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PROcoast

A PROactive approach for COmmunities to enAble Societal Transformation

D2.1 – State of the art review on transformative change and biodiversity

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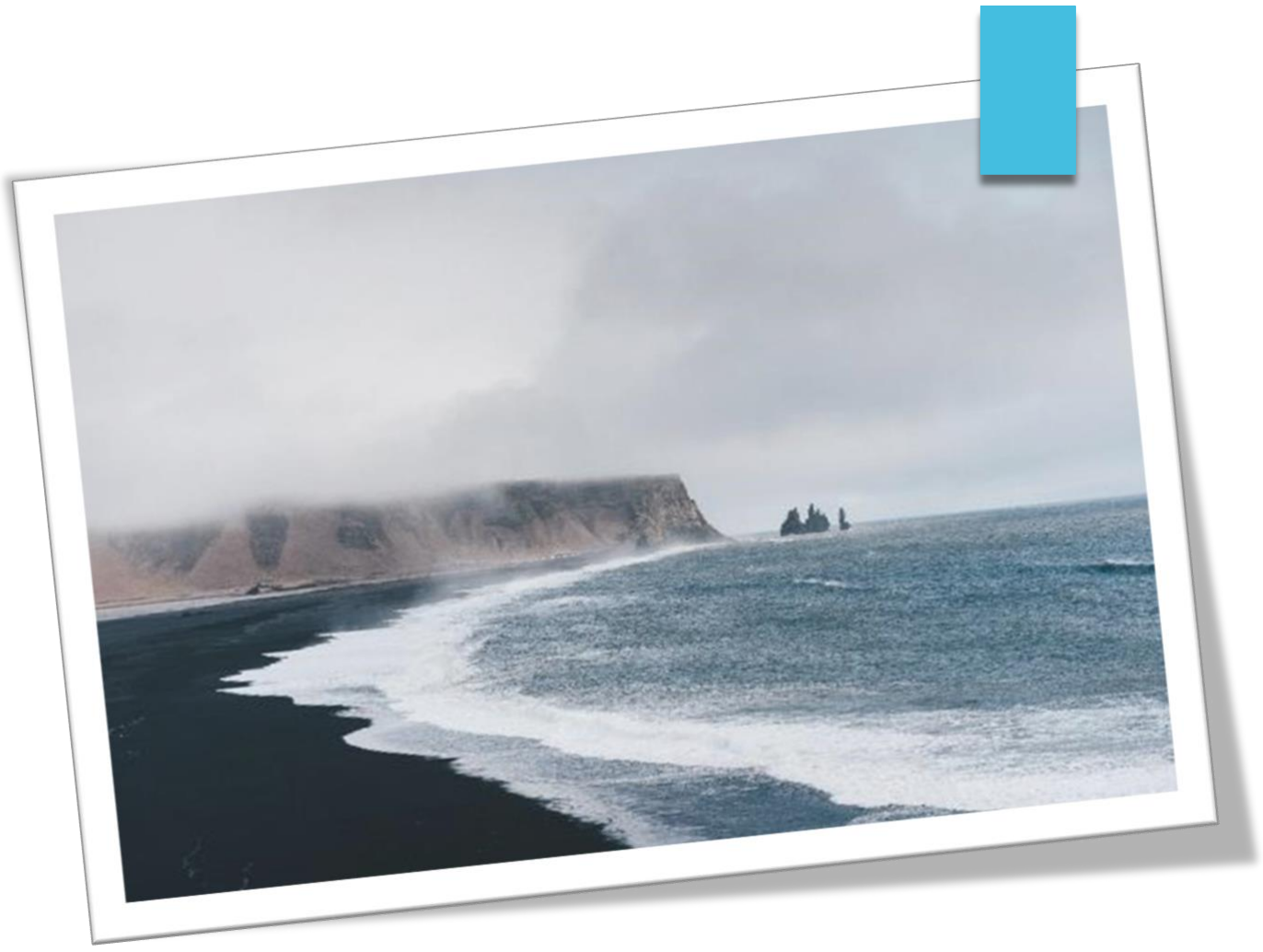

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BACKGROUND: ABOUT THE PRO-COAST PROJECT

The PRO-COAST project was launched to address the issue of biodiversity loss in European coastal ecosystems. Around 40% of Europeans live within 100km of the coast, relying directly on ecosystem services that are threatened by both quantitative and qualitative losses. Groups already facing socioeconomic vulnerabilities are likely to be disproportionately affected. PRO-COAST aims to empower local communities to support the restoration and maintenance of biodiversity and ecosystem services across Europe, integrating local knowledge into practice and policymaking. The project is now underway, coordinating the efforts of 20 partners across 14 countries working on 9 unique case studies. These case studies cover multiple conservation approaches across various coastal ecosystems, testing different governance models and social incentives to engage local actors in adopting technologies and actions for biodiversity conservation.

An important element of PRO-COAST is its holistic, interdisciplinary approach, based on a conceptual framework that treats social-ecological systems as interconnected. By mapping relationships between ecosystem components and uncovering feedback dynamics, the project seeks to identify leverage points for transformative change. PRO-COAST promotes integrated bottom-up decision-making, recognizing that environmental issues cannot be separated from social, economic, and political factors. Through extensive citizen engagement guided by state-of-the-art conservation science, the project aims to build community capacity for biodiversity management, providing scalable solutions that balance conservation needs with local socioeconomic priorities. Now in its early stages, PRO-COAST hopes to inform adaptive, participatory approaches to governance that avoid biodiversity losses and ensure sustainable, equitable access to coastal resources.

EXECUTIVE SUMMARY

This document is composed of six State of The Art Literature Reviews addressing various research questions. Each review aims to integrate findings into the development of PRO-COAST. The results of these reports will be discussed at a forthcoming workshop, which seeks to enhance the project's interdisciplinary goals. This process will also aid in developing a core set of hypotheses for use in case studies.

The Social-Ecological Systems (SES) Framework (McGinnis & Ostrom, 2014; Ostrom, 2009) plays a central role in the PRO-COAST project. It is used to understand and analyze the interactions between social and ecological systems. Researchers utilize this framework to incorporate new data, generate insights, formulate hypotheses, and explore the dynamic relationships within a social-ecological system. Thanks to its flexibility, the SES Framework can adapt to new findings and changing circumstances, allowing for continual expansion and refinement.

Following the workshop, these literature reviews, including this report, will further contribute to the development of the SES Framework by enriching it with additional knowledge. After these refinements, the literature reviews, together with an overarching summary, will be published and made available on the project website.

The titles of the State of the Art Literature Reviews are as follows:

1. **Report 1**: Yendell, A., Jaeckel, Y., & Rosteius, P.: **Impacts of biodiversity loss on coastal ecosystems and ecosystem services**. This particular report addresses the first research question: "In what ways are coastal ecosystems and ecosystem services impacted by biodiversity loss?" It provides, alongside the presentation of results from past studies, a foundation for the

formation of hypotheses and further research questions that are important for the project.

