is

essential for designing and implementing restoration projects, local knowledge and community engagement play equally vital roles. The active participation of local communities and stakeholders fosters a sense of ownership and stewardship over restored seagrass ecosystems, ultimately enhancing the likelihood of long-term success.

Importantly, our study also recognizes the concept of blue carbon in seagrass restoration. Blue carbon refers to the carbon captured and stored by marine and coastal ecosystems, including seagrass meadows. Seagrasses are highly efficient at sequestering carbon dioxide from the atmosphere and storing it in their biomass and sediments. This carbon sequestration not only mitigates climate change but also provides additional ecological benefits by enhancing sediment stability and supporting diverse marine life.

Incorporating the concept of blue carbon into seagrass restoration efforts highlights the broader environmental and climate-related implications of these restoration projects. By restoring seagrass meadows, we not only enhance biodiversity and support local fisheries but also contribute to global carbon mitigation efforts. This recognition underscores the interconnectedness of ecological and climate-related objectives in marine ecosystem management and emphasizes the holistic and multifaceted nature of seagrass restoration.

5.0 Conclusions and Recommendation

This study, investigates various aspects related to seagrass degradation, restoration, and stakeholder involvement in different study areas within Zanzibar. The causes, effects, and challenges of these ecosystems in all the areas studied are almost the same. Through an analysis of the results and an in-depth discussion, several key findings have emerged, shedding light on the complexities and significance of seagrass ecosystems in coastal environments.

1. The research revealed that climate change and fishing activity were consistently perceived as the primary threats to seagrass degradation across the surveyed sites. This underscores the urgent need for climate mitigation strategies and sustainable fishing practices to protect these valuable coastal habitats. The perceived impacts of seagrass degradation, particularly the loss of fish catch and invertebrate gleaning, emphasize the critical role of seagrass meadows in supporting both local fisheries and biodiversity.
2. Interestingly, the study identified a disparity in perception between professionals and community members. This discrepancy underscores the importance of considering multiple perspectives in seagrass conservation efforts. Professionals, with their broader viewpoints, may offer valuable insights into the broader ecological and economic impacts, while community members, reliant on seagrass for livelihoods, provide critical local context.
3. The recognition of seagrass restoration's benefits, such as habitat provision and support for fisheries, underscores the importance of investing in restoration efforts. However, challenges, including strong wave energy and technical complexities, call for innovative solutions and close collaboration between researchers, policymakers, and local communities.
4. Stakeholders, identified as key players in seagrass restoration, have roles ranging from conservation and protection to raising awareness and implementing zoning. Our study highlights the need for inclusive and participatory approaches that engage various stakeholders in the decision-making process. The lack of involvement by respondents in government or

NGO-led projects indicates opportunities for enhancing community engagement and ensuring that restoration projects align with local needs and priorities.

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Appendices

Appendix A: Questionnaire for community stakeholders

STAKEHOLDERS' PERSPECTIVE ON SEAGRASS DEGRADATION AND THE SIGNIFICANCE OF ITS RESTORATION TO CARBON SEQUESTRATION. A CASE STUDY OF ZANZIBAR, TANZANIA. (COMMUNITY STAKEHOLDERS)

Introduction

This interview guide has been designed in order to collect information on stakeholders' perceptions of seagrass degradation and the significance of restoration to carbon sequestration in Zanzibar.

The aim is to explore:

1. To identify threats and describe the impact of seagrass degradation on the livelihoods of local communities and other stakeholders.
2. To evaluate the economic, social and environmental benefits of seagrass restoration for blue carbon sequestration and storage.
3. To examine the role of stakeholder collaboration and partnerships in enhancing the effectiveness of seagrass restoration efforts for blue carbon.

The interview is purely for academic purposes being part of the requirement for the award of a Master of Science degree in Maritime Affairs at the World Maritime University.

Participation in this study is voluntary.

1. A participant shall be required to provide consent for use of data by signing a consent form.

2. A participant has the freedom to exit the study at any time or withdraw the consent.

3. All information from the participants will be held with strict confidentiality hence no divulging to third parties.

Questionnaire for community people
Please tick appropriate:

Section A: Demographic information

1. Gender: Male Female
2. How old are you? …….
3. Name of community……...
4. What is your occupation?.....
5. How long have you been working?

