

Linking Blue Carbon Ecosystems and Water Quality in Coastal Wetlands for Viable Small-Scale Fisheries

by
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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Doctor of Philosophy
in
Sustainability Management (Water)

Waterloo, Ontario, Canada, 2025

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AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

Navya Vikraman Nair is the sole author of Chapter I and Chapter V of this dissertation, which were written under the supervision of Dr. Prateep Kumar Nayak and were not intended for publication. This dissertation includes four research manuscripts (Chapters I–IV) that are either under consideration or under committee review for publication. These works stem from Navya Vikraman Nair’s doctoral research in Sustainability Management at the University of Waterloo, supported by the V2V Global Partnership (SSHRC Partnership Grant #895-2020-1021). Navya was the lead author on all manuscripts, responsible for the development of research questions, data collection, participatory mapping, qualitative and quantitative analyses, framework design (including the SEVVN framework), and drafting of manuscripts. Dr. Nayak supervised the research across all chapters, while Dr. Pittman, Dr. Basu, and Dr. Frayne contributed conceptual, methodological, and analytical insights. All co-authors provided detailed feedback on the manuscript drafts and contributed to their revision. These collaborations significantly informed the chapters on community perceptions of blue carbon ecosystems (Chapter II), social-ecological interdependencies in water quality (Chapter III), and the vulnerability and viability of small-scale fisheries (Chapter IV).

Chapter II: Nair, N. V., Nayak, P. K., & Pittman, J. (under consideration). *Community Perceptions and Participatory Mapping of Blue Carbon Ecosystems*. Manuscript submitted to *Communications, Earth & Environment, Nature*.

Chapter III: Nair, N. V., Nayak, P. K., & Basu, N. B. (under committee review). *Social-Ecological Interdependencies: Community Perspectives on Water Quality in Chilika Lagoon*. Manuscript to be submitted to *Environmental Research, Elsevier*.

Chapter IV: Nair, N. V., Nayak, P. K., Frayne, B., & Pittman, J. (under consideration). *Linking Vulnerabilities of Small-Scale Fisheries with Seagrass Health and Water Quality*. Manuscript submitted to *npj Ocean Sustainability, Nature*.

Integrated across Chapters I and IV: Nair, N. V., & Nayak, P. K. (under consideration). *A Social-Ecological Framework for Transitioning Small-Scale Fisheries to Viability through Blue Carbon Ecosystems and Water Quality Improvements*. Manuscript submitted to *Marine Policy, Elsevier*.

ABSTRACT

Coastal wetlands serve as critical social-ecological systems (SES), providing essential ecosystem services (ES), supporting biodiversity, and sustaining livelihoods, particularly for Small-Scale Fisheries (SSFs). However, these ecosystems are increasingly vulnerable due to the degradation of Blue Carbon Ecosystems (BCEs) such as seagrass meadows and mangrove forests, compounded by declining water quality and social-economic pressures. This doctoral research explores the interlinkages between BCEs, water quality, and SSFs in Chilika Lagoon, India, Asia's largest brackish water lagoon-through an interdisciplinary, participatory, and spatially explicit approach. Grounded in the Social-Ecological Vulnerability and Viability Nexus (SEVVN) framework, the study integrates ecological data, community knowledge, and governance analysis to understand the drivers, feedback, and outcomes influencing the resilience of coastal wetland systems.

The study explores the interlinkages between BCEs, water quality, and the viability of SSFs in Chilika Lagoon, India. It addresses four interrelated objectives using a mixed-methods approach grounded in SES thinking. First, the spatial distribution of seagrass meadows and mangrove patches is mapped and characterized through participatory mapping, remote sensing (RS), and field observations. By integrating traditional ecological knowledge (TEK) with historical and scientific data, the study reveals patterns of degradation and resilience, highlighting the role of co-produced knowledge in conservation planning. Second, key water quality parameters, salinity, turbidity, temperature, and nutrient loads, are assessed using literature, secondary datasets, and community observations. Seasonal variations and anthropogenic pressures, including plastic pollution and sedimentation, are found to affect BCE health and fishery habitats, impacting SSF productivity and livelihoods.

Third, the SEVVN framework is applied to analyze feedback loops and stressors linking BCE degradation and SSF vulnerability. Data from surveys, interviews, and focus group discussions (FGDs) show that fishers experience environmental and institutional vulnerabilities due to declining fish availability, weak governance, and limited adaptive capacity. Sectoral variations in exposure and resilience are documented across the lagoon's Northern, Central, Southern, and Outer Channel sectors. Finally, the study identifies governance pathways for building resilience. Ecosystem-based and community-centered strategies are proposed, including

TEK integration, water quality monitoring, and participatory co-management. Recommendations aim to foster inclusive decision-making and bridge scientific and local knowledge systems. Chilika Lagoon, a Ramsar site and biodiversity hotspot, provides a critical empirical context to study the trade-offs between conservation, development, and livelihood needs. This research contributes to policy and practice for coastal wetland sustainability in South Asia and beyond.

Key findings from the study underscore the urgent need for integrated social-ecological approaches in wetland governance. Participatory mapping revealed local awareness of BCE loss but limited community involvement in formal monitoring or conservation programs. Survey data showed that perceptions of water quality decline were strongly linked to observed reductions in fish catch and increased livelihood uncertainty. Participatory exercises surfaced the erosion of traditional knowledge (TK), exacerbated by policy shifts, environmental change, and generational gaps. The SEVVN analysis identified multiple entry points for intervention, including capacity-building, knowledge co-production, and inclusive policy formulation. Theoretically, the study contributes to the literature on SES, blue carbon science, and fisheries governance by developing and applying the SEVVN framework. Methodologically, it advances participatory and mixed-methods research in coastal environments. Practically, it offers actionable insights for policymakers, conservation practitioners, and local communities seeking to build adaptive capacity and enhance the viability of SSFs. By linking ecological data with social realities, and grounding analysis in community perspectives, this research contributes to sustainability science and global efforts to meet the Sustainable Development Goals (SDGs). It particularly aligns with SDG 1 (No Poverty), SDG 6 (Clean Water), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 17 (Partnerships for the Goals). Ultimately, the study argues for a shift from fragmented, top-down conservation models toward more inclusive, participatory, and ecosystem-based governance approaches that center the voices of those most dependent on coastal resources.

Keywords:

Blue Carbon Ecosystems, Water Quality, Small-Scale Fisheries, Chilika Lagoon, Social-Ecological Systems, Seagrass, Mangroves, Vulnerability, SEVVN Framework

ACKNOWLEDGEMENTS

This PhD journey has been an extraordinary blend of academic growth, personal transformation, and deep human connection. I am immensely grateful to all those who supported me, challenged me, and believed in me throughout this experience.

First and foremost, my deepest gratitude goes to Dr. Prateep Kumar Nayak, my supervisor not only during this PhD but also through my Master's journey. It is rare to walk such a long academic path under the mentorship of someone who believed in my potential long before I did. Coming from a civil–environmental engineering background, I had little exposure to the social sciences, but your guidance helped me bridge that gap, embracing participatory research, governance, and community-led approaches while unlearning rigid technical norms. Your patience, flexibility, and unwavering support allowed me to grow not just as a scholar but as a person. Even during moments of disagreement, I learned from the way you navigated complexity with clarity and grace, an invaluable life lesson. Thank you for mentoring me through both degrees and shaping the interdisciplinary researcher I am today.

My heartfelt thanks to my committee members-Dr. Bruce Frayne, Dr. Jeremy Pittman, and Dr. Nandita Basu-for your time, thoughtful feedback, and consistent encouragement. Dr. Bruce, your recognition, kindness, and steady support gave me the confidence to continue when I doubted myself. Thank you for reading and valuing my work. Dr. Jeremy, it has been a privilege to have you as part of both my Master's and PhD milestones. Your thoughtful questions and insightful feedback have continuously helped me deepen my thinking. I'm lucky to have had your support across both journeys.

To the faculty and staff at SEED and the Faculty of Environment, thank you for your academic and logistical support. A heartfelt thank you to Dr. Sisir Pradhan for guiding me whenever I felt stuck, and to his better half, Rashmi Pradhan, for offering love, care, and warmth that made Odisha feel like home. You both treated me like family, and I will forever cherish the love, laughter, and comfort your home provided. Your children's joyful presence brought light into my life during some of the most challenging periods of this research.

I am deeply grateful to Deepak Kumar Dey, Program Assistant at NIRMAN, Odisha, for his unwavering technical and administrative support, which made my fieldwork in Chilika possible. Heartfelt thanks to my incredible field assistants, Tapan Kumar Behera, a kind-hearted,

vibrant soul who has helped countless students integrate into the community, and Rabindra Nath Sahu, a dedicated conservationist protecting Olive Ridley Sea turtles in Rushikulya. Your companionship and wisdom shaped my time in the field. A special thank you to Pitamber Jali and his family for welcoming me into your home in Satapada. Learning to make samosas at your shop after long field days and being included in community gatherings remains some of my fondest memories. Despite language differences, your warmth spoke volumes.

I'm also thankful to the Dakshin Ganjam team, especially K Bhawna (Senior Program Associate) and her colleagues, for offering not just logistical help but genuine friendship. Those spontaneous field trips and shared laughter gave me space to breathe and heal. Immense thanks to Dipti bhaiyya (SIITA Travels), Magata bhai, Pramod bhaiyya, Sunil bhaiyya, and many other community members whose names I may not be able to list here, but whose kindness I carry with me. I also thank Dr. Basant Kumar Das (Director, ICAR–CIFRI) and Dr. Shreya Bhattacharya for the enriching experience at CIFRI. Shreya, thank you for being more than a colleague, a thoughtful guide, a friend, and an elder sister figure throughout this journey.

I am deeply grateful to my mother, Mrs. Geetha Devi, whose unconditional love, tireless prayers, and unwavering encouragement have been my anchor throughout this journey. My father, Mr. Vikraman Nair, with his quiet strength and wisdom, has been a profound influence in shaping my values and determination. Their grounded, down-to-earth upbringing instilled in me the humility and openness that allowed me to blend seamlessly with the communities I lived and worked with during my field research. My sister, Navami V. Nair, has been a constant cheerleader, and her belief in me has always meant more than words can express. To my life partner, Aby M Philip, thank you for walking beside me through every emotional high and low, for your immense patience, and for the countless ways you supported me, both big and small. I consider myself incredibly lucky to be embraced so warmly by the Mullikkattu family, Mrs. Elsa Philip, Mr. Philips Thomas, and all the extended members, for loving me like one of their own. Our wedding in 2023, which beautifully unfolded during my fieldwork, became more than a personal milestone, it deepened my belief in the richness of cultural understanding and the quiet strength found in shared values across differences.

I sincerely acknowledge the encouragement and leadership opportunities provided by Campus Housing, the Student Success Office, Centre for Teaching Excellence, SWIGS–Water Institute, and the PEGASUS team. Every kind smile, supportive colleague, and meaningful

conversation made a real difference. Special thanks to Nada Alshehabi for helping me discover my teaching potential and providing the space to grow. My heartfelt gratitude to Delores Lanni for recognizing the leader in me and nurturing that potential. Thank you both for your trust and the many recommendation letters you wrote for my scholarships and awards, they opened countless doors for me. Being part of the Water Institute gave me the honour of representing the University of Waterloo at global forums, including the UN World Water Conference and 10th World Water Forum. I also extend deep thanks to Maryam Latifpoor-Keparoutis and Lana Dadson from the Faculty of Environment Advancement team. Maryam, your motherly care and steadfast support meant the world to me. Finally, to the V2V Global Partnership, fellow researchers and friends, especially Dr. Prabhakar Shukla, Dr. Kirti Sundar Sahu, Bhavna Bharati, and Pritichhanda Mohanty, thank you for your invaluable support, friendship, and collaboration throughout this journey.

This research would not have been possible without funding support from: the Social Sciences and Humanities Research Council (SSHRC) Grants, IDRC Doctoral Research Awards, University of Waterloo scholarships (Davis Memorial Award, George Mulamoottil Graduate Scholarship, Dean's Doctoral Initiative, International Doctoral Student Award and many more), Conrad School of Entrepreneurship and Business, for awarding me the Entrepreneurial PhD Fellowship and supporting my MBET journey.

Thank you to my close friends, Mendu Harish, Jaya Sree Mugunthan, and Dr. Ajay Singh, for their constant presence and care. Harish, your unwavering belief in me through all my messy moments and doubts is something I can never thank you enough for. You've helped me understand myself better and taught me to focus on what truly matters. Ajay, thank you for your years of support in many capacities, and for that life lesson on not trusting too quickly or getting emotionally invested too easily. Polite or not, it was one I needed to learn.

To anyone whose name I may have missed, please know that your support, kindness, and contribution remain etched in my heart. This dissertation is a culmination of shared efforts, care, and inspiration from people across disciplines, geographies, and walks of life. Thank you all for walking this journey with me.

DEDICATION

“लोकः समस्ताः सुखिनो भवन्तु”

Lokaḥ samastāḥ sukhino bhavantu

May all beings in all worlds be happy and free

This ancient Sanskrit blessing captures the essence of my research-rooted in compassion, equity, and sustainability. It reminds me that the pursuit of knowledge must serve collective wellbeing, not just individual growth. This work is dedicated to the communities of Chilika Lagoon, those who welcomed me with open hearts, shared their stories, and offered trust without hesitation. Your resilience, warmth, and deep connection to the land and water gave this research its meaning and soul. I am forever grateful for your presence and generosity.

To my Amma and Achan, Mrs. Geetha Devi and Mr. Vikraman Nair, thank you for raising me with humility, compassion, and grounded values. Growing up in a small Kerala town amidst coconut trees and paddy fields taught me the strength in simplicity and the richness of community life. That upbringing helped me connect deeply with the people I lived among during fieldwork. Your unwavering support, quiet strength, and endless prayers carried me through the toughest times. To my husband, Aby M Philip, thank you for being my anchor, for enduring my emotional storms, celebrating my small wins, and loving me unconditionally. Even when our wedding collided with the chaos of fieldwork, you reminded me that life’s beauty lies in moments of shared joy, despite the deadlines.

To Dr. Prateep Kumar Nayak, thank you for believing in me before I believed in myself. Your guidance helped me transition from an engineering mindset to a transdisciplinary researcher grounded in social sciences. You offered the space to grow, unlearn, and evolve. Even in moments of disagreement or difficulty, I learned from your clarity and calmness. Your mentorship has been a gift I will carry forward. As a South Asian international woman researcher in Canada, I often found myself straddling spaces where I didn’t fully belong-culturally, intellectually, emotionally. But those very challenges became my strength. They shaped my voice, built resilience, and deepened my commitment to inclusive, participatory, and empathetic research. This thesis is a tribute to those learnings-and to all women who walk into unknown spaces, carrying not just data, but dreams. May our stories, layered and courageous, continue to shape the world we want to live in.

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LIST OF ABBREVIATIONS

Abbreviations	Definitions
BCEs	Blue Carbon Ecosystems
BOD	Biological Oxygen Demand
CDA	Chilika Development Authority
CMFRI	Central Marine Fisheries Research Institute, Kerala, India
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
ES	Ecosystem Services
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GIS	Geographic Information System
ICAR	Indian Council of Agricultural Research
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JSTOR	Journal Storage (Digital Library)
MoEFCC	Ministry of Environment, Forest and Climate Change (India)
MPAs	Marine Protected Areas
NGOs	Non-Governmental Organizations
NVivo	Qualitative Data Analysis Software
PES	Payments for Ecosystem Services
R	Statistical Computing Software
ROVs	Remotely Operated Vehicles
RS	Remote Sensing
Scopus	Elsevier's Abstract and Citation Database
SDGs	Sustainable Development Goals
SES	Social-Ecological Systems
SEVVN	Social-Ecological Vulnerability and Viability Nexus
SLF	Sustainable Livelihood Framework
SSFs	Small-Scale Fisheries
SSHRC	Social Sciences and Humanities Research Council (Canada)
TBTI Global	Too Big To Ignore Global Partnership for Small-Scale Fisheries
TEK	Traditional Ecological Knowledge
TK	Traditional Knowledge
UNEP	United Nations Environment Programme
V2V	Vulnerability to Viability
WoS	Web of Science (Database)
WTRC	Wetland Research and Training Centre (Barkul)

Chapter I: Introduction

1.1 Research Context and Problem Rationale

Blue Carbon Ecosystems (BCEs), a term referring to coastal vegetated habitats such as mangroves, seagrass meadows, and salt marshes, have gained increasing recognition as essential natural infrastructures that provide extensive ecological, economic, and social benefits. These ecosystems, which include mangroves, seagrass meadows, and salt marshes, are among the most biologically productive habitats on Earth. One of their most significant contributions is their ability to sequester carbon at rates far exceeding terrestrial forests, making them instrumental in global climate change mitigation (Duarte et al., 2005). However, beyond their carbon sequestration capacity, BCEs play a fundamental role in maintaining the sustainability of coastal ecosystems. They contribute to water quality regulation, mitigate shoreline erosion, and serve as crucial habitats for diverse marine and terrestrial species (McLeod et al., 2011).

In South and Southeast Asia, these ecosystems play a particularly vital role in buffering monsoonal impacts, supporting artisanal fisheries, and stabilizing coastlines in densely populated coastal zones. Importantly, BCEs support the sustainability of SSFs, which are vital for food security and livelihoods in many coastal regions. SSFs provide employment and sustenance to millions of people worldwide, particularly in developing countries where fisheries constitute a primary source of nutrition and economic stability. The well-being of SSFs is intricately linked to the health of BCEs, as these ecosystems function as breeding and nursery grounds for numerous commercially and ecologically valuable fish and shellfish species (Unsworth et al., 2019). However, despite their significance, BCEs are increasingly threatened by anthropogenic activities such as deforestation, pollution, and hydrological alterations, as well as natural climatic disturbances (Alongi, 2008). The degradation of BCEs disrupts essential ES, particularly their role in regulating water quality and sustaining fisheries, thereby exacerbating social-ecological vulnerabilities in SSF communities.

Coastal wetlands, a critical subset of BCEs, function as natural water filters, trapping sediments, nutrients, and pollutants to ensure clean water availability for both aquatic life and human use. These wetlands significantly enhance the resilience of coastal communities by mitigating the impacts of extreme climatic events such as cyclones and floods. However, pollution from industrial effluents, agricultural runoff, untreated sewage, and plastic waste poses a serious

threat to these ecosystems, leading to habitat degradation, declining fish populations, and compromised food safety. For example, the Sundarbans mangrove forest, a vital fishery hub in Bangladesh, faces severe water pollution challenges that threaten ecological stability and the livelihoods of local fishers (Hoq, 2007; Datta et al., 2024). Similarly, the Chilika Lagoon in India, a globally significant brackish water lagoon, has experienced substantial fish stock declines due to deteriorating water quality, directly impacting the economic well-being of SSF communities.

Water quality is a fundamental determinant of coastal ecosystem health and fisheries sustainability. Key parameters such as nutrient levels, salinity, dissolved oxygen (DO) content, and the presence of pollutants directly influence fish health, growth, and reproductive success (Boyd, 2000; Islam & Tanaka 2004). In SSFs, which frequently operate under resource constraints, access to clean and stable aquatic environments is indispensable. However, the degradation of coastal wetlands has exacerbated water quality challenges, leading to declining fish populations and the subsequent economic instability of SSF communities. Polluted waters compromise the safety and quality of fish for both local consumption and international trade, posing health risks to fishers and consumers alike. Additionally, declining biodiversity in degraded wetlands weakens ecosystem resilience, making SSFs more vulnerable to external shocks such as extreme weather events and market fluctuations.

Governance failures, such as fragmented policy regimes, lack of regulatory enforcement, and exclusion of local voices, also play a critical role in accelerating ecosystem degradation. Poor waste management, aquaculture encroachment, and inadequate coordination among agencies contribute to water quality deterioration in wetlands like Chilika. The impacts of water pollution extend beyond ecological damage; they also have profound social-economic consequences. The vulnerability of SSF communities is heightened by their dependence on healthy coastal ecosystems for their livelihoods (Armitage et al., 2012; Weeratunge et al., 2014). When water quality deteriorates, fish mortality rates increase, catch yields decline, and market access becomes more challenging due to concerns over food safety. Furthermore, degraded BCEs lose their ability to buffer against climatic events, exposing SSF communities to heightened risks of extreme weather, erosion, and flooding. The degradation of water quality in BCEs results from a combination of natural and anthropogenic factors. Natural phenomena such as cyclones, floods, and droughts disrupt water flow, alter sediment balance, and impact the ecological dynamics of wetlands.

Anthropogenic activities, including industrial discharge, agricultural runoff, aquaculture waste, and plastic pollution, further exacerbate these challenges.

For instance, the Sundarbans mangrove forest has been heavily affected by industrial effluents and agricultural residues, leading to habitat loss and a decline in fish stocks (Alongi, 2002). Similarly, large-scale hydrological alterations such as dam construction and land reclamation disrupt natural water flow in coastal wetlands, diminishing their capacity to filter pollutants and maintain ecological balance (Kuenzer et al., 2011; Davidson, 2014). The resultant eutrophication, driven by excessive nutrient input, leads to oxygen depletion and harmful algal blooms, further compromising water quality and aquatic life. Addressing these challenges requires integrated water quality management strategies that balance ecological preservation with social-economic development.

Despite the critical role of water quality in BCEs and SSF sustainability, significant knowledge gaps persist. First, existing research often takes a fragmented approach, focusing on isolated aspects of water quality, BCEs, or SSF sustainability without adequately considering their interconnectedness. There is a need for comprehensive frameworks that integrate ecological, social, and economic dimensions to better understand how water quality influences SSFs. Second, robust and reliable data on water quality parameters or BCEs and their direct impacts on SSFs remain limited. Many studies rely on generalized assumptions or outdated data, restricting their applicability to specific social-ecological contexts. Comprehensive assessments of water pollution impact in BCEs among South-East Asian countries such as the Sundarbans and Chilika Lagoon are scarce, hindering the development of evidence-based policies and management strategies. Third, participatory approaches that involve SSF communities in water quality monitoring, ecological or biodiversity assessments, and governance are underutilized. Fishers possess invaluable local knowledge that can inform sustainable management practices and adaptive strategies. However, they are often excluded from decision-making processes, resulting in policies that fail to address their needs and priorities. Strengthening the inclusion of fishers and local stakeholders in governance frameworks is essential for enhancing the resilience of SSFs and promoting inclusive resource management.

SSF communities are particularly vulnerable to water quality degradation due to their reliance on coastal resources for sustenance and income. Vulnerability in this context is defined by three interconnected dimensions: exposure, sensitivity, and adaptive capacity (IPCC, 2007).

Exposure to polluted waters heightens the sensitivity of fish populations to diseases and habitat loss, resulting in lower fish yields and declining income for fishers. Sensitivity is further compounded by limited access to alternative livelihoods, financial resources, and markets, constraining the ability of SSF communities to adapt to environmental changes. Conversely, resilience depends on the ability of both ecological systems and human communities to absorb disturbances and adapt to evolving conditions. Healthy BCEs enhance resilience by providing critical ES such as water filtration, habitat provision, and climate regulation. However, when wetlands are degraded, their capacity to support SSFs diminishes, increasing the risk of poverty, food insecurity, and displacement among coastal populations.

Addressing the vulnerabilities of SSFs necessitates a concerted effort to protect and restore BCEs while strengthening water quality management. This requires adopting integrated approaches that acknowledge the interdependencies between ecological processes and social-economic systems. Participatory governance frameworks that involve fishers, policymakers, and scientists in decision-making processes can ensure that water quality management strategies are context-specific and effective. Investment in monitoring and research is also critical to fill existing data gaps and inform policy interventions. Advanced technologies such as RS and real-time water quality sensors can provide valuable insights into ecological changes, enabling timely responses to emerging threats. Furthermore, promoting sustainable practices such as eco-friendly aquaculture, pollution control measures, and habitat restoration can enhance the resilience of BCEs and the viability of SSF communities. The degradation of BCEs and declining water quality pose significant threats to the sustainability of SSFs. Addressing these challenges requires an integrated, participatory approach that bridges ecological, social, and economic dimensions. By examining the intricate linkages between BCEs, water quality, and SSFs, this research aims to contribute to the development of viable strategies that enhance the resilience of coastal communities and ensure sustainable fisheries management.

1.2 Research Purpose and Objectives

Coastal wetlands, as dynamic SES, play a critical role in sustaining biodiversity, mitigating climate change, and supporting human livelihoods. Among these, BCEs such as seagrass meadows and mangrove forests are particularly vital due to their contributions to carbon sequestration, water purification, sediment stabilization, and the provision of essential nursery habitats for marine biodiversity. However, these ecosystems are under increasing pressure from anthropogenic

activities, pollution, and climate-induced changes, leading to their degradation and the decline of essential ES. This study aims to investigate the intricate relationships between BCEs and water quality in Chilika Lagoon, India, and assess their combined impact on the sustainability of SSFs. Chilika Lagoon, as a dynamic and ecologically significant coastal wetland, is an ideal case study to examine the interdependencies between BCE health, water quality, and fisheries sustainability. By integrating ecological restoration strategies with social-economic resilience measures, this research seeks to bridge critical knowledge gaps in BCE management, water quality dynamics, and SSF vulnerability. Through an interdisciplinary and participatory research approach, this study will generate actionable insights to inform conservation and governance strategies that align ecological restoration with social-economic viability. The findings will contribute to the broader discourse on sustainable coastal wetland management by providing a model for integrating scientific research, community knowledge, and policy frameworks in BCE conservation.

The research is structured around four core objectives, each addressing specific dimensions of the interconnections between BCEs, water quality, and SSF sustainability. These objectives contribute to a holistic understanding of the social-ecological dynamics within Chilika Lagoon and provide a foundation for developing sustainable management strategies. Within this context, the following objectives guide my research:

Objective 1: To map and characterize the spatial distribution of BCEs, including seagrass meadows and mangrove forests, within Chilika Lagoon to understand their ecological significance and role in supporting fisheries. (Chapter II). This objective employs participatory mapping techniques that integrate community knowledge with scientific data, offering a comprehensive understanding of BCE distribution and their social-ecological value. By identifying areas of ecological importance and threats, the research informs conservation planning and enhances local engagement in resource management.

Objective 2: To examine key water quality parameters and assess their ecological impacts on BCEs and SSFs within Chilika Lagoon. (Chapter III) . Water quality is a fundamental determinant of ecosystem health and fisheries productivity. This objective evaluates parameters such as transparency, turbidity, and pH, along with eutrophication to identify primary drivers of water quality degradation. By integrating existing scientific data and physical observations with community-based observations, the research bridges data gaps and provides a holistic perspective on water quality challenges.

Objective 3: To analyze the social-ecological linkages between BCE degradation, water quality decline, and SSF vulnerability using the SEVVN framework. (Chapter IV). This objective investigates the feedback loops and stressors that exacerbate ecosystem degradation and social-economic vulnerabilities. The research explores how the loss of BCEs impacts fish stocks, fisher livelihoods, and adaptive capacity, thereby reinforcing social-economic fragility and resilience challenges in Chilika Lagoon.

Objective 4: To identify governance and management strategies that integrate BCE conservation, water quality improvement, and SSF sustainability to foster vulnerability-to-viability transitions. (Chapter IV). This objective focuses on developing co-management approaches, participatory decision-making processes, and policy recommendations that support ecosystem-based management. The research highlights the role of TEK in complementing scientific findings and enhancing conservation effectiveness, proposing governance mechanisms for long-term ecological and social-economic sustainability.

This research is significant in its interdisciplinary approach, integrating ecological and social-economic perspectives to address the sustainability challenges facing Chilika Lagoon. By linking BCEs, water quality, and SSFs, the study provides actionable insights for policymakers, conservationists, and community stakeholders seeking to enhance coastal wetland resilience. The findings will not only contribute to regional conservation efforts but also offer a replicable model for managing BCEs in other similar social-ecological settings worldwide. Through participatory research and governance recommendations, this study aims to foster a more inclusive and sustainable approach to coastal wetland conservation and fisheries management.

In this study, vulnerability’ is defined as the degree to which a socio-ecological system is susceptible to harm due to exposure, sensitivity, and limited adaptive capacity (IPCC, 2007; Turner et al., 2003). ‘Viability’, in contrast, refers to the capacity of these systems, particularly SSFs, to sustain ecological function and human well-being over time through resilience, adaptability, and equitable resource access (Nayak & Berkes, 2019). While ‘viability’ and ‘well-being’ may overlap, viability here emphasizes a long-term system-oriented sustainability that includes but extends beyond immediate well-being.

1.3 Motivation and Positionality

My journey toward understanding and addressing the intricate linkages between BCEs, water quality, and the social-ecological dimensions of SSFs has been shaped by a rich tapestry of

academic, professional, and personal experiences. Born and raised in Kerala, India, my academic foundation lies in civil engineering, where I developed a strong technical grounding. My initial exposure to environmental engineering during my master's degree fueled my passion for water resource management, wastewater treatment, and bioenergy generation. These projects allowed me to delve deeply into the scientific and engineering aspects of environmental systems. However, my technical training often overlooked the human and social dimensions of these challenges. My realization of this gap emerged during my first visit to Chilika Lagoon as part of a field school. This experience served as the driving force behind my work with my supervisor, Dr. Prateep Nayak, and mentor, Dr. Sisir Pradhan. This experience profoundly altered my perspective, introducing me to the social-ecological realities of rural fishing communities. Witnessing the interplay of ecological health and human livelihoods inspired me to pursue a second master's degree in Sustainability Management at the University of Waterloo. My research during this period focused on water quality as a lens to understand the vulnerability and viability of SSFs in Chilika Lagoon. Despite the intellectual excitement of adopting an interdisciplinary approach, the COVID-19 pandemic posed significant challenges. Accessibility issues prevented me from conducting fieldwork, and virtual methods failed to capture the depth of community dynamics. Nevertheless, these challenges reinforced my resolve to pursue a PhD that integrated my technical expertise with a deeper exploration of community-based studies.

Attending the Chilika field school annually since 2018, both as a participant and later in a managerial capacity, cemented my connection to the community and the lagoon. These visits were not just academic exercises but opportunities to build bonds with local people. My motivation stems from the recognition that Chilika Lagoon is more than an ecological wonder; it is a living SES where communities and ecosystems are deeply intertwined. Addressing the challenges faced by these communities and ecosystems became a personal mission, underpinned by my professional aspirations to bridge the gap between technical knowledge and social-cultural understanding. As a researcher, my positionality is shaped by my identity, background, and experiences. Born in Kerala, I initially believed my familiarity with India's cultural and social fabric would seamlessly translate to my work in Odisha. However, my initial days in Chilika Lagoon revealed the stark differences in language, food, living conditions, and community dynamics. My overconfidence gave way to a humbling realization of the diversity within India and the importance of approaching research with humility and openness. To critically reflect on how my background, relationships,

and disciplinary lens influence the quality and impact of my research, I developed a personalized reflexive positionality framework (Figure 1.1). This framework integrates six dimensions-identity, disciplinary boundaries, institutional position, community engagement, emotional reflexivity, and ethical responsibility-to guide an ongoing, reflective, and relational research practice.

The initial reconnaissance period was fraught with challenges. The language barrier, unfamiliar living conditions, and cultural nuances made me feel alienated despite my shared nationality. These struggles mirrored the stories my grandmother had recounted about her own upbringing in a rural setting, yet I found it difficult to connect those narratives to the realities of Chilika Lagoon. Frequent emotional outbursts and feelings of isolation during this period underscored the enormity of the task I had undertaken. Support from my family and mentor, Sisir, who has extensive experience working with communities in Odisha, along with his family was instrumental in helping me navigate these challenges. Sisir's guidance encouraged me to adopt a community-centric approach-to be a listener first and a researcher second. His advice to simplify my language, avoid jargon, and ensure that my questions were accessible and meaningful to the community marked a turning point in my research. Learning few words in Odia language and blending it with my Hindi (another Indian language) became a gateway to building trust and rapport with the community. My regular visits, participation in local festivals, and genuine efforts to integrate into their daily lives were reciprocated with warmth and openness. Over time, I transitioned from being an outsider to becoming a familiar presence in the community. This positionality-as both a researcher and an engaged participant-has enabled me to gain insights that transcend academic data, capturing the lived realities of the people who depend on Chilika Lagoon for their survival. My supervisor has often shared reflections on his own PhD work in Chilika, describing how, despite being from Odisha, he too had to navigate similar challenges in building trust and understanding the complexities of the lagoon's SES. His experiences reinforced my own realization that familiarity with a region does not automatically translate into acceptance within a community, emphasizing the importance of patience, humility, and genuine engagement in research.

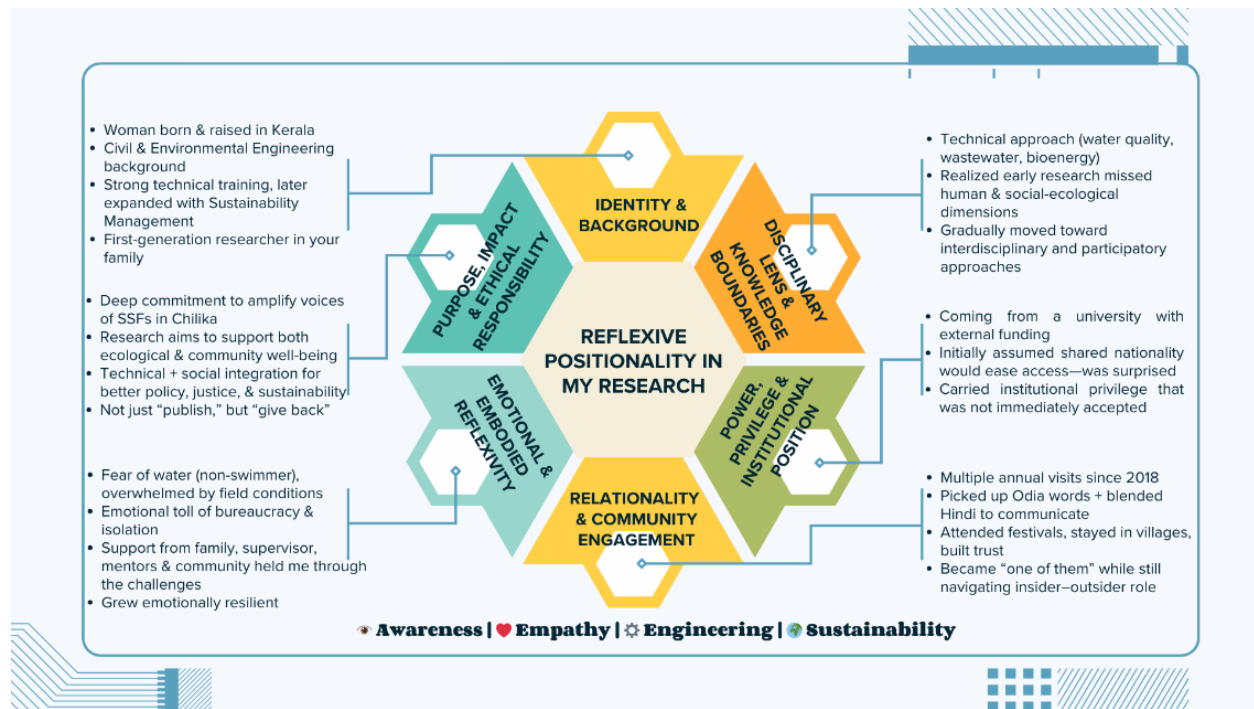


Figure 1.1 Reflexive positionality in my research

One of the most humbling aspects of my fieldwork was recognizing the immense resilience of the Chilika community. From crossing the lagoon on overcrowded boats without life jackets to forming connections with shopkeepers, children, women, and fishermen, every interaction enriched my understanding of their lives. I often felt overwhelmed by the logistical and emotional challenges of my research, particularly the difficulty in obtaining quantitative data and navigating bureaucratic hurdles in government offices. However, the support of my family and in-laws, my husband, my mentor along with his wife, and my supervisor, who was always available despite the time difference, along with the community’s openness and generosity, kept me motivated. Over time, the community began to see me not just as a researcher but as one of their own. My regular visits, genuine interest in their lives, and willingness to adapt to their way of life fostered a sense of belonging. This positionality, as both an insider and outsider, allowed me to navigate the complex social-cultural dynamics of the community while maintaining the objectivity required for my research.

The bond I have developed with the Chilika community has been a constant source of motivation for my research. The lived realities of SSFs, their dependence on BCEs, and the challenges they face due to water quality degradation and social-ecological-economic vulnerabilities have deeply influenced my research questions and objectives. My study aims to

amplify their voices and bring attention to the interconnected ecological and social dimensions of their struggles. This motivation is rooted in a personal commitment to bridge the gap between technical expertise and social understanding. As an engineer, I sought to address environmental challenges through quantitative methods and technical solutions. However, my experiences in Chilika have taught me the importance of integrating community knowledge, building trust, and adopting interdisciplinary approaches. This research is not just an academic pursuit but a personal journey to understand and contribute to the sustainability of SSFs in Chilika Lagoon. The visuals in Figure 1.2 are illustrated with personal field photographs from Chilika Lagoon. They reflect my evolving role as a reflexive researcher navigating technical expertise, empathy, and community engagement.

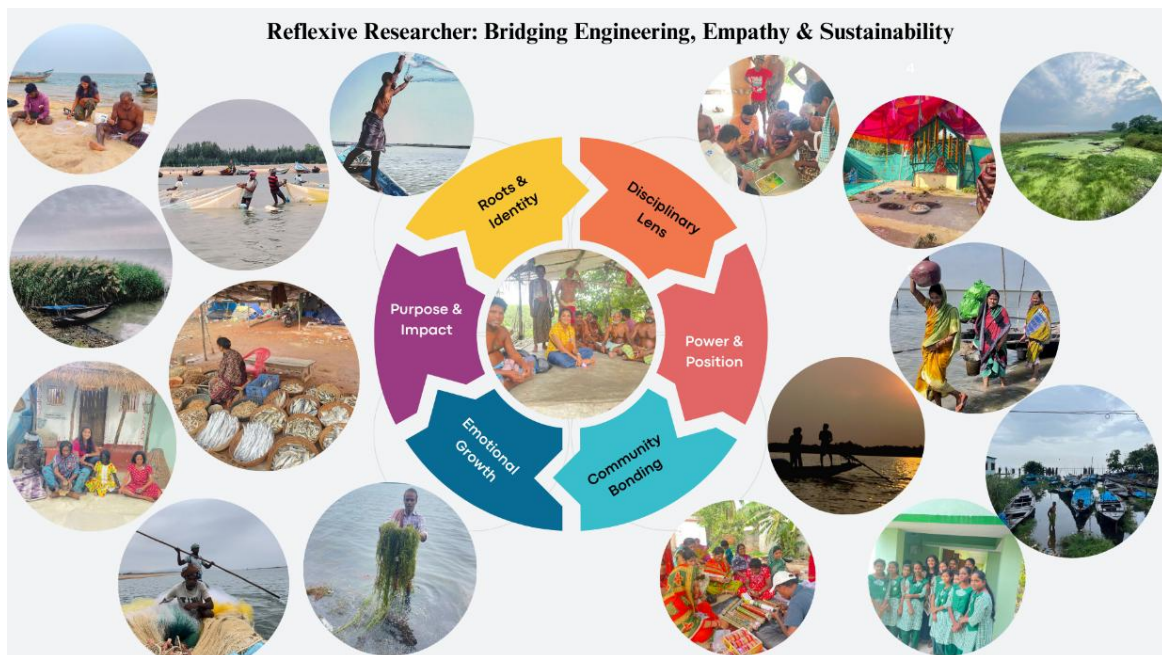


Figure 1.2 Reflexive positionality loop in my research journey

Reflecting on my positionality, I acknowledge the privilege and responsibility that comes with conducting research in a vulnerable community. The trust and openness of the Chilika community have been instrumental in shaping my research. I am committed to ensuring that this study not only contributes to academic knowledge but also supports the community's efforts to address their challenges and build resilience. As a researcher, I remain guided by the principles of humility, empathy, and reciprocity, striving to give back to the community that has taught me so much. One of the most transformative aspects of my positionality has been my evolving relationship with the Chilika Lagoon itself. As someone who cannot swim, crossing the lagoon

daily without a life jacket, packed in boats alongside locals and their goods, became a metaphor for my research journey. Each crossing reinforced my understanding of the lagoon not just as a research site but as a lifeline for the communities it supports.

Chilika Lagoon is a dynamic SES with stories waiting to be told. My positionality as an Indian-born researcher with technical training and an evolving understanding of social dynamics positions me uniquely to undertake this research. The bonds I have built with the community, coupled with my interdisciplinary perspective, enable me to approach the study of BCEs, water quality, and SSFs with both technical expertise and cultural sensitivity. This dual lens not only enriches my research but also honors the lived experiences of the people of Chilika Lagoon, ensuring that their voices are integral to the solutions proposed.

1.4 Theoretical Framework

The theoretical framework for this research integrates three critical themes: the disappearance of BCEs, water quality deterioration, and the vulnerability of SSFs. This framework is grounded in the SES perspective, emphasizing the interplay between ecological processes, hydrological dynamics, and the social-economic realities of SSF communities. By examining these interconnected themes, the research seeks to develop a holistic understanding of the drivers, impacts, and potential solutions to the challenges facing BCEs and SSFs. The figure 1.3 below provides a visual representation of these interconnected themes. It illustrates the relationships and feedback loops between BCEs, water quality, and SSFs, highlighting their interdependence and relevance to coastal wetland sustainability. The arrows represent dynamic feedback loops: BCEs influence water quality through processes like nutrient filtration, sediment stabilization, and carbon sequestration; water quality directly impacts the health of fish habitats and the productivity of SSFs; and SSFs, in turn, influence the health of BCEs through practices that can either degrade or sustain these ecosystems. The central intersection signifies the integrated SES where all three themes interact, creating opportunities and challenges for resilience and sustainability. This framework underscores the need for holistic, interdisciplinary approaches to address the complexities of coastal wetland management.

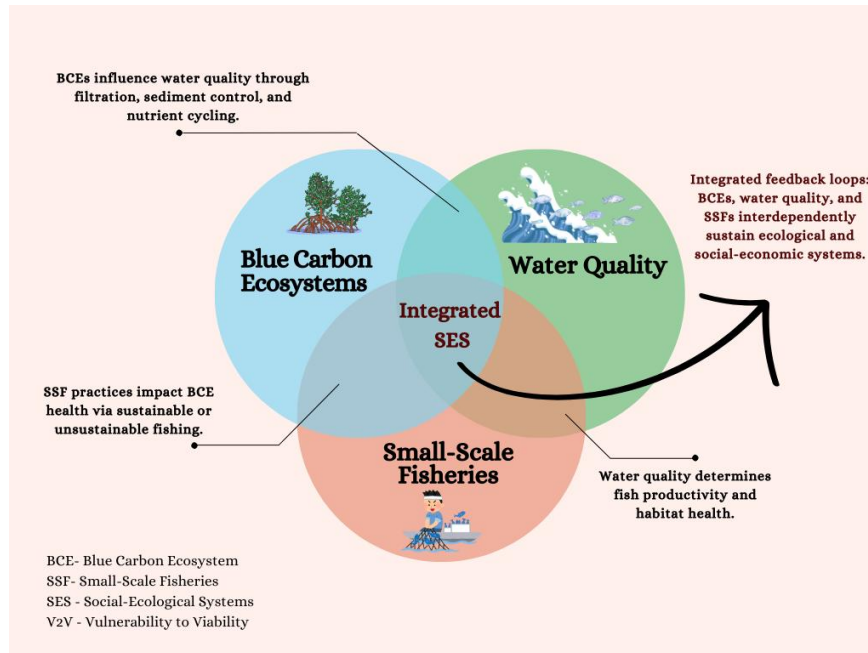


Figure 1.3 Theoretical Framework: Interrelationships between BCEs, Water Quality, and SSFs

1.4.1 Disappearance of Blue Carbon Ecosystems

BCEs, such as mangroves, seagrass meadows, and salt marshes, play an essential role in carbon sequestration, biodiversity conservation, and the provision of ES. However, these ecosystems are under severe threat due to human activities, including urbanization, aquaculture expansion, and land-use changes (Lovelock & Duarte, 2019). The loss of BCEs has profound ecological implications, including reduced carbon storage capacity, increased vulnerability to coastal erosion, and the destruction of habitats crucial for marine biodiversity (Dahdouh-Guebas et al., 2006; He et al., 2025).

Mangroves are well-documented contributors to SSFs, providing breeding and nursery grounds for economically significant fish species (Carrasquilla-Henao & Juanes, 2017). Similarly, seagrass meadows support SSFs by stabilizing sediments, improving water quality, and serving as nurseries for diverse marine species (Bujang et al., 2018; Jones et al., 2021). Despite these benefits, BCEs face degradation due to pollution, coastal development, and climate change. The Blue Carbon science highlights the critical need for interdisciplinary approaches to mitigate BCE loss and integrate their conservation into climate change adaptation and mitigation strategies (Lovelock & Duarte, 2019; Macreadie et al., 2019). The disappearance of BCEs disrupts the social-ecological balance, particularly in regions like Chilika Lagoon, where communities depend heavily on these ecosystems for their livelihoods. The complexity of BCE systems-intersecting with biophysical,

social, economic, and political factors-presents challenges in formulating effective conservation policies (Pendleton et al., 2012; Friess et al., 2016). Innovative, interdisciplinary research is essential to quantify and track changes in BCEs, understand their social-ecological impacts, and design equitable management strategies (Quiros et al., 2021; Duarte et al., 2022).

BCEs play a fundamental role in coastal resilience, biodiversity conservation, and carbon sequestration (Lovelock & Duarte, 2019). These ecosystems act as natural carbon sinks, trapping atmospheric carbon dioxide at rates significantly higher than terrestrial forests (Macreadie et al., 2021). Furthermore, they provide essential ES such as shoreline stabilization, nutrient filtration, and habitat provision for a wide array of marine organisms, including fish species vital for SSFs (McLeod et al., 2011). However, BCEs are increasingly under threat due to human activities, climate change, and poor governance frameworks (Alongi, 2015). The primary drivers of BCE disappearance include land-use changes, coastal development, aquaculture expansion, pollution, and climate change-induced sea-level rise (Duarte et al., 2005; Lovelock & Duarte, 2019; Duarte et al., 2022). Mangrove forests, for instance, have faced extensive deforestation due to agriculture, urban expansion, and shrimp farming, leading to the loss of critical nursery habitats for fish species (Richards & Friess, 2016). Similarly, seagrass meadows have declined due to sedimentation, eutrophication, and mechanical damage from fishing practices such as bottom trawling (Waycott et al., 2009). Climate change exacerbates these stressors by altering hydrological regimes, increasing the frequency of extreme weather events, and accelerating sea-level rise, which threatens the structural integrity of BCEs (Quiros et al., 2021; Alongi, 2023). For example, salt marshes are particularly vulnerable to increased tidal inundation and erosion, leading to their degradation and conversion into open waters (Kirwan & Megonigal, 2013). Such transformations disrupt the ecological balance of coastal systems and diminish their ability to support fisheries and mitigate climate impacts.

The disappearance of BCEs has profound ecological and social-economic consequences, particularly for SSFs. Mangroves, seagrass meadows, and salt marshes provide crucial breeding and feeding grounds for commercially important fish and shellfish species (Unsworth et al., 2019). Their degradation leads to declining fish stocks, reduced habitat complexity, and disruptions in trophic interactions, ultimately impacting fisheries productivity (Carrasquilla-Henao & Juanes, 2017). In addition to ecological losses, the decline of BCEs directly affects the livelihoods of coastal fishing communities, especially those dependent on SSFs. Chilika Lagoon, for instance,

has witnessed significant alterations in BCEs, leading to reduced fish catch and economic instability for local fishers (Nayak & Berkes, 2014). The loss of ES such as water filtration and erosion control further amplifies the vulnerabilities of these communities by increasing exposure to pollution and coastal hazards (Alongi, 2015). Moreover, the disappearance of BCEs contributes to the release of stored carbon back into the atmosphere, exacerbating climate change (Macreadie et al., 2014). This creates a negative feedback loop where climate change-induced stressors accelerate BCE loss, further weakening their ability to mitigate environmental disturbances. Addressing these challenges requires an integrated approach that incorporates conservation efforts, community-based management, and sustainable livelihood strategies.

Successful conservation strategies involve the establishment of marine protected areas (MPAs), restoration initiatives, and incentive-based approaches such as payments for ecosystem services (PES) (Herr & Landis, 2016). At the governance level, collaborative management approaches that incorporate TEK alongside scientific research have shown promise in sustaining BCEs (Himes-Cornell et al., 2018). For example, community-led mangrove restoration projects in Southeast Asia have demonstrated significant success in reversing habitat loss and improving fisheries yields (DasGupta & Shaw, 2013). However, these efforts require strong institutional support, financial investments, and stakeholder engagement to be effective in the long term. Governance issues compound the ecological threats to BCEs. Weak enforcement, conflicting land-use policies, and lack of interdepartmental coordination often result in habitat loss. Moreover, the absence of participatory management frameworks leaves SSF communities without agency, intensifying their vulnerability. This intersection of ecological degradation and institutional failure demands governance reforms that emphasize decentralization, equity, and cross-scale integration. In conclusion, the loss of BCEs poses a serious threat to coastal ecosystems and SSFs, requiring integrated strategies that combine ecological restoration, sustainable fisheries, and socio-economic resilience to ensure long-term sustainability and climate adaptation.

1.4.2 Water Quality Deterioration

Water quality is a fundamental determinant of ecosystem health and a critical factor influencing the viability of SSFs. Coastal wetlands, including lagoons, estuaries, and mangrove forests, serve as natural buffers that regulate water quality through nutrient cycling, sediment retention, and pollutant filtration (Perna, 2003; Day et al., 2024). However, human-induced pressures such as agricultural runoff, industrial waste discharge, aquaculture expansion, and

urbanization have led to significant water quality degradation, threatening biodiversity and fishery productivity (Hsieh et al., 2007; Breitburg et al., 2018). One of the primary drivers of water quality deterioration in coastal wetlands is eutrophication, caused by excessive nutrient inputs—primarily nitrogen and phosphorus—from agricultural and domestic sources (Anderson et al., 2002). These nutrients fuel the proliferation of harmful algal blooms (HABs), which deplete DO levels, disrupt aquatic food webs, and contribute to hypoxic or anoxic conditions that are lethal to fish and other marine organisms (Diaz & Rosenberg, 2008). Hypoxia, characterized by oxygen concentrations below 2 mg/L, has been linked to large-scale fish kills and severe declines in fish stocks, directly affecting the livelihoods of SSF communities (De Mutsert et al., 2016).

Water quality degradation also influences fish reproductive success, growth rates, and overall ecosystem stability. Poor water quality affects the physiological health of fish, leading to decreased reproductive success, increased susceptibility to diseases, and reduced growth rates (Steckbauer et al., 2011). Fluctuating DO levels and nutrient overloads will result in fish population declines, affecting the economic stability of SSFs. The degradation of fish habitats, including mangrove and seagrass meadows, further exacerbates these challenges by reducing the availability of nursery grounds for commercially important species (Jones et al., 2021). Increased turbidity, resulting from deforestation, sediment erosion, and unsustainable aquaculture, reduces light penetration in aquatic ecosystems, negatively impacting primary productivity and benthic habitats (Lunt & Smee, 2020; Lisdayanti et al., 2024). Furthermore, pollutants such as heavy metals, pesticides, and microplastics accumulate in fish tissues, posing serious health risks to human consumers and leading to economic losses in fisheries trade (Rochman et al., 2013). Contaminated or poor-quality fish from polluted waters face difficulties in accessing both local and global markets. Fisheries that fail to meet food safety standards due to pollution-driven declines in fish quality experience economic losses and increased vulnerability to external market shocks (Garzon et al., 2016). Additionally, bioaccumulation of toxins in fish tissues can lead to trade restrictions, affecting the livelihoods of SSF communities that rely on exports for income.

Polluted water sources not only affect fish populations but also pose serious health risks to SSF-dependent communities (Fleming et al., 2006; Garzon et al., 2016). Consumption of contaminated fish, exposure to toxic algal blooms, and reliance on polluted water for daily activities contribute to the public health burden in coastal regions (Fleming et al., 2006). The vulnerability of SSFs is compounded by limited access to healthcare and alternative livelihood

opportunities, making them highly susceptible to the social-economic impacts of water pollution. The loss of BCEs exacerbates water quality problems by reducing the capacity of wetlands to filter and regulate pollutants (Jackson et al., 2001; Greiner et al., 2013). Seagrass meadows, for example, play a crucial role in stabilizing sediments and mitigating nutrient overload, while mangroves act as biofilters, trapping contaminants and reducing coastal water pollution (Duarte, 2002; Duarte et al., 2013). However, widespread deforestation of mangroves for aquaculture and urban expansion has compromised these regulatory functions, leading to increased sedimentation, declining water quality, and heightened vulnerability of SSFs (Lovelock & Duarte, 2019).

Addressing water quality deterioration requires integrated management approaches that consider both ecological and social-economic dimensions. Community-based monitoring, sustainable aquaculture practices, and policy interventions aimed at reducing nutrient pollution are critical to safeguarding SSFs and maintaining the resilience of coastal ecosystems (Chuenpagdee & Jentoft, 2018). By linking water quality management to BCE conservation, this research highlights the need for interdisciplinary frameworks that address the root causes of ecosystem degradation while ensuring the sustainability of SSFs.

1.4.3 Vulnerability of Small-Scale Fisheries

SSFs are vital social-economic systems that contribute significantly to food security, livelihoods, and cultural identity in coastal communities, particularly in developing regions. Despite their importance, SSFs are highly vulnerable to a wide range of ecological and social-economic stressors, including environmental degradation, water quality deterioration, climate variability, and governance challenges (Allison et al., 2009; Johnson et al., 2018). These vulnerabilities are amplified in contexts where fishers lack access to social safety nets, institutional support, and alternative livelihood options. From a SES perspective, the vulnerability of SSFs is best understood as a function of three interrelated dimensions: exposure to external stressors, sensitivity to those stressors, and the capacity to adapt or respond effectively (IPCC, 2007). In the context of Chilika Lagoon and similar ecosystems, SSFs are exposed to both gradual environmental changes-such as declining water quality and habitat degradation-and sudden shocks, including cyclones and market disruptions. Their sensitivity is heightened by direct dependence on ES for income and sustenance, while adaptive capacity is constrained by poverty, marginalization, and lack of institutional recognition (Islam et al., 2021; Islam, & Chuenpagdee, 2022).

One of the most significant ecological factors contributing to SSF vulnerability is the degradation of BCEs. Mangroves, seagrass meadows, and salt marshes serve as critical habitats for fish spawning, nursery, and foraging. Their loss or degradation-often driven by pollution, overfishing, and coastal development-directly reduces fish abundance and diversity, undermining the ecological foundation of SSFs (Jones et al., 2021). Moreover, water quality deterioration, as discussed earlier, exacerbates habitat loss and reduces the resilience of fish populations, impacting fisher yields and income stability. Seasonal changes in salinity, sedimentation, and nutrient load further disrupt fish breeding cycles and migration patterns, creating unpredictability in catch composition and volume. These changes have been observed in various lagoon systems, including Chilika, where hydrological alterations and eutrophication have significantly altered ecological dynamics (Panigrahi et al., 2007; Nayak & Berkes, 2014).

Social-economic vulnerability among SSFs is deeply intertwined with broader issues of inequality, access to resources, and governance. Many SSF communities operate in informal or unregulated environments, lacking legal recognition of their fishing rights and facing competition from industrial and commercial fisheries. This marginalization often results in limited bargaining power, exclusion from decision-making processes, and reduced access to markets and infrastructure (Jentoft & Eide, 2011). Income instability is a persistent concern for SSF households, many of which rely on daily catches for their basic needs. Seasonal variability, overfishing, and climate-induced shifts further complicate planning and income predictability. Additionally, women and youth within SSF communities often face distinct forms of vulnerability due to gendered labour divisions, restricted mobility, and limited access to capital and training (Weeratunge et al., 2010). Migration, both seasonal and permanent, is increasingly adopted as a coping strategy, although it carries its own risks (Coulthard, 2008; Bennett & Dearden, 2014). Fishers who migrate to urban areas in search of alternative employment often encounter precarious working conditions and social dislocation, which may further deepen vulnerability at both individual and community levels (Béné, 2009).

Institutional and governance structures play a critical role in shaping the vulnerability and viability of SSFs. Top-down regulatory approaches often fail to recognize the local knowledge and customary practices of SSF communities, resulting in policies that are misaligned with ground realities. In contrast, participatory and co-management approaches have shown promise in enhancing community engagement, improving compliance, and fostering adaptive capacity

(Chuenpagdee & Jentoft, 2018). Vulnerability to Viability (V2V), a novel conceptual framework, provides a valuable lens for understanding how resilience can be built in SSF systems (Nayak and Berkes 2019; Dias et al., 2023). It emphasizes the need to consider diverse forms of capital-natural, social, financial, human, and cultural-as integral to enhancing well-being and adaptive capacity (Pollnac & Poggie, 2008). Strengthening access to education, healthcare, market infrastructure, and inclusive governance mechanisms are essential strategies for transitioning SSF communities from vulnerability to viability. The vulnerability of SSFs is shaped by the interplay of ecological degradation, social-economic marginalization, and institutional shortcomings. Addressing this vulnerability requires an integrated approach that acknowledges the social-ecological complexity of SSFs, promotes participatory governance, and invests in community resilience. In the context of coastal wetlands like Chilika Lagoon, protecting BCEs and improving water quality must be coupled with social-economic empowerment and inclusive policy frameworks. This research, grounded in the SES and V2V perspectives, aims to provide actionable insights for enhancing the sustainability and viability of SSFs in dynamic coastal environments.

The research emphasizes the need for interdisciplinary studies that combine ecological, social, and economic perspectives. For instance, understanding the spatial distribution of BCEs and their role in supporting fisheries can inform targeted conservation efforts (Zhong et al., 2023). Similarly, investigating the drivers of water quality changes and their impacts on fish populations can guide the development of sustainable management practices (Mashiatullah et al., 2009). The theoretical framework provides a comprehensive foundation for investigating the linkages between BCEs, water quality, and SSFs in coastal wetlands. By synthesizing insights from ecological, hydrological, and social-economic perspectives, the framework highlights the interconnected challenges and opportunities in managing these systems. Key strategies include enhancing community participation, promoting co-management approaches, and leveraging TEK to complement scientific insights (Chuenpagdee & Jentoft, 2018). The research aims to generate actionable knowledge that informs policy and practice, supports the resilience of SSF communities, and contributes to the sustainable management of coastal ecosystems.

1.5 Conceptual Framework: The Social-Ecological Vulnerability and Viability Nexus (SEVVN)

The SEVVN framework (Figure 1.4) developed for this research offers a robust conceptual foundation for examining the interlinked ecological and social dynamics that define the

sustainability of SSFs in coastal wetland systems such as the Chilika Lagoon. This framework is grounded in the foundational vulnerability analysis proposed by Turner et al. (2003), which emphasizes the importance of understanding how human and environmental systems are exposed to stressors, how sensitive they are to these stressors, and how they can adapt. Building on this, SEVVN integrates insights from Marshall et al. (2010) on adaptive capacity and resilience, aiming not only to assess vulnerability but also to explore viable pathways for sustainable transitions. The SEVVN framework conceptualizes SES as composed of two interlinked sub-systems: the ecological sub-system and the social sub-system. These sub-systems are characterized by their own internal attributes - exposure, sensitivity, and adaptive capacity, which interact dynamically. Importantly, the SEVVN framework does not treat these components in isolation but considers their recursive feedback loops that contribute to either system resilience or further degradation.

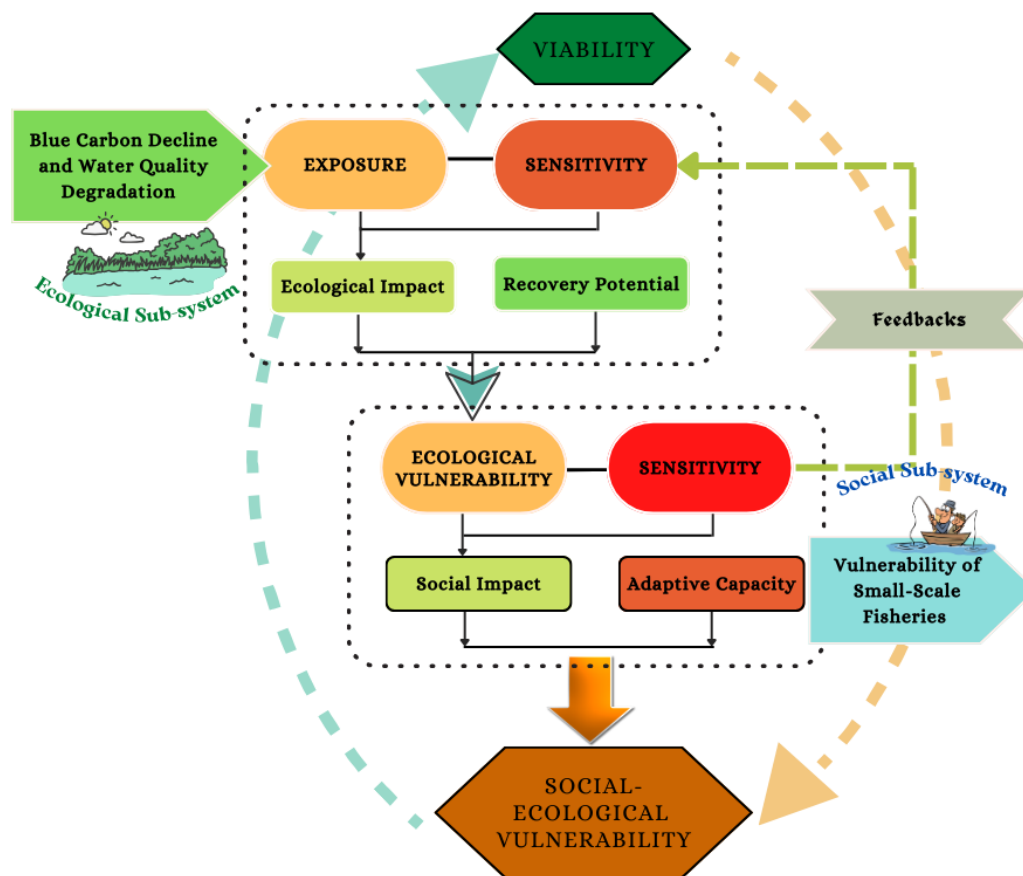


Figure 1.4 Conceptual framework illustrating SEVVN

The conceptual framework illustrates the interlinked ecological and social processes that shape the vulnerability and viability of SSFs in coastal wetland systems. The framework highlights

how ecological vulnerability cascades into social vulnerability, and how integrated, community-driven responses can foster transitions toward social-ecological viability.

1.5.1 Ecological Sub-system

The ecological sub-system of SEVVN focuses on stressors such as BCE degradation and water quality decline. These stressors contribute to increased exposure in ecosystems through nutrient loading, hypoxia, sedimentation, and pollution. For instance, seagrass meadows and mangrove forests in Chilika Lagoon face threats from eutrophication, aquaculture expansion, and hydrological changes. The sensitivity of the ecological sub-system is defined by its biodiversity, habitat integrity, and ecological functions, which influence how strongly the system responds to environmental stressors (Turner et al., 2003; Smit & Wandel, 2006). Highly sensitive ecosystems are more likely to suffer irreversible changes when exposed to stressors. When exposure and sensitivity are high, the system experiences ecological vulnerability. A notable example is the collapse of coral reef ecosystems in parts of the Great Barrier Reef, Australia, where increased sea surface temperatures and pollution, combined with high ecological sensitivity, have led to significant biodiversity loss and degradation of ecosystem functions (Hughes et al., 2017). This manifests in reduced ES, such as diminished carbon sequestration, weakened nutrient cycling, and loss of fish habitats.

The extent to which the ecosystem can recover-referred to as its recovery potential-determines whether ecological vulnerability will transition into a state of collapse or gradually move toward resilience. Recovery potential is influenced by factors such as restoration interventions, protected area management, and the natural regenerative capacity of BCEs (Iftekhhar, M. S., & Takama, 2008). In ecological systems, recovery potential depends on species diversity, habitat connectivity, and ecological redundancy (Folke et al., 2003), while in social systems, it is shaped by institutional flexibility, social learning, and the presence of adaptive governance mechanisms (Walker et al., 2004). In the Sundarbans region of Bangladesh, for example, community-based mangrove restoration initiatives have shown significant potential for ecological recovery when integrated with participatory conservation strategies. These efforts, supported by local non-governmental organizations (NGOs) and co-management institutions, have contributed to increased vegetation cover, improved habitat conditions, and enhanced coastal resilience (Iftekhhar & Takama, 2008).

1.5.2 Social Sub-system

The social sub-system within SEVVN examines the vulnerabilities of SSF communities who are directly impacted by ecological changes. The exposure of these communities results from external pressures such as declining fish stocks, degraded habitats, and reduced access to clean water. These ecological stressors are compounded by social-economic stressors, including market fluctuations, climate variability, and regulatory changes. Sensitivity in the social sub-system is determined by the degree of dependency on fisheries for livelihoods and food security, the availability of social safety nets, and levels of poverty and inequality. For instance, in Chilika Lagoon, many fisher households are engaged in daily subsistence fishing and have limited livelihood alternatives, making them particularly sensitive to ecological changes. Additionally, gender, age, and caste dynamics influence the distribution of sensitivity within communities, with women and youth often bearing disproportionate impacts.

Adaptive capacity refers to the ability of SSF communities to respond to and recover from ecological and social-economic changes. It includes access to education, healthcare, technology, financial resources, and institutional support. Communities with low adaptive capacity are less able to cope with shocks and more likely to experience long-term vulnerability. For instance, in the coastal regions of Mozambique, artisanal fishing communities faced significant social-economic setbacks in the aftermath of Cyclone Idai in 2019. Due to limited access to financial capital, infrastructure, and institutional support, these communities struggled to recover, highlighting the consequences of constrained adaptive capacity (Eriksen et al., 2015; Tschakert & Dietrich, 2010). Adaptive capacity, as defined by the IPCC (2007), refers to the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. Factors influencing adaptive capacity include access to assets, institutional frameworks, knowledge and information, innovation, and equitable governance structures (Smit & Wandel, 2006). SEVVN recognizes that adaptive capacity is not static and can be enhanced through targeted interventions such as skill development, community empowerment, and participatory governance.