2. **Report 2**: Yendell, A., Jaeckel, Y. & Rosteius, P.: **Direct and indirect drivers of biodiversity loss in coastal ecosystems**. This particular report addresses the second research question: “What are the main direct and indirect drivers of biodiversity loss in coastal ecosystems (on the micro, meso and macro level of society)? Who or what are responsible and in what ways are they responsible?" It provides, alongside the presentation of results from past studies, a foundation for the formation of hypotheses and further research questions that are important for the project.
3. **Report 3**: Jones, K., Nienaber, A.M., Imrie-Kuzu, D.: **Governance of Coastal Biodiversity**. This particular report addresses the third research question: “What do we know about the ways governance impacts on biodiversity conservation, including in coastal zones?” It provides, alongside the presentation of results from past studies, a foundation for the formation of hypotheses and further research questions that are important for the project.
4. **Report 4**: Pourhasanzade, F., Melsom, T. W., & Herbert, D.: **Communities impacted by biodiversity loss and their role in biodiversity restoration**. This particular report addresses the fourth research question: “How do coastal communities experience and respond to biodiversity loss, and what specific roles can these communities play in biodiversity restoration efforts to enhance coastal ecosystem resilience and sustainability?" or “How can the social dynamics within coastal communities affected by biodiversity loss influence their engagement and effectiveness in biodiversity restoration initiatives, contributing to the resilience and sustainability of coastal ecosystems from a social-ecological perspective?” It provides, alongside the presentation of results from past studies, a foundation for the formation of hypotheses and further research questions that are important for the project.
5. **Report 5**: Yendell, A., Jaeckel, Y., Bär, G., & Lerch, H.: **Influence of demographic, cognitive, affective, attitudinal, and societal factors on coastal biodiversity**. This particular report addresses the fifth research question: “How do various forms of diversity, including demographic, social, ethnic, religious, gender, as well as cognitive and affective and societal factors, impact the conservation of biodiversity, particularly in the context of protecting coastal biodiversity?” It provides, alongside the presentation of results from past studies, a foundation for the formation of hypotheses and further research questions that are important for the project.
6. **Report 6**: Nienaber, AM & Kuzu-Imrie, D.: **Ways that transformative change has been utilised to halt coastal biodiversity loss**. This particular report addresses the sixth research question: “In which ways has transformative change been utilized to halt coastal biodiversity loss?” It provides, alongside the presentation of results from past studies, a foundation for the formation of hypotheses and further research questions that are important for the project.

METHODS AND DATA SOURCES

The methodology for creating the six literature reviews was designed to ensure consistency, robustness, and comprehensiveness. All reports utilized the same databases for literature identification, ensuring a uniform approach to data collection. This procedure for identifying relevant journals and literature was developed collaboratively and approved by the entire project consortium.

Through extensive discussions among participants from Leipzig University, Coventry University, and the University of Bergen, a semi-structured approach was unanimously adopted. This approach centered on selecting keywords that were directly tied to the research questions outlined in the project proposal. Each set of keywords, tailored to its respective research question, underwent a thorough review process.

Further refinements were made in consultation with biologists and environmentalists within the project team, allowing for a comprehensive and relevant selection of keywords. After several meetings and extensive discussions with the wider consortium partners, the final set of keywords was approved. This structured approach ensured that the methodology behind each report was consistent and collaborative.

Specific inclusion and exclusion criteria were used to guide the search in the three main data sources. The scope focused on coastal biodiversity, explicitly excluding fields unrelated to coastal research, such as medicine. The search included papers from all periods and countries to avoid unnecessary limitations. However, papers that did not align with the project's definitions of transformation or those deemed outside the project's scope were excluded. This comprehensive and collaborative methodology ensured a reliable foundation for all six reports.

A study by Wanyama on the impact of bibliographic databases on systematic reviews reveals that the selection of databases significantly influences the results of retrieved literature. The research findings advise against relying on single databases and asserting comprehensiveness (Wanyama et al., 2022). Our methodology entailed rigorous search procedures across SCOPUS, Web of Science, and Google Scholar. The choice to utilize these platforms was influenced by the project's interdisciplinary nature and the diverse expertise within our consortium. Comprehensive searches were performed in each database to include a wide range of studies from both ecological and social science disciplines. Google Scholar was specifically used to incorporate relevant grey literature, thereby enriching the scope of our review.

The integrated use of Scopus, Web of Science, and Google Scholar provides significant benefits, each bringing distinct yet complementary features to our research. Scopus is renowned for its expansive collection of peer-reviewed materials across various disciplines and excels in providing detailed publication records, authorship details, and citation information, which aids in the detailed analysis of research trends and impacts. Web of Science complements this with strong citation tracking and advanced search capabilities, crucial for precise academic scrutiny and assessment. Google Scholar offers access to a broader spectrum of academic materials, including resources not typically available in more traditional databases.

By leveraging all three databases, we were able to conduct a more thorough and varied search, significantly enhancing both the scope and depth of our literature reviews. This approach is especially beneficial in interdisciplinary studies, where the integration of diverse perspectives and sources is crucial for developing a comprehensive understanding of complex topics.

Throughout the process, we adhered to a semi-systematic or narrative review approach, focusing on understanding the evolution of research within the selected field and identifying key research traditions. Data collection involved gathering descriptive information and synthesizing key themes and theoretical perspectives through thematic analysis. This method enabled us to map the field of research, synthesize the current state of knowledge, and identify gaps for further exploration related to our nine case studies. To enhance our research methodology, we initially conducted searches in Scopus, followed by a thorough check in Web of Science. This two-step verification process ensured that we included all relevant studies while avoiding duplication. After completing these searches, we then turned to Google Scholar to incorporate 'grey' literature into our review, further broadening the scope and depth of our analysis. This comprehensive approach allowed us to gather a wide array of both peer-reviewed and non-peer-reviewed materials, ensuring a robust and inclusive literature review.

In order to build our primary search, we meticulously curated a collection of search keywords and phrases tailored to each report, aligning with the prevalent themes identified in our study topic. These will be expounded upon in the Methods section of each respective report.

LINKS WITH OTHER PROJECT ACTIVITIES

There are seven Work Packages in the PRO-COAST project. These reports, along with the others, form the basis for the development of research tools and methods, which will be implemented in the case studies. For this reason, they are relevant to Work Packages 3, 4, and 5.

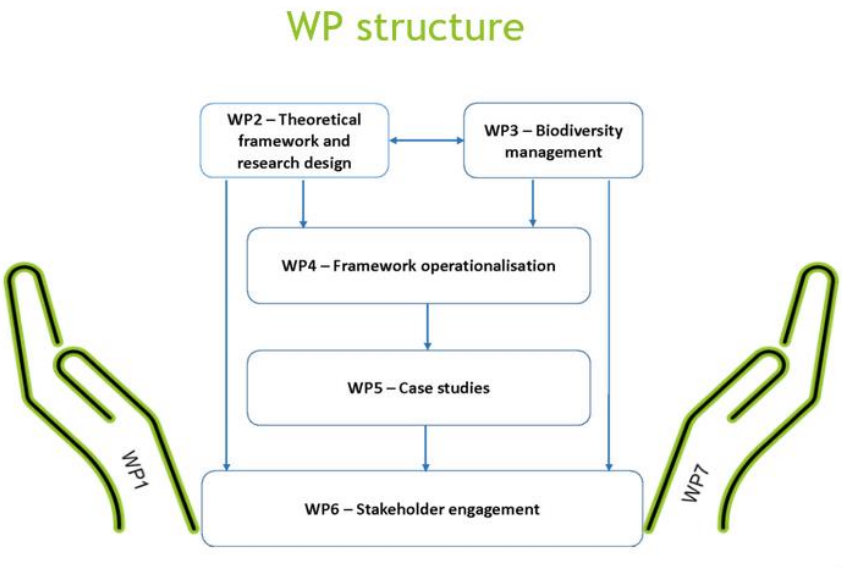

Figure 1: PRO-COAST Work Package structure.

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We also acknowledge that our research in Reports 1, 2, and 5 utilized artificial intelligence tools, including ChatGPT, Elicit, Deepl, and Google Translate, to enhance the scope and consistency of our search, communication, and organizational processes. Our use of these technologies was conducted with strict adherence to ethical standards, ensuring transparency in their application. The primary purpose of employing these AI tools was to facilitate linguistic accessibility and collaboration within our diverse team. Tools such as Deepl, ChatGPT, and Google Translate provided accurate translations, ensuring that all team members could fully contribute to and participate in our work. This approach enhanced inclusivity and understanding across linguistic divides.

