EDITORIAL NOTE

The present edition of the journal continues its commitment to scholarly excellence and relevance, featuring five original manuscripts that reflect both national and international dimensions. These contributions are drawn from multidisciplinary perspectives, highlighting pressing issues in maritime sustainability, technological advancement, environmental management, and economic development across Africa.

The first manuscript explores the influence of blue economy corporate social responsibility (CSR) initiatives on employee environmental citizenship behaviours within maritime institutions. Anchored in the stimulus-organism-response (S-O-R) theory, the study adopts a quantitative approach and applies structural equation modelling to assess how CSR practices stimulate ocean stewardship passion and environmental empathy among employees. The findings emphasise the role of emotional connection to marine ecosystems in fostering environmentally responsible behaviours, contributing significantly to blue economy discourse and practical CSR strategies for organisational sustainability.

The second manuscript focuses on the construction and maintenance of submarine fibre optic cables in East and West Africa, with particular attention to Tanzania and The Gambia. This paper investigates the potential of integrating marine big data analytics into submarine cable operations to reduce cable damage, improve monitoring, and promote eco-friendly practices. Through a mixed-methods approach, the study identifies the importance of regional cooperation, liability frameworks, and marine insurance in enhancing operational efficiency. The paper underscores the vital role submarine fibre infrastructure plays in driving digital marine economies and regional resilience.

The third manuscript examines the seasonal variation of atmospheric gravity waves (GWs) over the West African region using ERA5 reanalysis data from 2019 to 2023. The study calculates Gravity Wave Potential Energy (GWPE) and correlates it with climate dynamics, emphasising its relevance to coastal resilience and sea level variability. Findings reveal peak GW activity during the June-July-August period, aligning with previous studies and highlighting the importance of atmospheric-ocean interactions in climate-sensitive coastal planning. This research offers critical insights for policymakers and coastal engineers in adapting to the challenges of climate change.

The next paper assesses Ghana’s ship registration system, particularly focusing on the implications of maintaining a closed registry versus transitioning to an open registry. Drawing from qualitative interviews with stakeholders from the maritime sector, the study identifies systemic barriers such as high taxes, lack of incentives, and bureaucratic inefficiencies. It argues that an open registry could significantly boost socio-economic benefits, enhance competitiveness, and attract more vessels under the Ghanaian flag. The paper recommends comprehensive policy reforms, digitalisation, and streamlined processes to enable the successful implementation of an open ship registry.

The final manuscript addresses the socioeconomic and environmental implications of coastal sand mining in Kombo South, The Gambia. Employing a mixed-methods design, the study gathers data through household surveys, focus groups, key informant interviews, and field observations. It reveals that while sand mining contributes to economic development, it also poses serious threats to coastal livelihoods, governance structures, and ecological sustainability. The paper advocates for improved policy frameworks, community empowerment, and conflict-free governance models to support blue growth and sustainable development in line with regional and international frameworks such as the SDGs and Agenda 2063.

It is noted with satisfaction that the manuscripts in this edition make significant contributions to maritime and coastal research. They provide vital insights into sustainability, infrastructure development, socio-economic transformation, and environmental stewardship in the African maritime domain.

Blue Economy CSR Initiatives and Employee Environmental Citizenship Behaviour: Examining the Mediating Effects of Employee Ocean Stewardship Passion and Environmental Empathy

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Abstract

Acknowledging the critical role of employee environmental behaviour in advancing organizational sustainability, this study explores the influence of blue economy corporate social responsibility (CSR) initiatives on fostering employee environmental citizenship behaviours. By examining this relationship, the study highlights the potential of blue economy-driven CSR practices in promoting sustainable organizational development and contributing to environmental stewardship. Through the lens of the stimulus-organism- response (S-O-R) theory, the study investigates the mediating roles of employee ocean stewardship passion and environmental empathy in this relationship. With a quantitative, cross-sectional survey design and convenience sampling, data was gathered from 440 employees in maritime institutions implementing blue economy CSR programmes. The hypothesized mediation model was tested through structural equation modelling (SEM) with SPSS AMOS. The findings highlighted how blue economy CSR initiatives (stimulus) influence employee ocean stewardship passion and environmental empathy (organism), which further drive employee environmental citizenship behaviour (response). According to the study, employees who exhibit a stronger emotional connection to marine ecosystems engage in pro-environmental actions that support the blue economy. This research contributes to the growing body of knowledge on the blue economy, corporate social responsibility (CSR), and employee environmental behaviors, addressing the gaps in understanding the interplay between these concepts. Findings give insights to organizations seeking to foster employee engagement in corporate sustainability efforts. The study also has practical implications for the utilization of blue economy CSR programmes by organizations to cultivate employee passion for ocean stewardship and environmental empathy and encourage their participation in environmentally responsible behaviours that support the sustainable use of marine resources.

Keywords: *Blue Economy, Corporate Social Responsibility, Environmental Citizenship, Ocean Stewardship Passion, Environmental Empathy, Structural Equation Modeling*

Introduction

The global economic landscape increasingly recognizes the critical importance of sustainable ocean-based economic development, a concept encapsulated by the emerging paradigm of the Blue Economy (Pauli, 2010). As marine ecosystems face unprecedented challenges from climate change, pollution, overfishing, and other unsustainable practices, corporations are called upon to assume pivotal roles in marine conservation and sustainable development (United Nations, 2017). Corporate Social Responsibility (CSR) initiatives within the context of the Blue Economy have emerged as critical mechanisms for businesses to address marine environmental challenges and foster sustainable practices (Porter & Kramer, 2011).

Despite the growing emphasis on the Blue Economy, there remains a significant gap in understanding how corporate ocean-related initiatives translate into meaningful employee engagement and ocean stewardship (Ones & Dilchert, 2012; Pharm et al., 2024). While many organizations implement Blue Economy CSR programmes, the internal psychological processes that transform these initiatives into genuine employee ocean stewardship passion and environmental citizenship behaviour remain underexplored (Daily et al., 2009; McKinley et al., 2023). The interrelationship between organizational strategies, individual psychological factors, and employee commitment to marine sustainability presents a sophisticated challenge for researchers and practitioners alike. A substantial body of research attests to the efficacy of CSR in fostering environmentally conscious behaviour among employees (Wells et al., 2015). Evidence suggests that CSR initiatives influence employee pro-environmental behaviours through various psychological mechanisms, including organizational identification (Shah et al., 2020), environmental commitment (Afsar & Umrani, 2020), employee well-being (Ahmed et al., 2020), environmental orientation fit (Cheema et al., 2020b), employee-corporate relationships (Su & Swanson, 2019), and green practices (Suganthi, 2019). However, while CSR's external benefits, such as business competitiveness, corporate reputation, and environmental performance, are well-documented (Chuang & Huang, 2018; Khojastehpour & Johns, 2014), fewer studies have examined how CSR initiatives directed at marine ecosystems affect employees' psychological and emotional connections to ocean sustainability.

Promoting ocean stewardship passion, a deep emotional commitment to protecting and sustainably managing marine resources, is essential to fostering environmental citizenship behaviour among employees. Ocean stewardship passion emerges when employees internalize the importance of ocean sustainability through participation in CSR initiatives targeting marine conservation (Markóczy & Goldberg, 2020). Similarly, environmental empathy, an individual's capacity to emotionally connect with environmental issues, complements ocean stewardship passion by deepening employees' understanding and motivation to act in support of ocean sustainability (Musitu-Ferrer et al., 2019). Existing literature has largely focused on the external impacts of CSR initiatives, with limited attention to these internal psychological mechanisms (Daily et al., 2012). Specifically, the mediating roles of ocean stewardship passion and environmental empathy in translating CSR initiatives into voluntary, proactive, and non-compulsory environmental citizenship behaviours remain under-explored (Moon & Deleon, 2007; Bennett et al., 2022; Buchan et al, 2023; Buchan et al, 2024). Therefore, this research explores the mediation role of employees' ocean stewardship passion and environmental empathy on the relationship between blue economy CSR and environmental citizenship behaviour.

To address this gap, the present research employs the Stimulus-Organism-Response (S–O–R) theory to examine the psychological mechanisms linking Blue Economy CSR initiatives to environmental citizenship behaviour. Within this framework, CSR initiatives targeting ocean sustainability serve as the stimulus (S), ocean stewardship passion and environmental empathy represent the organism (O), and environmental citizenship behaviour acts as the response (R). This approach highlights the critical role of internal emotional and psychological processes in shaping employee engagement with marine conservation efforts.

Subsequently, the researchers gathered data from employees of marine-based companies via a survey questionnaire, to test proposed hypotheses. The structural equation results demonstrated that environmental CSR exerted a direct and indirect (through ocean stewardship passion and environmental empathy) influence on environmental citizenship behaviour. This study contributes to the literature in several ways by focusing on the individual-level impacts of Blue Economy CSR. The study enriches the body of knowledge on micro-CSR and environmental management. In summary, this research illuminates the psychological processes underlying the relationship between CSR initiatives and employee environmental citizenship behaviour in the context of the Blue Economy, emphasizing the pivotal roles of ocean stewardship passion and environmental empathy.

Theoretical Background

Stimulus-organism-response model

The Stimulus-Organism-Response (S-O-R) model, rooted in environmental psychology, posits that environmental stimuli (S) influence an individual's internal state (O), leading to behavioural responses (R) (Mehrabian & Russell, 1974). In organizational contexts, factors such as management policies and daily operations serve as stimuli affecting employees' cognitive and emotional states, including perceptions and psychological experiences (Jiang et al., 2010). These internal states shape responses, such as attitudes and behaviours exhibited within and beyond the organization.

This study adopts the S-O-R model for two main reasons. First, as a framework from environmental psychology, the S-O-R model aligns with the study's focus on Blue Economy Corporate Social Responsibility (CSR) and its role in fostering environmental citizenship behaviours. It has been applied in prior studies to explain organizational environments' effects, such as Jani and Han's (2015) exploration of how hotel environments influence guest loyalty. Second, the S-O-R model provides an integrated explanation of the psychological processes through which Blue Economy CSR shapes pro-ocean behaviours, filling gaps left by other theories such as the Theory of Planned Behavior or motivation theories (Heung & Gu, 2012). It enables a comprehensive analysis of how organizational practices inspire employee engagement in ocean stewardship initiatives.

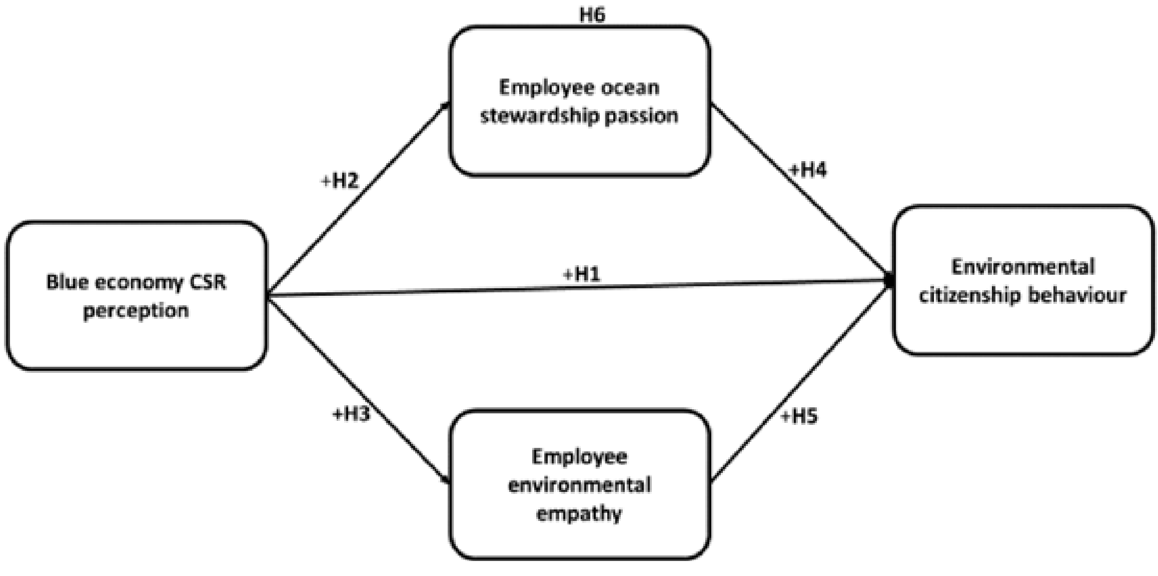

Fig 1 Conceptual model

Blue economy CSR perception and employee environmental citizenship behaviour

The convergence of Blue Economy CSR and employee environmental citizenship behaviour represents a critical paradigm in sustainable organizational development. The Blue Economy, which emphasizes sustainable marine and coastal resource management, offers a framework for integrating environmental stewardship into business strategies (Pauli, 2010). CSR links organizational environmental commitments to employee behaviours, with research showing that organizations demonstrating a genuine commitment to sustainability inspire employees to internalize these values and engage in proactive environmental citizenship behaviours (Ones & Dilchert, 2012). Blue Economy-focused CSR initiatives can foster a normative environment, triggering intrinsic motivation and encouraging employees to undertake environmentally responsible actions beyond their formal job roles (Ones & Dilchert, 2012). The study hypothesised accordingly: *Hypothesis 1. Environmental CSR perception positively relates to employee environmental citizenship behaviour.*

Blue Economy CSR Perception and Ocean Stewardship Passion

The concept of ocean stewardship emphasizes intrinsic motivation for protecting marine ecosystems, aligning with Blue Economy goals (De Bernardi & Pedrini, 2020). Research shows that corporate social responsibility (CSR) initiatives focusing on marine sustainability can positively shape employees' attitudes towards the ocean, fostering emotional connections and a passion for ocean stewardship (Junot et al., 2017). Participation in activities promoting ocean sustainability further enhances emotional engagement and passion for conservation (Onkila, 2009). CSR initiatives offer employees direct involvement in marine preservation, cultivating positive experiences and strengthening their commitment to marine conservation (Gousse-Lessard et al., 2013). In light of the above evidence, the following hypothesis is proposed:

Hypothesis 2: Blue Economy CSR perception positively relates to ocean stewardship passion.

Blue economy CSR perception and environmental empathy

Blue economy corporate social responsibility (CSR) significantly influences employees' environmental empathy through several mechanisms. First, employees' perceptions of environmental CSR deepen their understanding of how environmental protection impacts the Earth's development, fostering stronger environmental values and emotional connections (Berenguer, 2007). Second, environmental CSR as a management strategy conveys environmental protection values to employees, increasing their concern and inspiring empathy (Dolby, 2019). Additionally, engaging in conservation activities enhances perceptions of the natural environment, strengthening employees' empathy for it (Dono et al., 2010). These factors collectively promote environmental empathy among employees, leading to the formulation of the following hypothesis.

Hypothesis 3. Blue economy CSR perception is positively associated with environmental empathy.

Ocean Stewardship Passion and Environmental Citizenship Behaviors

Ocean stewardship passion is a key predictor of environmentally responsible behaviours, particularly in marine conservation contexts (Robertson & Barling, 2013; Ardoin et al., 2020). This passion transforms individuals' emotional connections to the ocean into actionable conservation behaviours, such as voluntary contributions to marine protection (Vallerand et al., 2007). It also fosters a positive emotional connection, enhancing employees' sense of purpose and inspiring engagement in environmental citizenship behaviours (Fineman, 1996). Furthermore, ocean stewardship passion aligns employees' values with organizational conservation goals, motivating ethical environmental behaviours (Stern, 2000). Positive affect, including stewardship passion, further influences employees' environmental conduct (Williamson et al., 2006; Li et al., 2020), leading to the formulation of the following hypothesis.

Hypothesis 4: Ocean stewardship passion is positively associated with environmental citizenship behavior.

Environmental empathy and environmental citizenship behaviours Environmental empathy is a key driver of environmental citizenship behaviour (Swim & Bloodhart, 2015). The altruistic and pro-social behaviour model (Batson et al., 1991) suggests that inducing empathy improves attitudes toward the environment, promoting citizenship behaviour. Schultz (2000) highlights that environmental empathy fosters tolerance, which supports positive environmental behaviours. Additionally, Berenguer (2007) found that nurturing environmental empathy encourages responsible environmental attitudes, while Dolby (2019) noted a positive correlation between empathy and environmental concern. Empathetic individuals are more likely to engage in eco-conscious behaviours (Musitu-Ferrer et al., 2019), making environmental empathy a catalyst for environmental citizenship (Kim & Cooke, 2020). Therefore, the study hypothesises as follows:

Hypothesis 5. Environmental empathy positively relates to environmental citizenship behaviour.

The Mediating Role of Ocean Stewardship Passion and Environmental Empathy Blue Economy CSR practices, while essential, may not alone drive employees to adopt ocean-conscious behaviours. Psychological incentives, such as intrinsic motivation, awareness of ocean ecosystems, and the belief in contributing to marine sustainability, are crucial in fostering such behaviours (Afsar et al., 2016). Ocean stewardship passion and environmental empathy are key predictors of ocean-conscious citizenship behaviours (Ardoin et al., 2020; Shahbaz et al., 2013). Ocean stewardship passion involves a deep emotional commitment to marine conservation, while environmental empathy enhances awareness of the interconnectedness of marine ecosystems (Shen & Benson, 2016). Thus, Blue Economy CSR influences ocean-conscious citizenship behaviours through the mediating roles of these positive employee attitudes:

Hypothesis 6: Blue Economy CSR will indirectly affect ocean-conscious citizenship behaviour through the mediation of ocean stewardship passion.

Hypothesis 7: Environmental CSR will indirectly affect environmental citizenship behaviour through the mediation of environmental empathy.

Research Methods

Sample and procedure

This study employed a quantitative methodology to test the proposed hypotheses. The researchers collaborated with several marine-based institutions to identify suitable respondents. Managers from five marine-focused organizations agreed to distribute questionnaires among selected employees. To minimize the risk of common method biases, data collection occurred in multiple phases over two months. A total of 600 questionnaires were distributed, and 440 valid responses were collected. The respondents were predominantly male (70%), with a median age range of 25-35 years (68.9%). The majority (88.9%) had been employed at their current organization for over five years. Descriptive statistics summarizing the respondents' profiles are presented in Table 1. Responses were rated on a 5-point Likert scale ranging from 1 (strong disagreement) to 5 (strong agreement).

Definition of Variables

Perception of Blue Economy Corporate Social Responsibility (CSR): The perception of CSR in relation to marine environments was measured using a modified version of the scale developed by Turker (2009). Four items reflecting CSR's relevance to marine sustainability and stewardship were used, including the statement: "*Our company actively engages in programmes that protect marine biodiversity and reduce environmental harm*."

Ocean Stewardship Passion: Ocean stewardship passion refers to a strong, enduring commitment to protecting and preserving marine environments. The researchers adapted the Environmental Passion Measure by Robertson and Barling (2013) to align with ocean stewardship. The scale consisted of ten items, including the statement: "I am deeply inspired to contribute to marine conservation efforts through my actions." Environmental empathy: The three environmental empathy measure items were adapted from Kim and Cooke (2020), including the item "To what extent do you feel compassion for the marine environment?"

Environmental citizenship behaviour is defined as the actions of individuals that contribute to the preservation and enhancement of the natural marine environment. Environmental citizenship behaviour was assessed using a scale developed by Raineri and Paillé (2016). The scale comprised seven items, including "I suggest new practices that could improve the marine environmental performance of my company."

Control variables. Previous research has demonstrated that demographic characteristics may partially explain differences in the conduct of environmental citizenship behaviours, which may affect the hypothesized relationships in this study (Andersson & Bateman, 2000). Therefore, this study introduced gender, age and working years of the employee into the analytical model as control variables. Gender (1 = female, 2 = male), age (1 = 18- 25, 2 = 26–35, 3 = 36–45, 4 = above 45), working years (1 = 0-5, 2 = 6–10, 3 = 11–15, 4 = Above 15).

Table 1
Characteristics of the sample (N = 450)

Demographic profile	Categories	Frequency	Percent (%)
Gender	Male	315	70.
	Female	135	30
Age	18-25	30	6.7
	26-35	310	68.9
	36-45	100	22.2
	Above 45	10	2.2
Working years	0-5	50	11.1
	6-10	200	44.4
	11-15	155	34.5
	Above 15	45	10

Measurement model test

The reliability and validity of the scales were assessed using principal component analysis (PCA) in SPSS 20.0 and confirmatory factor analysis (CFA) in AMOS 23.0. Cronbach's alpha values exceeded 0.75, surpassing the 0.7 threshold (Nunnally, 1978), confirming acceptable reliability. The composite reliabilities (CRs) ranged from 0.83 to 0.91, all above the recommended 0.7, indicating good reliability (Chin et al., 1997). For convergent validity, factor loadings exceeded 0.7 (Table 3) and average variance extracted (AVE) values were greater than 0.5, with most exceeding 0.6, demonstrating adequate convergent validity. Discriminant validity was confirmed as the square root of the AVE for each construct was higher than its correlations with other variables (Table 2).

Common method bias

To address potential common method bias due to the single-source sample, the authors took steps to minimise this risk. Reverse-coded questions were included in the questionnaire to assess response efficacy and identify significant discrepancies. Additionally, Harman's single-factor test was conducted, revealing that the most significant factor accounted for only 39.516% of the total variance. These results suggest minimal influence from common method bias in the study.

Results

Descriptive analysis

Table 2 presents the means, standard deviations, and correlations between the variables. The results presented in the table indicate a significant positive relationship between blue economy CSR and ocean stewardship passion ($r = 0.57$, $p < 0.01$), as well as a significant positive relationship between blue economy CSR and environmental empathy ($r = 0.56$, $p < 0.01$). Therefore, Hypotheses 1 and 2 were initially supported. Additionally, a significant positive relationship was observed between blue economy CSR and environmental citizenship behaviour ($r = 0.60$, $p < 0.01$). Furthermore, ocean stewardship passion was found to be significantly and positively correlated with environmental citizenship behaviour ($r = 0.56$, $p < 0.01$), and environmental empathy was also significantly and positively correlated with environmental citizenship behaviour ($r = 0.53$, $p < 0.01$). Consequently, Hypotheses 3 and 4 were also initially supported.

Table 2
Means, SDs, correlations, and the square root of AVE.