1.5.3 Feedback Loops, System Interactions, and Pathways to Viability

One of the core strengths of the SEVVN framework is its emphasis on feedback mechanisms that connect ecological and social sub-systems. For example, overfishing due to declining fish availability can further degrade ecosystems, leading to a vicious cycle of reduced

productivity and increased poverty. Conversely, positive feedback can emerge when community-led conservation enhances ecosystem health, which in turn supports more sustainable livelihoods. These feedback underscores the importance of considering SES holistically, as interventions in one part of the system invariably affect others. Beyond diagnosing vulnerability, SEVVN is oriented toward identifying viable pathways that transition SSFs from fragility to resilience. These pathways include enhancing social-ecological resilience through ecosystem restoration, promoting diversified livelihoods, increasing community participation in governance, and integrating TEK with scientific approaches. The framework supports collaborative management practices and emphasizes the need for enabling policy environments that prioritize equity and inclusivity. In the context of Chilika Lagoon, SEVVN serves as both an analytical and action-oriented tool. It enables the identification of stressors and feedback that shape social-ecological vulnerability while also guiding the formulation of resilience-building strategies. These may include capacity-building programs for fishers, ecosystem-based management practices, improved access to markets and infrastructure, and strengthened institutional linkages.

The SEVVN framework provides a comprehensive conceptual scaffold for this doctoral research, linking ecological degradation and water quality decline to the social-economic vulnerabilities of SSF communities. By integrating exposure, sensitivity, and adaptive capacity across ecological and social domains, SEVVN offers a systems-based approach to understanding vulnerability and viability. Its emphasis on feedback loops and participatory resilience strategies makes it particularly suited to dynamic and complex systems like Chilika Lagoon. As such, SEVVN informs both the theoretical underpinnings and practical recommendations of this study, with implications for sustainable coastal wetland governance and SSF empowerment more broadly.

1.6 Empirical Context

The study is situated within the SES of the Chilika Lagoon, the largest brackish water lagoon in Asia, located along the eastern coast of India in Odisha (Figure 1.5). Chilika's ecological richness, social-economic significance, and deep cultural ties make it a paradigmatic site to explore the interlinkages between BCEs, water quality, and the viability of SSFs. Its dynamic interface between freshwater and marine ecosystems, shaped by seasonal hydrological cycles and human interactions, presents a rich empirical setting to examine the ecological and social-economic feedback that defines coastal wetland resilience in South Asia.

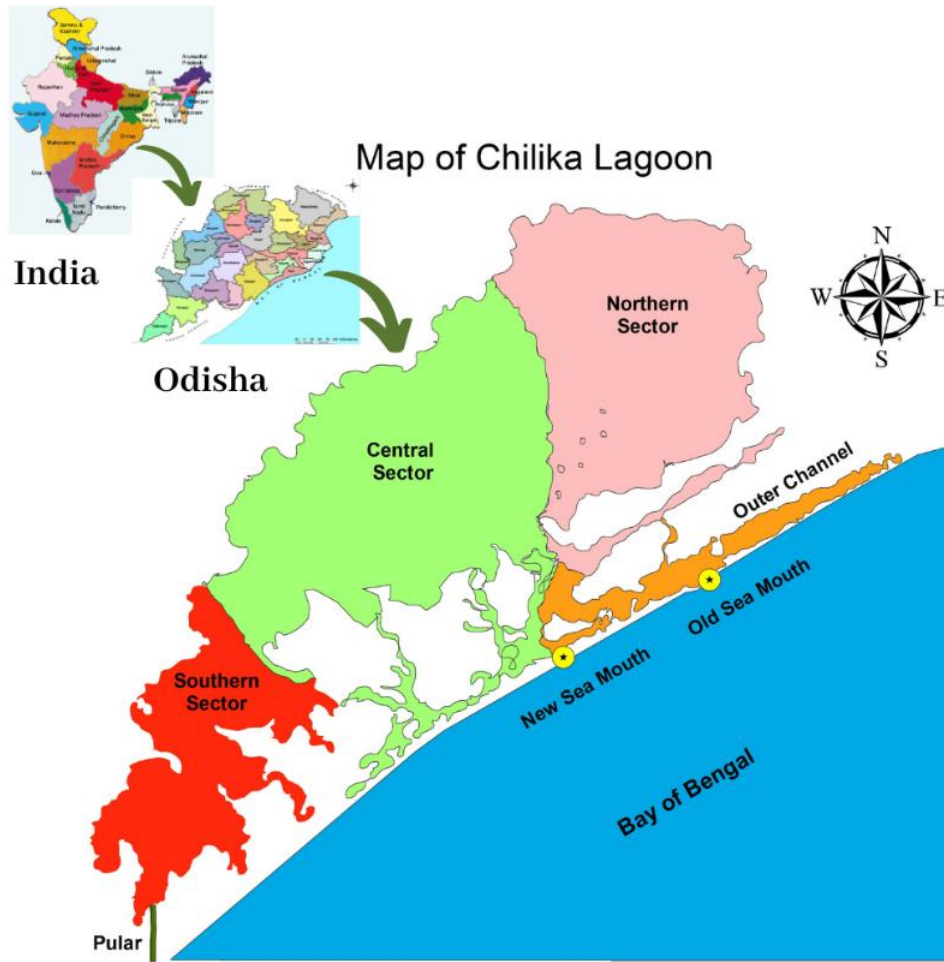


Figure 1.5 Study Area: Chilika Lagoon, India (Source: Created by the author, 2025)

1.6.1 Overview of Chilika Lagoon: Geographical and Ecological Significance

Chilika Lagoon spans approximately 1,100 km² and stretches across the districts of Puri, Khurda, and Ganjam. The lagoon connects to the Bay of Bengal through a narrow tidal outer channel. This inlet was realigned in 2000 by the Chilika Development Authority (CDA) to restore saline exchange and address ecological degradation. The lagoon was designated a Ramsar Site in 1981, later placed on the Montreux Record due to deteriorating ecological health and removed in 2002 following major restoration successes (Kumar et al., 2020b). Chilika sustains over 160 fish species, 225 bird species, and several key BCEs including extensive seagrass meadows, salt marshes, and patches of mangroves (Kumar & Pattnaik, 2012). Palynostratigraphic studies have indicated the past presence of mangroves such as *Rhizophora*, *Avicennia*, and *Bruguiera*, though today only a few mangrove associates like *Aegiceras corniculatum* survive, primarily due to

siltation, land-use change, and salinity shifts (Gupta & Khandelwal, 1992; Kumar & Pattnaik, 2012). Chilika is characterized by several distinct landform units, including spits and tidal inlets, lagoon fringe areas, a wide and elongated lagoon water body, distributary fan lobes of the Daya and Bhargavi Rivers originating from the Mahanadi delta, and an open marine shelf adjacent to the spits (Paul et al., 2014).

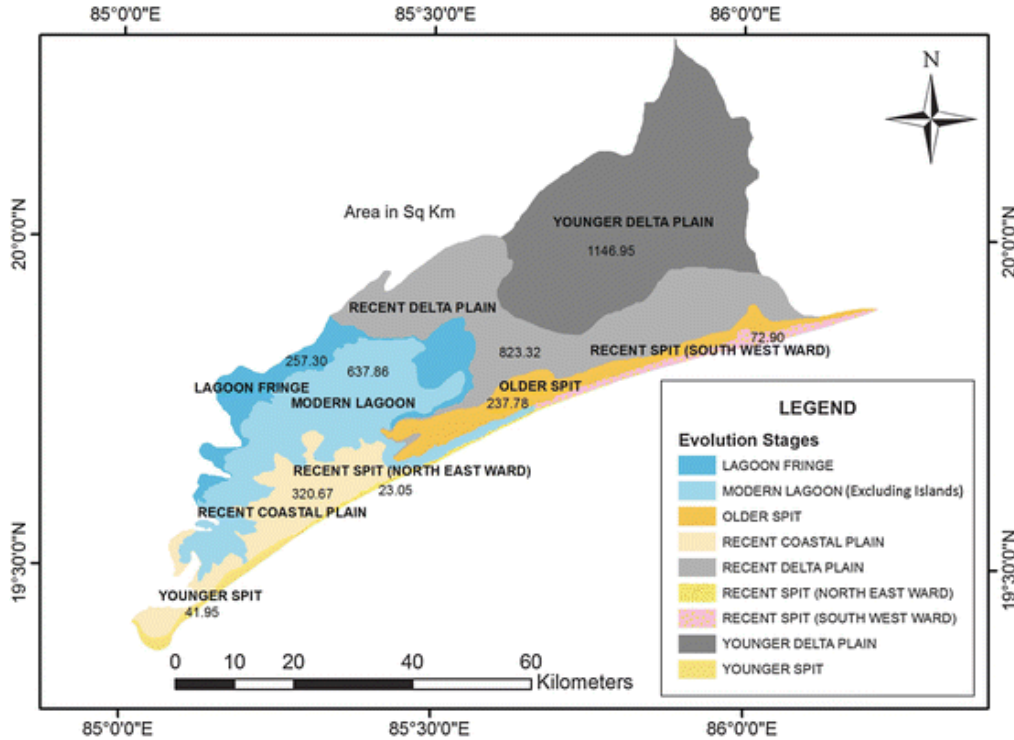


Figure 1.6 Geomorphic classification of Chilika Lagoon and its surrounding fringe areas (Paul et al., 2014)

1.6.2 Ecological Sub-Divisions: Sectoral Diversity and Social-Ecological Interactions

Administratively and ecologically, Chilika is divided into four sectors: Northern, Central, Southern, and Outer Channel. Each sector exhibits distinctive hydro-ecological attributes and plays a unique role in ecosystem dynamics and community livelihoods. Figure 1.6 shows geomorphic and ecological evolution zones of Chilika Lagoon, indicating the spatial extent and development stages of various landforms such as the modern lagoon, spits, delta plains, and fringe zones. These features influence sectoral ecological characteristics and biodiversity patterns. Table 1.1 outlines each sector's environmental features, social-economic contributions, and key challenges impacting biodiversity, fisheries, and water quality (Adapted from Kumar & Pattnaik, 2012; Pattnaik et al., 2020; Tripathy et al., 2021).

- a) **Northern Sector:** This predominantly freshwater zone is heavily influenced by the inflow of the Daya, Bhargavi, and Luna rivers. It is marked by extensive agriculture, nutrient-rich sediments, and freshwater macrophytes such as *Vallisneria natans* and *Hydrilla verticillata*. This sector experiences high eutrophication, weed proliferation (e.g., *eichhornia Crassipes*), and sedimentation, limiting the lagoon's connectivity to marine influences (Ghosh & Pattnaik, 2005; Tripathy et al., 2021).
- b) **Central Sector:** Regarded as the ecological heart of Chilika, the central sector is a transitional zone with brackish water influenced by both freshwater and saline tides. It supports high fish diversity, migratory birds, and macrophytes such as *Potamogeton pectinatus*. Nalabana Island and Krushna Prasad Island lie in this zone, known for their seagrass beds and bird sanctuaries. The sector has suffered from shrimp farm encroachment and degradation of floral diversity due to anthropogenic pressures (Kumar & Pattnaik, 2012; Kumar et al., 2020a; Pattnaik et al., 2020).

Table 1.1 Sector-wise overview of Chilika Lagoon

Sector	Hydrological Conditions	Ecological Characteristics	Social-economic Importance	Key Environmental Concerns
Northern Sector	Freshwater-dominated; river inflows	Wetland vegetation, nutrient-rich zones	Supports agriculture and inland SSFs; high community dependence	Siltation, wee infestation, eutrophication, nutrient loading, waste and wastewater from fish market, microplastics
Central Sector	Brackish - mix of fresh and saline water	Rich seagrass beds, high fish diversity, migratory bird habitat, presence of Nalabana Island	Core area for SSFs; highly productive ecosystem	Pollution, habitat disturbance, poor floral diversity and water transparency, aquaculture pressure, tourism waste
Southern Sector	Saline influence; tidal exchange	Productive fish breeding grounds, dense seagrass coverage, better floral diversity	Expanding aquaculture; traditional fishing	Overfishing, salinity fluctuation, poor species diversity, aquaculture pressure, dense human settlement, plastic pollution

Outer Channel	High saline exchange; coastal inlet	Tidal flushing zone, critical for water circulation	Navigation, access to sea; fisheries migration pathway	Erosion, coastal development, hydrological alteration, artificial sea mouth, illegal shrimp aquaculture, tourism waste, plastic pollution
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- c) **Southern Sector:** Located near the Rushikulya estuary, this sector experiences moderate salinity (7.29–13.2 ppt) and stable transparency (Barik et al., 2017). It supports dense seagrass meadows and acts as a nursery for shrimp and crab species. Salt-tolerant species thrive here due to saline intrusion through the Palur canal. The southern sector is also a hub for tourism and active fishing (Behera et al., 2017; Tripathy et al., 2021).
- d) **Outer Channel:** This narrow saline corridor links Chilika with the Bay of Bengal and plays a crucial role in tidal flushing and nutrient exchange. It supports seagrass beds dominated by *Halophila beccarii* and *Halodule pinifolia* (Tripathy et al., 2021). Mangrove plantations initiated in 2005 in this sector have shown luxuriant growth. However, the area is also exposed to coastal erosion, storm surges, and habitat loss (Kumar & Pattnaik, 2012; Pattnaik et al., 2020).

1.6.3 Blue Carbon Ecosystems in Chilika

Seagrass meadows are the most prominent BCEs in Chilika, covering approximately 85.47 km² (Geevarghese et al., 2018). Dominant species include *Halophila ovalis* and *Halodule uninervis*. Seasonal shifts in temperature, salinity, and turbidity influence their biomass and productivity. During dry seasons, seagrass biomass reached 6.10 Mg/ha, while wet seasons saw reductions due to turbidity and reduced light penetration (Ganguly et al., 2018; Kumar et al., 2020b). The blue carbon stock of Chilika's seagrass beds is estimated at 2.018 ± 0.673 MgC/ha (Kaladharan et al., 2021). The lagoon also supports rare and threatened species like *Cassipourea ceylanica* and *Capparis roxburghii* in uninhabited island habitats, necessitating in situ conservation. While mangrove associates like *Excoecaria agallocha* and *Pongamia pinnata* have been recorded, full mangrove regeneration has been limited except in managed plots in the Outer Channel (Kumar & Pattnaik, 2012; Pattnaik et al., 2020).

1.6.4 Environmental and Social-Economic Pressures

Chilika Lagoon faces escalating environmental and social-economic pressures that threaten both its ecological resilience and the well-being of SSFs. These pressures are compounded by water quality degradation, plastic pollution, habitat destruction, and social-political marginalization.

- a) ***Water Quality Concerns:*** Water quality is central to the health of BCEs and the sustainability of SSFs in Chilika. Seasonal fluctuations in parameters such as temperature, turbidity, salinity, and DO significantly influence fish productivity, seagrass health, and aquatic biodiversity (Ganguly et al., 2018). During the dry season, Chilika experiences elevated temperatures (30.1°C), higher salinity (22.4 PSU), and reduced particulate matter. In contrast, the wet season is marked by lower salinity (5.57 PSU), reduced temperature (27.4°C), and increased suspended particulate matter due to riverine discharge (Ganguly et al., 2018; Muduli & Pattnaik, 2020). These seasonal shifts directly affect water column productivity and the viability of seagrass meadows. For instance, reduced light penetration and nutrient overloading during the wet season can lower photosynthetic activity and damage seagrass beds, leading to cascading ecological effects on nursery habitats for fish and crustaceans (Tripathy et al., 2021). Despite its ecological relevance, Chilika lacks a comprehensive and consistent monitoring framework linking water quality parameters to ecological outcomes and livelihood implications.
- b) ***Plastic Pollution and Habitat Degradation:*** Plastic pollution has emerged as a severe threat to Chilika's water quality and ecological balance (Singh et al., 2023). Microplastic concentrations are notably higher during the dry season, especially in sediment samples from the southern and central sectors, reaching up to 245 particles per kilogram around Nalabana Island (Dhineka et al., 2025). These pollutants pose risks to benthic organisms, disrupt feeding behaviors of fish, and contaminate aquatic food webs. Macroplastic debris—such as bottles, packaging materials, and fishing gears such as nets—is commonly observed, especially in tourist-heavy areas like Balugaon and Satapada (Mengo et al., 2025). The entanglement of Olive Ridley turtles in plastic waste and ghost nets exemplifies the broader ecological impacts (Singh et al., 2013). Poor waste management infrastructure in surrounding villages contributes to the unregulated dumping of plastic, highlighting governance and community engagement deficits (Singh et al., 2013; Singh et al., 2023).

c) ***Social-Economic Vulnerability of SSFs***: Chilika supports around 200,000 SSFs, many of whom belong to traditional, economically vulnerable communities. Fishing techniques include cast netting, stake nets, gill nets, and fish cages, often passed down through generations. These SSFs are not only an economic mainstay but also represent intricate knowledge systems rooted in ecological stewardship (Nayak & Berkes, 2014). However, SSF livelihoods are increasingly jeopardized by multiple stressors: pollution, siltation, aquaculture encroachment, overfishing, and hydrological interventions such as sea mouth dredging. The shift to commercial aquaculture has displaced many traditional fishers, resulting in growing income inequality and social tensions (Nayak, 2017). Water quality deterioration further exacerbates this vulnerability. Declining DO levels, eutrophication, and increased turbidity reduce fish stock availability and degrade breeding grounds, directly affecting fishers' incomes and food security (Srichandan et al., 2015; Tripathy et al., 2021). Moreover, TEK is eroding as younger generations migrate or abandon fishing due to declining viability. Community engagement in conservation efforts remains limited, with minimal participation in post-restoration monitoring and ecosystem awareness initiatives. ES such as carbon sequestration by seagrass and the protective role of mangroves are often overlooked, further weakening the sustainability of conservation interventions. Notably, while the opening of a new sea mouth in 2000 improved salinity regulation and enhanced shrimp and crab catches, it also intensified social-economic disparities, disproportionately marginalizing SSF communities (Nayak, 2017). As reported by Kumar et al., 2020b, efforts at community-based mangrove restoration in abandoned prawn farms in the Outer Channel have demonstrated ecological success. However, local fishers perceive these initiatives as a threat due to barnacle infestations affecting their fishing gear and practices.

These ongoing social-ecological challenges underscore the urgent need for integrated water quality management, plastic pollution control, restoration of BCES, and participatory governance to ensure the long-term sustainability of Chilika's SES.

1.6.5 Why Chilika as a Case Study?

The selection of Chilika Lagoon as the empirical setting for this doctoral research is driven by its ecological uniqueness, social-economic importance, and policy relevance at both regional

and global scales. It provides a distinctive natural laboratory for examining the nexus between BCEs, water quality, and SSFs within a dynamic SES.

- a) ***Ecological Diversity and Richness of BCEs:*** Chilika is home to a mosaic of ecosystems, including expansive seagrass meadows, salt marshes, mangrove associates, and estuarine habitats that interact through seasonal and spatial hydrological processes. The presence of both tropical and subtropical flora and fauna makes it an ideal site for studying coastal wetland biodiversity and ecological functionality (Tripathy et al., 2021). Figure 1.7 visually depicts the spatial distribution of freshwater, brackish, and saline zones across the four sectors, along with land-use patterns including cropland, fish ponds, and human settlements. The sectoral distribution and land-use patterns of Chilika Lagoon showing freshwater (Northern sector), brackish water (Central sector), moderately saline (Southern sector), and saline zones (Outer Channel). The map also highlights rivers, settlements, cropland, plantations, and marshland, reflecting the interaction of ecological and human systems. The lagoon exhibits substantial variability in salinity gradients and sediment regimes across its sectors, creating diverse ecological niches (Pattnaik et al., 2020). However, despite its biodiversity, there is a significant gap in updated, geospatially accurate, and longitudinal data on BCEs, particularly mangroves and seagrass ecosystems. For instance, while six seagrass species have been identified (*Halophila ovalis*, *Halodule uninervis*, *Halophila beccarii*, etc.), systematic mapping of seagrass cover is lacking (Geevarghese et al., 2018). Similarly, mangrove records from past palynostratigraphic studies suggest historical diversity that is now poorly represented in current vegetation, and updated community-level inventories are missing (Gupta & Khandelwal, 1992).



Figure 1.7 Illustration of Chilika Lagoon and its basin area, depicting various land use and land cover types. Adapted from HEAL Earth (Adhya et al., 2024)

- b) ***Hydrological Complexity and Water Quality Dynamics:*** Chilika's hydrology is characterized by the inflow of multiple rivers and monsoonal discharge, counterbalanced by tidal ingress from the Bay of Bengal. These interactions cause substantial seasonal shifts in water quality parameters-such as turbidity, salinity, DO, and nutrient loads-which directly influence fish health and ecosystem processes (Ganguly et al., 2018; Srichandan et al., 2015). Despite a few studies, comprehensive water quality assessments linking BCE health and SSF productivity remain limited. Most government monitoring is episodic and lacks integration with ecological indicators or fisher knowledge. For instance, the influence of microplastics on benthic habitats and trophic chains is underexplored, though recent studies have revealed high sediment contamination in all sectors, especially during dry seasons (Dhineka et al., 2025).
- c) ***Social-Economic Significance and Vulnerability of SSFs:*** Approximately 200,000 fishers in Chilika depend on the lagoon's resources for their livelihoods. Fishing practices

are diverse and deeply rooted in cultural and TK systems (Nayak & Berkes, 2014). The lagoon serves as a social-economic lifeline for multiple marginalized communities. However, SSFs in Chilika face rising vulnerability from environmental degradation, declining fish stocks, resource-use conflicts, and social-political exclusion. The shift towards intensive aquaculture has disrupted traditional access rights and eroded local governance systems. Additionally, there is growing concern about the degradation of intangible cultural heritage and TEK as younger generations disengage from customary practices. Community awareness and participation in conservation activities, including post-intervention monitoring (e.g., after mangrove plantations or inlet opening), are notably weak. Local communities are rarely involved in long-term ecosystem monitoring, BCE protection, or plastic waste management, despite being key stakeholders. This disconnection limits the sustainability and inclusiveness of conservation interventions.

- d) ***Institutional and Governance Interventions:*** Chilika has been a site of large-scale ecological restoration, most notably through the re-opening of the sea mouth in 2000 by the CDA. This intervention improved hydrological flow, salinity regulation, and biodiversity, showcasing a successful example of adaptive ecosystem management (Kumar et al., 2020b). However, follow-up studies examining how these changes affected community dynamics, BCE regeneration, and SSF viability remain fragmented. Existing policy mechanisms, though well-intentioned, often operate in silos without a cohesive framework integrating social and ecological feedback (Nayak, 2014).
- e) ***Representativeness of Broader South Asian Trends:*** Chilika epitomizes several issues confronting coastal wetlands across South Asia-pollution, aquaculture encroachment, degradation of BCEs, and declining SSF resilience. Insights from this lagoon are transferable to other wetlands such as the Sundarbans (India/Bangladesh), Palk Bay (Tamil Nadu), and Indus Delta (Pakistan), all of which face comparable stressors.
- f) ***Policy and Global Conservation Relevance:*** Chilika Lagoon is a designated Ramsar Site and a vital migratory bird hub, supporting millions of birds annually, including those traveling along the Central Asian and East Asian–Australasian Flyways (Kumar et al., 2020a). It also serves as a protected habitat for the endangered Irrawaddy dolphin (*Orcaella brevirostris*), which is listed on the IUCN Red List due to increasing threats from habitat degradation and human-induced disturbances (Kumar et al., 2020a; Kumar et al., 2020b).

As an ecologically significant site, Chilika contributes directly to global environmental governance and biodiversity conservation frameworks. This study aligns with international policy objectives, including the Ramsar Convention and key SDGs: SDG 1 (No Poverty), SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life on Land), and SDG 17 (Partnerships), by promoting lagoon restoration, water quality improvement, ecosystem-based climate mitigation, and inclusive, community-centered governance.

This research seeks to address several critical knowledge and policy gaps that limit effective conservation and management of coastal wetlands like Chilika Lagoon. Key among these are the absence of periodic mapping and monitoring of BCEs distributions, and the inadequate integration of water quality data with ecosystem health and SSF viability. Moreover, there is limited understanding of the spatial distribution and ecological consequences of microplastic pollution, alongside weak community awareness and engagement in ecosystem monitoring. The degradation of TEK and the exclusion of local stakeholders from governance frameworks further compound the vulnerability of these systems. This study addresses these gaps through an integrated social-ecological framework that links BCEs, water quality, and SSF vulnerability. By grounding the research in Chilika's dynamic SES, it generates context-specific yet globally relevant insights that contribute to building resilient, participatory, and evidence-based wetland governance models.

1.7 Research Philosophy, Design and Methodology

This section outlines the research philosophy, design, and methodology adopted in this doctoral research using Chilika Lagoon as the case study. The approach integrates interdisciplinary perspectives to explore the social-ecological dynamics influencing wetland ecosystems and dependent communities. The philosophical stance underpinning this research is critical realism, which acknowledges that reality exists independently of human perceptions but can only be understood through socially constructed knowledge. This perspective is particularly useful for investigating complex SES like Chilika Lagoon, where ecological processes and social interactions co-evolve (Bhaskar, 2013). A critical realist lens enabled me to explore both observable phenomena (e.g., water quality changes, biodiversity loss) and underlying mechanisms (e.g., governance failures, social-economic marginalization) that shape outcomes in coupled human-environment systems. Table 1.2 outlines the key research instruments used in the study, describing

each method alongside its rationale for inclusion. From scoping reviews to participatory mapping, each tool was selected to support the study's interdisciplinary goals and ensure methodological triangulation.

The study also adopts elements of interpretivism, particularly in qualitative components such as interviews and FGDs. Understanding the lived experiences, perceptions, and TK of SSFs requires engaging with their worldviews, cultural values, and narratives, which are central to constructing a holistic picture of vulnerability and resilience (Schwandt, 2000). Participants ranged in age from 18 to 80. This age diversity enabled the collection of intergenerational insights into ecosystem changes, knowledge transmission, and livelihood adaptations. The research employs a mixed-methods, exploratory case study design integrating qualitative and quantitative methods to triangulate insights from ecological data, community perceptions, and institutional practices. The case study approach (Yin, 2017) facilitates an in-depth examination of Chilika Lagoon as a bounded system with embedded sectors (Northern, Central, Southern, Outer Channel) that exhibit unique social and ecological characteristics. Figure 1.10 visualizes the integration of quantitative and qualitative methods used in the study. Quantitative methods included rapid and household surveys, while qualitative methods included semi-structured interviews, FGDs, and participatory mapping. Participant observation and mixed analysis tools such as NVivo, Excel, R, and Geographic Information Systems (GIS) were central to data synthesis and triangulation.

1.7.1 Research Methods

a) Scoping Literature Review

Academic literature on the linkages between BCEs, water quality, and SSFs in SES is growing, yet remains fragmented across ecological, hydrological, and social science domains. Much of the scholarship on BCEs-particularly seagrasses, mangroves, and salt marshes-tends to focus on biophysical dynamics such as carbon sequestration, biodiversity, nutrient cycling, and climate mitigation potential (Duarte et al., 2005; Lovelock & Duarte, 2019). Meanwhile, water quality literature is often hydrology- or engineering-centric, with limited cross-linkages to ecosystem-based management or fisher livelihoods. The vulnerability and viability of SSFs, while gaining attention in sustainability and development studies, are frequently treated in isolation from ecosystem processes, creating a critical gap for interdisciplinary integration. Given the multi-scalar and transdisciplinary nature of this study, a systematic scoping literature review was undertaken. This approach was deemed suitable as a full systematic review was impractical due to the

disciplinary spread and volume of relevant but non-standardized literature (Arksey & O'Malley, 2005). Scoping reviews allow for the identification and mapping of key concepts, thematic intersections, and available data sources in fields where research is emerging or scattered (Tricco et al., 2015). Scoping reviews are especially useful in interdisciplinary environmental studies for synthesizing diverse literatures, refining research questions, and identifying knowledge gaps.

The scoping review was conducted in a reflexive and iterative manner, guided by the need to understand three broad thematic strands: (a) ecological roles and governance of BCEs, (b) water quality impacts and assessments in coastal wetlands, and (c) the social-economic vulnerability and adaptive capacity of SSFs. Searches were conducted using academic databases including Scopus, Web of Science, JSTOR, and Google Scholar, with keywords such as “blue carbon ecosystems”, “coastal wetlands” “seagrass and mangroves”, “coastal water quality”, “social-ecological systems”, “SSF vulnerability”, “resilience”, and “wetland governance”. The review initially generated over 400 publications. After screening for relevance, language, peer-reviewed status, and topical alignment with the conceptual framework of the study, a total of 128 academic articles were selected for in-depth review. These included high-impact journal articles, case studies, meta-analyses, and review papers published between 2000 and 2022. The selection also included grey literature such as technical reports from the Ramsar Convention, UNEP, IUCN, and national agencies like the CDA and the Ministry of Environment, Forest and Climate Change (MoEFCC), India.

Table 1.2 Summary of research methods and tools

Method	Description	Rationale
Scoping Literature	Review of academic, grey, and policy literature to identify gaps and inform framework	To ground the study in interdisciplinary evidence and identify knowledge gaps
Reconnaissance Survey	Initial field visits, informal interviews, and site assessments to scope key locations and community dynamics	To identify seagrass presence, prioritize sectors, and build rapport with potential participants
Rapid Surveys	Short-format survey to gauge general perceptions across sectors	To gather rapid, spatially broad insights into perceptions and ecosystem change
Household Surveys	Structured, in-depth survey to capture household-level data on BCEs and SSFs	To capture detailed social-economic, ecological, and adaptive indicators

Semi-Structured Interviews	Conversational interviews with diverse stakeholders on lived experiences	To explore deeper community insights and validate survey findings
Focus Group Discussions	Group-based discussions with women, youth, and elders on shared changes and values	To surface collective memory and enable participatory engagement
Participant Observation	Immersive observation and documentation of social-ecological interactions	To contextualize data collection through lived observation
Participatory Mapping	Community mapping of seagrass zones, fishing areas, and degraded regions	To co-produce spatial knowledge and validate ecological patterns
Secondary Data Collection	Analysis of long-term environmental and management records	To enrich primary data with long-term trends and sectoral data

To ensure comprehensive thematic representation, the scoping literature review concentrated on five core areas central to this study. First, it explored empirical studies of seagrass and mangrove ecosystems, particularly in South and Southeast Asia, where the ecological and livelihood relevance of BCEs is profound. These studies provided foundational insights into the spatial distribution, ecological functions, and restoration efforts of such ecosystems. Second, the review focused on literature examining water quality trends and the ecological responses of lagoons and estuarine systems-highlighting the dynamic interactions between salinity, nutrient loading, turbidity, and ecosystem health. Third, it included vulnerability assessments and livelihood studies of SSF communities, with emphasis on exposure to environmental stressors, adaptive strategies, and social-economic resilience. Fourth, the review addressed governance frameworks related to BCE and fisheries management, particularly participatory approaches such as co-management and the inclusion of TEK. Finally, it examined the application of interdisciplinary models such as the DPSIR (Drivers-Pressures-State-Impact-Response), SES frameworks, and the V2V approach. Collectively, this thematic synthesis informed the conceptualization of the SEVVN framework and guided the methodological design of the study, including the development of field instruments such as interview protocols, participatory mapping templates, and household survey questionnaires.

The scoping review also illuminated several key research gaps. One major gap is the limited integration of biophysical water quality data with social-economic analyses of fisheries

viability, which constrains the ability to evaluate ecological changes in relation to livelihood outcomes. There is also a notable scarcity of literature linking microplastic pollution to the health of seagrass meadows or SSFs in the South Asian context, despite growing global concerns over plastic waste in aquatic systems. Additionally, the review identified a lack of fine-scale participatory mapping studies of BCEs, especially in community-managed or co-managed coastal lagoons, where local knowledge could enrich ecological assessments. Finally, there was insufficient scholarly attention to the social-cultural dimensions of BCE degradation, particularly with respect to gendered knowledge systems, roles, and experiences in fishing communities. These identified gaps underscore the importance of an integrated, place-based, and participatory research approach. By grounding the study in these insights, the literature review not only offered the theoretical and empirical direction necessary for framing the research but also ensured alignment with contemporary academic and policy discourses on resilience, sustainability, and equity in coastal wetland governance.

b) Reconnaissance Survey

The reconnaissance survey served as a critical foundation for this research by facilitating site selection, community engagement, and contextual understanding of Chilika Lagoon's SES. Field visits across the four sectors enabled informal interactions with fishers, elders, and women, and provided insights into ecological variation, livelihood dynamics, and seagrass distribution. This phase adopted a purposive sampling approach (Patton, 2002), prioritizing villages with present or historical seagrass presence (based on 2019 field survey data and GIS mapping by the WTRC; Tripathy et al., 2021), sectoral representation, accessibility, and willingness to participate. This phase revealed widespread unfamiliarity with local species and a gap in TEK. Most of the community members were unfamiliar with the term "seagrass" or its ecological functions. Reconnaissance findings also highlighted challenges such as degraded seagrass habitats, limited community awareness of BCEs, plastic pollution, and lack of follow-up after prior interventions. The phase informed the design of surveys, participatory mapping, and FGDs, ensuring cultural sensitivity and logistical feasibility. It also affirmed the need for participatory and integrative research approaches. Ultimately, the reconnaissance survey helped refine research instruments and build trust, ensuring that the study remained grounded in Chilika's social-ecological realities and aligned with the SEVVN framework.

c) Village Surveys (Rapid Surveys)

As a foundational step in this study, village-level rapid surveys were conducted to capture broad spatial patterns in community perceptions, presence, and the cultural relevance of BCEs. These short-format surveys served as an essential reconnaissance tool and guided the selection of subsequent in-depth research sites. A total of 200 participants across 32 villages were surveyed, with proportional representation from the four major ecological sectors of the Chilika Lagoon: Central (47 participants), Northern (42), Outer Channel (37), and Southern (74). The survey focused on capturing perceptions regarding the presence of seagrass habitats and identifying the local names of diverse species. Respondents were purposively selected to ensure representation across different age groups, genders, occupations (fishers, traders, women, and elders), and community roles (Patton, 2002). Notably, the rapid survey revealed a significant gap in local awareness about seagrass ecosystems, so photo identification methods were integrated into the survey protocol. I used visual aids depicting local seagrass species to elicit recognition and vernacular names. This approach helped generate qualitative insights into past and present seagrass sightings and associated fishing practices. The rapid surveys provided a spatially diverse, community-based foundation for deeper qualitative inquiry and participatory mapping efforts.

d) Participatory Mapping

Participatory mapping was employed as a visual and community-led tool to document and validate local knowledge of seagrass distribution and ecological changes in Chilika Lagoon. This method aimed to bridge scientific observation with community perceptions, enhancing the credibility and local relevance of the study (Chambers, 2006). Three participatory mapping sessions were conducted in Barkul (Central Sector), Sipakuda (Outer Channel), and Sabulaya (Southern Sector), all locations known for either historical or active presence of seagrass meadows. These exercises followed the initial phase of rapid surveys and were guided by a participatory sampling approach, prioritizing communities with active SSFs, known ecological transitions, and demonstrated willingness to engage. Participants included fishers, women, community elders, and youth, who collaboratively identified and drew zones of seagrass presence, loss, degradation, and regeneration using base maps and field prompts. Local terms and TEK were integrated into these maps, capturing nuances that conventional GIS tools often overlook. The maps produced during these sessions offered spatially grounded insights into community awareness, ES of seagrass beds,

and perceived threats. These outputs were later cross-validated with historical GIS data from 2019 (Tripathy et al., 2021) and field observations, ensuring triangulation and analytical rigor. Participatory mapping in this study not only informed the empirical data but also fostered community ownership over ecological knowledge, which is vital for inclusive and effective conservation planning.

e) Household Surveys (In-Depth Surveys)

The household surveys constituted a central component of the empirical strategy. A total of 190 household surveys were conducted across selected villages in all four sectors of the lagoon. The sampling design adopted a stratified purposive approach to ensure equitable representation across ecological sectors and social-economic groups, focusing on active SSF households (Patton, 2002). The household survey captured both current experiences and historical perceptions of ecosystem changes over the past 10–15 years. Fifteen households were selected in each village except the Northern Sector. The reduced sampling (five each in two villages) in the Northern sector was intentional, as seagrass presence—a key selection criterion for this research—was not identified during the reconnaissance phase in that region. The bar chart (Figure 1.8) shows the number of participants in rapid and household surveys conducted across the four Chilika sectors. The surveys employed structured questionnaires comprising both closed and open-ended questions. Key thematic areas included household demographics, income diversification, fishing practices, resource dependency, perceptions of water quality and BCE degradation, access to governance structures, and indicators of vulnerability and adaptive capacity. Likert-scale assessments were embedded to quantify household perceptions on a scale of agreement, allowing for nuanced comparison across regions. Enumerator training was undertaken to ensure consistency, ethical sensitivity, and cultural appropriateness. Survey administration was supported by local interpreters, especially in communities with strong dialectical variations. These data were critical for triangulating qualitative findings from interviews and FGDs, and for grounding the SEVVN conceptual framework in community realities.

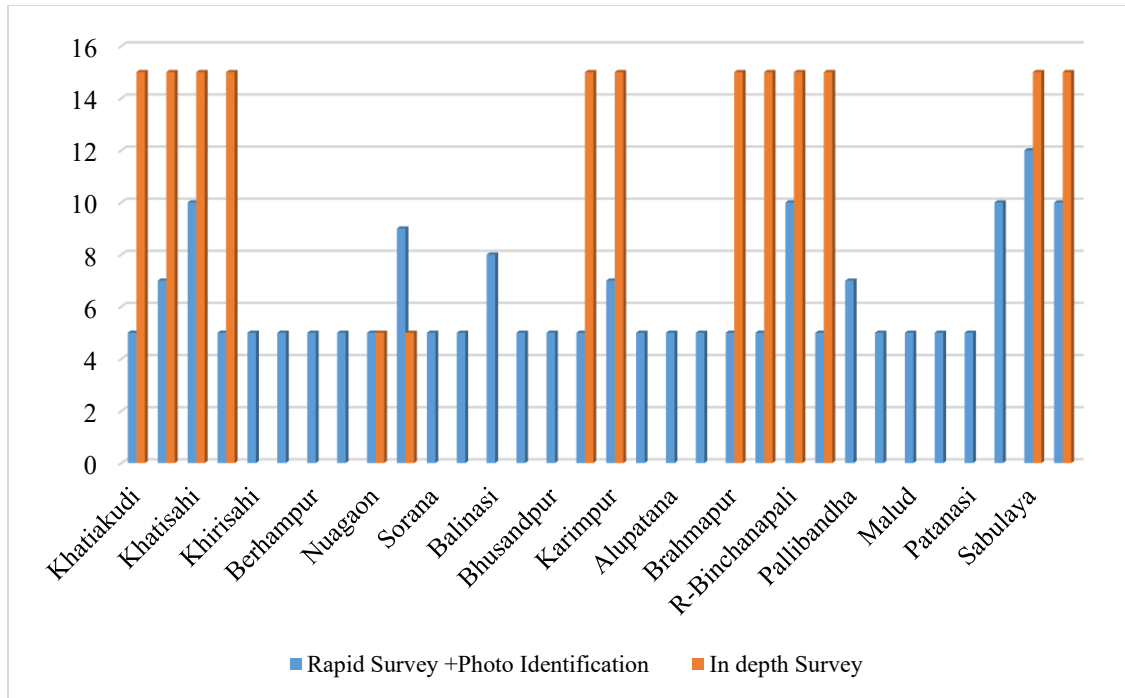


Figure 1.8 Distribution of rapid household surveys by sector

f) Semi-Structured Interviews

Semi-structured interviews served as a key qualitative tool for capturing the diverse perspectives and lived experiences of stakeholders connected to Chilika Lagoon's SES. A total of 62 interviews were conducted across the Central, Southern, and Outer Channel sectors, involving a broad range of stakeholders: SSFs (14), women (12), fish traders (9), boat operators and associations (6), government officials (4), local experts and community leaders (4), marine fishers (2), tourism operators (2), Chilika Matsyajibi Mahasangh (CMM) members (3), and representatives from fish markets (3). The pie chart in Figure 1.9 highlights the diversity and proportion of stakeholder groups involved in semi-structured interviews. Participants were selected through purposive sampling (Patton, 2002) to ensure representation across occupational categories, gender, age, and geographic distribution. The interviews were designed to elicit insights into ecosystem change, water quality, fishing practices, adaptive strategies, community knowledge, and governance structures. Open-ended questions were used to encourage participants to express their perceptions freely while allowing them to probe further based on emerging responses. This approach enabled the identification of nuanced and locally specific information that may not surface through structured surveys alone (Vaivio, 2012). Interviews were conducted in Odia or a mix of Odia and Hindi, based on participant comfort. The method provided critical

insight into the social-political dynamics shaping Chilika's ecological and fishery governance systems.

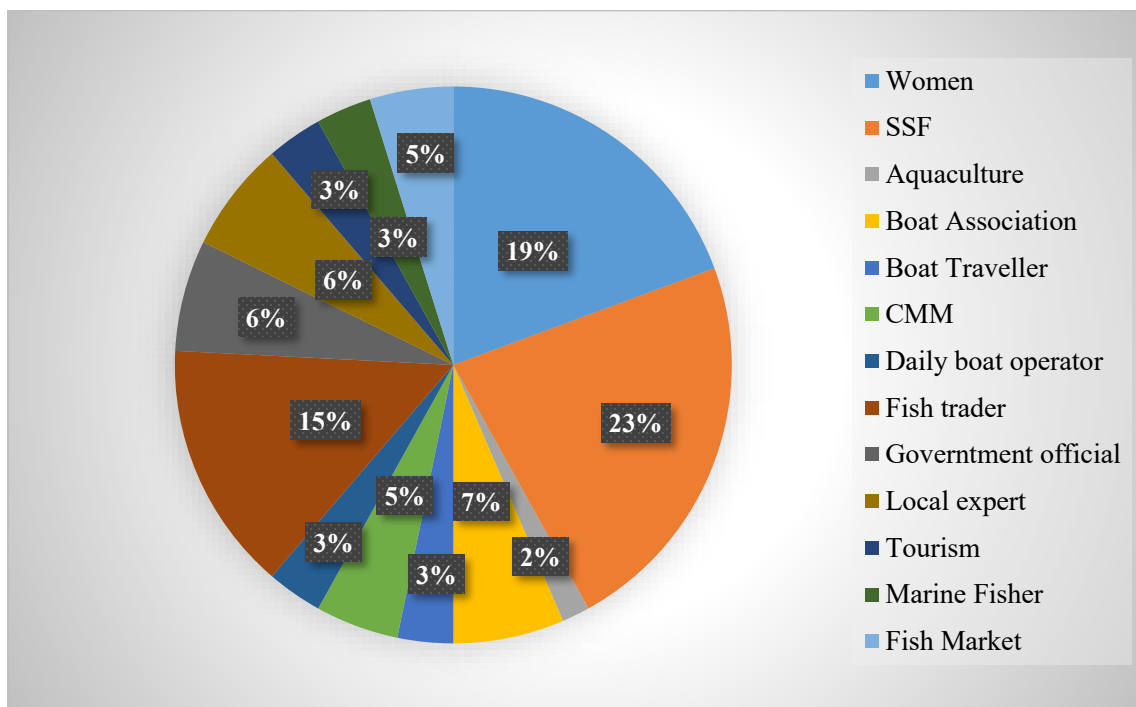


Figure 1.9 Stakeholder representation in semi-structured interviews

g) Focus Group Discussions (FGDs)

FGDs were an essential qualitative method employed in this research to capture collective narratives, local knowledge, and SES perspectives of SSFs and community members in Chilika Lagoon (Krueger, 2014). FGDs were designed to complement individual interviews and household surveys by facilitating interactive dialogue among diverse community stakeholders, including elders, women, and youth. The method aimed to unpack shared experiences related to BCE changes, water quality deterioration, and the social-economic implications on fishing livelihoods. Originally, three FGDs were planned in strategically selected villages representing the Central, Southern, and Outer Channel sectors- Barkul, Sabulaya, and Sipakuda-based on their proximity to known seagrass meadows and active SSF engagement. However, during field visits, an unplanned yet significant FGD was conducted in Balugaon (Central Sector), where the research team encountered a settled community of Bangladeshi-origin SSFs. Their unique migratory history, settlement patterns, and ecological interactions provided critical insights that enriched the dataset and highlighted governance and identity-based vulnerabilities. Each FGD comprised 8–12 participants and was conducted in Odia or Hindi with the help of trained facilitators and

interpreters. Discussions were guided by a semi-structured protocol covering ecological changes, livelihood adaptation, intergenerational knowledge, gender roles, and perceptions of governance interventions. FGDs played a pivotal role in triangulating data with household surveys and interviews, strengthening the reliability of social-ecological narratives.

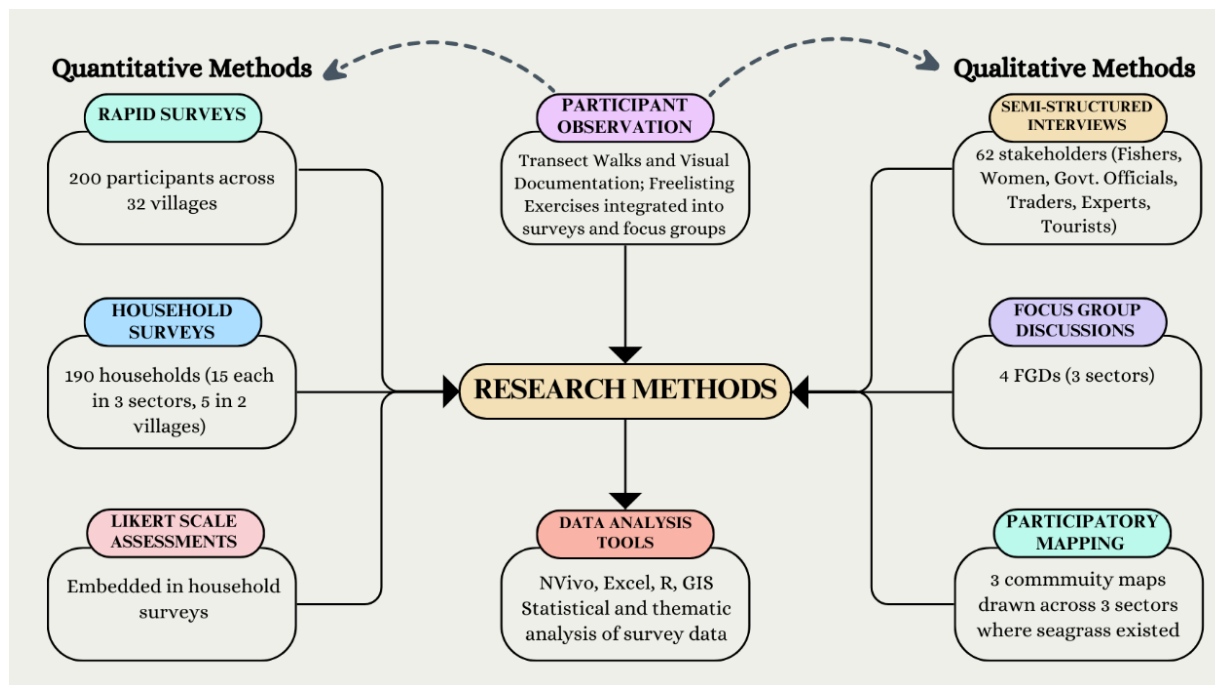


Figure 1.10 Types of research methodology

h) Participant Observation

Participant observation served as a crucial qualitative method in this research, enabling an immersive understanding of the social-ecological realities of Chilika Lagoon's coastal communities. Rooted in ethnographic traditions (Bernard, 2017), this method allowed me to engage directly with the lived experiences of SSFs and other community members. I participated in routine activities such as fish catching, auction processes, religious rituals, community gatherings, and seagrass identification walks and boat rides, thereby gaining contextual insights that could not be captured through surveys alone. Transect walks across selected villages and lagoon sectors were employed to observe environmental changes, pollution hotspots, and seagrass coverage. Visual documentation and photographic records were maintained to complement field notes. Free listing exercises, integrated within household surveys and FGDs, further supported the observational method by capturing local biodiversity knowledge and perceived ecosystem changes (Weller & Romney, 1988). This method proved particularly valuable during the reconnaissance

phase, helping establish trust and rapport. Observations informed the refinement of interview guides and survey instruments, ensuring they were grounded in local realities. My position as an engaged participant enabled a nuanced understanding of gendered roles, power dynamics, and community-environment interactions. Participant observation contributed to the triangulation of data, offering a rich, situated narrative that enhanced the interpretation of quantitative and qualitative findings. It also deepened reflexivity and enriched my positionality within the study context.

i) Secondary Data

Secondary data played a crucial role in complementing primary data collection and enhancing the empirical robustness of this study. The research utilized multi-year secondary datasets to examine seasonal, spatial, and inter-annual variability in water quality and ecosystem dynamics within Chilika Lagoon. These datasets were obtained from published sources of institutions such as the CDA, covering key water quality parameters and past distribution or mapping of BCEs. Additionally, physio-chemical parameter records published in earlier studies (e.g., Sahu et al., 2014; Muduli & Pattnaik, 2020) were used to understand long-term ecological baselines and post-restoration changes. Reports from the Indian Council of Agricultural Research (ICAR), Central Marine Fisheries Research Institute (CMFRI), and relevant journal articles provided insights into fish biodiversity, historical ecosystem change, and SSFs governance. Notably, studies such as Nayak and Berkes (2014) and Nayak (2014) provided rich contextual literature on SSFs in Chilika and their social-ecological challenges, informing the research framework and guiding thematic coding. Supplementary secondary sources included GIS shapefiles, satellite imagery and biodiversity assessments. These spatial datasets aided in generating maps and the contextualization of community observations.

1.7.2 Data Synthesis and Analysis

The data synthesis and analysis approach in this study integrates both quantitative and qualitative datasets using a mixed-methods framework. This design allows for the convergence of findings across methodological boundaries, enhancing the reliability and validity of results (Creswell & Clark, 2007). Quantitative data derived from household and rapid surveys were organized using Microsoft Excel and analyzed using R for frequency analysis and data visualization. Descriptive statistics were employed to assess demographic profiles, perceptions of

water quality, livelihood pressures, and responses to environmental changes. Sectoral comparisons were conducted to identify patterns in ES dependence and vulnerability across Chilika's ecological zones. Qualitative data collected from semi-structured interviews, FGDs, and participatory mapping were transcribed and thematically coded using NVivo and Excel (Guest et al., 2011). Coding followed both inductive and deductive approaches, mapping emergent themes onto the SEVVN framework. Themes such as perceptions of ecosystem decline, and drivers of water quality degradation were analyzed for interlinkages and explanatory depth. Participatory maps and free listing exercises were interpreted alongside GIS data to triangulate local knowledge with spatial patterns of BCE distribution and degradation.

Triangulation was employed at three levels: methodological (across interviews, surveys, and FGDs), data source (e.g., comparing community knowledge with scientific water quality data), and analytical (e.g., juxtaposing statistical outputs with thematic insights). This approach enabled a nuanced understanding of how water quality dynamics, BCE transformations, and social-economic vulnerabilities interact in Chilika's lagoon system. By integrating social-cultural narratives with environmental indicators, the analysis supports context-sensitive and actionable findings for wetland management and SSFs governance. Fieldwork was occasionally constrained by weather and religious events, political tensions such as elections and daily work/unavailability of participants. Language barriers were addressed through interpretation and my own efforts to learn important words in Odia associated with the research. Reflexive journals were maintained to document my positionality, challenges, and evolving understanding of the field. The use of mixed methods ensured robustness, but some limitations remain in data generalizability due to the case study design. Field notes, audio recordings, and transcripts were coded thematically, facilitating the extraction of recurring themes such as knowledge degradation, adaptation to ecosystem changes, and the role of institutions in resilience-building.

1.8 Ethics Protocol

This research study has been reviewed and received ethics clearance through the University of Waterloo's Research Ethics Board (REB #45322). The study complies with the University of Waterloo Statement on Human Research (2018) and is consistent with the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (TCPS2, 2014). The three core principles of this policy-respect for people, concern for welfare, and justice-guided all research activities. The approved ethics protocol addressed all relevant considerations, including informed

consent, participant privacy, data protection, and reciprocal relationships with the community. I have completed mandatory training Course on Research Ethics (CORE) 2022 in human research ethics as required by the Tri-Council agencies. The Office of Research Ethics (ORE) at the University of Waterloo reviewed this project and all related research activities.

Prior and informed consent was obtained from all participants before any data collection. Participants were briefed on the study objectives, voluntary nature of their participation, and their right to withdraw at any point. Local leaders and community members provided oral consent for field activities, including surveys, interviews, photo identification, and participatory mapping. Anonymity and confidentiality were strictly maintained, with all identifiable information removed from transcripts and reports. Data were securely stored on password-protected devices and institutional cloud platforms accessible only to the research team. Respect for local cultural norms was maintained, and interviews and discussions were conducted in the local language (Odia and Hindi) with the help of trained local research assistants. The study emphasized reciprocity and co-benefits by conducting community feedback sessions and hosting a knowledge-sharing workshop where local cultural expressions and ecological knowledge were showcased. These ethical protocols helped build mutual trust and ensured that the research respected the dignity, rights, and lived experiences of all participants

1.9 Organization of the Dissertation

This dissertation is structured into five chapters, each contributing to an integrated and interdisciplinary understanding of the linkages between BCEs, water quality, and the sustainability of SSFs within the SES of Chilika Lagoon. The visual diagram (Figure 1.11) presents the overall structure of the doctoral dissertation, organized into five interlinked chapters. The diagram emphasizes the progressive flow of inquiry from ecosystem mapping to policy implications, offering a comprehensive understanding of coastal SES.

Chapter 1: Introduction outlines the research context, rationale, purpose, and objectives of the study. It discusses the significance of the study in the South Asian and global contexts and presents the conceptual and theoretical frameworks guiding the research. The chapter also elaborates on the empirical setting of Chilika Lagoon, the research philosophy, methodological design, ethical considerations, and the rationale for the case study approach.

Chapter 2 presents the first manuscript, which focuses on mapping and characterizing the spatial distribution of BCEs-particularly seagrass meadows and mangrove forests-in Chilika

Lagoon. Through participatory mapping techniques that integrate TEK with scientific data, this chapter highlights the significance of BCEs and their role in supporting fisheries and coastal livelihoods.

Chapter 3 comprises the second manuscript, which investigates key water quality parameters and assesses their social-ecological impacts on BCEs and SSFs. The chapter integrates scientific measurements with community perceptions to identify drivers of degradation, assess ecological and livelihood impacts, and examine local responses, thereby bridging quantitative data with experiential knowledge.

Chapter 4 features the third manuscript, which employs the SEVVN framework to examine the interconnected vulnerabilities of SSFs arising from BCE degradation and water quality decline. It analyzes feedback loops, stressors, and social-ecological fragility while also identifying pathways toward resilience through governance strategies, TK, and participatory management.

Chapter 5: Conclusions synthesize the theoretical, methodological, and applied contributions of the research. It consolidates findings from participatory BCE mapping, water quality assessments, and vulnerability analyses to propose actionable governance recommendations. The chapter reflects on the broader implications of the study for sustainable coastal wetland management and outlines future research directions that emphasize climate resilience, TEK integration, and inclusive conservation.

This organization reflects the interdisciplinary, community-engaged, and policy-relevant orientation of the research, with each chapter building upon the insights of the previous to construct a comprehensive social-ecological analysis of Chilika Lagoon.

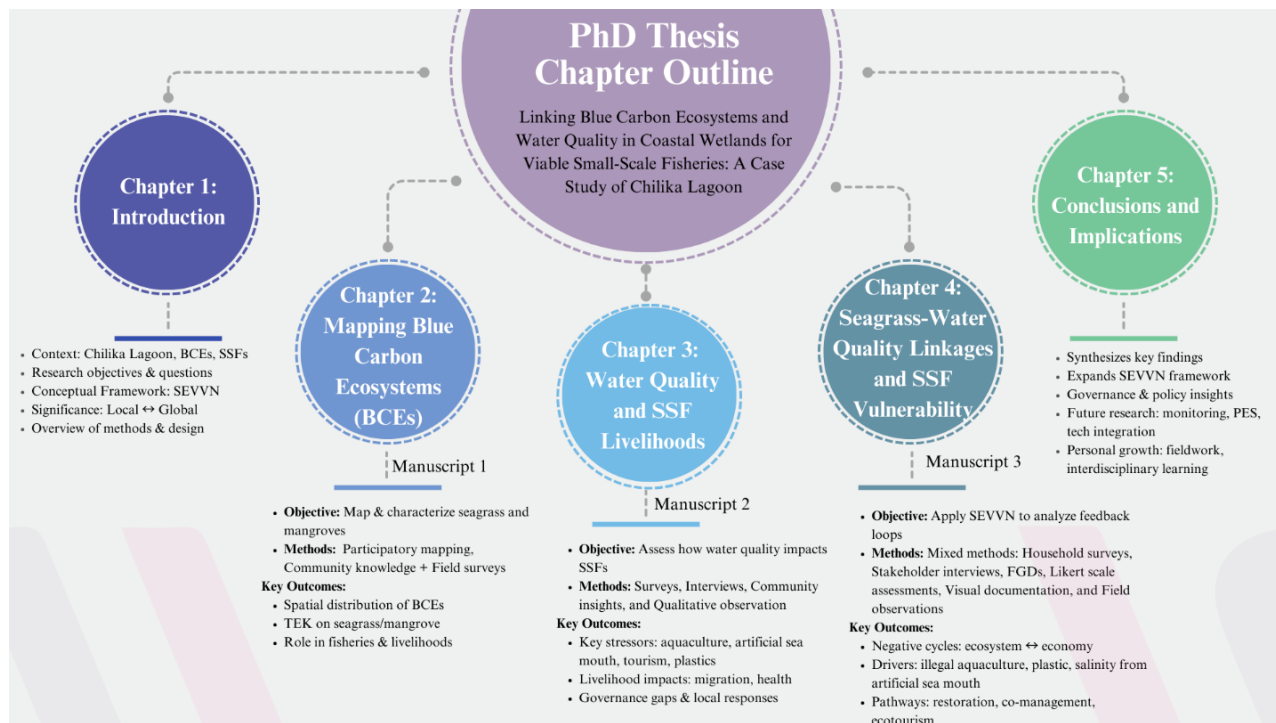


Figure 1.11 Chapter-wise structure of the PhD thesis

Chapter II

Community Perceptions and Participatory Mapping of Blue Carbon Ecosystems in Chilika Lagoon

2.1 Abstract

Blue Carbon Ecosystems (BCEs), including seagrass meadows and mangroves, play a vital role in climate mitigation, biodiversity conservation, and coastal livelihood sustainability. Chilika Lagoon, a Ramsar site and one of Asia's largest brackish water lagoons, hosts diverse BCEs critical for ecological balance and social-economic well-being. However, these ecosystems face significant threats from habitat degradation, pollution, climate change, and unsustainable practices. The need for exploring community perceptions arises from the limited understanding of these ecosystems' social-ecological-economic roles and gaps in prior scientific assessments. This study engages SSFs across the lagoon's four ecological sectors - Northern, Central, Southern, and Outer Channel-to document local knowledge through participatory mapping, rapid surveys, and stakeholder interviews. Employing qualitative methods engaged SSFs to document local knowledge, distribution, and the ecological and social-economic significance of BCEs. Results revealed extensive awareness of seagrass as crucial nursery habitats, yet limited understanding of their broader ecological functions, such as carbon sequestration. Participatory mapping identified seven seagrass species and highlighted gaps in earlier scientific records. Key challenges include habitat degradation, pollution, overfishing, and institutional limitations, underscoring the need for integrated conservation strategies. Opportunities identified include community-led restoration, education programs, sustainable livelihoods, and policy integration through co-management and financial incentives like PES. By combining TEK with scientific insights, the study emphasizes the potential of community-driven approaches to enhance conservation, promote resilience, and ensure the sustainable management of Chilika's BCEs.

Keywords: Blue Carbon Ecosystems, Seagrass Meadows, Mangrove Forests, Chilika Lagoon, Community Knowledge, Conservation, Sustainable Development Goals

2.2 Introduction

Blue Carbon Ecosystems (BCEs), such as seagrass meadows, mangroves, and tidal marshes, are critical coastal and marine habitats renowned for their role in carbon sequestration, biodiversity conservation, and ES. These ecosystems capture and store atmospheric carbon dioxide (CO₂) through processes like photosynthesis, with carbon stored in their biomass and sediments for centuries (Duarte, 2002; Duarte et al., 2005). Seagrasses, for instance, stabilize sediments, improve water quality, and serve as nurseries for marine biodiversity, while mangroves buffer coastlines against erosion and storm surges, storing up to five times more carbon per hectare than terrestrial forests (Donato et al., 2011). However, BCEs face mounting pressures from habitat degradation, pollution, overexploitation, and climate change, leading to biodiversity loss and the release of stored carbon, thus intensifying global environmental challenges (Pendleton et al., 2012). In regions like Chilika Lagoon, the lack of localized data and community involvement in conservation exacerbates these challenges.

Chilika Lagoon, the largest brackish water lagoon in Asia and a Ramsar Wetland of International Importance, is a biodiversity hotspot supporting BCEs such as seagrass meadows and planted mangroves. Covering over 1,100 square kilometers, it is a vital habitat for endangered species like the Irrawaddy dolphin and sustains more than 150,000 SSFs (Behera et al., 2023). Seagrass meadows in Chilika are essential to fisheries productivity, biodiversity, and shoreline stability, forming a foundation for ecological health and economic sustainability (Acharya et al., 2023). Despite this, habitat loss from artificial sea mouths, pollution from aquaculture, and overfishing have led to a decline in biodiversity, jeopardizing both ecosystems and community livelihoods. Addressing these challenges requires a deeper understanding of BCE distribution and the social-economic interdependencies of local communities.

SSFs possess TEK accumulated through generations of interaction with their environment (Berkes et al., 2000). TEK is defined as “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment” (Berkes, 2017, p. 8). TEK encompasses observations, practices, and beliefs about ecosystem health, biodiversity, and environmental changes. The rationale for exploring community perceptions stems from two critical gaps: (1) limited awareness of the ecological and economic value of BCEs, particularly seagrass meadows, and (2) underrepresentation of TEK in

formal conservation strategies. This study employs participatory mapping and qualitative methods to bridge these gaps, leveraging community insights to complement scientific research and propose actionable conservation strategies. In Chilika, fishers have noted shifts in fish abundance, seagrass coverage, and water quality over the past 5 to 10 years, reflecting temporal perceptions of ecological change based on lived experiences and generational observations. During interviews, participants were asked both about their current views and how these compared to ecological conditions they remembered from a decade ago. This retrospective approach allowed for a nuanced understanding of change over time. Their insights provide invaluable data for filling scientific gaps and shaping adaptive conservation strategies. Moreover, participatory approaches to conservation that engage communities in mapping and management are proven to enhance outcomes by fostering ownership and aligning ecological goals with local needs (Chambers, 2006). Participatory mapping is a powerful tool for documenting TEK, visualizing ecosystem distribution, and integrating community perspectives into formal conservation frameworks. Mapping exercises can bridge the gap between local observations and scientific research, fostering collaborative governance and empowering stakeholders. In Chilika Lagoon, where formal data on BCEs, particularly seagrass meadows, is limited, participatory mapping holds the potential to reveal under documented ecological patterns and improve conservation strategies.

This study aims to explore community perceptions of BCEs in Chilika Lagoon, with a focus on seagrass meadows, using participatory mapping to identify their spatial distribution and assess their ecological and social-economic significance. The objectives are to:

1. Utilize community knowledge and participatory mapping to document the spatial distribution of seagrass meadows and mangroves, including previously undocumented areas
2. Evaluate the ES provided by BCEs and analyze their ecological, social, cultural, and economic importance, highlighting community dependence for livelihoods and resilience.
3. Identify key challenges to BCEs and propose actionable solutions for sustainable management and resilience.

2.3 Study Area and Methods

Chilika Lagoon supports a diverse socio-economic landscape. The lagoon is home to SSFs, primarily from local non-Indigenous communities, many of whom have lived in the region for generations. Their livelihoods revolve around capture fisheries, fish processing, small-scale aquaculture, and seasonal tourism. The economic reliance on lagoon-based activities has

intensified due to limited alternative employment, and livelihood patterns have changed significantly over time. Traditionally reliant on open lagoon fishing, many fishers have shifted to shrimp aquaculture or outmigration in response to declining fish stocks and environmental degradation. Chilika is ecologically diverse and divided into four distinct sectors: Northern, Central, Southern, and Outer Channel (Figure 2.1). Each sector offers unique environmental conditions that influence biodiversity and community livelihoods. The Northern Sector is characterized by freshwater inflows from rivers, but no seagrass presence was identified in this region during surveys. The Central Sector exhibits a rich salinity gradient and biodiversity, making it an important ecological zone. Participatory mapping in this sector focused on the Barkul region, known for potential seagrass meadows. The Outer Channel, where tidal exchanges connect the lagoon to the Bay of Bengal, includes Sipakuda, another participatory mapping site for seagrass. Finally, the Southern Sector, dominated by shallow waters and submerged vegetation, serves as a key habitat for seagrass meadows, with Sabulaya selected for mapping activities. The study adopted a qualitative research design rooted in the interpretivist paradigm, emphasizing the subjective meanings and lived experiences of local communities. This approach was particularly suitable for exploring community perceptions of BCEs in Chilika Lagoon, with a specific focus on seagrass meadows. Interpretivism helped uncover how individuals and communities interact with their environment, revealing ecological and social-economic dependencies. Given the limited availability of formal scientific data on seagrass in the lagoon, the study relied on local knowledge, rooted in lived experiences and intergenerational observations, to fill critical data gaps and interpret changes over time.