Additionally, we used ChatGPT and Elicit in Reports 1, 2 and 5 for ideation, summarizing, and structuring. Similarly, these tools are used to generate summaries of scholarly articles in Report 4. These tools aided in deepening our understanding and the organization of our research. It is important to emphasize that all AI-generated insights underwent meticulous review and rigorous evaluation by our team to ensure the accuracy and reliability of our findings.

TABLE OF CONTENTS

Table of contents 8
Report 1: Impacts of biodiversity loss on coastal ecosystems and ecosystem services 12
1 Introduction 12
1.1 Scope of the document 12
1.2 Methods 13
1.3 Structure of the report 14
2 Literature review 14
2.1 Background and Context 14
2.2 Current Research Landscape 15
2.2.1 Overview of Existing Literature 15
2.2.2 Recent Trends and Developments 16
2.2.3 Key Studies and Findings 17
3 Hypotheses and questions for the case studies 26
4 Conclusions 28
5 References 28
Report 2: Direct and indirect drivers of biodiversity loss in coastal ecosystems 33
1 Introduction 33
1.1 Scope of the document 33
1.2 Methods 34
1.3 Structure of the report 35
2 Literature review 35
2.1 Background and Context 35
2.2 Current Research Landscape 36
2.2.1 Overview of Existing Literature 36
2.2.2 Recent Trends and Developments 37
2.2.3 Key Studies and Findings 37
3 Hypotheses and questions for the case studies 49
4 Conclusions 52
5 References 53
Report 3: Governance of Coastal Biodiversity 60
1 Introduction 60
1.1 Scope of the document 60
1.2 Methods 60
1.3 Structure of the report 61
2 Literature review 62
2.1 Background and Context 62
2.2 Current Research Landscape 63
2.2.1 Overview of Existing Literature 63
2.2.2 Recent Trends and Developments 69
3 Research Gaps and questions for the case studies 74

3.1 Ways governance impacts on biodiversity conservation....74
3.2 Case studies in PRO-COAST....75
4 Conclusions....77
5 References....78
Report 4: Communities impacted by biodiversity loss and their role in biodiversity restoration....87
1 Introduction....87
1.1 Scope of the document....87
1.2 Methods....87
1.3 Structure of the report....88
2 Literature review....88
2.1 Background and Context....88
2.2 Current Research Landscape....90
2.2.1 Overview of Existing Literature....90
2.2.2 Recent Trends and Developments....92
2.2.3 Key Studies and Findings....94
3 Hypotheses and questions for the case studies....94
4 Conclusions....96
5 References....97
Report 5: Influence of demographic, cognitive, affective, attitudinal, and societal factors on coastal biodiversity....103
1 Introduction....103
1.1 Scope of the document....103
1.2 Methods....103
1.3 Structure of the report....105
2 Literature review....105
2.1 Background and Context....105
2.2 Current Research Landscape....106
2.2.1 Overview of Existing Literature....106
2.2.2 Recent Trends and Developments....108
2.2.3 Key Studies and Findings....109
3 Hypotheses and questions for the case studies....133
4 Conclusions....138
5 References....140
Report 6: Ways that transformative change has been utilised to halt coastal biodiversity loss....147
1 Introduction....147
1.1 Scope of the document....147
1.2 Methods....148
1.3 Structure of the report....149
2 Literature review....150
2.1 Background and Context....150
2.1.1 Historical and Political Context....150
2.1.2 Theoretical definitions and concepts on transformation....151
2.2 Current Research Landscape....153
2.2.1 Overview of Existing Literature....153

2.2.2 Recent Trends and Developments....155
2.2.3 Key Studies and Findings....158
3 Hypotheses and questions for the case studies....162
3.1 Transformative Change for Biodiversity Conservation....162
3.2 Case Studies in PRO-COAST....163
4 Conclusions....164
5 References....165
Annex - Glossary....173

INDEX OF FIGURES

Figure 1: PRO-COAST Work Package structure. 7

Figure 2: Enhancing coastal resilience with social transformations: transitioning from future coastal risks to holistic development with social sciences (Philippenko & Le Cozannet, 2023: 10). 91

INDEX OF TABLES

Table 1: Examples of selected research papers categorized by key themes in social-ecological resilience and adaptive strategies for coastal communities facing climate change and biodiversity loss. 92

REPORT 1: IMPACTS OF BIODIVERSITY LOSS ON COASTAL ECOSYSTEMS AND ECOSYSTEM SERVICES

1 INTRODUCTION

1.1 Scope of the document

Objectives

This document is an essential component of the A PROactive Approach for Communities to Enable Societal Transformation (PRO-COAST) project, funded by the European Commission. It seeks to explore the complex relationship between biodiversity loss and the provision of ecosystem services within coastal environments. This exploration is crucial for aligning with the European Research Executive Agency's Green Europe strategy, emphasizing sustainability in biodiversity, the circular economy, and environmental concerns. The primary aim is to identify the direct and indirect drivers of biodiversity loss in coastal ecosystems and assess their impact on ecosystem services, underlining the critical role these ecosystems play in global biodiversity, human well-being, and environmental health.

Scope and Key Findings

The scope of this review is carefully curated to concentrate on coastal ecosystems, specifically mangroves, salt marshes, and seagrass meadows, and their interplay with biodiversity loss and ecosystem service provision. It also goes deeper into the innovative conservation methodologies and theoretical frameworks that are shaping contemporary research and policy-making in this area.

Through a comprehensive literature review, the document brings to light several themes central to understanding threats to coastal ecosystems' as well as their resilience and functionality. It underscores the vital importance of biodiversity in sustaining ecosystem services such as carbon sequestration, flood regulation, and fisheries support. It also highlights the significant threats from anthropogenic activities, including urbanization, pollution, and habitat destruction, which exacerbate biodiversity loss and undermine the capacity of ecosystems to provide essential services. The literature points to the necessity of adopting integrative management approaches that merge social and ecological dimensions, advocating for engaging with local stakeholders in conservation efforts.

Limitations

Despite its thorough approach, the document acknowledges several inherent limitations. The reliance on existing literature may introduce biases, particularly highlighting findings from well-researched areas and potentially neglecting less-studied regions or newly emerging issues not yet widely documented. The geographic focus is predominantly on European coastal regions, reflecting the project's funding source, which may limit the direct applicability of findings to non-European contexts. Due to the limited amount of scientific research on European coastal regions, additional research from non-European coastal areas was incorporated into the analysis, which may affect the transferability to the European context. Additionally, the complexity of socio-ecological systems poses challenges in deeply exploring interdisciplinary aspects, necessitating a nuanced balance between ecological insights and socio-economic considerations.

1.2 Methods

The methodology for conducting this literature review entailed a structured approach to comprehensively understand the role of biodiversity loss in coastal ecosystems, particularly focusing on the impact on ecosystem services and the involvement of local stakeholders. To achieve a broad and inclusive understanding, a systematic search was conducted across three prominent academic databases: Web of Science, Scopus, and Google Scholar. These databases were selected for their extensive repository of scientific and social sciences literature, offering a wide array of peer-reviewed articles, conference proceedings, and books pertinent to our investigation.

The search strategy employed a combination of keywords and Boolean operators to meticulously capture studies related to the role, impact, and influence of biodiversity loss on ecosystem services within coastal ecosystems or environments. The keywords were structured as follows:

- Topic Keywords: (role of biodiversity loss OR impact of biodiversity loss OR influence of biodiversity loss) AND (ecosystem service) AND (coastal ecosystem OR coastal environment)
- Subsequent Refinement: + AND (local stakeholder)

The use of the asterisk (*) wildcard was not specified, as the search aimed to capture specific phrases rather than variations of a root word. This precise approach was designed to ensure the relevancy and specificity of the search results to the research questions.