		M	**SD**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	GD	1.73	0.44	1							
2	AG	2.21	0.89	-0.24**	1						
3	WY	1.95	0.46	-0.17**	0.19**	1					
4	WP	2.39	1.24	0.22**	0.24**	0.28**	1				
5	BECSR	4.99	0.90	-0.01	-0.09*	-0.01	0.01	(0.87)			
6	OSP	4.60	0.74	0.07	-0.08	-0.03	0.02	0.57**	(0.80)		
7	EE	4.86	0.93	0.02	-0.12**	-0.03	-0.01	0.56**	0.49**	(0.83)	
8	ECB	4.85	0.81	-0.01	-0.12*	-0.01	-0.05	0.60**	0.56**	0.53**	(0.87)

*Note: ***p < 0.001, **p < 0.01, *p < 0.05; The number in parentheses is the square root of the AVE. GD: gender; AG: age; WY: working years; WP: work position; ECSR: environmental CSR perception; OSP: ocean stewardship passion; EE: environmental empathy; ECB: environmental citizenship behaviour.*

Table 3: Measurement model evaluation result.

Construct	Items		AVE	CR	Cronbach
Blue environmental CSR perception	BECSR1	0.73	0.65	0.87	0.83
	BECSR2	0.72			

	BECSR3	0.81			
	BECSR4	0.73			
Ocean Stewardship Passion	OSP1	0.70	0.62	0.94	0.91
	OSP2	0.76			
	OSP3	0.74			
	OSP4	0.80			
	OSP5	0.83			
	OSP6	0.78			
	OSP7	0.74			
	OSP8	0.77			
	OSP9	0.82			
	OSP10	0.72			
Environmental Empathy	EE1	0.82	0.72	0.80	0.85
	EE2	0.74			
	EE3	0.72			
Environmental citizenship behaviour	ECB1	0.71	0.76	0.92	0.92
	ECB2	0.84			
	ECB3	0.79			
	ECB4	0.88			
	ECB5	0.72			
	ECB6	0.75			
	ECB7	0.86			

Examining the direct effect

The researchers tested the proposed hypotheses using AMOS (Version 23.0) and a structural model to assess direct effects. The model fit indices indicated strong explanatory power: chi-square/df ratio (2.221), the root mean square error of approximation (RMSEA = 0.049), CFI (0.952), the Tucker-Lewis index (TLI =0.943), the adjusted goodness of fit index (AGFI = 0.834), the normed fit index (NFI = 0.921), and the incremental fit index (IFI = 0.932) (Li et al., 2020). The model explained 54% of the variance in environmental citizenship behaviour. The results confirmed the hypotheses as follows: Hypothesis 1, with a significant path coefficient of 0.542 ($\beta = 0.542$, $T = 11.343$, $p < 0.01$), linking blue economy CSR perception to ocean stewardship passion. Hypothesis 2, with a coefficient of 0.561 ($\beta = 0.561$, $T = 11.312$, $p < 0.001$), confirms the relationship between blue economy CSR perception and ocean stewardship passion. Hypothesis 3, with a coefficient of 0.620 ($\beta = 0.612$, $T = 11.364$, $p < 0.001$), supports the link between blue economy CSR perception and environmental empathy. Hypothesis 4, with a coefficient of 0.382 ($\beta = 0.382$, $T = 6.787$, $p < 0.05$), validates the relationship between ocean stewardship passion and environmental citizenship behaviour. Hypothesis 5, with a coefficient of 0.216 ($\beta = 0.216$, $T = 4.151$, $p < 0.01$), confirms the positive relationship between environmental empathy and environmental citizenship behaviour. These results support the direct effects as hypothesized.

Table 4 Results of the structural equation tests.

Structural path	Estimates	T-value	P-Value	Results
H1: Blue economy CSR perception - Environmental citizenship behaviours	0.542**	11. 343	0.01	Supported

H2: Environmental CSR perception - Ocean stewardship passion	0.561***	11.312	0.001	Supported
H3: Environmental CSR perception - Environmental empathy	0.612***	11.364	0.001	Supported
H4: Ocean stewardship passion - Environmental citizenship behaviour	0.382*	6.787	0.05	Supported
H5: Environmental empathy - Environmental citizenship behaviour	0.216**	4.151	0.01	Supported

Examining the mediating effects

The sixth hypothesis proposed that environmental CSR perception indirectly influences environmental citizenship behaviour through ocean stewardship passion. Initial results showed a significant direct effect of blue economy CSR perception on environmental citizenship behaviour ($\beta = 0.623$, $T = 12.123$, $p < 0.001$). After including ocean stewardship passion as a mediator, the path coefficient reduced to 0.437 ($\beta = 0.467$, $T = 7.847$, $p < 0.001$), confirming a partial mediating effect. The Sobel test ($Z = 5.6$, $p < 0.05$) and bootstrap analysis (95% CI = 0.121–0.291) further validated the mediating effect, supporting hypothesis 6.

For hypothesis 7, the direct effect of blue economy CSR perception on environmental citizenship behaviour was significant ($\beta = 0.645$, $T = 12.442$, $p < 0.001$). With environmental empathy as a mediator, the path coefficient decreased to 0.467 ($\beta = 0.458$, $T = 7.837$, $p < 0.001$), indicating a partial mediating effect. The Sobel test ($Z = 4.38$, $p < 0.001$) and bootstrap analysis (95% CI = 0.110–0.313) confirmed the significant indirect effect, supporting hypothesis 7.

Theoretical Implications

This study contributes to the theoretical foundation of corporate social responsibility (CSR) by addressing a critical gap in the literature on the relationship between Blue Economy CSR and employees' environmental citizenship behaviour (ECB). While prior research has focused broadly on CSR's impact on environmental conduct (Afsar & Umrani, 2020), limited attention has been given to how Blue Economy CSR influences employee behaviours. The study finds that Blue Economy CSR exerts both direct and indirect effects on ECB, mediated by employees' ocean stewardship passion and environmental empathy. By integrating micro-CSR perspectives, the study sheds light on the psychological and social processes that translate Blue Economy CSR into ECB. Blue Economy CSR, as a significant organisational-environmental policy, relies on voluntary employee participation for its success (Gattiker & Carter, 2010). ECB, a discretionary behaviour driven by personal volition (Deci & Ryan, 2000), can be stimulated by fostering positive intrinsic factors like stewardship passion and empathy. This research expands our understanding of the antecedents of ECB and offers empirical evidence of the mechanisms through which CSR initiatives in marine sustainability promote employee-driven environmental actions. It provides valuable insights for advancing sustainable development management practices within organizations.

Managerial Implications

This study confirms that Blue Economy CSR positively influences employees' environmental citizenship behaviour (ECB), offering actionable strategies for organisations. To encourage marine environmentally-conscious behaviours, organisations must actively cultivate a strong CSR image. This includes enhancing the visibility and frequency of Blue Economy CSR activities in marine conservation, thereby strengthening employees' perceptions of these initiatives. Regular monitoring of employee perceptions, as recommended by Afsar et al. (2018), is critical. Any gaps identified should be addressed through communication forums, internal reports, training, and other strategies to align perceptions with organizational goals.

Additionally, fostering positive environmental emotions, such as ocean stewardship passion and environmental empathy, is key to bridging Blue Economy CSR and ECB. Managers should clearly communicate the organization's marine environmental attitudes and the tangible impacts of its CSR activities on ecosystems and coastal communities. Integrating Blue Economy CSR into broader sustainability strategies and emphasizing contributions to human well-being, societal progress, and marine preservation will deepen employees' emotional connections to marine sustainability. This holistic approach not only enhances employee engagement but also builds a collective culture of environmental responsibility and stewardship, advancing both organizational and ecological goals.

Limitations and Future Research

This study is limited by its focus on marine-based institutions, potentially restricting the generalizability of findings to other industries. Additionally, the cross-sectional design used to test hypotheses could benefit from alternative methods such as experimental or mixed-method approaches. Future research should explore positive environmental emotions among a broader employee base to deepen understanding of the psychological mechanisms driving voluntary environmental behaviour.

Conclusion

This study advances understanding of the emerging nexus between Blue Economy Corporate Social Responsibility (CSR) and employees'environmental citizenship behaviour, addressing a critical gap in the literature. It confirms that effective implementation of Blue Economy CSR strategies fosters environmental citizenship behaviour among employees. Notably, the research highlights the mediating roles of positive environmental emotions, specifically ocean stewardship passion and environmental empathy, as pivotal mechanisms for transforming Blue Economy CSR into proactive, voluntary environmental actions. By demonstrating these connections, the study not only contributes to theoretical knowledge on CSR and marine environmental management but also underscores the importance of cultivating employee engagement through emotional and psychological pathways to drive organisational sustainability goals.

References:

Afsar, B., & Umrani, W. (2020). Corporate social responsibility and environmental commitment: Employee perspectives. Sustainability, 12(5), 222–238.

Afsar, B., Badir, Y. F., & Khan, M. M. (2016). Person-job fit, person-organization fit and innovative work behaviour: The mediating role of innovation trust. Journal of High Technology Management Research, 27(2), 107-120. https://doi.org/10.1016/j.hitech.2016.04.003

Ahmed, S., Khan, E., & Saeed, I. (2020). Employee well-being and pro-environmental behaviours: The mediating role of CSR. Journal of Environmental Psychology, 68, 101–110.

Andersson, L., Jackson, S. E., & Russell, M. (2018). Passion for conservation: Employees' commitment to ocean sustainability in marine industries. Conservation Biology, 32(4), 876–885.

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental behaviour change: A review of theoretical and empirical contributions. Society & Natural

Resources, 33(5), 621-640. https://doi.org/10.1080/08941920.2019.1609602

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental behaviour change: A review of theoretical and empirical contributions. Society & Natural Resources, 33(5), 621-640.

Bennett, N. J., Le Billon, P., Belhabib, D., & Satizábal, P. (2022). Local marine stewardship and ocean defenders. NPJ Ocean Sustainability, 1(1), 3.

Buchan, P. M., Evans, L. S., Pieraccini, M., & Barr, S. (2023). Marine citizenship: The right to participate in the transformation of the human-ocean relationship for sustainability. Plos one, 18(3), e0280518.

Cheema, S., Farooq, S., & Cheema, F. (2020). Environmental orientation fit and green behaviour. Journal of Business Research, 114, 38–47.

Chuang, C., & Huang, R. (2018). Environmental citizenship behaviour in organizations: Antecedents and outcomes. Journal of Organizational Behavior, 39(3), 230–245.

Daily, B. F., Bishop, J. W., & Steiner, R. (2012). The role of training in organizational commitment to environmental sustainability. Human Resource Management, 51(6), 881–906.

De Bernardi, P., & Pedrini, M. (2020). Environmental passion and its impact on employees' pro-environmental behaviours. Journal of Business Ethics, 164(2), 307–321.

Glavas, A. (2016). Corporate social responsibility and organizational psychology: An integrative review. Frontiers in Psychology, 7, 144.

Gousse-Lessard, A.-S., Vallerand, R. J., & Carbonneau, N. (2013). The role of passion in sustainable organizational practices. Journal of Environmental Psychology, 36, 193–203.

Joung, C., Oh, W.-Y., & Kang, C. (2020). CSR in marine industries: The nexus of sustainability and corporate responsibility. Marine Policy, 118, 104011.

Junot, A., Paquet, Y., & Fenouillet, F. (2017). The mediating role of environmental emotional experiences in promoting sustainable behaviours. Environment and Behavior, 49(2), 139–162.

Khojastehpour, M., & Johns, R. (2014). The role of CSR in corporate competitiveness and reputation. Corporate Social Responsibility and Environmental Management, 21(5), 268–280.

Lamm, E., Tosti-Kharas, J., & King, C. E. (2013). Corporate social responsibility and employee passion for sustainability: The role of employee perceptions. Journal of Organizational Behavior, 34(7), 946–964.

Li, N., Wang, Y., Wu, H., & Zhang, X. (2020). The role of emotional attachment in the formation of pro-environmental intentions. Journal of Cleaner Production, 242, 118451. https://doi.org/10.1016/j.jclepro.2019.118451

Markóczy, L., & Goldberg, J. (2020). The role of emotional factors in employee pro-environmental behaviours. Journal of Applied Psychology, 105(4), 341–357.

McKinley, E., Burdon, D., & Shellock, R. J. (2023). The evolution of ocean literacy: A new framework for the United Nations Ocean Decade and beyond. Marine Pollution Bulletin, 186, 114467.

Moon, J. H., & Deleon, C. (2007). Environmental citizenship and employee motivation. Environment and Behavior, 39(2), 195–211.

Musitu-Ferrer, D., Lezcano, P., & Jiménez, T. I. (2019). Environmental empathy as a predictor of pro-environmental behavior. Sustainability, 11(8), 2407–2416.

Onkila, T. (2009). Corporate social responsibility as an engagement tool for sustainability: Employee perspectives. Business Strategy and the Environment, 18(1), 1–12.

Patil, P. G., Virdin, J., Diez, S. M., Roberts, J., & Singh, A. (2018). Toward a sustainable blue economy: The promise and pitfalls of integrated ocean management. World Bank Group Report.

Pauli, G. (2010). The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs. Taos Institute Publications.

Pham, H. M., Pham, A. D., Tran, D. V., Vuong, N. L., & Nguyen, H. D. (2024). Integrating CSR with environmental consciousness and commitment: Pathways to employee stewardship in Vietnam's mechanical manufacturing sector. Business Strategy & Development, 7(4), e70036.

Porter, M. E., & Kramer, M. R. (2011). Creating shared value: How to reinvent capitalism and unleash innovation. Harvard Business Review, 89(1–2), 62–77.

Shah, S., Khurshid, H., & Khan, Z. (2020). CSR, organizational identification, and pro-environmental behaviour. Journal of Business Ethics, 162(3), 525–536.

Shahbaz, M., Arshad, A., & Anwar, M. (2013). Empathy in sustainability initiatives: Understanding the influence of emotional connection. Journal of Environmental Psychology, 34, 57-68. https://doi.org/10.1016/j.jenvp.2013.03.006

Shen, J., & Benson, J. (2016). When CSR creates positive employee outcomes: The role of corporate sustainability practices. Journal of Business Research, 69(11), 4421-4429. https://doi.org/10.1016/j.jbusres.2016.03.053

Smith, B. A., Murphy, T., & Coats, K. (2016). Social learning theory: A framework for environmental education in organizations. Journal of Environmental Management, 179, 22–30.

Su, L., & Swanson, S. R. (2019). Employee-corporate relationship and pro-environmental outcomes. Tourism Management, 74, 45–56.

Suganthi, L. (2019). Green HR practices and organizational outcomes. Sustainability, 11(12), 345–355.

Wells, J. D., Palmer, S., & Gilbert, R. (2015). Corporate sustainability initiatives and employee engagement. Business Ethics Quarterly, 25(3), 337–358.

LEVERAGING CONSTRUCTION AND MAINTENANCE OF SUBMARINE FIBER CABLES FOR MARINE BIG DATA ANALYTICS: A CASE STUDY OF TANZANIA AND THE GAMBIA

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Abstract
Submarine fibre cables are critical infrastructure, enabling global connectivity and fostering digital economies. In East Africa, particularly Tanzania, and West Africa, particularly The Gambia, these cables face shared challenges. This research explores how the construction and maintenance of submarine fiber cables can be leveraged to advance marine big data analytics, providing a pathway to mitigate risks, enhance operational efficiency, and drive economic resilience. Employing a mixed-methods approach, the study examined stakeholder insights, technological readiness, and regulatory frameworks across both nations. Findings highlight the urgent need for clear liability frameworks, collaborative marine insurance policies, and enhanced capacity-building initiatives to address recurring cable damage and operational inefficiencies. The research emphasizes the transformative potential of marine big data analytics in optimizing cable routes, enabling real-time monitoring, and supporting eco-friendly deployment. Collaboration between East Africa and West Africa is proposed as a model for shared learning, resource pooling, and regional standard-setting. The study concludes that stable submarine fiber cables underpin a robust digital marine economy, enabling sustainable growth and improved connectivity. Future research should explore AI-driven predictive maintenance, renewable energy solutions for cable operations, and the socioeconomic impact of big data-enabled marine systems.

Keywords: *Marine Big data analytics, Submarine fiber cable, Digitalization, Marine technological innovation*

Introduction

Submarine fiber optic cables form the backbone of global telecommunications, transmitting over %99 of international data and providing essential connectivity for financial transactions, internet services, cloud computing, and government communications (International Telecommunication Union [ITU], 2024). Recognizing their importance, global initiatives like the International Cable Protection Committee (ICPC) and ITU have focused on enhancing cable resilience and security against diverse threats (ITU, 2024; ICPC, 2023). In Tanzania and The Gambia, submarine cables serve as critical infrastructure driving digital transformation and economic growth. Tanzania hosts four operational cables namely 2Africa, SEACOM, Eastern Africa Submarine System (EASSy), and Seychelles East Africa System (SEAS) whereas The Gambia currently operates the Africa Coast to Europe (ACE) cable and plans to inaugurate a second cable by 2026 to accommodate growing internet demands (ICPC, 2023; Submarine Telecoms Forum, 2023). Despite their pivotal role, these countries face unique challenges that hinder effective cable construction, maintenance, and resilience against disruptions.

Marine big data analytics, an emerging field leveraging advanced computational techniques to analyse vast datasets from oceanographic sensors, satellite imagery, and cable network performance metrics, offers significant potential to transform cable management. Yet, its integration into submarine cable operations in Tanzania and The Gambia remains limited (Carter & Burnett, 2015). The underutilization of such analytics restricts predictive maintenance, real-time fault detection, and environmental risk assessment, leaving these systems vulnerable to disruptions from fishing activities, anchoring, and geopolitical conflicts (ICPC, 2024; Workshop Report, 2024). Globally, submarine cable networks are susceptible to faults caused by fishing activities, ship anchors, and natural disasters, with fishing and anchoring accounting for approximately %70 of cable damage annually (ICPC, 2023). Recent incidents, such as the 2024 Red Sea cable severance caused by geopolitical conflicts, underscore the vulnerabilities and far-reaching economic impacts of cable disruptions (ICPC-UNEP Report, 2019). In response, industry best practices recommend spatial separation, armouring, and automated identification systems to mitigate risks (ICPC, 2024). However, implementing these measures in regions like Tanzania and The Gambia demands localised strategies that balance global recommendations with regional constraints.

This research aims to explore how the construction and maintenance of submarine fibre cables can optimise the marine big data analytics in Tanzania and The Gambia, addressing the shared challenges of environmental risks, operational inefficiencies, and limited resources. Through adopting predictive analytics and integrating international best practices, the study seeks to enhance the sustainability and resilience of these critical infrastructures, ensuring uninterrupted digital connectivity and economic development in the region.

Methodology

This research was conducted within the contexts of Tanzania and The Gambia, two African nations reliant on submarine fiber cables as foundational infrastructure for digital connectivity and economic development (ITU, 2024). With Tanzania almost %99 connectivity depending on submarine fiber cables (TCRA, 2024) this is study is vital for development of all sectors within a country including Maritime industry. The study sought to investigate how leveraging the construction and maintenance processes of submarine fiber cables can advance the adoption and utility of marine big data analytics in these countries. This perspective emphasizes optimizing existing cable infrastructures to generate, process, and analyze large-scale marine data for enhanced technological, environmental, and economic outcomes. The research adopted a mixed-methods design, integrating both qualitative and quantitative approaches to achieve a comprehensive understanding of the intersection between submarine cable operations and marine big data analytics. This methodological triangulation facilitated the validation of findings and ensured the inclusion of diverse perspectives from key stakeholders in the submarine cable ecosystem.

The target population included stakeholders critical to submarine cable management: government policymakers, private sector leaders from telecommunications firms (Seacom, TTCL, and members of the Tanzania Internet Service Providers Association [TISPA]), regulatory bodies such as the Tanzania Communications Regulatory Authority (TCRA), environmental experts, and technical specialists involved in submarine cable construction, maintenance, and data analytics. A total of 50 participants were identified across Tanzania and The Gambia to provide regionally specific insights. A purposive sampling strategy was employed to ensure the inclusion of individuals with specialized expertise relevant to submarine cable management and big data integration. This approach maximized the depth and relevance of the data collected while ensuring representation across critical sectors.

The study focused on key variables, including the state of submarine cable infrastructure and construction practices, operational challenges, Stakeholder readiness to integrate marine big data analytics into cable management processes and the potential opportunities for data generation and analysis through enhanced cable operations. Data collection proceeded in two phases Quantitative Phase and Qualitative Phase. Structured questionnaires were distributed to stakeholders to capture metrics related to the current state of submarine cables, challenges in their construction and maintenance, and perceived opportunities for big data analytics integration. In-depth interviews and focus group discussions were conducted to elicit nuanced insights into stakeholder perspectives, organizational readiness, and potential barriers to the integration of big data solutions.

The Technology Acceptance Model (TAM) provided the theoretical lens to evaluate stakeholders' willingness to embrace innovations in marine big data analytics. This model helped assess perceived usefulness, ease of use, and readiness for adopting analytics tools within the submarine cable ecosystem. Quantitative data were analyzed using descriptive statistics to identify patterns, trends, and correlations, employing statistical software such as SPSS. Qualitative data from interviews and discussions were analyzed using thematic analysis, leveraging NVivo software to identify recurring themes and subthemes. This dual analytical approach ensured comprehensive insights and the triangulation of data. The methodology aimed to produce actionable insights on how construction and maintenance activities of submarine cables can be optimized to support and drive marine big data analytics in Tanzania and The Gambia. The findings are expected to inform policy frameworks, enhance operational practices, and enable sustainable management of submarine cable infrastructure while unlocking the potential of big data applications in marine ecosystems.

Results and findings

Participant Demographics

The participant pool reflected a diverse spectrum of stakeholders involved in submarine cable infrastructure and marine analytics. Government officials constituted %30 of respondents, representing policymakers and regulatory authorities. Private sector stakeholders, including telecommunications operators such as SEACOM and TTCL, and internet service providers, accounted for %40 of the sample. Researchers and academics from maritime and IT fields formed %20, while the remaining %10 comprised end-users, such as members of internet advocacy groups. Geographically, %60 of participants were from Tanzania, reflecting its broader submarine cable network, while %40 were from The Gambia. Participants were aged between 30 and 55, holding advanced degrees and professional experience ranging from 5 to over 20 years.

Key Findings from Technology Acceptance Model (TAM) Analysis

The Technology Acceptance Model (TAM) framework was instrumental in assessing stakeholder readiness to integrate marine big data analytics into submarine cable construction and maintenance processes. This section elaborates on stakeholders' perspectives concerning perceived usefulness, ease of use, and behavioural intention toward technology adoption.

Perceived Usefulness

Stakeholders unanimously acknowledged the value of leveraging construction and maintenance practices for marine big data analytics. The integration was widely regarded as a means to enhance predictive maintenance, improve fault detection, and optimise resource allocation. One government official stated, "Big data can help us anticipate issues before they become crises, significantly reducing the costs and disruptions associated with cable repairs."

