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Research paper

Sustainable Fisheries in Digha: Policy and Community-Based Approaches for Marine Conservation

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Abstract

Estuarine ecosystems like the Digha Mohona are highly productive yet vulnerable to economic losses caused by pollution, overfishing, and biodiversity degradation. This study presents a revised Gordon-Schaefer bioeconomic model incorporating an environmental quality index and economic biodiversity metric to evaluate the cost of inaction on ecosystem health. Profit-maximizing dynamics and sensitivity analyses offer insight into optimal fishery yields under various pollution scenarios. To strengthen policy relevance, the study integrates economic tools such as net present value (NPV), maximum economic yield (MEY), and cost-effectiveness of pollution mitigation. Furthermore, the paper explores innovative financial instruments like Blue Bonds, Payments for Ecosystem Services (PES), and marine subsidies to promote sustainable fisheries. Governance frameworks, including co-management models and regulatory incentives, are proposed to align ecological sustainability with economic resilience. While the Digha estuary serves as a regional case, limitations in generalizing findings to global fisheries are acknowledged. By coupling ecological models with policy finance mechanisms, the framework supports both environmental protection and economic valuation of marine resources. The findings advocate for ecosystem-based governance supported by targeted investment, making the case for an integrated, economically viable marine resource management strategy.

Keywords: *Coastal Ecosystems; Marine Management; Socio-economic Factor; Fishery; Water.*

1. Introduction

Ecosystems are intricate, interconnected, dynamic systems wherein organisms, their environments, and outside factors—such as weather patterns and ocean currents—cooperate to form communities and control population sizes(Salkić et al., 2021). The ecosystems that humans use and live in are a part of us. Humans are impacted by changes in ecosystems, and their activities on land and in the ocean have measurable effects on ecosystems (Ansong et al., 2017; Curtin &Prellezo, 2010). As a result, they typically support a rich biological diversity and have exceptionally high biological productivity(Razak et al., 2024). The coastal-marine spectrum can be divided into five major zones: coastal lands, where human activity is concentrated and directly impacts neighboring waters; offshore waters, primarily out to the edge of national jurisdiction and high seas, beyond the bounds of national borders; inland areas, which primarily impact the oceans through rivers and non-point sources of pollution; and coastal water, typically estuaries, where the effects of land-based activities are significant. Its many uses put a great deal of strain on the ecosystem(Rahman et al., 2024). Tourism and fishing are two of the ecosystem's main activities. Conflict between users is inevitable when there is a wide range of use (Samhouri et al., 2014; Barbier, 2017; Chlaihawi, 2023).

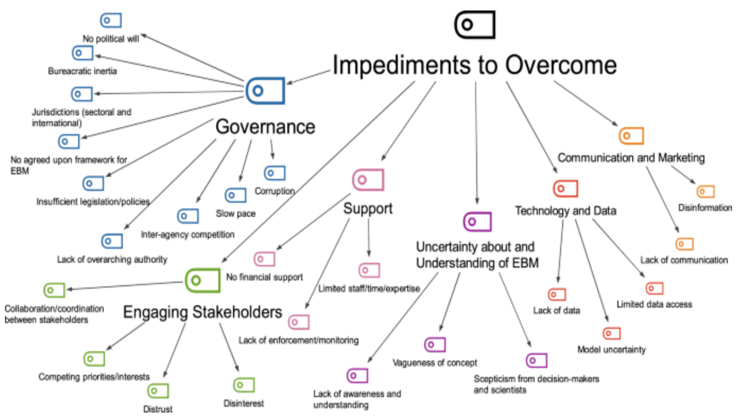

Fig. 1: Marine Ecosystem based Management

The development of fisheries is crucial for raising food production levels and enhancing the nutritional quality of diets in developing nations(Sumaila et al., 2020). Fish is a perfect supplement to the poor and boring diet that many people in tropical and sub-tropical countries eat daily (Sardà et al., 2014). The sea's natural resources are, in fact, incredibly valuable and replenishable. They may be able to generate ongoing returns without experiencing a decline in productivity if they are managed sustainably(Shinan et al., 2024). However, the way that coastal ecosystems are developing from the perspective of fisheries production is concerning(Ilori et al., 2021). Greater sustainability is anticipated to result from a more comprehensive strategy that considers interspecific interactions and environmental influences (Leslie & McLeod, 2007).