The initial query on the Web of Science database using the sequence “((role of biodiversity loss) OR (impact of biodiversity loss) OR (influence of biodiversity loss)) AND (ecosystem service) AND ((coastal ecosystem) OR (coastal environment))” resulted in 241 publications. Subsequently, to focus on local specifics, we added “local stakeholders”, which resulted in 12 further publications. In a second step, for further selection, the abstracts of these 253 publications were reviewed in pairs and sorted according to their relevance to the topic. This review resulted in 80 usable papers.

Another search was conducted on the Scopus database using the sentence “((role OR impact OR influence) AND (biodiversity loss)) AND (“ecosystem service*”) AND (coastal ecosystem OR coastal environment)”. The result comprised 49 publications, of which 11 were selected for further use in the second step.

To ensure the coverage, we extended the search to Google Scholar, but limited the results to the first 150 hits. Here, we were able to gain a further 8 publications.

In addition to the primary search, we employed a technique to include relevant literature that, although not initially captured in our sample through the database search, was cited within the identified sources. This snowballing method facilitated the inclusion of significant studies that directly addressed our research themes but might have been overlooked due to variations in keyword use or discrepancies in database indexing.

No restrictions were imposed based on geographic regions or the year of publication, allowing for a comprehensive review that encompasses a diverse range of contexts and temporal scopes. This inclusive strategy was intended to capture the global and historical nuances of biodiversity loss in coastal ecosystems.

The search results from each database were meticulously screened for relevance by examining titles, abstracts, and keywords. This preliminary screening served to identify studies that potentially contributed to our understanding of the specified themes. Following this, a full-text review of selected studies was conducted to evaluate their direct relevance to the research questions, particularly focusing on the impact

of biodiversity loss on ecosystem services, the role of coastal ecosystems, and the involvement of local stakeholders.

This methodical approach ensured that the literature review was underpinned by a comprehensive and robust evidence base, encompassing a broad interdisciplinary perspective on the intricate dynamics between biodiversity loss, ecosystem services, and stakeholder engagement in coastal environments.

1.3 Structure of the report

The report, structured around an intricate examination of coastal ecosystems, their biodiversity, and the impact of human activities, is organized into three core chapters, following the initial introduction.

Chapter 2: Literature Review delves into the rich biodiversity of coastal ecosystems, their critical ecosystem services, and the threats posed by human activities and climate change. It explores the historical, political, and key developmental contexts shaping the management of these ecosystems. This chapter reviews current research, highlighting the essential role of biodiversity in ecosystem resilience, the valuation of ecosystem services, and the importance of integrating social and ecological dimensions in ecosystem management.

Chapter 3: Hypotheses and Questions for the Case Studies outlines the research framework for investigating the dynamic interplay between biodiversity loss and ecosystem service provision in coastal regions. It presents hypotheses and research questions, both derived from the literature review and identified research gaps, aiming to advance understanding and develop effective conservation strategies.

Chapter 4: Conclusion synthesizes the findings, stressing the interconnectedness of social and ecological systems and the imperative for interdisciplinary approaches to conserve coastal ecosystems. It underscores the necessity of co-creation with local stakeholders and the exploration of socio-ecological factors influencing conservation success, guiding future research directions towards sustaining ecosystem functionalities and services.

2 LITERATURE REVIEW

2.1 Background and Context

Coastal ecosystems, characterized by their rich biodiversity, provide invaluable ecosystem services that underpin human well-being and the environmental health of our planet. These regions, encompassing wetlands, mangroves, salt marshes, and seagrass meadows, are not only sanctuaries for a vast array of species but are also critical for supporting complex ecological processes and socio-economic activities. The interconnectedness of these ecosystems and the human communities they support is fundamental to the PRO-COAST project's approach, which aligns with the European Research Executive Agency's (REA) Green Europe strategy that emphasizes biodiversity, circular economy, and environmental concerns. In this context, the insights provided by Hopkins (2008) on transitioning from oil dependency to local resilience are paramount, particularly in understanding the socio-economic transformations necessary for fostering sustainable coastal communities. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) further emphasizes the importance of preserving biodiversity as a foundation for sustainability and resilience in coastal communities, aligning with the core objectives of the PRO-COAST project.

Historical Context

Historically, coastal ecosystems have experienced fluxes in biodiversity due to natural climatic events (IPCC 2021 WPI, IPCC 2019 SR). However, the rate of change and the scale of biodiversity loss have

been exponentially increased by human activities since the industrial revolution. The demand for coastal land for urbanization, industrialization, and tourism has led to habitat destruction and a significant reduction in the integrity of these ecosystems.

Political Context

Politically, the shift in the approach to managing these ecosystems has evolved from exploitation to conservation and sustainability. This shift is reflected in numerous international agreements and local policies aimed at preserving biodiversity and ensuring the continued provision of ecosystem services. The inception of projects like PRO-COAST, financed by the European Commission, signifies a contemporary political will directed towards innovative frameworks that integrate social and ecological systems, advocating for the transformative potential of communities in the context of environmental action..

Current Key Developments

Several key developments have shaped the contemporary understanding and strategies concerning coastal ecosystems such as:

1. Recognition of the impact of climate change on coastal ecosystems (IPCC 2021 WPI, IPCC 2019 SR).
2. The advent of citizen science, which democratizes scientific inquiry and involves the public in data collection and problem-solving.
3. Development of integrated coastal zone management (ICZM) as a means to achieve sustainable coastal development.

2.2 Current Research Landscape

2.2.1 Overview of Existing Literature

A pivotal theme within the scholarly discourse is the intricate link between biodiversity and ecosystem functionality. Researchers emphasize the multifaceted ways in which the variety of life forms within coastal ecosystems underpins the resilience and adaptability of these environments. The debate extends to the mechanisms through which biodiversity loss—stemming from anthropogenic pressures such as pollution, habitat destruction, and climate change—compromises ecosystem services, ultimately affecting human health, livelihoods, and socio-economic development.

Another significant strand of debate centers on the valuation of ecosystem services. This encompasses discussions on methodological approaches to quantify and monetize these services, aiming to integrate ecological considerations into policy-making and management strategies. The discourse explores the challenges and opportunities in adopting such valuation methods, considering the inherent complexities and uncertainties in predicting ecosystem responses to environmental stressors.

The current body of literature also grapples with the scalability of ecosystem functions and the role of spatial and temporal dynamics in influencing ecosystem services. Scholars debate the extent to which findings from localized studies can be extrapolated to broader geographical scales, addressing the need for cross-scale methodologies to understand global patterns of biodiversity loss and its implications.

Furthermore, the discourse delves into the socio-ecological dimensions of coastal ecosystem management. This includes discussions on the governance frameworks, stakeholder engagement, and community-based conservation efforts required to mitigate biodiversity loss. Debates focus on balancing economic development with ecological sustainability, underscoring the need for interdisciplinary approaches that incorporate social, economic, and ecological perspectives.

In summary, the literature review foregrounds several key themes: the critical role of coastal ecosystems in global biodiversity and human well-being, the complex interdependencies between biodiversity and ecosystem services, the challenges of quantifying and valuing these services, and the imperative for integrated management and conservation strategies. These discussions set the stage for a deeper exploration of how biodiversity loss impacts coastal ecosystems and their ability to provide vital services, highlighting the urgency and complexity of addressing this global environmental challenge.

2.2.2 Recent Trends and Developments

Which are the emerging trends, innovative methodologies, and theoretical paradigms that are shaping contemporary research in this vital area?