This view aligns with Bashir and Gill (2018), who identified predictive maintenance and real-time fault detection as transformative benefits of big data in telecommunications infrastructure. Private sector representatives emphasised the role of real-time monitoring enabled by big data analytics. A telecommunications executive noted, "Using data to monitor cable conditions and environmental impacts in real-time would revolutionise how we ensure the resilience of this infrastructure."
This observation is consistent with the findings of Kordahi et al. (2017), who underscored the importance of advanced analytics in minimising outages caused by environmental and human activities.

Perceived Ease of Use
While stakeholders recognised the potential benefits, challenges in implementation were highlighted, particularly concerning technical expertise and infrastructure readiness. Academic respondents noted that "the tools for big data analytics need to be intuitive and supported by robust training programs to ensure their widespread adoption." Perera et al. (2020) similarly emphasised that ease of use significantly impacts the adoption rate of data-driven solutions in the marine and telecommunications sectors.

Behavioral Intention
The findings revealed strong stakeholder intent to adopt big data analytics if supported by appropriate investments in capacity building and policy frameworks. A respondent from the Tanzania Internet Service Providers Association remarked, "If stakeholders, particularly at the Tanzania Communications Regulatory Authority (TCRA), prioritise investments in analytics tools, we will see an industry-wide shift toward proactive management strategies."

Alignment with Broader Trends
The results resonate with industry-wide initiatives, such as those advocated by the International Cable Protection Committee (ICPC, 2023), which highlight the critical role of advanced analytics in enhancing the robustness of global submarine cable networks. Additionally, Drew et al. (2021) noted that integrating marine analytics into infrastructure projects provides operational insights that reduce risks and improve efficiency. These perspectives affirm the growing recognition of analytics as a cornerstone for resilient and sustainable cable systems.

Capacity Building and Technical Expertise
The importance of tailored capacity-building initiatives was another recurring theme. Respondents highlighted the critical need for local technical expertise to manage data analytics systems effectively and ensure their long-term sustainability. Investments in technical training programs, particularly in developing regions, are essential to fostering a workforce skilled in managing data infrastructure and marine technologies. These efforts reduce dependency on external expertise and enhance regional autonomy.

A recurring theme was the lack of local technical expertise. Participants expressed concerns about over-reliance on external experts for cable repairs and advanced technology integration. This corroborates findings by Perera et al. (2020), who stress the importance of building a skilled local workforce capable of managing complex submarine cable systems and leveraging them for big data applications. Regulatory issues were also raised, with respondents citing outdated frameworks that fail to accommodate emerging technological advancements. The International Cable Protection Committee (ICPC, 2023) has similarly called for more streamlined and forward-looking policies to address these gaps.

Findings from Questionnaire Responses

Facilitating Conditions

The creation of a supportive ecosystem is essential for leveraging construction and maintenance activities of submarine fiber cables to drive marine big data analytics. Participants across Tanzania and The Gambia consistently emphasized enabling conditions, such as access to funding, capacity-building initiatives, and the establishment of robust policy frameworks. A respondent from Tanzania underscored this need, stating, "Collaboration between government, academia, and the private sector is crucial to building the infrastructure and expertise needed to integrate big data analytics effectively." This sentiment reflects the growing consensus in research that deploying big data analytics in the marine sector requires not only technological advancements but also coordinated multi-stakeholder efforts (Drew et al., 2021).

Collaboration across Stakeholders

Governments, academia, and private enterprises each have distinct but complementary roles in enabling big data analytics integration. Governments are pivotal in crafting supportive policies, allocating funding for innovation, and incentivizing private sector participation (ICPC, 2023). Academia can contribute through technical research and workforce training programs tailored to the complexities of submarine cable operations. Meanwhile, private companies offer practical insights and implementation expertise, bridging the gap between policy and practice. A marine expert from The Gambia remarked, "Academia must develop specialized programs to train a workforce skilled in both marine technology and analytics. This will reduce reliance on foreign expertise and create local technical capacity." This aligns with Perera et al. (2020), who advocate for technical training programs that address challenges such as environmental variability, data integration, and maintenance complexities.

Need for Funding, External support and Capacity Building Gap

Access to funding emerged as a significant enabler of big data analytics deployment. Participants in The Gambia underscored the need for external support and capacity building to bridge the knowledge and skill gaps. According to Drew et al. (2021), such gaps are particularly pronounced in developing regions where access to training resources and technical expertise is limited. The researchers argue that the successful adoption of big data systems requires a robust framework for continuous education and technical training, tailored to the unique needs of the submarine cable industry. The ICPC (2023) recommends collaborative funding models that pool resources from governments, private operators, and global organizations to ensure sustainable implementation. A respondent working in Tanzania highlighted the importance of external partnerships, stating, "Development agencies and international organizations must step in to bridge the funding gaps, ensuring that essential infrastructure for big data analytics becomes a reality in resource-constrained environments."

The need for external support, as emphasized by participants from The Gambia, is also supported by the findings of the International Cable Protection Committee (ICPC, 2023), which advocates for collaborative initiatives to share expertise and resources. Their report highlights the importance of regional partnerships and the role of international organizations in providing technical assistance to countries with limited in-house capacity. Respondents stressed the financial demands associated with advanced analytics systems, including investments in hardware, software, and skilled human resources. Bashir and Gill (2018) noted that international partnerships and development agency contributions are often crucial for regions like Tanzania and The Gambia.

Policy and Regulatory Frameworks

Robust policy frameworks are critical for ensuring the effective adoption of big data analytics in submarine cable management. Clear regulations that standardize data collection, processing, and sharing practices among stakeholders are essential. According to Kordahi et al. (2017), such policies also address critical concerns related to data privacy, cybersecurity, and cross-border data sharing, which are particularly relevant given the global scope of submarine cable systems.

A participant from The Gambia emphasized the importance of regulatory clarity, noting, "Without well-defined policies, there is a risk of fragmented approaches to data management, which could undermine the benefits of analytics integration."

Facilitating conditions such as funding, capacity building, and supportive policies are indispensable for leveraging the construction and maintenance of submarine fiber cables to enable marine big data analytics. These efforts not only address immediate operational challenges but also lay the foundation for long-term technological and economic advancements in Tanzania and The Gambia.

Findings from Interview

Challenges in Submarine Cable Management

The findings revealed several persistent challenges affecting the construction and maintenance of submarine fibre cables, which have implications for their potential to support marine big data analytics. Respondents frequently highlighted the physical risks posed by human activities, such as fishing and ship anchoring, which remain primary causes of cable damage. These observations align with Drew et al. (2021), who identified shallow water zones as particularly vulnerable despite advancements in cable armouring and burial technologies. A stakeholder in Tanzania remarked, "Shallow areas are especially risky, and damage here disrupts not just connectivity but also analytics potential tied to real-time monitoring systems."

Both Tanzania and The Gambia struggle to secure adequate funding for consistent maintenance, upgrades, and timely repairs of submarine cables. According to Bashir and Gill (2018), the high costs of cable infrastructure maintenance place a disproportionate burden on developing economies, often leading to operational inefficiencies. Respondents emphasised the need for international partnerships and development agency support to bridge funding gaps.

Perceptions of Technology Integration

The level of technology integration into the construction and maintenance of submarine cables varied significantly across respondents. While some noted progress in adopting digital tools, many highlighted an ongoing reliance on manual processes. A telecommunications manager in The Gambia noted, "We have made progress, but we still rely heavily on manual processes and external support." This finding is consistent with Drew et al. (2021), who observed that operators in developing countries face barriers to implementing advanced technologies, including cost and technical constraints.

Despite challenges, there was a consensus on the value of adopting modern maintenance and monitoring technologies. Perera et al. (2020) argue that remote monitoring systems and predictive analytics are particularly valuable for improving operational efficiency and reducing response times during emergencies. However, respondents emphasized that realizing these benefits in Tanzania and The Gambia will require targeted investments in infrastructure and training.

Role of Marine Big Data Analytics

There was broad recognition among respondents of the transformative potential of marine big data analytics in enhancing the construction and maintenance of submarine cables. Common themes included route optimization, where big data can analyze environmental and maritime activity patterns to identify the safest and most efficient cable paths. This application mirrors findings by Bashir and Gill (2018), who highlighted big data›s utility in reducing risks during cable planning and installation. A Gambian participant remarked, "With big data, we could identify better routes that minimize risks and reduce future maintenance costs."

Another key theme was the value of real-time monitoring, where big data analytics combined with sensor technology enables operators to detect faults early and proactively mitigate risks. Drew et al. (2021) argue that such capabilities significantly lower repair costs and minimize disruptions. Respondents also emphasized the role of big data in environmental assessments. By mapping sensitive marine ecosystems, analytics can guide eco-friendly cable deployment and maintenance strategies. Kordahi et al. (2017) support this perspective, noting that integrating environmental data reduces ecological impacts while ensuring operational efficiency.

Finding from Various National and International Reports

Subgroup Analysis

The subgroup analysis highlighted critical differences between Tanzania and The Gambia regarding their capacity to leverage submarine cable construction and maintenance for advancing marine big data analytics. Tanzania demonstrated a comparatively higher readiness due to its larger submarine cable network, which includes systems such as SEACOM, 2Africa, and EASSy, and a more developed information and communication technology (ICT) sector due to the implementation of the Electronic and Postal Communications (EPOCA) national regulations. This reflects the nation's greater capacity for integrating marine big data analytics into cable operations, supported by a relatively robust technological ecosystem and skilled workforce (Perera et al., 2020).

Conversely, The Gambia faced more pronounced challenges due to its smaller cable network, which is currently limited to the Africa Coast to Europe (ACE) cable, and a higher dependency on external expertise for maintenance and technological integration. These challenges underscore the need for targeted investments in infrastructure and capacity-building programs to enhance The Gambia's operational resilience and analytic capabilities (Bashir & Gill, 2018). Both countries have ratified and implemented various national regulations, including the Submarine Cable Regulation (UN,2014) and the International Ship and Port Facility Security Code (ISPS Code).

Connectivity between Submarine Fiber Cables and the Shipping Industry

The cable cut incidents analysis also revealed the interdependence between submarine fiber cables and the shipping industry, particularly regarding maintenance, risk management, and the potential for data integration. Shipping routes are often proximate to submarine cable corridors, raising risks of damage from anchoring and maritime traffic.

Reports showing various incidents of cable cuts emphasized the need for enhanced coordination between the cable and shipping industries. Improved collaboration with the shipping sector will help mitigate risks and support shared data systems for monitoring maritime activities. This aligns with findings by Kordahi et al. (2017), who highlight the role of marine spatial planning in reducing operational conflicts.
Marine big data analytics could serve as a bridge between these sectors by providing real-time data on ship movements and environmental conditions. For instance, analytics could optimize cable routes to avoid high-risk shipping zones while also informing maritime operations about cable locations to prevent accidental damage. Drew et al. (2021) suggest that integrating sensor networks with marine big data platforms could enable predictive maintenance and enhance risk mitigation for both industries.

Prolonged Legal Battles, Liability and Blame in Cable-Cutting Incidents

One of the recurring issues identified in the management of submarine fiber cables is the ambiguity surrounding liability when cable cuts occur due to ship anchorage. This lack of clarity often leads to protracted legal disputes between telecommunications companies, shipping operators, and their respective insurance providers. The C-Lion1 incident in the Baltic Sea provides a prime example of this challenge, where the liability for a submarine cable cut due to vessel anchoring remains unresolved, creating operational and financial setbacks for all parties involved (Lieber Institute West Point, 2023).

Submarine cable cuts are caused by accidental anchoring or negligence on the part of vessels traversing routes near cable systems. In these scenarios, telecommunications companies typically hold the shipowners responsible for damages, while shipping companies argue that the cables were not properly charted or that the incident occurred in an unregulated zone. This blame-shifting is exacerbated by gaps in marine insurance policies, which rarely specify coverage for such incidents. Also, a respondent from Tanzania commented, "When a cable cut occurs, we often face delays because no party wants to assume responsibility everyone shifts the blame." Protracted legal disputes following cable-cut incidents impose significant economic costs. These include operational downtime, repair expenses, and reputational damage for telecommunications providers, as well as higher insurance premiums for shipping companies. The C-Lion1 case demonstrated how such disputes could create geopolitical and economic tensions, with shipping companies and telecommunication providers locked in protracted legal battles due to unclear jurisdictional and liability frameworks (Lieber Institute West Point, 2023).

Current insurance structures also fail to provide clarity. Third-party insurers for both the vessel and the cable often dispute the extent of their liability. According to ICPC reports, the lack of explicit marine insurance coverage for cable damage caused by ship anchorage leaves both sectors in a precarious position, requiring expensive legal recourse to settle disputes (ICPC, 2023).

The Need for a New Insurance Framework

There is a growing consensus on the necessity for a specialized marine insurance policy tailored to address cable damage caused by ship anchorage. Such a policy would define clear liability parameters for cable operators, ship owners, and third-party insurers, reducing the likelihood of protracted disputes. A standardized marine insurance policy that covers anchor-related cable damage could streamline resolution processes and improve accountability. Industry stakeholders, such as the International Cable Protection Committee (ICPC), have advocated for regulatory reforms to bridge this gap. Recommendations include mandating vessel owners to obtain specialized insurance that explicitly covers damage to submarine cables, as well as requiring telecommunications companies to collaborate with maritime agencies to ensure cable routes are clearly mapped and well-communicated (ICPC, 2023).

The recurring blame game in cable-cut incidents underscores the urgent need for regulatory clarity and new insurance frameworks. The legal ambiguity surrounding liability between telecommunications companies, shipping operators, and insurers not only escalates disputes but also delays repairs, causing significant economic and operational disruptions. Drawing lessons from incidents such as C-Lion1, stakeholders must collaborate to establish clear liability standards and implement specialized marine insurance to cover cable damage caused by anchoring. This approach would foster accountability, expedite resolution processes, and ensure the resilience of submarine cable systems globally.

Submarine cable cuts and Environmental Impacts

Submarine cable cuts often require repair operations that disturb the seabed, potentially affecting benthic organisms and habitats. During cable recovery or reburial, sediment is displaced, which can alter the local seabed structure and turbidity, impacting marine life such as corals, sponges, and other bottom-dwelling organisms (UNEP-WCMC & ICPC, 2019). These disturbances are generally temporary but can have long-term effects in sensitive ecosystems. Repair operations, involving cable ships and remotely operated vehicles (ROVs), may interfere with marine mammals by creating underwater noise pollution. This noise can disrupt the communication and navigation of species such as whales and dolphins (Kordahi et al., 2017).

During cable repairs and construction, the resuspension of sediments can increase water turbidity, potentially affecting photosynthetic organisms and filter feeders in the vicinity (Halpern et al., 2018). Interestingly, cables themselves can act as artificial habitats for marine life, providing surfaces for colonisation by species such as barnacles and corals (Drew et al., 2021). However, when cables are cut and exposed, the disruption to this habitat could displace these organisms. While the overall environmental footprint of submarine cables is generally considered small compared to other marine activities, repair operations and cable cuts can have localised effects on marine ecosystems. Effective marine spatial planning and the adoption of eco-friendly repair technologies can help mitigate these impacts (UNEP-WCMC & ICPC, 2019).

Recommendations

Establish Clear Liability Frameworks for Cable-Cutting Incidents: The ambiguity surrounding liability for submarine cable cuts caused by ship anchorage demands immediate regulatory action. Governments and international organisations must develop and enforce clear liability frameworks that outline the responsibilities of telecommunications companies, shipping operators, and third-party insurers. These frameworks should define specific scenarios of liability, ensuring accountability and reducing the occurrence of protracted legal battles. Standardised agreements, such as those recommended by the International Cable Protection Committee (ICPC), can streamline dispute resolution processes and provide a baseline for cross-border collaborations.

Develop Specialised Marine Insurance Policies: To mitigate the financial and operational risks associated with cable-cut incidents, the development of specialised marine insurance policies is crucial. These policies should explicitly cover damage to submarine cables caused by ship anchorage, providing clarity on the extent of coverage for all stakeholders. Governments and marine insurance providers should collaborate to design and mandate such policies, ensuring that both vessel owners and telecommunications operators are adequately protected. Implementing this recommendation would reduce the economic burden on individual stakeholders and expedite the repair process after incidents.

Enhance Marine Spatial Planning and Awareness Programs: To prevent cable damage caused by anchoring, governments and industry stakeholders should invest in marine spatial planning tools and awareness campaigns targeting the shipping industry. Submarine cable routes must be clearly charted and communicated to vessel operators, with mandatory inclusion in nautical charts and real-time geospatial systems such as Automatic Identification Systems (AIS). Awareness programs, coupled with robust monitoring, will enable ships to navigate safely and avoid areas with high cable density.

Strengthen Collaboration Among Stakeholders: Effective collaboration between the telecommunications and shipping industries is essential for reducing cable-cut incidents. Stakeholders must establish formal communication channels and joint task forces to coordinate activities. For instance, telecommunications companies can partner with shipping operators to share data on cable locations, maintenance schedules, and potential risk zones. Maritime authorities can serve as mediators, fostering cooperation and ensuring that both sectors work towards shared goals of safety and operational efficiency. With expected increase in submarine fiber cables from four to six in Tanzania between 20230 -2024, it is crucial for TCRA and TASAC to form a collaborative platform to work together on associated challenges.

Build Technical Capacity in Developing Regions: Developing countries such as Tanzania and The Gambia must prioritize building local technical expertise to manage cable maintenance and the integration of marine big data analytics. Capacity-building initiatives, supported by international development agencies, should focus on training programs that equip local professionals with the skills needed for cable repair, monitoring, and analytics integration. This investment would reduce reliance on external experts and strengthen the operational resilience of submarine cable systems.

Promote the Integration of Marine Big Data Analytics: Marine big data analytics must be fully integrated into cable construction and maintenance processes to enhance risk management and operational efficiency. Telecommunications operators should adopt advanced tools, such as predictive analytics and real-time monitoring systems, to identify potential risks proactively. These tools can optimize cable routes, reduce repair costs, and minimize disruptions caused by anchoring or environmental factors. Governments and private stakeholders should co-invest in infrastructure that supports data collection and analysis to enable these capabilities.

Advocate for International Regulatory Standards: Given the global nature of submarine cable networks, international regulatory bodies must prioritize the establishment of standardized policies for cable protection. A unified legal framework under organizations such as the United Nations or the International Maritime Organization (IMO) would ensure consistency across jurisdictions, addressing gaps in liability and insurance coverage. Such standards would facilitate seamless collaboration between countries and safeguard critical global connectivity infrastructure.

Conclusion

The findings of this research underscore the critical need for clarity in liability frameworks, enhanced collaboration, and innovative solutions to address the challenges associated with submarine cable construction and maintenance. Tanzania and The Gambia, as representatives of East and West Africa, face shared obstacles, including limited resources, technical expertise, and regulatory gaps. However, these challenges present an opportunity for both nations to collaborate strategically and set a benchmark for addressing global issues surrounding submarine cable stability and marine big data analytics.

Through working together, Tanzania and The Gambia can share resources, technical knowledge, and best practices, creating a model for other developing regions. Joint initiatives could include harmonizing regulatory frameworks to establish clear accountability in cable-cut incidents, co-developing specialized insurance policies tailored to their shared needs, and building regional capacity through targeted training programs. The stability of submarine fiber cables is integral to building a robust digital marine economy in both regions. Reliable cable infrastructure underpins uninterrupted connectivity, supports maritime operations, and enhances economic resilience through data-driven decision-making. Marine big data management, enabled by stable submarine cables, can revolutionize industries such as shipping, environmental monitoring, and resource management, driving sustainable growth across Africa.

Future research should focus on creating predictive models for cable risk management, exploring the potential of artificial intelligence in cable monitoring, and assessing the economic impact of stable submarine cable systems on regional development. Additionally, studies on the integration of renewable energy solutions into cable maintenance operations could offer sustainable and cost-effective approaches. Through championing innovative solutions, Tanzania and The Gambia can position themselves as leaders in submarine cable management, providing a roadmap for global best practices. This collaboration has the potential to set a new standard, ensuring the resilience of critical infrastructure, driving the digital marine economy, and safeguarding the future of global connectivity.

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References

Ash, R. (2013). Submarine cable systems and biodiversity: A review of impacts and opportunities. Oceanographic Studies, 429–412 ,(4)18.

Bashir, A., & Gill, S. (2018). Financial constraints in developing submarine cable infrastructure: A developing nations perspective. International Journal of Maritime Studies, 63–45 ,(3)12.

Carter, L., & Burnett, D. R. (2015). Subsea telecommunications: A review of challenges and opportunities. Marine Policy, 27–17 ,(1)53. https://doi.org/10.1016/j.marpol.2014.11.003

Drew, S., Perera, S., & Gill, S. (2021). Marine insurance and submarine cable risks. Journal of Marine Operations, 128–105 ,(2)8.

International Cable Protection Committee (ICPC). (2023). Best practices for cable protection and resilience. https://www.iscpc.org

International Telecommunication Union (ITU). (2024). Global connectivity through submarine cables: A report on resilience and sustainability. Geneva, Switzerland. Kordahi, M., Shapiro, N., & Wood, R. (2017). Submarine cables in a crowded ocean: Risks and mitigation strategies. Journal of Marine Engineering and Technology, ,(4)15 227–213.

Lieber Institute West Point. (2023). Baltic Sea cable cuts: Ship interdiction and the C-Lion1 incident. https://lieber.westpoint.edu/baltic-sea-cable-cuts-ship-interdiction-c- lion-1incident/

Perera, S., Bashir, A., & Drew, S. (2020). Emerging challenges in submarine cable management. Marine Analytics Journal, 74–56 ,(3)22.

Smith, H. D., Suárez de Vivero, J. L., & Agardy, T. S. (Eds.). (2015). Routledge handbook of ocean resources and management. Routledge.

UNEP-WCMC & ICPC. (2019). Submarine cables and the oceans: Connecting the world. UNEP World Conservation Monitoring Centre. https://www.unep-wcmc.org/ resources/publications

Burnett, D. R., Carter, L., & Drew, S. (2013). International law and submarine cables: Balancing interests and obligations. Ocean Yearbook, 122–99 ,27.

Halpern, B. S., Walbridge, S., Selkoe, K. A., et al. (2018). A global map of human impact on marine ecosystems. Science, 952–948 ,(5865)319.

Lacroix, D., et al. (2002). Submarine cable protection: An analysis of global practices. International Maritime Journal, 93–76 ,(2)14.