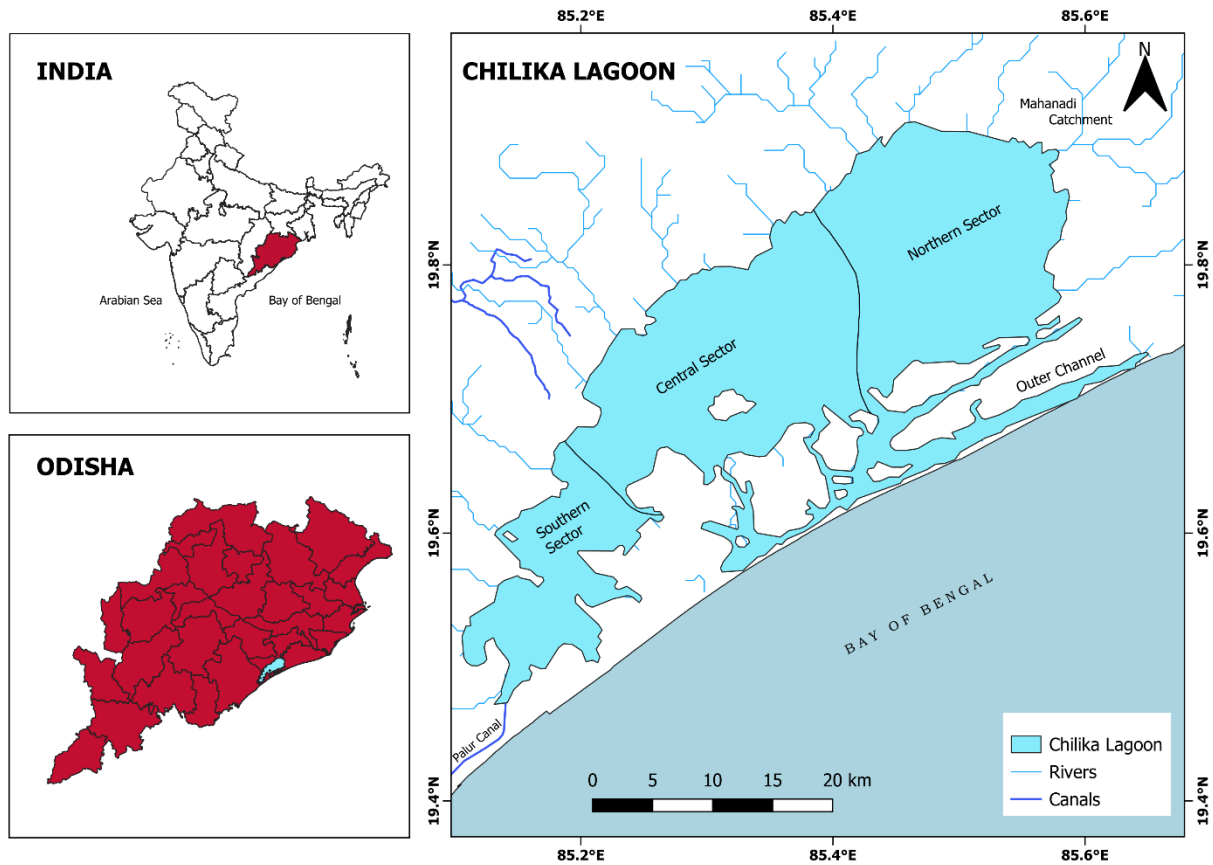


Figure 2.1 Map of Chilika Lagoon (Source: Created by the author, 2025)

The study employed qualitative research methods grounded in an interpretivist paradigm to explore community perceptions and map the ecological significance of BCEs in Chilika Lagoon. To ensure representation across the lagoon's ecological diversity, stratified sampling was used, covering its four key sectors: Northern, Central, Southern, and the Outer Channel. A two-week reconnaissance visit was conducted to build rapport with local communities, understand cultural and linguistic nuances, and identify key stakeholders. Efforts to learn basic Odia phrases helped overcome initial communication barriers, fostering trust and effective engagement with fishers and community leaders. The Northern Sector, characterized by freshwater inflows, was surveyed in fishing villages but showed no identified seagrass presence. The Central Sector, known for its biodiversity and salinity gradients, focused on Barkul, where surveys targeted potential seagrass meadows near the shoreline and within fishing zones. In the Southern Sector, dominated by shallow waters, the study concentrated on Sabulaya, a site with known seagrass habitats. Lastly, the Outer Channel, defined by tidal exchanges and connectivity to the Bay of Bengal, involved participatory mapping in Sipakuda. Data collection methods included rapid surveys, participatory

mapping, and semi-structured interviews. Participatory mapping visually represented community interactions with BCEs, while rapid surveys captured ecological awareness and misconceptions. Semi-structured interviews provided narratives on the ecological, cultural, and economic importance of BCEs, alongside the challenges communities face in conservation efforts. To address widespread misconceptions about seagrass, photo aids featuring documented seagrass species were used during interviews. Community members identified local names and areas of seagrass presence, clarifying misunderstandings and refining discussions on BCEs. This integrative approach offered a nuanced understanding of the interconnectedness of ecological health and community livelihoods, providing insights to inform sustainable management strategies for Chilika Lagoon.

The research employed a combination of methods, summarizing as follows (Table 2.1): (1) Rapid Surveys: Stratified sampling across four sectors to gather preliminary data on BCE awareness and distribution. Visual aids, including photo identification, were used to address initial misconceptions about seagrass. (2) Detailed Surveys: Following the rapid surveys, 190 detailed surveys were conducted in the Central (60), Northern (10), Outer Channel (60), and Southern (60) sectors. Participants were purposively selected based on their ecological knowledge and active involvement in fishing or conservation. These surveys delved deeper into community perceptions of seagrass meadows, their social-economic relevance, and environmental dynamics. (3) Participatory Mapping: Conducted in three key locations - Barkul (Central Sector), Sipakuda (Outer Channel), and Sabulaya (Southern Sector)-to document spatial distribution and validate findings against GIS data from the CDA (2019) to ensure accuracy. (4) Stakeholder Interviews: Open-ended interviews with purposively selected participants, including fishers and women, to capture ecological, social, and economic insights. Open-ended interviews encouraged participants to share detailed perspectives. Women highlighted the cultural and social values of BCEs, while fishers focused on their economic and ecological importance. This layered approach allowed the study to incorporate community-driven insights into a structured research framework, creating a holistic understanding of the seagrass ecosystems in Chilika Lagoon.

Table 2.1 Summary of methods employed for exploring seagrass distribution and community perceptions in Chilika Lagoon.

Method	Purpose	Sample Size	Sampling Technique	Location/ Sector	Tools/Techniques
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Rapid Survey	Initial awareness of BCEs and seagrass	200	Stratified Sampling	All four sectors	Questionnaire, Photo Identification
Detailed Survey	Deeper understanding of community insights	190	Purposive Sampling	All four sectors	Semi-structured Interviews
Participatory Mapping	Visual representation of seagrass presence	3 sessions	Participatory Sampling	Barkul, Sipakuda, Sabulaya	Community-Drawn Maps
Stakeholder Interviews	Understand BCE significance	26 (14 SSFs, 12 women)	Purposive and snowball sampling	Central, Southern, Outer Channel	Open-ended Interviews

The study employed a purposive sampling technique to target participants with relevant ecological knowledge and direct involvement in lagoon activities. This ensured that responses were informed and reflective of local expertise. Additionally, stratified sampling was used to ensure representation from all four sectors, with surveys distributed proportionally. For participatory mapping, communities with historical knowledge and active interaction with the lagoon were prioritized. The study followed a structured protocol, beginning with preparatory field visits to develop survey tools and mapping instruments. Rapid and detailed surveys were then conducted, followed by participatory mapping sessions. Data were cross-verified through multiple sources to ensure reliability. Ethical considerations, including informed consent and participant confidentiality, were adhered to throughout the study. This integrated approach combining qualitative methods with community-driven data collection proved effective in uncovering seagrass distribution and its social-economic significance, contributing to better conservation strategies for Chilika Lagoon.

2.4 Results and Discussions

2.4.1 Identification and Distribution of BCEs

The identification and distribution of BCEs, particularly seagrass meadows, in Chilika Lagoon, were examined using participatory mapping, rapid surveys, and detailed community

interactions. The participatory exercise mapped seagrass in Chilika using community knowledge alongside historical spatial data. The participatory mapping exercises conducted in Barkul (Central Sector), Sipakuda (Outer Channel), and Sabulaya (Southern Sector) highlighted valuable local insights into the presence, ecological significance, and cultural associations of seagrass meadows. These findings were compared against the published spatial distribution map of seagrass meadows from 2019 (Tripathy et al., 2021) (Figure 2.5), revealing both congruencies and additional information provided by the community. Identifying seagrass beds was challenging, as these plants grow underwater and are often confused with algae or other aquatic vegetation. In Chilika, community members initially struggled to recognize seagrasses, mistaking them for seaweed and grasses around the lagoon. Through rapid surveys and photo identification, I was able to pinpoint the locations of seagrass meadows, helping local communities gain a better understanding of their significance.

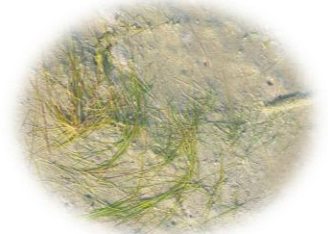
Through photo identification and rapid surveys, the community was able to recognize seven species of seagrass: *Halophila ovalis*, *Halophila ovata*, *Halodule uninervis*, *Halodule pinifolia*, *Halophila beccarii*, and the newly reported *Ruppia maritima*, and *Cymodocea serrulate* (Acharyya et al., 2023). While the first five species had prior documentation, *Ruppia* and *Cymodocea* were recognized as new additions to Chilika's seagrass biodiversity (Table 2.2, Figure 2.2). Due to overlapping characteristics, respondents frequently used shared or similar names for different species. For example, both *Ruppia maritima* and *Cymodocea serrulata* were called Chari Dollo or Chari Dollo type, while others were referred to with modifiers like Nalo Ghas (fine thread-like grass) or Pathiri Dollo (leaf-like shallow grass). These names were recorded as Local Name 1 and Local Name 2, based on frequency and variation in usage across respondents (Table 2.2, Figure 2.2).

Importantly, the local names not only described the appearance but also conveyed how these species were perceived or used by fishers. For example, Chari Dollo in Odia loosely translates to thread grass, indicating its thin, filament-like structure, while Pathiri Dollo means flat-leaf grass, referencing the broader leaf of *Halophila* species. The term Nalo Ghas refers to delicate submerged vegetation, which fishers associate with healthy shrimp and crab habitats. These terms demonstrate that while specific taxonomic knowledge may be limited, fishers possess a nuanced ecological understanding grounded in use-value and visual characteristics. This approach not only enhances scientific classification with cultural context but also demonstrates

the importance of integrating TEK into species documentation. Notable patterns included *Halodule pinifolia* thriving in the nutrient-rich waters of the Central sector, *Halodule uninervis* and *Halophila ovalis* dominating the Southern sector, and *Halophila beccarii* flourishing in the Outer Channel near Arakhakuda (Tripathy et al., 2021). The integration of scientific taxonomy with community knowledge illustrates the community's familiarity with the lagoon's ecology and enhances ecological research.

Table 2.2 Seagrass species identified and local names

Species (Image)	Scientific Name	Local (Odia) name
	<i>Halodule uninervis</i>	Chari Dollo (Local Name 1) Chari Patri (Local Name 2)
	<i>Halodule pinifolia</i>	Nalo Ghas (Local Name 1) Nalo (Local Name 2)
	<i>Halophila ovalis</i>	Pathiri Dollo (Local Name 1) Patri Chari (Local Name 2)
	<i>Halophila ovata</i>	Pathiri Dollo (Local Name 1) Pathiri Dollo type (Local Name 2) (Similar to <i>Halophila ovalis</i>)

	<i>Halophila beccarii</i>	Pathiri Dollo (Local Name 1) Pathiri Dollo type (Local Name 2) (Similar to <i>Halophila species</i>)
	<i>Ruppia maritima</i>	Chari Dollo (Local Name 1) Chari Dollo type (Local Name 2) (Similar to <i>Halodule species</i>)
<i>Underwater so unable to click clear picture</i>	<i>Cymodocea serrulata</i>	Chari Dollo (Local Name 1) Chari Dollo type (Local Name 2) (Similar to <i>Halodule species</i>)

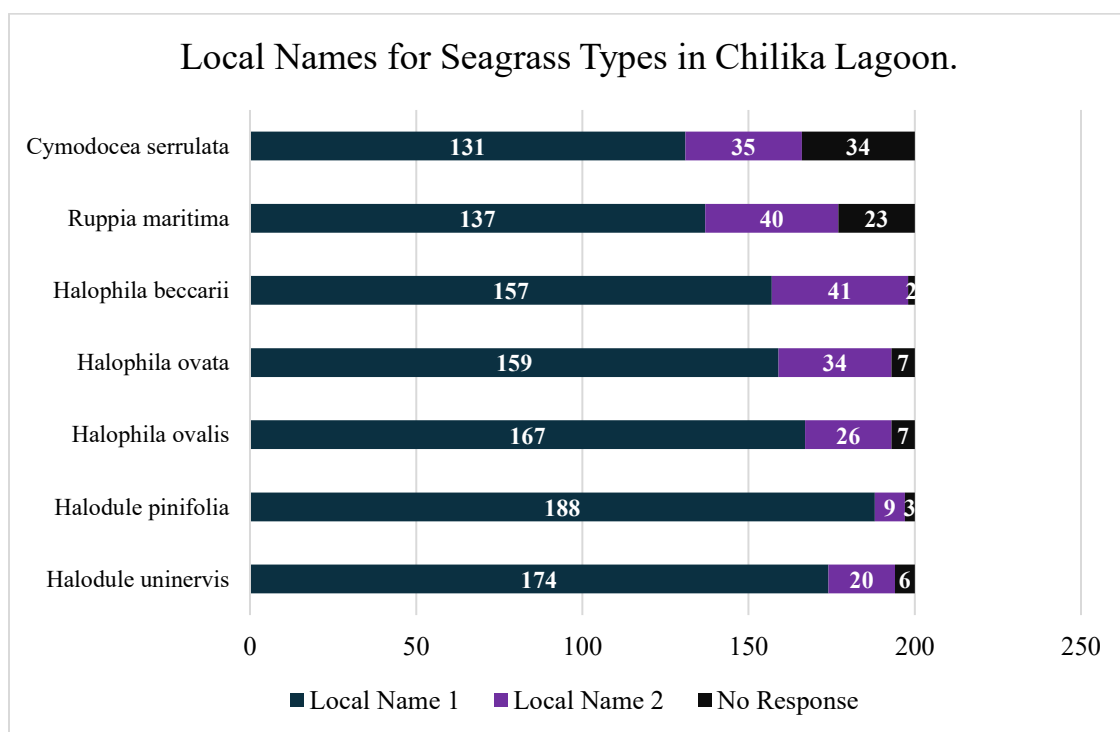


Figure 2.2 Local names of seagrass types in Chilika Lagoon based on 200 rapid surveys, highlighting frequency of responses and ‘No Response’ categories

Community perceptions of seagrass abundance varied significantly across the lagoon. Of the surveyed participants: 43 reported no seagrass presence near their villages; 51 observed low abundance and 83 reported moderate abundance, making this the most common perception. Only 1 participant identified with high abundance. 22 participants responded with “Don’t Know”, indicating variability in awareness or access to seagrass locations. This distribution reflects the uneven presence of seagrass meadows across sectors and highlights the need for further investigation into the factors affecting their growth and visibility. Participatory mapping exercises conducted in Barkul (Central Sector), Sipakuda (Outer Channel), and Sabulaya (Southern Sector) provided invaluable insights into the distribution and significance of seagrass meadows (Figure 2.4). These exercises revealed patterns of ecological knowledge and cultural significance not previously documented in scientific assessments. In Barkul, participants identified Kalijai Temple and Nalabana Island as central hubs for seagrass meadows. Nalabana, in particular, holds dual significance as both an ecological hotspot and a culturally restricted fishing zone. The participatory maps highlighted additional seagrass areas around Nalabana that were not prominently featured in the 2019 spatial distribution map, indicating potential gaps in earlier scientific research. This aligns with the community's emphasis on the ecological and cultural interconnectedness of the lagoon.

Data collected from rapid surveys ($n=200$), detailed surveys ($n=190$), and participatory mapping in three villages indicate that the presence of seagrass is concentrated in the Central, Southern, and Outer Channel sectors, with zero to minimal coverage in the Northern sector (Table 2.3). The radar chart (Figure 2.3) visualizes the percentage response from the community-based rapid survey on seagrass distribution across the four ecological sectors (see Table 1.1), illustrating the variability in seagrass presence and community knowledge. Categories include the absence of seagrass, low, moderate, high, and unknown levels of seagrass presence. It is important to note that the SSFs in this study are locally rooted communities who have engaged with the lagoon for generations. Many settlements date back several decades, with livelihood practices shaped by traditional fishing knowledge and recent adaptations to ecological changes. While not formally recognized as Indigenous Peoples, these communities hold deep relational ties to the lagoon, and their TEK reflects a long-standing interaction with the coastal environment.

Table 2.3 Observed distribution in seagrass coverage by ecological sector (Rapid Survey)

Ecological Sector	Communities Surveyed	Seagrass Presence	Species Observed	Community Knowledge
Northern	42	Low to none	N/A	Community referred to seagrass in southern and central sectors
Central	47	Moderate	<i>Halodule pinifolia</i> <i>Halodule uninervis</i> , <i>Halophila ovalis</i>	Nalabana Sanctuary identified as a hub of seagrass beds
Southern	74	Moderate	<i>Halodule uninervis</i> , <i>Halophila ovalis</i>	Seagrass present along the shoreline
Outer Channel	37	Low	<i>Halophila beccarii</i>	Excellent meadows near Arakhakuda

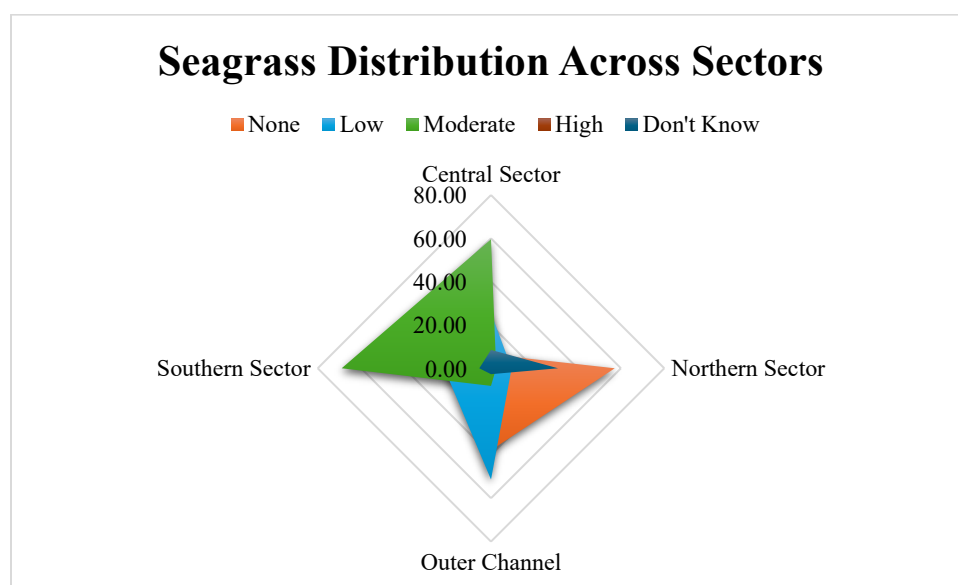


Figure 2.3 Seagrass distribution as perceived by the community based on a rapid qualitative survey conducted across four ecological sectors

The radar chart highlights the variance in local knowledge and ecological observations, with the Southern Sector showing the highest “Moderate” presence and the Northern Sector indicating a high “None” response. The Southern Sector, with the highest “Moderate” seagrass presence (68.92%), aligns with field observations where seagrass such as *Halodule uninervis* and *Halophila ovalis* is prevalent along the shoreline. Similarly, the Central Sector emerges as a key area in the survey (59.57% “Moderate”), corroborated by its ecological significance as a hub of

seagrass beds near the Nalabana Sanctuary, housing species like *Halodule pinifolia* and *Halophila ovalis*.

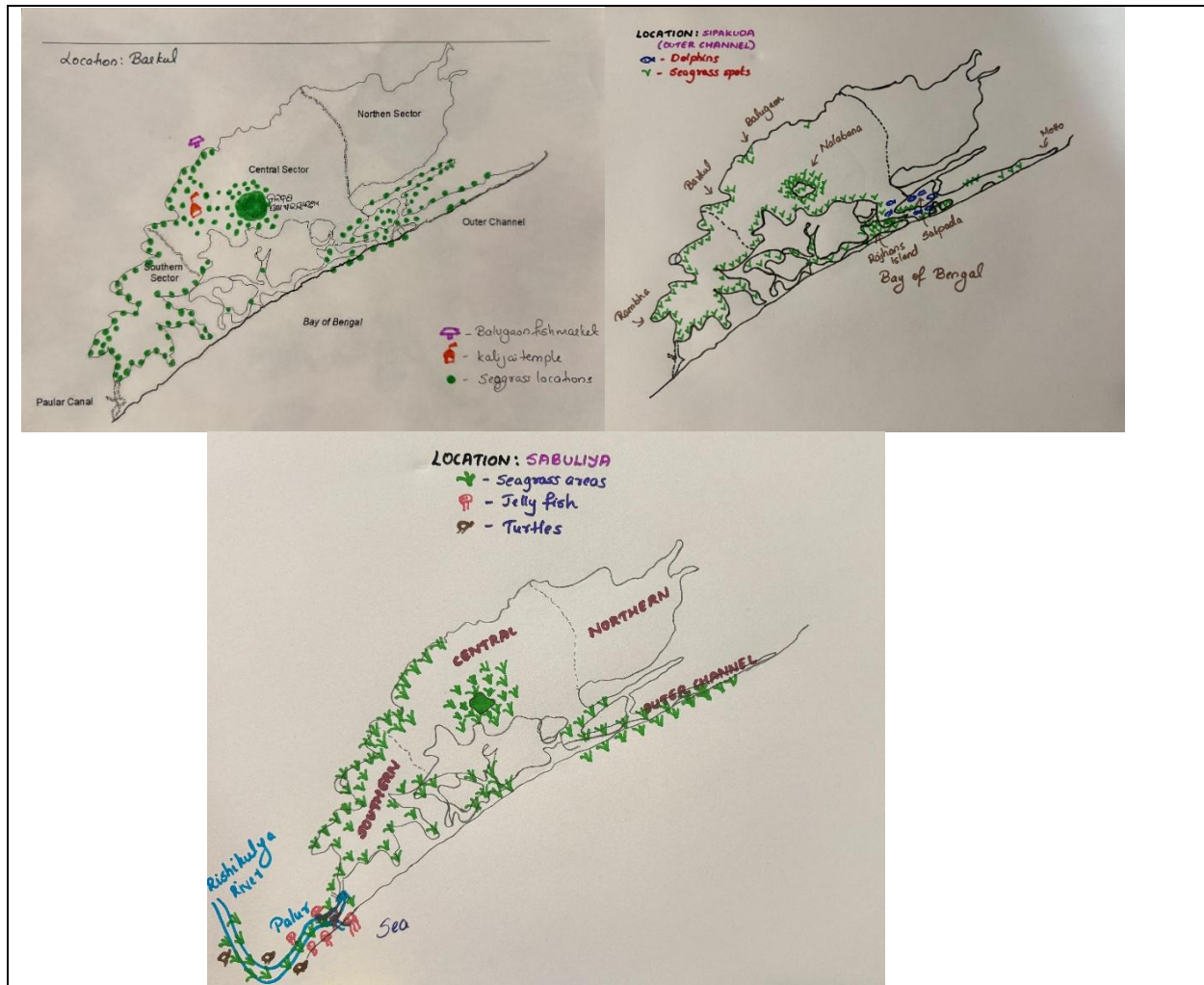


Figure 2.4 A map of Chilika Lagoon showing spatial distribution of seagrass meadows based on community input

In Sipakuda, respondents highlighted Nalabana and Rajhans Island as major seagrass habitats. These areas were also associated with dolphin activity, reinforcing the ecological importance of seagrass meadows in supporting broader biodiversity. Community maps (Figure 2.4) revealed more seagrass locations in this region compared to the 2019 map (Figure 2.5), suggesting either previously undocumented areas or dynamic changes in seagrass distribution over time. Participants from Sabulaya identified the Palur Canal and the Rishikulya River mouth as regions rich in seagrass. They also noted abundant populations of jellyfish and turtles in these areas, particularly near the Rishikulya River, further emphasizing the interconnectedness of

seagrass meadows with marine biodiversity. Nalabana and the Outer Channel were again mentioned as critical seagrass locations. These findings align with, but also expand upon, the 2019 spatial data by identifying additional underrepresented areas. Several key themes emerged across all mapping exercises: Nalabana Island consistently emerged as a vital hub for seagrass meadows. Its status as a restricted fishing zone adds complexity to its role, balancing ecological preservation with community livelihoods. Additional Seagrass areas were identified in all sectors, particularly around Nalabana, Rajhans Island, and the Palur Canal. These findings highlight the value of community knowledge in uncovering dynamic ecological changes or previously overlooked regions. Biodiversity and cultural significance were frequently mentioned, with seagrass meadows associated with species such as dolphins, turtles, and jellyfish, as well as culturally significant landmarks like Kalijai Temple.

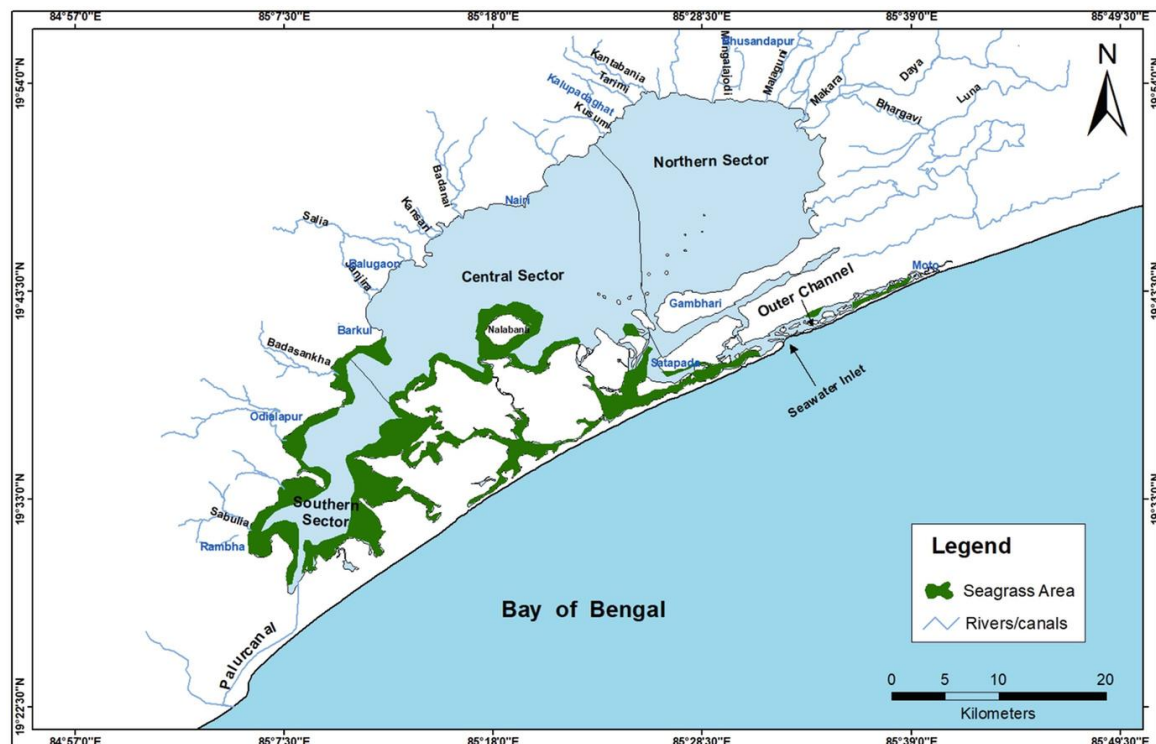


Figure 2.5 Spatial distribution map of seagrass meadows of year 2019 (Tripathy et al., 2021)

The participatory maps closely aligned with the 2019 published spatial distribution map, especially in the Central and Southern Sectors. However, community-driven mapping identified additional seagrass spots not recorded in the earlier data, such as those near the Palur Canal and Rajhans Island. These discrepancies underscore the dynamic nature of seagrass meadows and the critical role of local knowledge in complementing scientific research. The study highlights the

richness of community knowledge in understanding the distribution of seagrass meadows in Chilika Lagoon. The consistent emphasis on Nalabana Island as a key seagrass hub, along with the identification of additional locations, underscores the importance of incorporating community-driven data into conservation planning. The connections between seagrass meadows and broader biodiversity, including dolphins, turtles, and jellyfish, reaffirm the ecological significance of these habitats. This integrated approach provides a holistic understanding of the lagoon's ecosystems, offering valuable insights for sustainable management and conservation strategies. Results also showed moderate seagrass abundance in the Southern and Central sectors, with limited awareness in the Northern sector.

Mangroves are distributed across tropical and subtropical regions, typically found in coastal intertidal zones. These trees and shrubs are adapted to salty conditions and can tolerate flooding, making them invaluable for protecting coastlines from storm surges, erosion, and cyclones. Mangroves are also exceptional carbon sinks, storing up to five times more carbon than terrestrial forests. They are prevalent along the coasts of Southeast Asia, West Africa, Australia, and Central America. Mangrove forests cover an estimated 152,000 km² globally (Alongi, 2014). Southeast Asia, particularly Indonesia, houses the largest extent of mangrove forests, followed by Brazil and Nigeria (Jia et al., 2023; Basha, 2018). These forests thrive in estuarine environments where freshwater mixes with seawater, creating unique ecological conditions that support a diverse array of flora and fauna. In India, mangroves are mainly found in the Sundarbans, the Andaman and Nicobar Islands, and along the eastern and western coasts (Basha, 2018).

In the Chilika Lagoon, natural mangroves are absent, but significant plantation efforts were undertaken following cyclones in 2005 and 2015. These planted mangroves play a critical role in stabilizing the coastal zone and protecting against storm surges, even though local community awareness about their ecological importance remains limited. While organizations like the World Bank (2021) and Seacology (n.d.) report active community involvement in environmental restoration projects, such as planting mangroves and developing ecotourism to support local livelihoods, the on-ground reality indicates that these efforts are not always fully understood or valued by the entire community. For instance, Ramanath (2015) mentions that planted mangroves were introduced to safeguard biodiversity along the Chilika Lagoon, yet locals sometimes perceive these trees as a nuisance due to barnacles that attach to the roots, causing damage to fishing boats. Only a small segment of the community recognizes the mangroves' potential, using

them to shelter fishing equipment during cyclone alerts, highlighting an underappreciated benefit of these plantation efforts. Furthermore, community-driven participatory mapping reveals that while mangrove plantations are concentrated in the outer channels, the southern sector of the lagoon hosts significant seagrass meadows, essential for fisheries and coastal protection. Despite efforts reported in these articles (Figure 2.6) to involve and educate communities, the actual knowledge about these ecosystems-particularly the distribution and current state of planted mangroves-remains scarce. As these planted mangroves are not well-documented in local knowledge as well in journals, and the community members lacked specific information about their current status and distribution. This disconnect between reported community initiatives and actual community understanding underscores a gap in local awareness and documentation, with local perceptions often not aligning with the broader ecological goals promoted by conservation organizations.



Figure 2.6 Articles indicating mangrove plantation with community involvement

Identification of BCEs requires a multidisciplinary approach involving ecological surveys, community engagement, and spatial analysis. Surveys were conducted to assess the presence of

specific plant species and the overall health of the ecosystem. For instance, seagrass beds in Chilika Lagoon were identified through rapid surveys, which involved visually locating the plants and using photo identification to differentiate seagrasses from other aquatic vegetation. Detailed in-depth interviews with community members across the four sectors of the lagoon also provided insights into the perceived distribution of seagrass meadows. Engaging with local communities is essential for BCE identification, especially in regions where TEK can complement scientific data. Participatory mapping exercises in Chilika Lagoon helped local fishers and villagers pinpoint areas where seagrasses and planted mangroves were known to exist. These maps were crucial for understanding the spatial distribution of BCEs and integrating local knowledge into conservation strategies. GIS and RS technologies are valuable tools for mapping BCEs on larger scales. These technologies can detect changes in land cover, monitor the health of ecosystems, and provide a long-term view of carbon sequestration dynamics. However, in Chilika Lagoon, the unavailability of lab access and government data on water quality and seagrass distribution over the past decade limited the use of GIS in this particular study. The carbon content in the sediments beneath BCEs is a key indicator of their role in carbon sequestration. By analyzing soil samples from seagrass meadows, mangroves, and salt marshes, scientists can estimate the amount of carbon stored in these ecosystems. Although such analysis was not feasible in the Chilika study due to resource limitations, sediment characteristics remain a critical component in identifying BCEs .

2.4.2 Ecosystem Services of BCEs

Seagrass meadows, along with mangroves, are among the most productive ecosystems on Earth, playing vital roles in carbon sequestration, nutrient cycling, and providing nursery habitats for a wide range of marine species (Hemminga & Duarte, 2000). BCEs are increasingly recognized for their capacity to store large amounts of carbon, often referred to as “blue carbon”. These ecosystems are also linked to essential ES, contributing to food security, coastal protection, and biodiversity. Figure 2.7 illustrates the percentage analysis of responses highlighting the full range of ES -provisioning, regulating, supporting, and cultural-provided by seagrass in Chilika Lagoon. It categorizes services such as fishery enhancement, water quality regulation, sediment stabilization, biodiversity support, and community perceptions of cultural and ecological importance. The community insights from Chilika Lagoon reinforce the critical value these ecosystems hold for local livelihoods, biodiversity, and ecosystem health.

Provisioning Services: Provisioning services refer to the tangible goods and resources that these ecosystems provide, such as food and raw materials. Globally, seagrass meadows are crucial nursery grounds for commercially valuable species, including fish, crustaceans, and shellfish, which form the basis of coastal fisheries and livelihoods (Green & Short, 2003). Chilika’s communities noted that seagrass beds serve as key habitats for prawns and crabs, essential for sustaining the local fishing economy.

“We often find prawns and crabs in areas with thick seagrass meadows. These places are essential for our catch, especially for prawns”. [Interview Participant ISF09, Small-scale fisherman, Outer Channel]

Similarly, mangroves in Chilika, although primarily planted for cyclone protection, serve indirect provisioning benefits by protecting fishing equipment during storms. While the community did not actively harvest resources from the mangroves, these areas provide indirect benefits to their livelihoods.

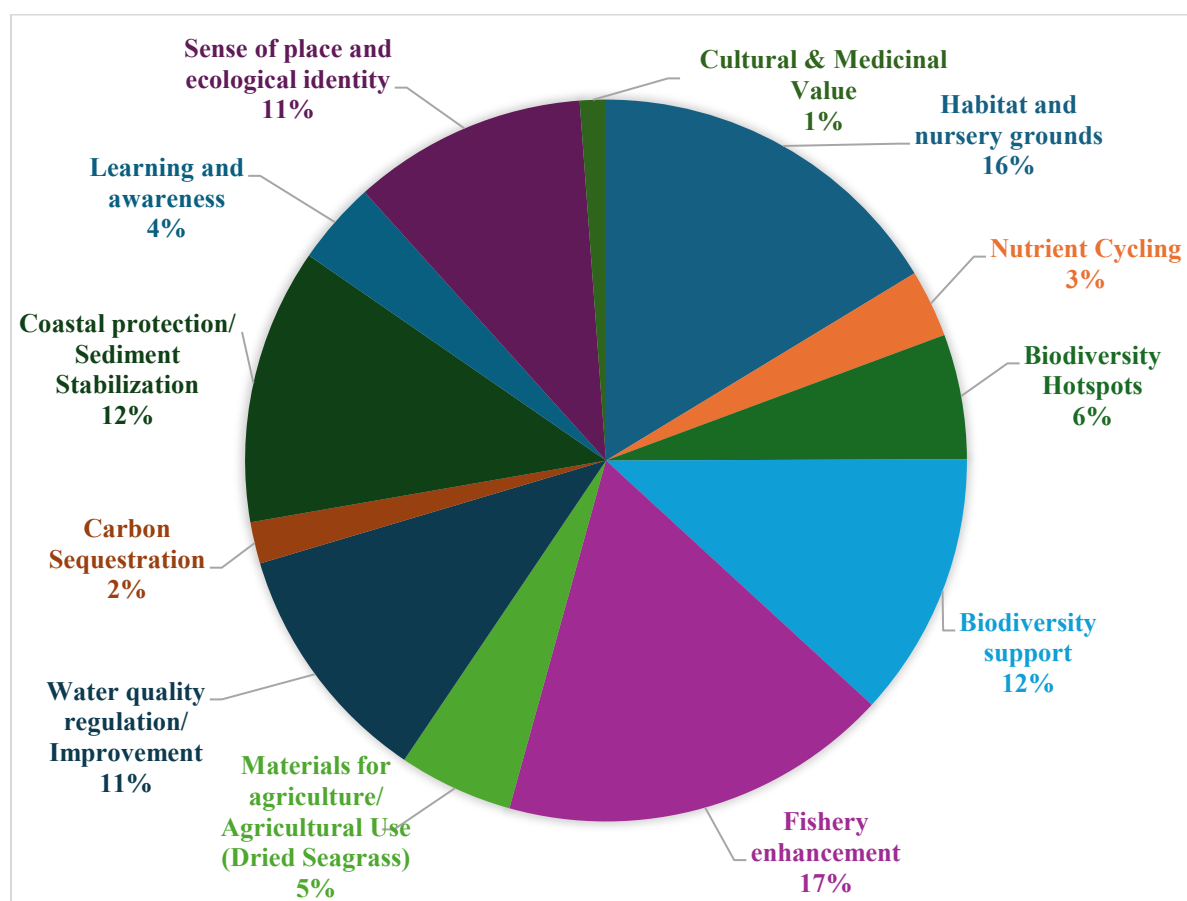


Figure 2.7 Detailed percentage analysis of responses highlighting ES provided by seagrass in Chilika Lagoon.

Regulating Services: Regulating services include carbon sequestration, coastal protection, and maintaining water quality. Seagrasses are recognized globally for their ability to sequester carbon in their root systems and sediments, which contributes to mitigating climate change (Duarte et al., 2005). In Chilika, local fishers mentioned the cooling effect of waters where seagrasses were dense, highlighting the role of seagrasses in regulating local water temperatures. Additionally, seagrass meadows stabilize sediments, reducing coastal erosion and protecting the shoreline from wave action.

“The water is cooler in areas with dense seagrass. The soil there is strong and doesn’t wash away easily”. [Interview Participant ISF02, Small-scale fisherman, Central Sector]

Similarly, mangroves play a critical role in coastal protection by acting as natural buffers against storm surges and cyclones, an ES appreciated by Chilika communities during cyclone alerts.

“We take our boats to the mangroves when a cyclone is coming. They help protect our nets and equipment from being washed away.” [Interview Participant ISF08, Small-scale fisherman, Outer Channel]

Globally, mangroves are also known to mitigate flooding, control erosion, and contribute to water purification by trapping sediments and pollutants, thereby improving overall water quality (Barbier et al., 2011).

Supporting Services: Supporting services are the ecological functions that maintain ecosystem health and biodiversity. Seagrasses and mangroves in Chilika provide vital nursery habitats for a wide variety of juvenile marine species, ensuring the sustainability of offshore fisheries and contributing to the biodiversity of the lagoon. Globally, seagrasses support a diverse range of species, including fish, invertebrates, and epiphytic algae, which are fundamental to marine food webs (Hemminga & Duarte, 2000).

“You can see many small fish and other creatures in the thick seagrass areas. It’s like a nursery for them.” [Interview Participant ISF12, Small-scale fisherman, Southern Sector]

Mangroves, despite being planted, also offer supporting services by maintaining biodiversity and providing habitat for birds, crabs, and other species. Although the community was not fully aware of the ecological importance of mangroves, they do acknowledge their role in providing safe spaces for boats during storms, indirectly supporting biodiversity by limiting human disturbance.

Cultural Services: Cultural services refer to the non-material benefits derived from ecosystems, such as recreation, spiritual significance, and educational value. In Chilika, the community expressed limited cultural connection to seagrass or mangrove ecosystems. There was no specific cultural or spiritual value attached to these ecosystems; however, community members did exhibit curiosity and willingness to learn about the environmental significance of seagrasses upon seeing research efforts. This indicates the potential for future educational and ecotourism opportunities.

“We didn’t know much about seagrass before, but after seeing you study it, we want to learn more about its importance.” [Survey Participant BAR-15, Small-scale fisherman, Central Sector]

Globally, mangroves often hold spiritual and cultural significance in various coastal societies. They are sites of traditional rituals, heritage conservation, and ecotourism activities. Seagrasses, although less associated with cultural services globally, are increasingly recognized for their aesthetic value and contribution to coastal ecotourism (UNEP, 2020). Table 2.4 captures community narratives that reveal how people perceive the ES provided by seagrass in Chilika. The community highlights supporting services, with seagrass seen as a habitat and nursery ground for small marine species, enhancing biodiversity, and contributing to nutrient cycling. Dense seagrass areas are often associated with cooler, clearer water, and are viewed as biodiversity hotspots with an abundance of fish, prawns, and crabs, especially juvenile species. Provisioning services include the enhancement of fisheries, although some community members have observed declines in fish abundance, attributed to changes like the opening of the sea mouth. Dried seagrass is also used in agriculture, recognized for its beneficial impact on soil quality.

Table 2.4 An ES chart for seagrass ecosystems, categorized into supporting, provisioning, cultural, and regulating services. This chart also includes community narratives to illustrate how the local people perceive and interact with these services (Source: Survey Responses)

Category	Ecosystem Service	Community Narratives
Supporting	Habitat and nursery grounds	<i>“We see a lot of small prawns and crabs in the seagrass areas. It’s like a nursery for them.”</i> [BIN-12] <i>“The water in the seagrass areas always feels cooler and full of life.”</i> [KAKH-07]
	Nutrient Cycling	<i>“The water near seagrass feels cooler and clearer than other places.”</i> [MO-06]
	Biodiversity Hotspots	<i>“There are more species of fish where the seagrass is dense.”</i> [NUA-02]

	Biodiversity support	<i>“There are more fish species where the seagrass is dense. It’s where you find different types of fish.” [PUR-11]</i> <i>“We catch a lot of prawns and crabs here.” [SAB-04]</i> <i>“I’ve noticed more juveniles of various species in these areas.” [MO-08]</i>
Provisioning	Fishery enhancement	<i>“We used to catch more fish from seagrass spots, but now there’s less because of the sea mouth opening.” [KHAS-08]</i> <i>“The dense seagrass spots provide a lot of species for us to fish.” [KAR-08]</i>
	Materials for agriculture/ Agricultural Use (Dried Seagrass)	<i>“I have seen dried seagrass taken to agricultural lands. It’s good for the soil.” [KAKH-03]</i> <i>“Some farmers use seagrass after it dries up; they say it helps the crops.” [MO-03]</i>
Regulating	Water quality regulation/ Improvement	<i>“The water is clearer in the seagrass areas, but pollution from aquaculture is affecting it.” [PUR-06]</i> <i>“We used to think seagrass makes the water cooler and cleaner, but now it’s being damaged.” [SAB-02]</i> <i>“There are fewer green patches in water near seagrass beds; it’s cleaner.” [SAB-11]</i>
	Carbon Sequestration	<i>“We don’t know much about it, but the seagrass helps keep the water cool.” [SIP-14]</i>
	Coastal protection/ Sediment Stabilization	<i>“The seagrass makes the soil strong. We’ve noticed it helps with the shorelines.” [SIP-08]</i> <i>“The floating seagrass is affected by the motorboats, but it helps hold the soil together.” [SIP-04]</i> <i>“The areas with seagrass have stronger soil, and they don’t erode easily.” [SAN-06]</i>
Cultural	Learning and awareness	<i>“We don’t know much about seagrass, but when you started studying it, we got curious. We want to learn more.” [SAM-11]</i> <i>“There’s no cultural use for seagrass, but it would be useful to learn more.” [SAM-07]</i>
	Sense of place and ecological identity	<i>“We see less seagrass now than 5-10 years ago, and it’s concerning us because we see fewer fish too.” [SAM-01]</i> <i>“It was strange at first, but now we want to know what else we can use seagrass for.” [MO-12]</i>
	Cultural & Medicinal Value	<i>“We don’t use seagrass for any medicine or special purpose.” [JAG-05]</i>

Regulating services are evident in the way seagrass improves water quality, aids in coastal protection by stabilizing sediment, and sequesters carbon, which some believe helps keep the water cooler. However, pollution and motorboat activity have negatively affected these benefits. Cultural services reflect an interest in learning more about seagrass, with some residents expressing concern over its decline. Seagrass, though not widely used for cultural or medicinal purposes, is valued for its role in supporting the ecosystem that shapes their sense of place and ecological identity. Overall, community members recognize both tangible and intangible benefits from seagrass, albeit with some concerns over its degradation. The southern and central sectors support extensive seagrass meadows, with the latter being particularly abundant around Nalabana Sanctuary, a region considered a hub for seagrass. However, there has been a notable decline in seagrass cover over the past 5–10 years, attributed to factors such as pollution from aquaculture, motorboat activity, and changes in hydrology following the opening of an artificial sea mouth. Mangrove distribution in Chilika is limited, with planted mangroves observed in certain areas. Community members had limited knowledge of the ecological significance of these ecosystems, though they acknowledged their role in cyclone protection. The prevalence of barnacles on mangroves discourages local use, and as a result, the potential of mangroves in providing ES such as coastal protection, supporting fisheries, and enhancing biodiversity remains underutilized in Chilika.

2.4.3 Ecological, Social, Cultural and Economic Significance of BCEs

The perceptions of local communities surrounding BCEs offer valuable insights into how these ecosystems are understood and valued at the grassroots level. In Chilika Lagoon, community interactions with seagrass meadows and mangroves reveal both direct and indirect relationships between ES and livelihoods. The data collected from surveys and interviews are highlighted in the framework (Figure 2.8) illustrating the multifaceted significance of BCEs in Chilika across four interconnected domains: ecological, social, cultural, and economic. The section now explicitly distinguishes significance from ES. ES refers to tangible and intangible benefits ecosystems provide, while significance relates to community-level perceptions and social-ecological interactions with BCEs. Community perceptions of BCEs are deeply tied to their everyday experiences and dependence on these ecosystems. Understanding these perceptions provides valuable insight into the ecological, social, cultural, and economic significance attributed to BCEs by the local populations. Ecologically, BCEs support biodiversity, regulate water quality

and climate, and provide critical habitats. Socially, they enhance community cohesion, disaster preparedness, and intergenerational knowledge. Culturally, BCEs foster emerging awareness, ecotourism potential, and evolving traditional ties. Economically, they sustain fisheries, provide indirect livelihood benefits, and offer untapped opportunities like carbon credits and ecotourism. This holistic view highlights the essential role of BCEs in ecological health, social-economic resilience, and cultural identity.

a) Ecological Significance

From an ecological standpoint, the communities living around Chilika Lagoon acknowledge the value of seagrasses and mangroves in maintaining the health of the lagoon's ecosystem, but their understanding is largely based on direct, observable benefits rather than detailed scientific knowledge. The majority of community members acknowledge the ecological roles of BCEs, particularly in relation to their immediate livelihoods, such as fishing. Many community members recognize that areas with dense seagrass beds are abundant with fish, prawns, and crabs, which are crucial to their daily catch. Seagrasses are perceived as a habitat that provides shelter and breeding grounds for various marine species, though there is limited awareness of the broader ecological services like carbon sequestration, nutrient cycling or sediment stabilization.

“Whenever we fish near the seagrass areas, the catch is good. The prawns and crabs hide there, and we know these places are rich in life.” [Interview Participant ISF13, Small-scale fisherman, Southern Sector]

“In areas with a lot of seagrasses, we catch more prawns and crabs. They seem to like it there because it's safer for them to grow.” [Interview Participant ISF11, Small-scale fisherman, Southern Sector]

The role of seagrass in maintaining water quality and reducing coastal erosion was less understood, though some fishers mentioned the cooler waters near dense seagrass meadows and the reduced movement of sediments in these areas. This observation aligns with scientific literature that emphasizes the ability of seagrasses to stabilize sediments and reduce turbidity in coastal waters (Duarte et al., 2005).

Mangroves, on the other hand, were largely perceived in terms of their protective value during cyclones. Community members recognized that mangroves act as natural buffers against storm surges, protecting their boats, nets, and other fishing equipment from being washed away.

Despite this appreciation, there was little awareness of the broader ecological functions of mangroves, such as their role in supporting biodiversity and regulating coastal water quality. The community did not extensively engage with mangroves for resources, partly due to the prevalence of barnacles, which made the areas less accessible for fishing activities.

“When a cyclone comes, we take our boats and equipment to the mangroves. They protect us from the storm’s waves.” [Interview Participant ISF09, Small-scale fisherman, Outer Channel]

“When the cyclone warnings come, we take shelter near the mangroves. They help reduce the strong winds and waves, protecting our boats and nets.” [Interview Participant ISF07, Small-scale fisherman, Outer Channel]

b) Social Significance

Socially, seagrass and mangrove ecosystems contribute to community cohesion through shared fishing practices and storm preparation activities. In Chilika, fishing is a communal activity, and many community members collaborate and share knowledge about seagrass-rich areas where fishing is the most productive. The knowledge of seagrass beds as key fishing grounds is often passed down through generations, though the deeper ecological importance of these ecosystems is less understood. During cyclone alerts, the community collectively takes refuge near mangroves, using these ecosystems for protection. This shared experience of utilizing natural systems during emergencies fosters a sense of community resilience and social solidarity. Mangroves, although seen as barriers during storms, also symbolize a space where local fishers can come together to face natural challenges.

“During the cyclone, we all gather near the mangroves. It's like a protective barrier for our fishing equipment, and we help each other through these times.” [Interview Participant ISF10, Small-scale fisherman, Outer Channel]

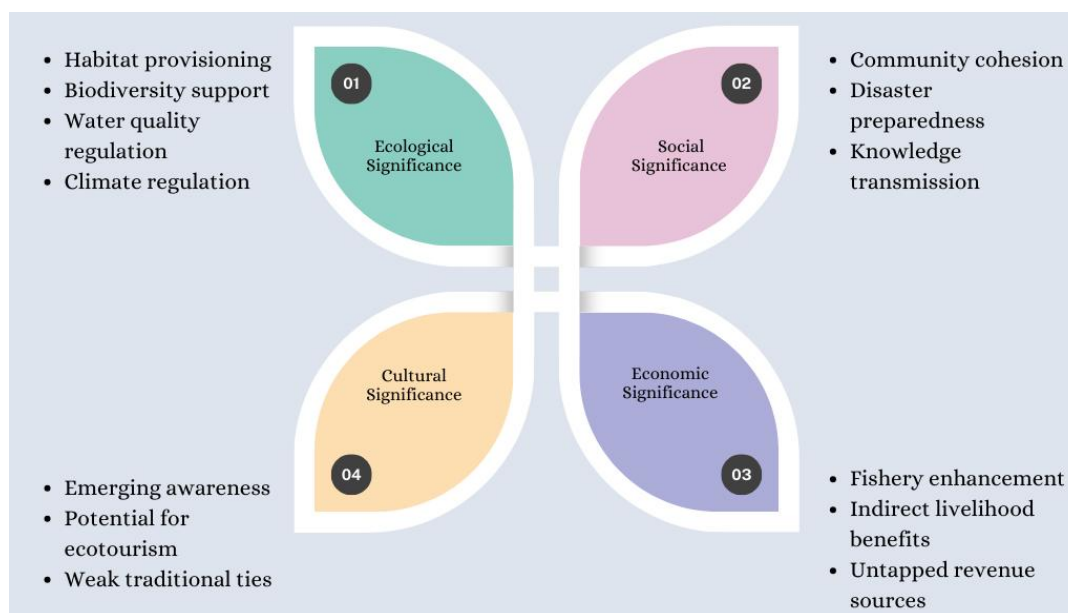


Figure 2.8 Comprehensive framework of BCE significance in Chilika Lagoon

c) Cultural Significance

Cultural connections to BCEs in Chilika Lagoon were relatively weak. While some communities around the world place spiritual and cultural significance on mangroves and seagrasses, in Chilika, these ecosystems were not widely regarded as culturally or spiritually significant. This may be partly due to the fact that mangroves in the area are mostly planted and relatively new, thus lacking deep-rooted cultural ties. Similarly, seagrass meadows did not appear to hold any spiritual or traditional value for the community. However, there is potential for increased cultural significance through education and awareness programs. The community demonstrated curiosity about the scientific importance of seagrasses and mangroves when informed of my ongoing study. The absence of traditional cultural connections does not preclude the future development of ecotourism or educational programs that could highlight the cultural value of these ecosystems.

“We didn’t know much about seagrass before, but seeing you study it has made us curious. Now we want to learn more about its importance.” [Interview Participant ISF05, Small-scale fisherman, Central Sector]

The community has expressed a desire to learn more about the broader roles of seagrasses and mangroves in maintaining the lagoon’s health, indicating potential for future cultural connection as conservation efforts and environmental education increase. This represents a significant opportunity to develop eco-cultural awareness among community members. In other

regions of the world, mangroves and seagrasses are integrated into cultural practices, rituals, and ecotourism activities. For example, in Southeast Asia, mangrove forests are used for heritage conservation and spiritual rituals, while seagrass meadows have been recognized for their aesthetic and recreational value in coastal ecotourism (UNEP, 2020). Chilika could similarly explore the cultural dimensions of BCEs, fostering a deeper connection between the community and these ecosystems.

d) Economic Significance

Economically, BCEs play a vital role in the livelihood of the Chilika community, primarily through the provisioning services they offer. Seagrass meadows provide essential habitat for economically important marine species, supporting both subsistence and commercial fisheries. Fishers rely heavily on seagrass ecosystems for their daily catch of prawns, crabs, and fish, which are critical sources of income. In particular, the community expressed concern over the recent decline in seagrass cover, which they attribute to pollution from shrimp aquaculture and changes in water flow following the opening of an artificial sea mouth. This decline has negatively impacted their fishing yields.

“The seagrass is disappearing, and it’s harder to catch prawns and crabs. We think it’s because of the dirty water and changes in the lagoon.” [Interview Participant ISF10, Small-scale fisherman, Outer Channel]

Mangroves also offer indirect economic benefits by protecting coastal infrastructure and reducing the damage caused by cyclones, thus safeguarding the economic activities of the community. However, the economic potential of mangroves, such as their use in sustainable forestry, fisheries, and ecotourism, remains largely untapped in Chilika.

“We leave our boats near the mangroves during the storm season. They act like a shield and save us from losing our fishing gear.” [Interview Participant ISF07, Small-scale fisherman, Outer Channel]

Mangroves, while not actively exploited for raw materials or food resources in Chilika, indirectly contribute to the economic resilience of the community. By protecting coastal infrastructure, boats, and fishing equipment during storms, mangroves help reduce economic losses from cyclone damage. This indirect economic benefit is significant, especially given the frequency of extreme weather events in the region. Globally, mangroves are known to contribute to sustainable livelihoods through the collection of timber, non-timber forest products, and the

support of adjacent fisheries (Alongi, 2012). While seagrass meadows in Chilika are directly tied to the fishing economy, their potential for carbon trading and climate finance is not yet realized. Globally, BCEs are recognized for their potential to generate revenue through blue carbon initiatives, where communities can receive financial incentives for protecting and restoring carbon-storing ecosystems (Pendleton et al., 2012). Such initiatives could be explored in Chilika as part of broader conservation and climate adaptation strategies.

2.4.4 Challenges, Drivers, and Impacts in BCE Conservation

The conservation of BCEs is critical for maintaining ecosystem health and supporting community livelihoods. Preservation and restoration of these ecosystems often face several challenges. These challenges stem from a mix of ecological, social, and governance factors. Understanding the dynamics of BCEs degradation and conservation requires a clear distinction between challenges, drivers, and impacts. This distinction helps identify immediate issues (challenges), their root causes (drivers), and the resulting effects on ecosystems and livelihoods (impacts). Derived from survey responses and stakeholder interviews, they provide a detailed breakdown of environmental, anthropogenic, social-economic, cultural, and institutional factors impacting the health and sustainability of BCEs like seagrass meadows and mangroves. The conceptual diagram (Figure 2.9) categorizes the interrelated challenges (e.g., habitat degradation, overfishing), their underlying drivers (e.g., artificial sea mouths, lack of education), and associated ecological and social impacts (e.g., reduced biodiversity, ecosystem degradation). It builds a visual pathway connecting causes and consequences across four key domains: environmental, anthropogenic, social-economic-cultural, and institutional-policy.

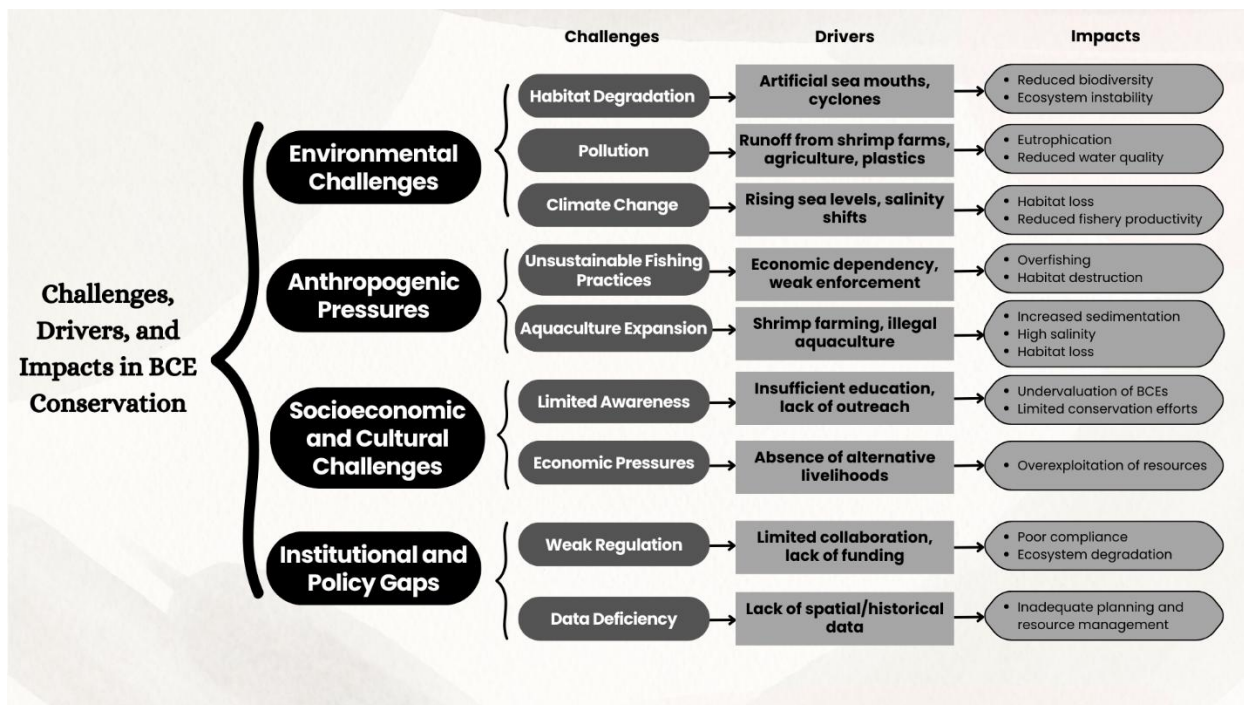


Figure 2.9 Key challenges, drivers, and impacts in BCE Conservation

Environmental Challenges

Environmental challenges facing BCEs in Chilika Lagoon are primarily driven by habitat degradation, pollution, and climate change (Table 2.5). Challenges, such as the loss of seagrass density and mangrove health, result from drivers including human interventions like artificial sea mouth construction, agricultural runoff, and aquaculture expansion. These activities disrupt natural water flows, leading to increased sedimentation and smothering of seagrass beds, compounded by eutrophication from excessive nutrient runoff. Cyclones and rising salinity, spurred by climate change, further destabilize these ecosystems. The impacts of these challenges are severe, manifesting as biodiversity loss, declining fish populations, and reduced water quality. For example, 63% of survey respondents highlighted habitat degradation as a pressing issue, citing reduced seagrass coverage due to sedimentation. A participant noted, “*Ever since the artificial sea mouth was opened, the water doesn’t flow properly, and more weeds have taken over, which makes fishing harder. We don’t see as much seagrass as we used to.*” [SIP-12, Outer Channel]. Pollution exacerbates these challenges, with 71% identifying shrimp farm waste and agricultural runoff as significant contributors to seagrass decline. These environmental pressures culminate in diminished ecosystem resilience, threatening both biodiversity and the livelihoods dependent on healthy BCEs.

Table 2.5 Key environmental challenges affecting BCEs in Chilika Lagoon

Challenges	Insights from Responses
Habitat Degradation	• 63% noted reduced seagrass density due to sedimentation caused by artificial sea mouths (e.g., BAR-03, BIN-01, SIP-10) • Cyclones causing uprooted seagrass were identified by 55% (e.g., SIP-12, KAR-15), emphasizing the vulnerability of these habitats
Pollution	• 71% identified agricultural runoff, shrimp farms, and plastic waste as major factors suffocating seagrass (e.g., MO-13, SIP-15)
Biodiversity Loss	• 57% attributed shrimp farms to disrupting fish breeding and biodiversity (e.g., PUR-13, KAR-09) • Overfishing of juvenile fish reported by 49% (e.g., SAB-08) exacerbates this loss
Climate Change	• 40% noted rising salinity and sea levels as major threats to habitat (e.g., BIN-05, SAN-15)

Anthropogenic Pressures:

Human-induced factors, or anthropogenic pressures, are significant contributors to BCE degradation. Challenges, such as unsustainable fishing practices and aquaculture expansion, arise from drivers including economic dependence on fisheries and inadequate regulatory enforcement (Table 2.6). Fishers often use destructive gear, such as fine-mesh nets, which damage seagrass beds and trap juvenile fish. Additionally, shrimp farming and aquaculture facilities increase sedimentation and salinity, further degrading the lagoon's habitats. The impacts of these pressures are widespread, with overfishing disrupting ecological balance and aquaculture pollution impairing water quality. Approximately 58% of respondents identified unsustainable fishing practices as a major issue, with one fisherman commenting, *"People are using zero nets that trap even the small fish even after the government ban. If we don't stop this, there won't be any fish left to catch in the coming years."* [SAB-07, Southern Sector]. Furthermore, 61% of respondents noted that shrimp farming significantly affects sedimentation and salinity levels, leading to habitat loss. These pressures not only damage BCEs but also undermine the long-term sustainability of fisheries, exacerbating economic vulnerabilities for local communities.

Table 2.6 Anthropogenic pressures on BCEs in Chilika Lagoon

Challenges	Insights from Responses
Unsustainable Fishing Practices	• 58% reported destructive fishing practices, such as drag and fine-mesh nets, damaging seagrass beds (e.g., SAB-08, KHAK-06) • 47% raised concerns about overfishing impacting fish stocks and ecosystem balance (e.g., SAN-07)
Aquaculture Expansion	• 61% noted shrimp farming impacts, including increased sedimentation, salinity, and pollution (e.g., PUR-13, SIP-07)

Social-economic and Cultural Challenges:

The social-economic and cultural challenges in conserving BCEs stem from drivers such as limited community awareness and economic pressures. Challenges, including undervaluation of BCEs and overexploitation of resources, are driven by the lack of education on the ecological roles of seagrass and mangroves, coupled with the absence of sustainable livelihood alternatives. For instance, while communities recognize seagrass as a breeding ground for prawns and crabs, only 35% are aware of their broader functions, such as carbon sequestration. A participant remarked, “*We didn’t know much about seagrass before, but seeing you study it has made us curious. Now we want to learn more about its importance.*” [SAM-11, Central Sector]. The impacts of these challenges include resource depletion, reduced ecosystem health, and ongoing habitat exploitation. Economic pressures drive unsustainable practices, such as overfishing and habitat conversion for shrimp farming, with 50% of respondents citing financial dependency as a primary driver of habitat loss. These factors perpetuate a cycle of environmental degradation and economic vulnerability, highlighting the need for education and sustainable livelihood programs to align conservation efforts with community well-being.

Table 2.7 Social-economic and cultural challenges in BCE conservation

Challenges	Insights from Responses
Limited Awareness	35% expressed willingness to learn about BCE protection and seagrass importance (e.g., SAB-01, KHAK-09) 15% mentioned cultural ties to seagrass (e.g., Nalabana) but lacked detailed understanding of its ecological role (e.g., BAR-01)
Economic Pressures	50% cited overfishing driven by economic dependence as a key driver of habitat loss and unsustainable practices (e.g., KAR-09)

Institutional and Policy Gaps

Institutional and policy gaps present significant obstacles to effective BCE conservation. Challenges, such as weak enforcement of environmental regulations and a lack of historical data on ecosystem health, arise from drivers including inadequate collaboration between communities and governing bodies, as well as limited resource allocation (Table 2.8). Approximately 70% of respondents criticized the poor enforcement of fishing bans and pollution control measures, with one fisherman stating, “*Decisions about the lagoon are often made by people who don’t fish here. If we could be part of the meetings, we could give valuable input.*” [KHAS-14, Outer Channel]. The impacts of these challenges include fragmented conservation efforts and ineffective policies that fail to integrate local knowledge. Without comprehensive data-sharing and participatory governance frameworks, conservation initiatives remain disjointed, leaving critical gaps in policy implementation. Additionally, 38% of respondents highlighted the absence of data-sharing mechanisms, which hinders the development of evidence-based strategies for protecting BCEs. Strengthening institutional support and fostering collaboration with local communities are essential steps toward addressing these governance shortcomings.

Table 2.8 Institutional and policy gaps hindering BCE conservation in Chilika Lagoon

Challenges	Insights from Responses
Data Deficiency	• 38% noted a lack of data-sharing from researchers and officials, making conservation efforts difficult (e.g., MO-13, PUR-03)
Weak Enforcement of Regulations	• 70% criticized the poor enforcement of laws related to illegal fishing and pollution control as barriers to conservation (e.g., SIP-10)

Figure 2.10 illustrates the proportion of survey respondents identifying specific challenges across four main categories. The chart reveals that pollution (71%), weak enforcement of regulations (70%), and habitat degradation (63%) were the most frequently identified challenges, emphasizing the need for targeted interventions in these areas. Anthropogenic pressures, such as unsustainable fishing (58%) and aquaculture expansion (61%), are significant contributors to ecosystem degradation. Social-economic challenges like economic pressures (50%) and limited awareness (35%) underscore the importance of integrating community education and sustainable livelihood initiatives. Institutional gaps, including data deficiencies (38%), further highlight the need for improved documentation and enforcement mechanisms. This visualization underscores

the interconnectedness of environmental, economic, and policy-related challenges in BCE conservation, providing actionable insights for targeted management strategies.