Emerging Trends

Recent scholarly efforts have underscored the escalating impacts of climate change on coastal ecosystems, highlighting the urgency of integrating climate resilience into conservation strategies. There's a burgeoning focus on understanding how phenomena such as sea-level rise, increased storm intensity, and ocean acidification jeopardize the integrity and functionality of coastal habitats, from mangroves to seagrass meadows. Concurrently, there's an increasing acknowledgment of the role of social-ecological systems (SES) in framing human-environment interactions, emphasizing the need for research that encapsulates both the biophysical and socio-economic dimensions of ecosystem services.

Methodological Advancements

Advances in remote sensing and Geographic Information Systems (GIS) have revolutionized our capability to monitor and analyze coastal ecosystems at unprecedented scales and resolutions. These technologies facilitate the mapping of habitat changes, biodiversity patterns, and the distribution of ecosystem services, enabling more nuanced and informed conservation planning. Additionally, the field is witnessing refined approaches to the valuation of ecosystem services, employing both market and non-market mechanisms to articulate the economic significance of biodiversity and ecosystem functions. These methodological strides are crucial for informing policy and management decisions aimed at sustaining ecosystem services.

Theoretical Perspectives

The resilience theory has gained prominence, offering a lens through which to view the capacity of ecosystems to withstand disturbances and maintain their service provision. This perspective is particularly relevant to coastal ecosystems, which are often on the frontline of climate change impacts. Moreover, the concept of Nature-based Solutions (NbS) has emerged as a guiding framework for addressing environmental challenges through the conservation and restoration of ecosystems. NbS emphasizes the utility of natural processes and biodiversity in mitigating climate change impacts, enhancing disaster resilience, and promoting biodiversity conservation.

Recent Developments

The recognition of blue carbon ecosystems represents a significant stride in the field, spotlighting the crucial role of coastal habitats like mangroves, salt marshes, and seagrass beds in sequestering carbon and mitigating climate change. This has catalyzed a global push towards the conservation of these ecosystems as part of broader climate change mitigation strategies. Furthermore, the discourse around ecosystem health and integrity has evolved to include more holistic measures that incorporate both ecological and human health indicators, advocating for management approaches that bolster ecosystem resilience and ensure the sustainability of ecosystem services.

2.2.3 Key Studies and Findings

Introduction

Coastal ecosystems are biodiverse regions encompassing habitats such as wetlands, mangroves, salt marshes, and seagrass meadows (Basset et al., 2013). These areas are critical for supporting a diverse array of species, including bacteria, zooplankton, polychaete worms, mollusks, macro-crustaceans, fishes, birds, and aquatic mammals (Rodrigues-Filho et al., 2023). The importance of these ecosystems extends beyond their biodiversity; they offer a range of ecosystem services vital for human well-being and environmental health (Newton et al., 2018, IPCC 2019 SR).

Ecosystem services derived from coastal ecosystems can be categorized into four main types: supporting, provisioning, regulating, and cultural services (MA, 2005).

Supporting services include functions such as wildlife refuges, nursery areas for juvenile marine species, water cycling, soil formation, nutrient cycling, and primary production. These services underpin all other ecosystem services by maintaining essential ecological processes (MA, 2005; Newton et al., 2018). *Provisioning services* refer to the direct benefits humans obtain from ecosystems, such as transportation, habitat for various species, mining, energy resources, cultivation opportunities, raw materials, food, and water (MA, 2005; Newton et al., 2018). *Regulating services* encompass the benefits derived from the regulation of ecosystem processes. These include air quality regulation, waste disposal, carbon sequestration, water quality regulation, climate moderation, waste treatment, water flow regulation, erosion prevention, natural hazard mitigation, biological control, and pollination (MA, 2005; Newton et al., 2018). *Cultural services* highlight the non-material benefits that enrich human culture and emotional well-being, including recreation and tourism, cultural identity, aesthetic appreciation, research opportunities, educational benefits, spiritual and religious significance, inspiration, and the provision of employment (MA, 2005; Newton et al., 2018).

The ecosystem services from coastal regions stem from a combination of species' ecological processes (like biomass production, excretion, and recruitment), behaviours (including movement, burrowing, feeding, foraging, and migration), and broader ecosystem processes (such as biochemical cycles, decomposition, and primary and secondary production). This intricate interplay of ecological functions is fundamental in providing the diverse ecosystem services upon which human societies and natural environments depend (Rodrigues-Filho et al., 2023). However, it is also noted that coastal regions are among the most threatened ecosystems globally. The dynamic zone between land and sea is under increasing threat from a complex interplay of anthropogenic pressures. With an increase in human population and climate change these ecosystems face a multitude of threats affecting the balance and health of these vital ecosystems (Williams et al., 2016). Therefore, understanding and preserving these ecosystems is crucial, not only for maintaining biodiversity but also for ensuring the continued provision of essential services that support human well-being (MA, 2005).

The reviewed literature considers numerous facets of the topic. Coastal environments are diverse ecosystems that boast remarkable diversity, hosting a wide array of species. Consequently, our exploration will encompass various dimensions of this issue, presenting diverse examples that together provide a comprehensive understanding of the current state of biodiversity loss in coastal ecosystems and its implications for ecosystem services.

Exploring Ecosystem Services: The Vital Role of Biodiversity in Mangroves, Mudflats, and Seagrass Meadows

In the following section, we aim to elucidate the ecosystem services offered by coastal ecosystems, including mangroves, mudflats, and seagrass meadows, to underscore the critical role that biodiversity plays in ecosystem service provision.

Mangrove ecosystems, as detailed by Williams et al. (2016), play a pivotal role in coastal defence, carbon sequestration, and biodiversity conservation. These ecosystems offer robust natural barriers against storm surges and coastal erosion, while also acting as vital carbon sinks that mitigate climate change impacts (Arkema et al., 2013; Newton et al., 2018; Williams et al., 2016). Furthermore, the complex root systems of mangroves provide habitat for a multitude of species which contribute to the livelihoods of local communities, thereby underscoring the multifaceted benefits of these ecosystems (Jaafar et al., 2004).

Transitioning to, mudflats, which are unvegetated intertidal zones, they play crucial roles in nutrient cycling, carbon cycling, and supporting macrofaunal assemblages. These habitats are essential for the maintenance of global fisheries and act as natural defence mechanisms against coastal erosion (Dissanayake et al., 2018).

Equally important are seagrasses, acting as foundational species, which create structurally complex habitats that facilitate the sustenance of diverse marine communities, ranging from microscopic invertebrates to large vertebrates. Their ecological functions extend beyond biotic interactions, contributing significantly to primary production, sediment accretion and stabilization, coastal protection, carbon sequestration, and water purification. Moreover, seagrass meadows are instrumental in supporting fisheries and recreational activities, punctuating their socio-economic and ecological relevance (Creed et al., 2023; Gaylard et al., 2023).

An example that highlights the varied ecosystem services provided by these coastal environments and their crucial roles in enhancing ecological balance and supporting human well-being within the region is a case study of lagoons in North Africa. North African lagoons act as hubs for ecological and economic activity. The coastal ecosystems support fisheries, a sector that has grown increasingly important with rising urbanization in the area, as it offers both food security and economic benefits to local populations. Fishing, shellfish harvesting, and the extraction of salt and sand provide employment to many locals and contribute to the local and regional economies. Additionally, tourism also plays a significant role in North African lagoons. The scenic and cultural character draws tourists, offering recreational activities such as sailing, bathing, bird watchingand nature watching (El Mahrad et al., 2020).