Lloyd's Register. (2020). Submarine cables and marine spatial planning: Challenges and best practices. Maritime Risk Analysis Report, 39–29 ,(2)17.

Monterey Bay National Marine Sanctuary. (2005). Cable laying and environmental protection: An integrated approach. NOAA Technical Reports.

Smith, J. E., & Williams, R. T. (2010). Submarine cable systems and the global economy. Oceanic Engineering Journal, 140–123 ,(6)35.

Rauscher, K. F. (2010). Protecting undersea cables: A critical infrastructure priority. Telecom Policy Journal, 332–321 ,(4)34.

Tanzania Communications Regulatory Authority (TCRA). (2024). Communication Statistics for end of June 2024 https://www.tcra.go.tz/uploads/text-editor/files/ Communication20%Statistics20%report20%for20%end20%of20%June202024%_EN_1721315046.pdf

TeleGeography. (2024). Submarine cable map: The state of global connectivity. Retrieved from https://www.telegeography.com

UNEP-WCMC & ICPC. (2019). Submarine cables and the oceans: Connecting the world. UNEP World Conservation Monitoring Centre. https://www.unep-wcmc.org/ resources/publications

West, R., & Anderson, J. (2018). Predictive maintenance and real-time monitoring of submarine cables. IEEE Journal of Oceanic Engineering, 575–567 ,(3)43.

Workshop Report on ICPC-CIL Cables Workshop. (2024). Law of the sea and submarine cables. ICPC & NUS Centre for International Law.

IMPLICATIONS OF GRAVITY WAVES POTENTIAL ENERGY ON COASTAL RESILIENCE AND SUSTAINABILITY

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Abstract
Atmospheric gravity waves (GWs) are pivotal in regulating atmospheric energy transfer, influencing climate dynamics, and directly impacting tropical and coastal regions. This study focuses on the West African region, investigating GW seasonal variation using five years (January 2019–December 2023) of ERA5 reanalysis data. Gravity Waves Potential Energy (GWPE), calculated from vertical temperature profiles of the West African region with Linear Perturbation Analysis, reveals that atmospheric disturbances are induced by GWs, with maximum GW activity and upward energy propagation occurring during the June-July-August (JJA) period. These findings align with previous observations, which reported seasonal energy density variations from 9 Jkg^{-1} to 15 – 26 Jkg^{-1} peaks over the same JJA period. The seasonal variations in GWPE have significant implications within the context of climate change, particularly for coastal resilience and sustainability because of the direct relationship between GWPE variations and seasonal sea levels. As climate change intensifies, coastal communities increasingly face the impacts of shifting atmospheric-ocean dynamics. The analysis of GWPE trends and their impact on rising sea levels will enable coastal planners to predict shifts in erosion patterns and adjust their strategies for coastal protection. By connecting GW seasonal patterns to broader climate processes, this study contributes valuable insights for supporting sustainable economic practices in coastal regions, which are climate-sensitive regions.

Keywords: gravity waves potential energy, climate dynamics, coastal resilience, sustainable economic practices

Introduction
Coastal regions are vital to global ecosystems, supporting diverse habitats and providing critical resources for human populations (Lakshmi, 2021). However, these areas are increasingly vulnerable to climate change impacts, including rising sea levels, intensified storms, and shifting erosion patterns. Understanding the atmospheric and oceanic processes influencing coastal dynamics is crucial for developing sustainable strategies to enhance resilience and sustainability. Among these processes, atmospheric gravity waves (GWs) have emerged as key drivers of atmospheric energy transfer, influencing climate dynamics and impacting tropical and coastal regions (Alexander et al., 2010). Atmospheric gravity waves are oscillations resulting from the displacement of air parcels in stable atmospheric layers. These waves facilitate energy transfer and momentum across different atmospheric levels, significantly impacting weather patterns, convection, and large-scale circulation. The potential energy associated with these waves, called Gravity Waves Potential Energy (GWPE), is a critical metric for assessing wave activity and its influence on atmospheric dynamics. Seasonal variations in GWPE have been linked to shifts in atmospheric energy distribution, particularly in tropical regions where convection dominates (Fritts & Alexander, 2003). In West Africa, gravity waves interact with tropical convection and monsoonal flows, significantly influencing regional climate and weather systems (Alexander et al., 2010). During the June-July-August (JJA) season, GW activity peaks, with energy density values ranging from 15 to 26 J/kg (Hindman & Gossard, 2013). The implications of these variations extend beyond atmospheric phenomena. GWPE influences

atmospheric-ocean coupling processes, such as sea-level dynamics, which in turn affect coastal erosion, flooding, and sediment transport (Lindzen, 1981). In the context of climate change, where extreme weather events are expected to intensify, understanding GWPE's seasonal dynamics is essential for mitigating risks to coastal ecosystems and communities (IPCC, 2021).

Despite its significance, the relationship between GWPE variations and coastal sustainability remains underexplored, especially in the West African region. This study addresses this gap by examining GWPE seasonal variation using five years (2019–2023) of ERA5 reanalysis data. By focusing on this region, the research provides insights into how GW activity shapes seasonal energy distributions and contributes to coastal resilience and sustainability.

Methodology

Data

Temperature profiles and sea level data from ERA5 produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), was utilized as the primary dataset for this study (ECMWF, 2024). ERA5 is a state-of-the-art global atmospheric reanalysis product that combines observational data with model output through advanced data assimilation techniques, providing comprehensive, high-resolution meteorological data. Hourly data were used, which were aggregated to daily and seasonal averages for analysis. This high temporal resolution enables a detailed investigation of short-term and seasonal variations in GW activity. The horizontal resolution of ERA5 data is approximately 0.25O×0.25O (about 31 km). This fine spatial resolution ensures that regional-scale features of atmospheric gravity waves and their energy distributions are captured accurately.

The dataset spans five years, from January 2019 to December 2023, ensuring sufficient temporal coverage to capture seasonal and interannual variations in atmospheric gravity waves. Vertical temperature profiles, a critical parameter for analyzing atmospheric gravity wave potential energy (GWPE), were extracted at multiple pressure levels. The analysis focused on the West African region, encompassing latitudes from 4°N to 18°N and longitudes from 17°W to 15°E. This region was selected due to its climatic significance, particularly its interaction with the monsoonal system and its vulnerability to climate change impacts. Additionally, data on sea levels were obtained to assess its coupling with GWPE.

Gravity waves potential energy model

For the present study, the gravity wave activity measure used is gravity wave potential energy (Tsuda et al. 2000). In general, gravity wave energy is the sum of potential and kinetic wave energy, but linear gravity wave theory predicts that on average the ratio of potential to kinetic Energy, Ep/Ek, is constant (Nastrom et al., 2000; Venkat Ratnam et al., 2004). Therefore, we can assume the total gravity wave energy to be proportional to potential energy, which can be calculated from temperature profiles alone. The calculation of potential energy from temperature profiles is described in detail by Tsuda et al. (2000) using linear perturbation analysis and linear theory of gravity waves.

The atmospheric temperature profile (T) from ERA 5 as a function of pressure levels consists of the background temperature profile and the fluctuating component T'. The Ep has been used as a proxy for studying the gravity wave activities as presented by Tsuda et al. (2000) is given by:

$$E_p = \frac{1}{2}\frac{g^2}{N^2}\left(\frac{T'}{\overline{T}}\right)^2$$

(1)

where Ep is the Gravity wave potential energy, g is the gravitational field strength, N is the Brunt-Vaisala Frequency, T' is the mean temperature and T is the temperature perturbation.

The calculation of Ep is based on T' given by T' = T - T (2)

ıd $N^2 = \frac{g}{\bar{T}} \left[\frac{\partial \bar{T}}{\partial h} + \frac{g}{C_p}\right]$

(3)

where Cp is the specific heat capacity of air at constant pressure and h is the altitude. Python-generated time-series plots, box plots, and correlation graphs were used to analyze the data.

Results

Yearly Trend of Gravity Waves Potential Energy

Figure 1 shows the temporal evolution of GWPE over five years, highlighting seasonal and interannual variations. The GWPE trend demonstrates a distinct peak (23.8 J/kg) in 2019 and trough (21.1 J/kg) in 2020, indicating the influence of atmospheric conditions such as convection, wind shear, and seasonal variations in thermal gradients.

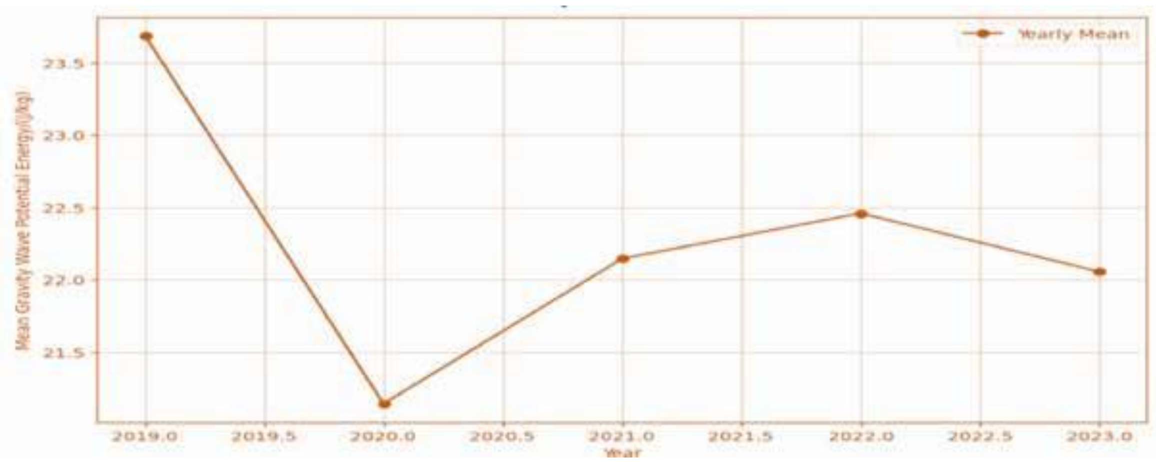


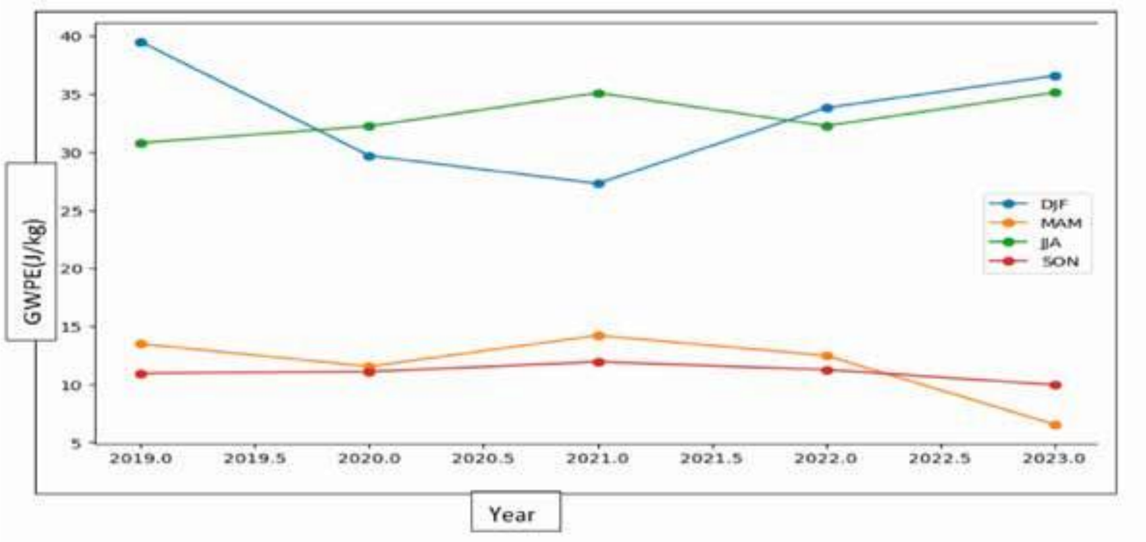
Figure 1. Yearly Trend of Gravity Waves Potential Energy (2019-2023)

Seasonal Variation of GWPE

To examine the seasonal variation of gravity wave activity, monthly means of all Ep profiles were formed. The data were grouped into four climatological seasons: December-January-February (DJF), March- April- May (MAM), June-July-August (JJA), and September-October-November (SON).

GWPE values were averaged for each season to determine seasonal trends and peak activity periods. Seasonal energy density variations were compared to reported values (9 J/kg in DJF, 15–26 J/kg in JJA) to ensure reliability.

Figure 2. Seasonal variation of mean Gravity wave potential energy



The year 2019 stands out with the highest recorded potential energy (Ep) of 39 J/kg, as shown in Figure 2. This figure also highlights clear interannual variations in wave activity. Notably, the wave activity pattern observed in 2019 differs significantly from other years in several respects. The peak Ep in 2019 occurred during the DJF (December-January-February) period, indicating unusually strong wave activity during this season. Such heightened DJF wave activity has also been reported in previous studies, such as Venkat Ratnam et al. [2004b]. Conversely, the lowest wave activity in 2019 was recorded in January, a trend consistently observed across all years without significant year-to-year variation. While interannual variations are evident, they require further detailed analysis, which will be addressed in future studies. Aside from the anomalies observed in 2019 and 2023, a dominant seasonal cycle is consistently present in the data.

Sea Levels Trends

Figure 3 illustrates an increasing trend in annual average sea levels over the five-year period from 2019 to 2023. The sea level values rise consistently, from 80.2 mm in 2019 to 98.2 mm in 2023, indicating a sustained and significant increase. This trend is likely indicative of ongoing global sea level rise caused by climate change-related factors, such as thermal expansion of seawater and increased contributions from melting glaciers and ice sheets. This rising trend in sea levels is expected to intensify issues such as coastal erosion, extreme marine flooding, and saltwater intrusion into coastal aquifers, as noted by Nicholls and Tol (2006), Nicholls et al. (2007), and Nicholls and Cazenave (2010). While Figure 3 illustrates yearly average trends of sea levels, Figures 4 a and 4b give detail monthly average trends for the years 2019 and 2020.

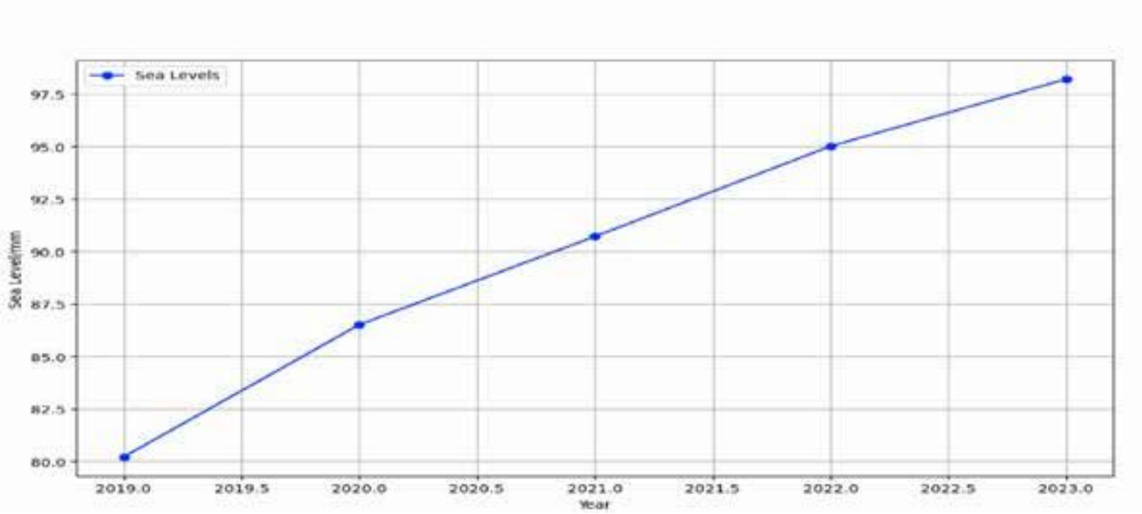


Figure 3 Mean Sea level variation from 2019 to 2023

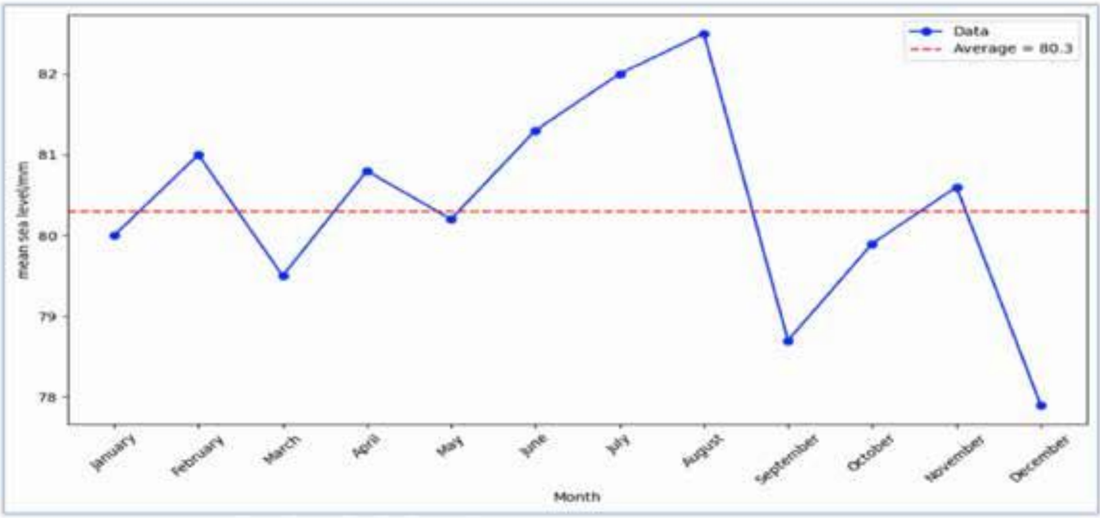


Figure 4a Time series plot of sea levels for 2019

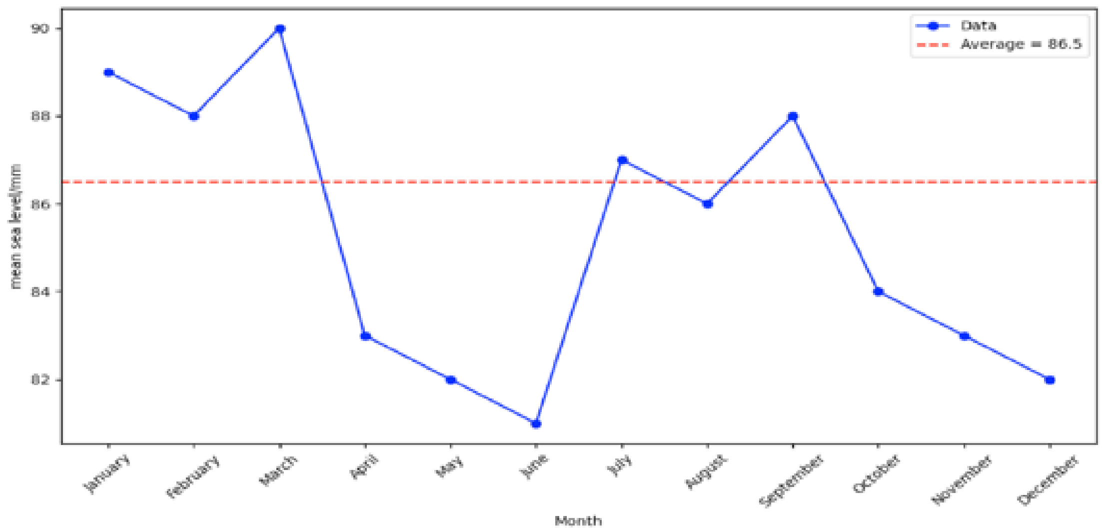


Figure 4 b Time series plot of sea levels for 2020

Interannual Variation of Sea Levels

There is upward trend in the mean sea levels from 2019 to 2023 as shown by the interannual variability of sea levels from 2019 to 2023 in Figure 5. Starting from the lowest range in 2019 (77.9 to 82.5), the values progressively increase each year, reaching their highest in 2023 (98.1 to 99.5). This indicates a consistent rise in sea level across these five years. The steady rise in sea levels from 2019 to 2023, suggests a long-term trend in global mean sea level (GMSL) increase.

The median sea levels show a clear increasing trend over the years. Starting at around 80 mm in 2019, the median rises progressively to approximately 99 mm by 2023. This consistent increase suggests long-term drivers of sea-level rise, such as thermal expansion and melting ice.

Minimal outliers are visible, indicating that the monthly sea levels are relatively consistent within each year.

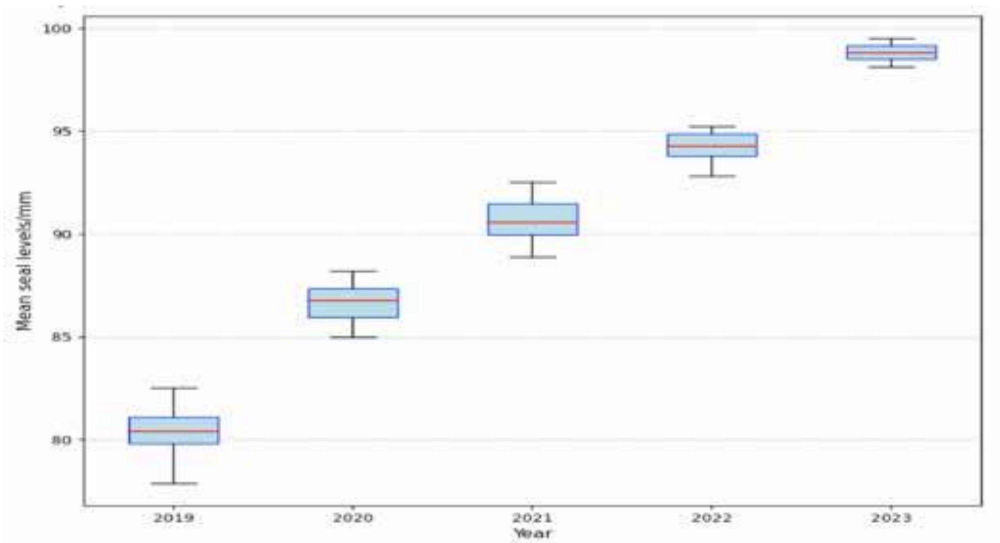


Figure 5 Yearly mean sea levels

Seasonal and Interannual Variations in Monthly Sea Levels (2019–2023)
The analysis of monthly sea level data from 2019 to 2023 reveals distinct seasonal and interannual variations, reflecting the dynamic nature of coastal environments. Seasonally, sea levels exhibit recurring patterns, with higher values typically observed during specific periods of the year, likely influenced by factors such as thermal expansion of water, regional ocean currents, and atmospheric pressure variations (Wolski & Wiśniewski, 2023).