Section B: Perception on seagrass degradation and its significance to carbon sequestration

6. Have you ever heard of seagrasses?
7. Have you noticed any changes in seagrass meadow in your area?
   i) Yes ii) No If Yes, what changes have you observed?.....
8. How concerned are you about the degradation of seagrass ecosystems in your community?
   i) Much concern ii) Least concern iii) Not concern at all
9. In your opinion, what are the main drivers of seagrass degradation in your community?
   i) Climate change ii) Fishing activity iii) Pollution
   Other specify…….
10. Do you believe that seagrass restoration can help mitigate the impacts of climate change?
    i) Yes ii) No iii) No idea
11. Have you ever heard about carbon sequestration?
12. Do you think that seagrasses are an important part of carbon sequestration?
13. What actions do you think should be implemented to protect seagrass meadows?

14. Which ecosystem do you think is most important to protect regarding carbon sequestration: seagrass or mangrove?
15. What are the main challenges associated with seagrass restoration in your community? ……
16. How effective do you think seagrass restoration efforts have been in your community?
    i) Very effective ii) Not effective iii) Nothing has been done
17. What role do you believe different stakeholders (e.g., government, NGOs, local communities) should play in seagrass restoration?.....
18. Have you ever been invited by the government on a seagrass project?.....
    ...
19. How do you think seagrass restoration can be made more successful and sustainable in your community?
    i) Technocratic (Top-Down) ii) Participatory (Bottom-Up) iii) Both
20. In your opinion, what are the key factors that should be considered when prioritizing seagrass restoration efforts in your community?.....
    .....
21. Would you be interested to take part in a seagrass restoration project, so called citizen science?
    i) Yes ii) No iii) No idea

Appendix B: Questionnaire for Professionals stakeholders

STAKEHOLDERS' PERSPECTIVE ON SEAGRASS DEGRADATION AND THE SIGNIFICANCE OF ITS RESTORATION TO CARBON SEQUESTRATION. A CASE STUDY OF ZANZIBAR, TANZANIA. (PROFESSIONALS)

Introduction

This interview guide has been designed in order to collect information on stakeholders' perceptions of seagrass degradation and the significance of restoration to carbon sequestration in Zanzibar.

The aim is to explore:

1. To identify threats and describe the impact of seagrass degradation on the livelihoods of local communities and other stakeholders.
2. To evaluate the economic, social and environmental benefits of seagrass restoration for blue carbon sequestration and storage.
3. To examine the role of stakeholder collaboration and partnerships in enhancing the effectiveness of seagrass restoration efforts for blue carbon.

The interview is purely for academic purposes being part of the requirement for the award of a Master of Science degree in Maritime Affairs at the World Maritime University.

Participation in this study is voluntary.

1. A participant shall be required to provide consent for use of data by signing a consent form.

2. A participant has the freedom to exit the study at any time or withdraw the consent.

3. All information from the participants will be held with strict confidentiality hence no divulging to third parties.

Questionnaire for Government officials, Agency, Academic Institutions and NGO's

Section A: Demographic information

Please tick appropriate

1) Gender: Male Female

2) Name of your organization

……..

3) What is your position in the organization?

……..

b) How long have you been working? ……

4) Does this Agency/organization deal with the issue of seagrass management and restoration in Zanzibar? i) Yes ii) No

b) If yes, what is it responsible for……..

5) Is there existing policies or regulations for the management and protection of seagrass meadows in Zanzibar?

i) Yes ii) No iii) No idea

6) Which type of government structure do you have for seagrass protection and management?

i) Top to Down approach (Technocratic) ii) Bottom to Up approach (Participatory)

Section B: Perception on seagrass degradation and its significance to carbon sequestration

7) Have you notice any change in seagrass coverage in your area over the last 10 years?

8) If Yes, in your opinion, what are the main factors contributing to seagrass degradation in your

area?.....

9) Do you think seagrass degradation has any impact on the local economy or tourism industry?

i) Yes ii) No

10) Do you think that seagrasses are an important part of the marine/coastal environment?

11) How familiar are you with the concept of carbon sequestration?

……..

12) Do you think that seagrasses are an important part of carbon sequestration?

13) What actions do you think should be implemented to protect seagrass meadows?

14) What role do you think restoring seagrass ecosystems will have for the impact of carbon sequestration? ……..

15) Have you or your organization ever been involved in any seagrass restoration projects?

i) Yes ii) No

If Yes, what was your experience?.....

16) Were the community people involved in the restoration project?

17) How important do you think it is to involve local stakeholders in seagrass restoration efforts?

18) Do you think there are any potential drawbacks or negative impacts associated with seagrass restoration projects?

i) Yes ii) No

If Yes, what are they? .....

19) What steps do you think should be taken to increase to increase public awareness about the importance of seagrass ecosystems, carbon sequestration, and the need for seagrass restorations?.....
.....