Importance of Biodiversity for Ecosystem Services

The significance of biodiversity in sustaining ecosystem services is a well-documented aspect within scientific research (IPCC 2021 WPI, IPCC 2019 SR). Biodiversity forms the foundation of ecosystem health and resilience, playing a crucial role in the ability of ecosystems to deliver a range of services essential for human well-being and environmental balance (Rodrigues-Filho et al., 2023).

In coastal environments, certain species, such as seagrass, serve as keystone components by offering a plethora of ecosystem services critical for the survival and well-being of numerous other species. Similarly, specific communities like benthic and stygofaunal communities are indispensable for providing vital ecosystem services (Lam-Gordillo et al., 2022; Saccò et al., 2022). These communities' functionality, health, and resilience are intrinsically linked to biodiversity. The complex interdependencies within ecosystems imply that the loss of a single species can ripple through the ecosystem, affecting its overall functioning and, consequently, the ecosystem services it can provide (Sarà et al., 2021). According to Newton et al. (2018), coastal lagoons furnish 26 distinct ecosystem services (Newton et al., 2018). Rodrigues-Filho et al. (2023) elucidates how a diverse range of taxa, including bacteria, zooplankton, worms, molluscs, crustaceans, fish, birds, and mammals, play a part in delivering these services through

their ecological roles. Both biotic (living) and abiotic (non-living) components interact synergistically to facilitate these services (Rodrigues-Filho et al., 2023). Biodiversity is essential for maintaining the health, diversity, and resilience of ecosystems. Only when coastal ecosystems are healthy, diverse, and resilient can they support the ecological functions and processes that yield benefits for humans, ranging from water purification and flood control to climate regulation (Buonocore et al., 2020).

Biodiversity's role extends beyond ensuring ecosystem resilience and productivity; it is also pivotal for genetic diversity, which is vital for food security, medicinal resources, and adaptation to changing environmental conditions (Albert et al., 2021). The marine environment, supplies the "raw materials" necessary for the food chain and seafood production, further underscoring the critical role of biodiversity in supporting ecosystem services (Price, 2001).

The significance of biodiversity in sustaining ecosystem functionality is a central theme in ecological research, as highlighted by various studies across different ecosystems. Mora's research on reef fishes for example underscores this point by demonstrating a positive correlation between biodiversity and ecosystem functioning in reef ecosystems. The study illustrates that an increase in the diversity of species and their functions leads to a rise in the biomass of reef fishes. This relationship indicates that biodiversity not only enhances the ecosystem's capacity to support more biomass but also serves as a crucial indicator of its health and functionality (Mora et al., 2011).

Species communities, such as benthic macrofauna or stygofauna, play crucial roles in providing essential ecosystem services, including nutrient cycling, organic matter mineralization, and pathogen removal. Additionally, they contribute to maintaining and mitigating potential impacts of eutrophication and enhancing aquifer transmissivity. Recent research has demonstrated a close association between the abundance and diversity of these communities and their capacity to provide these vital ecosystem services (Lam-Gordillo et al., 2022; Saccò et al., 2022).

Seagrass ecosystems are increasingly recognized for their crucial role in offering a wide range of ecosystem services, integral to both marine life and human welfare. These underwater meadows, according to a series of studies within our literature review, provide significant benefits through the provision of food and raw materials, support for fisheries production and biodiversity, climate regulation, nutrient cycling, and recreational opportunities for humans (Lima et al., 2023). Specifically, seagrass meadows are highlighted for their essential contribution to fisheries and biodiversity. Studies by Unsworth and Cullen (2010) underscore how these ecosystems directly and indirectly bolster habitat connectivity, serving critical nursery functions and foraging areas that support marine life diversity and abundance. This, in turn, underpins commercial and subsistence fisheries, which are vital for food security and economic wellbeing in coastal communities (Unsworth & Cullen, 2010). Moreover, seagrass beds play a pivotal role in climate change mitigation. Through their capacity for carbon sequestration, they help regulate the Earth's climate by absorbing carbon dioxide, thereby acting as an efficient and natural carbon sink. The ability of seagrass meadows to sequester carbon is not only crucial for combating climate change but also enhances their value in protecting coastlines by stabilizing sediments and reducing erosion. Nutrient cycling and waste treatment are other significant ecosystem services provided by seagrass meadows. Lima's research points to the biodiversity within these ecosystems as being vital for their effectiveness in these roles (Lima et al., 2023). The variety of life forms within seagrass beds ensures the resilience of these habitats to environmental changes, thus maintaining their ability to support marine ecosystems and human needs. Gaylard's work further emphasizes the importance of seagrass biodiversity, particularly in nitrogen waste treatment along urbanized coastlines. Seagrass meadows' ability to assimilate nitrogen highlights their critical role in treating wastes naturally, offering a sustainable alternative to costly technological interventions. However, this service is closely linked to the health and density of seagrass

beds. As Gaylard notes, a decline in seagrass biodiversity, due to loss of species that possess varied nutrient uptake and processing capabilities, significantly impairs these ecosystems' efficiency in pollutant filtration and breakdown (Gaylard et al., 2023).

Ecosystem services enable the estimation of an ecosystem's natural capital value. A study estimated the natural capital value of seagrass meadows within a Marine Protected Area in Southern Italy at 12 million euros, demonstrating the significant economic contribution of ecosystem services provided by these habitats (Buonocore et al., 2020).

Collectively, these studies exemplify the indispensable role of biodiversity in maintaining ecosystem functioning across different environments. Whether it's the biomass of reef fishes, the nutrient cycling in lagoons, or the water quality in coastal groundwater systems, biodiversity emerges as a fundamental pillar supporting ecological health and sustainability.

Threats to Coastal Ecosystems

Coastal ecosystems, including specialized habitats like salt marshes, mangroves, and coastal dunes, are facing significant threats from both climate change and human activities (IPCC 2021 WPI, IPCC 2019 SR). These unique and biodiverse environments are particularly vulnerable to the impacts of rising sea levels, increasing temperatures, and habitat destruction caused by expanding human populations.

A plethora of research documented in the scientific literature elaborately delineates the myriad pressures faced by these critical ecosystems, underscoring their vulnerability to a host of environmental challenges.

The expansion of urban areas in coastal regions is a critical threat to the biodiversity and integrity of coastal ecosystems, as documented in numerous studies. In China, for example, urbanization has significantly encroached upon natural habitats, leading to habitat displacement, degradation, and fragmentation (Liu et al., 2023). Rojas et al. (2019) quantified the urban expansion in a metropolitan area in Chile, revealing a 28% increase between 2004 and 2014, with projections estimating a future surge of 238%. Concurrently, wetlands experienced a 10% reduction, illustrating a direct link between urban expansion and habitat loss (Rojas et al., 2019). Urbanization not only replaces natural habitats with built environments but also often necessitates the expansion of coastal infrastructure and physical alterations to coastlines, further exacerbating the issue (Williams et al., 2016).

Agricultural expansion also plays a significant role in habitat loss (Yin et al., 2021). The study on reef fishes highlighted the negative impact of human population density on biodiversity, indicating that human presence and activities intensify biodiversity loss and its adverse effects on ecosystem functioning (Mora et al., 2011).

The tourism industry, particularly in areas with developed infrastructure catering to high volumes of tourists, contributes to increased nitrogen levels in ecosystems such as coral reefs. It was observed that more variable nitrogen levels near tourist-heavy developed areas compared to less developed regions. The fluctuations in nitrogen were strongly correlated with tourist activities, suggesting that sewage-derived nitrogen significantly affects the nitrogen content in species biomass. This finding emphasizes the profound influence of land-based activities, especially from tourism, on the health and productivity of coral reefs (Baker et al., 2013).