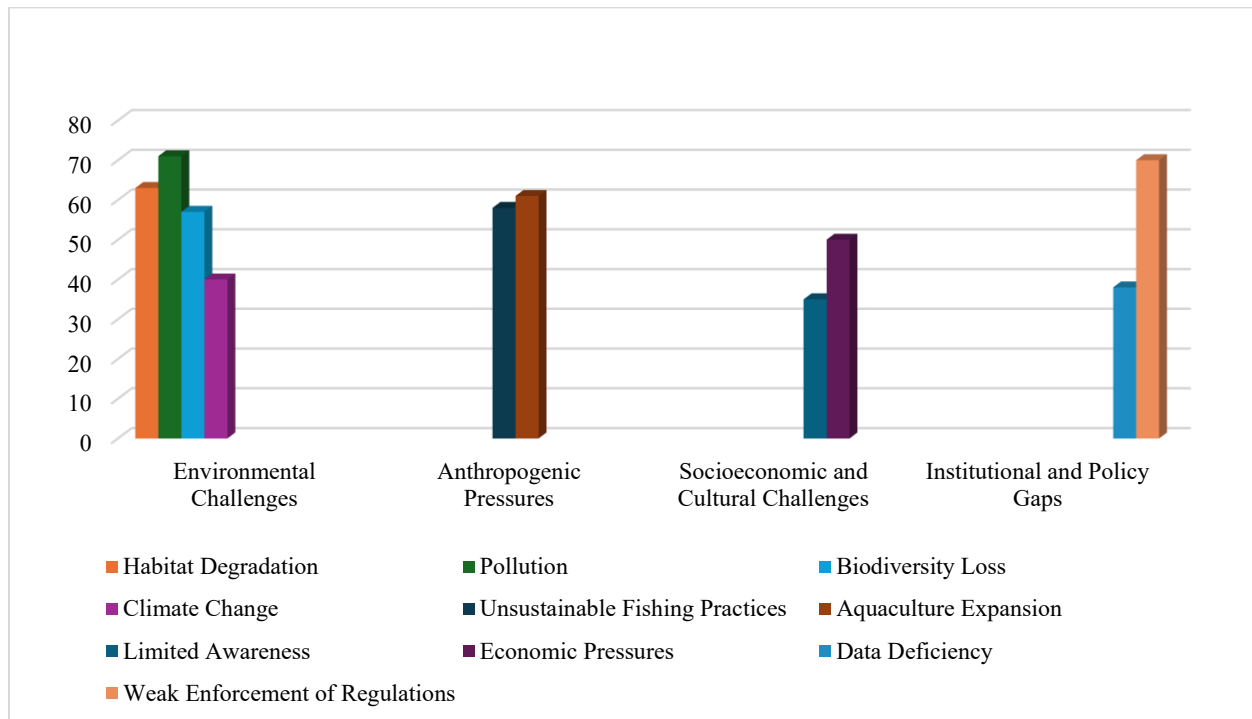


Figure 2.10 Percentage distribution of challenges identified in Chilika Lagoon based on survey responses (Source: Survey Responses)

The conservation of BCEs in Chilika is hindered by interconnected environmental, human, and governance challenges. The insights from community perceptions and participatory analysis illustrate not only the ecological impacts but also the systemic social-political deficiencies that exacerbate vulnerability. Tackling these issues requires a shift toward inclusive, ecosystem-based, and community-driven strategies that integrate TK with scientific and policy frameworks. Together, Figures 2.9 and 2.10 provide a roadmap for designing targeted interventions that address both the symptoms and root causes of ecosystem degradation in Chilika Lagoon.

2.4.5 Opportunities

Despite the significant challenges facing BCE conservation, the findings highlight the critical role of TEK in identifying seagrass distribution and understanding community perceptions of BCEs. While fishers recognized seagrass as a nursery habitat, awareness of its broader ecological functions remains limited. Participatory mapping revealed discrepancies between scientific data and community observations, emphasizing the need for co-management

approaches. The proposed opportunities (summarized in Table 2.9) focus on enhancing community engagement, increasing education and awareness, and embedding conservation efforts within broader policy frameworks.

Education and Awareness Programs: Raising awareness about the ecological and social-economic value of seagrass meadows and mangrove ecosystems remains a cornerstone for effective conservation. Community education programs can demystify the interconnectedness of these ecosystems and their role in fisheries, coastal protection, and climate regulation. Responses from participants underscored the importance of integrating local knowledge into these programs. For instance, educating children and youth about BCEs through school curricula and community workshops can instill long-term stewardship. By combining TEK with scientific insights, such programs can empower communities to participate actively in conservation.

“Our children play by the lagoon and sometimes even fish with us. If they learned about protecting seagrass and fish in school, they could grow up understanding its value.” [Survey Participant BAR-07]

Community-Led Restoration and Conservation Initiatives: Engaging local communities in restoration projects provides both ecological and social-economic benefits. Training programs on ecosystem monitoring, mangrove planting, and sustainable fishing methods can equip communities with valuable skills, fostering a sense of ownership and stewardship. Many respondents expressed a willingness to participate in initiatives such as replanting seagrass and monitoring water quality, emphasizing their vested interest in the lagoon's health for future generations.

“If someone could teach us how to replant and protect seagrass, we’d work together for the future of our children.” [Survey Participant BAR-03]

Such community-driven efforts not only enhance ecosystem resilience but also empower local populations by creating employment opportunities and improving their connection to conservation outcomes.

Table 2.9 Opportunities for enhancing BCE conservation in Chilika Lagoon (Source: Survey Responses)

Opportunity Category	Key Actions Identified	Example Quotes/Responses
Education and Awareness	Develop community-based education programs to highlight the importance of seagrass and mangroves	<i>“Most of us don’t fully understand how important seagrass is to fish and the lagoon’s health. If we had education programs in the village, we could learn more.”</i> [BIN-07]
	Introducing school curricula on lagoon conservation and sustainable practices	<i>“If our children learned about how to care for the lagoon in school, they’d grow up knowing how important it is.”</i> [KAR-12]
	Provide community workshops on conservation and sustainable fishing practices	<i>“If someone could teach us how to replant and protect seagrass, we’d work together for the future of our children.”</i> [BAR-03]
Community-Led Restoration	Train locals in ecosystem monitoring, restoration techniques, and sustainable fishing methods	<i>“We want to help with conservation, but we need tools and training. If we were taught how to monitor water quality or manage seagrass meadows, we’d do our part.”</i> [KHAK-05]
	Organize restoration projects like seagrass replanting and mangrove planting	<i>“If we all worked together to plant and restore seagrass, it would bring back the fish and crabs. The lagoon would heal.”</i> [BER-13]
	Establish community-based lagoon monitoring programs	<i>“If we were taught how to monitor water and seagrass, we could help protect it ourselves.”</i> [BAR-11]
Sustainable Livelihood Alternatives	Promote ecotourism, including guided tours and bird-watching, as an alternative income source	<i>“Tourists come to Chilika to see its beauty. If we set up eco-tourism ventures, like guided boat tours, we could earn money while teaching visitors about the lagoon’s importance.”</i> [NUA-02]
	Support skills training in boat repair, crafts, or other eco-friendly small businesses	<i>“If we had skills training in things like repairing boats, making crafts, or eco-tourism, we wouldn’t have to rely only on fishing.”</i> [BIN-01]
	Facilitate access to better tools and sustainable fishing gear	<i>“If we had better fishing tools that didn’t harm the lagoon, we’d use them. Right now,</i>

		<i>we use what's cheap, but it might damage the seagrass."</i> [KAR-08]
Policy Integration and Co-Management	Involve communities in decision-making and co-management plans for the lagoon.	<i>"Decisions about the lagoon are often made by people who don't fish here. If we could be part of the meetings, we could give valuable input."</i> [KHAS-14]
	Incorporate TEK into regional policies	<i>"We've been fishing here for generations and know the lagoon like no one else. If the government listens to our ideas, we could create better rules to protect the lagoon."</i> [BER-11]
	Develop seasonal fishing bans and clear fishing guidelines to protect biodiversity.	<i>"Fishermen should be aware of the rules and avoid catching small fish or hatchlings to protect fish populations."</i> [SAM-06]
Financial Incentives	Offer PES or financial rewards for conservation work	<i>"If the government or NGOs could give us money to help protect the lagoon, we would feel more motivated to keep it clean."</i> [SAM-11]
	Provide carbon credit opportunities for preserving wetlands and restoring seagrass	<i>"We've heard about carbon credits. If we could get some of that money, it would help us protect the lagoon and reduce migration for work."</i> [SAN-09]
	Support alternative income programs during fishing bans or low-catch periods.	<i>"When the fish are fewer, we struggle. If the government or NGOs gave us financial support during these times, we wouldn't need to overfish."</i> [MO-05]

Sustainable Livelihood Alternatives: BCEs offer significant potential for alternative income generation through activities like ecotourism and sustainable fishing. Ecotourism initiatives that showcase the biodiversity of BCEs and involve local communities as guides and educators can provide a steady income while fostering environmental awareness among visitors. Respondents frequently mention the potential of eco-tourism to alleviate economic pressures while promoting conservation.

"Tourists come to Chilika to see its beauty. If we set up eco-tourism ventures, like guided boat tours or bird-watching trips, we could earn money while teaching visitors about the lagoon's importance." [Survey Participant NUA-02]

Additionally, sustainable fishing practices-supported by training, better fishing gear, and seasonal fishing bans-can improve long-term fish stocks and ensure economic resilience. Respondents stressed the need for education and government support to transition to such methods effectively.

“If we had better fishing tools that didn’t harm the lagoon, we’d use them. Right now, we use what’s cheap, but it might damage the seagrass or catch too many fish” [Survey Participant

KAR-08]

Policy Integration, Collaborative Management, and Incentives for Conservation: Integrating community-driven conservation strategies into formal management frameworks is a critical opportunity for enhancing BCE conservation. Co-management strategies, where government agencies, NGOs, and local communities collaborate on planning and implementation, were frequently cited as a means to foster trust and shared responsibility. Respondents emphasized the importance of recognizing and incorporating their TK into policies and decision-making processes.

“We live here and depend on this lagoon, so we know how important it is to keep it healthy. If we’re taught how to care for the seagrass and monitor the fish, we’d feel responsible for keeping this place alive.” [Survey Participant BIN-11]

Incentives such as PES, financial rewards for conservation work, and support for sustainable livelihoods (e.g., eco-tourism and carbon credits) were highlighted as critical enablers. Such mechanisms can motivate widespread community participation while addressing immediate economic pressures.

“We are struggling. If we receive any financial help for keeping the ecosystems healthy, we would be willing to protect the seagrass and mangroves.” [Interview Participant IWO05,

Fisherwoman, Outer Channel]

Table 2.10 presents a heatmap summary of the most cited opportunities based on respondent frequency. It shows that community workshops (63%), seagrass replanting (50%), and co-management plans (53%) were among the most frequently mentioned interventions. This data-driven table reinforces the narrative by identifying priority areas of engagement and illustrating community interest in co-developed solutions for conservation.

Table 2.10 Heatmap chart of opportunities for community-driven BCE conservation
(Source: Survey Responses)

Opportunity Category	Subcategory	Respondent Count	% of Total Respondents
Education and Awareness	Community workshops	120	63%
	School-based programs	80	42%
Community-Led Restoration	Seagrass replanting	95	50%
	Ecosystem monitoring	65	34%
Policy Integration	Co-management plans	100	53%
	Involving community in decision-making	85	45%
Financial Incentives	Payments for ecosystem services	70	37%
	Support for alternative livelihoods	60	32%

The findings emphasize the interdependence between ecological conservation and social-economic well-being. Opportunities such as education, community-led restoration, policy integration, and financial incentives not only address conservation goals but also promote sustainable livelihoods. These initiatives have the potential to transform BCE conservation into a holistic, community-driven effort by fostering collaboration among communities, governments, and NGOs, and integrating TEK with scientific knowledge.

2.5 Key Findings

The study revealed that local knowledge of seagrass meadows in Chilika Lagoon is rich in descriptive detail and practical ecological insight, despite gaps in formal taxonomy. Community participants often referred to seagrass using names like *Pathiri Dollo* (thin grass) or *Chingudiya*

Dollo (prawn grass), reflecting either physical traits or the species' association with important aquatic fauna such as prawns and crabs. This linguistic ecology highlights a foundational understanding of ecosystem function, even though scientific distinctions between species remain unclear. Participatory mapping, combined with photo identification, enabled the identification of seven distinct species underscoring the value of integrating TEK with formal ecological research. While local communities recognize the role of seagrass meadows as breeding and nursery grounds, their understanding of broader ecological functions-such as sediment stabilization, water purification, and carbon sequestration-was limited. Only a third of respondents associated seagrass with regulating climate, even as most recognized pollution and eutrophication as threats. This disconnect illustrates the need for targeted educational interventions that bridge immediate, tangible ES with abstract benefits like climate mitigation. Participants expressed curiosity and openness to learning, suggesting strong potential for conservation awareness programs that align with community experiences and values.

Participatory mapping exercises further revealed the existence of ecological hotspots that were either absent or underrepresented in scientific data from 2019. Local knowledge highlighted sites such as Nalabana Sanctuary, Rajhans Island, and Palur Canal as seagrass-rich areas, pointing to discrepancies between observed ecological conditions and formal documentation. These findings reinforce the importance of including TEK in spatial assessments to fill knowledge gaps and identify emerging zones of ecological significance. By aligning community insights with scientific mapping, more adaptive and inclusive management strategies can be designed to reflect the dynamic nature of coastal ecosystems. At the same time, economic dependence on lagoon-based livelihoods emerged as a significant driver of unsustainable practices. Communities reported increased use of destructive fishing gear and conversion of habitat for shrimp aquaculture, contributing to habitat degradation, sedimentation, and salinity shifts. Many fishers acknowledged the long-term consequences of these practices but cited economic necessity and lack of alternatives as limiting factors. Interest in ecotourism, financial incentives like PES, and diversified livelihoods was high, indicating that community members are willing to shift toward sustainable practices if appropriately supported. Such interventions can reduce pressure on BCEs while improving economic resilience.

However, the study also found that cultural affiliations with BCEs remain weak compared to other resources like fish or farmland. This absence of symbolic or ritual value for seagrass and

mangrove habitats may limit community motivation for conservation in the absence of tangible benefits. Moreover, governance challenges, including limited community participation in decision-making and weak enforcement of fishing regulations, further undermine effective conservation. Several respondents voiced frustration over top-down policies made without fisher involvement, suggesting that incorporating TEK into policy frameworks and co-management plans could significantly enhance local ownership and compliance. Despite these challenges, the research revealed a strong willingness among community members to engage in conservation activities if provided with the necessary training and resources. Many expressed interest in hands-on efforts such as seagrass replanting, mangrove restoration, and ecosystem monitoring. These findings underscore the value of community-led restoration as both an ecological and social-economic strategy, offering opportunities for employment, stewardship, and local capacity building. Empowering fishers to become active participants in conservation not only strengthens the legitimacy of interventions but also promotes a more resilient relationship between people and place.

Education emerged as a transformative opportunity across all sectors and age groups. Respondents repeatedly emphasized the need to include BCE awareness in school curricula and community-based workshops. By engaging children and youth-many of whom already interact with the lagoon through family fishing activities-these programs could foster intergenerational stewardship and ensure long-term sustainability. Educational initiatives that combine visual tools, storytelling, and local knowledge have the potential to demystify complex ecological concepts and build a conservation ethic rooted in community identity. Overall, the study illustrates that while significant gaps remain, Chilika's communities possess both the willingness and contextual knowledge needed to lead in BCE conservation-provided they are empowered through inclusive governance, economic alternatives, and sustained education.

2.6 Conclusions

The findings revealed that participatory mapping identified seven seagrass species, underscoring community familiarity with BCEs. Gaps in earlier scientific records were highlighted, emphasizing the importance of integrating TEK into formal assessments. Key challenges included habitat degradation, pollution, overfishing, and weak policy enforcement. Opportunities for conservation were identified in community-led restoration, education programs, and policy integration. The study underscores the vital role of community-driven conservation in

safeguarding BCEs like seagrass meadows in Chilika Lagoon. By combining participatory mapping and TEK, the study identified significant ecological, social, and economic benefits of BCEs while addressing pressing challenges like habitat degradation and limited awareness. The findings advocate for inclusive conservation strategies that integrate local knowledge with scientific insights. Key recommendations include scaling up community-led restoration, fostering educational initiatives, and implementing co-management frameworks with financial incentives like PES. This approach can ensure sustainable management of BCEs, fostering resilience against climate change while supporting local livelihoods.

Chapter III

Social-Ecological Interdependencies: Community Perspectives on Water Quality in Chilika Lagoon

3.1 Abstract

Water quality is a critical determinant of ecosystem health, influencing biodiversity, human livelihoods, and ecological stability. In Chilika Lagoon, water quality is a central factor driving both the ecological balance of the lagoon and the sustainability of the SSFs that many local communities depend on. However, water quality in the lagoon has been steadily declining due to a combination of anthropogenic pressures, including shrimp aquaculture, agricultural runoff, industrial waste discharge, and tourism, alongside natural factors such as sedimentation and cyclones. Declining water quality directly threatens biodiversity, habitat health, and the social, ecological and economic well-being of dependent communities. This study investigates the drivers and impacts of water quality changes in Chilika Lagoon through a mixed-methods approach by prioritizing community involvement and leveraged ethno-hydrological knowledge to complement scientific insights. The core research gap addressed here is the limited incorporation of local knowledge and lived experiences of the community into formal water quality monitoring and management frameworks that can complement, at the least, the existing scientific datasets. Key findings highlight that water quality degradation is driven by pollution, overfishing, invasive species, and climate change, resulting in significant ecological, social, and economic impacts. Eutrophication, habitat loss, and declining fish populations were frequently reported, alongside social-economic challenges such as reduced income, increased fishing effort, and health issues. Despite government interventions like the Ban on Zero Net Fishing and mangrove plantation efforts, community perceptions revealed widespread dissatisfaction with their effectiveness due to poor enforcement and lack of community engagement. Adaptive responses by fishers included shifts in fishing practices, livelihood diversification, and limited conservation efforts, underscoring their resilience and capacity for sustainable resource management. The study underscores the critical role of integrating local ecological knowledge with scientific monitoring to address water quality issues. It calls for collaborative governance frameworks, enhanced enforcement of regulations, and community-based conservation initiatives to ensure the ecological health and

social-economic sustainability of Chilika Lagoon. The findings contribute to understanding the complex social-ecological dynamics of lagoon systems and provide actionable insights for sustainable management strategies.

Keywords: Chilika Lagoon, Water quality, Small-scale fisheries (SSFs), Eutrophication, Social-ecological systems

3.2 Introduction

Water quality serves as a critical indicator of ecosystem health, directly influencing biodiversity, ecological processes, and human livelihoods. In aquatic systems, it determines species composition, habitat conditions, and the productivity of ecosystems, making it a central focus for environmental management. In Chilika Lagoon, India's largest brackish water ecosystem and a Ramsar-designated wetland of international importance, water quality plays an essential role in maintaining ecological balance and supporting the social-economic well-being of the fishing communities dependent on SSFs. However, in recent decades, Chilika Lagoon's water quality has been steadily declining due to both anthropogenic pressures and natural factors. Chilika Lagoon faces complex challenges stemming from both natural and anthropogenic factors. Previous studies highlight the detrimental effects of agricultural runoff, shrimp aquaculture, and industrial waste discharge on lagoon ecosystems (Sarkar et al., 2012; Panigrahi et al., 2007). These stressors contribute to eutrophication, algal blooms, and habitat loss, exacerbating social-economic vulnerabilities (Srichandan et al., 2015). Although monitoring efforts by the CDA provide valuable scientific insights, limited accessibility to data has hindered community-based conservation initiatives (Sahu et al., 2014). By integrating ethno-hydrological knowledge with quantitative analysis, this study builds on existing literature to offer a nuanced understanding of water quality dynamics and their social-ecological implications.

Monitoring water quality is essential for understanding these changes and ensuring sustainable management of ecosystems like Chilika. Key water quality parameters, such as DO, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate and phosphate levels, pH, and turbidity, are critical indicators of ecosystem health (Svobodová, 1993; Nair & Nayak, 2023). Low DO levels and high BOD/COD values, for example, indicate organic pollution, leading to oxygen depletion and hypoxic conditions detrimental to aquatic life (Wu, 2009; Bulbul Ali & Mishra, 2022). Similarly, nutrient overloading from agricultural runoff, rich in nitrogen and

phosphorus, causes eutrophication, resulting in harmful algal blooms and fish mortality (Akinnowo, 2023). Despite CDA's regular monitoring efforts, much of this data remains inaccessible, limiting the development of evidence-based management strategies (Sahu et al., 2014). The problem at hand is the escalating degradation of water quality in Chilika Lagoon, driven by multiple factors including pollution, overfishing, and invasive species. These changes are not only disrupting the lagoon's ecological balance but also threatening the sustainability of SSFs, which are vital for local communities. Despite existing interventions, such as the Ban on Zero Net Fishing and mangrove plantations, poor enforcement and limited community engagement have hampered their effectiveness (Suresh et al., 2018; Singh et al., 2023; Mengo et al., 2025). This study aims to address these gaps by identifying key drivers of water quality changes, analyzing their social-ecological impacts, and exploring adaptive strategies employed by communities. By integrating local ecological knowledge with scientific data, the study provides a holistic understanding of the challenges and offers actionable recommendations for sustainable lagoon management.

In addition to scientific monitoring, the TEK of local communities offers invaluable insights into water quality changes. Fishing communities in Chilika have long observed shifts in water clarity, salinity, and fish populations, linking these changes to specific drivers like illegal shrimp aquaculture and industrial pollution. Such ethno-hydrological knowledge provides an early warning system for environmental degradation and complements scientific findings (Berkes, 2017). However, there remains a gap in integrating these community-based observations into formal conservation and management frameworks. The study aims to address these challenges by adopting a community-based approach to exploring water quality changes in Chilika Lagoon and their social-ecological impacts. This study aims to explore the social-ecological interdependencies influencing water quality in Chilika Lagoon by examining its key drivers and associated impacts. It analyzes community perceptions, adaptive strategies, and challenges faced by fishing communities, and identifies governance gaps to propose actionable recommendations for sustainable management. The primary objective of this study is to explore the social-ecological interdependencies influencing water quality in Chilika Lagoon. Specifically, it aims to

- Examine the key drivers of water quality changes and their ecological and social-economic impacts

- Analyze the perceptions, adaptive strategies, and challenges faced by fishing communities in response to these changes
- Identify gaps in governance and community engagement and propose actionable recommendations for sustainable management

By combining qualitative methods and local ecological knowledge, this study seeks to provide a holistic understanding of water quality dynamics in Chilika Lagoon. The findings aim to bridge the gap between scientific monitoring and community-based insights, offering actionable recommendations for sustainable management and the co-management of lagoon resources. Through this approach, the study contributes to broader efforts to balance ecological resilience with social-economic sustainability in Chilika Lagoon.

3.3 Research Area and Methods

Chilika Lagoon is not only a biodiversity hotspot but also holds considerable ecological and social-economic significance. The unique brackish water ecosystem, characterized by a mixture of freshwater from inland rivers and saltwater from the Bay of Bengal, has been recognized as a Ramsar site since 1981 due to its ecological significance (Kumar & Pattnaik, 2012; Sarkar et al., 2012). Ecologically, Chilika is a dynamic and complex system where freshwater inflows from rivers like the Mahanadi, Daya, and Bhargavi mix with saltwater from the Bay of Bengal, creating a unique estuarine environment (Sarkar et al., 2012; Paul et al., 2014). This hydrological mixing supports a vast range of biodiversity, including over 225 species of fish and numerous resident and migratory birds, making it a biodiversity hotspot (Mohanty et al., 2015; Suresh et. al, 2018). Social-economically, Chilika Lagoon sustains the livelihoods of more than 200,000 people, most of whom belong to traditional caste-based fishing communities (Nayak & Berkes, 2010). Over centuries, the relationship between the lagoon and its communities has shaped their cultural identity and social structures. However, the communities face increasing challenges due to changes in the lagoon's ecology and external pressures from anthropogenic activities, including shrimp aquaculture, agricultural runoff, and industrial pollution (Sahu et al., 2014). Over the decades, Chilika Lagoon has experienced substantial shifts in water quality, influenced by a combination of anthropogenic activities, natural disasters, and social-economic factors. Over time, Chilika's ecological balance has been influenced by both natural processes and human

interventions. Understanding these incidents is essential for mapping water quality changes and developing sustainable management strategies.

To investigate the water quality changes and their impacts on SSFs in Chilika Lagoon, I employed a mixed-methods approach over an eight-month period in 2023. This approach combined qualitative and quantitative techniques to capture a diverse range of perspectives while ensuring the methods were culturally and contextually relevant. The study prioritized community participation, particularly in light of the absence of publicly available water quality data for the region over the past decade. (a) ***Reconnaissance and Familiarization***: The study began with a 1–2-week reconnaissance phase aimed at building trust and understanding the local context. During this phase, I engaged informally with community members, attended cultural events, and learned basic phrases in the local Odiya language. These activities helped familiarize me with the region's cultural and ecological nuances, enabling the development of contextually sensitive study tools, such as household survey questionnaires and interview guides. (b) ***In-Depth Surveys***: To capture broad perceptions of water quality changes, I conducted 190 detailed household surveys in 15 villages, focusing on 15 households each in the Central, Southern, and Outer Channel sectors and 5 households each in two villages from the Northern sector. These surveys provided in-depth narratives about water quality changes, adaptive strategies, and social-ecological impacts. The integration of Likert scale assessments enabled participants to express varying degrees of agreement on issues such as biodiversity loss, livelihood challenges, and institutional responses. This combination of qualitative narratives and quantitative data enhanced the study's analytical depth. (c) ***Stakeholder Interviews***: 32 in-depth interviews were conducted with stakeholders, including SSFs (14), women (12), boat association staff (4), and daily boat operators (2). These interviews offered a range of perspectives on water quality changes and institutional responses, such as the ban on zero-net fishing, invasive plants, algal blooms and plastic pollution. The rich narratives from stakeholders enriched the study's thematic analysis and provided nuanced insights into the social-ecological dynamics of the lagoon. (d) ***FGDs***: Three FGDs were conducted in each of the Central, Southern, and Outer Channel sectors with 10–12 participants in each group, including SSFs, women fish vendors, and village leaders. FGDs provided a platform for collective reflection on water quality changes, surfacing shared narratives and community priorities that individual interviews or surveys might not capture. FGDs were not conducted in the Northern sector due to limited wetland presence; however, survey and interview data sufficiently

represented this region. (e) ***Free listing, Transect Walks and Participant Observation***: Free listing exercises were integrated into rapid surveys and FGDs, allowing participants to list key environmental changes, affected species, or social-ecological concerns. This method highlighted community priorities, such as declining fish stocks, increasing salinity, and pollution. I also employed transect walks where community members identified areas with notable ecological changes, such as plastic pollution and algal blooms. Transect walks through fishing areas and shorelines provided ground-level observations, corroborating the qualitative data with visual evidence. Participant observation was a crucial aspect of the study, enabling immersion in daily village life, fishing practices, and market dynamics. Over the eight-month study period, I observed fishing techniques, community interactions, and the lagoon's ecological conditions. These observations were systematically recorded in detailed field notes, complementing data from surveys, FGDs, and interviews.

All study tools, including surveys and interview guides, were prepared in Odiya and English. With the help of research assistants, Tapan Behera and Rabindranath Sahu, interviews and surveys were administered in Odiya, ensuring cultural and linguistic accessibility. Participants who spoke Hindi communicated directly with me, and their responses were documented in real-time. The mixed-methods approach was designed to address the complexity of water quality changes and their social-ecological impacts. The absence of open water quality data necessitated a community-based approach, leveraging local knowledge and experiences. The use of multiple data sources ensured the triangulation of findings, enhancing the reliability and validity of the study. This comprehensive methodology captured the diverse experiences and perceptions of water quality changes across the lagoon's ecosystem.

3.4 Results and Discussion

3.4.1 Drivers of Water Quality Changes

Drivers are underlying forces that lead to changes in environmental conditions, including social, economic, political, and environmental factors. In the case of Chilika Lagoon, fishing communities identified several key drivers of water quality changes. These were primarily anthropogenic, although natural events also played a role. Frequently mentioned drivers include the creation of artificial sea mouths, shrimp aquaculture, sewage waste, agricultural runoff, tourism, and extreme weather events, particularly cyclones. Understanding these drivers and their

influence on water quality is essential for addressing the challenges faced by this unique ecosystem. Anthropogenic pressures, such as pollution from shrimp aquaculture and tourism, combined with natural factors like cyclones, exert significant stress on the lagoon's biodiversity, water quality, and the livelihoods of surrounding communities. Collaborative efforts involving local knowledge, policy intervention, and sustainable practices are crucial to mitigate these challenges and safeguard Chilika Lagoon for future generations.

Pollution from Villages, Cities, and Tourism

Pollution from settlements and tourism is the leading driver of water quality degradation in Chilika Lagoon, with 38.5% of respondents identifying it as the primary issue. The rapid growth of settlements around the lagoon has increased domestic waste entering the water. Villages and cities like Bhubaneswar discharge untreated sewage, plastics, and thermocol into the lagoon, especially during rains. Respondents described the lagoon's water as “*murky*” (111 respondents) and “*somewhat unsafe*” for aquatic life (97 respondents), reflecting the visible impacts of pollution. Tourism, while beneficial economically, has intensified the issue. Popular areas such as Barkul and Balugaon experience significant waste accumulation from tourists, including plastic wrappers and food waste. As one respondent (ISF08 from Satapada) noted, “*The water near tourist spots is always dirty, with floating trash making it unfit for fishing or recreation.*” To address this challenge, communities emphasized the urgent need for structured waste management systems, public awareness campaigns, and stricter regulations to curb pollution from both domestic and tourism-related sources.

Industrial and Agricultural Pollution

Agricultural and industrial activities have a profound impact on Chilika Lagoon's water quality, as noted by 27% of respondents. Farmers in the catchment area rely heavily on chemical fertilizers and pesticides, which runoff into the lagoon during rains. This leads to eutrophication, turning the water green and promoting harmful algal blooms. A total of 136 survey respondents rated the presence of excessive nutrients as “*high*” or “*very high*”, indicating the severity of agricultural runoff. Industrial effluents from upstream factories add to the problem by introducing toxins that degrade water quality and harm aquatic life. Shrimp aquaculture compounds these issues, with respondents describing areas near farms as having “*greenish*” and “*foul-smelling*” water. One respondent (IWO03 from Mota) stated, “*The chemicals from shrimp farms pollute the*

lagoon, making it harder to catch healthy fish.” Efforts to mitigate these effects must include promoting eco-friendly farming practices, regulating industrial discharges, and ensuring aquaculture operations adopt sustainable methods to protect the lagoon.

Overfishing and Use of Illegal Nets

Overfishing and the use of zero nets emerged as significant concerns, with 23.5% of respondents highlighting these practices as detrimental to the lagoon's health. Zero nets trap fish of all sizes, including juveniles, leading to a decline in fish populations and disrupting the lagoon's ecological balance. Respondents reported a “*significant decrease*” in aquatic life (104 respondents) and emphasized that such practices also damage the seagrass meadows that are critical for fish breeding. One respondent (ISF06 from Khatiakudi) noted, “*Zero nets catch everything, leaving nothing for future seasons.*” Additionally, 161 respondents described the fishing pressure as “*moderate*” or “*higher*”, indicating unsustainable exploitation of resources. The lack of enforcement of fishing regulations exacerbates the problem. Addressing overfishing requires strict bans on harmful fishing methods, community-based fisheries management, and education on sustainable practices to ensure the long-term health of Chilika Lagoon's ecosystem.

Invasive Species and Habitat Loss

Invasive plants, such as water hyacinth and *Phragmites Karka*, have become a significant issue, with 17.5% of respondents mentioning their impact. These species block sunlight, disrupt water flow, and outcompete native vegetation, affecting aquatic ecosystems. Seagrass meadows, which serve as critical habitats for fish and prawns, are particularly vulnerable. 69 respondents observed a “*significant decrease*” in seagrass cover, with many attributing it to habitat degradation caused by invasive species. Additionally, boat activity exacerbates this issue, with 57 respondents identifying a “*sufficient impact*” of boats on seagrass health. A daily boat operator (BO-2) from Satapada remarked, “*These plants choke the water, making fishing and navigation increasingly difficult*”. Effective management of invasive species, habitat restoration, and restrictions on activities like careless boat operations are necessary to protect and revitalize the lagoon's ecosystem.

Climate Change and Extreme Weather Events

Climate change, particularly the increasing frequency and intensity of cyclones, was highlighted by 18% of respondents as a major driver. Cyclones bring saltwater, debris, and sediment into the lagoon, damaging freshwater systems and seagrass meadows. 161 respondents reported “*significant impacts*” from cyclones on seagrass habitats, while 169 respondents described the recovery of seagrass after disturbances as “*very slow*”. Rising temperatures, linked to climate change, further affect the lagoon by promoting algal blooms and altering aquatic ecosystems. One respondent (IWO07 from Balugaon) noted, “*Cyclones make the water murkier and destroy fish habitats, taking months for recovery*”. Building resilience through climate-adaptive strategies, such as mangrove restoration and community-led conservation efforts, is essential to mitigate these impacts and enhance the lagoon’s ability to withstand future climate-related events.

Lack of Waste Management Infrastructure

The lack of effective waste management systems is a persistent issue, as noted by 24.5% of respondents. Garbage, including plastics, thermocol, and untreated sewage, often flows directly into the lagoon through drainage channels. Areas near markets, like Balugaon, are particularly affected, with respondents describing drainage channels clogged with waste that directly enters the water. 81 respondents reported difficulty accessing clean water for fishing, while 106 respondents found it challenging to obtain clean water for daily needs. A staff from Kalijai Motor Boat Association (BA-02) noted, “*The absence of waste management systems is choking the lagoon with garbage and sewage*”. Addressing this challenge requires investments in proper waste disposal systems, enforcement of pollution control regulations, and community engagement to promote cleaner practices and reduce the inflow of waste into the lagoon.

Community Awareness and Governance Gaps

A lack of awareness and weak governance exacerbate Chilika Lagoon’s challenges, with 21% of respondents indicating concerns related to exclusion from decision-making and lack of environmental education. 162 respondents indicated they were “*not very aware*” of the importance of seagrass and water quality for sustainable fishing. Restoration projects have been largely ineffective, with 173 respondents rating them as “*not effective at all*”. Additionally, 178 respondents reported having no access to modern fishing technologies, and 67 respondents noted the absence of active community organizations to manage resources. As one respondent (ISF04

from Khatiakudi) expressed, “*Policies are made without involving us, and we are left unaware of how to protect the lagoon*”. Strengthening governance structures, educating communities, and fostering participatory resource management are critical steps to bridge these gaps and promote sustainable practices to safeguard Chilika Lagoon’s resources.

The communities around Chilika Lagoon have experienced significant population growth over the past decades. Increased population density has led to the expansion of settlements and greater demand for resources, exerting pressure on the lagoon's natural systems (FGDs). Community members reported that waste disposal practices have not kept pace with population growth, leading to increased domestic waste entering the lagoon. Agricultural activities in the catchment area have also intensified, with increased use of chemical fertilizers and pesticides. Runoff from these agricultural lands carries nutrients and pollutants into the lagoon, contributing to eutrophication and algal blooms . Figure 3.1 highlights the multifaceted pollution challenges faced by Chilika Lagoon. Panel (a) shows waste accumulation near a Wetland Research and Training Centre (WTRC) in Barkul, emphasizing inadequate waste management practices. Panels (b) and (d) depict eutrophication in Kalupada Ghat, with invasive species like *Phragmites karka* obstructing water transport and aggravating ecological imbalance. Panel (c) illustrates waste disposal issues in a canal near Balugaon fish market, contributing to pollution in Chilika. Panel (e) captures the degradation around Balugaon, where plastics, thermocol, and algal blooms dominate the shoreline. Lastly, panel (f) showcases minor drainage channels in the Balugaon fish market, clogged with plastics and thermocols, directly flowing into the lagoon. These images underscore the urgent need for improved waste disposal and agricultural runoff management to safeguard the Chilika Lagoon ecosystem.



Figure 3.1 Pollution around Chilika Lagoon: (a) Waste accumulation near Barkul WRTC, (b, d) eutrophication in Kalupada Ghat with invasive *Phragmites karka*, (c) waste dumping in a canal at Balugaon fish market, (e) plastics, thermocol, and algal blooms near Balugaon shoreline, and (f) clogged drainage channels flowing into Chilika Lagoon.

Industrialization in nearby towns and cities has been perceived as a significant driver of water quality degradation. Although specific data on industrial effluents are unavailable, community members expressed concerns about untreated wastewater from fish market entering the. The proliferation of aquaculture, particularly shrimp or benami farming, has altered the lagoon's ecology. Waste from aquaculture ponds, including excess feed and chemicals, is discharged into the lagoon, impacting water quality. Fishers reported a decline in native fish species and an increase in disease occurrences among aquatic organisms. Local fishers have observed changes in water clarity and fish behavior, attributing these to agricultural runoff and illegal shrimp aquaculture. Table 3.1 summarizes the key drivers influencing water quality changes

in Chilika Lagoon, incorporating community perspectives and observations gathered from qualitative research methods. Each driver is briefly described above, with examples illustrating how they manifest in the local context.

Table 3.1 Key drivers of water quality changes in Chilika Lagoon

Category	Key Drivers	Supporting Data
Pollution from Villages, Cities, and Tourism	- Plastic waste from villages and tourists - Untreated sewage from nearby cities like Bhubaneswar - Tourism garbage left unmanaged Estimated % of Respondents: 38.5%	<i>“Plastic bottles, thermocol, and untreated sewage flow directly into the water.”</i> (BAR-01) <i>“Tourists leave behind trash, and the water near tourist spots is full of floating waste.”</i> (BAR-03, SAN-10) <i>“Waste from villages, like plastic and food scraps, enters the lagoon during rains.”</i> (BIN-11)
Industrial and Agricultural Pollution	- Fertilizer and pesticide run off from farms - Untreated waste from factories - Chemicals and waste from shrimp aquaculture Estimated % of Respondents: 27%	<i>“Fertilizers and pesticides from farms wash into the lagoon, making it greenish.”</i> (KHAS-11, SAB-15) <i>“Factories upstream release untreated waste into the water.”</i> (SAM-15) <i>“Waste from shrimp farms makes the water smelly and unhealthy.”</i> (MO-01, PUR-14)
Overfishing and Use of Illegal Nets	- Use of zero nets trapping fish of all sizes - Unsustainable overfishing practices Estimated % of Respondents: 23.5%	<i>“Zero nets trap everything, leaving no chance for fish to grow.”</i> (SAN-09, SIP-14) <i>“Illegal nets damage the lagoon bed and trap even the smallest fish.”</i> (BAR-05, PUR-11)
Invasive Species	- Spread of water hyacinth and <i>Phragmites karka</i> - Destruction of seagrass beds critical for fish breeding Estimated % of Respondents: 17.5%	<i>“Invasive plants like water hyacinth block sunlight and harm fish.”</i> (KHAS-12, BIN-08) <i>“Seagrass areas are shrinking due to pollution and boat activity.”</i> (BAR-02, BIN-01)
Sedimentation and Habitat Disruption	Altered water flow due to artificial sea mouth	<i>“Artificial sea mouth increased sedimentation, making fishing areas shallow.”</i> (MO-04, SIP-09)

	• Cyclones bringing debris, mud, and saltwater Estimated % of Respondents: 18%	<i>“Cyclones bring debris and mud, making it harder for fish to survive.”</i> (PUR-12, SAN-14)
Lack of Waste Management Infrastructure	• Absence of proper garbage and sewage disposal systems • Limited enforcement of pollution and fishing regulations Estimated % of Respondents: 24.5%	<i>“Sewage from houses and garbage flow directly into the water.”</i> (SAB-11) <i>“Despite bans, zero nets and illegal shrimp farming continue unchecked.”</i> (SAM-06, KAR-12)
Climate Change and Natural Disasters	• More frequent and severe cyclones • Rising temperatures and algae blooms Estimated % of Respondents: 13%	<i>“Cyclones are stronger and bring in more saltwater and sediment.”</i> (JAG-1, KAR-11) <i>“The water feels warmer and smells bad, with fewer fish.”</i> (BIN-10)
Loss of Community Involvement and Awareness	• Lack of education on lagoon’s natural features • Exclusion of locals from decision-making Estimated % of Respondents: 21%	<i>“No one explains why mangroves or seagrass are important.”</i> (SIP-12, SAB-07) <i>“Policies come from the top, but no one asks us for our knowledge.”</i> (MO-06, SIP-06)

The drivers of water quality degradation in Chilika Lagoon are deeply interconnected. Pollution, invasive species, overfishing, and climate events create a feedback loop of environmental degradation. These challenges are compounded by governance gaps, with limited enforcement of regulations and minimal involvement of local communities in decision-making processes.

3.4.2 Impacts of Water Quality on Chilika Lagoon

The degradation of water quality in Chilika Lagoon has led to far-reaching consequences, affecting not just the ecological balance but also the social and economic well-being of the communities dependent on it. Respondents from the surrounding fishing villages highlighted significant changes in fish populations, habitat health, and water usability due to pollution, salinity, and sedimentation. Sedimentation refer to the accumulation of eroded soil and silt from river

inflows - smothers benthic habitats and reduces water transparency, thereby disrupting aquatic ecosystems and fish breeding grounds. These impacts, rooted in anthropogenic pressures and weak governance, are exacerbated by the lack of awareness about sustainable practices. The interconnected effects on biodiversity, livelihoods, and community health underline the urgent need for targeted interventions to restore and protect Chilika Lagoon. The data shows that overall water quality was rated as neutral by a majority (74.21%), but a significant minority perceived it negatively (20.53% very negative). This underscores the need for immediate attention to address the underlying drivers of poor water quality. Water clarity was predominantly rated negatively (58.42%), reflecting the impact of sedimentation and pollutants on the lagoon's visibility. Conversely, water turbidity garnered more positive perceptions, with 48.42% rating it positively, suggesting localized improvements or adaptation to turbidity in fishing practices. The perception of excessive nutrients highlighted a critical concern, with 71.58% of respondents rating it negatively. This aligns with observations of nutrient pollution from agricultural runoff and sewage waste, leading to eutrophication and algal blooms that degrade the aquatic ecosystem. When considering water safety for aquatic life, 51.05% of respondents rated it negatively, emphasizing the pressures on biodiversity and habitat conditions. However, 18.42% viewed it positively, potentially reflecting areas where conservation efforts or natural resilience have mitigated some impacts. Community perceptions of water quality in Chilika Lagoon reveal varied responses across five key parameters: overall water quality, water clarity, water turbidity, presence of excessive nutrients, and water safety for aquatic life. The chart (Figure 3.2) highlights areas of concern and offers insights into the drivers influencing these perceptions.

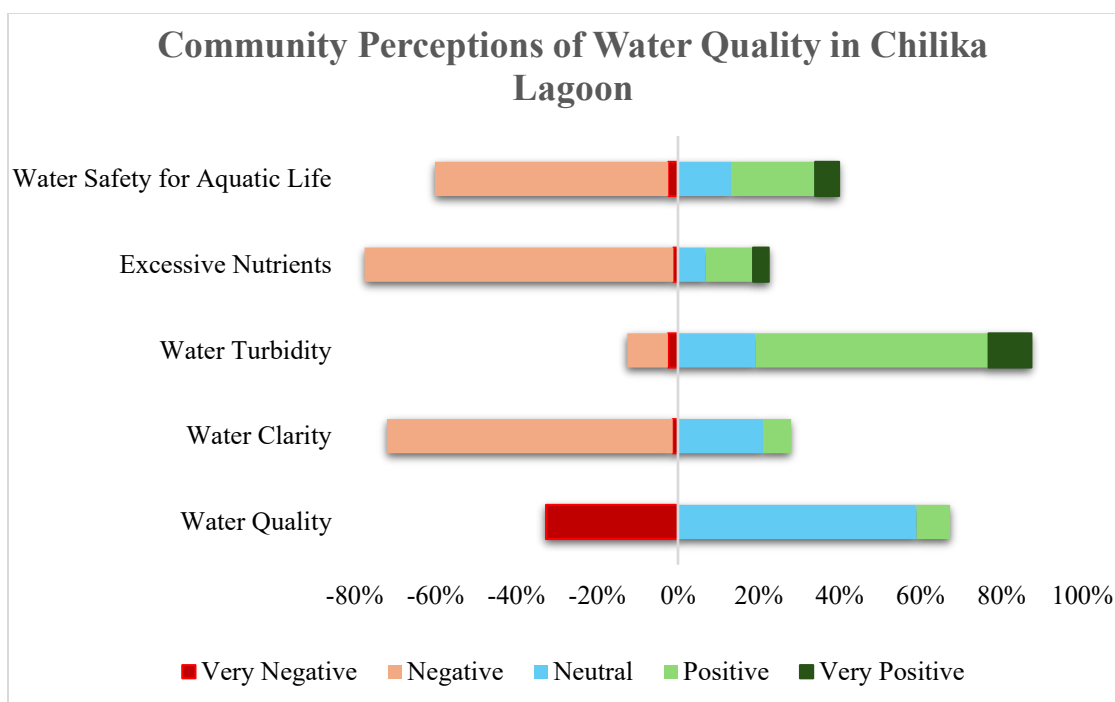


Figure 3.2 Community perceptions of water quality in Chilika Lagoon based on Likert scale assessments ($n=190$).

Table 3.2 categorizes the major impacts of water quality degradation in Chilika Lagoon into ecological, social, and economic dimensions. It details specific effects, supporting narratives from community respondents, and the percentage of respondents highlighting each issue. This comprehensive overview underscores the multifaceted consequences of poor water quality on the lagoon’s ecosystem and the people who depend on it.

Table 3.2 Summary of water quality impacts in Chilika Lagoon across ecological, social, and economic dimensions

Impact	Supporting Qualitative Data
Decline in fish population and health	“We used to catch many types of fish, but now only a few species are left.” (SAB-13) “The water isn't healthy enough for fish to grow.” (BAR-03)
Reduced availability of prawns and crabs	“Prawns can't breed as they used to because of salinity and pollution.” (SAB-15) “We catch fewer crabs than before.” (SAN-01)
Increased murkiness and turbidity	“Earlier, the water was clear in some areas, but now it's always murky.” (SAN-13) “The lagoon used to feel fresh and cool, but now it feels warm.” (BIN-08)

Presence of green algae and sediment	<i>“The lagoon is covered in green algae, suffocating fish and prawns.” (SAB-10)</i> <i>“Sediment makes the water cloudy and affects breeding areas.” (PUR-06)</i>
Decrease in seagrass cover	<i>“Seagrass beds are shrinking, leaving fewer safe places for fish to grow.” (SAB-14)</i> <i>“Seagrass has turned yellow or is disappearing.” (SAN-05)</i>
Damage to seagrass beds due to pollution and sedimentation	<i>“Shrimp farms are killing seagrass beds, affecting breeding grounds for fish and prawns.” (SIP-04)</i>
Visible waste, plastic, and oil in the water	<i>“Plastic and garbage are everywhere in the lagoon.” (BIN-13)</i> <i>“We see oil floating on the water’s surface.” (SAN-10)</i>
Strong unpleasant odors from waste and chemicals	<i>“The water smells bad, especially near shrimp farms and waste outlets.” (BER-02)</i>
Destruction of breeding areas due to sedimentation and invasive plants	<i>“Cyclones bring debris and destroy fish breeding areas.” (BAR-08)</i> <i>“Invasive plants block areas where fish used to lay eggs.” (KHAS-14)</i>
Loss of native habitats for fish and crabs	<i>“The fish used to rely on seagrass beds, but these are disappearing due to pollution.” (BAR-11)</i>
Littering and habitat disturbance	<i>“Tourists leave behind plastic bottles and wrappers, polluting the lagoon.” (MO-09)</i> <i>“Tourist boats disturb breeding grounds.” (SIP-05)</i>
Increased erosion and sedimentation due to boat activities	<i>“Tourist boats create strong waves, eroding the lagoon’s banks.” (MO-06)</i>
Increased salinity disrupting freshwater ecosystems	<i>“The water has become saltier, driving away freshwater fish.” (SIP-08)</i> <i>“Saltwater changes have made some areas unlivable for fish.” (SAN-06)</i>
Reduced availability of species that depend on brackish water	<i>“Freshwater fish that we used to catch are harder to find now.” (BAR-10)</i>
Decline in fish catches and income	<i>“We’re catching fewer fish than ever before.” (KHAS-10)</i> <i>“The fish stocks are declining fast.” (BIN-10)</i>
Increased effort and cost for fishing due to poor water quality	<i>“We have to go farther into the lagoon to fish.” (SAB-01),</i> <i>“Fishing is harder in polluted or murky water.” (BAR-12)</i>

Rashes and health issues caused by polluted water	<i>“Sometimes, the water causes rashes when we touch it.”</i> (PUR-05) <i>“Polluted water affects our health and skin.”</i> (SAM-07)
Overall decline in biodiversity and ecosystem balance	<i>“The lagoon is losing its life. We see fewer birds and fish.”</i> (NUA-03) <i>“Invasive species are taking over, displacing native plants.”</i> (SAM-10)

The impacts of water quality in Chilika Lagoon can be categorized into ecological, social, and economic impacts. Each category is detailed below, supported by qualitative data and percentages derived from respondents’ feedback.

Ecological Impacts

The ecological impacts of water quality degradation in Chilika Lagoon are profound, affecting biodiversity, habitat health, and ecosystem balance. Over 65% of respondents reported a decline in fish populations, with several native species disappearing or being replaced by invasive species. *“The lagoon is losing its life. We see fewer birds and fish,”* noted one respondent (NUA-03). Prawns and crabs, critical to the local economy, have also declined due to pollution and increased salinity. *“Prawns can’t breed as they used to because of salinity and pollution,”* observed another respondent (SAB-15). Seagrass meadows, vital for fish breeding and shelter, have suffered due to sedimentation, pollution, and aquaculture activities. 45% of respondents highlighted the shrinking of seagrass beds, with some describing them as *“yellow or disappearing”* (SAN-05). Eutrophication caused by fertilizers and waste has led to algal blooms, which 53% of respondents described as suffocating fish and blocking sunlight. *“The lagoon is covered in green algae, suffocating fish and prawns,”* said a respondent (SAB-10). Invasive plants, such as water hyacinth and *Phragmites Karka*, have spread across the lagoon, displacing native species and making fishing challenging. These plants were mentioned by several respondents, who stated, *“Invasive plants block areas where fish used to lay eggs and make fishing difficult”* (KHAS-14). These ecological challenges not only disrupt the natural balance but also threaten the long-term sustainability of the lagoon.

Social Impacts

Poor water quality has had significant social repercussions for the communities around Chilika Lagoon. Health issues, including rashes and skin irritation, were reported by 15% of

respondents, particularly near areas with visible pollution or chemical discharge. *“Sometimes, the water causes rashes when we touch it,”* shared a respondent (PUR-05), highlighting the direct impact on daily life. Livelihoods dependent on fishing have been heavily affected. Over 70% of respondents described declining fish catches, lower incomes, and increased fishing effort. *“We’re catching fewer fish than ever before,”* remarked a respondent (KHAS-10), while others mentioned traveling farther into the lagoon to find fish, increasing time and costs. Access to clean water sources for fishing and daily needs was also a concern, with 56% of respondents reporting difficulties. *“The water has become too salty, making it harder to catch freshwater fish,”* noted a respondent (SIP-08). The social fabric of these communities is also strained by the loss of income and increased competition for limited resources. Awareness about sustainable practices remains low, with 85% of respondents acknowledging a lack of understanding about the ecological importance of seagrass and water quality. *“Most people don’t understand how important it is to protect the lagoon,”* observed one respondent (KHAK-13), emphasizing the need for community education and involvement.

Economic Impacts

The economic implications of degraded water quality in Chilika Lagoon are severe, directly impacting the livelihoods of fishing communities. 70% of respondents noted reduced fish populations as a primary cause of declining incomes. *“The number of fish we catch has gone down drastically,”* stated a respondent (SAM-15). Overfishing, pollution, and habitat destruction have compounded these challenges, leading to reduced availability of prawns and crabs as well. *“Poor water quality and pollution have driven fish away,”* said another respondent (SAM-02). Increased costs for fishing have added to the economic burden. Many respondents mentioned traveling farther into the lagoon or spending more time fishing due to reduced catches. *“We have to go farther into the lagoon to fish,”* shared a respondent (SAB-01). Additionally, pollution damages nets and equipment, further increasing expenses. Tourism, while a potential source of alternative income, has contributed to pollution and habitat disturbance. 34% of respondents noted that littering and boat activities associated with tourism negatively affect fish habitats. *“Tourists leave behind plastic bottles and wrappers, polluting the lagoon,”* observed a respondent (MO-09). The lack of alternative livelihood options and the economic dependence on fishing underscore the urgent need for sustainable resource management and economic diversification.

The impacts of degraded water quality in Chilika Lagoon are profound and multifaceted, affecting both the ecological health of the lagoon and the social-economic well-being of its dependent communities. The ecological impacts are interconnected with social and economic effects, forming a cycle of degradation and dependency. The declining health of fish stocks and habitats directly affects livelihoods, while pollution and poor governance exacerbate the challenges faced by communities. Respondents consistently pointed out that without robust governance and awareness programs, addressing these issues will remain a significant challenge. These findings highlight the urgent need for a holistic approach that includes stricter enforcement of environmental regulations, investment in community education, sustainable tourism practices, and improved waste and water management systems.

3.4.3 Responses to Water Quality Changes

The fishing communities of Chilika Lagoon have been deeply impacted by changes in water quality, driven by pollution, salinity shifts, and declining seagrass coverage. In response, fishers have adapted their practices, diversified their livelihoods, and engaged in conservation efforts to sustain their way of life. This section explores these responses in detail, shedding light on the community's resilience and innovative approaches. Despite various government initiatives, including the Ban on Zero Net Fishing (2002) and Mangrove Plantation programs, gaps in enforcement and community engagement have limited their perceived effectiveness. By understanding these responses, stakeholders can identify pathways for improved co-management, training, and support to enhance both ecological and social-economic outcomes.

Figure 3.3 illustrates the perceived effectiveness of six government initiatives in addressing the needs of SSFs in Chilika Lagoon, based on a survey of 190 respondents. These initiatives include the Opening of Sea Mouth (2000), Mangrove Plantation programs, the Ban on Zero Net Fishing (2002), the Plastic Ban (2002), Community Environmental Education, and Weather Warning and Cyclone Resilience Programs. Key findings highlight that 83.68% of respondents found Mangrove Plantation efforts “*Very Ineffective/Unaware*” while 98.95% deemed the Ban on Zero Net Fishing “*Ineffective/Aware but Not Impactful*”. Similarly, 88.42% rated the Plastic Ban as “*Ineffective*”. Community Environmental Education received a unanimous 100% rating as “*Very Ineffective/Unaware*” showing a significant gap in awareness and impact. Meanwhile, 80% rated the Opening of the Sea Mouth initiative as “*Neutral/Somewhat Aware*” indicating moderate recognition of its relevance. The Weather Warning and Cyclone Resilience Programs reflected a

mixed perception, with 76.32% considering them “*Very Ineffective/Unaware*” and 11.05% assigning a “*Neutral*” rating. The absence of ratings for “*Effective*” or “*Very Effective*” across all initiatives underscores a critical need for enhanced implementation, enforcement, and community engagement to improve their impact on the social-economic and ecological sustainability of Chilika Lagoon.

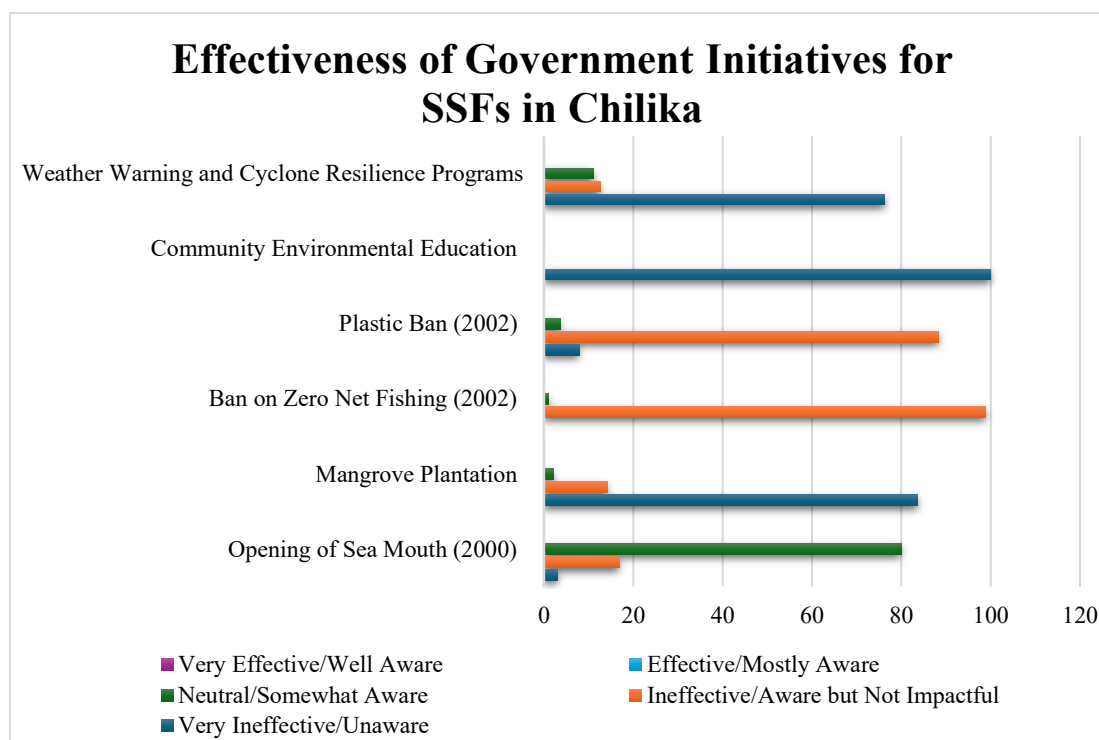


Figure 3.3 Perceived effectiveness of government initiatives for SSFs in Chilika Lagoon

Table 3.3 categorizes the adaptive strategies employed by fishers in Chilika Lagoon in response to water quality changes. It includes examples and quantitative insights into key themes, such as fishing practice adaptations, livelihood diversification, conservation initiatives, and community-driven suggestions. It highlights the perceived effectiveness of government interventions, based on a survey ($n=190$), to provide context for community perspectives on institutional support.

Adaptation in Fishing Practices

Fishing communities in Chilika Lagoon have exhibited remarkable adaptability in response to water quality changes. About 78% of respondents indicated shifting to cleaner or deeper areas of the lagoon due to pollution near shrimp farms and tourist spots: “*The water near shrimp farms is too polluted, so we fish in less polluted areas*”. Moreover, 64% of fishers have shifted to more

adaptive gear such as gill nets with modified mesh sizes, cast nets, and hook-and-line systems, which are better suited for current fish distributions and comply with sustainable fishing regulations. Seasonal shifts in fishing patterns were noted by 58%, with fishers targeting early mornings or evenings when fish activity is higher in cooler, clearer waters: *“We fish early in the morning to avoid the worst water conditions”*. To address declining fish populations, 72% have shifted their focus to alternative species like crabs and prawns, which are more tolerant of the lagoon’s changing salinity and pollution levels. Government efforts such as the Ban on Zero Net Fishing (2002) are widely recognized by the community, though 99% of respondents rated its effectiveness as *“Ineffective”* or *“Neutral”*. The lack of strong enforcement diminishes its impact, despite its potential to curb overfishing and protect juvenile fish. These findings highlight a pressing need for stricter implementation and community involvement in policy enforcement.

Livelihood Diversification

In the face of declining fish stocks, fishers are diversifying their livelihoods to sustain their families. Migration to other states like Kerala and Tamil Nadu for marine fishing during off-seasons was reported by 45% of respondents: *“When fishing isn’t enough, we migrate to Kerala or Tamil Nadu to work in marine fishing”*. Additionally, 42% of the respondents have shifted to alternative income sources such as tourism, farming, or crafting, often leveraging Chilika’s scenic beauty: *“We’ve started making toys for tourists or guiding boat tours to earn additional income”*. These trends align with the community awareness programs led by the CDA, though 100% of respondents rated this initiative as *“Very Ineffective or Neutral”*. Many participants expressed frustration at the lack of practical training and tangible benefits. Improved vocational training for eco-tourism, craft-making, and sustainable farming could enhance the relevance and reach of such programs.

Table 3.3 Responses to water quality changes in Chilika Lagoon

Category	Specific Response/Action	Supporting Qualitative Data/Narratives
Adaptation in Fishing Practices	Shifted to deeper or cleaner areas for fishing	<i>“The water near shrimp farms is too polluted, so we fish in less polluted areas.”</i> (BAR-01)
	Changed fishing methods or gear	<i>“We’ve switched from khanda nets to phasi nets because they’re better for catching the fish that are still in the lagoon.”</i> (KAR-11)

	Adjusted fishing schedules based on fish movement	<i>“We’ve adjusted our schedules and now fish early in the morning or late in the evening when they seem to move more.” (SIP-05)</i>
	Targeted alternative species (e.g., crabs, prawns)	<i>“With fewer fish around, we’ve started focusing more on crabs and prawns since they’re easier to find and provide a better catch.” (BAR-07)</i>
Livelihood Diversification	Migrated for work during poor fishing seasons	<i>“When the fishing season is bad, some of us leave for Kerala or Tamil Nadu to work in marine fishing.” (BAR-02)</i>
	Shifted to tourism, farming, or craft-making	<i>“With fishing becoming unpredictable, some families make toys and sell them to tourists during the busy season.” (BAR-03)</i>
Efforts Toward Conservation	Avoided overfished or polluted areas	<i>“We know that certain areas have been overfished or polluted, so we avoid those.” (BER-06)</i>
	Released juvenile fish to preserve future stocks	<i>“Now, when we accidentally catch juveniles, we release them back into the water to allow them to grow.” (SIP-15)</i>
	Advocated for education and involvement in seagrass restoration	<i>“If someone could teach us how to replant and protect seagrass, we’d work together for the future of our children.” (BAR-03)</i>
Community-Driven Suggestions	Called for stricter enforcement of rules	<i>“We know that there are laws to protect the lagoon, but many people don’t follow them, like illegal fishing or dumping waste. We need better enforcement and more awareness about these rules.” (BAR-01)</i>
	Proposed eco-tourism as an income alternative	<i>“If we bring tourists to show them the lagoon and teach them about seagrass and our fish, we can earn money while protecting the environment.” (MO-08)</i>
	Requested training in sustainable fishing practices	<i>“If we had better fishing gear and could fish in ways that don’t harm the seagrass, it would help.” (SAB-10)</i>

Efforts Toward Conservation

Conservation efforts are gaining traction within the community. About 38% of respondents actively avoid overfished or polluted areas to allow ecosystems to regenerate: *“When areas look overfished, we avoid them to give the fish time to replenish”*. Another 36% practice selective

fishing, releasing juvenile fish back into the water to ensure future stock sustainability. Furthermore, 60% expressed interest in participating in seagrass restoration efforts if provided training and resources: *“If we knew how to plant and protect seagrass, we’d gladly help”*. Initiatives such as Mangrove Plantations have the potential to support conservation goals, yet 99% of respondents rated them as *“Very Ineffective or Neutral”*. While these plantations protect the coastline and improve ecosystem resilience, the lack of integration with community livelihoods has hindered their perceived impact.

Community-Driven Suggestions

Fishers emphasize co-management and inclusion in decision-making as critical to sustainable fisheries. 50% of respondents advocate for stricter enforcement of laws against illegal fishing and pollution, while 40% propose eco-tourism as a complementary livelihood: *“If tourists learned about the lagoon, we could earn money while protecting the environment”*. Another 48% highlighted the need for training in sustainable fishing practices to align their efforts with conservation goals. Programs like the Opening of Sea Mouth (2000), critical for maintaining the lagoon's ecological balance, were acknowledged by 80% as *“Neutral”*. While this intervention improved fish migration, fishers feel disconnected from its implementation and monitoring. Incorporating their TK and experiences into such initiatives could strengthen outcomes. Similarly, Weather Warning and Cyclone Resilience Programs were deemed relevant but underutilized, with 77% of respondents rating them as *“Ineffective”* or *“Neutral”*. Enhanced community training on disaster preparedness could amplify their utility.

3.5 Key Findings and Insights

The research on Chilika Lagoon's water quality and its social-ecological impacts has revealed several critical insights. The findings underscore the interconnected nature of environmental degradation, governance gaps, and community responses, highlighting the urgent need for an integrated and participatory approach to sustainable management.

a. Water quality decline is a result of multiple, interlinked drivers

The degradation of water quality in Chilika Lagoon is not caused by a single factor but is the result of a complex interplay of anthropogenic and natural drivers. The most frequently mentioned contributors were pollution from settlements, tourism, and shrimp aquaculture (34.2%

of respondents), followed by agricultural and industrial pollution (26.3%), overfishing and illegal net use (21.1%), and invasive species (15.8%). Climate change-related events, such as cyclones and rising temperatures, were also cited by 10.5% of respondents as exacerbating the problem. These multiple stressors create a feedback loop where pollution and habitat destruction reduce fish populations, forcing fishers to increase their effort and adopt unsustainable practices, further exacerbating the lagoon's decline. The findings align with previous studies (Sarkar et al., 2012; Panigrahi et al., 2007), which identified pollution and overexploitation as key threats to the lagoon's ecological stability. However, this study extends these findings by incorporating local ecological knowledge, revealing how these drivers interact on the ground.

b. Governance gaps and weak policy enforcement hinder sustainable management

Despite various government initiatives aimed at addressing water quality and fisheries sustainability—such as the Ban on Zero Net Fishing (2002), Mangrove Plantation efforts, and the Plastic Ban—community perceptions indicate widespread dissatisfaction with their implementation and enforcement. Nearly 99% of respondents rated the Ban on Zero Net Fishing as "ineffective," while 88.42% deemed the Plastic Ban as ineffective. Community Environmental Education, which is crucial for long-term awareness and conservation efforts, was rated as completely ineffective by 100% of respondents. These governance failures stem from a lack of community engagement, limited enforcement capacity, and insufficient resources for implementing sustainable waste management and pollution control measures. The findings corroborate the conclusions of Berkes (2017) and Sahu et al. (2014), which emphasize the necessity of involving local communities in co-management structures for effective conservation outcomes. Addressing these governance gaps is essential to ensuring that regulations are not only in place but also actively enforced and supported by local stakeholders.

c. Water quality degradation is driving social and economic hardships

The declining water quality has had severe repercussions on fishing communities, manifesting as ecological, social, and economic challenges. Over 65% of respondents reported a decline in fish populations, leading to reduced incomes and increased fishing efforts. The loss of biodiversity, particularly in seagrass meadows and breeding grounds, has made traditional fishing practices less viable. Economic hardships have pushed many fishers to migrate to Kerala and Tamil Nadu during off-seasons, with 45% of respondents reporting temporary migration for marine fishing. Others

have diversified their income sources, shifting to alternative livelihoods such as tourism, farming, or handicraft production (42%). The direct impact on public health was also evident, with 15% of respondents reporting rashes and other skin conditions caused by polluted water. These findings reinforce previous studies on SSFs (Berkes, 2017), which highlight the vulnerability of fishers to environmental changes and the importance of social-economic resilience strategies.

d. Community-based conservation efforts exist but lack institutional support

Despite facing numerous challenges, Chilika's fishing communities have demonstrated resilience and adaptation by modifying fishing techniques, shifting to alternative fish species, and engaging in informal conservation activities. For instance, 38% of respondents actively avoid overfished or polluted areas, while 36% release juvenile fish back into the lagoon to support population recovery. Additionally, 60% expressed willingness to participate in seagrass restoration programs if given adequate training and support. However, the lack of structured institutional backing for these community-led initiatives remains a major obstacle. While the Mangrove Plantation program has the potential to support conservation, 83.68% of respondents found it to be ineffective or were unaware of its benefits. These findings highlight the importance of integrating local ecological knowledge with scientific monitoring to develop community-led conservation strategies, as suggested by Akinawo (2023) and Nair & Nayak (2023).

e. A holistic, participatory approach is necessary for sustainable lagoon management

The findings indicate that fragmented and top-down policy interventions are unlikely to succeed in addressing the complex social-ecological challenges faced by Chilika Lagoon. Instead, a co-management approach that integrates scientific research, local ecological knowledge, and active community participation is essential for sustainable lagoon management. Respondents strongly emphasized the need for: Stronger enforcement of environmental regulations (50% of respondents); Increased investment in eco-tourism and alternative livelihoods (40%); Training in sustainable fishing practices (48%); Greater involvement of fishers in decision-making (multiple respondents). The need for co-management is further reinforced by the lack of awareness about conservation initiatives, with 85% of respondents acknowledging that they do not fully understand the ecological importance of seagrass or sustainable fishing practices. This aligns with the findings of Sahu et al. (2014), who highlighted the barriers posed by limited data accessibility and weak institutional coordination in community-based conservation efforts.