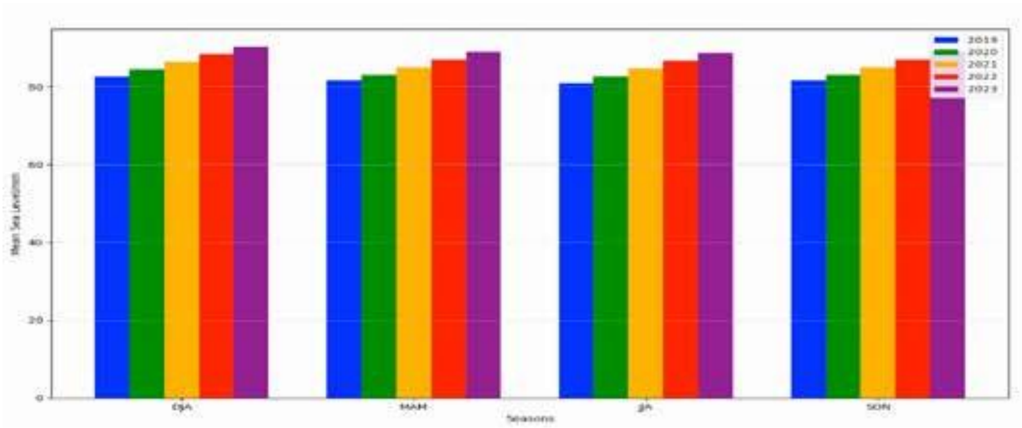


Figure 6. Seasonal variations in sea levels

Figure 6 shows a consistent increase in sea levels across all seasons from 2019 to 2023. This suggests a gradual rise in sea levels over the years. The increase is most prominent in the DJA and JJA seasons, indicating stronger dynamics during these periods.

Impact of GWPE on Sea Levels
To study the impact of GWPE on sea levels, the correlation between the two parameters and correlation coefficients were plotted against the years under consideration

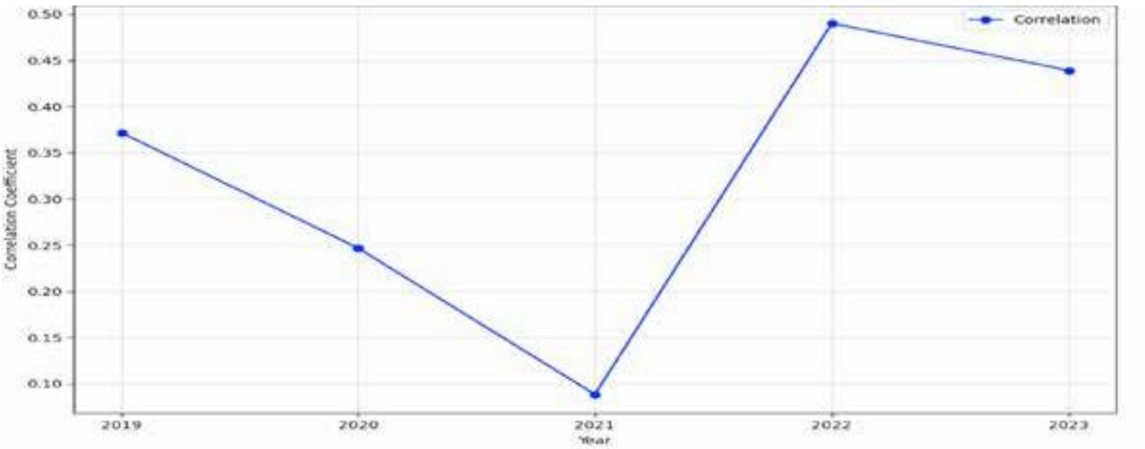


Figure 7 Correlation coefficient between sea level and gravity wave potential energy

Moderate positive correlation in 2019 as indicated in Figure 7 suggests that as GWPE increases, sea levels also show a tendency to rise. This year may reflect a balance between regional gravity wave influences and other factors affecting sea level, such as thermal expansion or glacial melt. The lower correlation in 2020 indicates a weaker relationship between GWPE and sea levels. External factors such as ocean currents, local meteorological conditions, or delayed effects of GWPE on sea levels could explain the reduced strength of the relationship. The very low correlation in 2021 suggests almost no direct relationship between GWPE and sea levels during this year. It's possible that other dominant factors, such as atmospheric pressure variations (e.g., ENSO effects) or local processes, overshadowed the influence of GWPE. The highest correlation among the years, 0.49, reflects a stronger association between GWPE and sea levels. This could indicate a year where gravity wave activity significantly influenced atmospheric and oceanic dynamics, leading to observable changes in sea levels. A moderately high correlation in 2023 further supports the idea that GWPE had a substantial impact on sea levels. This year may have experienced conditions where gravity waves played a critical role in vertical energy transfer, influencing atmospheric stability and subsequently affecting sea level dynamics.

Discussion

Interpretation of GWPE's role in influencing sea-level changes

Gravity waves can influence atmospheric circulation and pressure systems, which in turn affect sea levels. For example, enhanced GWPE may contribute to changes in atmospheric pressure gradients, indirectly influencing oceanic currents and sea levels. Strong wave activity could affect coastal dynamics, especially during extreme weather events, contributing to higher observed sea levels. The variability in correlation coefficients from year to year suggests that the relationship between GWPE and sea levels is not linear or constant. This could result from differences in regional or global atmospheric and oceanic conditions. Also, the influence of other dominant factors like global warming, glacial melt, and thermal expansion.

It's also possible that GWPE influences sea levels with a lag, meaning the effects of wave energy from one year may manifest in subsequent years, which could dampen the apparent correlation in certain years. The moderate correlations in 2022 (0.49) and 2023 (0.44) suggest that GWPE plays a significant role in influencing sea levels, especially when coupled with other climate factors. The weaker correlations in other years highlight the complexity of sea level dynamics, where multiple factors such as thermal expansion, melting ice, atmospheric pressure, and regional ocean currents interact to determine sea level variations.

Impact on Coastal Sustainability

Gravity wave potential energy (GWPE) influences sea-level variations through its interaction with atmospheric and oceanic processes, with significant implications for coastal communities. These variations are primarily driven by atmospheric pressure changes, wave-induced wind patterns, and the modulation of ocean tides, resulting in localized shifts in sea level (Fritts & Alexander, 2003). Such fluctuations, though transient, can exacerbate the impacts of storm surges, tidal flooding, and long-term sea-level rise. One major effect of GWPE-driven sea-level variations is the heightened risk of flooding in low-lying coastal areas. During events such as high tides or intense storms, GWPE-induced changes can amplify water levels, increasing the likelihood and severity of inundation. This poses serious threats to coastal infrastructure, ecosystems, and human settlements, particularly in regions already vulnerable to rising sea levels (Hoffmann et al., 2013). Furthermore, these variations can disrupt sediment transport dynamics, contributing to shoreline erosion in some areas and sediment accumulation in others, altering coastal landscapes and affecting habitats for marine and terrestrial species (Smith, 2012).

For human communities, the socioeconomic impacts of GWPE-driven sea-level variations are significant. Increased flooding can damage homes, roads, and other critical infrastructure, disrupt livelihoods, and necessitate costly repairs. The intrusion of seawater into freshwater systems can lead to salinization, reducing the availability of potable water and affecting agricultural productivity. These challenges are particularly acute in developing regions, where limited resources and adaptive capacities exacerbate vulnerabilities (Alexander et al., 2010). Addressing these challenges requires an improved understanding and modelling of GWPE and its interactions with ocean dynamics. Early warning systems and predictive models can help anticipate and mitigate the impacts of sea-level variations. Additionally, incorporating GWPE considerations into coastal management plans and infrastructure designs can enhance resilience and reduce the vulnerability of coastal communities to these dynamic processes (Hendon & Salby, 1994).

Strategies for integrating QWPE trends into coastal protection and resilience planning

Integrating gravity wave potential energy (GWPE) trends into coastal protection and resilience planning is essential for mitigating the risks associated with dynamic sea-level variations and their impacts on coastal communities. GWPE influences atmospheric and oceanic interactions, and its variability can significantly affect weather patterns, storm surges, and sea-level changes.

Robust monitoring systems, including satellite observations and ground-based measurements, are essential to track GWPE trends and their impacts on sea-level variations, improving predictive models and preparedness for extreme events. Integrating GWPE trends into numerical models can provide insights into how gravity waves influence coastal flooding, erosion, and sediment transport, supporting better urban planning and disaster management. Coastal infrastructure should incorporate adaptable and nature- based solutions, like mangrove restoration and permeable pavements, to address the variability in sea levels influenced by GWPE. Community-based resilience programs, through education and awareness campaigns, can empower local populations to adopt adaptive practices and improve emergency preparedness. Policymakers must integrate GWPE considerations into coastal management and climate adaptation strategies, fostering collaboration among scientists, planners, and authorities. Securing climate adaptation financing is crucial to fund research and implement resilience measures that address the impacts of gravity wave dynamics on sea-level variability.

Conclusions

Temperature profiles and mean sea levels were obtained from ERA 5 to study the impact of gravity wave potential energy on rising sea levels. Potential energies calculated from the temperature profiles showed significant seasonal variation. The Ep were correlated with seasonal sea levels. The correlation coefficients highlight that GWPE has a weak to moderate influence on sea levels, with stronger impacts in certain years (2022 and 2023). This variability underscores the complexity of coastal and atmospheric systems, emphasizing the need for comprehensive studies to the contributions of different factors to sea level changes.

Future work

A time-lagged correlation analysis should be conducted to determine if GWPE impacts sea levels with a delay.

Combined effects of GWPE, atmospheric pressure, thermal expansion, and other factors on sea levels should be explored using regression or machine learning models.

Further studies should be done to investigate whether correlations vary regionally, as local factors (e.g., topography, coastal infrastructure) may influence the relationship.

References

Alexander, M. J. (1998). Interpretations of observed climatological patterns in stratospheric gravity wave variance. Journal of Geophysical Research, 103(D8), 8627–8640. https://doi.org/10.1029/97JD03325

Alexander, M. J., Geller, M., McLandress, C., Watanabe, S., & 12 others. (2010). Recent developments in gravity-wave effects in climate models and the global distribution of gravity-wave momentum flux from observations and models. Quarterly Journal of the Royal Meteorological Society, 136(650), 1103–1124. https://doi.org/10.1002/qj.637

Allen, S. J., & Vincent, R. A. (1995). Gravity wave activity in the lower atmosphere: Seasonal and latitudinal variations. Journal of Geophysical Research, 100(D1), 1327–1350. https://doi.org/10.1029/94JD02688

ECMWF (2024) ERA5 reanalysis data http://cds.climate.corpenicus.eu , accessed on 06 – 12 - 2024

Fritts, D. C., & Alexander, M. J. (2003). Gravity wave dynamics and effects in the middle atmosphere. Reviews of Geophysics, 41(1), 1003. https://doi. org/ 10.1029/2001RG000106

Hendon, H. H., & Salby, M. L. (1994). The life cycle of the Madden-Julian Oscillation. Journal of the Atmospheric Sciences, 51(15), 2225–2237. https://doi.org/10.1175/1520-0469(1994)051

Hoffmann, L., Alexander, M. J., & Ern, M. (2013). Gravity waves generated by deep tropical convection: Observations and modeling. Atmospheric Chemistry and Physics, 13(4), 2037–2049.https://doi.org/10.5194/acp-13-2037-2013

Intergovernmental Panel on Climate Change (IPCC). (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [V. Masson-Delmotte,
P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, et al. (Eds.)]. Cambridge University Press. https://doi.org/10.1017/9781009157896

Lakshmi, A. (2021). Coastal ecosystem services & human wellbeing. The Indian Journal of Medical Research, 153(3), 382–387. https://doi.org/10.4103/ijmr.IJMR_695_21

Intergovernmental Panel on Climate Change (IPCC). (2021). Climate Change 2021: The
Physical Science Basis. Contribution of Working Group I to the Sixth AssessmentReport of the Intergovernmental Panel on Climate Change [V. Masson-Delmotte,
P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, et al. (Eds.)]. Cambridge University Press. https://doi.org/10.1017/9781009157896

Nicholls, R. J., & Cazenave, A. (2010). Sea-level rise and its impact on coastal zones. Science, 328(5985),1517–1520.https://doi.org/10.1126/science.1185782

Nicholls, R. J., & Tol, R. S. J. (2006). Impacts and responses to sea-level rise: A global analysis of the SRES scenarios over the twenty-first century. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 364(1841), 1073–1095. https://doi.org/10.1098/rsta.2006.1754

Nicholls, R. J., Wong, P. P., Burkett, V. R., Codignotto, J. O., Hay, J. E., McLean, R. F., Ragoonaden, S., & Woodroffe, C. D. (2007). Coastal systems and low-lying areas. In Climate Change 2007: Impacts, Adaptation and Vulnerability (pp. 315–356). Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [V. Masson-Delmotte,
P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, et al. (Eds.)]. Cambridge University Press. https://doi.org/10.1017/9781009157896

Smith, M. D.(2012). Climatechange, coastalflooding, andthedesignofurbaninfrastructure: A case study of the New York Metropolitan region. Climatic Change, 106(1), 93–127. https://doi.org/10.1007/s10584-011-0027-2

Venkat Ratnam, M., Patra, A. K., Rama Gopal, K., & Rao, S. V. B. (2004). Characteristics of gravity waves generated by tropical deep convection: Case studies from Gadanki (13.5° N, 79.2° E). Annales Geophysicae, 22(8), 2675–2688. https://doi.org/10.5194/angeo-22-2675-2004

ADOPTING OPEN SHIP REGISTRY IN GHANA: PROSPECTS AND BARRIERS

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Abstract

Registering a ship is a crucial phase in vessel ownership, mandated by legal requirements that afford vessels access to the global market and open seas. Ship registration plays a pivotal role in contributing to the socio-economic development of flag states. The extent to which flag states benefit from ship registration varies due to the specific registry systems they adopt. This study delved into the current state of ship registration in Ghana, focusing on the impact of the closed ship registry system. Additionally, it attempted to delineate the potential advantages of transitioning to an open ship registry in Ghana. The study identified barriers that might impede the benefits of adopting an open ship registry and suggested strategies to overcome these barriers. The research employed a qualitative methodology for data collection and thematic data analysis. Given the study's nature, a convenience sampling technique was utilized and overall, 23 industry experts participated in the study from the maritime sector, including individuals from the Ghana Maritime Authority, shipowners, seafarers, academics, and ship managers were interviewed. The findings indicated that the socio-economic benefits derived by Ghana from its current ship registration system are limited, and an open ship registry has the potential to enhance both financial and social gains. Obstacles such as the inconvenient and cumbersome registration process, nationality as a determinant factor in registration, substantial tax burdens without government incentives, corruption, inadequate capacity, implementation bottlenecks, competition, and lax policies pose challenges that could impede the effective implementation and benefits of an open ship registry. The study recommends development of a comprehensive policy framework for implementation of open ship registration, automation and digitalisation of registration systems, delegation of some functions to recognised organisations as well as easing of tax regime and introduction of incentive schemes.

Keywords: *Ship Registration, Open Ship Registry, National Registry, Optimal Benefits, Barriers*

Introduction

Background to the Study

Ship registration is an essential condition in the shipping domain (Shaheen, Ziauddin and Islam, 2020), which allows ships to enjoy the freedom of navigation on the high seas (Shaheen, 2018). Through ship registration, ships acquire the nationality of a State and gain the legal rights to enter ports in order to carry out their operations (Rojas, 2019). When a State confers its nationality to a ship, it becomes the flag state and administrative authority of that ship. As the administrative authority, the Flag State is mandated by the international law to ensure the seaworthiness and compliance of ships registered under its jurisdiction. Other states that a vessel is not registered to but visits for business purposes are known as the Port States of the vessel. Port States are also mandated by law to conduct inspections and surveys on vessels to verify their seaworthiness and compliance to international regulations during their visits (Rojas, 2019).

Ship registration has the potential of generating income and creating potential job opportunities for states (Shaheen, et. al., 2020). Over the years, states have adopted different forms of registration system, among these are closed, open and hybrid registration (Shaheen, et. al., 2020). The closed registration system is the maiden and oldest system of registration which largely permits registration of vessels under a state's jurisdiction to the citizens or registered enterprises of the State (Xiao, 2021). This system was birthed by the British government legislation in the 14th century and operated mostly by European countries (Xiao, 2021). The open ship registration system started by the Panamanian government in the 1920s, permits the registration of ships under a state's jurisdiction regardless of the nationality of the ship owner. This system is mostly practiced by small island states and the least developed countries, such as the Marshall Islands and Liberia (Shaheen, 2018). The hybrid ship registration system combines both the open and closed systems of registration. This system was initiated by European countries that operated the closed registry system (Xiao, 2021).

Approximately, 70% of the world's trading fleet is registered under states that have adopted the open registration system (Shaheen, et. al., 2020). Open ship registry has been a major contributor to national revenue for many flag States and has created many job opportunities in States' maritime industry (Hung, et. al., 2015). As the world's first and leading open ship registry State, Panama Ship Registry was estimated to have made about $87.3 million from ship registration in 2021(International Shipping News, 2022) and the Liberian ship registry is estimated to make approximately $18 million worth of income annually (Hung & Son, 2015). With regards to creation of employment avenues, Singapore in 1969, switched to open ship registration system with the expectation of resolving its then unemployment issue (Shaheen, 2018).

Ghana adopted the closed ship registry purposely to protect the then national shipping line (established to provide employment opportunities for Ghanaian seafarers and supporting Ghana's economy in times of crisis), in a time when the country's agenda of championing national independence and self-reliance was in initiation (Afful, 2016). However, presently the closed ship registry seems to no longer serve the country to the optimum, after the goal behind the establishment of the Black Star line was curtailed as a result of it crumpling in the late 1990s. The country's register (Table 1) has one of the most crippling numbers of total registered vessels (247), with fishing vessels have the most share of about 42% of the total fleet. Inland water crafts have a share of 21% whilst other crafts such as pleasure crafts, tug boats, work boats and other small crafts makeup the rest of the 35 share (GMA, 2019).

Table 1: Flag Vessels Classification

s/n	Type of Vessel	Number	Percentage
1	Merchant Vessels	1	1
2	Fishing Vessels	104	42
3	Inland water vessels	52	21
4	Other small crafts (Pleasure Crafts, tug boats, mooring launches, supply boats and small dredgers)	90	36
	Total	**247**	**100**

Source: GMA, 2019

The size of the national fleet and its composition are a reflection of the country's low performance in revenue generation from ship registration. Also, with few job opportunities coming from the flag fleet, the country suffers a teeming seafarer unemployment and heavy reliance on foreign vessels for employment opportunities (Afful, 2016). Ajarfor (2016) indicated that about 4000 Ghanaian seafarers were unemployed as of 2016, due to the unavailability of Ghanaian-flagged merchant vessels.

Problem statement

The Ghana Maritime Authority also noted in a press briefing in 2021 that about one thousand, one hundred and eighty-nine (1,189) Ghanaian seafarers were employed under an MoU with London and Brunei (Anaadem, 2022). On top of it all, the country's registration process is being condemned by shipowners for being hostile, especially to incoming shipowners because of its bureaucratic nature and cost (Afful, 2016). This research, therefore, seeks to explore the prospects and barriers of adopting an open ship registry and make recommendations on how the identified barriers could be overcome. Ship registration in Ghana would also be assessed in this research.

Research Objective

The study is guided by the following specific objectives:

i. To assess the current situation of ship registration in Ghana;
ii. To establish the benefit of adopting open ship registry in Ghana;
iii. To identify barriers of adopting open ship registry in Ghana;
iv. To recommend ways of overcoming the barriers of adopting open ship registry in Ghana

LITERATURE REVIEW

Concept of Ship Registration

Ship registration is the general mechanism for registering a ship/vessel in a particular State (IMO, 2019). This allows the inscription of a vessel into the public records (Rojas, 2019) and provides vessels with internationally recognised legal identity (Fast Capital, 2023). Generally, ships are registered under one of three systems; closed, open or hybrid system. Closed Ship Registry (CSR) restricts ship registration to nationals or entities meeting a country's legal criteria. It typically requires ships to be owned and crewed by citizens, though restrictions vary by country. CSR allows for better fleet supervision, ensures compliance with safety and pollution standards, protects domestic shipping interests and promotes local employment. However, its strict requirements can limit fleet expansion, reduce tax revenue, and increase operational costs, as shipowners cannot access cheaper international labour markets. The economic pressures associated with this system often lead shipowners to re-flag under less restrictive systems. (Xiao, 2021)

The Open Ship Registry (OSR) system allows vessels to register under a country's flag regardless of the shipowner's nationality. Established during World War II, OSRs have become dominant in global shipping, holding over 70% of registered ships (Hung and Son, 2015; Shaheen, et. al., 2020). Major OSR countries like Panama, Liberia, and the Marshall Islands benefit from significant economic returns through fees and taxes, despite having low registration charges and offering incentives (Hung et al., 2015; UNCTAD, 2022). For instance, Panama generated $87.3 million in 2021. The fruitfulness of open ship registries over the years, is attributed to their attractiveness to shipowners due to flexible tax regimes and cost-saving opportunities, including hiring international crews at competitive rates (Rojas, 2019). The major drawback of adopting this system could be insufficient resources and surveillance capacity, both in terms of infrastructure and personnel for monitoring and controlling vessels, potentially leading to navigational safety and security issues (Petrossian et al., 2020; Negret, 2016). OSRs are also criticized for fostering unfair competition, violating collective agreements between labour and management and jeopardizing the interests of seafarers (Xiao, 2019).

The hybrid ship registration system consists of both closed and open registration features (Shaheen, et. al., 2020). States establish offshore “second registers” to attract shipowners, offering benefits similar to open registries, including financial incentives and reduced restrictions. Hybrid registries emerged as a response to the dominance of open registries, which had significantly reduced fleet sizes and revenues in traditional closed registry states (Shaheen et al., 2020; Xiao, 2021). The countries that adopt this system are mostly developed countries. They establish the second register mostly in former colonies and dependent states or territories, making this system unsuitable for developing countries like Ghana (Rhea, 2010).