2. Methodology

In most coastal countries, coastal areas are extremely important from an economic, social, and environmental standpoint. Their abundance of natural resources and facilities, including beaches, productive wetland areas, and fisheries, makes them very appealing places for people to live and work(Ruckelshaus et al., 2008). However, the coastal zone's valuable and varied resources are under tremendous strain due to this very attraction, and this pressure is only going to get worse (Buhl-Mortensen et al., 2017). Evidence that traditional sectoral approaches to resource and activity management in coastal areas are insufficient is mounting. Natural coastal systems continue to deteriorate despite best efforts in many cases, conflicts over resource use are intensifying, and the social and economic advantages that could be gained from the coastal zone's natural resources are disappearing (Long et al., 2015). The dynamic process of integrated coastal zone management (ICZM) involves the development and application of a coordinated plan for the distribution of institutional, sociocultural, and environmental resources in order to accomplish the conservation and sustainable multiple use of the coastal zones (Altman et al., 2011).

Table 1: Descriptive Statistics

Items	Mean	Variance
How can governance structures be adapted to support ecosystem-based management in marine ecosystems?	84	49
What are the institutional barriers to implementing ecosystem-based management in marine ecosystems?	99	51
What role can traditional knowledge play in informing marine ecosystem-based management?	139	76%
How can ecosystem-based management address the needs of multiple user groups in marine ecosystems?	44	24%
What are the economic implications of adopting ecosystem-based management in marine ecosystems?	180	98.36
How can stakeholder engagement and participation be effectively integrated into marine management decisions?	2	1.10
How can invasive species be effectively managed in marine ecosystems?	1	0.54
What is the impact of climate change on marine ecosystems, and how can management frameworks adapt?	0	0
How can ecosystem services be integrated into marine management decisions?	44	24
What are the key ecological indicators for monitoring marine ecosystem health?	139	76
How do different marine ecosystems respond to various management strategies?	0	0
What are the most effective methods for monitoring and evaluating ecosystem-based management in marine ecosystems?	0	0
What are the implications of ecosystem-based management for existing marine management frameworks?	139	76
How can international cooperation and agreements support ecosystem-based management in marine ecosystems?	44	24
What is the role of policy and legislation in supporting ecosystem-based management in marine ecosystems?	0	
How can scenario planning and modeling be used to inform ecosystem-based management decisions?	0	
What role can remote sensing and other technologies play in supporting ecosystem-based management in marine ecosystems?	139	76
How can uncertainty and risk be addressed in ecosystem-based management decisions?	44	24
What are the implications of scale and context for ecosystem-based management in marine ecosystems?	0	

Source: Prepared by the author

3. Data Analysis Techniques

Appropriate statistical tools like Microsoft Excel and SPSS are used to ascertain the reliability and validity of questionnaires and to validate the online consumer's belief, opinion, perception, and buying behavior concerning fashion apparel. Techniques like Descriptive Statistics, Chi-square, t-test, and ANOVA (one-way/two-way) have been used for the data analysis(Smith et al., 2017; Ilori et al., 2021).

Table 2: Purpose of Coastal Ecosystem

Purpose	Frequency	Percentage
How can ecosystem services be integrated into marine management decisions?	99	51
What are the key ecological indicators for monitoring marine ecosystem health?	84	49
How do different marine ecosystems respond to various management strategies?	99	51
What are the most effective methods for monitoring and evaluating ecosystem-based management in marine ecosystems?	139	76%
What are the implications of ecosystem-based management for existing marine management frameworks?	44	24%
How can international cooperation and agreements support ecosystem-based management in marine ecosystems?	180	98.36
What is the role of policy and legislation in supporting ecosystem-based management in marine ecosystems?	2	1.10
How can scenario planning and modeling be used to inform ecosystem-based management decisions?	1	0.54
What role can remote sensing and other technologies play in supporting ecosystem-based management in marine ecosystems?	0	0
How can uncertainty and risk be addressed in ecosystem-based management decisions?	44	24
What are the implications of scale and context for ecosystem-based management in marine ecosystems?	139	76

Source: Prepared by the author

The ANOVA and t-test results (Table 4) demonstrate that every independent factor, along with the related subscales.