Furthermore, human activities and tourism contribute to pollution through plastic and microplastics, detrimentally affecting the diversity and richness of species such as macrozoobenthos (Specchiulli et al., 2023). Industrial activities, too, have been identified as a factor in the decline of coastal ecosystems through pollution. It was found that phosphogypsum discharges from industrial sites have been linked to a significant reduction in coastal fisheries landings in seagrass meadows (El Zrelli et al., 2020).

Coastal ecosystems face threats not only from direct human activities but also from the consequences of climate change, including increasing temperatures, sea level rise, and the acidification of oceans (Williams et al., 2016). For instance, as oceans absorb more carbon emissions resulting from human activities, they become more acidic. This acidification process, leads to changes in community structures and the degradation of habitats (Hall-Spencer & Harvey, 2019). Additionally, the increasing frequency of extreme weather events, such as heatwaves and episodes of low oxygen (hypoxic events) potentially causes widespread mortality among vulnerable species (Gammal et al., 2017). The elevation in sea levels poses another significant threat, as it could result in the loss of habitats. This scenario is particularly problematic for specialized species that cannot easily relocate to new environments (Williams et al., 2016).

Anthropogenic Pressures on Northern African Coastal Lagoons

An example that illustrates the negative impacts on coastal lagoons is the study of coastal lagoons in Northern Africa. This case study sheds light on some of the primary pressures these ecosystems endure which include the following:

The drainage associated with agricultural activities introduces contaminants such as fertilizers, pesticides, herbicides, and manure into coastal habitats (El Mahrad et al., 2020). These pollutants adversely affect water species and can stimulate phytoplankton blooms (Béjaoui et al., 2017; El Mahrad et al., 2020).

In addition, urban sewage, often released untreated or poorly treated, alongside industrial discharges, poses another significant threat to coastal ecosystems. This challenge is compounded by urban expansion and climate change, which increase the volume of urban stormwater discharges entering lagoons without adequate treatment (Gooré Bi et al., 2015). Moreover, infrastructure development for lagoon management, including the construction of artificial channels, harbors, and ports, and urban sprawl, significantly jeopardizes these ecosystems. Such activities can modify natural landscapes, disrupt ecological balances, and result in biodiversity loss (El Mahrad et al., 2020).

Furthermore, activities such as fishing, shellfish gathering, dredging, and sand quarrying inflict considerable damage by selectively removing species, causing death or injury to marine life, introducing non-native species, destroying the substrate, causing abrasion, resuspending sediments, mobilizing nutrients, and generating underwater noise (El Mahrad et al., 2020).

Lastly, the movement of motorized ferries, vessels, and yachts generates underwater noise pollution, while accidental oil spills and the use of anti-fouling agents containing highly toxic metals like copper and zinc contribute to eutrophication, further affecting ecosystem services (El Mahrad et al., 2020; Newton et al., 2018).

Consequences

Anthropogenic activities and climate change significantly impact coastal regions, leading to a reduction in biodiversity. Habitat loss stands out as the primary factor driving biodiversity loss, while pollution, eutrophication and other anthropogenic impacts contribute to the decline of numerous species communities. While these changes affect the biodiversity, they impair the ecosystems' ability to offer vital ecosystem services. The literature offers numerous examples demonstrating how human impacts adversely affect the provision of these services.

A study conducted by Zrelli et al. (2020) for example quantifies the economic losses resulting from human impacts on seagrass ecosystems. Activities such as sponge harvesting, seabed trawling, and the discharge of phosphogypsum from industrial processes since the mid-1970s have significantly diminished seagrass meadows. This reduction is directly linked to a decline in the landings of commercial coastal species. It was estimated that the economic loss to coastal fisheries due to the degradation of seagrass

habitats amounted to approximately 60 million euros in 2014, with a total cumulative loss of over 750 million euros between 1990 and 2014. This study underscores the critical role of seagrasses in supporting marine biodiversity and the local economy, illustrating the substantial environmental and economic costs associated with the negative externalities of local industrial activities (El Zrelli et al., 2020).

To further emphasise the consequences of human activities, we will explain the effects of hypoxia on ecosystem functioning:

Hypoxia in coastal zones, primarily resulting from excessive nutrient loading and subsequent eutrophication, leads to a drastic reduction in oxygen levels, affecting the abundance, biomass, and species richness of macrofaunal communities. These communities play a pivotal role in nutrient transformation processes at the sediment-water interface, including the mineralization of organic matter and the regeneration of nutrients. The decline in macrofaunal diversity and abundance due to hypoxia alters these nutrient cycling processes, leading to increased effluxes of nutrients such as phosphate and ammonium from the sediment. This change in nutrient fluxes can exacerbate the conditions of eutrophication, creating a feedback loop that further degrades the ecosystem. It reveals that even small variations in environmental conditions can significantly influence ecosystem functioning, indicating a high context-dependency of macrofauna-ecosystem functioning relationships. Consequently, the loss of biodiversity, particularly the decline of functionally important macrofauna species due to human activities, has profound implications for ecosystem services, such as nutrient cycling (Gammal et al., 2017).

Ecosystems function as interconnected networks, where the existence and health of each species are interdependent. The removal or loss of a single species can disrupt this balance, leading to cascading effects throughout the ecosystem. Foundation species, which are those that have a disproportionate effect on their environment relative to their abundance, play a critical role in structuring communities and ecosystems. The loss of a foundation species can lead to significant changes at various ecological levels, from individual to community and ecosystem functioning (Sarà et al., 2021).

As an example, the paper by Sarà et al. (2021) underscores the cascading effects on the ecosystem following the loss of a foundational species due to Multiple Extreme Climate Events (MECEs). These effects manifest through several interconnected stages:

At the individual level, the study reports significant impacts of heatwaves and hypoxia, alone and in combination, on the oxygen consumption rates of a species of mussels. Survival analysis showed that the combined stressors of hypoxia and heatwave significantly reduced survival rates, underscoring the compounded detrimental effects of multiple stressors.

The decrease in mussel density led to significant changes in the abundance and species richness of associated macrobenthos. This relationship highlights the foundational role of mussels in structuring the community by providing habitat and influencing the trophic dynamics. The loss of the mussel resulted in a functional reordering of the pond's community, evident in the altered feeding behaviours and reduced diversity of macrofaunal species. The collapse of the mussel filtering machinery, a critical ecosystem function provided by this foundational species, resulted in increased water turbidity and altered sedimentary conditions, indicating a loss of trophic control within the ecosystem (Sarà et al., 2021).

Challenges

The exploration of the connections between biodiversity and ecosystem service provision, alongside the influence of biodiversity on ecosystem functioning, presents several complexities and challenges.

One primary challenge is the complex nature of ecosystem functions, especially when considering the scalability of ecological relationships within diverse and heterogeneous environments. Factors that

influence ecosystem functions, such as primary productivity, can vary significantly depending on the spatial and temporal scale of observation. This scale-dependent influence necessitates a multifaceted approach that integrates data from both small-scale experiments and large-scale observational studies to comprehend how these drivers operate and interact across different scales (Lohrer et al., 2015).

Environmental heterogeneity introduces a broad spectrum of conditions due to variations in physical, chemical, and biological factors. This variability complicates the extrapolation of results from small-scale experiments to larger scales because it might not accurately capture the complex interactions and feedback mechanisms occurring in natural ecosystems. Additionally, ecosystems are influenced by many external factors, such as weather conditions, further complicating the isolation of biotic interactions from abiotic environmental factors (Lohrer et al., 2015).

The complex interactions among species within an ecosystem suggest that changes in one component can have cascading effects on others, potentially amplifying or dampening overall ecosystem function. This complexity challenges researcher's ability to predict ecosystem responses to various stressors or management actions. The relationship between biodiversity, particularly in marine ecosystems, and productivity is still poorly understood, making it difficult to predict the effects of species loss on ecosystem performance and, by extension, ecosystem services (Buonocore et al., 2020; Price, 2001).