Ship Registration in Ghana

As a prominent maritime and costal state, the country has a coastline of approximately 540 kilometres (270 nautical miles), stretching from Aflao in the Volta Region to Cape Three Points in the Western Region. It shares borders with the Gulf of Guinea and the Atlantic Ocean in the south (GMA, 2021, Maritime Page, marine insight). Ghana’s location along the Gulf of Guinea offered a strategic advantage, leading to the establishment of the Black Star Line (BSL) in 1957. Initially supported in terms of finance and management, by ZIM Shipping, BSL became fully state-owned in 1960. Its purpose was to bolster trade, capture 40% of ocean traffic, create jobs, and prevent foreign dominance in Ghana’s shipping sector. Operating under a closed registry system which was adopted to protect from foreign competition, the BSL owned vessels such as MV Keta and Lake Bosomtwe, transporting key exports like cocoa and timber. The company contributed to maritime development by influencing the establishment of the today Regional Maritime University and dry docks (Afful, 2016).

Despite these achievements, challenges led to BSL’s collapse in the 1990s. The closed registry system has since struggled to achieve its objectives, with Ghanaian seafarers facing high unemployment. Approximately 4,000 seafarers remain jobless due to the lack of state-owned ships. While the closed registry system initially protected Ghana’s shipping interests, its limited flexibility and reliance on BSL constrained its long-term effectiveness, particularly in fostering sustainable growth and employment in the maritime sector (Afful, 2016). Today, Ghana continues to grapple with these challenges, highlighting the need for a re-evaluation of its ship registration policies to maximize maritime sector benefits. Seagoing vessels are registered, inspections and surveyed under the provisions of the Ghana Shipping Act, 2003 Act (645) which allows ship ownership by Ghanaian citizens, corporations, partnerships, and foreign entities in joint ventures with Ghanaians. According to Sawer (2024), Ghanaians involved in joint venture arrangement are in these arrangements through fronting schemes and using corporate structures to conceal the real ownership of foreign owned vessels. Ghana’s Shipping Act, Section 99, empowers the Minister to regulate manning requirements for Ghanaian vessels, emphasizing nationality and crew qualifications of seafarers manning Ghanaian vessels. The 2021 Cabotage Regulations reserve 50% of officer positions and 75% of ratings for Ghanaian seafarers on foreign vessels that operate in the shores of the country, fostering local employment and safeguarding national shipping infrastructure (Kwofi, 2022; Dugbartey, 2023). The regulations also seek to protect the domestic shipping industry from foreign competition, preserve domestically-owned shipping infrastructure for national security purposes, and ensure safety in Ghana’s territorial waters (Dugbartey, 2023.

The step-by-step process to get a ship registered under the flag of Ghana, as outlined on the maritime administration's website *https://ghanamaritime.org/home/ship-registry/*, shows that the process takes up to five (5) working days. Afful (2016), indicated that Ghanaian ship owners find the registration process as demanding and discouraging for their business and to new entrance. This is because, the obligation that comes with the registration process is bureaucratic, laborious and cost intensive. The shipowners advocated that the registration process be reviewed to a more user-friendly, less bureaucratic and less costly.

According to Section 478 of Act 645, ship owners are required to remit fees to the Ghana Maritime Authority for certificates issued for registration, survey, inspection of a ship, or services provided in the engagement and discharge of seafarers. The minimum fees for registering a vessel with a gross tonnage of 150 and above in Ghana amount to approximately USD 3,695, equivalent to GHC 36,950.

Table 2: Ship Registration Fees and Charges

s/n	Fees and Charges Item	Approved Fees and Charges (USD)
1	Application Form for Vessel Registration	50
2	Examination of Importation Document	1,000
3	Processing of Application	1,150
4	Certificate of Survey of Registration	1,150
5	Ship Carving and Marking notes	115
6	Issue or re-issue of Certificate	230
	Total	**3,695**

Note: Fees and Charges (Miscellaneous Provisions) Act of 2022 (Act 1080).

There is limited study and literature on the specific ship registration tax system under Ghana's ship registration system. However, Afful (2016), established that, Ghanaian shipowners do not enjoy any tax discounts or incentives from the administration.

Ship registration policies that are enticing to ship owners, such as tax exemptions; lenient application of labour laws, social security systems, and regulations on ship operation and crew hiring; and financial incentives has significant and positive relationship with increased number of registered vessels, employment and taxable revenue to government (Godson, 2020) affirmed that The shipping business rides on the phenomenon of maximising profits while minimising cost of operations (Park, et. al., 2022). Consequently, by ship owners avoid registries with high taxes, low incentives and inflexible, given the capital intensiveness of the shipping business. Singapore, for instance mitigated unemployment with the policy of awarding vessels a 50% refund on the annual tonnage tax for recruiting a minimum of 25% Singaporean crew.

Overview of Some Prominent Open Ship Register

For the objective of this study, the subsequent subsections entail a review of Panama, Liberia and Singapore system of open ship registry. The review of the system of registry of these countries covers the registration procedures, conditions as well as ship registration policies adopted by them.

Table 3. Implementation of Open Ship Registry in Panama, Liberia and Singapore

	Panama	Liberia	Singapore
Period of Adoption	Open Ship Registry was adopted in the early 1920s	Adopted in 1948	Switched to Open registry in the 1969
Registration Condition	• No restriction on ship owners' nationality • Open to all types of ships • No prerequisite tonnage requirement for registration. • Pre-survey is required for vessel that are over 20 years old	• No restriction on ship owners' nationality • Open to all types of vessels that are 20 years of age and below	• No restriction on ship owners' nationality • All types of vessels for registration that are 17 years and below except fishing vessels, hydrofoils and wooden vessels. • Vessel classed by a recognised classification societies are considered for registration
Registration Process	Two major steps of registration, that is provisional registration and permanent registration	The Registration process comes with ease and its user friendly with no delay in operation	The procedure for registering a ship with the Singapore Registry has 5 major steps
Ship Registration Policies	• Merchant Marine Act (Law No. 57 allows indefinite renewal of vessel registration. • All the taxes are low and competitive. • Grants up to 50% special discounts on registration fees to ship-owners depending on the type, number, size and tonnages of ship. • No nationality restriction on crew recruitment. • The income of the Crew is not subject to income tax, just like the operations of the vessel. • No currency restrictions and limits on monetary transfers between countries	• Vessels registered are taxed annually with a fixed fee per the net tonnage of the vessel. • Ship operations and profit are not taxed. • Offers 3% annual tonnage tax discounts under Green Award program. • No nationality restriction on crew recruitment.	• Offers 50% reduction on the Initial Registration Fees to Ships that exceed the requirements of IMO's MARPOL Annex VI Phase 3 EEDI by 10% or more • Offers 80% discount under the Green Ship Programme (GSP), on the initial registration fee (IRF) to ship owners who register their ships fulfilling the BTS criteria. • Ship owners' profits and personnel income are exempt from Singapore income tax. • No nationality restriction on crew recruitment.

Research Methodology

The study applied a qualitative research approach to explore perspectives on Ghana's ship registry, prospects and barriers of adopting an open registration system in Ghana. This method allowed the research to examine the unique experiences and insights of participants regarding the characteristics and impacts of the various ship registration systems on nations and other key maritime players. According to Cleland (2017), qualitative research allows a researcher to appreciate situations, occurrences, and experiences by answering the 'how' and 'why' questions of a research. It also helps researchers to address question in a comprehensive manner that would be difficult to provide with numbers (Islam & Aldaihani, 2022). This method was utilised in this research for both data collection and analysis because of the nature of the research and questions that the research sought to address.

Data Collection: Both secondary and primary data sources were employed. Secondary data included literature reviews of ship registration systems worldwide, especially open registries in Panama, Liberia, and Singapore. Primary data involved first-hand insights gathered through interviews with some key stakeholders in Ghana's maritime industry. The interviews were conducted face-to-face or via digital platforms to accommodate participant preferences.

Data Analysis and Sampling: Using the interpretative phenomenological analysis (IPA), the study interpreted participants' lived experiences, aiming to provide an unbiased view of their perspectives. A purposive sampling technique was employed to target 23 maritime experts, including individuals from the Ghana Maritime Authority, shipowners, seafarers, ship managers and lecturers for their specialised knowledge. These participants offered valuable insights into Ghana's current ship registry and the possible advantages of an open registration system.

Results and Discussions

Current situation of ship registration in Ghana

This study revealed that currently, Ghana has a slow growing ship registry that contribute minimally to economy of the country. The data collected from GMA showed that the registry generate less than 1% of the administration's annual incomes. The seafaring profession in Ghana holds great potential but faces limited job opportunities, especially for cadets due to the unavailability of national vessels and limited Ghanaian beneficial ship ownership.

About 80% of the Ghanaian flagged vessels are owned under Ghanaian/foreign joint venture arrangement where the foreigners have the highest investment. The foreigners' high investment gives them dominance in management and operational decision making which consequently leads to high recruitment of foreign seafarers on Ghanaian vessels, especially for managerial roles. This situation defeats the purpose of job creation for Ghanaians bases that the closed registry was opted.

The findings on the registration process and procedures indicate that they would have a regressive impact on OSR if considered in Ghana. Panama, Liberia, and Singapore are renowned for their simplified registration procedures, automated processes, and short registration times. The primary data confirmed that shipowners associate the registration process with complexity, inconvenience, and delays that incur them financial costs. The service for ship registration is exclusively available at the headquarters of Ghana's Maritime Administration (GMA), lacking automation and digitalization of procedures and correspondence. The expensive cost of registration is exacerbated by exchange rate instability and delays in the registration process.

Ship operation in Ghana's domestic shipping industry is burdened by substantial tax obligations without corresponding tax incentives, fee reductions, or voluntary government initiatives to support Ghanaian shipowners. This challenging and hostile business environment negatively impacts Ghanaian shipowners. Ship registration policies influence a system's performance, attracting shipowners through tax benefits, discounted fees, and incentives. Ghana's lack of such measures diminishes its competitiveness for Open Ship Registry marketing.

Benefits of adopting open ship registry in Ghana

About 87% of respondents believe Ghana's closed ship registry inadequately benefits socio-economic development, citing limited Ghanaian shipping companies and exposure to foreign competition. They established that there are no major Ghanaian-owned shipping companies to protect from foreign shipping companies such as MSC and Maersk, especially after the collapse of the Black Star Line. Conversely, some argue CSR ensures maritime safety, security, and protects Ghanaian waters and emphasised that the country has limited capacity to manage alternative regimes while maintaining a good international maritime reputation.

Increase revenue for the Maritime Administration and by extension contribution to national income: Industry experts suggest adopting OSR could boost Ghana's revenue by increasing fleet registration fees and auxiliary income from seafarer training and certifications, inspired by successes in Panama and Liberia.

Create an increased and wider range of employment opportunities in the seafaring profession and other maritime professions such as ship broking, and insurance companies, just to mention a few: OSR adoption could create jobs for Ghanaians, particularly seafarers, and reduce youth unemployment, drawing lessons from Singapore's 1970s incentive policies. Additionally, maritime professions like ship management, broking, and insurance could benefit from expanded global market exposure.

Increased international recognition by giving Ghana a strong voice on influencing international maritime decisions at the International Maritime Organisation (IMO): The interviews established that States with significant gross tonnage on the register OSR has the potential of providing Ghana with the number of tonnages that would amplify the country's voice on influencing international maritime decisions. A few of the respondents from GMA also testified to this.

OSR can contribute to Ghana's blue economy and green shipping: the participating experts in this research argued that ship registration policies like the Liberian Green Award program and the Green Ship Programme (GSP) scheme of Singapore which encourages shipowners to improve the safety and environmental performance of their vessels can be utilised in Ghana's agenda to being among the blue economy and operating green shipping.

Barriers of adopting open ship registry in Ghana

Somewhat cumbersome, inconvenient and expensive registration procedure. Given that OSR targets not only the domestic but also the foreign market, Ghana's current registration process, as described by respondents as included bureaucratic, lengthy and complex administrative procedures, slow digital communication, and frustration with multiple travels during the registration process could pose a barrier to the country benefiting from adopting OSR. oHaving nationality as a determining factor for registration. Overviews and assertions regarding OSR states reveal a negative correlation between nationality restrictions and the growth of a flag state register. While Ghana's nationality restriction is not overly stringent, it still poses a barrier to optimizing the benefits of OSR in the country. Therefore, a reconsideration of this condition is necessary for effective OSR adoption.

Zero government incentives for shipowners coupled with a huge tax burden. A huge

tax burden coupled with zero tax reduction policies, attributed to shipping business in Ghana can be considered as one of the significant obstacles to the national fleet expansion, thereby, negatively impacting the growth of the country's register upon implementation of OSR.
Inadequate resource capacity to regulate, manage and inspect vessels to ensure navigation. The shipowner respondents highlighted that, delays due to the limited number of survey and inspection surveyors available. Inadequate capacity can have a detrimental effect on the successful implementation of an OSR regime.
Implementation Bottleneck as a Result of Bureaucracy and Policy Politicisation. The interview highlighted the politicisation of public policies and bureaucratic procedures in policy implementation within Ghana's operational systems. This situation creates bottlenecks in the execution of many development projects and ideas in the country. The respondents highlighted that certain significant government policies and projects have experienced delays, if not outright abandonment, due to a lack of continuity resulting from changes in government or public officers. According to the respondents, if the adoption of an Open Ship Registry (OSR) is considered and any of these scenarios unfolds, the entire initiative of adopting OSR could face significant delays or even come to a complete halt

Overcoming barriers that could hinder the benefit of open ship registry in Ghana

Automated and simplified registration process coupled with increasing accessibility of the Maritime Administration to the shipowners, through 24hour service provision and visual correspondence. Accessibility to shipowners at all times promotes responsiveness and good customer relations, potentially contributing to the success of an OSR system. As noted by Shaheen et al. (2020), delays in registration due to complex processes frustrate and incur costs for shipowners considering flag state registration. Therefore, there is a need to simplify Ghana's registration process, introduce automation and digitization, and ensure 24/7 service provision to optimize the benefits of adopting OSR.
Remove nationality restrictions as registration conditions and utilise the Cabotage law and other enticing and incentive policies to secure jobs for Ghanaian seafarers.
Introduction of fee and tax incentives as well as supportive government initiatives targeting shipowners and promoting seafaring employment opportunities.
Ship registration policies that are well-defined, focused and attractive to shipowners and influence employment creation. using policies to encourage shipowners to adhere to safety, security, and environmentally friendly shipping initiatives can be gleaned from the initiatives undertaken by Liberia.
Built Requisite Capacity and Take Lessons from Successful OSR Countries. The interviews indicated that the Maritime Administration should enlist and train additional skilled personnel, particularly surveyors, to effectively address the potential demand that may arise with an Open Ship Registry (OSR). It was also proposed that the GMA could consider temporarily outsourcing technical responsibilities to classification societies.
Strong Dedication by the Maritime Administration to Prevent Implementation Bottleneck. Respondents argued that it would take strong dedication and will of GMA in the facilitation of the implementation process, in order to mitigate institutional delays and bureaucracy. Exhibiting time-consciousness and ensuring consistency in tracking the implementation progress can also play a significant role in mitigating delays and bureaucracy.

Conclusions and Recommendations

Conclusions of the study

Investing in shipping business is a significant undertaking, given the capital intensiveness and fierce competition in the shipping market therefore, shipowners try to take advantage of cost-effective alternatives in decision making, to achieve the highest possible returns on their investment in a long run. Knowing this, prominent OSR States, arrange flexible fee and business-friendly policy to entice shipowners. In return, OSR States today, hold remarkable share of the world's fleets and gain significant benefits from it.

Since time immemorial, the number of vessels under the flag of Ghana and the accrued socio-economic benefits have been insignificant. The findings of the research evidence that OSR system has the potential to increase the national fleet and essentially the contribution to +national revenue as well as increase employment prospects in seafaring. However, existence of factors such as cumbersome registration process, cost of registration, high tax burden, zero ship registration policies and limited capacity of the Maritime Administration, just to mention a few would hinder Ghana from benefiting to the optimum upon adopting open ship registration regime.

Recommendation

The analysis of the findings of the study clearly points out that there are some barriers and suggests some possible solutions have been identified to mitigate these challenges. To achieve optimal benefit of adopting open ship registration in Ghana, the study recommends the following:

Developing Comprehensive Policy Framework for Implementation of Open Ship Registration

The Maritime Administration should consider developing a comprehensive policy framework which defines the objectives, strategies, and stakeholder roles in the idea of adopting open ship registry. This would then influence decisions on suitable registration conditions, structures and procedures for the registration process and ship registration policies. This will also make the monitoring and tracking of progress easier. Easy tacking and monitoring of progress help in early and easy detection of policy or plan that might need revision or realignment.

Automation and Digitalisation of Registration Systems

GMA should consider an automated registration procedure coupled with digital correspondence in the form of an online application platform on its website, emails for exchange of document, paperless payment system, and digital issuance of certificates and licenses to increase its administrative efficiency and promote productivity. To ensure the protection and verification of security details on vessel certificates and licenses, an automated system could incorporate a barcode verification System. This will not only promote good customer service and enhance the Authority's productivity around the clock, thereby increasing its attractiveness to shipowners, but would also save shipowners significant cost and time.

Delegation of Some Functions to Recognised Organisation (RO)

The Maritime Administration ought to engage the expertise of acknowledged classification societies to conduct surveys and inspections, particularly for foreign vessels that may be drawn to Ghana's registry under an Open Ship Registry (OSR) regime.

Easing Tax Regimes and Introduction of Incentive Schemes

Shipowners consistently favour a flag State that offers increased flexibility and economic advantages. To make Ghana's registry economically appealing to both domestic and foreign shipowners, it would be essential to eliminate taxes on the importation of vessels; and streamline fee discounts and tax discounts towards increasing employment opportunities for Ghanaian seafarers. Incentive schemes can also be utilised in promoting safety and environmentally friendly practices, thereby supporting the global blue economy agenda.

REFERENCES

Afful, P. A. (2016). Private ownership of shipping lines in Ghana: the challenges and the way forward. Retrieved from https://commons.wmu.se/all_dissertations

Aladwan, Z. (2020). Dual Nationality of the Ships and its Legal Impact. Hasanuddin Law Review, 6(2), 109-124. Retrieved from http://pasca.unhas.ac.id/ojs/index.php/halrev/article/view/2246

Anaadem, P. (2022). 1189 seafarers employed in maritime sector. Retrieved from https://ghanatoday.gov.gh/sector-news/1189-seafarers-employed-in-the-maritime-sector/

Beckman, R., & Sun, Z. (2017). The relationship between UNCLOS and IMO instruments. Asia-Pacific Journal of Ocean Law and Policy, 2(2), 201-246. Retrieved from https:// brill.com/view/journals/apoc/2/2/article-p201_201.xml

Bhat, A. (2019). Types of Sampling: Sampling Methods with Examples. Retrieved from https://www.questionpro.com/blog/types-of-sampling-for-social-research/

Busetto, L., Wick, W., & Gumbinger, C. (2020). How to use and assess qualitative research methods. Neurological Research and practice, 2, 1-10. Retrieved from https://link.springer.com/article/10.1186/s42466-020-00059-z

Calag, A. M. E., & Cruz, C. B. (2019). Developing a shipping registration strategy for the Philippines: a business and policy framework. Retrieved from https://commons.wmu.se/cgi/viewcontent.cgi?article=2204&context=all_dissertations

Delve,Ho,L.,&Limpaecher,A.(2023).ThematicAnalysisvs.InterpretativePhenomenological Analysis in Qualitative Research. Retrieved from https://delvetool.com/blog/interpretative-phenomenological-analysis-vs-thematic-analysis

Dugbartey, A. J. (2023) Cabotage regulations will secure maritime future – GMA. Retrieved from https://thebftonline.com/2023/08/14/cabotage-regulations-will-secure-maritime-future-gma/

Eysink, P. (2023). The Value of Policies and a Policy Framework. Retrieved from https://www.linkedin.com/pulse/value-policies-policy-framework-digital-transformation-navigator#:~:text=Policies%20are%20an%20essential%20part,objectives%20
more%20effectively%20and%20efficiently.

Fast Capital. (2023). Ship Registration: Unlocking the Benefits of Flagging Your Vessel. Retrieved from https://fastercapital.com/content/Ship-Registration--Unlocking- the-Benefits-of-Flagging-Your-Vessel.html

Fees and Charges (Miscellaneous Provisions) Act, 2022 (Act 1080)

Fiatui, D. A. (2022, October 27). Is the open ship registry system worth implementing? Retrieved from https://thebftonline.com/2022/05/13/closed-ship-registry-system/#

General Consulate of Panama in Marseille. (2018). The Procedure to Register a Ship with The Panamenian Pavilion. Retrieved from https://www.consulatgeneraldepanamamarseille.com/the-flagging/procedure-to-register-a-ship/?gclid=CjwKCAjwnOipBhBQEiwACyGLumerj0_kpC0ddy5PbEc7kYQJI5ltfxTB321bKvaEmZQSzDzbANk4hRoCe1UQAvD_BwE

Ghana Maritime Authority. (2019). Overview of Ghana Maritime Authority. Retrieved from https://ghanamaritime.org/home/who-we-are/

Ghana Merchant Navy Officers Association (2023) The Role of Seafaring in Trade Facilitation and Bridging the Employment Gap. Retrieved from https://shippers. org.gh/index.php/the-role-of-seafaring-in-trade-facilitation-and-bridging-the- employment-gap/#:~:text=Seafaring%20in%20Ghana,and%20commodities%20 across%20the%20world.

Ghana Shipping (Cabotage) Regulations, (2021). (L.I 2438).

Ghana Shipping Act, 2003 (ACT 645). Retrieved from https://faolex.fao.org/docs/pdf/ gha93388.pdf

Gomes Neves Mota, A. C. (2023). Enhancement of search and rescue missions in the West coast of Africa: examining the possibilities of use of drones in Cabo Verde search and rescue. Retrieved from https://commons.wmu.se/cgi/viewcontent .cgi?article=3288&context=all_dissertations

Hellenic Shipping News Worldwide. (2022). The Panama Ship Registry will invest in technological transformation in 2022. Retrieved from https://www. hellenicshippingnews.com/the-panama-ship-registry-will-invest-in-technological-transformation-in-2022/

Hung, V. L. & Son, H. V. N. (2015). An analysis of Open Registry system and its potential application in Vietnam maritime industry. Retrieved from http://cdhh.edu.vn/?p_ id=tin&id=an-analysis-of-open-registry-system-and-its-potential-application-in- vietnam-maritime-industry-638

Hunt, F & Lee D. (2021). Open Ship Registries and Implications for the Maritime Community. Retrieved from https://www.millsoakley.com.au/thinking/open-ship-registries-and-implications-for-the-maritime-community/

International Maritime Organisation. (2019). Introduction to IMO. Retrieved from https:// www.imo.org/en/About/Pages/Default.aspx#:~:text=As%20a%20specialized%20 agency%20of,environmental%20performance%20of%20international%20 shipping.