The study highlights that water quality degradation in Chilika Lagoon is a multifaceted challenge that requires an integrated approach to governance, conservation, and community engagement. The findings emphasize that: The drivers of water quality decline are deeply interconnected, requiring coordinated interventions. Governance gaps and poor enforcement weaken the impact of existing policies. Fishing communities are experiencing severe social-economic hardships due to environmental degradation. Community-led conservation efforts exist but require institutional support to be effective. A participatory, science-backed, and locally driven approach is crucial for sustainable lagoon management. Addressing these challenges through collaborative governance frameworks, enhanced policy enforcement, and community-driven conservation initiatives, Chilika Lagoon can be safeguarded for future generations while ensuring the well-being of its dependent communities.

3.6 Conclusions

Chilika Lagoon's water quality is a crucial determinant of its ecological health and the social-economic well-being of the communities that depend on it. This study highlights that water quality degradation in the lagoon is primarily driven by anthropogenic pressures such as pollution from villages and industries, agricultural runoff, shrimp aquaculture, and illegal fishing practices, compounded by natural factors like cyclones and climate change. These drivers have created a cascade of ecological impacts, including eutrophication, habitat loss, and declining fish populations, which in turn have led to social-economic challenges such as reduced incomes, increased fishing effort, and health issues for local communities. Government interventions, including the Ban on Zero Net Fishing and mangrove plantation programs, have been largely perceived as ineffective due to poor enforcement and minimal community involvement. Community-based adaptive strategies, such as shifting fishing practices, diversifying livelihoods, and advocating for conservation, demonstrate resilience but require greater institutional support to scale their impact. The findings emphasize the need for a holistic approach that integrates scientific monitoring with local ecological knowledge to address the complex challenges of water quality management in Chilika Lagoon.

To mitigate the impacts of water quality degradation, the study advocates for improved governance frameworks that actively involve local communities in decision-making and resource management. Strengthening enforcement mechanisms, promoting sustainable practices in agriculture and aquaculture, and investing in community education and capacity-building

programs are critical steps to enhance ecological resilience and social-economic sustainability. Collaborative efforts between government agencies, NGOs, and local stakeholders are essential to develop effective co-management strategies that balance ecological conservation with the livelihoods of fishing communities. This study contributes valuable insights into the social-ecological dynamics of lagoon ecosystems and provides actionable recommendations to safeguard Chilika Lagoon for future generations.

Chapter IV

Linking Vulnerabilities of Small-Scale Fisheries with Seagrass Health and Water Quality: Insights from Chilika Lagoon

4.1 Abstract

Coastal ecosystems like Chilika Lagoon are critical for maintaining biodiversity, supporting livelihoods, and ensuring ecological resilience. However, these systems face escalating pressures from anthropogenic activities and climate-induced stressors, leading to complex social-ecological vulnerabilities. Seagrass meadows, vital for water quality and as habitats for marine life, are particularly susceptible to degradation from pollution, sedimentation, and illegal aquaculture. These ecological challenges are intricately linked to the social-economic instability of SSFs who rely on these resources for their livelihoods. The loss of seagrass health disrupts fish stocks, exacerbating economic hardships and perpetuating unsustainable practices that further degrade the ecosystem. This study leverages the SEVVN framework to analyze the interconnected vulnerabilities and identify pathways to resilience. A mixed-methods approach was employed, including rapid surveys, in-depth household interviews, FGDs, and participant observation, across four sectors of Chilika Lagoon. Findings reveal that key drivers such as illegal shrimp aquaculture, plastic pollution, and overfishing contribute to ecological degradation, while governance gaps and limited adaptive capacity heighten social-economic vulnerabilities. These feedback loops underscore the urgent need for integrated management strategies. The SEVVN framework highlights actionable pathways to sustainability, including enhanced governance, community participation, education initiatives, and diversified livelihoods like ecotourism. Pathways to sustainability include enhanced governance, community participation, education programs, and diversified livelihoods such as ecotourism. This study contributes actionable insights for policymakers, emphasizing the need for integrated and context-specific interventions to ensure the long-term health of Chilika Lagoon and its dependent communities.

Keywords: Seagrass meadows, water quality, small-scale fisheries, Chilika Lagoon, social-ecological vulnerability, blue carbon ecosystems.

4.2 Introduction

The intricate interplay between ecological systems and human societies forms the cornerstone of SES, where vulnerabilities and resilience dynamically shape sustainability outcomes. Understanding and addressing the vulnerabilities of these coupled systems has become a critical imperative in the face of escalating environmental degradation and social-economic challenges. This study focuses on understanding how linkages between seagrass health and water quality contribute to social-ecological vulnerabilities, with particular emphasis on small-scale fishers (SSFs) in Chilika Lagoon. Seagrass meadows play a pivotal role in maintaining water quality, supporting fish stocks, and ensuring carbon sequestration. However, their degradation—driven by pollution, sedimentation, and illegal aquaculture—has cascading effects on biodiversity and the livelihoods of dependent communities. Linking seagrass health and water quality to understand vulnerabilities and pathways to viability is a novel area of research, contributing significantly to the theory of SES. This study builds on foundational SES insights from Berkes (2000) and Ostrom (2009), who emphasize system complexity, feedback loops, and adaptive governance as critical to resilience-building. Furthermore, it integrates livelihood-oriented approaches (Chambers & Conway, 1992; Allison & Ellis, 2001), acknowledging that vulnerability is embedded not only in ecological changes but also in economic and institutional contexts that shape SSF responses.

The SEVVN framework emerges as a vital tool in this context, offering a comprehensive lens to assess the interconnected vulnerabilities and resilience pathways within SES. By integrating foundational insights from the vulnerability framework of Turner et al. (2003) and adaptive capacity theories advanced by Marshall et al. (2010), the SEVVN framework enables a systematic exploration of the dynamic interplay between ecological and social-economic factors. The study applies SEVVN to Chilika Lagoon, focusing on exposure and sensitivity by identifying stressors like pollution and illegal aquaculture impacting seagrass health and water quality, while addressing adaptive capacity through governance gaps and social-economic constraints faced by SSFs. By highlighting recovery potential through ecological restoration opportunities, the study offers a novel application of SEVVN, providing critical insights into the intersection of ecological and social-economic vulnerabilities and identifying resilience pathways for sustainable SSFs.

Chilika Lagoon's ecological health is intricately tied to its seagrass meadows, which play a pivotal role in maintaining biodiversity, supporting fish stocks, and ensuring carbon

sequestration. These ecosystems are under siege from illegal shrimp aquaculture, agricultural runoff, plastic pollution, and hydrological disruptions caused by artificial sea mouths. Simultaneously, the lagoon's SSFs are grappling with declining fish stocks, economic instability, and governance gaps that undermine their ability to adapt to changing environmental conditions. The social-ecological vulnerabilities are further exacerbated by feedback loops where ecological degradation directly intensifies social-economic stresses, and vice versa. For instance, habitat loss and water quality decline reduce fish availability, forcing fishers to overexploit remaining resources, perpetuating a cycle of ecological and social-economic deterioration. The SEVVN framework's capacity to analyze these feedback loops and identify resilience pathways underscores its significance in advancing sustainable governance and adaptive management for Chilika Lagoon.

Seagrass meadows are essential ecological components that play a critical role in regulating water quality and sustaining marine biodiversity. Despite their importance, these habitats are increasingly subject to degradation driven by a combination of anthropogenic stressors and climatic disturbances. The deterioration of seagrass ecosystems has cascading ecological and social-economic consequences, particularly for SSF communities whose livelihoods and food security are closely tied to the health of these coastal systems. The decline in seagrass coverage reduces water clarity and diminishes habitat complexity, contributing to declining fish stocks. In response, many SSFs are compelled to adopt unsustainable fishing practices, which in turn accelerate environmental degradation, creating a reinforcing cycle of vulnerability. These ecological challenges are further compounded by governance deficits, including limited enforcement of environmental regulations and insufficient engagement of local communities in resource management. Addressing such interlinked vulnerabilities necessitates a holistic, integrated response that recognizes the ecological and social-economic dimensions of lagoon sustainability.

The study proposes the SEVVN framework as a guiding approach to confront these challenges. SEVVN emphasizes the integration of ecological restoration with social-economic strategies to disrupt negative feedback loops and build resilience. The central objective of this study is to examine the dynamic interconnections between seagrass health and water quality, and to explore their implications for ecological integrity and community well-being in the context of Chilika Lagoon. In doing so, the study contributes to a deeper understanding of how ecosystem-

based approaches can inform adaptive governance and policy interventions aimed at promoting long-term resilience. By situating seagrass health within broader discussions of water quality and social vulnerability, the SEVVN framework offers a context-specific pathway to sustainable lagoon management—one that foregrounds collaboration, adaptability, and the co-production of knowledge between scientists, policymakers, and local communities.

4.2.1 Literature Section

The ecological and social-economic dynamics of SES, particularly in vulnerable ecosystems like Chilika Lagoon, have been extensively studied in literature. Scholars such as Folke et al. (2005) and Cinner et al. (2012) highlight the importance of cross-scale interactions, institutional diversity, and social capital in maintaining SES resilience. The livelihoods approach (Ellis, 2000; Scoones, 1998) underscores that adaptive capacity is shaped by access to assets, institutions, and the enabling environment, a lens that aligns with SEVVN's integration of social vulnerability dimensions. In SSF literature, governance frameworks such as interactive governance (Kooiman et al., 2005; Jentoft & Chuenpagdee, 2015), community-based and co-management (Jentoft, 2000; Béné et al., 2009), and adaptive governance (Chuenpagdee & Jentoft, 2018) provide relevant models to interpret Chilika's evolving institutional context and its limitations. Coastal lagoons and their associated fisheries are frequently highlighted for their ecological importance and economic contributions. Turner et al. (2003) emphasized the significance of integrating ecological and social dimensions to address coupled vulnerabilities in SES, while Marshall et al. (2010) underlined the role of adaptive capacity in fostering resilience. Seagrass ecosystems are identified as critical habitats supporting marine biodiversity and functioning as blue carbon sinks (Duarte et al., 2005). However, their vulnerability to anthropogenic stressors such as eutrophication and sedimentation is widely documented (Orth et al., 2006; Waycott et al., 2009). In the Indian context, Nayak and Berkes (2010, 2011, 2014) explored the social-ecological linkages of Chilika Lagoon, highlighting governance challenges and the impacts of illegal aquaculture. Similarly, Dujovny (2009) and Sahu et al. (2014) discussed the lagoon's ecological degradation due to pollution and artificial hydrological interventions.

Studies also point to the social-economic vulnerabilities of SSFs dependent on coastal ecosystems. Bavinck et al. (2014) and Pomeroy et al. (2015) emphasize the critical role of participatory governance in managing SSFs, while Berkes & Turner (2006) advocates for integrating TEK in resource management. The interconnected impacts of ecological degradation

and social-economic pressures are well-articulated in studies by Nayak (2014), which stress the need for co-management approaches to sustain livelihoods and biodiversity. This study builds upon these insights, applying the SEVNN framework to analyze the compounded vulnerabilities in Chilika Lagoon. By synthesizing ecological and social-economic dimensions, the research identifies actionable pathways to enhance resilience and viability in the face of escalating stressors.

4.3 Conceptual Social-Ecological Vulnerability and Viability Nexus (SEVNN) framework

The SEVNN framework offers a comprehensive lens to analyze the dynamic interplay of vulnerabilities and resilience within coupled human-environment systems. Grounded in the vulnerability framework of Turner et al. (2003), the SES perspective of Ostrom (2009), and adaptive capacity insights of Marshall et al. (2010), the SEVNN framework offers a pluralistic lens to analyze SES resilience. It aligns with the calls by Adger (2006) and Berkes & Ross (2013) for frameworks that incorporate both environmental and social capital to address cumulative and interacting stressors in coastal systems. This framework is particularly relevant for addressing the complexities of SSFs and lagoon ecosystems, such as the Chilika Lagoon, which face escalating pressures from ecological degradation and social-economic vulnerabilities. While the SEVNN framework adeptly integrates vulnerability and resilience across SES, its utility extends further by facilitating an in-depth exploration of the linkages between BCEs, such as seagrass meadows, and water quality. Seagrass meadows serve as crucial BCEs, playing an essential role in maintaining biodiversity, supporting fish stocks, and sequestering carbon. These functions are directly influenced by water quality, which governs the ecological health and productivity of seagrass habitats. Studies (e.g., Orth et al., 2006; Unsworth et al., 2015) have consistently emphasized the interplay between nutrient levels, sedimentation, and light penetration as critical drivers of seagrass health. In this context, SEVNN enables a holistic analysis by integrating these ecological dimensions with social-economic aspects, such as the dependence of SSFs on seagrass-dependent fisheries.

To effectively situate this discussion, it is essential to first establish the literature connecting seagrass ecosystems and water quality. Seagrass meadows require high water clarity for photosynthesis, which can be impeded by eutrophication, sedimentation, and pollution (Waycott et al., 2009). Nutrient overloading from agricultural runoff and shrimp aquaculture often leads to algal blooms, reducing light availability and altering seagrass growth cycles (Duarte et al., 2008). Conversely, healthy seagrass meadows enhance water quality by stabilizing sediments,

reducing turbidity, and cycling nutrients. Thus, the interdependence of seagrass health and water quality creates feedback loops that amplify ecological vulnerabilities and social-economic challenges for SSFs. By integrating these insights, the SEVVN framework provides a robust platform for analyzing ecological stressors, such as declining water quality, propagating social-economic vulnerabilities, and identifying pathways to enhance resilience.

The ecological sub-system of Chilika Lagoon highlights its exposure and sensitivity to key stressors, significantly impacting its recovery potential. As indicated in the Figure 4.2, “Exposure”, such as blue carbon decline and water quality degradation, arises from a combination of anthropogenic and natural factors. Key drivers include pollution, artificial sea mouth opening, illegal aquaculture, resource overexploitation, and climate stressors. These factors collectively result in significant “Ecological Impacts,” including habitat degradation, biodiversity loss, and reduced water quality. Blue carbon decline, for example, is closely linked to seagrass degradation, which reduces carbon sequestration and accelerates sediment destabilization. This, in turn, leads to increased turbidity and hypoxia, further deteriorating the lagoon's ecological health. Stakeholders, including SSFs and local experts, have emphasized the loss of critical habitats like seagrass meadows, which are essential for supporting biodiversity and fish stocks. For instance, respondents such as BAR-06 observed that areas with healthy seagrass are more productive for fish and crabs, underscoring its ecological significance. Lagoon's high exposure to stressors such as agricultural runoff, illegal shrimp aquaculture, and plastic pollution exacerbates its ecological sensitivity, further threatening its recovery. These stressors contribute to declining fish populations, directly impacting the livelihoods of fishers. As noted by PUR-12, the loss of biodiversity diminishes the resilience of the entire lagoon ecosystem, making it harder for communities to sustain their traditional practices. Stakeholders have highlighted the urgent need for effective waste management systems to mitigate these challenges. Respondents such as MO-11 emphasized that reducing pollutants, particularly from agricultural runoff and plastic waste, is critical to protecting and restoring the lagoon. Addressing these issues is vital for maintaining the ecological integrity of Chilika Lagoon and ensuring its long-term sustainability.

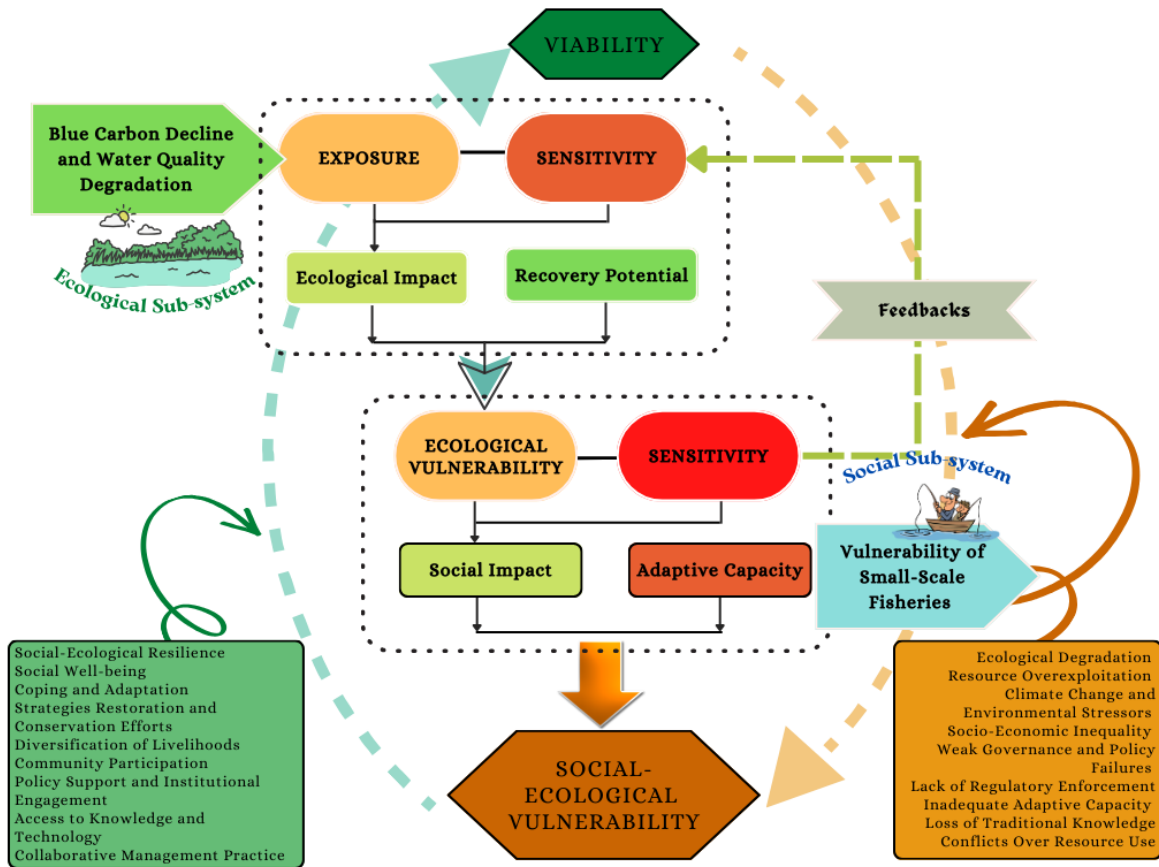


Figure 4.1 SEVVN framework for Chilika Lagoon

The social sub-system of Chilika Lagoon underscores the vulnerability of SSFs, which serve as the primary livelihood for local communities. This vulnerability arises from the heavy dependence of SSFs on lagoon resources, compounded by limited adaptive capacity stemming from weak governance, social-economic inequality, and inadequate access to knowledge. Governance gaps and a lack of regulatory enforcement hinder the effective implementation of initiatives such as the zero net fishing ban and mangrove restoration efforts. Resource overexploitation and ecological degradation further amplify the challenges faced by SSFs by reducing fish stocks and economic returns. Climate stressors, including cyclones and disruptions in water salinity, also pose significant threats to the resilience of these fisheries. Pollution, particularly plastic toxins, exacerbates the decline in fish availability and market value, directly impacting the livelihoods of fishers and traders. These stressors create negative feedback loops that perpetuate economic hardship and drive further overexploitation, ultimately threatening the social-economic stability of SSF-dependent communities.

For many communities, SSFs represent their primary or sole livelihood. However, declining fish stocks, unpredictable weather patterns, and restricted access to resources exacerbate economic instability. Respondents like MO-08 expressed concerns about sustaining their families in the face of reduced catches, while BIN-10 described the struggle to balance traditional fishing practices with the need to explore alternative income-generating activities. Economic insecurity has forced many fishers to migrate in search of new livelihoods, fracturing community ties and diminishing local knowledge bases. The exclusion of local communities from decision-making processes further amplifies their vulnerability. Fishers like MO-01 noted feeling marginalized in lagoon management, which prevents the integration of their TK into conservation efforts. This exclusion not only undermines conservation initiatives but also exacerbates the social-economic challenges faced by these communities.

The SEVVN framework emphasizes the dynamic interplay between ecological vulnerability and social sensitivity. Negative feedback loops emerge when ecological degradation—such as seagrass loss and water quality decline—results in reduced fish stocks, which, in turn, exacerbate the social-economic vulnerabilities of SSFs. For example, reduced ecological recovery potential (e.g., sedimentation, pollution) directly limits the productivity of the lagoon, worsening the economic struggles of fishing communities. Conversely, unsustainable practices driven by social-economic stressors (e.g., overfishing, illegal practices) amplify ecological impacts, creating a vicious cycle of decline. This interdependence underscores the urgent need to address ecological and social vulnerabilities simultaneously.

The framework also identifies pathways to viability, focusing on enhancing adaptive capacity and fostering resilience. Adaptive capacity in the social sub-system can be strengthened through several strategies. Community participation and policy support play a vital role in empowering SSFs in governance and decision-making. Co-management approaches that integrate TK with scientific insights help bridge the disconnect between local needs and policy initiatives, enabling the development of effective conservation strategies. Restoration and conservation efforts, such as seagrass replanting and improved waste management, directly enhance ecological recovery potential, improving fish stocks and ecosystem health. Diversification of livelihoods, including the promotion of alternative income sources like ecotourism and sustainable aquaculture, reduces pressure on lagoon resources while enhancing economic stability. Education and capacity

building, through environmental education and skills training programs, foster long-term resilience by promoting sustainable practices and stewardship among communities.

The inclusion of feedback mechanisms highlights how positive ecological changes-such as improved blue carbon storage and water quality-can reinforce social resilience. Healthier ecosystems support sustainable fish stocks, reduce economic pressures, and enhance community well-being. Building on the resilience and adaptive capacity concepts from Marshall et al. (2010), the SEVVN framework emphasizes systems' ability to adapt to and recover from stressors while sustaining functionality and integrity. For instance, restoring seagrass meadows and improving water quality are critical for reinforcing the ecological foundation of the lagoon. Community-led initiatives, such as seagrass planting and habitat monitoring, foster ecological recovery while instilling a sense of stewardship among local residents (JAG-2, BER-07). Moreover, diversifying income sources through ecotourism, sustainable aquaculture, and craft-making provides alternative pathways for economic resilience. Respondents like SIP-01 highlighted the potential of ecotourism as a dual strategy to generate income and promote conservation.

Empowering local communities through co-management strategies and inclusive decision-making enhances adaptive capacity. Respondents such as SAB-01 emphasized the importance of incorporating TK into governance frameworks for more effective and sustainable outcomes. Strengthened policies, including stricter enforcement of fishing regulations and incentives for sustainable practices, can bridge governance gaps. Community-government collaboration, as highlighted by respondents like PUR-15, is essential in creating viable solutions. Additionally, building awareness and technical skills among community members equips them to adopt sustainable practices and actively engage in conservation. Respondents like KHAS-10 underscored the need for education to highlight the ecological significance of seagrass and its role in sustaining fish populations.

The SEVVN framework uniquely integrates the dual dimensions of vulnerability and viability, emphasizing their dynamic interplay in shaping SES. This integration is particularly critical for addressing the challenges and opportunities in Chilika Lagoon. The feedback loops captured by SEVVN illustrate the mutual reinforcement between ecological health and social well-being. For instance, improved seagrass health enhances fish stocks, stabilizing livelihoods and reducing economic pressures that drive overfishing. Conversely, better governance and community practices can directly mitigate ecological degradation, fostering resilience. The

framework adopts a systems approach, viewing the lagoon as an interconnected entity where ecological and social factors are interdependent. Ecological restoration efforts, such as planting seagrass (JAG-2) and pollution reduction (SAM-03), are inseparable from social-economic initiatives like livelihood diversification (SIP-08) and community education (KHAS-13). SEVVN also emphasizes dynamic adaptation, advocating for strategies that evolve with changing circumstances. By integrating TK with modern scientific insights, the SEVVN framework ensures that management approaches remain responsive and inclusive. Respondents like SAB-07 stressed the importance of leveraging local knowledge for sustainable governance. However, to fully address the main objective of the study-the examination of seagrass and water quality as drivers of vulnerability-it is crucial to foreground their ecological and social-economic implications within the SEVVN framework.

Seagrass ecosystems and water quality function as interlinked drivers that shape the vulnerability and resilience of Chilika Lagoon SES. Research demonstrates that nutrient inputs from anthropogenic activities, such as shrimp farming and agricultural runoff, degrade water quality, triggering cascading effects on seagrass health (Waycott et al., 2009; Unsworth et al., 2015). Degraded seagrass meadows, in turn, lose their capacity to sequester carbon and support biodiversity, compounding the ecological challenges faced by the lagoon. Simultaneously, declining fish stocks and habitat loss exacerbate the social-economic vulnerabilities of SSFs, who depend on these resources for their livelihoods. The SEVVN framework captures these dynamics by emphasizing feedback loops between ecological degradation and social-economic stressors. By focusing on both vulnerabilities and pathways to viability, SEVVN not only identifies critical challenges but also highlights actionable strategies to enhance sustainability. For instance, restoring seagrass meadows improves water quality and fish stocks, reinforcing both ecological health and economic stability. Through its emphasis on feedback loops, community participation, and adaptive management, the framework offers a comprehensive pathway to ensure the long-term health of both the ecosystem and the livelihoods it supports. In doing so, SEVVN transforms vulnerability into an opportunity for collaborative, resilient, and viable solutions. By incorporating a nuanced understanding of seagrass and water quality dynamics, the framework strengthens its capacity to guide sustainable interventions tailored to the unique challenges of Chilika Lagoon.

4.4 Research Area and Methods

4.4.1 Study Area

Chilika Lagoon, located along the eastern coast of India, represents a quintessential case of a complex SES, where ecological integrity and human well-being are deeply intertwined. Covering over 1,100 square kilometers, this Ramsar-designated wetland is ecologically significant for its mosaic of habitats - including seagrass meadows, mangroves, and brackish water ecosystems-which support high biodiversity and sustain SSFs (Kumar & Pattnaik, 2012). These fisheries are vital to the livelihoods of more than 200,000 people, particularly from resource-dependent fishing communities (Nayak & Berkes, 2010). In recent decades, Chilika Lagoon has been increasingly subjected to anthropogenic pressures such as illegal shrimp aquaculture, plastic and organic pollution, sedimentation, and salinity alterations triggered by the construction of artificial sea mouths (Nayak & Berkes, 2011; Padhi et al., 2020). These stressors collectively compromise water quality, disrupt the ecological functions of seagrass meadows, and erode the social-economic stability of communities reliant on fisheries. To account for the spatial variability in ecological conditions and community dynamics, the study stratified the lagoon into four sectors: Northern, Central, Southern, and the Outer Channel. Each sector exhibits distinct environmental challenges and adaptive strategies, thus offering a rich landscape for analyzing how feedback loops between ecological degradation and social-economic vulnerability unfold. Anchored in the SEVNN framework, this study adopts a systems-oriented and context-specific approach to investigate the interconnected stressors, community perceptions, and resilience-building mechanisms operating across these sectors.

4.4.2 Data Collection

The study adopted a mixed-methods approach to generate both qualitative and quantitative data from a broad range of stakeholders, ensuring a comprehensive understanding of social-ecological vulnerabilities in Chilika Lagoon. Given the lack of up-to-date open-access data on water quality and seagrass distribution in the region, all data were collected through primary, community-based methods. This approach enabled a grounded analysis rooted in local knowledge and lived experiences. The research commenced with a two-week reconnaissance phase, during which the research team engaged in preliminary visits across the lagoon's four sectors. This phase was essential to gain familiarity with local customs, spatial characteristics, and linguistic nuances.

Informal discussions and site observations during this period informed the design of culturally appropriate survey instruments and interview protocols. Building on these insights, rapid surveys were carried out to 200 participants across 32 villages, distributed across the Northern (7), Central (8), Southern (10), and Outer Channel (7) sectors. These surveys aimed to capture community perceptions of changes in water quality, seagrass health, and related livelihood concerns. To supplement this overview with more nuanced data, 190 household surveys were conducted using a stratified sampling strategy. Specifically, 15 households were surveyed in each of four villages within the Central, Southern, and Outer Channel sectors, while two villages in the Northern sector contributed five households each. The household surveys combined structured questions with Likert-scale assessments, facilitating both descriptive and comparative analysis across sectors. Quantitative survey data were entered into and analyzed in Excel to generate frequency distributions and identify cross-sectoral trends, which supported the triangulation of qualitative findings.

To explore sector-specific vulnerabilities in greater depth, the study also conducted 62 semi-structured interviews with a diverse group of stakeholders. These included SSFs (14), women (12), government officials (4), fish traders (9), market owners (3), tourists (2), local experts (4), daily boat operators and travelers (6), members of fishers' associations (3), and aquaculture practitioners (1). These interviews enabled a detailed examination of localized knowledge, ecological concerns, and adaptation strategies from multiple perspectives. In parallel, four FGDs were held in selected villages within the Central, Southern, and Outer Channel sectors. These FGDs brought together a cross-section of participants, including fishers, women, and community leaders, to facilitate collective reflection on environmental changes, governance challenges, and community responses. Although FGDs were not conducted in the Northern sector due to logistical constraints, rich data obtained through surveys and interviews in that region ensured adequate representation.

To complement these methods, participatory techniques such as free listing were integrated into surveys and FGDs to capture respondents' spontaneous identification of environmental concerns, key species, and perceived ecological transformations. Additionally, participant observation played a crucial role in contextualizing the data. By engaging in daily activities such as fishing, market interactions, and lagoon-based travel, I gained first-hand insights into practices and conditions shaping the SES. Transect walks conducted across villages and ecological zones

further enabled systematic visual documentation of pollution hotspots, fishing areas, and seagrass habitats. These observations were recorded through field notes, photographs, and video footage, offering both empirical depth and visual representation of the lagoon’s changing landscape. This integrated and iterative data collection process ensured that both environmental and social dimensions of vulnerability were captured in a manner sensitive to local realities and grounded in community perspectives. The iterative and interconnected nature of these research activities is depicted in Figure 4.1, which illustrates the sequential flow of methods-including reconnaissance, surveys, participatory techniques, and visual documentation-leading to comprehensive data analysis.

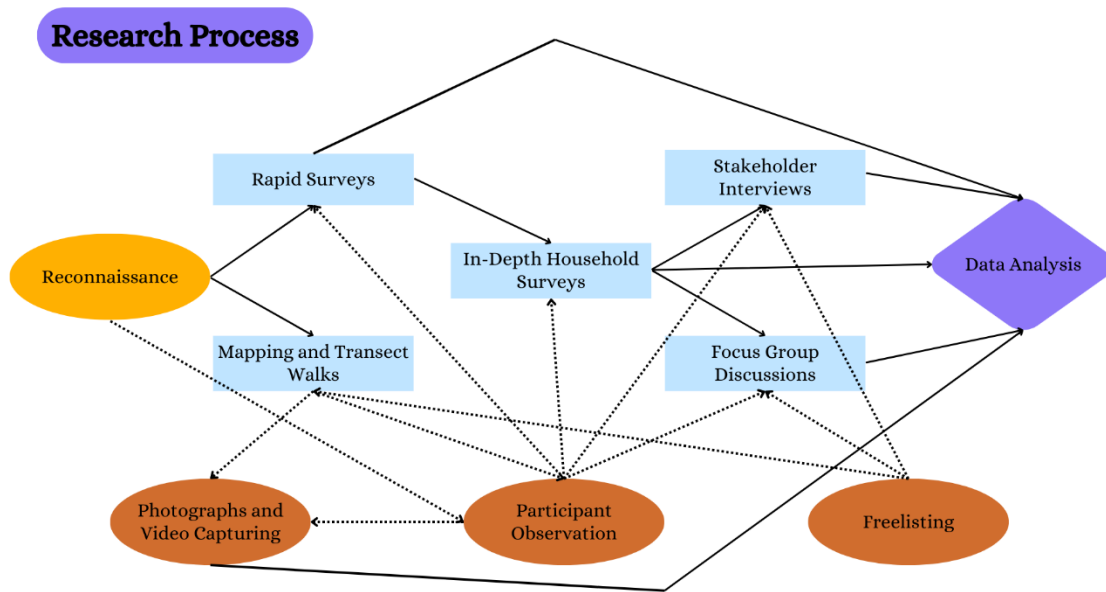


Figure 4.2 Step-by-step research process flowchart

4.4.3 Data Analysis

The analysis phase of this study was designed to synthesize diverse data types and uncover the interlinkages between seagrass degradation, water quality changes, and their socio-economic implications. To ensure coherence across the dataset, qualitative and quantitative strands were analyzed in parallel, each informing and reinforcing the other. Qualitative data-including transcripts from interviews, observation notes, and recordings from FGDs -were subjected to thematic analysis through open coding using NVivo software. Although not employing the full grounded theory methodology, open coding was applied as an exploratory, inductive technique to identify and organize recurrent patterns and themes. Key thematic categories that emerged

included pollution, habitat loss, governance gaps, ecological knowledge, and community adaptation strategies. NVivo facilitated the systematic coding and categorization of textual data, while Excel was used to support frequency counts, cluster similar codes, and conduct visual cross-comparisons across sectors. To enhance analytical rigor and credibility, peer debriefing sessions were conducted with academic colleagues, and iterative coding reviews helped refine emerging themes and minimize researcher bias.

In parallel, quantitative survey data were entered into Excel and analyzed to generate descriptive statistics, cross-tabulations, and frequency distributions. Responses to Likert-scale items provided insight into participants' perceptions of the severity and impacts of various ecological and social stressors. These numerical trends not only captured variations across sectors but also served to triangulate qualitative findings, ensuring alignment between community-reported experiences and field-level observations. Throughout data collection and analysis, ethical considerations were prioritized. All participants were informed of the research objectives, and verbal consent was obtained before their involvement. Anonymity and confidentiality were strictly maintained during both fieldwork and reporting. The use of the Odiya language during interviews and surveys-facilitated by local research assistants-further ensured cultural sensitivity and enhanced the accuracy of the data collected.

Each method employed in this study contributed uniquely to achieving the research objectives. Surveys helped quantify the extent of perceived environmental changes and the distribution of stressor impacts across lagoon sectors. Semi-structured interviews and FGDs provided context-specific insights into causal mechanisms and the adaptive strategies employed by different stakeholder groups. Free listing and participant observation offered spontaneous, grounded accounts of community knowledge and perceptions, often highlighting underrepresented issues and perspectives. Together, this integrated and participatory approach enabled a holistic analysis of the dynamic feedback loops between ecological degradation and social-economic vulnerability in Chilika Lagoon, thus advancing the objectives of the SEVVN framework and offering a robust foundation for resilience-oriented governance and ecosystem restoration.

4.5 Linkages Between Seagrass Health and Water Quality

Seagrass meadows in the Chilika Lagoon are vital ecological habitats that serve as natural nurseries for fish, prawns, and other marine life, directly supporting the livelihoods of SSFs. The interconnected impact of degraded water quality and declining seagrass health on SSFs is one of

the most concerning findings. These ecosystems are under significant pressure, cascading social-economic and ecological vulnerabilities. Table 4.1 outlines the critical drivers affecting seagrass meadows and water quality in Chilika Lagoon, emphasizing their interconnected impacts. Key anthropogenic and natural factors such as agricultural runoff, shrimp aquaculture, tourism, and cyclones are highlighted. Each driver demonstrates a dual impact: direct consequences on the health and distribution of seagrass meadows and corresponding effects on water quality parameters such as clarity, nutrient levels, and DO. The table serves to illustrate the intricate relationships within the lagoon's SES, underscoring the need for integrated management approaches to address these challenges effectively. The radar chart (Figure 4.3) visually represents how different stakeholder groups in Chilika Lagoon perceive the impact of key environmental and anthropogenic drivers on SSFs. Eight critical drivers-Agricultural Runoff, Illegal Shrimp Aquaculture, Tourism and Waste, Cyclones and Storm Surges, Artificial Sea Mouths, Plastic Pollution, Illegal Fishing Practices, and Climate Change-are rated on a Likert scale (1 = Very Low Impact to 5 = Very High Impact). Each stakeholder group is plotted to show their average perception of the drivers' impacts.

Table 4.1 Key drivers and their impacts on seagrass meadows and water quality in Chilika (Synthesized from surveys and interview responses)

Driver	Impact on Seagrass Meadows	Impact on Water Quality
Agricultural Runoff	- Excess nutrients lead to eutrophication, reducing light penetration - Sedimentation covers seagrass beds	- Increased nitrogen and phosphorus cause algal blooms - Reduced DO levels affect aquatic life
Shrimp Aquaculture	- Habitat destruction due to illegal expansion - Wastewater discharges increase salinity and chemical pollutants	- Pollution from aquaculture lowers water quality - Chemicals contribute to nutrient overload and hypoxia.
Tourism and Waste	- Physical damage to meadows from boat activity - Litter and plastics entangle and suffocate seagrass	- Plastics and food waste increase turbidity - Oil spills from boats degrade water quality.
Cyclones and Storm Surges	- Uprooting of seagrass and sediment displacement - Loss of habitat for fish and prawns	- Increased sedimentation reduces clarity - Debris and organic waste deplete oxygen levels.

Artificial Sea Mouths	• Altered hydrology leads to erosion and habitat fragmentation • Salinity changes affect species composition	• Salinity fluctuations impact biodiversity • Disrupted sediment flow increases turbidity
Plastic Pollution	• Plastics block sunlight, preventing photosynthesis • Microplastics accumulate in seagrass ecosystems	• Microplastics degrade water quality • Chemical leachates harm aquatic organisms.
Illegal Fishing Practices	• Drag nets uproot seagrass and disturb the sediment • Juvenile overfishing reduces ecosystem regeneration	• Oil spills and waste from fishing boats pollute water. - Overfishing alters aquatic population dynamics.
Climate Change	• Rising temperatures affect seagrass growth cycles • Increased salinity impacts meadow resilience.	• Elevated temperatures exacerbate algal blooms. - Rising sea levels contribute to saltwater intrusion.

Key human-induced drivers such as illegal shrimp aquaculture (mean rating 5.0 across multiple stakeholders like ISF, IWO, and BA), plastic pollution (mean ratings 4.44 to 5.0), and tourism and waste (mean ratings 4.0–5.0 across stakeholders) are directly impacting seagrass meadows and water quality. For instance, shrimp aquaculture releases excess nutrients into the lagoon, causing eutrophication, algal blooms, and increased turbidity. These conditions block sunlight, which is critical for seagrass photosynthesis. Respondents repeatedly emphasized this issue, with one fisher (ISF12) stating, “*The shrimp farms make the water murky, and the seagrass disappears.*” Plastic pollution rated 5.0 by several groups including Local Experts (LE), Boat Associations (BA), and Daily Boat Operators (BO), exacerbates the degradation of water quality by introducing microplastics and toxins. These contaminants not only harm seagrass meadows but also degrade the aquatic environment, resulting in reduced fish stocks and biodiversity loss. Stakeholders also identified tourism and waste as significant stressors, particularly physical damage caused by boating and plastic entanglement, with a mean rating of 4.0 to 5.0 across fisher groups, traders, and local experts.

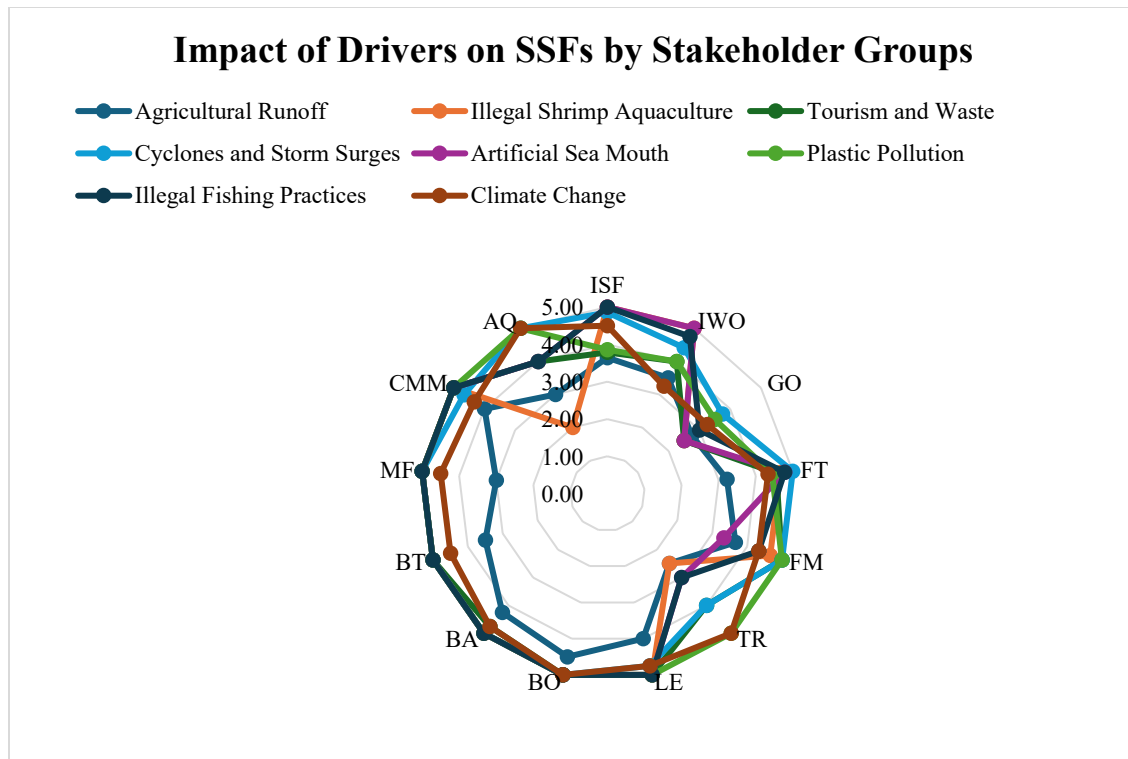


Figure 4.3 Perceived impact of various drivers on SSFs by stakeholder groups in Chilika

Natural drivers such as cyclones and storm surges were highlighted as critical pressures, particularly by stakeholders such as SSFs (4.86) and fish traders (5.0). These extreme weather events increase sedimentation, destabilize seagrass roots, and reduce water clarity, which disrupts both habitat stability and light penetration. Similarly, artificial sea mouths, with high ratings (5.0) from multiple groups, contribute to altered salinity regimes and destabilized aquatic ecosystems, further impairing seagrass health. The flowchart (Figure 4.4) clearly depicts the feedback loop between water quality and seagrass health. As seagrass meadows degrade due to sedimentation, eutrophication, and pollution, their natural ability to trap sediments and improve water clarity is compromised. This creates a cycle where poor water quality hampers seagrass recovery, leading to further degradation. Respondents confirmed this cycle, with one (MF-01) noting, “*The water is too murky now. Without seagrass, we lose fish, and fishing becomes harder.*”

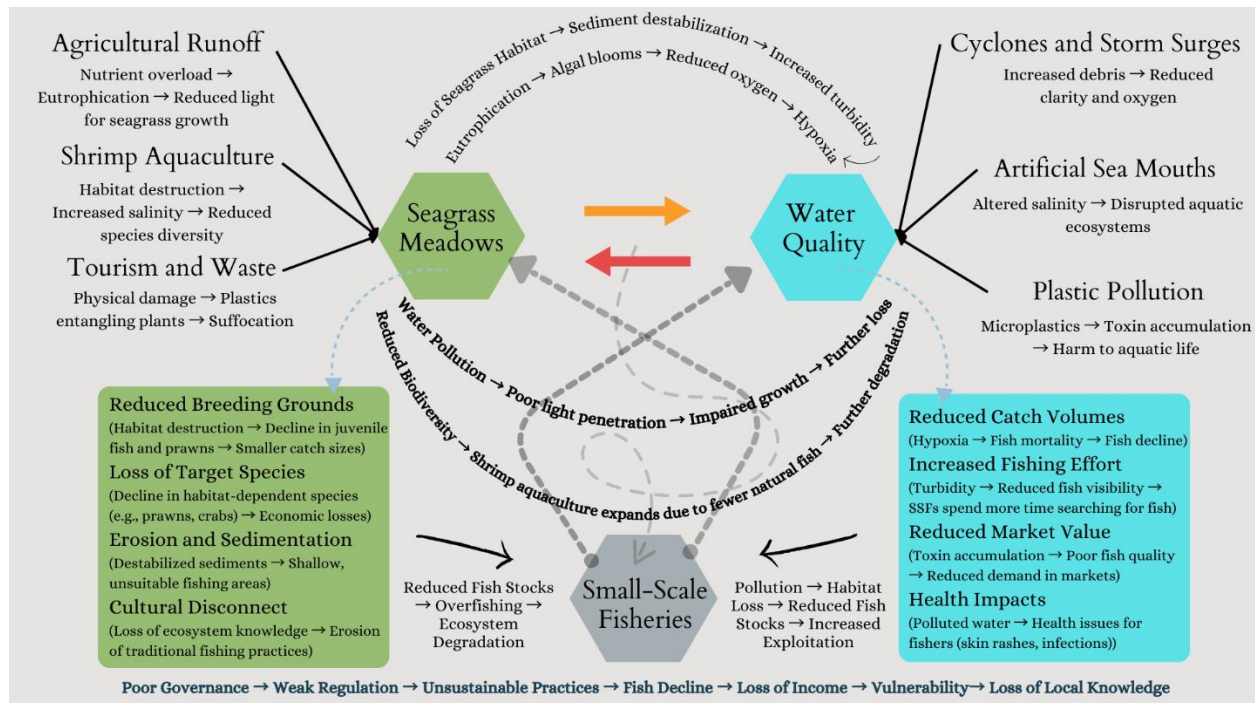


Figure 4.4 Flowchart of drivers, impacts, and vulnerabilities in Chilika Lagoon

The interconnected impact on SSFs is one of the most concerning findings. As shown in the image, degraded water quality and seagrass health lead to reduced fish stocks and biodiversity loss, which are the foundation of SSF livelihoods. The mean ratings for illegal fishing practices (5.0 for ISF, BO, and MF) and climate change (4.5–5.0 across multiple groups) reveal these drivers as compounding pressures. SSFs are particularly vulnerable as they rely heavily on seagrass-dependent species such as prawns and crabs. With reduced breeding grounds, highlighted by fisherwomen and fish traders, fishers experience lower catch volumes, increased fishing efforts, and economic losses. For instance, stakeholders such as SSFs rated illegal fishing practices and artificial sea mouth at 5.0, linking them directly to ecosystem degradation and unsustainable fishing practices. The collapse of seagrass meadows forces SSFs to overexploit remaining fish stocks, intensifying ecological stress. A fisherwoman (IWO11) reported, “*We spend more time and energy catching fewer fish now because the habitat has been destroyed.*”

The SEVVN framework (Figure 4.2) was instrumental in unraveling the linkages, offering insights into how BCEs interact with water quality parameters. By connecting ecological degradation with social-economic vulnerabilities, the framework highlights the compounded challenges facing SSFs and identifies areas for intervention. For instance, the loss of seagrass meadows compromises sediment stabilization and water clarity, creating a feedback loop where

poor water quality further inhibits seagrass recovery, perpetuating ecological and economic instability. Stakeholders like Government Officials (GO) rated shrimp aquaculture and artificial sea mouths lower (2.5–3.0), suggesting gaps in regulatory oversight and limited monitoring of environmental pressures. Adaptive strategies, such as stricter regulations on shrimp farms, improved waste management in tourism zones, and community-led seagrass restoration, are essential to breaking this cycle. Local Experts (LE), who consistently rated most drivers at 5.0, highlighted the importance of integrating TK and involving fisherfolk in conservation efforts to restore seagrass meadows and improve water quality.

The linkages between seagrass health, water quality, and SSF vulnerabilities in the Chilika Lagoon are deeply intertwined. Anthropogenic drivers such as illegal shrimp aquaculture, plastic pollution, and tourism and waste are key contributors to this feedback loop, exacerbating both ecological and social-economic stresses. Figure 4.4 effectively visualizes these relationships, showcasing how seagrass degradation leads to sediment destabilization, increased turbidity, and reduced biodiversity. The flowchart maps the interconnected impacts of key environmental drivers-such as agricultural runoff, shrimp aquaculture, tourism waste, cyclones, and plastic pollution-on seagrass meadows, water quality, and SSFs in Chilika Lagoon. It visualizes how ecosystem degradation, including loss of seagrass habitat and water pollution, leads to cascading effects such as reduced fish stocks, increased fishing effort, and social-economic challenges like loss of income and health impacts. Feedback loops exacerbate ecological stress and vulnerabilities, emphasizing the urgent need for integrated management and sustainable governance to restore resilience. The integration of stakeholder perspectives and the quantitative findings (mean ratings) highlight a clear need for holistic interventions. Reducing nutrient runoff, regulating shrimp farming, and controlling plastic pollution can restore water quality and create favorable conditions for seagrass recovery. Simultaneously, social-economic strategies, including alternative livelihoods and fisher education, can mitigate vulnerabilities faced by SSFs. Chilika Lagoon can move toward long-term resilience and sustainability by addressing both ecological and community challenges.

4.6 Vulnerability of SSFs using SEVVN Framework

Empirical data from Chilika Lagoon reveal the intricate interactions between ecological degradation and social-economic distress. Pollution, sedimentation, and salinity shifts exacerbate ecological exposure directly impacting fish stocks and seagrass health. For instance, fisherfolk

describe how plastic waste and shrimp farm runoff degrade habitats, while sedimentation from artificial sea mouths buries crucial breeding grounds. Simultaneously, social-economic vulnerabilities manifest through declining fish catches, food insecurity, and forced migration, with respondents reporting increased reliance on unsustainable practices like zero nets. By linking ecological and social dimensions, the SEVVN framework highlights the compounded vulnerability of SSFs. For instance, narratives about limited adaptive capacity-such as gaps in education and lack of involvement in policy decisions-underscore the need for inclusive, knowledge-based interventions. The SEVVN framework not only aids in diagnosing vulnerabilities but also emphasizes the importance of integrating community participation and ecological restoration to enhance resilience, ensuring the long-term viability of both ecosystems and SSF livelihoods.

4.6.1 Ecological Vulnerability of SSF

a) Exposure to Water Quality Degradation

SSFs in the Chilika Lagoon are under increasing threat due to significant water quality degradation, as evidenced by numerous first-hand accounts from local fisherfolk. The unchecked influx of pollutants, including plastic waste, untreated sewage, and chemicals from shrimp farms and agricultural runoff, is a recurring theme in their narratives. For instance, respondents frequently report *“catching more plastic than fish”* and note that *“plastic waste, like bottles and bags, floats everywhere in the lagoon.”* Agricultural runoff also carries fertilizers and pesticides into the water during rains, causing eutrophication and algal blooms that harm aquatic life. The presence of oil slicks from motorboats and waste left behind by tourists further exacerbates the pollution problem. As one respondent put it, *“Tourists bring money but also leave behind garbage,”* reflecting the dual-edged impact of tourism. Over the years, the lagoon has shifted from a relatively clean and thriving ecosystem to one described as *“murky, polluted, and lifeless,”* directly threatening the livelihoods of SSFs.

b) Sensitivity to Sedimentation and Salinity

The ecological sensitivity of the Chilika Lagoon to sedimentation and salinity changes poses significant challenges for SSFs, as highlighted by fisherfolk narratives. Artificial sea mouths have disrupted natural water flow, leading to increased sedimentation that buries vital seagrass

meadows and fish breeding grounds. One fisher observed, “*Now, mud and silt are covering everything because of pollution and construction.*” Cyclones and deforestation have further intensified erosion, exacerbating sedimentation issues. Meanwhile, shrimp farms and rising sea levels have contributed to higher salinity levels, which are displacing freshwater species. Fisherfolk have expressed concern over the “*disappearing fish*” and the “*murky, sediment-filled waters*” that make fishing increasingly difficult. The narratives also reveal how these changes force fishers to venture farther and expend more resources for smaller catches, deepening their economic and social vulnerabilities. This double burden of sedimentation and salinity underscores the urgent need for intervention.

c) Low Recovery Potential of Seagrass Meadows

Seagrass meadows, critical habitats for marine biodiversity and the foundation of SSFs in Chilika Lagoon, are experiencing a steep decline. Pollution from shrimp farms, untreated sewage, and agricultural runoff is weakening these ecosystems, as fisherfolk frequently report. One respondent noted, “*Seagrass is disappearing, and we’re seeing fewer fish, making it harder to sustain our families.*” Sedimentation from artificial sea mouths and motorboat activities physically damages seagrass, while cyclones and invasive plants like *Phragmites Karka* exacerbate their degradation. Many fisherfolk recall the past abundance of seagrass, describing it as “*a shelter for baby fish,*” and lament the current scarcity due to pollution and habitat destruction. Efforts to restore these meadows are hampered by the pervasive environmental challenges and lack of coordinated management. Fisherfolk narratives emphasize the dire situation: “*If things keep going like this, we’re afraid we might lose the seagrass for good.*” The recovery potential of these meadows remains critically low without stringent pollution controls and comprehensive restoration initiatives. These findings highlight the urgent need for sustainable management practices to safeguard the ecological and economic stability of SSFs.

Table 4.2 outlines the key dimensions of the SEVVN framework applied to the Chilika Lagoon's SSFs. Each dimension is categorized under ecological and social subsystems, detailing major drivers and factors contributing to exposure, sensitivity, recovery potential, and adaptive capacity. Ecological exposure includes pollution, sedimentation, and salinity changes, while social exposure highlights economic dependencies and migration pressures. Sensitivity is defined by ecological degradation, such as habitat destruction, and social practices like overfishing. The recovery potential focuses on the ecological system's ability to rebound from damage, whereas

adaptive capacity addresses social challenges like education gaps and lack of policy involvement. This integrative approach emphasizes the interplay between ecological degradation and social-economic vulnerabilities, providing a foundation for targeted resilience-building interventions.

Table 4.2 SEVVN Framework dimensions and the respective ecological and social subsystems. (Synthesized from surveys and interview responses)

Dimension	Ecological Subsystem	Social Subsystem
Exposure (Ecological + Social)	• Pollution (plastic waste, chemicals, sewage) • Sedimentation from artificial sea mouths • Salinity shifts from rising sea levels	• Economic reliance on diminishing fish stocks • Migration pressures • Increased competition among fishers
Sensitivity (Ecological + Social)	• Seagrass degradation • Habitat destruction from motorboats • Invasive species proliferation	• Overfishing practices (e.g., zero nets) • Dependency on traditional fishing zones
Recovery Potential (Ecological)	• Low recovery potential of seagrass meadows due to sedimentation, pollution, and invasive species	N/A
Adaptive Capacity (Social)	• Limited ecological resilience due to habitat fragmentation and loss of biodiversity	• Limited access to education and training • Lack of involvement in policymaking • Economic dependence on unsustainable practices

4.6.2 Social-Economic Vulnerability of SSF Communities

a) Economic and Food Insecurity

Economic and food insecurity among SSF communities in the Chilika Lagoon has become a critical issue, driven by environmental degradation and declining fish stocks. Fisherfolk narratives highlight the increasing challenges of making a living as catches shrink and costs rise. Many respondents report traveling farther and spending more on fuel and time to secure diminishing returns: “*We have to travel further and spend more money to catch enough fish.*” The presence of pollution, illegal nets, and sedimentation in the lagoon has drastically reduced fish

populations, with one fisher lamenting, *“It feels like the lagoon is losing its strength, and we are losing our way of life.”* Shrinking seagrass meadows and overfishing practices exacerbate these challenges, leaving communities struggling to maintain their traditional livelihoods. This has direct implications for food security, as fish serve as both a dietary staple and a source of income. Families are forced to explore alternative livelihoods, with some fisherfolk turning to labor-intensive jobs or small-scale crafts to survive. The economic strain is compounded by pollution-induced health issues, which further burden these already vulnerable communities.

b) Social Sensitivity: Family Disruption and Migration

The social fabric of SSF communities is under significant strain due to environmental and economic pressures. Family disruption and migration are recurring themes in fisherfolk narratives. Declining fish stocks and polluted waters have driven some families to migrate in search of better opportunities. A respondent shared, *“Some of us have to look for other work or migrate to other places, but we don’t want to leave.”* This forced displacement disrupts community cohesion and traditional ways of life. Moreover, the loss of seagrass meadows and polluted waters has led to reduced fishing zones, intensifying competition among fishers. This competition sometimes sparks conflicts within communities. Many families are also forced to rely on children to contribute to fishing activities, leading to school dropouts: *“The young boys in our village have left school to help with fishing.”* These disruptions strain relationships within households and the larger community, creating a ripple effect of social instability. For those who remain, the psychological toll of uncertainty about their future further compounds the vulnerabilities faced by SSF communities.

c) Limited Adaptive Capacity Due to Education Gaps

The limited adaptive capacity of SSF communities is deeply rooted in educational gaps and a lack of awareness about sustainable practices. Fisherfolk frequently express their desire for knowledge but highlight the absence of structured support: *“We’ve never been told about the importance of the lagoon’s natural features like seagrass or mangroves.”* This lack of information hampers their ability to implement sustainable fishing practices or advocate for better resource management. Many respondents also report that policies and decisions about the lagoon are made without consulting the communities that depend on it: *“Decisions about the lagoon are made without us. Policies come from the top, but no one asks us for our knowledge or ideas.”* This

disconnect undermines their ability to adapt to changing ecological and economic conditions. Additionally, with limited formal education, many fishers are unable to transition into alternative livelihoods or engage effectively in conservation efforts. While NGOs and researchers occasionally visit the lagoon, fisherfolk note that these interactions seldom translate into actionable insights for their benefit. As one respondent stated, “*Researchers and NGOs working in the lagoon don’t share what they learn with us.*” Without targeted education programs and inclusive decision-making processes, SSF communities remain ill-equipped to navigate the multifaceted challenges they face.

4.7 Pathways to Viability: Current Challenges and Opportunities for SSFs

SSFs in Chilika Lagoon face multifaceted challenges that arise from ecological degradation, governance limitations, and social-economic vulnerabilities. A comprehensive analysis of stakeholder perspectives highlights both the challenges and pathways to building resilience using government initiatives and community-driven approaches. Figure 4.5 illustrates the perceived effectiveness of six key government initiatives aimed at supporting SSFs in Chilika Lagoon, as rated by various stakeholder groups. The radar chart visualizes stakeholder perspectives on the effectiveness of government initiatives, including the opening of sea mouth (2000), mangrove plantation, ban on zero net fishing (2002), plastic ban (2002), community environmental education programs, and weather warning and cyclone resilience programs. Weather warning and cyclone resilience programs emerged as the most effective initiative across most groups, with Government Officials (mean: 3.75) and SSFs (3.64) rating it highly. Mangrove plantation and community environmental education programs were perceived as the least effective, with consistently low scores (mean: ~1.0–1.5) across all groups, highlighting the need for better implementation and community engagement. Government officials rated most initiatives higher, reflecting their involvement in these programs, while groups such as women fishers, fish traders, and fish market owners highlighted limited on-ground impact. The radar chart underscores a significant gap between policy implementation and its perceived benefits among key stakeholders, emphasizing the need for participatory governance and improved outreach strategies to enhance the viability of SSFs.

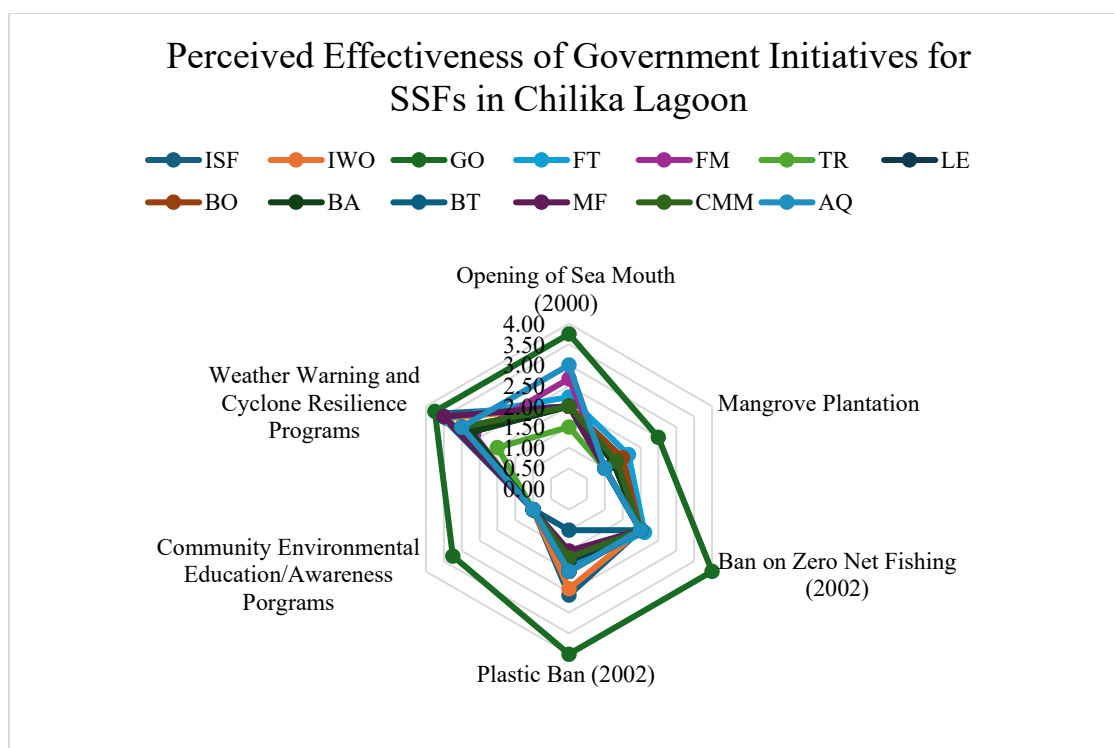


Figure 4.5 Perceived effectiveness of government initiatives for SSFs in Chilika Lagoon by stakeholder groups

The effectiveness of government initiatives varies significantly across stakeholder groups, as shown by their mean ratings. Programs like “weather warning and cyclone resilience programs” were rated the most effective, with scores ranging from 2.67 (fish market owners) to 3.75 (government officials). This reflects the tangible benefits of early warning systems and disaster preparedness efforts in reducing vulnerabilities during extreme weather events. In contrast, initiatives such as “mangrove plantation” and “community environmental education programs” received the lowest scores, averaging between 1.0 and 1.5 across most groups. Women fishers and SSFs, in particular, expressed dissatisfaction with the lack of visible benefits or community involvement in these programs. Many respondents highlighted the diminishing health of seagrass meadows, a crucial habitat for fish and crabs. BER-04 emphasized, “*Without healthy seagrass, these fish and shrimp won’t thrive, and it affects our livelihood.*” Pollution, unregulated waste disposal, and climate change exacerbate the decline of these ecosystems (MO-11, SAM-03). Overfishing, including illegal practices like using harmful nets and hatchling fishing, has led to declining fish stocks. SIP-12 noted, “*Fishing used to be easy, but now we have fewer fish.*” The

lack of sustainable fishing practices and enforcement of existing rules undermines the lagoon's productivity (SAB-06, KHAS-11).

Weak enforcement of regulations, such as the “ban on zero net fishing (2002),” exacerbates overfishing and habitat degradation. Stakeholders, including SSFs and fish traders, rated this initiative moderately, with mean scores around 2.0. Despite the regulation's intent to protect fish stocks, respondents emphasized poor implementation and monitoring. One fisher (KHAK-13) noted, *“Rules exist, but no one checks if we follow them.”* This lack of enforcement allows unsustainable fishing practices to persist, further depleting fish resources. SSFs also face significant environmental stressors such as habitat destruction, pollution, and the expansion of shrimp aquaculture. Among these, illegal shrimp aquaculture was consistently rated as the highest-impact driver across stakeholder groups, with a mean score of 5.0 by both SSFs and women fishers. Shrimp farms have destabilized salinity levels, reduced fish diversity, and increased ecological degradation. These findings underscore the need for stringent controls and alternative livelihood options to reduce reliance on shrimp farming.

Social-economic insecurities further compound the challenges. Many fishers are forced to overexploit resources due to economic pressures and a lack of livelihood alternatives. Stakeholders also highlighted significant gaps in education and awareness programs. The “community environmental education programs” received uniformly low ratings (mean = 1.0), reflecting an absence of efforts to educate communities on the importance of sustainable practices and seagrass conservation. One local expert (LE-02) emphasized, *“If education programs existed, fishers could better understand how protecting seagrass benefits their future.”* Economic insecurity and limited livelihood alternatives compel fishers to overexploit resources. KHAK-08 observed, *“We use what’s cheap, but it might damage the seagrass.”* Furthermore, poor waste management systems (MO-15, SAM-03) and lack of access to eco-friendly tools compound the problem. The community feels marginalized in policy and management decisions. MO-01 shared, *“Whenever the government or researchers come to study the lagoon, they don’t involve us much.”* This exclusion limits the effectiveness of conservation measures and fosters distrust. A significant gap in understanding the importance of seagrass and sustainable practices was noted. KHAS-12 stated, *“Many of us don’t know why seagrass is so important. We need education programs in our villages.”* Finally, inadequate infrastructure and waste management systems exacerbate pollution, harming the lagoon’s water quality. The “plastic ban (2002)” initiative, for instance, received low

ratings from fish traders (mean = 1.89) and government officials (mean = 4.0), highlighting its partial success and continued gaps. Cleaner waters are essential for the recovery of seagrass meadows, which are critical habitats for fish and prawns.

Despite the challenges, there are clear pathways to enhance the resilience of SSFs using a multi-dimensional approach under the SEVVN framework. One significant opportunity lies in strengthening cyclone resilience programs, which received the highest ratings across stakeholders (mean = 3.44–3.75). Expanding these programs through improved early warning systems, community awareness, disaster preparedness training, livelihood resilience initiatives, fisher-focused insurance programs and restoration of natural barriers can further reduce vulnerabilities to extreme weather events and build trust between fishers and governing bodies. Empowering community-based education and awareness programs is another key pathway to address ecological and social-economic vulnerabilities. The uniformly low scores for education initiatives (mean = 1.0) highlight the urgent need for targeted programs on sustainable fishing practices, seagrass conservation, and ecosystem restoration. KHAS-10 noted, *“If someone taught us more about the value of seagrass, we could help protect it better.”* Integrating this knowledge into school curricula and community outreach efforts can foster long-term stewardship of the lagoon (KHAS-13, PUR-08).