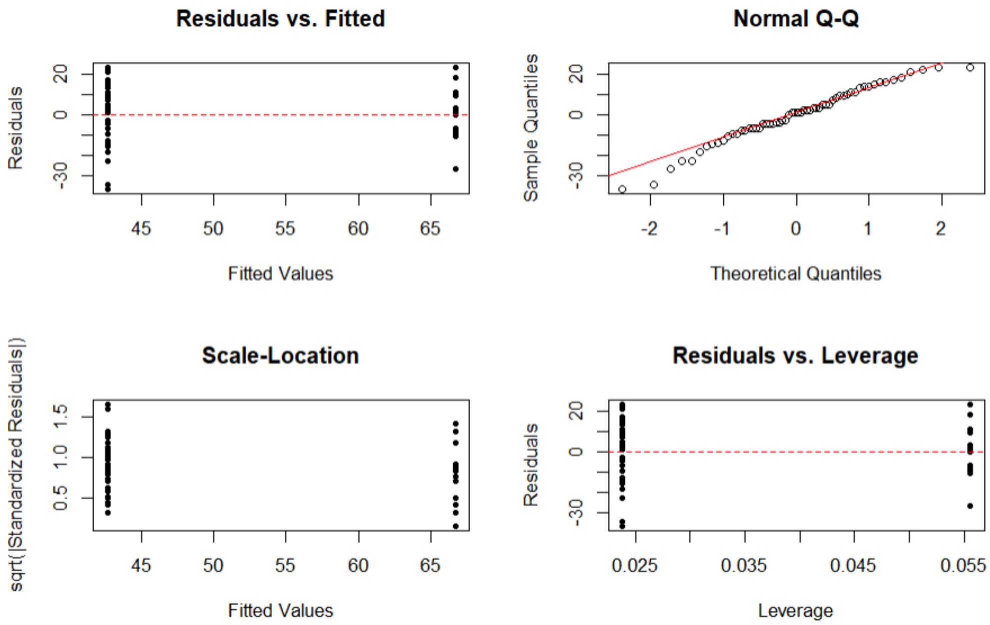

Fig. 2: Regression Analysis (Source: Prepared by author)

The three main sources of fish production in the world are inland catch, which comes from lakes and rivers; freshwater and marine aquaculture; and marine catch, which includes all species caught in coastal waters or on high seas. Marine fishing fleets account for 78% of the total catch. The increase in the marine harvest is a result of both the growing demand for fish from a growing global population and the steady increase in the number of fishing vessels and the sophistication of the gear used in the catch process.

Table 3: t-test Result

Category	t-test					
	Mean	**SD**	**N**	**t**	**df**	**Sig.**
What are the implications of the case study findings for broader ecosystem-based management applications?	3.27	1.048	751	-.665	1132	.506
How can ecosystem-based management be adapted to address the specific challenges and opportunities of the case study site?	3.33	1.000	383			
What are the key stakeholders and their interests in the case study site?	3.28	.967	180	-.195	1132	.845
How have historical and current management practices impacted the case study site?	3.30	1.041	954			
What are the unique ecological, social, and economic characteristics of the case study site?	3.30	1.029	873	.420	1132	.675
What role can remote sensing and other technologies play in supporting ecosystem-based management in marine ecosystems?	3.26	1.032	261			

Source: Prepared by the author

The past few decades have seen an increase in fishing activity. As a result, it is now crucial to forecast catches and analyze how changes in fishing activity linked to increased fishing effort affect catches. There is an average catch or yield that can be consistently extracted from a stock for a particular fishery resource under specific environmental circumstances. So it is necessary to assess the maximum sustainable yield.

4. Financial Mechanisms for Sustainable Fisheries

To ensure long-term financial sustainability in marine conservation, this study proposes integrating economic instruments such as Blue Bonds, which provide concessional finance for marine restoration projects, and PES schemes, where stakeholders like tourism operators compensate fishing communities for preserving ecosystem services. Government subsidies can also be repurposed to support compliance with eco-certification and responsible fishing practices. These mechanisms create a financial incentive structure aligned with conservation goals, transforming traditional marine governance into an investment-oriented blue economy framework.

5. Conclusion

In recent times, there has emerged a growing realization of ecosystem effects affecting the productivity of fishing. The two most important factors affecting the productivity of a fishery are environmental conditions and biodiversity. This study intends to examine the issues involved in the sustainable utilization of marine fisheries through the incorporation of ecosystem factors that are rapidly becoming an integral part of fishery management. These will be analyzed using modified versions of the conventional fishery model. We intend to incorporate an environmental quality variable and a constructed economic biodiversity index in the theoretical structure of the Gordon-Schaefer model and empirically test the same. We have been incorporating components of ecosystem management in our models of fisheries. Thus, the effect of water pollution due to the tourism industry is linked to the loss of biodiversity and its impacts on fish harvested. This twin problem has been addressed simultaneously and modeled in an aggregated Gordon Schaefer model for the Digha Mohona (Estuary) fishery. An economic biodiversity index and an environmental quality variable have been included to modify the aggregated Gordon-Schaefer model. This adds realism in exploring the sustainability of fish catch in Digha Mohona (Estuary). While this case study of the Digha Estuary provides valuable insights into economic modeling of fisheries management, caution should be exercised when generalizing these findings to other ecosystems. Variations in institutional capacity, funding mechanisms, and socio-political structures across global fisheries may limit the applicability of proposed models. Future research should validate these approaches in diverse geographies using standardized metrics of marine economic valuation.

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