International Shipping News. (2020). The Panama Ship Registry will invest in technological transformation in 2022. Retrieved from https://www.hellenicshippingnews .com/ the-panama-ship-registry-will-invest-in-technological-transformation-in-2022/

Islam, M. A., & Aldaihani, F. M. F. (2022). Justification for adopting qualitative research method, research approaches, sampling strategy, sample size, interview method, saturation, and data analysis. Journal of International Business and Management, 5(1), 01-11. Retrieved from https://rpajournals.com/wp-content/uploads/2021/12/ JIBM-2021-09-1494.pdf

Kuwornu, B. (2023). Impact of portable piloting units on the situation awareness of maritime pilots' perspectives of Danish and West African pilots. Retrieved from https://commons.wmu.se/cgi/viewcontent.cgi?article=3289&context=all_ dissertations

Kwofi, M. (2022). Domestic Shipping Regulations passed. Retrieved from https://www. graphic.com.gh/business/business-news/domestic-shipping-regulations-passed. html

Lawinsider. (n.d.). Port State definition. Retrieved from https://www.lawinsider.com/ dictionary/port-state

Liberian Registry. (n.d.) About The Liberian Registry. Retrieved from https://www.liscr. com/unique-advantages

Marine Insight. (2022). Top 10 Largest Flag States in the Shipping Industry. Retrieved from https://www.marineinsight.com/maritime-law/top-10-largest-flag-states-in-the-shipping-industry/

Maritime and Port Authority of Singapore. (2023). Overview of Ship Registration. Retrieved from https://www.mpa.gov.sg/singapore-registry-of-ships/about-srs/overview-of-ship-registration

Michalson. (2019). The benefits of a good policy framework. Retrieved October 11, 2023 from https://www.michalsons.com/blog/policy-framework/4765

Moffett, F. (2013). Isle of Man: Ship Registration in The Isle Of Man. Retrieved from https://www.mondaq.com/isleofman/offshore-financial-centres/220070/ship-registration-in-the-isle-of-man

Mohd Arifin, S. R. B. (2018). (PDF) Ethical Considerations in Qualitative Study. Retrieved from https://Www.Researchgate.Net/Publication/328019725_Ethical_ Considerations_ in_Qualitative_Study.

Morales, L. A. (2023). Benefits and Advantages of Ship Registration in Panama. Retrieved from https://fmm.com.pa/benefits-and-advantages-of-ship-registry-in-panama/

Mukherjee, R. (2020). Ship Nationality, Flag States and the Eradication of Substandard Ships: A Critical Analysis. Maritime Law in Motion, 581-606. Retrieved from https://link.springer.com/chapter/10.1007/978-3-030-31749-2_27

National Development Planning Commission. (n.d). Vision 2057: long-term national development perspective framework.

Negret, C. F. L. (2016). Pretending to be Liberian and Panamanian; Flags of Convenience and the Weakening of the Nation State on the High Seas. J. Mar. L. & Com., 47, 1. Retrieved from https://heinonline.org/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/jmlc47&section=4

Palindrome Communications. (2024). What is an industry expert and how does content marketing help? Retrieved from https://palindromecommunications.com/what-is- an-industry-expert-blog/#:~:text=Industry%20experts%20are%20essentially %20 forefront,expert%20opinions%20and%20reliable%20information.

Park, S., Kim,T., Ryu, H., Kim, H.,& Kwon, J.(2022).Theeconomiceffectandpolicyperformance of ship registration—A case of Korea. Marine Policy, 144, 105234. Retrieved from https://www.sciencedirect.com/science/article/pii/S0308597X22002810

Pastra, A., Klenum, T., Johansson, T. M., Lennan, M., Pribyl, S., Warner, C., & Rødølen, F. (2023). Lessons learned from maritime nations leading autonomous operations and remote inspection techniques. In Smart Ports and Robotic Systems: Navigating the Waves of Techno-Regulation and Governance (pp. 363-386). Cham: Springer International Publishing. Retrieved from https://link.springer.com/chapter/10.1007/978-3-031-25296-9_19

Petrossian, G. A., Sosnowski, M., Miller, D., & Rouzbahani, D. (2020). Flags for sale: An empirical assessment of flag of convenience desirability to foreign vessels. Marine Policy, 116, 103937. Retrieved from https://www.sciencedirect.com/science/article/pii/S0308597X19306372

Piniella, F., Alcaide, J. I., & Rodriguez-Diaz, E. (2017). The Panama ship registry: 1917–2017. Marine Policy, 77, 13-22. Retrieved from https://www.sciencedirect.com/science/article/pii/S0308597X16306996

Rahman, M. S. (2020). The advantages and disadvantages of using qualitative and quantitative approaches and methods in language “testing and assessment” research: A literature review. Retrieved from https://pearl.plymouth.ac.uk/handle/10026.1/16598

Rhea, R. (2010). Ship registration: a critical analysis. Retrieved from https://commons.wmu.se/all_dissertations/447

Rodrigue, J. P. (2020). The Geography of Transport Systems, 3rd Edition. Retrieved from https://transportgeography.org/media/e-book/

Rojas, B. C. L. (2019). Open registries and recognized organization: synergy or Open registries and recognized organization: Synergy or dysfunction Recommended Citation Recommended Citation. Retrieved from https://commons.wmu.se/all_dissertations/1175

Sawer, L. (2024). Ghanaians actively assist foreigners to register fishing businesses – Retrieved from https://gna.org.gh/2024/02/ghanaians-actively-assist-foreigners- to-register-fishing-businesses-cemlaws/

Shaheen, Md. M. (2018). Ship Registration in Panama, Singapore, Bangladesh Flag: A Comparative Study Approach. International Journal of Science and Research (IJSR).
7. 795-803. 10.21275/ART2019277. Retrieved from https://www.researchgate.net/publication/337965649_Ship_Registration_in_Panama_Singapore_Bangladesh_Flag_A_Comparative_Study_Approach

Shaheen, Md. M., Alamgir, Z., & Islam, D. M. (2020). Ship Registration System of Bangladesh: An Assessment. In BMJ (Vol. 4). Retrieved from https://bsmrmu.edu.bd/public/files/econtents/5f806409d862avol4_issue1_article_2_shaheen.pdf

Smith, J. A., & Osborn, M. (2015). Interpretative phenomenological analysis as a useful methodology for research on the lived experience of pain. British journal of pain, 9(1), 41-42. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4616994/

Swiss Institute of Comparative Law. (2018). Maritime Registration: Euromar/Portugal, Germany, Hong Kong, Liberia, Luxembourg, Marshall Islands, Sweden, Antigua & Barbuda. Retrieved from https://www.isdc.ch/media/1676/e-2018-15-17-183- maritime-registration.pdf

The Panama legislation mandates that a shipowner should have and maintain a local legal representative (preferably an attorney of a law firm) or local registered agent (PMA Certification, 2020).

Tobey, J., Normanyo, A. K., Osei, P., Beran, K., & Crawford, B. (2016). Subsidies in Ghana's Marine Artisanal Fisheries Sector. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. GH2014_POL059_CRC, 53. Retrieved from https://www.crc.uri.edu/download/GH2014_POL059_CRC_-FIN508.pdf Treves, T. (2008). 1958 Geneva Conventions on the Law of the Sea. Geneva, 29 April 1958.
Retrieved from https://legal.un.org/avl/ha/gclos/gclos.html

Trochim, W. M., Donnelly, J. P., & Arora, K. (2016). Research methods: The essential knowledge base. Cengage learning. Retrieved from https://iro.uiowa.edu/esploro/outputs/9984214724402771?institution=01IOWA_INST&skipUsageReporting=true&recordUsage=false

UNCTAD. (2023). Review Of Maritime Transport 2023: Facts and Figures On Latin America And The Caribbean. Retrieved from https://fullavantenews.com/unctad-review-of- maritime-transport-2023-facts-and-figures-on-latin-america-and-the-caribbean/

United Nations. (1986). United Nations Convention on Conditions for Registration of Ships. Retrieved from https://unctad.org/system/files/official-document/tdrsconf23_en.pdf

Voxco. (2021). Descriptive Research Design. Retrieved from https://www.voxco.com/

blog/descriptive-research-design/

Xiao, Y. (2021). Comparative Study of Different Ship Registries and Reflection on Comparative Study of Different Ship Registries and Reflection on China's Innovation of International Ship Registration System China's Innovation of International Ship Registration System. Retrieved from https://commons.wmu.se/cgi/viewcontent.cgi?article=1324&context=msem_dissertations

Towards Sustainable Blue Growth: Socioeconomic effects of sand mining on coastal communities of Kombo South, The Gambia

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Abstract

Coastal areas worldwide are crucial for humanity. They provide habitat for over 70% of the global population and provide various livelihood means highlighting its significance for humans and other ecosystems. Sand mining along the coast is a common practice in many developing coastal states, including the Gambia for numerous economic benefits. Although there is huge economic value in the sand mining industry, sand mining operations have significant negative socioeconomic impacts on coastal communities of Kombo South, the Gambia. The study was conducted in three selected coastal communities of Sanyang, Gunjur and Tujereng. Using a mixed method research approach, a concurrent exploratory research design was adopted for data collection. A semi-structured questionnaire was administered face-to-face to 400 household heads to collect data on the socioeconomic effects of sand mining and in addition, three focus group discussions at the study communities, 10 key informants interviewed from government and communities, and field observation, while for the quantitative study. This study aims to examine socioeconomic effects of coastal sand mining and its governance in the context of blue growth. Through triangulation of the qualitative and quantitative findings, the study anticipates revealing significant challenges to sustainable livelihoods and environmental conservation due to sand mining. Also, the study provides recommendations to for improve sustainable resource management in a conflict-free environment, empower communities, and enhance blue growth in line with Sustainable Development Goals 10, 14, 15, 16, and 17, and the African Agenda 2063.

Key words: Blue growth, coast, sand mining, socioeconomic effect, sustainable development.

1. Introduction

Coastal ecosystem areas continued to sustain human existence for centuries serving as a source of food, habitat for biological species, and provision of various materials for the construction of shelters and habitation for over 70% of the global population within 150km of the global coastline, job creation as well as provision of other livelihood ventures (Neumann, 2017; Sartono, 2019; United Nations, 2023). An average population growth of 3.5% has been experienced in the coastal systems since 1950 with an increase in coastal cities from 472 to 2226 between 1950 and 2020 (UN-Habitat, 2020; Rangel-Buitrago et al., 2023). This is a result of the strategic geography of the coast (between the land and the sea) culminating in its capacity as an environmental hotspot that provides multiple ecosystem services (Fegley & Michel 2021; Rangel-Buitrago et al., 2023).

Sand, also known as "the new gold" or "the new currency," forms one of the greatest and most used natural resources in the world after water (Bendixen et al., 2019; UNEP, 2022). Sand mining along the coast is a common practice worldwide, especially in developing coastal states, including the Gambia (Komma, 2019). Due to its extractive character, mining is one of the most pervasive, damaging, and fast-growing activities developing along the world's coasts (Asare et al., 2023). Also, it advances real and possible repercussions to coastal livelihoods, sustainable development, and the resilience of coastal communities (Mensah &

Mattah, 2023). Sand mining is a pivotal economic activity in many developing countries globally (Bendixen et al., 2023). Often, sand is mined within coastal areas where the ecosystem and other economic activities are entangled with the daily life and livelihood of the inhabitants of those communities.

Globally, over 59 billion tonnes of material is mined annually, of which sand and gravel, hereafter referred to as aggregates, account for both the largest share and the fastest extracted resources (Bendixen et al., 2019; UNEP, 2019). An estimated 30 to 49 billion tons of sand aggregates are mined globally per annum, hence the most used resource globally next to water (UNEP, 2022; Asare et al., 2024) with a global projected value of $405 billion by 2030 (Global Construction Perspectives and Oxford Economics, 2022). This huge demand for sand has caused the practice of sand mining to become both a global and societal environmental issue posing a significant 21st century challenge for humanity (UNEP, 2022). Sand mining impacts are so crucial that this harmful activity generates major conflicts within all the 17 United Nations Sustainable Development Goals (Bendixen et al., 2023).

In Africa, thirty-eight (38) of the fifty-five (55) states are found in coastal areas (United Nations, 2016). The coast and its resources in these 38 countries generate approximately 49 million jobs mainly in the blue economy space (United Nations, 2016; 2023). As a result of an increasing human population along the coast resulting in competition for finite resources, human needs and wants for resources have led to heavy competition among the intended users of the scarce coastal resources (United Nations, 2016). Like in many continents, Africa has its fair share of issues associated with sand mining both on the socioeconomic status of the coastal communities and the environment (Mbaka & Rono, 2022). Unexpectedly, reliable data on sand and gravel mining remains a challenge in many underdeveloped and developing countries with an exception few developed countries in recent years (Essaw et al., 2023)

In the Gambia, 800 metres from the sea is designated as a Tourism Development Area (TDA) (Sambou, 2023). Interesting to note that the TDA meant for tourism recreation facilities is where the mining takes place. Tourism being another important economic activity along the coast is of great value to the economy of the Gambia. The sector is the third largest contributor to the GDP of the Gambia amounting to over 20% of the GDP (International Trade Administration, 2022; Amnesty International, 2023). Approximately 100,000 to 160, 000 m3 of sand is extracted annually in the Gambia (NEA, 2020). Several factors have contributed to this rapid coastal sand mining such as; the commercialization of sand mining, road construction, housing, and other infrastructural developments proximity to the sand (Komma, 2019). Notwithstanding those economic benefits, the mining operations coupled with outstanding impacts on both the livelihood of the communities and the environment (Sambou, 2023). Moreover, sand mining activities have a direct and significant effect on the blue economy of the coastal communities.

Coastal communities of Kartong, Gunjur, Sanyang, and Tujereng in the Kombo South district are examples of areas where extensive sand mining is widespread within the coastline including the Tourism Development Area (TDA) and the beaches. The land tenure system is complex, with the land belonging to the community under the custody of the village head (Alkalo), clan head or the family head, whiles the government having control on the development of the land as per the so-called TDA policy. Consequently, there is lack of land policy and inadequate regulation of sand mining, competing land use for agriculture, fish and fish oil meals factories, beach bars, land disputes loss of livelihoods, and multiple land allocations to different parties (Komma, 2019; Sambou, 2023).

Despite UNEP (2019) has noted sand mining and sustainable development to be at odds globally, research to highlight the intricate effects of sand mining particularly in the context of blue growth and efforts to aid in developing effective governance and economic diversification on coastal communities is only at its early stages particularly in the Gambia. The available literature on effects of sand mining and governance is heavily skewed towards Asian countries and parts of West Africa, particularly, Indonesia, China, Nigeria, and Ghana. It shows the lack of understanding of sand mining effects, governance and implications on blue economy. This paper therefore, examines the effects, governance, and implications of sand mining in three communities in Kombo South district. It addresses the following research questions; (1) what are the socioeconomic and environmental effects of sand mining? and (2) how is sand mining governed in Kombo South?

2. Literature review

Sand forms an integral source to economic growth development in both the underdeveloped and developing countries (Mngeni et al., 2016). This developmental trajectory culminates in the growth of towns and cities that demand more and better infrastructures through construction of strong structures such as commercial shopping malls, schools, roads, bridges, and housing for an ever-increasing population (Mensah & Mattah, 2023). Hence as a result of the rapid socioeconomic development, there lies high chances of environmental, social, and economic disturbances on the natural environment and communities as far as sand mining is concerned. Sand is the second most sought natural resource after water (Beiser, 2018), and its extraction forms the largest global mineral extraction, accounting for over 80 per cent of the global mineral extraction (Chandran, 2019; Pearce, 2019). The global demand for sand aggregates is rapidly increasing faster than its natural replenishing process leading to rising prices and shortage of sand in many developing urban areas (Mark, 2021; Miller, 2022). The rapid economic development around the world, especially in the developing states such as the United Arab Emirates, China, Singapore, and India, causes strong growth of the construction industry (Johnbull & Brown, 2017). Thus, making sand mining a common practice in many coastal countries globally (Mensah, 1997).

Rais et al. (2019) study in Batauga District, Indonesia found that illegal sand mining has cause surface land changes as a result of pits created which are inundated and becomes mosquitoes breeding sites thus a potential source of diseases for residents. Moreso, Anokye et al. (2023) on their study in Awutu-Senya East and West of the Central Region of Ghana found divergent views were expressed among the respondents. Truck drivers and block makers highlighted positive impact of sand mining on their livelihood whiles the key informants from the communities hold a contrary view as they see mining to have negatively affected their livelihoods through reduction in farm size, crop yield, and income. This shows that, depending on which actors are asked on the impact of sand mining, the interest of each individual or group always manifest over the other. However, the inherent negative environmental effects cannot be disputed.

Madyise (2013) in his case study in Gaborone, South Africa found sand as a source of revenue for the government in as in the form of royalties levied on mining companies, lease fees, while at the same time provides job opportunities for many youths thus reducing the unemployment burden and increase the purchasing power of many others especially the local.

Whiles Asare et al. (2024) study in Accra, Ghana, acknowledges the financial gains in the mining sector, they found a huge disparity on the revenue gained from the mines as most of the revenue goes to the miners, land owners, and truck drivers rather the majority of the local residents who are more negatively affected with mining impacts due to environmental damaged. Similarly, Bendixen et al. (2023) in their extensive systematic review on Scopus journal articles on the drivers and effects of sand mining in Sub-Saharan Africa found that various literatures on sand mining in Sub-Saharan Africa have highlighted job creation, infrastructural buildings, taxes and income as some of the positive effects of sand mining. They however, stated that, infrastructural damages, pollution, erosion, and loss of agricultural lands are negative hall marks of sand mining as a result of the high dependency for the many of the Sub-Saharan countries for livelihood sustainability and development.

Komma's (2019) investigation on high-risk zone (cell 6) of the Gambian coastline found sand mining to be one of the human induced activities impacting the coastal zone specifically the cell 6 of the coastline. Similarly, Sambou (2023) in his empirical study using qualitative approach to assess resource-developmental challenges faced by residents of Kombo South, have found sand mining to be one of the major issues affecting many coastal communities in the Kombo South District of the Gambia as a result of its extraction. In his conclusion, he highlighted sand mining as one of the potential activities to cause conflicts. Interestingly, sand mining in the Gambia is both legal and illegal within the cost areas of the Gambia.

Several empirical studies (Bosco & Sumani, 2019; Komma, 2019; Ashraf et al., 2020; Ankiilu, 2021; Ado, 2021; Ibrahim et al. 2021; Mensah, 2022; Mensah and Mattah, 2023; Choudhary, 2023; Bendixen t al., 2023; Asare et al., 2024) agreed on the multiplicity of sand mining effects and absence of effective regulations for many sub-Saharan African countries, despite sand mining being recognised as a major economic activity along the coast. The many effects of sand mining and weak governance has been attributed to a multifaceted and insufficient sand mining regulatory frameworks. Cognisant to the various studies, there is a consensus on the existence of sand mining effects and resource conflicts resource users in various parts of the globe, yet little is unknown as to the nature and magnitude of these effect of sand mining on coastal communities particularly in Kombo South Gambia. Thus, is essential to look into the effects of sand mining considering the many economic activities along the coast for blue growth. This paper aims to fulfil these gaps and expand the scope of research in this area.

3. Methodology

Study area

This study was conducted in three communities in Kombo South district in the Gambia (Figure 1). Kombo South District lies at latitude 13.25 and longitude -16.75. The district of Kombo South has 48 villages, of which 17 villages are along the coast line. For this study, the three selected communities of interest (Sanyang, Gunjur [Sambuya], and Tujereng) have a combined population of 61,583 people with 7698 households, a growth rate of 3.1% and an average household size of 8 people(GBoS, 2013). The district is one of the most populated districts in the Brikama Administrative Area, West Coast region of the country (GBoS, 2013). The study areas are 10, 14, and 26 km from Brikama, thereby making them relatively accessible for truck drivers to convey sand to Brikama and other cities. The three selected communities for the study are characterised by an agrarian economy, with majority of the residents engaged in horticulture and other subsistence farming (GBoS, 2013). The lands are the study areas are under customary ownership, predominately manage by Alkalos, clan heads or family heads who make land-use decisions (GBoS, 2013). The three study communities purposely selected based on the mining intensity as per the National Environment Agency insights within the last decades.

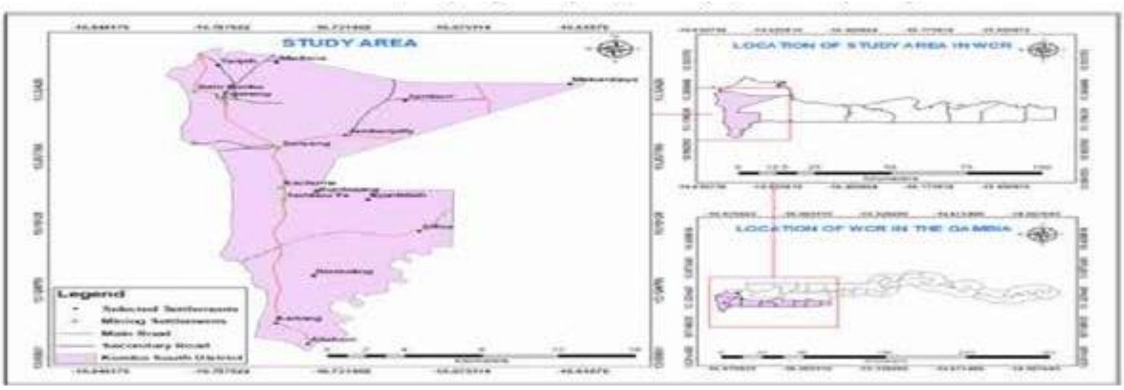

Figure 4: Map of the Gambia Showing Kombo South district and the study area

Sampling, data collection, and analysis

The research was designed as mixed method study. The complexity of the sand mining sectors and the multiplicity of actors made the study to adopt mixed method study. Also, the ability to triangulate the findings from both qualitative and quantitative study and to discuss realities from the respondents' perspectives inform the decision to adopt this approach. The primary data were collected through a semi-structured questionnaire, field observation checklist, FGD guide, KII guide, and the secondary data was collected through a desk review. A multi-stage (systematic and convenience) sampling was use to select 400 household heads, and 3 FGDs were conducted, one in each community. A purposive sampling technique was used to select 10 key informants from the Government institutions, private individuals, local council, and the communities. Furthermore, a direct field observation was conducted and GIS mapping was done. The aims of the FGDs and KIIs was to sound the collective experience of the communities and the expert opinions on the effects of sand mining and its governance. The field visit and GIS were meant to ascertain the actual land-use and land cover changes pattern oof the mining sites. A content analysis was conducted on relevant regulations using strength, weaknesses, opportunities, and threats (SWOT) analysis with respect to sand mining governance in the Gambia in the context of sustainable development and blue growth. The data was collected between February 2024 and October, 2024.