Improving the enforcement of sustainable practices, such as the “Zero Net Fishing Ban,” is crucial to protect fish stocks and promote ecological recovery. Co-management approaches, where fishers actively participate in governance, can help integrate TK with scientific insights. One stakeholder (CMM-02) aptly stated, *“If fishers had a voice in enforcing the rules, they would follow them better.”* Investing in ecological restoration initiatives can stabilize habitats and support biodiversity. Community-based restoration programs, such as planting seagrass (JAG-2, KAR-07), and tools for monitoring water quality (KAR-02) can empower fishers to protect and revive the ecosystem. Although the “mangrove plantation” initiative received low scores (mean = 1.0–1.5), revising these efforts to involve communities in participatory restoration can improve both ecosystem health and community ownership. Diversifying income sources is essential to reducing pressure on fish stocks. Ecotourism is a promising pathway. As SIP-01 suggested, *“Develop eco-tourism where we guide tourists and show them the importance of the lagoon.”* Training in alternative skills, such as craft-making or PES, can bolster financial security (BIN-10, MO-09).

Improved infrastructure for waste management is also essential to mitigate pollution and plastic waste. Better waste management systems and incentives for conservation efforts can motivate compliance with sustainable practices. KHAS-11 highlighted, *“If we had better waste facilities, the water would stay cleaner, and the seagrass could grow again.”* Reward systems, such as PES, can further incentivize stewardship (SAM-08). Stakeholders emphasized that cleaner waters would support seagrass recovery, enhance fish stocks, and secure livelihoods. Strengthening plastic bans through effective waste collection systems and incentives for eco-friendly alternatives can directly benefit both ecological and social-economic conditions.

The SEVVN framework highlights how feedback loops between ecological restoration and social-economic resilience can drive long-term sustainability. For instance, healthier seagrass meadows enhance fish stocks, which secure livelihoods and reduce pressure on natural resources. Improved education and governance further strengthen these positive feedback loops by fostering stewardship and reducing vulnerabilities. As KHAS-08 aptly stated, *“The seagrass protects us from storms and keeps our lagoon alive. If we protect it, it will protect us back.”* The framework highlights the need for shared governance to enhance adaptive capacity. Co-management approaches, where fishers collaborate with policymakers, can integrate TK with scientific insights. SAB-01 proposed, *“Our voices should matter in decisions about Chilika’s future.”* A holistic and multi-dimensional approach is essential to address the challenges facing SSFs in Chilika Lagoon. While initiatives such as weather warning and cyclone resilience programs show promise, others like education programs and waste management systems require significant strengthening. By integrating ecological restoration, community education, and participatory governance, the SEVVN framework offers a clear roadmap to sustain both the lagoon ecosystem and the livelihoods of its dependent communities.

4.8 Major Findings from the Study

This study reveals several interrelated findings that underscore the ecological and social-economic vulnerabilities facing Chilika Lagoon and its SSFs. A key insight is the strong interdependence between seagrass health and water quality. Both are vital to sustaining fish stocks, which serve as the primary livelihood for SSFs. Degradation in water quality-driven by pollution, eutrophication, and sedimentation-directly undermines seagrass meadows, resulting in biodiversity loss and declining fish availability. The study identified illegal shrimp aquaculture (mean rating 5.0), plastic pollution (mean rating 4.44–5.0), and agricultural runoff as the most

significant drivers of water quality deterioration and habitat loss. Community members frequently reported catching “*more plastic than fish*,” a striking reflection of the lagoon’s ecological stress and the resulting economic strain. These ecological challenges generate negative feedback loops that exacerbate social and economic vulnerability. As fish stocks decline due to seagrass degradation, fishers are compelled to intensify their efforts, often resorting to unsustainable practices such as zero-net fishing, which in turn accelerates ecosystem decline. Respondents assigned high-impact ratings (5.0) to illegal fishing practices and artificial sea mouth operations, emphasizing their central role in disrupting the lagoon’s ecological balance. As one fisherwoman noted, “*We spend more time and energy catching fewer fish now*,” highlighting how ecological degradation translates into livelihood insecurity.

Compounding these challenges are significant governance gaps and constraints on adaptive capacity. Weak regulatory enforcement, limited fisher participation in decision-making, and the absence of effective environmental education emerged as major barriers to sustainable management. While programs related to weather warnings and cyclone resilience were rated as relatively effective (mean: 3.64–3.75), community-based initiatives such as mangrove restoration and environmental education consistently received low effectiveness ratings (~1.0–1.5) across all respondent groups. The widespread lack of awareness regarding seagrass conservation further reflects a gap in knowledge systems and underscores the need for targeted educational and capacity-building programs. As one respondent put it, “*Decisions about the lagoon are made without us*,” indicating the frustration felt by communities excluded from formal governance processes. In response to declining fish stocks, many SSFs have been forced to seek alternative livelihoods or migrate in search of better opportunities. However, limited access to training and education severely restricts their ability to transition into more sustainable income-generating activities. The study found that ecotourism, sustainable aquaculture, and community-led seagrass restoration are viewed by local stakeholders as promising pathways toward resilience. Respondents expressed interest in guiding visitors and sharing knowledge about the lagoon’s ecological importance. Participatory conservation efforts, such as community-based seagrass planting (e.g., JAG-2, BER-07), were seen as viable strategies to enhance both ecological recovery and social-economic stability.

Ultimately, the findings affirm the importance of integrated management strategies that simultaneously address ecological degradation and social-economic vulnerability. The SEVVN

framework highlights how holistic, cross-sectoral approaches are essential to breaking the cycle of decline. Strengthening the enforcement of zero-net fishing bans, expanding waste management infrastructure, and promoting community-driven conservation were identified as critical policy priorities. Importantly, the need for co-management models that incorporate both scientific insights and TEK was emphasized by several respondents. As one fisher aptly stated, “Our voices should matter in decisions about Chilika’s future.” Together, these insights offer a clear roadmap for policy and practice—one that places communities at the heart of ecosystem restoration and positions integrated governance as the key to long-term sustainability in Chilika Lagoon. Triangulating with broader literature, the pathways identified here resonate with livelihood resilience models (Tanner et al., 2015) that emphasize diversification, empowerment, and institutional integration. Climate change adaptation in coastal fisheries requires not only ecological restoration but also recognition of historical marginalization, power asymmetries, and institutional learning (Pelling & High, 2005; Eriksen et al., 2015). Effective SSF governance—as advocated in the FAO’s Voluntary Guidelines (FAO, 2015)—requires inclusive decision-making, respect for TK, and multilevel coordination, all of which are embedded within the SEVVN framework’s emphasis on community participation and feedback loops.

4.9 Conclusions

The study highlights the intricate interdependence between ecological systems and human livelihoods in Chilika Lagoon, with a focus on the critical roles of seagrass meadows and water quality. Findings demonstrate that the degradation of these ecological assets—driven by pollution, illegal shrimp aquaculture, and sedimentation—not only threatens biodiversity but also undermines the social-economic stability of SSFs. Using the SEVVN framework, the study identifies how negative feedback loops perpetuate ecological and social-economic vulnerabilities. However, the framework also reveals opportunities to break these cycles through integrated management approaches. Enhanced governance, stricter regulation of harmful practices, community-led restoration efforts, and livelihood diversification are essential for building resilience. The study underscores the importance of co-management strategies that combine TK with scientific insights to address both ecological and social-economic dimensions. Education programs tailored to SSF communities can foster sustainable practices, while infrastructure investments—such as improved waste management systems—can mitigate pollution. Alternative income sources like ecotourism and sustainable aquaculture offer pathways to economic stability while reducing pressure on

lagoon resources. This study contributes to the broader discourse on sustainable development by demonstrating the need for context-specific, participatory interventions in SES. Chilika Lagoon serves as a model for balancing ecological health with social-economic viability, offering actionable strategies for policymakers and stakeholders committed to long-term sustainability.

Chapter V: Conclusions

5.1 Chapter Outline

This concluding chapter synthesizes the theoretical and applied contributions of this research on **Linking Blue Carbon Ecosystems and Water Quality in Coastal Wetlands for Viable Small-Scale Fisheries**, with a focus on Chilika Lagoon, India. The research underscores the innovative use of the SEVVN framework as a novel analytical tool that bridges environmental, social, political, and governance dimensions to holistically assess SSF vulnerabilities and identify pathways to viability. The framework helps to understand the interdependencies between environmental degradation, governance structures, and community resilience. A reductionist approach to lagoon management that focuses solely on biophysical or economic dimensions overlooks the complex interplay of non-market social relationships and ecological feedback mechanisms, both of which are critical in shaping the long-term sustainability of SSFs (Jentoft & Chuenpagdee, 2009; Berkes, 2011; Nayak & Berkes, 2019). Ignoring these interactions can lead to fragmented governance, inadequate policy interventions, and unintended social-ecological consequences that compromise the resilience of SSFs and the ecosystems they depend on. Integrating a SES perspective acknowledges the reciprocal linkages between ecosystem health, resource governance, and community well-being, thereby fostering a more holistic and adaptive approach to lagoon conservation and management (Adger, 2006; Nayak & Berkes, 2014; Cinner & Barnes, 2019). Coastal wetlands such as Chilika Lagoon, embedded within complex SES, cannot be examined in isolation from their interconnected ecological, social, economic, and governance processes (Berkes, 2011).

The chapter begins by restating the purpose and objectives of research, emphasizing the need for an integrated approach to understand how BCEs and water quality affect SSFs and coastal livelihoods. A narrow biophysical or economic view of lagoon management neglects non-market relationships and ecological feedback that significantly influence SSFs' sustainability. To address this knowledge gap, this dissertation advances the understanding of BCE-Water Quality-SSF interactions using an SEVVN framework. This framework facilitates an integrated analysis of vulnerabilities and viable governance solutions by linking BCE conservation, water quality management, and SSF resilience. The research highlights the importance of participatory approaches, ecosystem-based management, and co-governance structures to bridge scientific and

local knowledge systems (Berkes & Usher, 2000; Berkes, 2011; Nayak & Berkes, 2019). The key findings section consolidates results from the three core research manuscripts (Chapters 2-4). Findings from participatory mapping of BCEs demonstrate the importance of TEK in understanding seagrass distribution and ecosystem functions. Community perceptions of water quality reveal major stressors such as pollution, habitat loss, and governance gaps affecting fishery viability. SSF vulnerability and viability nexus explains the interconnected risks of degraded seagrass health and declining water quality, exacerbating social-economic hardships for fishers. These findings underscore the necessity of inclusive conservation policies, effective regulatory frameworks, and locally driven adaptation strategies (Adger, 2006; Cinner & Barnes, 2019).

The chapter articulates theoretical, methodological, and practical contributions, where the research expands the SEVVN framework by integrating community-driven conservation, policy insights, and adaptive co-management approaches. The research enhances participatory methodologies and highlights the role of multi-stakeholder governance in achieving SSF sustainability. The chapter also identifies barriers such as weak policy enforcement, economic constraints, and the need for climate-resilient strategies. Future directions for improving conservation incentives, integrating TEK in decision-making, and strengthening fisher participation in governance are also suggested. The chapter concludes with personal reflections on the research process, including engagement with local communities, interdisciplinary fieldwork experiences, and the broader implications for sustainable coastal governance. The broader implications of this research emphasize the importance of integrating ecological and social-economic dimensions in sustainability science. By offering a nuanced understanding of BCE conservation, water quality management, and SSF sustainability, the research contributes to developing more inclusive and adaptive governance strategies for coastal wetlands. This work reinforces the need for co-management frameworks that incorporate local ecological knowledge, scientific research, and participatory decision-making to ensure the long-term sustainability of Chilika Lagoon and similar coastal ecosystems worldwide.

5.2 Framing the Research: Purpose, Rationale, and Objectives

This doctoral research aimed to advance the understanding of the interlinkages between BCEs and water quality, and their implications for the sustainability of SSFs in coastal wetlands, using Chilika Lagoon, India, as a case study. BCEs such as seagrass meadows and mangrove forests provide critical ES-including carbon sequestration, habitat provision, and water quality

regulation-yet they remain underrepresented in coastal management policies. The degradation of these ecosystems, coupled with deteriorating water quality, has heightened the vulnerability of SSF communities, whose livelihoods are closely tied to the ecological health of the lagoon. While considerable research has addressed BCE conservation, water quality monitoring, and SSF sustainability in isolation, the lack of an integrated understanding of their interdependent social-ecological dynamics presented a clear knowledge gap. This research responds to that gap by integrating scientific assessments, TEK, participatory methods, and governance analysis to promote a more holistic approach to coastal wetland management. The SEVVN framework serves not only as an analytical scaffold for understanding environmental vulnerabilities, but also as a diagnostic tool to interrogate how socio-political inequalities, regulatory failures, and institutional fragmentation undermine ecosystem services and human well-being in coastal SES. This integrated framing is particularly critical in coastal contexts, where caste, class, gender, and political power relations significantly shape access to resources and participation in governance. This research was structured around four key objectives that reflect the fundamental challenges and opportunities associated with BCE degradation, water quality decline, and SSF resilience:

Objective 1: Mapping and Characterizing BCEs in Chilika Lagoon

The first objective aims to conduct a comprehensive mapping and spatial characterization of BCEs such as seagrass meadows and mangrove forests in Chilika Lagoon. This includes documenting their extent, distribution, and species composition through a combination of existing GIS or RS data, participatory mapping, and field-based validation. Integrating TEK with scientific mapping methodologies enhances the accuracy of ecosystem identification and acknowledges community knowledge as a valuable resource in conservation planning. This objective directly contributes to SDG 14 (Life Below Water) by highlighting the importance of preserving coastal ecosystems that sustain marine biodiversity and fisheries productivity.

Objective 2: Examining Water Quality Dynamics and their Ecological Impacts

Water quality is a key determinant of the ecological health of BCEs and the viability of SSFs. The second objective focuses on assessing water quality trends over time, analyzing key parameters such as salinity, transparency, turbidity, and nutrient levels concentrations to determine their impacts on seagrass health, mangrove stability, and fish populations. Given the challenges in data availability, this research combines historical government or literature datasets, qualitative assessments, and participatory monitoring approaches. Examining how pollution from

aquaculture, coastal developments, tourism, natural disasters, and settlements interacts with BCE health contributes to SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action) by addressing pollution mitigation strategies and climate-related stressors on coastal wetlands.

Objective 3: Understanding the Social-Ecological Linkages between BCE Degradation and SSF Vulnerability

The third objective investigates the interdependencies between BCE degradation, water quality decline, and the vulnerabilities of SSFs. This involves analyzing how changes in seagrass and mangrove cover influence fish stocks, fishing grounds, and livelihood security. Through community surveys, interviews, and FGDs, this research documents how SSF communities perceive and respond to ecosystem changes, resource constraints, and governance challenges. Understanding these social-ecological linkages is critical to developing resilience-based management strategies that account for both ecological and social dimensions. This objective aligns with SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 10 (Reduced Inequalities) by promoting policies that support marginalized fishers dependent on healthy coastal ecosystems.

Objective 4: Identifying Governance and Management Strategies for Enhancing BCE-SSF Sustainability

The final objective focuses on identifying governance challenges and proposing adaptive management strategies that integrate BCE conservation with sustainable fisheries management. Using the SEVVN framework, this research assesses the effectiveness of existing policy interventions, co-management initiatives, and institutional support mechanisms for SSFs. Findings highlight the gaps in regulatory enforcement, community participation, and knowledge integration in current wetland governance. Advocating for participatory governance models, fisher-led conservation programs, and incentive-based ecosystem management supports SDG 16 (Peace, Justice, and Strong Institutions) and SDG 17 (Partnerships for the Goals) by emphasizing inclusive decision-making and multi-stakeholder collaboration.

This research provides a novel interdisciplinary approach to understanding the interconnected challenges of BCE degradation, water quality decline, and SSF sustainability. By integrating scientific knowledge and local ecological understanding, this research ensures that BCE conservation strategies are socially relevant and ecologically sound. The use of participatory research methodologies strengthens the inclusion of fisher knowledge in conservation planning, addressing critical gaps in existing environmental governance frameworks. The research also

highlights the need for long-term water quality monitoring systems and high-resolution ecosystem mapping, which are essential for improving environmental decision-making and adaptive management. The lack of comprehensive baseline data has been a challenge in BCE-water quality-SSF research, and this research emphasizes the importance of continuous monitoring efforts to assess ecosystem changes effectively.

A key contribution of this research lies in its transdisciplinary governance perspective, advocating for co-management models that empower SSF communities while maintaining ecosystem integrity. The application of the SEVVN framework provides new insights into how governance structures can reduce vulnerability and enhance the viability of SSFs by integrating ecological, economic, and institutional factors. Furthermore, the research reinforces the importance of aligning conservation policies with global sustainability efforts. The findings support multiple SDGs, including SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 10 (Reduced Inequalities), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 16 (Peace, Justice, and Strong Institutions). Ensuring that policies and management strategies are community-centered, inclusive, and adaptable is critical to achieving long-term sustainability in coastal wetlands.

This research advances the understanding of how BCEs, water quality, and SSF sustainability are interconnected in the context of coastal wetlands. The research presents a science-policy roadmap for adaptive governance, ensuring that BCE conservation is not only ecologically effective but also socially equitable and economically viable. The insights generated from this research have broad applicability beyond Chilika Lagoon, contributing to global discussions on wetland conservation, SSF resilience, and blue carbon governance. By integrating interdisciplinary methods, participatory approaches, and governance frameworks, this research offers practical solutions for enhancing sustainability and resilience in coastal SES.

5.3 Key Findings

The findings of this dissertation are presented in chapters 2, 3, and 4, each addressing a specific research objective while collectively contributing to a comprehensive understanding of the interconnections between BCEs, water quality, and SSFs in Chilika Lagoon. These chapters, while produced as independent manuscripts, are interrelated in their approach and findings, advancing interdisciplinary scholarship on the ecological and social-economic dimensions of coastal wetland management. The degradation of BCEs, coupled with declining water quality and

weak institutional governance, has been identified as a major factor influencing SSF sustainability, necessitating an integrated governance framework that bridges ecological conservation and community livelihoods. Table 5.1 presents a consolidated overview of the major findings from each of the study's three core research objectives. It highlights critical insights into BCE mapping, water quality dynamics, and the social-ecological vulnerabilities of SSFs in Chilika Lagoon. The results underscore the value of integrating TEK with scientific methods, the urgent need for participatory governance, and the role of community-led conservation in promoting long-term resilience and sustainability.

The second research chapter explores community perceptions of BCEs in Chilika Lagoon, with a particular focus on seagrass meadows, using participatory mapping to identify their spatial distribution and assess their ecological and social-economic significance. The research applied a hybrid approach integrating TEK with empirical ecological assessments to address gaps in BCE mapping and local ecosystem awareness. Three primary research objectives were pursued: (i) Utilize community knowledge and participatory mapping to document the spatial distribution of seagrass meadows and mangroves, including previously undocumented areas; (ii) Evaluate the ES provided by BCEs and analyze their ecological, social, cultural, and economic importance, highlighting community dependence for livelihoods and resilience; (iii) Identify key challenges related to BCE degradation, including anthropogenic pressures and governance gaps.

Findings revealed that fishers possess substantial place-based ecological knowledge, as evident in their use of local names for seagrass species, reflecting physical characteristics and habitat functions. However, scientific taxonomic awareness was lacking, underscoring the need for educational interventions. The participatory mapping exercise identified seven seagrass species, including *Ruppia maritima* and *Cymodocea serrulata*, which was recently documented in literature, highlighting the value of integrating TEK with scientific assessments. The mapping process also identified ecological hotspots such as Nalabana Sanctuary, Rajhans Island, and Palur Canal, where BCEs play a critical role in supporting biodiversity. These findings challenge prior scientific assessments, demonstrating dynamic ecosystem changes that warrant continuous community-driven monitoring. Importantly, these findings demonstrate how environmental degradation cannot be disentangled from the broader political economy of Chilika Lagoon. Issues such as regulatory capture, the political influence of aquaculture lobbies, and the marginalization of fisher voices in decision-making all shape the landscape of BCE decline and SSF precarity. The

SEVVN framework makes visible these power-laden dynamics by analyzing how feedback loops are conditioned by policy effectiveness, social inclusion, and access to justice.

Table 5.1 Summary of research objectives and key findings

Objective 1: Mapping and Characterizing BCEs
➤ Community nomenclature demonstrates detailed ecological understanding (e.g., Pathiri Dollo, Chingudiya Dollo) ➤ Seven species confirmed, consistent with literature ➤ Limited community awareness of broader ecosystem functions such as climate regulation and sediment stabilization ➤ Participatory mapping revealed key ecological hotspots (e.g., Rajhans Island, Palur Canal) not captured in existing scientific data ➤ Livelihood dependence drives destructive practices (e.g., overfishing, habitat conversion for shrimp aquaculture) ➤ Cultural significance of BCEs is minimal, reducing conservation motivation ➤ High interest in community-led restoration initiatives and capacity-building opportunities ➤ Strong demand for BCE-focused environmental education, particularly for youth
Objective 2: Assessing Water Quality Dynamics and Ecological Impacts
➤ Multiple stressors identified: shrimp aquaculture, tourism, urban waste, agricultural runoff and industrial effluents ➤ Widespread dissatisfaction with existing regulations (e.g., Zero-Net Ban, Plastic Ban), rated as largely ineffective ➤ Declining water quality linked to reduced fish availability and income insecurity ➤ Seasonal migration and livelihood diversification reported as coping strategies ➤ Public health concerns noted, including skin ailments linked to water pollution ➤ Informal conservation actions (e.g., releasing juvenile fish, avoiding polluted areas) are present but lack institutional support ➤ Emphasis on the need for integrated governance and participatory co-management approaches
Objectives 3 & 4: Analyzing BCE-SSF Interlinkages and Governance Strategies
➤ Strong interdependence between seagrass health, water quality, and fishery productivity ➤ Key degradation drivers include illegal aquaculture, artificial sea mouth, plastic pollution, and sedimentation ➤ Ecological decline triggers negative feedback loops that intensify social and economic vulnerability ➤ Women report increased labour burdens and reduced economic returns

- Weak policy enforcement, limited community inclusion, and inadequate environmental education identified as key governance gaps
- Structural power asymmetries (e.g., elite control over aquaculture and policy processes) contribute to fishers' exclusion and reduce the effectiveness of top-down conservation interventions
- Community-led initiatives such as seagrass restoration and sustainable aquaculture recognized as viable resilience pathways
- Stakeholders advocate for co-management models integrating TEK and scientific approaches
- Emphasis on cross-sectoral policy integration, waste management improvements, and inclusive conservation planning

Furthermore, BCEs provide vital ES, including carbon sequestration, nursery habitats for commercially valuable fish species, and shoreline stabilization. However, community awareness of these broader ecological functions remains limited. The research also found that BCEs hold cultural and economic significance, with fishers depending on them for sustaining livelihoods, yet their degradation threatens long-term resource viability. Economic pressures-particularly from shrimp aquaculture, artificial sea mouth and plastic pollution-were identified as key drivers of habitat degradation, reinforcing the need for conservation incentives like PES and sustainable ecotourism development. Weak governance, regulatory gaps, and exclusion of fishers from decision-making were also identified as significant barriers to effective conservation.

The third chapter examined water quality dynamics and their social-ecological implications for SSFs. This section builds upon the spatial and ecological findings from Chapter 2 by focusing on the specific anthropogenic drivers affecting water quality, as well as their cascading effects on fisheries-based livelihoods. A multi-scalar assessment of water quality identified pollution from settlements, tourism, and shrimp aquaculture (34.2%) as primary contributors to declining water quality. Agricultural runoff and industrial discharge accounted for an additional 26.3% of pollution sources, while overfishing and invasive species contributed to long-term ecosystem degradation. Climate change-driven stressors, such as increased cyclone frequency and rising temperatures, were also cited as exacerbating factors. Governance failures emerged as a central theme, with nearly 99% of respondents rating the Ban on Zero Net Fishing (2002) as ineffective, and 88.4% expressing dissatisfaction with the enforcement of the Plastic Ban. Weak institutional frameworks, lack of community participation, and resource constraints were identified as major governance bottlenecks.

Social-economically, the declining water quality has led to declining fish stocks, resulting in increased economic hardship among SSFs. Over 45% of respondents reported seasonal migration to Kerala and Tamil Nadu due to dwindling fisheries productivity, while 42% diversified into alternative livelihoods, such as tourism and handicrafts. Public health concerns also surfaced, with 15% of respondents reporting skin-related health issues due to prolonged exposure to polluted waters. Despite governance failures, informal conservation actions were documented, including voluntary fish stock replenishment and modified fishing techniques aimed at reducing ecosystem impacts. However, these initiatives lacked institutional support, emphasizing the need for structured participatory governance approaches.

Chapter 4 synthesized the ecological and social-economic linkages identified in the previous chapters to assess how BCE degradation and water quality decline exacerbate SSF vulnerabilities. This section provides a systems-based analysis of SES feedback loops and governance failures, proposing policy pathways for transitioning SSFs from vulnerability to viability. This research leverages the SEVVN framework to analyze the interconnected vulnerabilities and identify pathways to resilience. The SEVVN framework offers a comprehensive lens to assess the interlinked social-ecological challenges facing SSFs. By integrating foundational insights from the vulnerability framework of Turner et al. (2003) and adaptive capacity theories advanced by Marshall et al. (2010), SEVVN enables a systematic exploration of the dynamic interplay between ecological and social-economic factors. The research confirmed a strong correlation between seagrass health and water quality, with pollution, eutrophication, and sedimentation being the most critical stressors. Illegal shrimp aquaculture (mean impact rating: 5.0) and plastic pollution (mean impact rating: 4.44–5.0) emerged as major drivers of habitat degradation, reducing fish stocks and biodiversity.

Negative feedback loops between environmental decline and economic instability were identified as reinforcing SSF vulnerabilities. As habitat degradation led to lower fish yields, fishers increased their efforts, leading to further resource depletion. This cycle of overexploitation perpetuates social-economic instability, with SSFs increasingly reliant on external income sources. Women engaged in fisheries reported increased labour burdens, with longer working hours yielding lower economic returns. Governance gaps remain a key challenge, particularly in the areas of environmental education, fisher representation in decision-making, and enforcement of conservation policies. While community environmental education and mangrove restoration

programs exist, they were rated the least effective initiatives (~1.0–1.5), reflecting their limited impact in fostering long-term ecological stewardship. The research identified several pathways for resilience, including participatory conservation, alternative livelihood support, and co-management governance models. Notably, 60% of respondents expressed interest in structured training for seagrass restoration, while many highlighted eco-tourism and sustainable aquaculture as viable economic alternatives.

The interconnections across chapters illustrate the complex social-ecological relationships that shape BCE dynamics, water quality, and SSF vulnerabilities in Chilika Lagoon. Figure 5.1 provides a visual synthesis of the three core manuscript chapters, structured around the study's primary research objectives. Chapter 2 provided a foundational understanding of BCE spatial distributions and community knowledge, emphasizing the role of participatory mapping in filling knowledge gaps. Chapter 3 explored water quality challenges and governance failures, highlighting their cascading effects on fisheries-based livelihoods. Chapter 4 synthesized these insights by integrating the SEVVN framework, which enables a comprehensive assessment of interconnected vulnerabilities and pathways toward resilience. This research makes several key contributions to the scholarship on BCE governance and SSF sustainability. **First**, it bridges local and scientific knowledge, demonstrating the value of integrating TEK with formal ecological assessments to strengthen conservation strategies (Berkes et. al., 2000; Berkes, 2012). Participatory mapping revealed previously undocumented BCEs, confirming the importance of community-driven ecological monitoring. **Second**, the research advances understanding of the role of BCEs in water quality management, expanding prior work that has largely focused on carbon sequestration to include ecosystem functions such as water purification and fisheries productivity (Duarte et al., 2013; Macreadie et al., 2019; Nair & Nayak, 2023). **Finally**, the research underscores the importance of participatory governance strategies, advocating for co-management models that integrate fisher-led conservation efforts with policy enforcement to enhance SSF resilience (Plummer & Armitage, 2010).

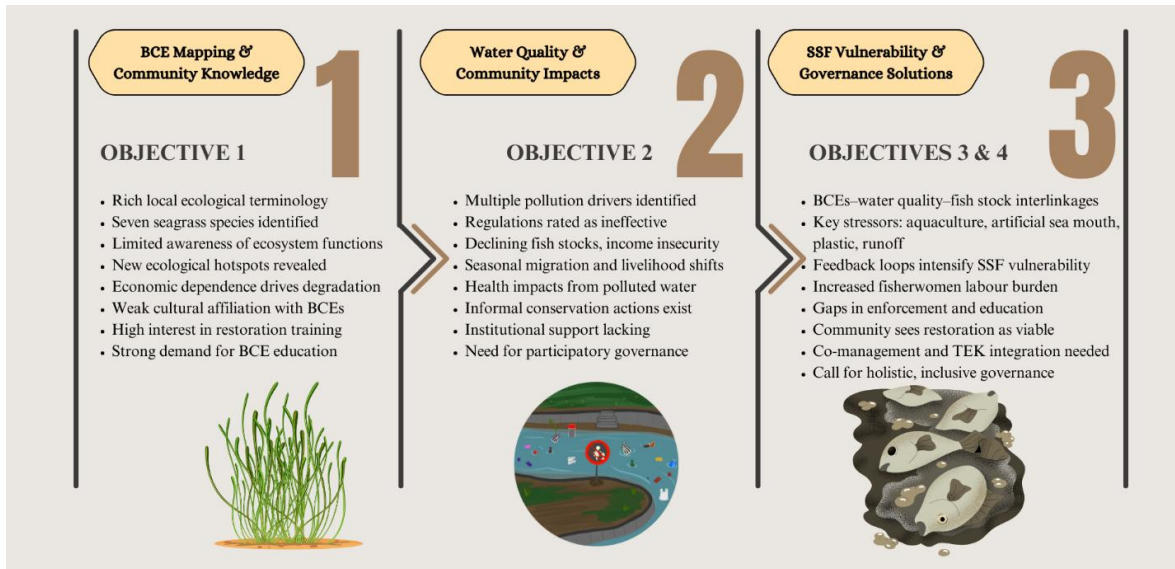


Figure 5.1 Summary of manuscript chapters: research objectives and core findings

The application of the SEVVN framework within this research provides a novel analytical perspective on SSF vulnerabilities and adaptation strategies. By integrating insights from Turner et al. (2003) on vulnerability and Marshall et al. (2010) on adaptive capacity, SEVVN captures the dynamic interplay between ecological degradation and social-economic instability. This framework highlights the non-linear feedback loops that drive system vulnerability—such as the way declining seagrass health leads to reduced fish stocks, which in turn forces fishers into unsustainable practices, further exacerbating ecosystem degradation. Recognizing these interdependencies allows for a more targeted policy response that moves beyond conventional top-down regulatory approaches toward community-driven resilience initiatives. This research also contributes to discussions on integrated governance approaches in coastal resource management. The findings reveal that fragmented regulatory frameworks and weak policy enforcement have undermined conservation efforts, leaving fishers and BCEs increasingly vulnerable. The inclusion of fisher perspectives in policy dialogues is particularly crucial, as many community members expressed frustration with existing regulations that do not reflect local realities.

This research also challenges the conventional separation of conservation and development by advocating for social-ecological wellbeing as a central performance metric. By incorporating social-ecological interactions, this research reimagines BCE governance as a holistic, place-based strategy that accounts for cultural, economic, and ecological dimensions. By shifting the narrative from resource exploitation to sustainable resource stewardship, the research provides a roadmap for designing policies that align conservation priorities with community needs. This dissertation

underscores the urgent need for integrated governance approaches that align BCE conservation with sustainable fisheries management. Key takeaways from the research include:

- BCE degradation and water quality decline are interconnected threats that exacerbate SSF vulnerabilities, necessitating coordinated conservation and management strategies.
- Governance failures and lack of community participation undermine conservation efforts, highlighting the importance of institutional reforms that enhance transparency and stakeholder engagement.
- Participatory conservation initiatives, such as seagrass restoration and community-based monitoring need to be implemented as it offers viable pathways for resilience, and should be scaled up through targeted policy support.
- A transdisciplinary governance framework that merges TEK, scientific research, and policy engagement is critical for achieving long-term sustainability in Chilika Lagoon and other coastal SES.

This research advances the discourse on adaptive management strategies for BCEs and SSFs by integrating these insights into coastal governance frameworks. The research demonstrates that effective conservation must be inclusive, community-driven, and adaptive, recognizing the complex feedback loops that shape social-ecological vulnerabilities and opportunities for resilience.

5.4 Advancing Sustainability Science: Theoretical, Methodological, Scholarly, and Applied Contributions

This section outlines the theoretical, methodological, scholarly, and applied contributions of this research within the broader sustainability discourse. The research advances knowledge in sustainability science by integrating SES thinking, governance analysis, and participatory methodologies to assess the interdependencies between BCE health, water quality, and SSF resilience. The research findings contribute to multiple SDGs, particularly SDG 14 (Life Below Water), SDG 6 (Clean Water and Sanitation), SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 1 (No Poverty). These contributions are relevant for policymakers, coastal communities, and researchers working on blue carbon, fisheries governance, and adaptive environmental management.

5.4.1 Theoretical and Scholarly Contributions to Sustainability Science

This research makes a significant theoretical contribution to sustainability science by advancing the conceptualization of social-ecological vulnerability and resilience in SSFs through the refinement of the SEVVN framework. By situating BCEs, water quality, and SSF livelihoods within an integrated SES framework, the study deepens the understanding of how feedback loops between ecological degradation and social-economic stressors reinforce systemic vulnerabilities while also identifying viable adaptation pathways. The central contribution of this thesis lies in expanding the application of SES theory (Folke, 2016) to include dynamic and context-specific feedback mechanisms that connect BCE degradation, water quality deterioration, and livelihood instability in SSFs. By refining vulnerability assessments developed by Turner et al. (2003) and incorporating adaptive capacity principles from Marshall et al. (2010), the SEVVN framework not only identifies exposure and sensitivity but also highlights how negative feedback intensify vulnerability and how resilience can be cultivated through inclusive governance, diversification, and ecological restoration.

In doing so, the thesis redefines the role of BCEs beyond carbon sequestration by positioning them as pivotal to water quality regulation, biodiversity support, and social-economic resilience—thereby enriching the ES framework (MEA, 2005). This redefinition aligns with global sustainability targets, especially SDG 14.2 (marine ecosystem protection), by foregrounding ES that are socially embedded and locally valued. Furthermore, the SEVVN framework draws on the Sustainable Livelihood Framework (SLF) to examine how SSF actors navigate trade-offs and constraints imposed by environmental and institutional stressors. By integrating livelihood capitals and ecological functions, the study underscores the resource trap that emerges from overdependence on a degraded resource base (Berkes, 2003; Roscher et al., 2022), reinforcing calls for sustainable livelihood diversification (SDG 8 – Decent Work and Economic Growth).

The research contributes to theory by operationalizing SEVVN as an integrative framework that reveals how intertwined ecological and institutional dynamics shape both vulnerability and viability in coastal systems. It offers a scalable and context-sensitive tool to assess the conditions under which SSFs can transition from fragility to resilience, contributing to broader debates on adaptive governance and sustainability transformations. Beyond its conceptual value, the SEVVN framework contributes a grounded and politically sensitive lens that captures how structural inequities, such as disenfranchisement of fisher cooperatives, corruption in enforcement regimes, and socio-cultural hierarchies, constrain adaptive capacity. By embedding questions of power and

governance within its vulnerability analysis, the framework extends beyond ecological modeling to become a critical governance tool. This makes it especially relevant for countries like India where environmental challenges are deeply entangled with social justice and institutional performance.

5.4.2 Methodological Innovations and Transdisciplinary Approach

This research contributes methodological innovations by integrating qualitative and quantitative analysis, including participatory tools, to assess BCE-SSF interdependencies. The research aligns with SDG 17 (Partnerships for the Goals) by demonstrating how collaborative research can bridge scientific inquiry with policy implementation and community engagement. The research advances participatory mapping and TEK integration as tools for BCE mapping and conservation monitoring. This methodological approach empowers local communities as knowledge producers, reinforcing SDG 4.7 (ensure all learners acquire knowledge and skills needed to promote sustainable development).

By employing qualitative and quantitative policy evaluation, this research enhances policy gap analysis to provide actionable recommendations for adaptive fisheries governance (Armitage et al., 2009), supporting SDG 16.7 (ensure responsive, inclusive, participatory, and representative decision-making at all levels). Furthermore, this research expands the methodological landscape of water quality assessment by integrating community-led monitoring programs with scientific water quality indicators. This approach ensures that real-time water quality data is linked to SSF health, addressing emerging concerns about pollution, eutrophication, and salinity changes in BCEs. Given the current global urgency of climate change-induced coastal degradation, the research highlights BCEs as nature-based solutions for mitigating water pollution and enhancing resilience to extreme weather events, reinforcing SDG 6.6 (protect and restore water-related ecosystems, including wetlands, rivers, and lakes) and SDG 13.1 (strengthen resilience and adaptive capacity to climate-related hazards).

5.4.3 Applied and Policy Contributions

The research offers critical policy insights that can inform effective coastal governance, conservation policies, and sustainable fisheries management. Findings emphasize the necessity of inclusive, science-based policymaking that integrates local ecological knowledge with scientific monitoring to ensure adaptive and resilient governance frameworks. One of the key policy

recommendations is the incentivization of community-based conservation initiatives. Establishing PES programs can encourage fishers and coastal communities to actively participate in BCE restoration and monitoring efforts. Such initiatives align with SDG 15.9 (integrate ecosystem values into national and local planning) and ensure long-term ecological and economic sustainability. This research also highlights the urgent need for improved water quality governance in coastal ecosystems. Policy measures should include stringent pollution controls, sustainable aquaculture regulations, and the enhancement of wastewater treatment infrastructure. Integrating community-led water quality monitoring can bridge scientific knowledge gaps and enhance environmental accountability, reinforcing SDG 6.6 (protect and restore water-related ecosystems, including wetlands, rivers, and lakes).

The research calls for climate adaptation policies tailored to SSFs. Climate resilience strategies, such as mangrove afforestation, artificial reef installations, and climate-smart fisheries management, can mitigate the impacts of extreme weather events and coastal degradation. These measures directly support SDG 13.1 (strengthen resilience and adaptive capacity to climate-related hazards and natural disasters). Equally important is the integration of alternative livelihood strategies into fisheries management policies. Diversifying SSF livelihoods through ecotourism, sustainable aquaculture, and skill-based education programs can reduce economic vulnerabilities and enhance resilience, supporting SDG 1 (No Poverty) and SDG 2 (Zero Hunger). Lastly, the research emphasizes the importance of co-governance frameworks that empower SSFs in decision-making processes. Strengthening fisher cooperatives, ensuring participatory marine spatial planning, and fostering equitable access to marine resources align with SDG 16.7 (ensure responsive, inclusive, participatory, and representative decision-making at all levels). Coastal ecosystems and fisheries-dependent communities can transition toward sustainable, resilient, and inclusive resource management models by incorporating these policies

5.5 Challenges and Future Research Recommendations

5.5.1 Challenges in Research Implementation

Conducting this research presented multiple challenges, ranging from data availability constraints to methodological complexities. One of the key challenges was the limited availability of long-term ecological data, as well as open-access datasets on GIS BCE data, water quality parameters, and ecosystem health metrics. While some publicly available data sources exist, they

are often fragmented, outdated, or inconsistent in temporal and spatial coverage. This limitation hindered efforts to conduct comprehensive spatial and temporal assessments of BCE dynamics and water quality trends. The absence of standardized long-term water quality monitoring programs further exacerbates these issues, underscoring the need for sustained investment in integrated coastal monitoring systems. Another major challenge was the unavailability of laboratory facilities for water quality testing in the study region. While the research sought to conduct detailed physio-chemical and biological analyses of water samples, the lack of accessible, well-equipped laboratories significantly constrained the scope of water quality assessments. Future research should prioritize collaborative partnerships with research institutions to improve laboratory infrastructure and facilitate real-time water quality monitoring.

Mapping seagrass ecosystems in Chilika Lagoon was also constrained by the inability to conduct underwater transect surveys, which are essential for accurately assessing seagrass cover and health. The lack of resources, specialized equipment, and trained divers limited the ability to undertake in-depth seagrass habitat mapping. Unlike other BCE components such as mangroves, which can be surveyed remotely, seagrass require in-water assessments, making it challenging to document its spatial extent. This highlights the need for dedicated funding and logistical support to advance seagrass research in Chilika Lagoon. Furthermore, accessibility issues posed significant barriers to studying mangrove ecosystems. Large portions of the mangrove forests were inaccessible due to barnacle infestations, which created hazardous conditions for field researchers as well as threat to boats of fishermen. This physical limitation restricted direct field observations and sample collection, preventing a more detailed analysis of mangrove health, biomass, and carbon sequestration potential. Future research should explore RS approaches and drone-based surveys as alternative methods to overcome these challenges.

5.5.2 Methodological Constraints and Adaptations

The research faced methodological constraints, particularly in applying participatory methods. While participatory mapping and TEK integration proved valuable for mapping BCEs, language barriers and local skepticism toward research initiatives initially hindered community participation. Engaging with fishers and wetland-dependent communities required iterative trust-building exercises, demonstrating the importance of long-term field presence in community-based conservation research (Berkes, 2012). Future research should experiment with co-designed methodologies, such as community-led water quality monitoring programs, to enhance local

participation and ensure that knowledge production aligns with community priorities. Constraints related to data validation and field logistics also impacted the research. Due to limited GIS and RS data, efforts to validate spatial patterns of BCE distribution were challenging. The reliance on secondary datasets from multiple agencies introduced discrepancies in accuracy and scale, highlighting the need for ground-truthing protocols and integrated RS methodologies in future research. Moreover, weather and seasonal variations posed practical challenges during field surveys, affecting accessibility to remote wetland areas. Developing seasonally adaptive fieldwork strategies and utilizing drones or underwater ROVs (Remotely Operated Vehicles) can help overcome these constraints in future studies.

5.5.3 Addressing Interdisciplinary Knowledge Gaps

The research encountered challenges in bridging ecological, engineering, and social science perspectives on BCEs and SSFs. While BCEs are often examined through an ecological and biogeochemical lens, SSF research traditionally focuses on social-economic vulnerabilities and governance frameworks, whereas engineering approaches tend to emphasize hydrodynamic modeling, coastal infrastructure resilience, and technological interventions. The integration of these disciplines required reconciling diverse methodological approaches and knowledge systems, which proved to be a complex but essential task. Engineering aspects such as hydrological modeling, sediment transport analysis, and structural assessments of coastal ecosystems were underrepresented in BCE studies. Future research should incorporate numerical modeling techniques to assess how hydrodynamic changes influence BCE degradation, water circulation patterns, and pollutant dispersion.

Additionally, engineering solutions such as nature-based infrastructure (e.g., artificial reefs, living shorelines, and constructed wetlands) should be explored to enhance the resilience of coastal wetlands and mitigate human-induced pressures (Duarte et al., 2013). Moreover, the integration of engineering-based monitoring systems such as real-time water quality sensors, automated carbon flux measurements, and RS technologies remains a critical research gap. The development of low-cost, scalable engineering solutions that can be implemented in data-deficient regions like Chilika Lagoon would significantly advance BCE and SSF research. Addressing these interdisciplinary challenges requires stronger collaboration between ecologists, engineers, economists, and policymakers to develop comprehensive, technology-driven conservation strategies that align with SDG 6 (Clean Water and Sanitation), SDG 14 (Life Below Water), and

SDG 13 (Climate Action). Future research should also incorporate political ecology perspectives to examine how competing interests over resource control, lobbying by aquaculture or tourism sectors, and historically entrenched social inequities influence the implementation of conservation policies. A more explicit engagement with governance dynamics, such as the role of Panchayats, state agencies, and informal power networks, can enrich the application of SEVVN across diverse contexts.

5.6 Future Research Directions

Future research should prioritize long-term monitoring of BCEs and water quality, integrating in situ sensors with satellite-based RS techniques to track seasonal variations, pollution hotspots, and ecosystem stressors (Duarte et al., 2013). This aligns with SDG 6.6 (protect and restore water-related ecosystems) and SDG 14.1 (reduce marine pollution). Evaluating the effectiveness of co-governance models that incorporate local fishers, conservationists, and policymakers will also help assess how PES models can incentivize community-led BCE restoration. Strengthening policy research aligns with SDG 13.1 (climate adaptation and resilience) and SDG 16.6 (effective, accountable institutions).

Given the economic vulnerabilities faced by SSFs, future studies should explore alternative livelihood pathways such as sustainable ecotourism, aquaculture diversification, and blue carbon credit programs. Conducting cost-benefit analyses and market-based assessments will provide insights into the economic feasibility of sustainable transitions (SDG 1: No Poverty and SDG 8: Decent Work and Economic Growth). Additionally, incorporating traditional and local knowledge in BCE conservation can provide valuable insights into traditional fishing regulations, customary practices, and sacred ecological sites (Berkes & Usher, 2000). Promoting knowledge co-production models that integrate community expertise with scientific assessments will strengthen SDG 10.2 (empower and promote social inclusion) and SDG 14.b (support for SSFs).

Despite the challenges faced during this research, the research provides a foundation for future explorations into the interconnections between BCEs, water quality, and SSF sustainability. Expanding the SEVVN framework to include metrics of political representation, regulatory accountability, and stakeholder power mapping will allow for deeper policy diagnostics and inform the design of equitable co-management models. Addressing research gaps in governance, monitoring, and alternative livelihoods will be crucial for enhancing resilience in coastal wetlands. The recommendations outlined above emphasize collaborative, interdisciplinary, and policy-

driven approaches to ensure that BCEs are effectively managed as SES that support both biodiversity conservation and human well-being. Strengthening research efforts in these domains will contribute to achieving multiple SDGs, reinforcing the need for globally informed but locally adaptable conservation strategies.

5.7 Personal Reflections: A Journey Through Research, Learning, and Growth

Embarking on this doctoral research has been an intellectually stimulating and personally transformative journey. The experience of conducting interdisciplinary research in Chilika Lagoon, engaging with diverse stakeholders, and confronting the real-world complexities of environmental sustainability has deepened my understanding of the intricate linkages between ecological systems and human livelihoods. This research has not only enhanced my academic and technical competencies but has also provided invaluable insights into the social-cultural and governance dimensions of coastal wetland conservation.

One of the most profound aspects of this journey has been the opportunity to engage directly with SSFs, community members, and conservation practitioners. The interactions with local fishers, whose lives and livelihoods are intricately connected to the health of the lagoon, reinforced the importance of community-driven conservation efforts. Their knowledge of ecosystem changes, traditional fishing practices, and the challenges they face due to declining water quality and habitat degradation underscored the necessity of integrating TEK with scientific assessments (Berkes et.al., 2000; Berkes, 2012). The ability to witness and document the community's resilience and adaptation strategies was both inspiring and humbling. While the fishers were keen to share their experiences, they also expressed their concerns about governance inefficiencies, climate change impacts, and resource conflicts, which highlighted the broader social-political dimensions of wetland management.

Despite being an Indian (from Kerala, South India), I faced significant cultural and environmental challenges during my extended stays in Chilika Lagoon. The differences in food habits, climate, and living conditions while staying with fishing families initially posed difficulties, including health issues due to dietary adjustments. Language barriers further compounded these challenges, making communication with the community more complex. However, my repeated visits to Chilika Lagoon every year as part of the field school led by my supervisor, Dr. Nayak, since 2019 played a crucial role in building trust and familiarity with the local communities. These

annual visits, which continued almost every year until 2024, helped me establish deeper connections and gain a more nuanced understanding of the social-ecological realities of the region.

A particularly daunting challenge was communicating my research effectively to the local fishers. During my initial reconnaissance phase, when I asked about seagrass, community members mistakenly pointed to terrestrial grasses around the lagoon. This miscommunication left me disheartened and, for the first one to two months, I felt as though my PhD research was on the verge of failure. It was through discussions with my mentor, Dr. Pradhan and my supervisor—who are experts in social sciences—that I realized the need to communicate my research in a way that resonated with the daily lives of the community members. Transitioning from technical descriptions to storytelling, using visual aids such as pictures, relatable narratives, and local terminology, drastically changed my interactions. This shift not only improved mutual understanding but also deepened community engagement and participation in the research process.

However, some of the most difficult moments of my research arose from my inability to fully integrate quantitative data due to methodological constraints. The challenges of conducting water quality analyses and directly mapping BCEs in Chilika Lagoon were significant setbacks. The lack of laboratory access for detailed physicochemical assessments, limited GIS data availability, and the inability to conduct underwater transects for seagrass mapping prevented me from capturing the full ecological picture I initially envisioned. This realization was incredibly frustrating, as I had hoped to provide a more robust empirical foundation for my findings. There were times when I questioned the completeness of my research and whether my interdisciplinary approach could adequately compensate for these gaps. Overcoming this disappointment required a shift in perspective—recognizing that the integration of qualitative insights, TEK, and participatory mapping could still yield valuable contributions to sustainability science.

One of the most fulfilling moments in my research journey occurred during the Chilika Field School in August 2024. Seeing men, women, and youth from the local community articulate their understanding of seagrass, mangroves, and water quality to the field school participants was an incredible achievement. Their ability to explain the importance of these ecosystems to their livelihoods and the health of the lagoon, as well as the current degradation of these ecosystems, was a testament to the progress made through sustained engagement, knowledge-sharing, and participatory research. Witnessing this transformation—from initial miscommunication to active

community-led discussions-was not only a professional success but also a deeply personal victory that validated the core objectives of my PhD research.

5.7.1 Growth in Interdisciplinary and Transdisciplinary Research

Beyond research contributions, my doctoral journey has been enriched by several milestones and recognition. In 2024, I was selected as one of the top 10 Young Water Sustainability Leaders (YWSL) by the 10th World Water Forum in Bali, Indonesia and further won the Favorite Winner of YWSL 2024. In 2023, I was a finalist in the SSHRC Storytelling Challenge for my work on Coastal Wetlands for Viable Small-Scale Fisheries, which allowed me to bring my research to a broader audience. These recognitions have reinforced the importance of communicating scientific research in an engaging and accessible manner to influence policy and inspire change. Additionally, I had the privilege of presenting my research at multiple international conferences, including: (i) February 2024: 13th ICAR-Indian Fisheries and Aquaculture Forum (IFAF), Kolkata, India; (ii) April 2024: SSF Regional Symposium for Asia-Pacific, Shizuoka City, Japan, jointly organized by TBTI Global and local partners; (iii) February 2025: 14th ICAR-Asian Fisheries and Aquaculture Forum (14AFAF), New Delhi, India. Engaging in these global platforms provided valuable opportunities to exchange ideas, receive feedback, and strengthen collaborations with researchers working on similar themes in BCEs, SSFs governance, and coastal sustainability.

My academic journey has now been rooted in environmental and sustainability science, blending technical expertise with SES research. However, transitioning from an engineering background to interdisciplinary sustainability research required developing a broader systems-thinking perspective, integrating policy frameworks, social science methodologies, and participatory research approaches. Reflecting on this journey, I recognize that my doctoral research has been more than an academic endeavor-it has been an exploration of how sustainability science can bridge technical expertise with community-centered conservation. The experience of working at the interface of science, policy, and community engagement has solidified my belief that effective environmental management requires transdisciplinary approaches that integrate engineering innovations, ecological assessments, and social inclusivity.

Moving forward, I hope to continue exploring ways to strengthen participatory governance, advance environmental monitoring technologies, and promote knowledge co-production in wetland conservation. This research has been a catalyst for intellectual, professional, and personal

transformation. It has reinforced the importance of interdisciplinary collaboration, policy integration, and community participation in tackling complex sustainability challenges. The lessons learned from Chilika Lagoon extend far beyond the research itself, shaping my aspirations to contribute meaningfully to the fields of water resources management, blue carbon conservation, and SSF's sustainability. As I move forward, I carry with me not only the academic insights gained through this research but also the invaluable human connections and field experiences that have fundamentally shaped my approach to environmental sustainability.

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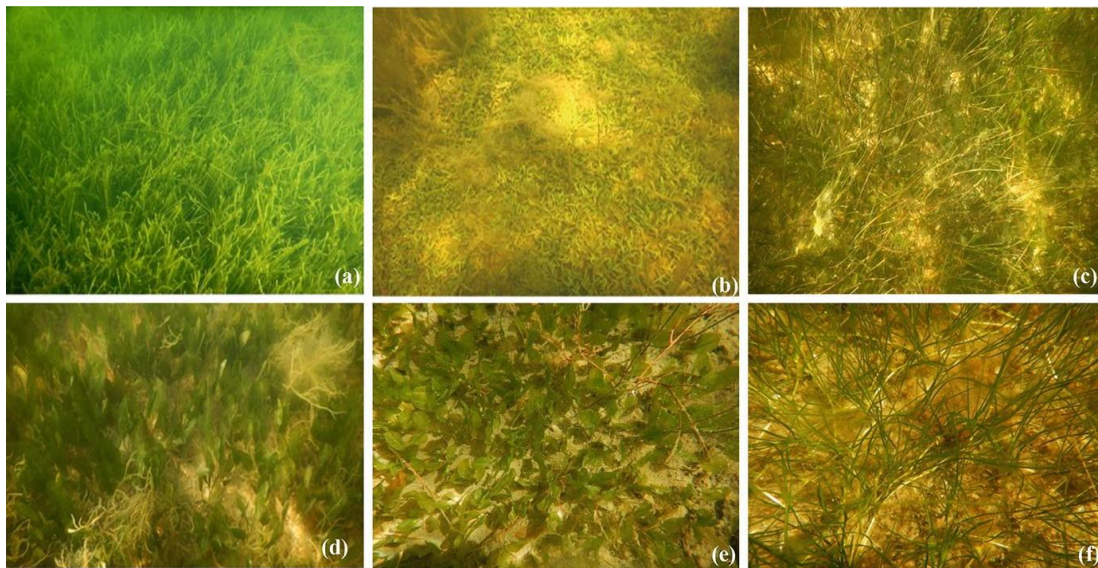
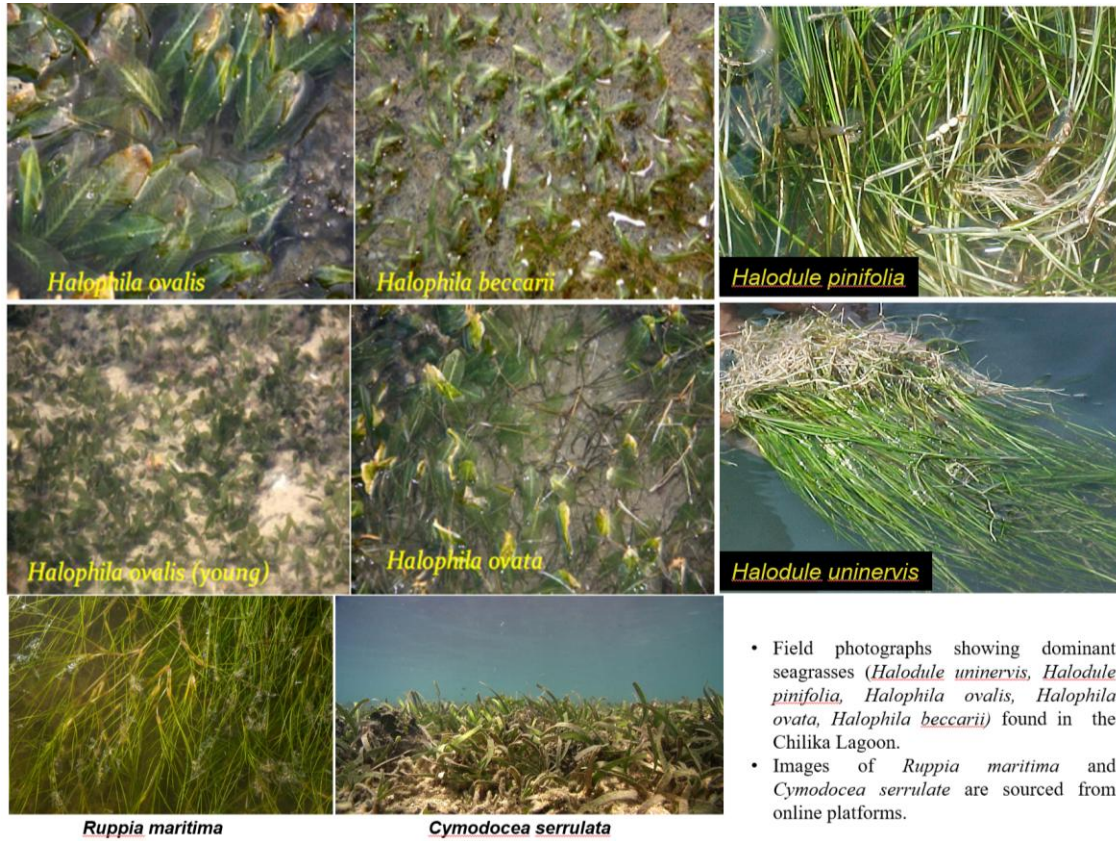
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APPENDICES

APPENDIX A: DATA COLLECTION INSTRUMENTS

a) Photo Identification Protocol



Underwater photographs of seagrass meadows from southern sector of the lagoon. (a) *Halodule pinifolia*, (b) *Halophila beccarii*, (c) mixed bed of *Halodule* and *Halophila*, (d) *Halophila ovalis*, (e) *Halophila ovata*, and (f) *Halodule uninervis* (Tripathy et. al., 2021)

b) Village Rapid Survey Guide

Phase 1: Rapid Survey - Seagrass Presence Assessment

DATE:

Location Identification

- Respondent's Name: _____ Code of Respondent's Name: _____
- Village Name: _____
- Gender: **Male/Female/Other** Age: _____
- Education Level: _____
- Occupation: _____

Preliminary Seagrass Presence

- Have you observed seagrass meadows in or around your village? **YES / NO**
 - If yes, please describe the locations or areas where seagrass has been observed.
_____; _____; _____
_____; _____; _____
- Are there specific seasons/months (including Hindu months) when seagrass is more visible or abundant? **YES / NO**
 - If yes, which months? _____; _____
- Any historical information about seagrass presence? _____

Seagrass Species Recognition (using picture cards): Please identify any types of seagrass you recognize from the pictures shown:

<i>Halodule uninervis</i>	_____	<i>Halophila beccarii</i>	_____
<i>Halodule pinifolia</i>	_____	<i>Ruppia maritima</i>	_____
<i>Halophila ovalis</i>	_____	<i>Cymodocea serrulata</i>	_____
<i>Halophila ovata</i>	_____	<i>Other</i>	_____

Community Perception

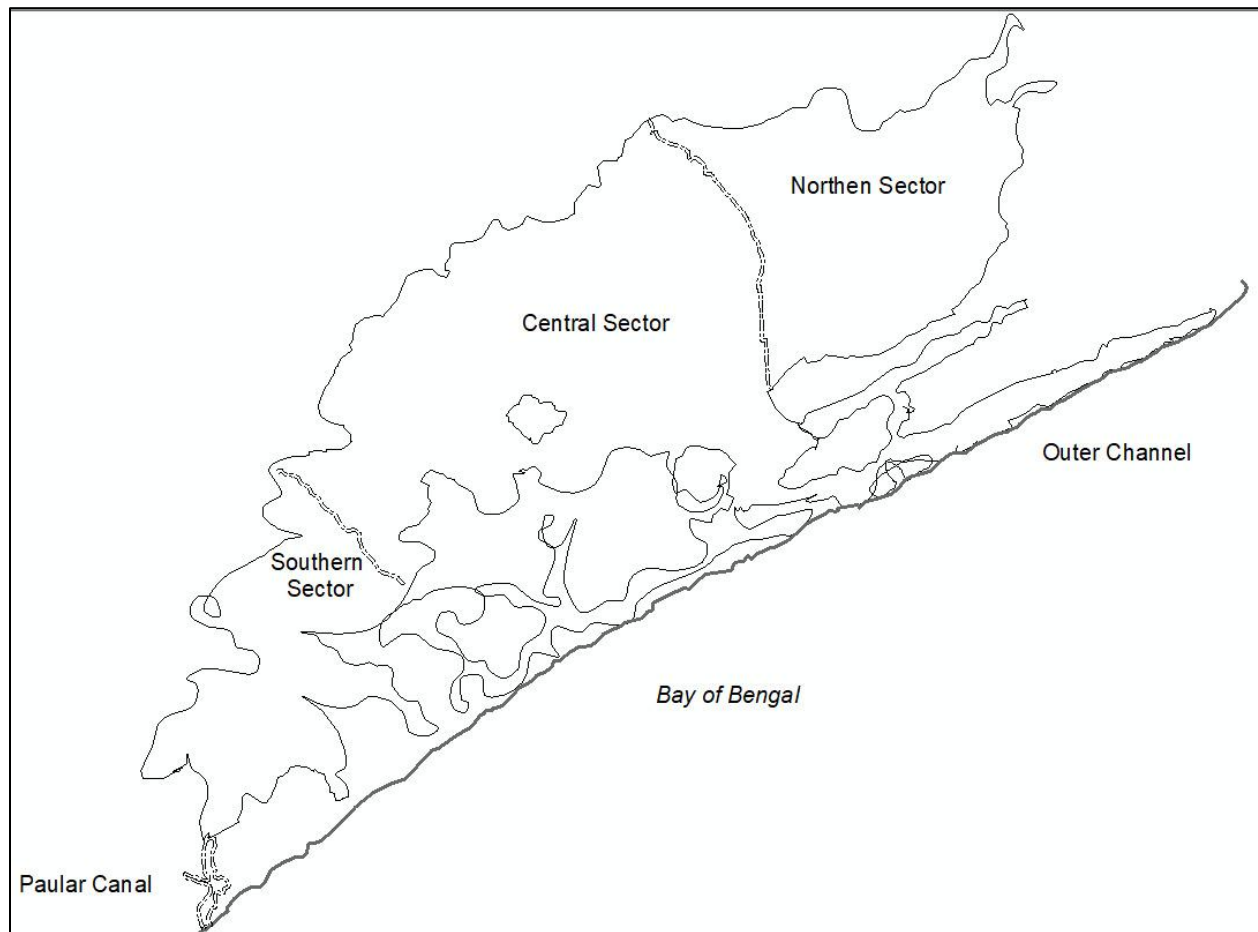
- Do local fishers or community members consider seagrass meadows important? **YES / NO**
 - If yes, what/why is it important? _____

Local Usage

- Are there any traditional practices or uses of seagrass within the community? **YES / NO**
 - If yes, what are the traditional practices or uses of seagrass in community?

- Does the presence of seagrass influence fishing practices or livelihoods? **YES / NO**
 - If yes, how? _____

c) Participatory Map Template



d) Household In-depth Survey Guide

Phase 2: Detailed Survey

Survey Respondent Information

DATE:

- Respondent's Name: _____ Code of Respondent's Name: _____
- Village Name: _____ GP: _____
- Block: _____ District: _____
- Fisher Caste: _____
- Gender: Male/Female Age: _____
- Education Level: _____
- Family Details: Married/Unmarried/Divorced/Prefer not to answer.
- Number of Household members: _____
- Occupation: _____ How long have you been fishing? _____
- Any alternative livelihood income sources: _____
- Occupation 5 years ago? _____ 10 years ago? _____
- Any debt (total ₹): _____ Reason: _____
- Any assets: House/Boat (motor/non motor)/Net/Other: _____
 - Net Type: _____ Number of nets: _____
- Have you changed fishing vessels, gears, and techniques? Yes/No
 - If yes, why? _____
- What are the species caught in these gears? Fish/Crab/Shrimp/Other: _____
- Which are the target species? _____
- Have you observed any changes in fish abundance or species composition in recent years? Increase/Decrease/No change. Why? _____
- What resources does the lagoon provide in your community? _____
- Have you noticed any changes in these resources? Yes/No
 - If yes, what? _____
 - why? _____
- What are the significant changes that have occurred in your fishing during recent years? (Positive and negative) _____
 - New sea mouth/Aquaculture/ Tourism/COVID-19/Other: _____

Section 1: Seagrass Distribution, Significance and Trends

- 1.1 Are you aware of the presence of seagrasses in your fishing area? **YES/NO.**
 - If yes, what specific species? _____
 - Local Names: _____
 - Where? _____
- 1.2 How would you describe the importance of seagrass meadows in Chilika Lagoon from your personal or community perspective? _____

1.3 Have you or your community traditionally relied on seagrasses for any specific purposes, such as livelihoods, cultural practices, medicinal use or well-being? **YES/NO**.