4. Results and Discussions

Environmental/ Socioeconomic effects

The study reveals several environmental effects of sand mining. Among the effects identified include inadequate land, erosion, and biodiversity loss to be the most noticeable effects on sand mining in the communities. Also, road damage, flooding health hazards and other effects were found to be other severe effects as perceived by the communities in relation to sand mining. These findings indicate that the local variation of environmental effects is distinct with varying degree on each community. Also, the finding reveals that the severity of the effects varies from community to community. This indicates that community specific factors influence the severity of the environmental effects, thus the need for tailored interventions to tackle the individual challenges of each community.

Table 1: Environmental effects of sand mining as affected by categorical variables

	Frequency

		No	Yes	Total
Variable	Category			
Sex	Female	170	33	203
	Male	158	39	197
Community	Gunjur	147	45	192
	Sanyang	105	19	124
	Tujereng	76	8	84
Ownership	Clan	183	40	223
	Individuals	145	32	177
Marital status	Married	216	58	274
	Single	88	13	101
	Divorced/Widow	24	1	25
Age	18-25	77	10	87
	26-30	60	7	67
	31-45	117	28	145
	45+	74	27	101
Total		**328**	**72**	**400**

On socioeconomic effects of sand mining based on key categorical variables like sex, community, ownership, marital status, and age, the study found that male respondents are perceived to be the most affected gender on socioeconomic effects of sand mining from the survey. However, insights from FGDs and KIIs are contrary to that claim, as most of the participants highlighted perceived female to be the most affected. This claimed by the FGD participants is largely due to the destruction of women gardens by sand mining activities. This as sad by one woman participant who doubles as a gardener;

"the Chinese will use their machines and enter in the between women's "faroos" and spoil everything with their machines that place people grow their food stuff to use that to feed their families. And if they do that when heavy wind comes there is no tree to help our gardens because they brought down all the trees there so the wind will spoil all our garden" (Arokey 45, F).

These findings support Nurhasan and Saputra (2018) study, which they found sand mining o have direct impact on agricultural land causing decline in the economic condition of the community. This as they continued triggers income decline, loss of livelihoods to farmers and increase social disparities between sand miners and farmers. The FGD and KIIs respondents, the field observation, and subsequent land-use land- change analysis shows similar effects of sand mining on the communities. On the issue of agricultural land loss, the participants highly associate it to the intensity of the mining activities as most of the mining are happening in the same parcel of land which serve as farms and gardens for the community. This says; *"Ah it usually causes us flooding during rainy season and they usually spoil women's "faroos" and our lands are been spoiled for agriculture" (Yusupha 55, M).*

Another participant made emphasis that their farms have been completed out of touch for crop production as a result of lagoons formed post-mining. This, they said, *".... and now the women can no longer cultivate rice in those fields and these has also affected our food sufficiency. This is because rice can no longer grow in those fields" (Female FGD participant from Sanyang) "But that is like a lagoon of its own now. Where no one will be able to grow any crop or even to plant any tree there. .... nothing is able to be done there you are mining the farmland or the garden land of those women. So you are directly taking away their source of livelihood from them." (KI respondent from*

Sanyang).

These concerns as confirmed by Adedeji et al. (2020) study, communities take greater burden of environmental effects of sand mining activities compare to other stakeholders. Similarly, the issue of tree felling was a notable concerned associated to sand mining. This issue as one FGD participant succinctly put, *"…those big trees around our beach side have been cut down by those companies. Any trees they remove they just bury it and after those operation." (Male FGD participant from Tujereng).*

These findings confirm Amour and Haji (2024) study. Which they found findings, serious environmental damages, such as land destruction, damage to farmlands, ecosystem damage, and deforestation as a result of sand mining activities in the North 'B' district of Zanzibar, Tanzania. Moreso, the finding agreed with Adedeji et al. (2020) which found trees along the Sagamu/Ore highway to have almost cut off due to sand mining.

Threat to sea level rise and climate change impacts were associated with sand mining. Studies have confirmed human anthropogenic activities to be connected with impacts of climate change (Mbaka and Rono, 2022; Essaw et al., 2023) which the coastal communities of Kombo South are not an exception. This as stated by one respondent; *"In the past, people were mining beach sand, which is having a serious impact on the marine ecosystem. You cannot just come and dig, because we know that those dunes also serve as a barrier of protection from storm surges or the sea level rise. And within these coastal communities, we have mined all the dunes, except the dunes that we call the frontliners. …. if those dunes are cleared, the impact on the marine environment will be severe because you are calling for the ocean or the sea to come in and when that happens, we are in the era of climate change. (KI respondent 6, Government Official).*

Another key effects sand mining faced by the communities is the issue of road damage caused by heavy truck plying community roads to and from the mining sites. This according to them makes accessing the beach difficult. This as one participant stated; *"The road network is completely destroyed, affecting the people that are living within that particular area. And where the mining is happening, mostly it's along the beach. So they either use the main beach highway or the other highway. All of these roads are destroyed. So when they are destroyed, the economic activity that is supposed to take place at the beach is affected." (KI respondent from Sanyang).*

These remarks are similar to Adedeji et al. (2020) findings, which they found sand mining to have generates heavy traffic which impairs the road networks and the environments. This as a result caused road damage especially when those roads where not design for heavy trucks.

Equally, the land use/land cover changes observed in the 30km2 study area between Tujereng and Gunjur (presented in red in Figure 8), provides compelling evidence of environmental and anthropogenic effect of sand mining and its related activities shaping the landscape from 2017 to 2023. These land use and land cover changes (Table 2) and (Figure 3 and 6) highlight significant shifts in key land use features such as increased water bodies, flooded vegetation, and built areas, alongside notable declines in tree cover, agricultural crops, and bare ground.

Table 2: Land Use/Land Cover Change in square km, 2017 and 2023

Study Area Land Use (km2)							
Year	**Water**	**Trees**	**flooded vegetation**	**Crops**	**built area**	**bare ground**	**Rangeland**
2017 (km2)	10.85	6.31	1.66	0.76	2.25	0.77	7.55
2023 (km2)	12.51	2.86	2.75	0.19	5.01	0.61	6.23
Km2 change (2017-2023)	1.66	-3.45	9.17	-0.57	2.76	-0.16	-1.32
% change (2017-2023)	5.53	-11.50	3.64	-1.90	9.20	-0.54	-4.40

Conversely, from Table 2, the decreasing presence of trees (-11.5% change), crops (-1.9% change), and bare ground (-0.5% change), all indicate a rapid increase in mined areas in addition to other land use activities (Figure 2).

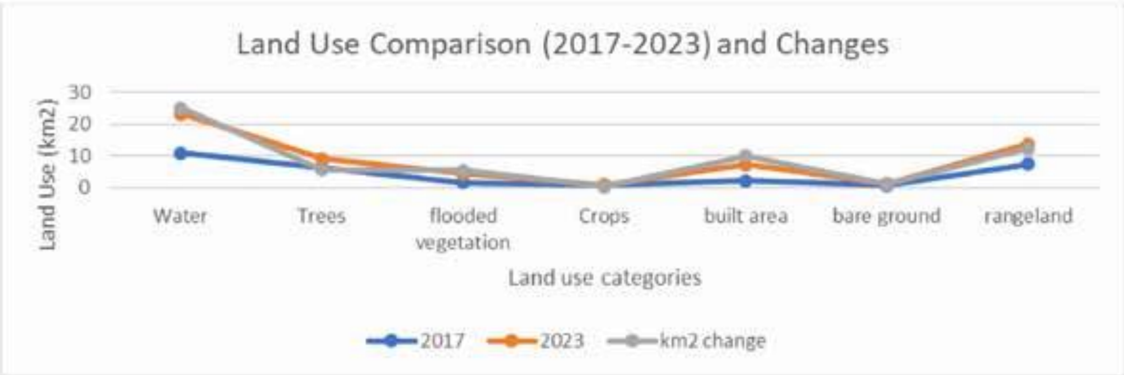

Figure 5: Land use comparison in square km, 2017 and 2023)

Figures 3 and 4 presents the land use land cover changes between 2017 and 2023 in the study area. The figures show the change in water, flooded vegetation, trees and built areas.

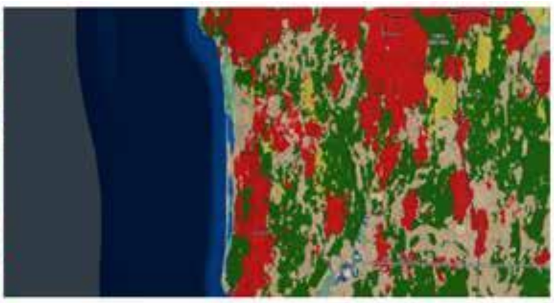

Figure 6: Land-use land-cover changes, 2017

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Figure 7: Land-use land-cover changes, 2023

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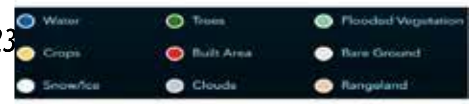

As observed in Table 2, water coverage has significantly increased to 5.50 percent. This is directly associated to the encroachment of sand mining, which erodes the lands of its topsoil and vegetation, thus leaving behind depressions that fill with water over time. This finding is consistent with (Anokye et al., 2023) findings in central region of Ghana, which artificial ponds and water bodies were associated to have been created as a results of sand mining. Similarly, the proportion of flooded vegetation has also increased by 3.6 percent. Also, the built-up area as increased by 9.2 percent. This rapid increase shows the conversion of previously natural and serene coast into residential and other infrastructural developments. This finding is not surprising, as aligns with the global patterns of urbanization, particularly along the coast where economic drive and population growth drives the expansion of cities (UN-Habitat, 2016). However, the rapid growth in urban development in the study area coupled with lack of land use planning, poses challenges for environmental conservation and resource management including sand mining and sustainable coastal protection. This trends as stated by Bendixen et al. (2023), built-up areas have been noticed to be on expansion at the expense of ecological valuable lands in Sub-Saharan Africa.

Another striking concern associated with sand mining activities is the decline in tree cover (%11.5) in the study area. This tree decline is as result of tree feeling by sand miners, this as stated by KII informants;

".... all the trees, the baobabs and other things, the big trees that are around the coast, they›ve all gone. So, all the big trees have gone" (KI respondent, Tujereng). This as re-echoed by a youth environmental activist, "... it›s just crazy. So, the huge destruction of the forest cover as well. Because wherever they are mining, they will cut down trees there. And we all know how important trees are to our environment. So, instead of them preserving those trees, they go ahead, cutting down all of those trees" (KI respondent, Sanyang).

These observed changes in Figures 3 and 4 are similar to Nurhasan and Saputra (2018) findings in Indonesia, where sand mining has led to deforestation and biodiversity loss in some parts of the coastal areas.

Similarly, agricultural land areas decreased by 1.9 percent in the study area. This decline highlights the growing pressure on agricultural land, which are increasingly being converted into mining or other related land uses and it directly affects the local women gardener, many of whom heavily depend on gardening for their sustenance. These changes are indictive of sand mining's intensification, urban development, and the consequential environmental deterioration. Comparing these results to previous studies in similar contexts highlights the regional and global relevance of the observed changes.

Governance

A desk review on regulatory frameworks was conducted on key acts and regulations governing sand mining and its related activities. Through a content analysis using the SWOT methodology, gaps in sand mining governance in the Gambia were identified and discussed in the context of sustainable development and blue growth. As the primary environmental laws, the National Environment Management Act (NEMA) 1994, focuses primarily on environmental protection but does not adequately address the specific challenges posed by sand mining. Notwithstanding the act's provision of legal basis for general environmental management, it falls short to explicitly address the sustainable management of sand resources, a concerned that has been raised in similar study by Suleiman (2020) in Zanzibar, Tanzania. For the Mines and Quarry Act 2005, serves as the primary legal tool for resource exploration including sand mining. Although, the act is clear in its delineation of roles and responsibilities for both miners and regulators, it is found to be weak in its enforcement mechanisms particularly in combating illegal mining and ensuring post-mining rehabilitations. Similar to NEMA 1994, the Mines and Quarry Act 2005 does not address the growing demand for sand, which leads to unsustainable sand mining practices.

The Environment Impact Assessment (EIA) regulations 1994 proof to be an essential regulatory tool for monitoring development projects and environmental activities at all spheres including sand mining activities. While the EIA act encourages public participation and promotes transparency, its enforcement is found to be weak particularly for EIA stakeholders on monitoring to legal sand mining sites. In addition, the fines levied against violators are often insufficient to serve as deterrent for illegal sand mining activities and non-compliance. Besides, the act seen an obstacle and faces opposition from industrial players in need of sand. This reflects the challenges stated in past studies, which noted that economic pressures and demand often undermine enforcement of environmental laws (Bendixen et al., 2023).

5.0 Conclusion

Sand is an important resource for economy wellbeing; however, the socioeconomic and environmental effects of its extraction highlight a critical intersection between sustainable development and the blue economy. Coastal ecosystems are integral for human survival and economic activities. However, are face with significant degradation due to sand mining, particularly in the coastal districts like Kombo South in the Gambia. Often driven by increasing demand from the construction industry and infrastructural development, sand mining comes at a substantial economic, environmental and social cost. Agricultural land loss, erosion, road damage, deforestation, and damage to TDA are among the severe effects of sand mining disrupting community livelihoods and exposing to climate vulnerabilities. These adverse effects highlight the need for sustainable resource management, as unrestricted exploitation of sand resources compromises the long-term viability of the coastal communities and their ecosystems.

In the context of blue economy, the nexus between sand mining and coastal resource management reflects a subtle balance between economic growth and environmental conservation. Whiles mining generate employment, revenue, and supports construction industry, its unregulated nature leads to conflicts over resource allocation, undermine community resilience, sustainable development and potential to impede blue growth. Governance frameworks, such as NEMA 1994, Mines and Quarry Act 2005, and EIA 1994 remains insufficiently equipped to address these challenges. Integrating sustainable practices and strengthening policy enforcement are essential in harmonising economic benefits with economical conservation and blue growth. Ultimately, ensuring the sustainability of sand mining within the blue economy requires collaborative effects across governance, community involvement, and innovative resource management strategies. To address the effects of sand mining for sustainable development and blue growth, the following recommendations are made for the regulatory agencies and local authorities; (1) it is prudent for the regulatory agencies and their stakeholders to review the various exiting laws and regulation governing sand mining and streamlined with the current realities of integrated coastal management for environmental conservation, (2) Strengthening enforcement through the national police and the organised youth vigilantes at the communities for monitoring of illegal sand mining activities. The police and organised groups can aid to minimise the illegal mining especially at night, (3) the government to come up with land policy and where possible zoning for proper and coordinate land use and management, particularly within the TDA. This will help in safeguarding the existing potential tourism space and promotes tourism at community level, (4) the government and partners to scout for alternative construction materials and chart ways for offshore sand dredging with proper coordination and for blue growth, (5) diversification of livelihood ventures at the community level to minimise the engagement into illegal and uncontrolled sand mining, (6) it is crucial for the central and local government and their partners to ensure that those negatively affected with sand mining are duly compensated.

Limitation

This study could not track and monitor illegal sand mining activities from the study area because of the sporadic and clandestine operations of the miners. Thus, makes it difficult to identify and know the perspective of illegal miners.

Declaration of competing interest

The author declares no known competing financial and personal relationship that could have appeared to influence the work reported in this paper.

Reference

Adedeji, O. H., Adeofun, C. O., Tope-Ajayi, O. O., & Ogunkola, M. O. (2020). Spatio-temporal analysis of urban sprawl and land use / land cover changes in a suburb of Lagos and Ogun metropolises, Nigeria (2014-1986). Ife Journal of Science, 42–27 ,(1)22. https://doi.org/10.4314/ijs.v22i1.4

Amnesty International. (2023). Devastating impact of overfishing on local communities, The Gambia. https://www.amnesty.org/en/latest/news/05/2023/the-gambia-devastating-impact-of-overfishing-on-local-communities/

Amour, R., & Haji, H. (2024). Geospatial Assessment of Impacts of Sand Mining Activities in Zanzibar. Journal of ICT Systems, 71–59 ,(1)2. https://doi.org/10.56279/jicts.v2i1.60

Anokye, N. A., Mensah, J. V., Potakey, H. M. D., Boateng, J. S., Essaw, D. W., & Tenkorang, E. Y. (2023). Sand mining and land-based livelihood security in two selected districts in the Central Region of Ghana. Management of Environmental Quality: An International Journal, 36–21 ,(1)34. https://doi.org/10.1108/MEQ0263-2021-11- Asare, K. Y., Dawson, K., & Hemmler, K. S. (2023). A sand-security nexus: Insights from peri-urban Accra, Ghana. Extractive Industries and Society, 101322)15). https://doi. org/10.1016/j.exis.2023.101322

Asare, K. Y., Hemmler, K. S., Buerkert, A., & Mensah, J. V. (2024). Scope and governance of terrestrial sand mining around Accra, Ghana. Social Sciences and Humanities Open, 9. https://doi.org/10.1016/j.ssaho.2024.100894

Beiser, V. (2018). The world in a grain: The story of sand and how it transformed civilization (RiverheadBooks).

Bendixen, M., Best, J., Hackney, C., & Iversen, L. L. (2019). Time is running out for sand. In Nature (Vol. 571, Issue 7763, pp. 31–29). Nature Research. https://doi.org/10.1038/d4-02042-019-41586

Bendixen, M., Noorbhai, N., Zhou, J., Iversen, L., & Huang, K. (2023). Drivers and effects of construction-sand mining in Sub-Saharan Africa. Journal of The Extractive Industries and Society, 16. https://doi.org/10.1016/j.exis.2023.101364

Bosco, J., & Sumani, B. (2019). Possible Environmental and Socio-economic Ramifications of Sand and Gravel Winning in Danko, Upper West Region of Ghana. In Ghana Journal of Geography (Vol. 11, Issue 2).

Chandran, R. (2019). Sand mining 'mafias' destroying environment, livelihoods. U.N. Reuters.

Essaw, D. W., Mensah, J. V., Nana Amma Anokye, Tenkorang, E. Y., Boateng, J. S., & Potakey, H. M. D. (2023). Governance for Sustainable Sand Mining in Two Selected Local Government Areas in the Central Region of Ghana. Society & Natural Resources. https://doi.org/08941920.2023.2169799/10.1080

GBoS, (Gambia Bureau of Statistics). (2013). Population and Housing Census Report.

Global Construction Perspectives and Oxford Economics. (2022). Global Construction 2030. A global forecast for the Construction Industry to 2030. Global Construction Perspectives and Oxford Economics. www.globalconstruction2030.com

International Trade Administration. (2022). Travel and Tourism. Gambia, The - Country Commercial Guide.

Johnbull, S., & Brown, I. (2017). Socio-economic Consequences of Sand Mining along the Victory River in Port Harcourt, Nigeria. Asian Journal of Environment & Ecology, ,(2)3 15–1. https://doi.org/10.9734/ajee/34087/2017

Komma, L. (2019). Towards implementing integrated coastal zone management in The Gambia: coastal adaptation to climate change and human impacts in the high risk zone (cell 6). https://commons.wmu.se/all_dissertations/1192

Madyise, T. (2013). Case studies of Environmental Impacts of Sand Mining and Gravel Extraction for Urban Development in Gaborone [Master's Thesi]. University of South Africa.

Mark, M. E. (2021). The governance of global sand mining [Masters Thesis]. University of Waterloo.

Mbaka, J. G., & Rono, C. C. (2022). Socio-economic and Environmental Impacts of Sand Mining in Mbiuni Ward, Mwala Constituency, Machakos County, Kenya. East African Journal of Environment and Natural Resources, 288–278 ,(1)5. https://doi. org/10.37284/eajenr.5.1.798

Mensah, J., & Mattah, P. A. D. (2023). Illegal sand mining in coastal Ghana: The drivers and the way forward. Extractive Industries and Society, 13. https://doi.org/10.1016/j. exis.2023.101224

Miller, M. A. (2022). A transboundary political ecology of volcanic sand mining. Annals of the American Association of Geographers, 96–78 ,(1)112.

Mngeni, A., Musampa, C. M., & Nakin, M. D. V. (2016). The effects of sand mining on rural communities. Sustainable Development and Planning VIII, 453–443 ,1. https://doi. org/10.2495/sdp160371

NEA. (2020). State of the Environment Report- The Gambia.

Nurhasan, U., & Saputra, P. Y. (2018). Analysis of Sand Mining Areas in Lumajang Using WEBGIS. Advances in Economics, Business and Management Research. International Conference on Energy and Mining Law (ICEML 59 , .(2018.

Pearce, F. (2019). The hidden environmental toll of mining the world's sand. Yale Environment. https://e360.yale.edu/features/the-hidden-environmental-toll-o f-mining-the-worlds-sand

Rais, M., Abdullah, R., Malik, E., Mahmuda, D., Pardana, D., Abdullah, L. O. D., Dja'Wa, A., Suriadi, Jasiyah, R., Naping, H., & Manuhutu, F. Y. (2019). Impact of sand mining on social economic conditions of community. IOP Conference Series: Earth and Environmental Science, 1)343). https://doi.org/012132/1/343/1315-1755/10.1088

Rangel-Buitrago, N., Neal, W., Pilkey, O., & Longo, N. (2023). The global impact of sand mining on beaches and dunes. Ocean and Coastal Management, 235. https://doi.org/10.1016/j.ocecoaman.2023.106492

Sambou, O. (2023). An In-Depth Analysis of Natural Resource Conflict in the Gambia: A Study in Sanyang Village. OALib, 9–1 ,(04)10. https://doi.org/10.4236/oalib.1109581

Suleiman, A. (2020). Socio_Economic Impacts of Sand Mining Activities in Zanzibar, Tanzania. Open University of Tanzaania.

UNEP. (2019). Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources.

UNEP. (2022). Sand and sustainability: 10 strategic recommendations to avert a crisis. GRID.

UN-Habitat. (2016). Urbanization and Development: Emerging Futures, World Cities Report 2016.

United Nations. (2016). Africa's Blue Economy: A Policy Handbook. United Nations Economic Commission for Africa.