➤ If yes, please describe: _____

1.4 Can you share any specific experiences or examples of how seagrass have benefited your community or fishing practices? _____

1.5 Please refer to the photos of sea grass species(*chaari dala* and *pathiri dala*) we have, and help us understand the important differences in their significance, like:

1.5.1 Which of them are more abundant in Chilika and which one is less found ?

1.5.2 Which of them produces more fish/crab/prawn?

1.5.3 Which of them were abundant before the dredging of mouth at Shipakuda but much reduced now (why & where)?

1.5.4 Which of them were less found before the dredging of mouth at Shipakuda but much increased now (why & where)?

A1	Seagrass meadows are abundant in our village.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A2	Seagrass meadows are found in multiple locations within our village.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A3	Seagrass meadows are important for the abundance	Not Important	Somewhat Important	Neutral	Important	Very Important

	and availability of fish					
A4	Health of seagrass is affected by water pollution in coastal wetlands	Not at all Impacted	Slightly Impacted	Moderately Impacted	Significantly Impacted	Extremely Impacted

1.6 Have you noticed any notable changes/events in the distribution or health of seagrass meadows in recent years? **Increased/Decreased/No change**. Please describe: _____

Section 2: Water Quality

2.1 How would you rate the current water quality in your area? **Excellent/Good/Fair/Poor/Very Poor**

2.2. Please elaborate your response to the above question : _____

2.3. What are some of the factors/indicators that influence your perception of water quality? (e.g., color, odour, clarity) _____

2.4. In your opinion, how has water quality changed over the past years? Please describe any noticeable trends.

2.4.1 5 years ago? _____

2.4.2 10 years ago? _____

2.5. Have you or members of your community experienced any health issues related to water quality in the _____ Lagoon?

Section 3: Small-Scale Fisheries (SSFs)

3.1 Have you observed any shifts in fish species or abundance that you believe are related to changes in water quality? **Yes/No**

3.1.1 Why? _____

3.2 How is the presence and health of seagrass meadows affect small-scale fishing in your area? _____

3.3 Have you or others in your community made any adaptations in fishing practices due to changes in seagrass distribution or water quality? **Yes/No**

3.3.1 If yes, Please provide examples: _____

Section 4: Drivers

4.1 In your opinion, how have the following factors influenced small-scale fisheries (SSF) in Chilika

- 4 Lagoon: _____
- Aquaculture: _____
 - Artificial sea mouth opening: _____
 - Tourism: Agriculture: _____
 - Changes in fishing gear: _____
 - COVID-19: _____

4.2 Are there any other drivers or factors that you believe play a significant role in affecting seagrass, water quality, or SSF in Chilika Lagoon? Please specify. _____

B1	Aquaculture practices in Chilika Lagoon impact the local ecosystem and small-scale fisheries.	Strongly negative impact	Somewhat negative impact	No impact	Somewhat positive impact	Strongly positive impact
B2	How concerned are you about the expansion of aquaculture in Chilika Lagoon?	Very concerned	Concerned	Neutral	Not concerned	Not at all concerned
B3	Do you believe aquaculture practices are regulated and managed sustainably in Chilika Lagoon?	Very regulated well	Well regulated	Moderately regulated	Poorly regulated	Not regulated at all
B4	Artificial sea mouth opening impacted severely on the health of Chilika Lagoon's ecosystem and its effects	Strongly negative impact	Somewhat negative impact	No impact	Somewhat positive impact	Strongly positive impact

	on small-scale fisheries.					
B5	How aware are you of the processes and consequences of artificial sea mouth opening in Chilika Lagoon?	Very aware	Somewhat aware	Neutral	Not very aware	Not at all aware
B6	To what extent do you believe the management of artificial sea mouth opening takes care of what small-scale fishermen need and what's good for nature?	Very good	Kind of good	Not sure	Not very good	Not good at all
B7	Tourism activities in Chilika Lagoon severely impact on the ecological health of the area and its impact on small-scale fisheries.	Strongly negative impact	Somewhat negative impact	No impact	Somewhat positive impact	Strongly positive impact
B8	How do you perceive the level of regulation and control over tourism activities in Chilika Lagoon?	Very well regulated	Well regulated	Moderately regulated	Poorly regulated	Not regulated at all
B9	How concerned are you about the potential growth of tourism in Chilika Lagoon?	Very concerned	Concerned	Neutral	Not concerned	Not at all concerned

B10	Agricultural practices in the Chilika Lagoon watershed severely impact water quality and the overall health of the ecosystem.	Strongly negative impact	Somewhat negative impact	No impact	Somewhat positive impact	Strongly positive impact
B11	How concerned are you about agricultural runoff and its impact on water quality in Chilika Lagoon?	Very concerned	Concerned	Neutral	Not concerned	Not at all concerned
B12	How aware are you of the agricultural practices and their potential effects on Chilika Lagoon?	Very aware	Somewhat aware	Neutral	Not very aware	Not at all aware
B13	Agricultural practices in the watershed are managed sustainably to protect the lagoon's ecosystem and small-scale fisheries	Very well managed	Well managed	Moderately managed	Poorly managed	Not managed at all
B14	Changes in fishing gears impact the health of seagrass in Chilika Lagoon.	Harmful to Seagrass	Somewhat Harmful to Seagrass	No Impact	Somewhat Beneficial to Seagrass	Beneficial to Seagrass
B15	How do you perceive the effects of changes in fishing gears on the livelihoods of small-scale fishers in	Very detrimental	Detrimental	Neutral	Beneficial	Very beneficial

	Chilika Lagoon?					
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Section 5: Conservation and Governance

5.1 Are there any community-led initiatives or government efforts aimed at conserving seagrass meadows in your village or region? **Yes/No**

If yes, please mention: _____

5.2 How do you think governance and management strategies can be improved to integrate seagrass conservation, water quality, and the well-being of small-scale fishers? _____

Section 6: Future Outlook

6.1 What are your concerns about the future of seagrass meadows, water quality, and small-scale fisheries in your area? _____

6.2 In your opinion, what steps can be taken to ensure the long-term sustainability of small-scale fisheries and the health of coastal wetlands like seagrass meadows? _____

C1	How would you rate your income or earnings from SSFs? [Material Wellbeing]	Very low	Low	Average	High	Very high
C2	Are you able to meet your basic needs (food, shelter, healthcare, etc.) through your involvement in SSFs? [Material Wellbeing]	Yes	No	Partially	-	-
C3	How happy are you with your life as a small-scale fisherman (SSF)? [Subjective Wellbeing]	Very happy	Somewhat Unhappy	Neutral	Somewhat Unhappy	Very Unhappy
C4	How often do you feel content and satisfied with your work as a small-scale fisherman (SSF)? [Subjective Wellbeing]	Rarely or never	Occasionally	Sometimes	Often	Very often

C5	Do you feel like you're a part of the SSF community and that you belong here? [Relational Wellbeing]	Yes	No	Partially	-	-
C6	How supported do you feel by your fellow SSFs and the community at large? [Relational Wellbeing]	Not supported	Somewhat supported	Moderately supported	Well supported	Very well supported
C7	Are you actively involved in community decision-making processes related to SSFs? [Community Engagement]	Yes	No	-	-	-
C8	How satisfied are you with the level of participation and influence you have in shaping community policies and regulations? [Community Engagement]	Very dissatisfied	Dissatisfied	Neutral	Satisfied	Very satisfied
C9	Do you believe that collaborative efforts among government agencies, local communities, and fisher associations are essential for the sustainable management of seagrass meadows and water quality?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C10	How effective have current conservation and management strategies been in preserving seagrass	Not effectively at all	Not very effectively	Moderately effectively	Very effectively	Extremely effectively

	meadows and maintaining water quality?					
C11	I have sufficient access to natural resources (e.g., fish stocks, mangroves) for sustainable livelihoods.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C12	I have adequate financial resources and access to credit for investment in SSFs.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C13	I have access to social and human capital (e.g., knowledge, skills, networks) that support the resilience of SSFs.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C14	Healthy BCES positively influence water quality, benefiting SSFs and their productivity	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C15	Degraded water quality negatively affects SSFs and their ability to thrive.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C16	Rate the overall vulnerability/risk of SSFs to changes in BCEs and water quality?	Very low	Low	Average	High	Very high
C17	Effective conservation and management of BCEs and water quality are crucial for the long-term sustainability of SSFs.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C18	To what extent do SSF communities perceive changes	Not at all	Slightly	Moderately	Significantly	Extremely

	in water quality affecting their fishing activities and livelihoods?					
C19	How effectively do SSF communities adapt their fishing practices in response to changes (fish decline, water pollution, seagrass decline)?	Not effectively at all	Not very effectively	Moderately effectively	Very effectively	Extremely effectively
C20	How well do you think small-scale fishing communities can handle and bounce back from challenges they may face? [Resilience]	Not at all	Not very well	Moderately well	Very well	Extremely well
C21	Please rate the level of collaboration and cooperation among SSF communities in adapting to changes.	Very low	Low	Average	High	Very high
C22	How supportive are local policies and regulations in promoting the resilience of SSF communities in relation to water quality?	Not supportive at all	Not very supportive	Moderately supportive	Very supportive	Extremely supportive
C23	Rate the availability and accessibility of alternative livelihood options for SSF communities in case their fishing activities are impacted	Very limited	Limited	Moderate	Sufficient	Abundant
C24	How well do SSF communities perceive their knowledge and skills in adapting	Very limited	Limited	Moderate	Sufficient	Extensive

	to changes in water quality and maintaining sustainable fishing practices?					
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Section 7: Additional Comments

Please share any additional comments, observations, or insights related to the drivers and their impacts on the social-ecological system of Chilika Lagoon.

SOCIAL-ECOLOGICAL VULNERABILITY ASSESSMENT

		1	2	3	4	5
		Ecological Exposure				
A		Pollution Levels				
A1	To what extent do you believe pollution levels from industrial and agricultural runoff affect the health of seagrass meadows in your area?	Not at all	Slightly	Moderately	Very	Extremely
A2	How concerned are you about the impact of pollution on the overall ecosystem of Chilika Lagoon, including seagrass meadows?	Not concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
B		Climate Change Impacts				
B1	In your opinion, how has cyclones affected the seagrass meadows in your area over the past decade?	No impact	Slight impact	Moderate impact	Significant impact	Severe impact
B2	Have you experienced increased climate-related incidents that you believe have influenced the health of Chilika Lagoon, including its	Never	Rarely	Occasionally	Frequently	Very frequently

	seagrass meadows?					
C	Fishing Pressure and Habitat Degradation					
C1	How would you rate the fishing pressure on Chilika Lagoon and its seagrass meadows?	Low pressure	Moderate pressure	High pressure	Very high pressure	Extreme pressure
C2	In your opinion, have you observed noticeable changes in seagrass cover in your area over the last few years due to habitat degradation or other factors?	No change	Slight decrease	Moderate decrease	Significant decrease	Severe decrease
C3	How do you perceive the adverse impact of boats on the existence & health of sea grasses?	Severe impact	Sufficient impact	Moderate impact	Low impact	No impact at all
C4	How do you perceive the adverse impact of zero mesh nets on the existence & health of sea grasses?	Severe impact	Sufficient impact	Moderate impact	Low impact	No impact at all
	Ecological Sensitivity					
D	Seagrass Species Diversity and Health					
D1	Please rate the current health and diversity of seagrass species in Chilika Lagoon.	Poor	Fair	Average	Good	Excellent
E	Ecosystem Resilience to Disturbances					

E1	How well do you think the seagrass ecosystem in Chilika Lagoon can withstand problems like storms or pollution from people and still remain healthy?	Not Well at All	Slightly Well	Moderately Well	Well	Very Well
F	Water Quality and Nutrient Levels					
F1	Please rate the current water quality in Chilika Lagoon in terms of clarity and nutrient levels.	Poor	Fair	Average	Good	Excellent
G	Seagrass Species Composition					
G1	How would you describe the variety of seagrass species in Chilika Lagoon?	Very Limited	Limited	Moderate	Diverse	Highly Diverse
H	Recovery Time After Disturbances					
H1	In your opinion, how quickly does the seagrass ecosystem recover after being disturbed? [Aquaculture/ Cyclone/Boat operations/Pollution]	Very Slow	Slow	Moderate	Fast	Very Fast
I	Water Quality Parameters					

I1	[Water Clarity] How would you describe the clarity of the water in Chilika Lagoon?	Vary Murky	Murky	Somewhat Clear	Clear	Crystal Clear
I2	[Water Temperature] How would you rate the temperature of the water in Chilika Lagoon?	Very Cold	Cold	Moderate	Warm	Very Warm
I3	[Turbidity (Suspended Particles)] What's your perception of the presence of suspended particles or sediment in the water?	Highly Turbid	Turbid	Somewhat Turbid	Clear with few particles	Clear with no particles
I4	[Salinity (Saltiness)] How salty does the water in Chilika Lagoon taste or feel to you?	Extremely Salty	Very Salty	Moderately Salty	Slightly Salty	Not Salty at all
I5	[Water Odor] How would you describe the smell or odor of the water in Chilika Lagoon?	Strong Unpleasant Odor	Moderate Odor	Slight Odor	No Noticeable Odor	Fresh and Pleasant Odor
I6	How do you perceive the presence of excessive nutrients, such as fertilizers or pollution, in the water of Chilika Lagoon?	Very High	High	Moderate	Low	Very Low

I7	Have you noticed any changes in the number of fish or aquatic life in Chilika Lagoon?	Significant decrease	Moderate decrease	No noticeable change	Moderate increase	Significant increase
I8	How would you describe the condition of the fish and aquatic life in Chilika Lagoon?	Poor, many sick or dead fish	Fair, some sick or stressed fish	Average, fish seem healthy overall	Good, fish appear healthy and vibrant	Excellent, fish are thriving
Recovery Potential						
J	Natural Regeneration Rates of Seagrass					
J1	How would you rate the natural regeneration rates of seagrass in Chilika Lagoon?	Very slow	Slow	Moderate	Fast	Very fast
K	Effectiveness of Restoration Projects					
K1	In your opinion, how effective have restoration projects been in helping seagrass meadows recover in Chilika Lagoon?	Not effective at all	Somewhat ineffective	Neutral	Somewhat effective	Very effective
L	Adaptation of Seagrass to Changing Environmental Conditions					
L1	To what extent do you believe seagrass species in Chilika Lagoon are adapting to changing environmental conditions, such as climate	Poor adaptation	Limited adaptation	Moderate adaptation	Strong adaptation	Very strong adaptation

	change and pollution?					
Social Exposure						
M	Proximity to Seagrass Meadows					
M1	How close is your village to seagrass meadows in Chilika Lagoon?	Very close	Close	Somewhat close	Not very close	Not close at all
N	Dependence on Chilika Lagoon for Livelihood					
N1	To what extent does your household depend on Chilika Lagoon for your livelihood?	Completely dependent	Highly dependent	Moderately dependent	Slightly dependent	Not dependent at all
N2	What percentage of your household income comes from fishing activities in Chilika Lagoon?	75% or more	50-74%	25-49%	Less than 25%	None
O	Access to Clean Water Sources					
O1	Please rate the water in Chilika Lagoon in terms of being safe for fish and other aquatic life.	Unsafe	Somewhat Unsafe	Neutral	Somewhat Safe	Safe
O2	How easy is it for your household to access clean water sources for fishing?	Very easy	Easy	Neutral	Difficult	Very difficult
O3	How easy is it for your household to access clean water sources	Very easy	Easy	Neutral	Difficult	Very difficult

	for daily needs?					
Social Sensitivity						
P	Socioeconomic Status of Fishing Communities					
P1	How would you rate the overall economic well-being of your fishing community?	Very Prosperous	Prosperous	Moderately Well-off	Struggling	Impoverished
Q	Access to Resources and Markets					
Q1	Do fishing households in your community have access to modern fishing equipment and technology?	Strong Access	Moderate Access	Limited Access	Minimal Access	No Access
Q2	How easy is it for fishing households in your community to access local and regional markets to sell their catch?	Very easy	Easy	Moderate	Difficult	Very difficult
R	Poverty Levels Among Fishing Households					
R1	How would you describe the poverty levels among fishing households in your community?	Very Low Poverty	Low Poverty	Moderate Poverty	High Poverty	Very High Poverty
S	Availability of Alternative Livelihood Options					
S1	Are there diverse and viable alternative livelihood options available to fishing households in your	Many Options Available	Several Options Available	Limited Options Available	Very Few Options Available	No Alternative Options Available

	community, aside from fishing?					
Adaptive Capacity						
T	Education and Awareness					
T1	To what extent do members of your community have access to formal education?	Very High	High	Moderate	Low	Very Low
T2	How aware are community members of the importance of seagrass ecosystems and water quality for sustainable fishing?	Very Aware	Aware	Somewhat Aware	Not Very Aware	Not Aware at All
U	Access to Information and Technology					
U1	How easily can fishermen access weather and climate information to plan their fishing activities?	Very Easily	Easily	Moderately	With Difficulty	Not at All
U2	Does your community have access to modern fishing technology and equipment that enhance sustainable fishing practices?	Yes, with the latest technology	Yes, with basic technology	Limited access to technology	Rarely have access to technology	No access to technology
V	Social Cohesion and Community Organization					
V1	How strong is the sense of community cohesion among the fishing	Very Strong	Strong	Moderate	Weak	Very Weak

	community members?					
V2	Are there community-based organizations or cooperatives in your village that work together to manage and protect fishing resources?	Multiple active organizations	One active organization	Organizations with limited activity	No active organizations	Not sure

Survey Questionnaire in Odia

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ବିଶଦ ସର୍ବେକ୍ଷଣ

ଉତ୍ତରଦାତାଙ୍କ ବିବରଣୀ

ତାରିଖ

- ନାମ: କୋଡ୍ ନମ୍ବର:
- ଫୋନ ନମ୍ବର: ଜାତି:
- ଗ୍ରାମ : ଗ୍ରାମ ପଞ୍ଚାୟତ: ବ୍ଲକ୍: ଜିଲ୍ଲା:
- ଲିଙ୍ଗ: ବୟସ:
- ଶିକ୍ଷାର ସ୍ତର (କେଉଁ ପର୍ଯ୍ୟନ୍ତ ପଢ଼ିଛନ୍ତି):
- ପାରିବାରିକ ବିବରଣୀ: ବିବାହିତ / ଅବିବାହିତ / ଛାଡ଼ପତ୍ର / ଏହାର ଉତ୍ତର ନ ଦେବାକୁ ପସନ୍ଦ କରିବେ
- ଘରର ମୋଟ ସଦସ୍ୟ ସଂଖ୍ୟା:

1 | Page ଗବେଷିକା ଡିପୁଣ୍ଡା ନବ୍ୟା ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ଉପକ୍ରମ ଥିଲା ଅନୁବିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ଦ୍ଧିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

- ବୃତ୍ତି: ଆପଣ କେବେ ଠାରୁ ଚିଲିକାରେ ମାଛ ଧରୁଛନ୍ତି ?
- ଅନ୍ୟ କିଛି ବିକଳ ଜୀବିକା/ ଆୟର ଅନ୍ୟ ଉତ୍ସ ଅଛି କି ? (ଯଦି ଅଛି , ତା'ର ବିବରଣୀ)
- ପାଞ୍ଚ ବର୍ଷ ତଳେ ଆପଣଙ୍କ ବୃତ୍ତି କ'ଣ ଥିଲା ?
- ଦଶ ବର୍ଷ ତଳେ ଆପଣଙ୍କ ବୃତ୍ତି କ'ଣ ଥିଲା ?
- କିଛି ରଣ କରିଛନ୍ତି କି ? ଯଦି ହଁ , କେତେ ଟଙ୍କାର ? ରଣ କରିବାର କାରଣ:
- ସମ୍ବଳ କ'ଣ ରହିଛି ? (ଘର /ମୋଟର ବୋର୍ଟ / ଆହୁଳାମରା ଟଙ୍କା /କାଲ /ଅନ୍ୟ କିଛି)

2 | Page ଗବେଷିକା ଡିପୁଣ୍ଡା ନବ୍ୟା ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ଉପକ୍ରମ ଥିଲା ଅନୁବିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ଦ୍ଧିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

- କି ପ୍ରକାର ଜାଲ ଅଛି ?

କେତୋଟି ଜାଲ ?

- ଆପଣ ମାଛଧରା ଉପାୟ ଓ ଉପକରଣରେ ପରିବର୍ତ୍ତନ କରିଛନ୍ତି କି ? (ହଁ/ନା)

ଯଦି ହଁ, କାହିଁକି ?

- ଏଇସବୁ ଜାଲରେ କି ପ୍ରକାର ମାଛ ଆଦି ପଡ଼ନ୍ତି ? (ମାଛ /କଙ୍କଡ଼ା /ଚିଙ୍ଗୁଡ଼ି /ଅନ୍ୟ କିଛି)

- କ'ଣ ସବୁ ଧରିବା ଆପଣଙ୍କର ଲକ୍ଷ୍ୟ ?

- ଆପଣ ନିକଟ ଅତୀତରେ ମାଛ/କଙ୍କଡ଼ା/ଚିଙ୍ଗୁଡ଼ିର ପ୍ରାର୍ଥ୍ୟ କିମ୍ବା ବିବିଧତା(ପ୍ରକାର)ରେ କୌଣସି ପରିବର୍ତ୍ତନ ଦେଖିଛନ୍ତି କି ? (ବଢ଼ିଛି / କମିଛି / କୌଣସି ପରିବର୍ତ୍ତନ ନାହିଁ)

କାହିଁକି ?

3 | Page ଗବେଷିକା ଓ ପ୍ରଶ୍ନା ନବ୍ୟ ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ରଥଙ୍କ ଦ୍ଵାରା ଅନୁଦିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ତ୍ତିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

- ଚିଲିକା ଆପଣଙ୍କୁ କ'ଣ ସବୁ ସମ୍ପଦ ଯୋଗାଇଥାଏ (ମାଛ ଇତ୍ୟାଦି ସହିତ ଅନ୍ୟ କିଛି , ଯଦି ଥାଏ , ଯେପରିକି ମଇଁଷି ପାଇଁ ଖାଦ୍ୟ):

- ଚିଲିକାରୁ ମିଳୁଥିବା ଏଇ ସବୁ ସମ୍ପଦର କୌଣସି ପରିବର୍ତ୍ତନ ଦେଖିଛନ୍ତି କି ? (ହଁ/ନା)

ଯଦି ହଁ, କ'ଣ ?

କାହିଁକି ?

- ଆପଣଙ୍କର ନିକଟ କିଛି ବର୍ଷର ଅଭିଜ୍ଞତା ଭିତରେ ମାଛଧରା କାମରେ ସବୁ ଠାରୁ ଗୁରୁତ୍ଵପୂର୍ଣ୍ଣ ପରିବର୍ତ୍ତନ(ସକାରାତ୍ମକ / ନକାରାତ୍ମକ) କ'ଣ ଦେଖିଛନ୍ତି? ଏବଂ କାହିଁକି?

➤ ନୂଆ ମୁହାଣ /ଚିଙ୍ଗୁଡ଼ି ଘେରି /ପର୍ଯ୍ୟଟନ /କୋଭିଡ଼ /ଅନ୍ୟ କିଛି.....

4 | Page ଗବେଷିକା ଓ ପ୍ରଶ୍ନା ନବ୍ୟ ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ରଥଙ୍କ ଦ୍ଵାରା ଅନୁଦିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ତ୍ତିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

ଅନୁଭାଗ-୧: ସାମୁଦ୍ରିକ ଦଳର ବିଭାଗ କ୍ଷେତ୍ର, ମହତ୍ତ୍ୱ ଏବଂ ଭିତ୍ତିର ଗତିଧାରା

1.1 ଆପଣଙ୍କ ମାନ୍ୟତା ଅଞ୍ଚଳରେ ସାମୁଦ୍ରିକ ଦଳର ଉପସ୍ଥିତି ବିଷୟରେ ଆପଣ ଅବଗତ କି? (ହଁ/ନା)

➤ ଯଦି ହଁ, ତେବେ ଏହାର କେଉଁ ନିର୍ଦ୍ଦିଷ୍ଟ ଜାତି/ପ୍ରକାର ବିଷୟରେ ଆପଣ ଜାଣନ୍ତି (ନାମଗୁଡ଼ିକ ଉଲ୍ଲେଖ କରାଯିବ)

➤ କେଉଁଠାରେ କେଉଁ ପ୍ରକାର ସାମୁଦ୍ରିକ ଦଳ ଦେଖାଯାଏ (ସ୍ଥାନ ଅନୁଯାୟୀ ଦଳର ନାମ ଉଲ୍ଲେଖ କରାଯିବ)

1.2 ଆପଣଙ୍କ ବ୍ୟକ୍ତିଗତ ଅଥବା ଗୋଷ୍ଠୀଗତ ଦୃଷ୍ଟିକୋଣରୁ ଏସବୁ ସାମୁଦ୍ରିକ ଦଳର ଚୂଣ୍ଟାମୂଳିଗୁଡ଼ିକର ମହତ୍ତ୍ୱ ସବୁ କ'ଣ ?

5 | Page ଗବେଷିକା ଓ ପ୍ରଶ୍ନା ନବ୍ୟା ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ରଥଙ୍କ ଦ୍ୱାରା ଅନୁଦିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ଦ୍ଧିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

1.3 ଆପଣ କିମ୍ବା ଆପଣଙ୍କର ସମ୍ପ୍ରଦାୟ ପାରମ୍ପରିକ ଭାବରେ କୌଣସି ନିର୍ଦ୍ଦିଷ୍ଟ ଉଦ୍ଦେଶ୍ୟ ପାଇଁ (ଯେପରିକି ଜୀବିକା, ସାଂସ୍କୃତିକ ପରମ୍ପରା /ରୀତିନୀତି , ଔଷଧୀୟ ବ୍ୟବହାର କିମ୍ବା ସୁଖ ସ୍ୱାସ୍ଥ୍ୟ , ଇତ୍ୟାଦି) ଏଇ ସବୁ ସାମୁଦ୍ରିକ ଦଳ ଉପରେ ନିର୍ଭର କରିଛନ୍ତି କି ? (ହଁ/ନା)

➤ ଯଦି ହଁ, ତେବେ ଦୟା କରି ତା'ର ବିବରଣୀ ଦିଅନ୍ତୁ (କେଉଁ ସାମୁଦ୍ରିକ ଦଳ କେଉଁ କାମରେ ଲାଗିଥାଏ)?

1.4 ଏଇ ସାମୁଦ୍ରିକ ଦଳଗୁଡ଼ିକ ମାନ୍ୟତା ଅଥବା ଆପଣଙ୍କ ମତ୍ୟକୀର୍ତ୍ତୀ ସମ୍ପ୍ରଦାୟ ପାଇଁ କିଭଳି ଉପକାର କରିଛି , ତା'ର କିଛି ନିର୍ଦ୍ଦିଷ୍ଟ ଅଭିଜ୍ଞତା ବା ଉଦାହରଣ ଦେବେ କି ? (ଉଦାହରଣର ବିବରଣୀ ଉଲ୍ଲେଖ କରାଯିବ , ଯଦି ଥାଏ)

.....

1.5 ଫଟୋରେ ଯେଉଁ ସବୁ ସାମୁଦ୍ରିକ ଦଳ ଦେଖୁଛନ୍ତି (ଚାରି ଦଳ , ପଥିରି ଦଳ , ଇତ୍ୟାଦି), ସେମାନଙ୍କ ଭିତରେ ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ ପାର୍ଥକ୍ୟ କ'ଣ ଦେଖନ୍ତି ? ଯେପରିକି :

1.5.1 ଚିଲିକାରେ ଏମାନଙ୍କ ଭିତରୁ କେଉଁଟି ଅଧିକ ଦେଖାଯାଏ ଓ କେଉଁଟି କମ୍ ?

1.5.2 ଏମାନଙ୍କ ଭିତରୁ କେଉଁ ପ୍ରକାର ଦଳରେ କେଉଁ ପ୍ରକାର ମାଛ-କଙ୍କଡ଼ା-ଚିଲୁଡ଼ି ଅଧିକ ମିଳିଥାଏ ?

6 | Page ଗବେଷିକା ଓ ପ୍ରଶ୍ନା ନବ୍ୟା ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ରଥଙ୍କ ଦ୍ୱାରା ଅନୁଦିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ଦ୍ଧିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

1.5.3 ଏମାନଙ୍କ ଭିତରୁ କେଉଁ ପ୍ରକାର ଦଳ ଶିପକୁଦା ମୁହାଣ ଖୋଳାଯିବା ପୂର୍ବରୁ ଅଧିକ ଥିଲା କିନ୍ତୁ ବର୍ତ୍ତମାନ କମିଯାଇଛି (କେଉଁଠି ଓ କାହିଁକି) ?

1.5.4 ଏମାନଙ୍କ ଭିତରୁ କେଉଁ ପ୍ରକାର ଦଳ ଶିପକୁଦା ମୁହାଣ ଖୋଳାଯିବା ପୂର୍ବରୁ କମ ଥିଲା କିନ୍ତୁ ବର୍ତ୍ତମାନ ବଢ଼ି ଯାଇଛି ?

A	ପ୍ରଶ୍ନ/ସିଦ୍ଧାନ୍ତ /ଧାରଣା	ଉତ୍ତରର ବିବରଣୀ (ଉଚିତ ସ୍ଥାନରେ ✓ ଚିହ୍ନ ଦିଅନ୍ତୁ)				
A.1	ସାମୁଦ୍ରିକ ଦଳମାନ ଆପଣଙ୍କ ଗାଁରେ ପ୍ରଚୁର ଦେଖିବାକୁ ମିଳିଥାଏ- -ଏକଥା ଆପଣ ସ୍ୱୀକାର କରନ୍ତି କି ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
A.2	ସାମୁଦ୍ରିକ ଦଳମାନ ଆପଣଙ୍କ ଗାଁର ପରିସୀମା ଭିତରେ ବହୁଗୁଡ଼ିଏ ସ୍ଥାନରେ ଦେଖିବାକୁ ମିଳେ- -ଏକଥା ଆପଣ ସ୍ୱୀକାର କରନ୍ତି କି ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
A.3	ସାମୁଦ୍ରିକ ଦଳମାନ ମାଛର ପ୍ରଚୁର ଉପଲବ୍ଧତା ପାଇଁ ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ- -ଏକଥା ଆପଣ ସ୍ୱୀକାର କରନ୍ତି କି ?	ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ ନୁହେଁ	କିଛିତା ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ	କିଛି କହିବାର ନାହିଁ	ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ	ଅତି ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ
A.4	ସାମୁଦ୍ରିକ ଦଳର ସ୍ୱାସ୍ଥ୍ୟ ଉପକୂଳ ଅଞ୍ଚଳରେ କଳର ପ୍ରଦୃଷ୍ଟି ଦ୍ୱାରା ପ୍ରଭାବିତ ହୋଇଥାଏ- - ଏକଥା ଆପଣ ସ୍ୱୀକାର କରନ୍ତି କି ?	ଆଦୌ ପ୍ରଭାବିତ ହୁଏ ନାହିଁ	କିଛିତା ପ୍ରଭାବିତ ହୁଏ	ମଧ୍ୟମ ଧରଣର ପ୍ରଭାବିତ ହୁଏ	ଯଥେଷ୍ଟ ପ୍ରଭାବିତ ହୁଏ	ଖୁବ୍ ପ୍ରଭାବିତ ହୁଏ

1.6 ସାମୁଦ୍ରିକ ବର୍ଷଗୁଡ଼ିକରେ ସାମୁଦ୍ରିକ ଦଳର ବିକ୍ରୟ କ୍ଷେତ୍ର କିମ୍ବା ସ୍ୱାସ୍ଥ୍ୟରେ କୌଣସି ଉଲ୍ଲେଖନୀୟ ପରିବର୍ତ୍ତନ / ଘଟଣା ଆପଣ ଲକ୍ଷ୍ୟ କରିଛନ୍ତି କି? (ବଢ଼ିଛି / କମିଛି / କୌଣସି ପରିବର୍ତ୍ତନ ନାହିଁ)

➤ ଯଦି ହଁ, ଦୟା କରି ତା'ର ବିବରଣୀ ଦିଅନ୍ତୁ

ଅନୁଭାଗ -୨: ଜଳର ଗୁଣାତ୍ମକତା

2.1 ଆପଣଙ୍କ ଅଞ୍ଚଳରେ ବର୍ତ୍ତମାନର ଚିଲିକାର ପାଣିର ଗୁଣାତ୍ମକତାକୁ ଆପଣ କିପରି ମୂଲ୍ୟାଙ୍କନ କରିବେ ? (ଉତ୍କୃଷ୍ଟ / ଭଲ / ଚଳନୀୟ / ନିକୃଷ୍ଟ / ଅତି ନିକୃଷ୍ଟ)

2.2 ଉପରୋକ୍ତ ପ୍ରଶ୍ନର ନିର୍ବାଚିତ ଉତ୍ତରକୁ ଦୟା କରି ବୁଝାଇ ଦିଅନ୍ତୁ (ଅଧିକ ବିବରଣୀ):

2.3 କେଉଁ ସବୁ ଗୁଣ ବା ଲକ୍ଷଣ ଦ୍ୱାରା ଆପଣ ଜଳର ଗୁଣାତ୍ମକତାକୁ ବିଚାର କରନ୍ତି ? (ଯଥା : ରଙ୍ଗ, ସ୍ୱାଦ, ଗନ୍ଧ , ନିର୍ମଳତା , ଇତ୍ୟାଦି)

2.4 ଆପଣଙ୍କ ମତରେ, ବିରାଟ ବର୍ଷଗୁଡ଼ିକରେ ଚିଲିକା ପାଣିର ଗୁଣ କିପରି ବଦଳିଛି?

ଦୟା କରି କୌଣସି ଉଲ୍ଲେଖନୀୟ ପରିବର୍ତ୍ତନର ଧାରାର ବିବରଣୀ ଦିଅନ୍ତୁ.....

2.4.1 ପାଞ୍ଚ ବର୍ଷ ପୂର୍ବେ

2.4.2 ଦଶ ବର୍ଷ ପୂର୍ବେ

2.5 ଆପଣ କିମ୍ବା ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟର ସଦସ୍ୟମାନେ ଚିଲିକାରେ ପାଣି ସହିତ ଜଡ଼ିତ କୌଣସି ସ୍ୱାସ୍ଥ୍ୟ ସମସ୍ୟା ଅନୁଭବ କରିଛନ୍ତି କି?

ଅନୁଭାଗ -୩: କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟ-ଜୀବିକା (ଯେଉଁ ପ୍ରକାର ମାଛଧରା ବିପୁଳ ବ୍ୟାବସାୟିକ ପରିମାଣର ନୁହେଁ)

3.1 ଚିଲିକାରେ ମାଛର ବିବିଧତା ଓ ପ୍ରାଚୁର୍ଯ୍ୟରେ ଏଭଳି କୌଣସି ପରିବର୍ତ୍ତନ ଆପଣ ଦେଖୁଛନ୍ତି କି ଯାହା ପାଣିର ଗୁଣ ବଦଳିବା ଯୋଗୁଁ ଘଟିଛି ବୋଲି ଆପଣ ବିଶ୍ୱାସ କରନ୍ତି ? (ହଁ/ନା)

3.1.1 ଯଦି ହଁ, କାହିଁକି ?

3.2 ସାମୁଦ୍ରିକ ଦଳର ଉପସିଦ୍ଧି ଓ ସ୍ୱାସ୍ଥ୍ୟ ଆପଣଙ୍କ ଅଞ୍ଚଳରେ ମାଛଧରାକୁ କିଭଳି ପ୍ରଭାବିତ କରିଥାଏ ?

3.3 ପାଣିର ଗୁଣ ଅଥବା ସାମୁଦ୍ରିକ ଦଳର ବିଭାଗରେ ପରିବର୍ତ୍ତନ ଦେଖି ଆପଣ ଅଥବା ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟ ନିଜର ମାଛଧରା ପଦ୍ଧତି ବା ଶୈଳୀରେ କୌଣସି ପରିବର୍ତ୍ତନ କରିଛନ୍ତି କି ? (ହଁ/ନା)

3.3.1 ଯଦି ହଁ, କିଭଳି ପରିବର୍ତ୍ତନ କରିଛନ୍ତି , ଦୟା କରି ତା'ର ଉଦାହରଣ ଦିଅନ୍ତୁ ?

ଅନୁଭାଗ -୪: ପ୍ରଭାବକାରୀ ତତ୍ତ୍ୱ ସମୂହ

4.1 ଆପଣଙ୍କ ମତରେ ନିମ୍ନ ଲେଖିତ ତତ୍ତ୍ୱମାନ ଚିଲିକାରେ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟ-ଜୀବିକାକୁ ପ୍ରଭାବିତ କରିଛି ?

- ଏକ ଉପହୁଦ ରୂପେ ଚିଲିକାର ଭୌଗୋଳିକ ସୁବିଧା ଅସୁବିଧା (ଯାହା ହୁଦ ବା ନଦୀ , ପୋଖରୀ , ସମୁଦ୍ର ଆଦିରେ ପ୍ରାୟ ନଥାଏ)
- କଳକୃଷି(ଚିଲୁଡ଼ି ଘେରି)
- ଯତ୍ନ ଲଗାଇ କୃତ୍ରିମ ମୁହାଣ ଖୋଳା

- ପର୍ଯ୍ୟଟନ
- କୃଷି
- ମାଛଧରା ଉପକରଣରେ ପରିବର୍ତ୍ତନ
- କୋଭିଡ଼ ମହାମାରୀ

4.2 ଏହା ବ୍ୟତୀତ ଅନ୍ୟ କୌଣସି ଘଟଣା ବା ପ୍ରଭାବକାରୀ ଚକ୍ର ସାମୁଦ୍ରିକ ବଳ , କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବିକା , ଅଥବା ଜଳର ଗୁଣାତ୍ମକତାକୁ ବିଶେଷ ପ୍ରଭାବିତ କରିଥାଏ କି ? ଯଦି ହଁ , ଦୟା କରି ତା'ର ବିବରଣୀ ଦିଅନ୍ତୁ !.....

B1	ଚିଙ୍ଗୁଡ଼ି ଘେରି ଆପଣଙ୍କ ଅଞ୍ଚଳର ପରିବେଶ ଓ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବିକାକୁ ପ୍ରଭାବିତ କରିଥାଏ : ଏ ବିଷୟରେ ଆପଣ କ'ଣ ଭାବନ୍ତି ?	ଭୀଷଣ କ୍ଷତିକାରକ ପ୍ରଭାବ	କିଛିତା କ୍ଷତିକାରକ ପ୍ରଭାବ	କୌଣସି ପ୍ରଭାବ ନାହିଁ	କିଛିତା ଭଲ ପ୍ରଭାବ	ବହୁତ ଭଲ ପ୍ରଭାବ
B2	ଚିଲିକା ହ୍ରଦରେ ଜଳବୃଷି(ଚିଙ୍ଗୁଡ଼ି ଘେରି) ବଢ଼ିବା ବିଷୟରେ ଆପଣ କେତେ ଚିନ୍ତିତ ?	ବହୁତ ଚିନ୍ତିତ	ଚିନ୍ତିତ	ନିରପେକ୍ଷ	ଚିନ୍ତିତ ନୁହେଁ	ଆଦୌ ଚିନ୍ତିତ ନୁହେଁ
B3	ଚିଲିକା ହ୍ରଦରେ ଜଳବୃଷି(ଚିଙ୍ଗୁଡ଼ି ଘେରି) ନିୟନ୍ତ୍ରିତ ଏବଂ ପରିମିତ ଭାବରେ ପରିଚାଳିତ(ଅର୍ଥାତ , ବିପଜ୍ଜନକ ଭାବେ ବଢ଼ିବାକୁ ବା କାମ କରିବାକୁ ଦିଆଯାଏ ନାହିଁ) ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି କି?	ଖୁବ୍ ଭଲ ଭାବେ ନିୟନ୍ତ୍ରିତ	ଭଲ ଭାବେ ନିୟନ୍ତ୍ରିତ	ମଧ୍ୟମ ଭାବେ ନିୟନ୍ତ୍ରିତ	ଦୁର୍ବଳ ଭାବେ ନିୟନ୍ତ୍ରିତ	ଆଦୌ ନିୟନ୍ତ୍ରିତ ନୁହେଁ

11 | Page ଗବେଷିକା ଓ ପ୍ରଶ୍ନା ନବ୍ୟା ନାୟରଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ରଥଙ୍କ ଦ୍ଵାରା ଅନୁବିତ, ପରିମାଳିତ, ଓ ପରିବର୍ଦ୍ଧିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

B4	କୃତ୍ରିମ ମୁହାଣ ଖୋଳା ଚିଲିକାର ପରିବେଶ ଓ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବିକାକୁ ଭୀଷଣ ପ୍ରଭାବିତ କରିଛି : ଏ ବିଷୟରେ ଆପଣ କ'ଣ ଭାବନ୍ତି ?	ଭୀଷଣ କ୍ଷତିକାରକ ପ୍ରଭାବ	କିଛିତା କ୍ଷତିକାରକ ପ୍ରଭାବ	କୌଣସି ପ୍ରଭାବ ନାହିଁ	କିଛିତା ଭଲ ପ୍ରଭାବ	ବହୁତ ଭଲ ପ୍ରଭାବ
B5	ଚିଲିକା ହ୍ରଦରେ କୃତ୍ରିମ ମୁହାଣ ଖୋଳିବାର ପ୍ରକ୍ରିୟା ଏବଂ ପରିମାଣ ବିଷୟରେ ଆପଣ କେତେ ସଚେତନ ?	ଖୁବ୍ ସଚେତନ	କିଛିତା ସଚେତନ	କିଛି କହିବାର ନାହିଁ	ବିଶେଷ ସଚେତନ ନୁହେଁ	ଆଦୌ ସଚେତନ ନୁହେଁ
B6	କୃତ୍ରିମ ମୁହାଣ ଖୋଳିବାର ପରିଚାଳନା/ପ୍ରକ୍ରିୟାରେ ମତ୍ସ୍ୟଜୀବୀମାନଙ୍କର ଆବଶ୍ୟକତା ଏବଂ ପ୍ରକୃତି ପାଇଁ କ'ଣ ଭଲ, ସେ ସବୁ ବିଷୟ ପ୍ରତି କେତେ ପରିମାଣରେ ଧ୍ୟାନ ଦିଆଯାଇଥାଏ ବୋଲି ଆପଣ ବିଶ୍ଵାସ କରନ୍ତି ?	ଭଲ ଭାବେ ଧ୍ୟାନ ଦିଆଯାଇଥାଏ	କିଛିତା ଧ୍ୟାନ ଦିଆଯାଇଥାଏ	ମୁଁ ନିଶ୍ଚିତ ନୁହେଁ	ସେତେ ଭଲ ନୁହେଁ	ଆଦୌ ଭଲ ନୁହେଁ
B7	ପର୍ଯ୍ୟଟନ କାର୍ଯ୍ୟକଳାପ ଚିଲିକାର ପରିବେଶ ଓ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବିକାକୁ ଭୀଷଣ ପ୍ରଭାବିତ କରିଛି: ଏ ବିଷୟରେ ଆପଣ କ'ଣ ଭାବନ୍ତି ?	ଭୀଷଣ କ୍ଷତିକାରକ ପ୍ରଭାବ	କିଛିତା କ୍ଷତିକାରକ ପ୍ରଭାବ	କୌଣସି ପ୍ରଭାବ ନାହିଁ	କିଛିତା ଭଲ ପ୍ରଭାବ	ବହୁତ ଭଲ ପ୍ରଭାବ
B8	ଚିଲିକାରେ ପର୍ଯ୍ୟଟନ କାର୍ଯ୍ୟକଳାପକୁ କେଉଁ ଷ୍ଟର ପର୍ଯ୍ୟନ୍ତ ନିୟନ୍ତ୍ରିତ ଓ ନିୟମାଧୀନ କରାଯାଇପାରିଛି ବୋଲି ଆପଣ ମନେକରନ୍ତି ?	ଖୁବ୍ ଭଲ ଭାବେ ନିୟନ୍ତ୍ରିତ	ଭଲ ଭାବେ ନିୟନ୍ତ୍ରିତ	ମଧ୍ୟମ ଭାବେ ନିୟନ୍ତ୍ରିତ	ଦୁର୍ବଳ ଭାବେ ନିୟନ୍ତ୍ରିତ	ଆଦୌ ନିୟନ୍ତ୍ରିତ ନୁହେଁ
B9	ଚିଲିକା ହ୍ରଦରେ ପର୍ଯ୍ୟଟନ ବଢ଼ିବାର ସମ୍ଭାବନା ନେଇ ଆପଣ କେତେ ଚିନ୍ତିତ ?	ବହୁତ ଚିନ୍ତିତ	ଚିନ୍ତିତ	ନିରପେକ୍ଷ	ଚିନ୍ତିତ ନୁହେଁ	ଆଦୌ ଚିନ୍ତିତ ନୁହେଁ

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B10	ଚିଲିକା କୂଳରେ କରାଯାଉଥିବା ଚାଷର ପ୍ରଥା ଓ ପଦ୍ଧତି ସ୍ଥାନୀୟ ପରିବେଶ ଓ ଜଳର ଗୁଣକୁ ଭାଷଣ ପ୍ରଭାବିତ କରିଛି : ଏ ବିଷୟରେ ଆପଣ କ'ଣ ଭାବନ୍ତି ?	ଭାଷଣ କ୍ଷତିକାରକ ପ୍ରଭାବ	କିଛିଟା କ୍ଷତିକାରକ ପ୍ରଭାବ	କୌଣସି ପ୍ରଭାବ ନାହିଁ	କିଛିଟା ଭଲ ପ୍ରଭାବ	ବହୁତ ଭଲ ପ୍ରଭାବ
B11	ଚାଷରୁ ବହି ଯାଇ ଚିଲିକା ପାଣିରେ ମିଶୁଥିବା ସାର ଓ କୀଟନାଶକ ଆଦି କ୍ଷତିକାରକ ପଦାର୍ଥ ଚିଲିକା ପାଣିର ଗୁଣକୁ ନଷ୍ଟ କରୁଛି ବୋଲି ଆପଣ କେତେ ଚିନ୍ତିତ ?	ବହୁତ ଚିନ୍ତିତ	ଚିନ୍ତିତ	ନିରପେକ୍ଷ	ଚିନ୍ତିତ ନୁହେଁ	ଆଦୌ ଚିନ୍ତିତ ନୁହେଁ
B12	ଚିଲିକା ହ୍ରଦ ଭିତରେ କୃଷିର ପ୍ରଭାବ ଏବଂ ପରିଣାମ ବିଷୟରେ ଆପଣ କେତେ ସଚେତନ ?	ଖୁବ୍ ସଚେତନ	କିଛିଟା ସଚେତନ	କିଛି କହିବାର ନାହିଁ	ବିଶେଷ ସଚେତନ ନୁହେଁ	ଆଦୌ ସଚେତନ ନୁହେଁ
B13	ହ୍ରଦରେ ପରିବେଶ ଓ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀଙ୍କର ସୁରକ୍ଷା ପାଇଁ ଚିଲିକାରେ କରାଯାଉଥିବା କୃଷିର ସୁପରିମିତ ପରିଚାଳନା କରାଯାଇଥାଏ (ଅର୍ଥାତ୍, ଯେଉଁ ପ୍ରକାର ଚାଷ କଲେ ପରିବେଶ ଓ ଚିଲିକାର କ୍ଷତି ନହେବ, ଏବଂ ଭବିଷ୍ୟତରେ ବି ଭଲ ଫସଲ ମିଳୁଥିବ, ସେଇ ପ୍ରକାରେ ଭାବି ଚିନ୍ତି ପରିଚାଳନା କରାଯାଏ) ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି କି ?	ଏ ବିଷୟ ଖୁବ୍ ଭଲ ଭାବେ ପରିଚାଳିତ	ଭଲ ଭାବେ ପରିଚାଳିତ	ମଧ୍ୟମ ପ୍ରକାରର	ଦୁର୍ବଳ ପରିଚାଳନା	ଏଭଳି କୌଣସି ପରିଚାଳନା ଆଦୌ ନାହିଁ
B14	ମାଛଧରା ଉପକରଣରେ ପରିବର୍ତ୍ତନ ସାମୁଦ୍ରିକ ଦଳର ସ୍ବାସ୍ଥ୍ୟ ଉପରେ କେତେ ଦୂର ପ୍ରଭାବ ପକାଇଥାଏ ?	ଯଥେଷ୍ଟ କ୍ଷତିକାରକ ପ୍ରଭାବ	କିଛିଟା କ୍ଷତିକାରକ ପ୍ରଭାବ	କୌଣସି ପ୍ରଭାବ ନାହିଁ	କିଛିଟା ଉପକାରୀ ପ୍ରଭାବ	ଯଥେଷ୍ଟ ଭଲ ଉପକାରୀ ପ୍ରଭାବ

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B15	ମାଛଧରା ଉପକରଣରେ ପରିବର୍ତ୍ତନ ଚିଲିକାର କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀଙ୍କ ଜୀବିକାକୁ କିଭଳି ପ୍ରଭାବିତ କରିଛି ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି ?	ଅତ୍ୟନ୍ତ କ୍ଷତିକାରକ	କ୍ଷତିକାରକ	ଭଲ ନୁହେଁ କି ମଧ୍ୟ ନୁହେଁ	ଉପକାରୀ	ଅତ୍ୟନ୍ତ ଉପକାରୀ
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ଅନୁଭାଗ -୫: ସଂରକ୍ଷଣ ଓ ଅଭିଶାସନ

5.1 ଆପଣଙ୍କ ଅଞ୍ଚଳରେ ସାମୁଦ୍ରିକ ଦଳର ସଂରକ୍ଷଣ ପାଇଁ କୌଣସି ଲୋକ ଉଦ୍ୟମ ଅଥବା ସରକାରୀ ଉଦ୍ୟମ ବିଷୟରେ ଆପଣ ଜାଣିଛନ୍ତି କି ? (ହଁ/ନା)

➤ ଯଦି ହଁ, ଦୟା କରି ତା'ର ବିବରଣୀ ଦିଅନ୍ତୁ.....

5.2 ସାମୁଦ୍ରିକ ଦଳର ଟ୍ରାଣ୍ସମିଗ୍ରେସନ୍ ସଂରକ୍ଷଣ, ଚିଲିକା ପାଣିର ଗୁଣାତ୍ମକ ଉନ୍ନତି, ଏବଂ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀଙ୍କର ସୁଖସ୍ବାସ୍ଥ୍ୟ - ଏସବୁର ସମନ୍ୱୟ (ଯେହେତୁ ଏମାନେ ପରସ୍ପର ସହିତ ଜଡ଼ିତ) କରିବା ପାଇଁ (ଅର୍ଥାତ୍, ପରସ୍ପର ସହିତ ଯୋଡ଼ି ଦେଖିବା ପାଇଁ) ପ୍ରଚଳିତ ବିଧି ବ୍ୟବସ୍ଥା ଓ ପରିଚାଳନା ରଣନୀତିରେ କି ପ୍ରକାର ଉନ୍ନତି/ ପରିବର୍ତ୍ତନ ଆସିବା ଦରକାର ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି ?

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ଅନୁଭାଗ -୭: ଭବିଷ୍ୟତ ଚିନ୍ତା

6.1 ସାମୁଦ୍ରିକ ଦଳର ତୃଣଭୂମି, ଚିଲିକା ପାଣିର ଗୁଣାତ୍ମକତା , ଏବଂ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀଙ୍କର ସୁଖସ୍ବାସ୍ଥ୍ୟ - ଏସବୁର ଭବିଷ୍ୟତ ସମ୍ପର୍କରେ ଆପଣଙ୍କର କ'ଣ ସବୁ ଉଦବେଗ ରହିଛି ?

6.2 ସାମୁଦ୍ରିକ ଦଳର ତୃଣଭୂମି ଭଳି ଉପକୂଳ ଆର୍ତ୍ତଭୂମି (ଜଳାଭୂଇଁ) ତଥା କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀଙ୍କ ଭବିଷ୍ୟତରେ ପୁରସ୍କୃତ ରହୁ - ଏଥିପାଇଁ କି ପଦକ୍ଷେପମାନ ନିଆଯିବା ଦରକାର ବୋଲି ଆପଣ ମନେ କରନ୍ତି ?

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C1	ଆପଣ ମାଛଧରାରୁ ଆପଣଙ୍କର ଆୟ କିପ୍ରା ରୋଜଗାରକୁ କିପରି ମୂଲ୍ୟାଙ୍କନ କରିବେ? (ଭୌତିକ ସୁଖ ସ୍ବାସ୍ଥ୍ୟ ଦୃଷ୍ଟିରୁ)	ଖୁବ୍ କମ୍	କମ୍	ଚଳନୀୟ	ଚଳନୀୟ	ଖୁବ୍ ଅଧିକ
C2	ମାଛ କାମରୁ ହେଉଥିବା ଆୟ ଦ୍ଵାରା ଆପଣଙ୍କ ପରିବାରର ସର୍ବନିମ୍ନ ଆବଶ୍ୟକତା (ଖାଦ୍ୟ, ବାସଗୃହ , ସ୍ବାସ୍ଥ୍ୟ , ଇତ୍ୟାଦି) ଆପଣ ପୂରଣ କରିପାରୁଛନ୍ତି କି ?	ହଁ	ନା	ଆଂଶିକ	-----	-----
C3	ଜଣେ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀ ହିସାବରେ ଆପଣ କେତେ ପୁଞ୍ଜୀ ?	ଖୁବ୍ ପୁଞ୍ଜୀ	ଏକ ପ୍ରକାର ପୁଞ୍ଜୀ	ପୁଞ୍ଜୀ ନୁହେଁ କି ଦୁଃଖୀ ନୁହେଁ	ଏକ ପ୍ରକାର ଦୁଃଖୀ	ଖୁବ୍ ଦୁଃଖୀ
C4	ଜଣେ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀ ହିସାବରେ କେତେ ଥର ଆପଣ ନିଜର କାମକୁ ବେଳ ଆମ୍ଭସତ୍ତା ଅନୁଭବ କରିଥାନ୍ତି ?	କେବେ ବି ନୁହେଁ	କ୍ଷୁଦ୍ର	ବେଳେ ବେଳେ	ଅନେକ ସମୟରେ	ବହୁତ ସମୟରେ
C5	ଆପଣ ନିଜକୁ ଏଇ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀଙ୍କ ଭିତରୁ ଜଣେ ଏବଂ ଏଠିକାର ହିଁ ଲୋକ ବୋଲି ଅନ୍ତରଙ୍ଗ ଭାବେ ଅନୁଭବ କରନ୍ତି କି (ଅର୍ଥାତ୍ , ନିଜର ଭିନ୍ନ କିଛି ପରିଚୟ ଖୋଜନ୍ତି ନାହିଁ)?	ହଁ	ନା	ଆଂଶିକ	-----	-----
C6	ଆପଣଙ୍କର ସହ-ମତ୍ସ୍ୟଜୀବୀ (ଯେଉଁମାନେ ସାଥୀରେ ଥାଆନ୍ତି) ଏବଂ ମତ୍ସ୍ୟଜୀବୀ ସମାଜ	କୌଣସି ସାହାଯ୍ୟ ମିଳେ ନାହିଁ	କିଛିଟା ମିଳିଥାଏ	ମଧ୍ୟମ ଧରଣର	ଭଲ ସାହାଯ୍ୟ ସହଯୋଗ ମିଳିଥାଏ	ବହୁତ ଭଲ ସହଯୋଗ

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	ଠାରୁ ଆପଣ କିଭଳି ସାହାଯ୍ୟ ଓ ସହଯୋଗ ପାଇଥା'ନ୍ତି ?					
C7	ଏକ ମାଛଧରା ଜାବିକା ନେଇ ହେଉଥିବା ସାମୁଦ୍ରିକ ନିଷ୍କାରି ପ୍ରହର ପ୍ରକ୍ରିୟାରେ ଆପଣ ସକ୍ରିୟ ଭାବେ ଭାଗ ନେଇଥା'ନ୍ତି କି ?	ହଁ	ନା	---	----	---
C8	ଆପଣଙ୍କର ମହାଜୀବୀ ସମ୍ପ୍ରଦାୟର ନୀତିନିୟମ ପ୍ରଣୟନରେ ଆପଣଙ୍କର ଅଂଶଗ୍ରହଣ ଏବଂ ପ୍ରଭାବ ଯେଉଁ ଭର ପର୍ଯ୍ୟନ୍ତ (ଅର୍ଥାତ୍ ଯେତିକି) ସମ୍ଭବ ହେଉଛି, ସେଥିରେ ଆପଣ କେତେ ସକ୍ରିୟ?	ଖୁବ୍ ଅସକ୍ରିୟ	ଅସକ୍ରିୟ	ସକ୍ରିୟ ନୁହେଁ କି ଅସକ୍ରିୟ ନୁହେଁ	ସକ୍ରିୟ	ଖୁବ୍ ସକ୍ରିୟ
C9	ଆପଣ ବିଶ୍ୱାସ କରନ୍ତି ଯେ ସାମୁଦ୍ରିକ ଦଳର ଟୁଣ୍ଡୁମି ଏବଂ ଜଳ ଗୁଣବତ୍ତାର ସ୍ଥାୟୀ ପରିଚାଳନା (ଯେପରିକି ଚିଲିକାର ପାଣି ଓ ସାମୁଦ୍ରିକ ଦଳ ଭବିଷ୍ୟତରେ ମଧ୍ୟ ଭଲ ଅବସ୍ଥାରେ ରହିବ) ପାଇଁ ସରକାରୀ ସଂସ୍ଥା, ସ୍ଥାନୀୟ ଲୋକ ଏବଂ ମହା ସଙ୍ଗଠନ ମଧ୍ୟରେ ନିଜର ପ୍ରୟାସ କରୁନା ଅଟେ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
C10	ସାମୁଦ୍ରିକ ସଂରକ୍ଷଣ ଏବଂ ପରିଚାଳନା ରଣନୀତି (ସରକାରୀ ବ୍ୟବସ୍ଥା /ଲୋକଙ୍କର ବ୍ୟବସ୍ଥା) ସାମୁଦ୍ରିକ ଦଳର ଟୁଣ୍ଡୁମିର ସଂରକ୍ଷଣ ଏବଂ ଜଳର ଗୁଣବତ୍ତା ବଜାୟ ରଖିବାରେ କେତେ ପ୍ରଭାବକାରୀ ହୋଇଛି?	ଆସିବା ପ୍ରଭାବକାରୀ ନୁହେଁ	ବିଶେଷ ପ୍ରଭାବକାରୀ ନୁହେଁ	ମଧ୍ୟମ ଧରଣର ପ୍ରଭାବ	ବହୁତ ପ୍ରଭାବକାରୀ	ଖୁବ୍ ପ୍ରଭାବକାରୀ
C11	ସ୍ଥାୟୀ ଜାବିକା ପାଇଁ ଆପଣଙ୍କର ସ୍ଥାନୀୟ ପ୍ରାକୃତିକ ସମ୍ପଦ (ଯଥା, ଚିଲିକାର ମାଛ-	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ

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	କଙ୍କଡ଼ା-ଚିଙ୍ଗୁଡ଼ି, ଜୁଣା ଜଙ୍ଗଲ, ଇତ୍ୟାଦି)ର ସବ୍ୟବହାର ପାଇଁ ପର୍ଯ୍ୟାପ୍ତ ସୁଯୋଗ ଅଛି - ଏ କଥାରେ ଆପଣ ସହମତ କି (ଅର୍ଥାତ୍ ଏକଥା ଠିକ୍ ବୋଲି ଆପଣ ଭାବନ୍ତି କି) ?					
C12	ମାଛଧରା କାମରେ ପୁଞ୍ଜି ଖଟାଇବା ପାଇଁ ପର୍ଯ୍ୟାପ୍ତ ଆର୍ଥିକ ସମ୍ବଳ ଓ ରଣ ମିଳିବାର ସୁବିଧା ସୁଯୋଗ ଆପଣଙ୍କ ପାଖରେ ଅଛି - ଏ କଥାରେ ଆପଣ ସହମତ କି (ଅର୍ଥାତ୍ ଏକଥା ଠିକ୍ ବୋଲି ଆପଣ ଭାବନ୍ତି କି) ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
C13	ନିଜର କ୍ଷୁଦ୍ର ମହାଜୀବିକାକୁ ବଞ୍ଚାଇ ରଖିବା ଭଳି ଆବଶ୍ୟକ ସାମାଜିକ ଏବଂ ମାନବ ସମ୍ବଳ (ଯଥା, ଜ୍ଞାନ କୌଶଳ, ବକ୍ଷତା, ଓ ସାମାଜିକ ଯୋଗାଯୋଗତନ୍ତ୍ର) ଆପଣଙ୍କ ପାଖରେ ଅଛି - ଏ କଥାରେ ଆପଣ ସହମତ କି (ଅର୍ଥାତ୍ ଏକଥା ଠିକ୍ ବୋଲି ଆପଣ ଭାବନ୍ତି କି) ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
C14	ପରିବେଶ ଓ ପରିସଂସ୍ଥା ସୁସ୍ଥ ରହିଲେ ଚିଲିକାର ପାଣି ମଧ୍ୟ ଭଲ ରହିବା ସହିତ କ୍ଷୁଦ୍ର ମହାଜୀବିକାର ଉପକାର କରିଥାଏ ଓ ମାଛ ଉତ୍ପାଦନ ବଢ଼ାଇଥାଏ - ଏ କଥାରେ ଆପଣ ସହମତ କି (ଅର୍ଥାତ୍ ଏକଥା ଠିକ୍ ବୋଲି ଆପଣ ଭାବନ୍ତି କି) ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
C15	ଚିଲିକା ପାଣିର ମାନ ଖ୍ରୀଷ୍ଟ ପାଇଲେ (ପାଣି ଭଲ ନ ରହିଲେ) କ୍ଷୁଦ୍ର ମହାଜୀବିକା ଉପରେ କୁପ୍ରଭାବ ପଡ଼ିଥାଏ - ଏ କଥାରେ ଆପଣ	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ

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	ସହମତ କି (ଅର୍ଥାତ ଏକଥା ଠିକ୍ ବୋଲି ଆପଣ ଭାବନ୍ତି କି) ?					
C16	ଚିଲିକା ପାଣିର ମାନ ତଥା ପରିବେଶ ଓ ପରିସଂସ୍କାରେ ପରିବର୍ତ୍ତନ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବିକାକୁ କେତେ ଦୂର ବିପନ୍ନ କରିଥାଏ ବୋଲି ଆପଣ ଭାବନ୍ତି ?	ଖୁବ୍ କମ୍	କମ୍	ସାମାନ୍ୟ /ସାଧାରଣ	ଅଧିକ	ଖୁବ୍ ଅଧିକ
C17	ଚିଲିକା ପରିବେଶ ଓ ପରିସଂସ୍କାର ପ୍ରଭାବକାରୀ ସଂରକ୍ଷଣ ଏବଂ ପରିଚାଳନା ଏବଂ ଜଳର ଗୁଣାତ୍ମକତା କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବିକାର ବୀର୍ଯ୍ୟଶାୟୀତ୍ୱ ପାଇଁ ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ- ଏ କଥାରେ ଆପଣ ସହମତ କି (ଅର୍ଥାତ ଏକଥା ଠିକ୍ ବୋଲି ଆପଣ ଭାବନ୍ତି କି) ?	ଦୃଢ଼ ଭାବେ ଅସହମତ	ଅସହମତ	କିଛି କହିବାର ନାହିଁ	ସହମତ	ଦୃଢ଼ ଭାବେ ସହମତ
C18	ଚିଲିକା ପାଣିର ଗୁଣାତ୍ମକ ମାନରେ ପରିବର୍ତ୍ତନ ସେମାନଙ୍କର ମାଛଧରା କାର୍ଯ୍ୟକଳାପ ଏବଂ ଜୀବିକାକୁ କେତେ ପରିମାଣରେ ପ୍ରଭାବିତ କରୁଛି ବୋଲି ମତ୍ସ୍ୟଜୀବୀ ସମ୍ପ୍ରଦାୟଗୁଡ଼ିକ ଅନୁଭବ କରନ୍ତି ?	ଆଦୌ ନୁହେଁ	ଅଳ୍ପ	ମଧ୍ୟମ ପ୍ରକାରେ	ଯଥେଷ୍ଟ	ବହୁତ
C19	ଚିଲିକାରେ ହେଉଥିବା ପରିବର୍ତ୍ତନଗୁଡ଼ିକର(ମାଛ କମିଯିବା , ଜଳ ପ୍ରଦୂଷଣ, ସାମୁଦ୍ରିକ ବଳ କମିଯିବା , ଲଙ୍ଘାଦି) ପ୍ରତିକ୍ରିୟାରେ ସ୍ଥାନୀୟ ମତ୍ସ୍ୟଜୀବୀମାନେ ସେମାନଙ୍କର ମାଛଧରା ଅଭ୍ୟାସକୁ କେତେ ପ୍ରଭାବକାରୀ ଭାବରେ ଖାପ ଖୁଆଇପାରନ୍ତି ?	ଆଦୌ ପ୍ରଭାବକାରୀ ଭାବରେ ନୁହେଁ	ସେତେ ପ୍ରଭାବକାରୀ ଭାବରେ ନୁହେଁ	ମଧ୍ୟମ ପ୍ରକାରେ ପ୍ରଭାବକାରୀ	ବହୁତ ପ୍ରଭାବକାରୀ ଭାବରେ	ଖୁବ୍ ପ୍ରଭାବକାରୀ ଭାବରେ

19 | Page ଗବେଷିକା ଓ ପୁଣି ନବ୍ୟା ନାୟକଙ୍କ ମୂଳ ଇଂରାଜୀ ପ୍ରଶ୍ନାବଳୀର ବିକାଶ ରଥଙ୍କ ଦ୍ୱାରା ଅନୁଦିତ, ପରିମାର୍ଜିତ, ଓ ପରିବର୍ଦ୍ଧିତ ରୂପାନ୍ତର (ଅକ୍ଟୋବର ୨୦୨୩)

C20	କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀ ସମ୍ପ୍ରଦାୟଗୁଡ଼ିକ ସେମାନେ ସମ୍ପ୍ରଦାୟ ହେବାକୁ ଥିବା ସମସ୍ୟା ବା ଆହ୍ୱାନଗୁଡ଼ିକର ମୁକାବିଲା କରିପାରିବା ସହିତ ସେଥିରୁ ମୁକୁଳି ଆସି ପାରିବା ପାଇଁ କେତେ ଦୂର ସମର୍ଥ ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି ?	ଆଦୌ ନୁହେଁ	ସେତେ ଭଲ ଭାବରେ ନୁହେଁ	ମଧ୍ୟମ ପ୍ରକାରେ ସମର୍ଥ	ଭଲ ଭାବେ ସମର୍ଥ	ଖୁବ୍ ଭଲ ଭାବେ ସମର୍ଥ
C21	ପରିବର୍ତ୍ତନଗୁଡ଼ିକ ସହିତ ଖାପ ଖୁଆଇବା ପାଇଁ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀ ସମ୍ପ୍ରଦାୟଗୁଡ଼ିକ ଭିତରେ ରହିଥିବା ପାରାବରିକ ସହଯୋଗର ଖରକୁ ମୂଲ୍ୟାଙ୍କନ କରନ୍ତୁ ।	ଖୁବ୍ କମ୍ ପାରାବରିକ ସହଯୋଗ	କମ୍	ସାମାନ୍ୟ /ସାଧାରଣ	ଅଧିକ	ଖୁବ୍ ଅଧିକ
C22	ଜଳର ଗୁଣାତ୍ମକ ମାନ ପରିପ୍ରେକ୍ଷାରେ କ୍ଷୁଦ୍ର ମତ୍ସ୍ୟଜୀବୀ ସମ୍ପ୍ରଦାୟଗୁଡ଼ିକର ପ୍ରତିରୋଧ କ୍ଷମତାକୁ ବଢ଼ାଇବାରେ (ଯେପରିକି ଚିଲିକା ପାଣିର ମାନ ହ୍ରାସ ଘଟିଲେ ମତ୍ସ୍ୟଜୀବୀମାନେ ଆବଶ୍ୟକ ପ୍ରତିକାର କରିପାରିବେ) ସ୍ଥାନୀୟ ସରକାରୀ ନୀତି ଏବଂ ବିଧିବ୍ୟବସ୍ଥା କେତେ ଦୂର ସାହାଯ୍ୟ କରୁଛି ?	ଆଦୌ ସାହାଯ୍ୟ କରୁନାହିଁ	ସେତେ ବେଶି ସାହାଯ୍ୟ କରୁନାହିଁ	ମଧ୍ୟମ ପ୍ରକାର	ବହୁତ ସାହାଯ୍ୟ କରୁଛି	ଖୁବ୍ ସାହାଯ୍ୟ କରୁଛି
C23	ସେମାନଙ୍କର ମାଛଧରା ଜୀବିକା ସଂକଟରେ ପଡ଼ିଲେ ଅନ୍ୟାନ୍ୟ ବିକଳ ଜୀବିକାର ବ୍ୟବସ୍ଥା ସ୍ଥାନୀୟ ମତ୍ସ୍ୟଜୀବୀଙ୍କ ପାଇଁ କେତେ ଦୂର ଉପଲବ୍ଧ ଓ ସୁଗମ ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି ?	ଅତି ଅଳ୍ପ ବିକଳ ରହିଛି	ସାମାନ୍ୟ ବିକଳ ରହିଛି	ମଧ୍ୟମ ପ୍ରକାରର (କମ୍ ନୁହେଁ କି ବେଶି ନୁହେଁ)	ଯଥେଷ୍ଟ ବିକଳ ରହିଛି	ବହୁ ପ୍ରକାର ବିକଳ ରହିଛି
C24	ପାଣିର ଗୁଣାତ୍ମକମାନରେ ପରିବର୍ତ୍ତନ ସହିତ ଖାପ ଖୁଆଇବା ତଥା ପରିମିତ ମାଛଧରାର ବ୍ୟବସ୍ଥାକୁ ଅବ୍ୟାହତ ରଖିବା ପାଇଁ ସେମାନଙ୍କର ଆବଶ୍ୟକ ଜ୍ଞାନ ଓ ଦକ୍ଷତା	ଖୁବ୍ ସାମାନ୍ୟ	ସାମାନ୍ୟ	ମଧ୍ୟମ ପ୍ରକାରର	ଯଥେଷ୍ଟ	ବ୍ୟାପକ

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କେତେ ଦୂର ରହିଛି ବୋଲି ସ୍ଥାନୀୟ ମାଧ୍ୟମଦ୍ୱାରା ସମ୍ପ୍ରଦାୟମାନେ ଜାଣୁଛନ୍ତି ?					
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ଅନୁଭାଗ -୭: ଅତିରିକ୍ତ ମତାମତ

ଚିଲିକା ହ୍ରଦର ସାମାଜିକ-ପାରିବେଶିକ ପ୍ରଣାଳୀକୁ ପ୍ରଭାବିତ କରୁଥିବା ଚରା ବା କାରଣ ଓ ସେଗୁଡ଼ିକର ପରିଣାମ ବିଷୟରେ ଅନ୍ୟ କୌଣସି ସୂଚନା, ମନ୍ତବ୍ୟ, ପର୍ଯ୍ୟବେକ୍ଷଣ, କିମ୍ବା ଅନ୍ତର୍ବୃତ୍ତି ଥିଲେ ଦୟା କରି ଆମକୁ ଜଣାନ୍ତୁ ।

ସାମାଜିକ -ପାରିବେଶିକ ବିପନ୍ନତା ଆକଳନ

[ସର୍ବେକ୍ଷଣକାରୀଙ୍କ ପାଇଁ ସୂଚନା:

ସିର ଅଥବା ଧୀର ପାଣିରେ ଅନେକ ପ୍ରକାର ଜଳଜ ଉଦ୍ଭିଦ(aquatic vegetation) ଦେଖାଯାଇଥାଏ । ଆମେ ଯାହାକୁ 'ଦଳ' ବୋଲି କହିଥାଉ, ଯାହା ପାଣିରେ ଜନ୍ମିଥାଏ ଓ ଭାସୁଥାଏ, ସେଥିରେ ଅନେକ ପ୍ରକାର ଜଳଜ ବା ଭାସମାନ ଉଦ୍ଭିଦ ଅନ୍ତର୍ଭୁକ୍ତ, ଯେପରିକି ବିଲ୍ୱାଟି ଦଳ । ଏଗୁଡ଼ିକୁ ପାଣିର ଘାସ-ଲତା ବୋଲି କୁହାଯାଇପାରିବ ।

କିଛି ଦଳ କେବଳ ମଧୁର ଜଳରେ ଦେଖାଯାଏ; ସେଗୁଡ଼ିକ ସମୁଦ୍ର ପାଣିରେ ଚିଣ୍ଡିବ ନାହିଁ କି ଦେଖିବାକୁ ମିଳିବ ନାହିଁ (ଯେପରିକି ଚିଲୁଡ଼ିଆ ଦଳ) । ଆଉ କିଛି ଦଳ ସମୁଦ୍ରର ଲୁଣା ପାଣିରେ ହିଁ ଦେଖାଯାଇଥାଏ, ସେଗୁଡ଼ିକ ପୋଖରୀ ବା ନଦୀର ମଧୁର ଜଳରେ ଚିଣ୍ଡିବ ନାହିଁ ।

ଏଇ ସବୁ ଦଳ ମାଛ ଆଦି ଜଳଚର ଜୀବଙ୍କ ପାଇଁ ଅନେକ ପ୍ରକାରେ ଗୁରୁତ୍ୱପୂର୍ଣ୍ଣ ; ପ୍ରଥମତଃ , ଗାଈମଇଁଷି ମାଟି ଉପରର ଘାସ-ଲତା ଖାଇବା ଭଳି ଅନେକ ଜଳଚର ପ୍ରାଣୀ ପାଣି ଭିତରର ଏଇ ଦଳକୁ ହୁଏତ ଖାଇଥା'ନ୍ତି, କିମ୍ବା ତାହାରି ଭିତରେ ସେମାନଙ୍କର ଖାଦ୍ୟର ସନ୍ଧାନ ପାଇଥା'ନ୍ତି । ଦ୍ୱିତୀୟତଃ, ଏହି ଦଳ ଭିତରେ ମାଛ ଭଳି ପ୍ରାଣୀକୁ ଲୁଚି ରହିବାକୁ ଓ ପ୍ରଜନନ କରିବାକୁ ସୁବିଧା ହୋଇଥାଏ , ପୁଣି ଉପରେ ପ୍ରବଳ ଖରାବ ପ୍ରଭାବରୁ ମଧ୍ୟ ନିଷ୍କାର ମିଳିଥାଏ ।

ସାମୁଦ୍ରିକ ଦଳ ବା ଘାସ-ଲତାକୁ ଇଂରାଜୀରେ କୁହନ୍ତି 'sea grass' । ଅନେକ ପ୍ରକାରର ସାମୁଦ୍ରିକ ଦଳ ରହିଛି, ସେଥିରୁ କିଛି ପ୍ରାୟ ଘାସ ଭଳି ଦେଖାଯାଉଥିବା ବେଳେ ଅନେକ କିନ୍ତୁ ଅନ୍ୟାନ୍ୟ ଗଛଲତା ଭଳି ଦେଖାଯାଇଥାଏ । ସାମୁଦ୍ରିକ କଇଁଛ(marine turtle), ସମୁଦ୍ର ଗାଈ (dugong) ଭଳି ଅନେକ ସାମୁଦ୍ରିକ ପ୍ରାଣୀ ଏଇ ସାମୁଦ୍ରିକ ଦଳ ବା ଘାସ-ଲତାକୁ ଖାଇଥା'ନ୍ତି ।

ଚିଲିକା ହ୍ରଦ ହେଉଛି ମଧୁର ଜଳ ଓ ଲୁଣା ଜଳର ସନ୍ଧି ସ୍ଥଳ; ଏହାର ପାଣିରେ କେବେ ମଧୁରତା ବଢ଼ିଯାଏ ତ କେବେ ଲବଣତା (salinity) । ସେଥିପାଇଁ ଏହାର ଖାରି ପାଣିରେ କେଉଁଠି ମଧୁର ଜଳର ଦଳ ଦେଖାଯାଏ ତ କେଉଁଠି ସାମୁଦ୍ରିକ ଦଳ ବି ଦେଖାଯାଏ ; ପୁଣି କେଉଁଠି ହୁଏତ ଉଭୟ ପ୍ରକାର ଦଳ ମିଶି ରହିପାରେ । ସ୍ଥାନୀୟ ପାରମ୍ପରିକ ମାଧ୍ୟମଦ୍ୱାରାମାନେ ଚିଲିକାରେ 'ଚାରି ଦଳ' ବୋଲି ଯେଉଁସବୁ ଜଳଜ ଘାସ-ଲତାକୁ ବୁଝନ୍ତି , ତାହା ଅନେକ ପ୍ରକାରର ଏବଂ ସେଥିରେ *Halophila ovalis*

ବୋଲି ଏକ ପ୍ରକାର ସାମୁଦ୍ରିକ ଦଳ ମଧ୍ୟ ଅନ୍ତର୍ଭୁକ୍ତ । ପଥରୀ ଦଳ ମଧ୍ୟ ଅନ୍ୟ ପ୍ରକାରର ସାମୁଦ୍ରିକ ଦଳ ବୋଲି ଲୋକଙ୍କ ଠାରୁ ଜାଣିବାକୁ ମିଳିଥାଏ ଯଦିଓ କିଏ କେଉଁ ପ୍ରକାରିକୁ କେଉଁ ନାମରେ ଚିହ୍ନିଛନ୍ତି ସେଥିରେ ପାର୍ଥକ୍ୟ ରହିବା ଅସମ୍ଭବ ନୁହେଁ (ଅନ୍ୟ ଦଳକୁ ବି ଚାରି ଦଳ କୁହାଯାଇଥାଏ) ।

ଚିଲିକା ହ୍ରଦ ତା'ର ଅନେକ ବୈଶିଷ୍ଟ୍ୟ ଯୋଗୁଁ ବିଶ୍ୱବିଖ୍ୟାତ, ଏବଂ ସେଥିରୁ ଗୋଟିଏ ବୈଶିଷ୍ଟ୍ୟ ହେଉଛି ସାମୁଦ୍ରିକ ଦଳ । ୨୦୨୨ ମସିହାର ତଥ୍ୟ ଅନୁଯାୟୀ ଭାରତର ମୋଟ ସାମୁଦ୍ରିକ ଦଳର ପ୍ରାୟ ତିନି ଭାଗରୁ ଭାଗେ ଏଇ ଚିଲିକାରେ ହିଁ ରହିଛି । ବୈଜ୍ଞାନିକମାନେ ଚିଲିକାରେ ଯେଉଁ ଚାରି ଗୋଟି ପ୍ରକାରିର ସାମୁଦ୍ରିକ ଦଳ ପାଇଛନ୍ତି, ସେଗୁଡ଼ିକର ବୈଜ୍ଞାନିକ ନାମ ହେଉଛି *Halophila beccarii*, *Halophila ovata*/*Halophila ovalis*, *Halodule pinifolia*, ଏବଂ *Halodule uninervis* । ଏହା ଭିତରେ *Halophila ovalis* ଅଧିକ ଦେଖାଯାଇଥାଏ ବୋଲି କୁହାଯାଏ ।

ଏହି ସବୁ ସାମୁଦ୍ରିକ ଦଳ ବଡ଼ ସମ୍ବେଦନଶୀଳ ଏବଂ ଜଳୀୟ ପରିବେଶ ସେମାନଙ୍କର ପ୍ରତିକୂଳ ହେଲେ ସେମାନେ ନଷ୍ଟ ହୋଇଯାଆନ୍ତି । ଚିଲିକା ପାଣିରେ ଆବଶ୍ୟକ ଲବଣତାର ଅଭାବ କିମ୍ବା ଆଧିକ୍ୟ ହେଲେ, ଅଥବା ପାଣି ନିର୍ମଳ ନ ରହି ଅଧିକ ଗୋଳିଆ ହେଲେ, କିମ୍ବା କୌଣସି ରାସାୟନିକ ପ୍ରଦୂଷଣ ହେଲେ ଏମାନେ ଭଲ ବଢ଼ିବେ ନାହିଁ; ପୁଣି ଗ୍ରହର କିମ୍ବା ମୋଟର ବୋର୍ ଆଦିର ଆଘାତରେ ମଧ୍ୟ ସେମାନେ ନଷ୍ଟ ହୋଇପାରନ୍ତି । ତେଣୁ ଏମାନଙ୍କର ବିସ୍ତୃତି(extent) ଓ ବିବିଧତା(diversity) ବଢ଼ିଲେ ଚିଲିକାର ପାଣି ଓ ପରିବେଶ ନିର୍ମଳ ଓ ସୁସ୍ଥ ଅଛି ବୋଲି ଧରାଯାଏ , ବିସ୍ତୃତି ଓ ବିବିଧତା କମିଲେ ପ୍ରଦୂଷଣ ଅଥବା ଅନ୍ୟାନ୍ୟ ପ୍ରତିକୂଳତା ବଢ଼ିଛି ବୋଲି ଧରାଯାଏ ।

ଏଇ ଦଳମାନଙ୍କର ପାଣି ଭିତରେ ବ୍ୟାପକ ବିସ୍ତାର ଜଳୀୟ ଚୂର୍ଣ୍ଣଭୂମି(meadows) ବା ପାଣି ଭିତରର ଘାସ ପଡ଼ିଆ /ଚାଟଣ ଭୂମି ସୃଷ୍ଟି କରିଥାଏ ଯେଉଁଠି ଅନେକ ଚୂର୍ଣ୍ଣଭୋଜୀ ଜଳଚର ପ୍ରାଣୀ ପାଣି ଭିତରେ ବୁଡ଼ି ବୁଡ଼ି ଖାଇଥାନ୍ତି । ଚିଲିକା ମଲ୍ଟି ମଧ୍ୟ ଏହି ପ୍ରକାରେ ଖାଇଥାଏ ।

ଚିଲିକାର ସାମୁଦ୍ରିକ ଦଳମାନଙ୍କ ଉପରେ କାନାଡ଼ାର ଷାଟରଲୁ ବିଶ୍ୱବିଦ୍ୟାଳୟର ଛାତ୍ରୀ ନବ୍ୟା ଡାଙ୍କର ପି.ଏଚ୍.ଡି. ଗବେଷଣା ଲାଗି ଏକ ସର୍ବେକ୍ଷଣ ମାଧ୍ୟମରେ ସ୍ଥାନୀୟ ଅଭିଜ୍ଞ ଲୋକଙ୍କ ଠାରୁ ତଥ୍ୟ ସଂଗ୍ରହ କରୁଛନ୍ତି ଯାହା ଚିଲିକାର ଏକ ସ୍ୱଚ୍ଛ-ଆଲୋଚିତ ଦିଗ ବିଷୟରେ ଅନେକ କଥା ଜାଣିବାରେ ଓ ଜଣାଇବାରେ ସାହାଯ୍ୟ କରିବ । ତେଣୁ ଏହି ସର୍ବେକ୍ଷଣରେ ସେ ଯେପରି ଉପଯୁକ୍ତ ତଥ୍ୟ ପାଆନ୍ତି, ସେଥିପାଇଁ ସତର୍କ ଓ ସଚେତନ ରହିବାକୁ ହେବ ।

ଏହି ଗବେଷଣା ଚିଲିକାରେ କ୍ଷୁଦ୍ର ମାଧ୍ୟକାବିକା(small scale fishery /SSF)ର ପୃଷ୍ଠଭୂମିରେ କରାଯାଇଛି । ‘କ୍ଷୁଦ୍ର ମାଧ୍ୟକାବିକା’ ଅର୍ଥ ପାରମ୍ପରିକ ମାଧ୍ୟକାବୀ ନିକର ତନ୍ମା ନେଇ ଦୈନନ୍ଦିନ ଯେଉଁ ଅଳ୍ପ ମାଛ ଧରି ଆଣିଥାଏ, ତା'ର ପରିମାଣ ଗ୍ରହଣ କିମ୍ବା ଯନ୍ତ୍ରଚାଳିତ ମାଛଧରାର ବିପ୍ଳବ ପରିମାଣ ସହିତ ସମାନ ନୁହେଁ ।]

ଗ୍ରାମର ନାମ:

କୋଡ଼:

ତାରିଖ:

	ପ୍ରଶ୍ନାବଳୀ	ଉତ୍ତରର ବିକଳମାନ (ଉଚିତ ସ୍ଥାନରେ ✓ ଚିହ୍ନ ଦିଅନ୍ତୁ)				
		୧	୨	୩	୪	୫
	ପରିବେଶଗତ ଦିଗ					
A	ପ୍ରଦୂଷଣ ସ୍ତର					
A1	ଶିଳ୍ପ ଏବଂ କୃଷି ((ଯେପରିକି ଚିଙ୍ଗୁଡ଼ି ଶିଳ୍ପ ବା ଅନ୍ୟ କାରଖାନା ଓ ରାସାୟନିକ କୃଷି) ଯୋଗୁଁ ସୃଷ୍ଟି ହେଉଥିବା ପ୍ରଦୂଷଣ ସ୍ତର ଆପଣଙ୍କ ଅଞ୍ଚଳରେ ସାମୁଦ୍ରିକ ଦଳର ସ୍ୱାସ୍ଥ୍ୟ ଉପରେ କେତେ ପ୍ରଭାବ ପକାଇଥାଏ ବୋଲି ଆପଣ ବିଶ୍ୱାସ କରନ୍ତି?	ଆଦୌ ନୁହଁ	ଅଳ୍ପ	ମଧ୍ୟମ ଭାବରେ (ଅଳ୍ପ ନୁହେଁ କି ବହୁତ ନୁହେଁ)	ବହୁତ	ଅତ୍ୟନ୍ତ
A2	ଚିଲିକା ହ୍ରଦର ସାମଗ୍ରିକ ପରିବେଶ/ପରିସଂସ୍ଥା(ସାମୁଦ୍ରିକ ଦଳ ରହିଥିବା ଜଳୀୟ ଚୂଷ୍ଣଭୂମି ସମେତ) ଉପରେ ପ୍ରଦୂଷଣର ପ୍ରଭାବକୁ ନେଇ ଆପଣ କେତେ ଚିନ୍ତିତ?	ଆଦୌ ନୁହଁ	ଅଳ୍ପ	ମଧ୍ୟମ ଭାବରେ	ବହୁତ	ଅତ୍ୟନ୍ତ
B	ଜଳବାୟୁ ପରିବର୍ତ୍ତନର ପ୍ରଭାବ					
B1	ଆପଣଙ୍କ ମତରେ, ଗତ ଦଶନ୍ଧି ମଧ୍ୟରେ ଆସିଥିବା ବାତ୍ୟାମାନ ଆପଣଙ୍କ ଅଞ୍ଚଳରେ ଥିବା ସାମୁଦ୍ରିକ ଦଳ ଜଳୀୟ ଚୂଷ୍ଣଭୂମିକୁ କିପରି ପ୍ରଭାବିତ କରିଛି (ଯେପରିକି ବାତ୍ୟାରେ ନୂଆ ମୁହାଣ ସବୁ ଖୋଲିଯିବା ଫଳରେ ଏହିସବୁ ଚୂଷ୍ଣଭୂମିରେ କିଛି ପରିବର୍ତ୍ତନ ଆସିଛି କି)?	କୌଣସି ପ୍ରଭାବ ନାହିଁ	ଅଳ୍ପ ପ୍ରଭାବ	ମଧ୍ୟମ ପ୍ରଭାବ	ବହୁତ ପ୍ରଭାବ	ଭୀଷଣ ପ୍ରଭାବ

B2	ଆପଣ କ'ଣ ସେଇ ସବୁ ଜଳବାୟୁଗତ ସମସ୍ୟାଗୁଡ଼ିକ (ଝଡ଼, ବାତ୍ୟା, ପ୍ରଚଣ୍ଡ ଗରମ, ଅଦିନିଆ ବର୍ଷା, ଇତ୍ୟାଦି) ବହୁଥିବାର ଅନୁଭବ କରୁଛନ୍ତି କି ଯାହା ଚିଲିକା ହ୍ରଦର ସାମଗ୍ରିକ ପରିବେଶ/ପରିସଂସ୍ଥା(ସାମୁଦ୍ରିକ ବଳ ରହିଥିବା ଜଳାୟତ୍ତ ଚୂଣାଭୂମି ସମେତ)ର ସ୍ବାସ୍ଥ୍ୟକୁ ପ୍ରଭାବିତ କରିଛି ବୋଲି ଆପଣ ଦେଖୁଛନ୍ତି ?	କେବେ ନୁହେଁ	କ୍ଷତି/ ବିରଳ	କେବେ କେବେ	ପ୍ରାୟତଃ	ବାରମ୍ବାର
C ମାଛଧରାର ତାପ ଏବଂ ପରିବେଶର ଅବସ୍ଥା						
C1	ଚିଲିକା ହ୍ରଦର ପରିବେଶ/ପରିସଂସ୍ଥା ଏବଂ ଏହାର ସାମୁଦ୍ରିକ ବଳ ରହିଥିବା ଜଳାୟତ୍ତ ଚୂଣାଭୂମି ଉପରେ ଚିଲିକାରେ ହେଉଥିବା ମାଛଧରାର ତାପ କେତେ ପଡ଼ିଛି ?	ଅଳ୍ପ	ମଧ୍ୟମ ଭାବରେ (ଅଳ୍ପ ନୁହେଁ କି ବହୁତ ନୁହେଁ)	ବହୁତ	ପ୍ରବଳ	ଅତି ପ୍ରବଳ
C2	ଆପଣଙ୍କ ଅଞ୍ଚଳରେ ଗତ କିଛି ବର୍ଷ ଭିତରେ ପରିବେଶ ନଷ୍ଟ କିମ୍ବା ଅନ୍ୟ କାରଣରୁ ଚିଲିକାରେ ସାମୁଦ୍ରିକ ବଳର ଆହ୍ୱାନ ବା ଛିତିରେ କିଛି ବୃଦ୍ଧିମାନ ପରିବର୍ତ୍ତନ ଆସିଛି ବୋଲି ଆପଣ ମନେ କରନ୍ତି କି ?	କୌଣସି ପରିବର୍ତ୍ତନ ନାହିଁ	ଅଳ୍ପ କମିଛି	କମିଛି କିନ୍ତୁ ଅଳ୍ପ ନୁହେଁ କି ଅଧିକ ନୁହେଁ (ମଧ୍ୟମ)	ବହୁତ କମିଛି	ଭାସି କମିଛି
C3	ଆପଣଙ୍କ ଜାଣିବାରେ ତଙ୍ଗାର ଆଘାତ ସାମୁଦ୍ରିକ ବଳର ଛିତି ଓ ସ୍ବାସ୍ଥ୍ୟକୁ କେତେ ଦୂର ପ୍ରଭାବିତ କରିଥାଏ ?	ବହୁତ କମିଥାଏ	କମିଥାଏ	ମଧ୍ୟମ ଧରଣର କମିଥାଏ	ଅଳ୍ପ କମିଥାଏ	ଅଧିକ କମିଥାଏ
C4	ଆପଣଙ୍କ ଜାଣିବାରେ ମଶାରୀ ଜାଲର ବ୍ୟବହାର ସାମୁଦ୍ରିକ ବଳର ଛିତି ଓ ସ୍ବାସ୍ଥ୍ୟକୁ କେତେ ଦୂର ପ୍ରଭାବିତ କରିଥାଏ ?	ବହୁତ କମିଥାଏ	କମିଥାଏ	ମଧ୍ୟମ ଧରଣର କମିଥାଏ	ଅଳ୍ପ କମିଥାଏ	ଅଧିକ କମିଥାଏ

ପରିବେଶ ସମ୍ବେଦନଶୀଳତା						
D ସାମୁଦ୍ରିକ ବଳର ସ୍ବାସ୍ଥ୍ୟ ଏବଂ ବିବିଧତା						
D1	ବୟା କରି ଚିଲିକା ହ୍ରଦରେ ସାମୁଦ୍ରିକ ବଳର ବର୍ତ୍ତମାନର ସ୍ବାସ୍ଥ୍ୟ ଏବଂ ବିବିଧତାର ମୂଲ୍ୟାଙ୍କନ କରନ୍ତୁ ।	ଖରାପ	ମନ୍ଦ ନୁହେଁ	ମୋଟାମୋଟି ଚଳନାୟ	ଭଲ	ଅତି ଭଲ
E ପରିବେଶ ପ୍ରତି ଘଟୁଥିବା ବ୍ୟାଘାତର ପ୍ରତିରୋଧ ସାମର୍ଥ୍ୟ						
E1	ଆପଣ କେତେ ସୁନିଶ୍ଚିତ ଯେ ଚିଲିକାରେ ସାମୁଦ୍ରିକ ବଳର ପରିସଂସ୍ଥା ବାତ୍ୟା କିମ୍ବା ପ୍ରଦୂଷଣ ଭଳି ସମସ୍ୟାକୁ ସହ୍ୟ କରିପାରିବ ଏବଂ ତଥାପି ସୁସ୍ଥ ରହିବ ?	ଆଦୌ ସୁନିଶ୍ଚିତ ନୁହେଁ	ଅଳ୍ପ ସୁନିଶ୍ଚିତ	ମଧ୍ୟମ ଭାବରେ ସୁନିଶ୍ଚିତ	ବେଶ୍ ସୁନିଶ୍ଚିତ	ଅତ୍ୟନ୍ତ ସୁନିଶ୍ଚିତ
F ଜଳର ଗୁଣାତ୍ମକତା ଓ ପୋଷଣ ସ୍ତର						
F1	ଚିଲିକା ହ୍ରଦରେ ବର୍ତ୍ତମାନର ପାଣି କେତେ ସ୍ୱଚ୍ଛ/ନିର୍ମଳ ଓ ପୁଷ୍ଟିକର, ବୟା କରି ତାହାର ମୂଲ୍ୟାଙ୍କନ କରନ୍ତୁ ।	ଖରାପ	ମନ୍ଦ ନୁହେଁ	ମୋଟାମୋଟି ଚଳନାୟ	ଭଲ	ଅତି ଭଲ
G ସାମୁଦ୍ରିକ ବଳର ବିବିଧତା(ପ୍ରକାର)						
G1	ଆପଣଙ୍କ ଜାଣିବାରେ ଚିଲିକା ହ୍ରଦରେ ଦେଖାଯାଉଥିବା ସାମୁଦ୍ରିକ ବଳର ବିବିଧତା(ପ୍ରକାର) କେତେ ?	ଖୁବ୍ ସୀମିତ (ଖୁବ୍ କମ୍ ପ୍ରକାରର)	ସୀମିତ(ଅଳ୍ପ ପ୍ରକାରର)	ମଧ୍ୟମ (ବହୁ ପ୍ରକାରର ନୁହେଁ କି ଅଳ୍ପ ପ୍ରକାରର ମଧ୍ୟ ନୁହେଁ)	ଅନେକ ପ୍ରକାରର	ବହୁ ପ୍ରକାରର
H ବ୍ୟାଘାତ ବିରୁଦ୍ଧରେ ପ୍ରତିରୋଧ କ୍ଷମତା						
H1	ଆପଣଙ୍କ ମତରେ, ସାମୁଦ୍ରିକ ବଳର ପରିସଂସ୍ଥା (ବାତ୍ୟା/ତଙ୍ଗା/ପ୍ରଦୂଷଣ/ଚିଲିକାରେ ଆଦି ଦ୍ୱାରା) ବ୍ୟାଘାତପ୍ରାପ୍ତ ବା ବିକ୍ଷୁବ୍ତ ହେବା ପରେ କେତେ ଶୀଘ୍ର ନିଜର ପୁନରୁଦ୍ଧାର କରାଇ ନିଏ ?	ଖୁବ୍ ଧୀରେ	ଧୀରେ	ମଧ୍ୟମ ଗତିରେ (ଧୀରେ ନୁହେଁ କି ଶୀଘ୍ର ନୁହେଁ)	ଶୀଘ୍ର	ଅତି ଶୀଘ୍ର

I	ଜଳର ଗୁଣାତ୍ମକତାର ମାନକ					
I1	ଚିଲିକା ପାଣି କେତେ ସ୍ବଚ୍ଛ /ନିର୍ମଳ ବୋଲି ଆପଣ ଭାବନ୍ତି ?	ଅତି ଅପରିଷ୍କାର	ଅପରିଷ୍କାର	କିଛିଟା ପରିଷ୍କାର	ନିର୍ମଳ	ଅତି ନିର୍ମଳ
I2	ଚିଲିକା ପାଣିର ତାପମାତ୍ରା କେତେ ବୋଲି ଆପଣ ଭାବନ୍ତି ?	ଅତି ଥଣ୍ଡା	ଥଣ୍ଡା	ମଧ୍ୟମ (ଥଣ୍ଡା ନୁହେଁ କି ଗରମ ନୁହେଁ)	ଉଷ୍ମମ	ଅତି ଉଷ୍ମମ
I3	ଚିଲିକା ପାଣି କେତେ ପକ୍କିଳ /ଆବିଜ(ପାଣିରେ ମାଟି ଭଳି ଗୁଣ୍ଡମାନ ଭାସୁଥିବ) ବୋଲି ଆପଣ ଭାବନ୍ତି ?	ଅତି ଗୋଳିଆ	ଗୋଳିଆ	ଅଳ୍ପ ଗୋଳିଆ	ନିର୍ମଳ କିନ୍ତୁ ସାମାନ୍ୟ କିଛି ଗୁଣ୍ଡ ଭାସୁଥାଏ	ସମ୍ପୂର୍ଣ୍ଣ ନିର୍ମଳ (କିଛି ଭାସୁ ନ ଥାଏ)
I4	ଚିଲିକା ପାଣି ଆପଣଙ୍କୁ କେତେ ଲୁଣି /ଖାରି ଲାଗେ ?	ଅତି ଲୁଣି	ବହୁତ ଲୁଣି	ମଧ୍ୟମ ଧରଣର ଲୁଣି	ଅଳ୍ପ ଲୁଣି	ଆଦୌ ଲୁଣି ନୁହେଁ
I5	ଚିଲିକା ପାଣିର ଗନ୍ଧ/ବାସ୍ନା ଆପଣଙ୍କୁ କିପରି ଲାଗେ ?	ତୀବ୍ର ଅପ୍ରୀତିକର ଦୁର୍ଗନ୍ଧ	ମଧ୍ୟମ ଧରଣର ଦୁର୍ଗନ୍ଧ	ଅଳ୍ପ ଦୁର୍ଗନ୍ଧ	ଗନ୍ଧ କଣା ପଡ଼େ ନାହିଁ	ସତେଜ ଓ ସୁଗନ୍ଧିତ
I6	ଆପଣଙ୍କ ଜାଣିବାରେ ଚିଲିକା ପାଣିରେ ସାର(କ୍ଷେତ୍ରରୁ ବର୍ଷାରେ ଧୋଇ ହୋଇ ଆସି ପାଣିରେ ମିଶିଥାଏ) କିମ୍ବା ପୋକ୍ଷଣ- ପ୍ରଦୂଷଣ(ବିଲୁଡ଼ି ଘେରି ଆସିବେଳେ ଉପାଦାନ ବଢ଼ାଇବାକୁ ବ୍ୟବହୃତ ରାସାୟନିକ ଉପାଦାନ ଯାହା ପାଣିରେ ମିଶିଯାଏ) ପରି ପୁଷ୍ଟିକାରକ ପଦାର୍ଥ ବା ଉପାଦାନ (ଯାହା ବିଭିନ୍ନ ପ୍ରକାର ଦଳକୁ ହୁଏତ ଅଧିକ ବଢ଼ାଇଦେଇପାରେ କିମ୍ବା ମାରିଦେଇପାରେ ; କେତେକ ଅଞ୍ଚଳରେ ବିଲାତି ଦଳ ବଢ଼ିବାର ଏହା ଗୋଟିଏ କାରଣ) ଅତ୍ୟଧିକ ଉପସ୍ଥିତି ଅଛି କି ?	ଖୁବ୍ ଅଧିକ	ଅଧିକ	ମଧ୍ୟମ ଧରଣର	କମ୍	ଖୁବ୍ କମ୍

I7	ଚିଲିକା ହ୍ରଦରେ ମାଛ କିମ୍ବା ଅନ୍ୟାନ୍ୟ ଜଳଜୀବଙ୍କର ସଂଖ୍ୟାରେ କୌଣସି ପରିବର୍ତ୍ତନ ଆପଣ ଲକ୍ଷ୍ୟ କରିଛନ୍ତି କି?	ବହୁତ କମିଛି	ମଧ୍ୟମ ଧରଣର କମିଛି (ଅତି ନୁହେଁ କି ଅଳ୍ପ ନୁହେଁ)	କୌଣସି ପରିବର୍ତ୍ତନ ଜଣାପଡୁନାହିଁ	ବଢ଼ିଛି	ବହୁତ ବଢ଼ିଛି
I8	ଚିଲିକା ହ୍ରଦରେ ମାଛ କିମ୍ବା ଅନ୍ୟାନ୍ୟ ଜଳଜୀବଙ୍କର ଶିତି ବିକଳ ଅଛି ବୋଲି ଆପଣ ଭାବୁଛନ୍ତି ?	ଖରାପ ; ଅନେକ ମାଛ ରୋଗା ହୋଇଯାଇଛନ୍ତି କିମ୍ବା ମରିଯାଇଛନ୍ତି	ଠିକ୍ ଅଛି ; କିଛି ମାଛ ରୋଗା ଅଥବା ତାପଗ୍ରସ୍ତ	ମାଛମାନେ ମୋଟାମୋଟି ସୁସ୍ଥ ଅଛନ୍ତି	ଭଲ ; ମାଛମାନେ ସୁସ୍ଥ ଓ ପ୍ରାଣବତ୍ତ ଅଛନ୍ତି	ତମକାର ; ମାଛମାନେ ଭଲ ବଢୁଛନ୍ତି
ପୁନରୁଦ୍ଧାର ସାମର୍ଥ୍ୟ						
J	ସାମୁଦ୍ରିକ ଦଳର ପ୍ରାକୃତିକ ପୁନର୍ଜନନ ହାର					
J1	ଚିଲିକା ହ୍ରଦରେ ସାମୁଦ୍ରିକ ଦଳର ପ୍ରାକୃତିକ ପୁନର୍ଜନନ ହାରକୁ ଆପଣ କିପରି ମୂଲ୍ୟାଙ୍କନ କରିବେ (ଅର୍ଥାତ୍, ସେଇ ଦଳମାନେ ନିଜକୁ ନିଜେ କେତେ ଭଲ ବଢୁଛନ୍ତି) ?	ଖୁବ୍ ଧୀରେ	ଧୀରେ	ମଧ୍ୟମ ଗତିରେ (ଧୀରେ ନୁହେଁ କି ଶୀଘ୍ର ନୁହେଁ)	ଶୀଘ୍ର	ଅତି ଶୀଘ୍ର
K	ପୁନରୁଦ୍ଧାର ପ୍ରକଳ୍ପର ପ୍ରଭାବକାରିତା					
K1	ଆପଣଙ୍କ ମତରେ, ଚିଲିକା ହ୍ରଦରେ ସାମୁଦ୍ରିକ ଦଳର ପୁନରୁଦ୍ଧାର ପାଇଁ ହାତକୁ ନିଆଯାଇଥିବା(ଯଦି ଥାଏ) ପୁନରୁଦ୍ଧାର ପ୍ରକଳ୍ପ/କାର୍ଯ୍ୟକ୍ରମ କେତେ ପ୍ରଭାବକାରୀ/ସଫଳ ହୋଇଛି?	ଆଦୌ ପ୍ରଭାବକାରୀ ନୁହେଁ	କିଛିଟା ପ୍ରଭାବହୀନ	ସଫଳ ନୁହେଁ କି ବିଫଳ ନୁହେଁ	କିଛିଟା ପ୍ରଭାବକାରୀ	ଖୁବ୍ ପ୍ରଭାବକାରୀ

L	ପରିବର୍ତ୍ତିତ ପରିବେଶଗତ ସ୍ଥିତି ସହିତ ସାମୁଦ୍ରିକ ଦଳର ଖାପ ଖୁଆଇ ପାରିବାର ସାମର୍ଥ୍ୟ					
L1	ଚିଲିକା ହ୍ରଦରେ ସାମୁଦ୍ରିକ ଦଳର ପ୍ରକାଶିତ ଜଳବାୟୁ ପରିବର୍ତ୍ତନ ଏବଂ ପ୍ରତ୍ୟକ୍ଷ ପରି ପରିସ୍ଥିତି ସହିତ ଖାପ ଖୁଆଇପାରୁଛନ୍ତି ବୋଲି ଆପଣ କେତେ ପରିମାଣରେ ବିଶ୍ୱାସ କରନ୍ତି?	ଖାପ ଖୁଆଇବାର ସାମର୍ଥ୍ୟ ଦୁର୍ବଳ	ଖାପ ଖୁଆଇବାର ସାମର୍ଥ୍ୟ ସାମାନ୍ୟ	ଖାପ ଖୁଆଇବାର ସାମର୍ଥ୍ୟ ମଧ୍ୟମ	ଖାପ ଖୁଆଇବାର ସାମର୍ଥ୍ୟ ଦୃଢ଼	ଖାପ ଖୁଆଇବାର ସାମର୍ଥ୍ୟ ଅତି ଦୃଢ଼
ସାମାଜିକ ଦିଗ						
M	ସାମୁଦ୍ରିକ ଦଳର ଟୁଣ୍ଡୁମିର ନିକଟତା					
M1	ସାମୁଦ୍ରିକ ଦଳର ଟୁଣ୍ଡୁମି ଆପଣଙ୍କ ଗାଁର କେତେ ପାଖରେ ?	ବହୁତ ପାଖରେ	ପାଖରେ	କିଛିତା ପାଖରେ	ସେତେ ପାଖରେ ନୁହେଁ	ଆଦୌ ପାଖରେ ନାହିଁ
N	ଚିଲିକା ଉପରେ ନିର୍ଭରଶୀଳତା					
N1	ଜୀବିକା ପାଇଁ ଆପଣଙ୍କ ପରିବାର ଚିଲିକା ଉପରେ କେତେ ପରିମାଣରେ ନିର୍ଭର କରେ?	ସମ୍ପୂର୍ଣ୍ଣ ନିର୍ଭରଶୀଳ	ବହୁତ ନିର୍ଭରଶୀଳ	ମଧ୍ୟମ ଧରଣର ନିର୍ଭରଶୀଳ	ଅଳ୍ପ ନିର୍ଭରଶୀଳ	ଆଦୌ ନିର୍ଭରଶୀଳ ନୁହେଁ
N2	ଆପଣଙ୍କ ଘରର ଆୟର କେତେ ପ୍ରତିଶତ ଚିଲିକା ହ୍ରଦରେ ମାଛ ଧରିବା କାର୍ଯ୍ୟରୁ ଆସିଥାଏ ?	୭୫% ରୁ ଅଧିକ	୫୦-୭୪%	୨୫-୪୯%	୨୫% ରୁ ଅଧିକ	କିଛି ନୁହେଁ
O	ନିର୍ମଳ ପାଣି ମିଳିବାର ସୁଗମତା					
O1	ମାଛ ଏବଂ ଅନ୍ୟାନ୍ୟ ଜଳଜୀବ ପାଇଁ ଚିଲିକା ହ୍ରଦର ପାଣି କେତେ ନିରାପଦ , ବୟା କରି ତା'ର ମୂଲ୍ୟାଙ୍କନ କରନ୍ତୁ ।	ଅସୁରକ୍ଷିତ/ ବିପଜ୍ଜନକ	କିଛିତା ଅସୁରକ୍ଷିତ	ସୁରକ୍ଷିତ ନୁହେଁ କି ଅସୁରକ୍ଷିତ ନୁହେଁ	କିଛିତା ସୁରକ୍ଷିତ/ ନିରାପଦ	ସୁରକ୍ଷିତ
O2	ମାଛ ଧରିବା ପାଇଁ ଆପଣଙ୍କ ପରିବାର ଲୋକେ ନିର୍ମଳ ଜଳ ପାଇବା କେତେ ସହଜ?	ଅତି ସହଜ	ସହଜ	ସହଜ ନୁହେଁ କି କଠିନ ନୁହେଁ	କଠିନ	ଅତି କଠିନ

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O3	ବୈନଦିନ ଘରୋଇ ବ୍ୟବହାର ପାଇଁ ଆପଣଙ୍କ ପରିବାର ଲୋକେ ନିର୍ମଳ ଜଳ ପାଇବା କେତେ ସହଜ?	ଅତି ସହଜ	ସହଜ	ସହଜ ନୁହେଁ କି କଠିନ ନୁହେଁ	କଠିନ	ଅତି କଠିନ
ସାମାଜିକ ସମ୍ବେଦନଶୀଳତା						
P	ମତ୍ସ୍ୟଜୀବୀଙ୍କର ସାମାଜିକ-ଆର୍ଥିକ ସ୍ଥିତି					
P1	ଚିଲିକା ମତ୍ସ୍ୟଜୀବୀ ସମ୍ପ୍ରଦାୟର ସାମଗ୍ରିକ ଆର୍ଥିକ ସ୍ୱଚ୍ଛଳତାକୁ ଆପଣ କିପରି ମୂଲ୍ୟାଙ୍କନ କରିବେ?	ଖୁବ୍ ସ୍ୱଚ୍ଛଳ	ସ୍ୱଚ୍ଛଳ	ମଧ୍ୟମ ଧରଣର ସ୍ୱଚ୍ଛଳ	ସଂଘର୍ଷମୟ	ଗରିବ
Q	ସମ୍ବଳ ଓ ବଜାରର ସୁଗମତା					
Q1	ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟର ମତ୍ସ୍ୟଜୀବୀ ପରିବାରଗୁଡ଼ିକ ଆଧୁନିକ ମାଛଧରା ଉପକରଣ ଏବଂ ପ୍ରଯୁକ୍ତିବିଦ୍ୟା(technology) ପାଇପାରିଛନ୍ତି କି?	ଭଲ ଭାବେ ପାଇଛନ୍ତି	ମଧ୍ୟମ ପ୍ରକାରେ ପାଇଛନ୍ତି	ସାମାନ୍ୟତା ପାଇଛନ୍ତି	ଅତି କମ୍ ପାଇଛନ୍ତି	ପାଇନାହାଁନ୍ତି
Q2	ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟର ମତ୍ସ୍ୟଜୀବୀ ପରିବାରଗୁଡ଼ିକ ସେମାନଙ୍କ ମାଛ ବିକ୍ରି ପାଇଁ ଶ୍ଚାନ୍ତ ଏବଂ ଆଞ୍ଚଳିକ ବଜାରରେ ପ୍ରବେଶ କରିବା କେତେ ସହଜ?	ଅତି ସହଜ	ସହଜ	ସହଜ ନୁହେଁ କି କଠିନ ନୁହେଁ	କଠିନ	ଅତି କଠିନ
R	ଦାରିଦ୍ର୍ୟର ସ୍ତର					
R1	ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟର ମତ୍ସ୍ୟଜୀବୀ ପରିବାରମାନଙ୍କ ମଧ୍ୟରେ ଆପଣ ଦାରିଦ୍ର୍ୟର ସ୍ତର(କେତେ ଗରିବ)କୁ କିପରି ବର୍ଣ୍ଣନା କରିବେ?	ସାମାନ୍ୟ ଗରିବ	ଅଳ୍ପ ଗରିବ	ଦାରିଦ୍ର୍ୟର ମଧ୍ୟମ ସ୍ତର	ଅଧିକ ଗରିବ	ଅତ୍ୟଧିକ ଗରିବ
S	ବିକଳ ଜୀବିକା					
S1	ମାଛ ଧରିବା ବ୍ୟତୀତ ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟରେ ମତ୍ସ୍ୟଜୀବୀ ପରିବାର ପାଇଁ ଅନ୍ୟ କିଛି କାର୍ଯ୍ୟକ୍ଷମ ବିକଳ ଜୀବିକା ରପାଇଛ କି?	ବହୁ ପ୍ରକାର ବିକଳ ରହିଛି	ଅନେକ ପ୍ରକାର ବିକଳ ରହିଛି	ସାମାନ୍ୟତା ବିକଳ ରହିଛି	ଅତି ଅଳ୍ପ ବିକଳ ରହିଛି	କିଛି ବିକଳ ନାହିଁ

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ଖାପ ଖୁଆଇବାର ସାମର୍ଥ୍ୟ					
T	ଶିକ୍ଷା ଓ ସଚେତନତା				
T1	ଆପଣଙ୍କ ସମ୍ପ୍ରଦାୟର ସଦସ୍ୟମାନେ ଆନୁଷ୍ଠାନିକ ଶିକ୍ଷା(ସ୍କୁଲ, କଲେଜ ଆଦିରେ ବିଧିବଦ୍ଧ ଶିକ୍ଷା) ପାଇଁ କେତେ ପରିମାଣରେ ସୁଯୋଗ ପାଇଥା'ନ୍ତି ?	ପ୍ରଚୁର ସୁଯୋଗ	ଯଥେଷ୍ଟ ସୁଯୋଗ	ମଧ୍ୟମ ଧରଣର ସୁଯୋଗ (ଭଲ ନୁହେଁ କି ମନ୍ଦ ନୁହେଁ)	ଅଳ୍ପ ସୁଯୋଗ ଅତି କମ୍ ସୁଯୋଗ
T2	ତିଳିକାରେ ମାଛଧରା ନିରନ୍ତରତା ରକ୍ଷା ପାଇଁ ସାମୁଦ୍ରିକ ବଳ ଏବଂ ଜଳର ଗୁଣାତ୍ମକତାର ମହତ୍ତ୍ୱ ସମ୍ପର୍କରେ ((ଅର୍ଥାତ ପାଣି ଭଲ ରହିଲେ ଓ ସାମୁଦ୍ରିକ ବଳ ପୁରସ୍ଥିତ ରହିଲେ ସବୁବେଳେ ଭଲ ମାଛ ମିଳୁଥିବ) ମତାମତାବଳୀ ସମ୍ପ୍ରଦାୟର ସଦସ୍ୟମାନେ କେତେ ସଚେତନ?	ଖୁବ୍ ସଚେତନ	ସଚେତନ	କିଛିତା ସଚେତନ	ଯଥେଷ୍ଟ ସଚେତନ ନୁହେଁ ଆଦୌ ସଚେତନ ନୁହେଁ
U	ସୂଚନା ଓ ପ୍ରଯୁକ୍ତିବିଦ୍ୟାର ସୁଗମତା				
U1	ମତାମତାବଳୀମାନେ ସେମାନଙ୍କର ମାଛଧରା ଯୋଜନା କରିବା ପାଇଁ ପାଣିପାଗ ଏବଂ ଜଳବାୟୁ ସମ୍ପର୍କିତ ସୂଚନାକୁ କେତେ ସହଜରେ ପାଇଥା'ନ୍ତି ?	ଅତି ସହଜରେ ପାଇଥା'ନ୍ତି	ସହଜରେ ପାଇଥା'ନ୍ତି	ମଧ୍ୟମ ପ୍ରକାରେ (ସହଜରେ ନୁହେଁ କି କଷ୍ଟରେ ନୁହେଁ)	କଷ୍ଟରେ ପାଇଥା'ନ୍ତି ଆଦୌ ପାଇନଥା'ନ୍ତି

U2	ପରିମିତ ମାଛଧରା(ଯେପରିକି ମାଛ କମିବ ନାହିଁ ଓ ନିରନ୍ତର ମିଳୁଥିବ) ଅଭାବର ପ୍ରସାର ପାଇଁ ଆଧୁନିକ ପ୍ରଯୁକ୍ତିବିଦ୍ୟା ଓ ଉପକରଣ ବ୍ୟବହାରର ସୁଯୋଗ ଆପଣଙ୍କ ମତାମତାବଳୀ ସମ୍ପ୍ରଦାୟର ଲୋକେ ପାଇଛନ୍ତି କି ?	ହଁ (ସର୍ବାଧୁନିକ ପ୍ରଯୁକ୍ତିବିଦ୍ୟା)	ହଁ, ତେବେ ପ୍ରାଥମିକ ସ୍ତରର ପ୍ରଯୁକ୍ତିବିଦ୍ୟା	ସୀମିତ ସୁଯୋଗ	କୃତ୍ରିମ ଏଭଳି ସୁଯୋଗ ମିଳିଥାଏ	ଆଦୌ ପାଇନାହାଁନ୍ତି
V	ସାମାଜିକ ଏକତା ଓ ଗୋଷ୍ଠୀ ସଙ୍ଗଠନ					
V1	ମତାମତାବଳୀ ସମ୍ପ୍ରଦାୟର ଲୋକମାନଙ୍କ ଭିତରେ ଏକତାର ଭାବନା କେତେ ଶକ୍ତିଶାଳୀ?	ଖୁବ୍ ଶକ୍ତିଶାଳୀ	ଶକ୍ତିଶାଳୀ	ମଧ୍ୟମ ଧରଣର	ଦୁର୍ବଳ	ଅତି ଦୁର୍ବଳ
V2	ଆପଣଙ୍କ ଗ୍ରାମରେ ଗୋଷ୍ଠୀଭିତ୍ତିକ ସଂଗଠନ କିମ୍ବା ସମବାୟ ସମିତିମାନ ଅଛି କି ଯାହା ମତାମତାବଳୀ ସମ୍ପ୍ରଦାୟର ପରିଚାଳନା ଏବଂ ସୁରକ୍ଷା ପାଇଁ ନିର୍ଦ୍ଧାରିତ ଭାବରେ କାର୍ଯ୍ୟ କରନ୍ତି?	ଏଭଳି ଅନେକ ଗୁଡ଼ିଏ ସକ୍ରିୟ ଅନୁଷ୍ଠାନ ରହିଛି	ଏଭଳି କେବଳ ଗୋଟିଏ ସକ୍ରିୟ ଅନୁଷ୍ଠାନ ରହିଛି	ସୀମିତ ଭାବେ ସକ୍ରିୟ ଅନୁଷ୍ଠାନମାନ ରହିଛି	କୌଣସି ସକ୍ରିୟ ଅନୁଷ୍ଠାନ ନାହିଁ	ମୁଁ ନିଶ୍ଚିତ ନୁହେଁ

e) Interview Guide

Phase 3: Stakeholder Interview Questionnaire

DATE:

Stakeholder Group: _____

Respondent Code / Pseudonym: _____

Location: _____

Sector/Sub-Sector (if applicable): _____

Age: _____

Gender: ☐ Male ☐ Female ☐ Other

Primary Occupation / Role in Chilika Lagoon: _____

Section 1: Environmental Perception & Uses

1. How do you feel about the current condition of Chilika Lagoon? Any positive or negative ecological or social changes?
2. What are the main purposes for which the lagoon water is used in your community?
3. What are the natural drivers (e.g., tides, salinity, cyclones) that impact fishing or lagoon health? If any, how?
4. Have external agencies implemented any interventions? If yes, what are they and how have they impacted the lagoon?
5. Has the opening of the new sea mouth or aquaculture expansion affected the water quality or biodiversity?

Section 2: Blue Carbon Ecosystems (BCEs) & Awareness

1. How familiar are you with seagrass ecosystems and their role in the lagoon?
2. How familiar are you with mangrove ecosystems and their role in the lagoon?
3. What is your perception of the importance of BCEs (seagrass, mangroves, saltmarshes) for maintaining water quality and supporting SSFs?
4. Have you noticed any biodiversity changes? If yes, what species have increased or declined?

Section 3: Water Quality Perceptions

1. How would you describe the current water quality in Chilika Lagoon?
☐ Very Poor ☐ Poor ☐ Moderate ☐ Good ☐ Excellent
 ► Please explain your answer:
2. Have you observed any visible signs of water pollution in the lagoon?
☐ Yes ☐ No
 ► If yes, what kind of signs (e.g., discoloration, foam, dead fish, smell, plastic, etc.)?
3. Do you or your community take any steps to monitor or respond to water quality concerns?
☐ Yes ☐ No ☐ Don't Know ► If yes, what are those steps?

Section 3: Threats, Vulnerability & Livelihoods

1. What threats do you think are particularly concerning for BCEs and water quality?
2. Can you provide examples of challenges/stressors that have affected the resilience of SSFs in your area?
3. How have these challenges affected livelihoods and income?
4. What are the important types of capital (e.g., natural, financial, social, physical, human) that support well-being and fishing livelihoods?
5. How do you perceive the interactions between climate change, BCEs, water quality, and SSF vulnerability?
6. What changes in well-being have you observed among small-scale fishers due to shifts in ecosystem health?

Section 4: Knowledge, Awareness & Training

1. How would you rate your awareness of water quality issues in Chilika Lagoon?

1 – Very Low	2 – Low	3 – Moderate	4 – High	5 – Very High
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2. Have you received any training/information on water quality or seagrass conservation?

► If not, would you be interested?

► What kind of knowledge/training would be most helpful to you?

Section 5: Governance & Management

1. What are your thoughts on current governance/management strategies for BCEs, water quality, and SSFs? Are they effective? Why or why not?
2. What governance improvements or management strategies would you recommend for better integration of BCEs and SSF sustainability?
3. What should be the roles of key stakeholders (fishers, boat associations, govt, communities, etc.) in implementing these strategies?

Section 6: Sustainability, Research & Future Outlook

1. What do you think about the future of SSFs in Chilika Lagoon, given the need to protect BCEs and improve water quality?
2. Are there specific research needs or knowledge gaps that need to be addressed?
3. Any additional comments, suggestions, or stories you'd like to share?

Section 7: Rating Drivers of Environmental Change

Please rate the following drivers by their impact on your livelihood or ecosystem

Drivers	1 (Very Low Impact)	2 (Low Impact)	3 (Moderate Impact)	4 (High Impact)	5 (Very High Impact)
Agricultural Runoff					
Illegal Shrimp Aquaculture					
Tourism and Waste					
Cyclones and Storm Surges					
Artificial Sea Mouth					
Plastic Pollution					
Illegal Fishing Practices					
Climate Change					

Section 8: Perceived Effectiveness of Government Interventions

Please rate how effective you think the following government initiatives have been for supporting SSFs in Chilika Lagoon:

	Very Ineffective/ Unaware	Ineffective/A ware but Not Impactful	Neutral/ Somewhat Aware	Effective/ Mostly Aware	Very Effective/ Well Aware
Opening of Sea Mouth (2000)					
Mangrove Plantation					
Ban on Zero Net Fishing (2002)					
Plastic Ban (2002)					
Community Environmental Education/Awareness Programs					
Weather Warning and Cyclone Resilience Programs					

Note: A few additional sector-specific questions will be tailored for each stakeholder group to reflect their unique roles and experiences.

f) Focus Group Guide

Phase 4: Focus Group Guide

DATE:

- Structure: 6–10 participants per session
- Duration: 60–90 minutes
- Tools: Flip chart, maps, markers, printed visuals of seagrass/mangroves

SECTION 1: INTRODUCTIONS & CONTEXT SETTING

Q1. Let's begin with introductions. Please share your name and your role or relationship with Chilika Lagoon (fisher, boat operator, trader, etc.).

Q2. How would you describe the importance of Chilika Lagoon in your life/community?

SECTION 2: WATER QUALITY – COMMUNITY PERCEPTIONS

Q3. How would you describe the current water quality in the lagoon? Is it better or worse than before? Why?

Q4. What visible signs of poor or changing water quality have you observed (e.g., colour of water, fish deaths, algae, smell)?

Q5. Are there particular seasons or areas where water quality becomes especially poor or hazardous?

SECTION 3: BLUE CARBON ECOSYSTEMS (SEAGRASS & MANGROVES)

Q6. What types of vegetation do you observe in the lagoon (e.g., seagrass, mangroves)? Where are they most commonly found?

Q7. Do you or your community use seagrass or mangroves for any purposes (e.g., fuel, fodder, rituals, fishing indicators)?

Q8. How do these ecosystems support fish habitats, shoreline protection, or other functions that benefit you?

SECTION 4: LIVELIHOODS & SMALL-SCALE FISHERIES

Q9. What are the most important species for your livelihoods? Have there been any changes in availability or quality of fish/crabs/prawns in recent years?

Q10. What are the major challenges faced by small-scale fishers today (e.g., illegal nets, pollution, aquaculture)?

Q11. How do water quality or ecosystem degradation affect income, migration, or household stress?

SECTION 5: CLIMATE STRESSORS, DRIVERS, AND IMPACTS

Q12. Have you noticed any changes in the climate or weather (e.g., cyclones, rainfall patterns, temperature)?

Q13. How do these climate events affect fishing, aquaculture, tourism, or transport in the lagoon?

Q14. Let's rank the following drivers of change from most to least impactful (Use cards and group voting):

Agricultural Runoff; Illegal Shrimp Aquaculture; Tourism & Waste; Cyclones and Storm Surges; Artificial Sea Mouth; Plastic Pollution; Illegal Fishing Practices; Climate Change

SECTION 6: GOVERNANCE, PARTICIPATION, & AWARENESS

Q15. Are you aware of any government or NGO programs related to Chilika's management (e.g., plastic ban, zero net ban, sea mouth opening)?

Q16. How effective do you think these programs have been? Why?

Q17. Do you feel your community has a voice in lagoon management decisions?

SECTION 7: ADAPTATION, SUPPORT & FUTURE ACTION

Q18. What actions has your community taken to adapt to environmental or livelihood challenges?

Q19. What type of training, knowledge, or support would help you become more resilient?

Q20. How do you envision the future of Chilika? What do you want to protect most? What must change?

CLOSING REFLECTIONS

Q21. If you could send one message to the government or researchers working in Chilika, what would it be?

Q22. Is there anything else you would like to share that hasn't come up today?

Note: *Questions may be adjusted during the discussions to allow for deeper exploration, encourage interaction, and confirm emerging trends or patterns identified in the primary data.*

APPENDIX B: Ethics Protocol

PROTOCOLS



#45322 - Linking Blue Carbon Ecosystems and Water Quality in Coastal Wetlands for Viable Small-Scale Fisheries

Protocol Information

Review Type	Status	Approval Date	Renewal Date
Expedited	Approved	Sep 25, 2023	Sep 03, 2024

Expiration Date	Initial Approval Date	Initial Review Type
Sep 26, 2024	Sep 25, 2023	Expedited

Feedback

Approval Comment

This study has received ethics clearance. If you have any questions please contact Karen Pieters at karen.pieters@uwaterloo.ca.

Navya Vikraman Nair

From: no-reply=kuali.co@mx3.kuali.co on behalf of Kuali Notifications <no-reply@kuali.co>
Sent: September 25, 2023 3:38 PM
To: Navya Vikraman Nair
Subject: Research Ethics - Initial application # 45322 has ethics clearance

Dear Prateep Nayak and other members of the research team:

Your application has been reviewed by Delegated Reviewers. We are pleased to inform you the **Initial application for 45322 Linking Blue Carbon Ecosystems and Water Quality in Coastal Wetlands for Viable Small-Scale Fisheries** has been given ethics clearance.

This research must be conducted in accordance with the most recent version of the application in the research ethics system and the most recent versions of all supporting materials.

Ethics clearance for this study is valid until Thursday, September 26th 2024.

The research team is responsible for obtaining any additional institutional approvals that might be required to complete this Expedited study.

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS2 2022), the Ontario Personal Health Information Protection Act (PHIPA), and all laws and regulations of the province of Ontario (as applicable). Additionally, CREB operates in a manner consistent with the International Conference for Harmonization of Technical Requirements for Pharmaceuticals for Human Use (ICH) Guidance E6(R2): Good Clinical Practice, the International Organization for Standardization of Good Clinical Practices (GCP) as set out by ISO 14155 - Clinical investigation of medical devices for human subjects, Part C, Division 5 of the Food and Drug Regulations, Part 4 of the Natural Health Products Regulations, Part 3 of the Medical Devices Regulations. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

Renewal: Multi-year research must be renewed at least once every 12 months unless a more frequent review has been specified on the notification of ethics clearance. This is a requirement as outlined in Article 6.14 of the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS2, 2014). The annual renewal report/application must receive ethics clearance before Tuesday, September 3rd 2024. Failure to receive ethics clearance for a study renewal will result in suspension of

ethics clearance and the researchers must cease conducting the study. Research Finance will be notified ethics clearance is no longer valid.

Amendment: Changes to this study are to be submitted by initiating the amendment procedure in the research ethics system and may only be implemented once the proposed changes have received ethics clearance.

Adverse event: Events that adversely affect a study participant must be reported as soon as possible, but no later than 24 hours following the event, by contacting the Director, Research Ethics. Submission of an [adverse event form](#) is to follow the next business day.

Deviation: Unanticipated deviations from the approved study protocol or approved documentation or procedures are to be reported within 7 days of the occurrence using a [protocol deviation form](#).

Incidental finding: Anticipated or unanticipated incidental findings are to be reported as soon as possible by contacting the Director, Research Ethics. Submission of the [incidental findings form](#) is to follow within 3 days of learning of the finding. Participants may not be contacted regarding incidental findings until after clearance has been received from a Research Ethics Board to contact participants to disclose these findings.

Study closure: Report the end of this study by submitting a study closure report through the research ethics system.

Coordinated Reviews: If your application was reviewed in conjunction with Wilfrid Laurier University, Conestoga College, Western University or the Tri-Hospital Research Ethics Board, note the following: 1) Amendments must receive prior ethics clearance through both REBs before the changes are put in place, 2) PI must submit the required annual renewal report to both REBs and failure to complete the necessary annual reporting requirements may result in Research Finance being notified at both institutions, 3) In the event that there is an unanticipated event involving a participant that adversely affects them, the PI must report this to both REBs within 24 hours of the event taking place and any unanticipated or unintentional changes which may impact the research protocol shall be reported within seven days of the deviation to both REBs.

Initial application ethics clearance notification: Your clearance notification will be added to the record within 24 hours. Go to “Admin Notes and Files” in the research ethics system (right-hand side) to print a copy of the initial application ethics clearance notification.

Best wishes for success with this study.

If you have any questions concerning this notification, please contact the [Research Ethics Office](#) or email researchethics@uwaterloo.ca.

#45322 - Linking Blue Carbon Ecosystems and Water Quality in Coastal Wetlands for Viable Small-Scale Fisheries

Protocol Information

Review Type	Status	Approval Date	Renewal Date
Expedited	Approved	Jul 24, 2024	Sep 03, 2025

Expiration Date	Initial Approval Date	Initial Review Type
Sep 26, 2025	Sep 25, 2023	Expedited

Feedback

Approval Comment

Renewal approved. Study may continue for another 12 months.---Karen Pieters

Navya Vikraman Nair

From: no-reply=kuali.co@mx3.kuali.co on behalf of Kuali Notifications <no-reply@kuali.co>
Sent: July 24, 2024 8:49 AM
To: Navya Vikraman Nair
Subject: Research Ethics – Renewed #45322 may proceed as described in the protocol/ethics application

Dear Prateep Nayak and other members of the research team:

We are pleased to inform you the Renewed application for #45322, Linking Blue Carbon Ecosystems and Water Quality in Coastal Wetlands for Viable Small-Scale Fisheries, may proceed. This research must be conducted in accordance with the most recent version of the protocol/application in the research ethics system and the most recent versions of all supporting materials. An annual report for this study is due before Friday, September 26th 2025. You will receive a system notification prompting you to submit this report. The research team is responsible for obtaining any additional approvals, licenses, or permits that might be required.

Reminders

New protocols/applications: To access this study's ethics clearance certificate, or acceptance of clearance from another institutional research for multi-jurisdictional research, you may download it from the "Admin Notes and Files" in the research ethics system (right-side menu). This email may not be accepted by some institutions to demonstrate ethics clearance.

Renewal: Multi-year research must be renewed at least once every 12 months unless a more frequent review has been specified on the notification of ethics clearance. This is a requirement as outlined in Article 6.14 of the [Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans](#) (TCPS2, 2022). Failure to receive ethics clearance for a study renewal will result in suspension of ethics clearance and you must cease conducting the study. Research Finance will be notified ethics clearance is no longer valid.

Study closure: Report the end of this study by submitting a study closure report through the research ethics system.

Amendment: Changes to this study are to be submitted by initiating the amendment application in the research ethics system and may only be implemented once the proposed changes have received ethics clearance.

Adverse event: Events that adversely affect a study participant must be reported as soon as possible, but no later than 24 hours following the event, by contacting the Director, Research Ethics. Submission of an [adverse event form](#) is to follow the next business day.

Deviation: Unanticipated deviations from the approved study protocol or approved documentation or procedures are to be reported within 7 days of the occurrence using a [protocol deviation form](#).

Incidental finding: Anticipated or unanticipated incidental findings are to be reported as soon as possible by contacting the Director, Research Ethics. Submission of the [incidental findings form](#) is to follow within 3 days of learning of the finding. Participants may not be contacted regarding incidental findings until after clearance has been received from a Research Ethics Board to contact participants to disclose these findings.

Best wishes for success with this study.

If you have any questions concerning this notification, please contact the [Research Ethics Office](#) or email researchethics@uwaterloo.ca.

APPENDIX C: Field Photographs



Community engagement during the rapid survey phase



Participatory mapping activity



Locally authored Odia books on Chilika's heritage by a 98-year-old poet, reflecting deep-rooted knowledge and lived community narratives



Fishing boats surrounded by dense stands of *Phragmites kara*



Brackish water aquaculture pond adjacent to Chilika Lagoon



Fishing boats anchored near the shore in a degraded water zone



A woman and her child engaged in sorting freshly caught fish for drying



Fish drying on traditional nets



Women participating in early morning fish auctions



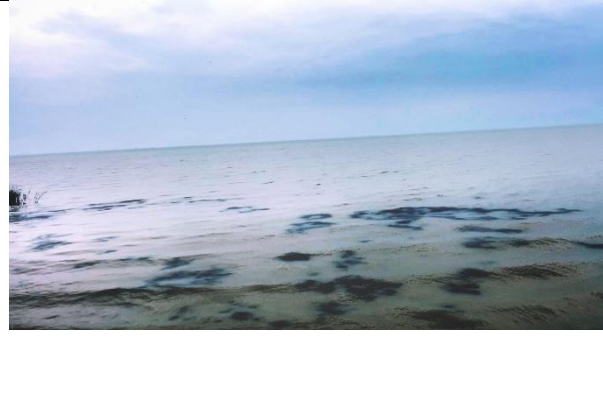
A fisherman showing cut and dried seagrass entangled in boat motor blades and nets



Women fish traders at a local market hub



In-depth interviews conducted with community members

		
Dense mangrove patches in Chilika Lagoon- boats avoid going closer due to barnacle infestation along the roots and shallow terrain.	Floating mats of dead seagrass on the lagoon's surface	Water sample collection at a boat jetty near Kalijai Temple
		
Goddesses Kalijai Temple, Barkul	Boat access obstructed by dense growth of invasive <i>Phragmites karka</i>	Cattle grazing on wetland fringes of Chilika



Canal choked with plastic waste near Barkul fish market



Shoreline littered with plastic and organic waste on Mahisa Island



Unmanaged household waste accumulation near settlement areas in Motto Village



Thick growth of aquatic weeds and stagnant water near reed beds



Lagoon clogged with decaying matter, aquatic vegetation, and oil spills at Mangalajodi



Seagrass bed with patches of degradation and discolouration



Barnacle-infested boat hull



Community mural at a cyclone shelter



Traditional fishers navigating through fixed fishing structures and gears



Fisherman displaying a traditional bamboo crab trap-an older, now rarely used fishing gear



Conducting ecological observations and interviews aboard a fishing boat



Overloaded passenger boat crossing Chilika Lagoon



Cattle grazing along Chilika shoreline amidst scattered plastic waste, Balugaon



Intensive aquaculture setup with inlet/outlet pipes, Sorada-Rambha region (Ganjam side)



Wall painting depicting gender roles in fisheries, Balugaon



New government-launched luxury cruise 'Garuda' docked at WTRC, Barkul



Senior fishers involved in participatory mapping



Focus group discussion with women and elders