Another challenge highlighted is the limitation of scientific models to accurately account for threats. For instance, models assessing habitat quality often consider landscape threats to be additive, ignoring evidence that the collective impact of multiple threats can exceed the sum of individual threats. This oversight suggests that while models may treat threats as merely cumulative, the real-world interactions between different threats can amplify the overall impact on habitat quality. Furthermore, even when the area of focus is well-defined, it is part of a larger landscape, meaning that threats to habitats within the study area can also arise from adjacent areas outside of it. This could lead to an underestimation of the actual intensity of threats at the study area's margins, indicating that the model's approach might not fully capture the complexity of landscape-level interactions and their impact on biodiversity (Zullo et al., 2022).

To address these challenges, scientists advocate for multidisciplinary approaches to assess the effects on biodiversity and ecosystem services. For example, studying groundwater ecosystems with a focus on stygofaunal diversity requires medium- and large-scale assessments combined with conventional stygofaunal surveys and citizen-science initiatives to understand the impacts of urbanization and artificial recharge on groundwater ecology (Saccò et al., 2022). The complexity of species interactions and the ecological risks associated with climate change add further layers of difficulty in capturing all impacts, underscoring the need for ongoing efforts to fully understand and mitigate these effects (D'Agata & Maina, 2022).

The inherent complexity of this field of study, along with the multifaceted approaches required to investigate it, may result in an underestimation of the impacts on biodiversity. Mora et al. (2011) for example suggests in their work about the vulnerability of reef fish assemblages, particularly the most diverse, to anthropogenic stressors that the consequences of biodiversity loss in coral reefs have been greatly underestimated in recent studies (Mora et al., 2011).

Micro Level, Meso Level and Macro Level of Society

In the project, the analytical distinction between the micro, meso, and macro levels runs through the perspective on the research field. Regarding the current literature review, the following summary can be provided

The found literature does not directly address the micro level of society in terms of individual behaviours, perceptions, or actions within immediate social contexts such as families, workplaces, or friendship circles.

There is no explicit mention of interpersonal relationships, communication patterns, attitudes, and individual identity formation within small settings. Therefore, no results were found that directly pertain to the micro level of society.

At the meso level, which focuses on communities, organizations, institutions, and subcultures, the literature review outlines several instances where the ecosystem's health directly influences or is influenced by these intermediate-sized units. For example, the discussions on the critical roles of mangroves, mudflats and seagrass meadows, in providing ecosystem services such as supporting fisheries, tourism, and local economies are relevant. These ecosystem services directly influence and are influenced by the social norms, values, and behaviours of communities and groups residing in coastal regions. Furthermore, the participatory conservation strategies mentioned, involving co-creation with local stakeholders to enhance the resilience of coastal ecosystems, are aligned with the meso level's focus on how larger societal forces and individuals influence each other.

The literature extensively discusses macro-level concerns, highlighting societal-wide trends, governance structures, societal climates, political cultures, global crises, and systems such as economies and political systems. It emphasizes the significant threats coastal ecosystems face from climate change and human activities, such as urbanization, pollution, and habitat destruction. These pressures are macro-level phenomena that transcend individual and local contexts, affecting large-scale social processes and structures. The discussions on global biodiversity loss, its impact on ecosystem services, and the subsequent socio-economic implications, including the valuation of natural capital and the economic losses due to ecosystem degradation, reflect macro-level analysis. The role of international cooperation and the need for multidisciplinary approaches to address the effects of biodiversity loss on ecosystem service provision further underscore the macro-level perspective.

Further research and conservation strategies

There are still many uncertainties and research gaps within this field of study. Many authors call for further research to close these knowledge gaps.

The authors emphasize the need for a more profound comprehension of both direct and indirect anthropogenic impacts on coastal ecosystems. Furthermore, they highlight the significance of investigating species interactions and functional-level responses. Additionally, there is a call for further research on the importance and impacts of biodiversity on ecosystem service provision. Understanding these aspects can offer a more comprehensive view of the holistic properties of ecosystems and can inform strategies for their preservation and restoration. (Baker et al., 2013).

Beyond advocating for further research, various scholars propose specific conservation strategies to counteract the adverse effects of human activities:

Monitoring and assessing land use changes are critical activities for understanding and mitigating the impacts of human development on natural habitats. Strategic Environmental Assessments (SEAs) and Land Use and Cover Change (LUCC) analyses are two pivotal methods that play a significant role in this process (Rojas et al., 2019). By quantifying the extent of urban expansion and projecting future developments, SEAs enable policymakers and planners to anticipate and mitigate the negative consequences of such growth on biodiversity and ecosystem services. Land Use and Cover Change analyses, through the application of remote sensing and Geographic Information Systems (GIS), provide a powerful tool for real-time monitoring and quantification of changes in coastal areas due to urban expansion. These approaches help understand the historical and projected impacts of urbanization, thereby facilitating informed decision-making to balance developmental needs with environmental preservation (Rojas et al., 2019).

Numerous studies underscore the importance of sustainability measures to alleviate pressures on biodiversity. Marine Protected Areas (MPAs) have been highlighted as an effective strategy to safeguard marine and coastal species, given their role in optimizing fishery yields and conserving biodiversity (Price, 2001).

In response to urbanization and wetland concerns, Rojas et al. recommend revising urban planning to prevent wetland loss, conserve biodiversity, and maintain ecosystem services. Strategies might include amending zoning plans, restricting specific urban developments in sensitive areas, and integrating wetland conservation into urban strategies. The restoration and protection of degraded coastal ecosystems is also critical (Rojas et al., 2019).

International cooperation and a binding international agreement, as advocated by Hall-Spencer and Harvey (2019), are crucial for addressing the broad effects of climate change. Enhanced scientific cooperation can play a vital role in minimizing and addressing the impacts of climate change, providing a framework for nations to share knowledge, strategies, and technologies. Such cooperation can lead to more effective and equitable solutions to climate change, benefiting both developed and developing countries by pooling resources and expertise (Hall-Spencer & Harvey, 2019).

Addressing barriers such as local government policies, financial capacity, and communication and education needs is essential for implementing effective local responses to climate change, as noted by Zullo et al. (2022). Ecosystem-based adaptation emerge as practical local responses, but their implementation often faces significant obstacles. Overcoming these barriers requires a concerted effort from all stakeholders. Enhancing local capacities, improving policy frameworks, and investing in education and communication can empower communities to adopt more resilient and adaptive strategies in the face of sea-level rise (Zullo et al., 2022).

The integration of ecosystem service assessments into urban planning, as highlighted by multiple authors, is a pivotal strategy for promoting conservation within urban biodiversity hotspots. This approach can aid urban planners and managers by providing a deeper understanding of the contributions of various species to ecosystem services. By recognizing the intrinsic value of coastal biodiversity, planners can develop strategies that not only preserve but also enhance the ecological functions of urban areas, leading to more sustainable and resilient ecosystems (Liu et al., 2023; O'Farrell et al., 2012; Rojas et al., 2019).

In addition to changes and adaptations in policy structures, engaging the local public can be another powerful tool. For instance, raising public awareness about the significance of the impacts of human activities on ecosystems can enhance community engagement in conservation efforts (Rojas et al., 2019).

To illustrate the interconnection of various aspects within this complex topic, we will now elucidate the findings of a study conducted by Lee and Khim. The study focuses on biodiverse ecosystems in East Asia, which provide a range of crucial ecosystem services. (Lee et al., 2014).

These vital ecosystems are under threat from various sources. Urban expansion, land conversion for aquaculture and agriculture, and the construction of barriers like seawalls significantly disrupt tidal connectivity, leading to habitat degradation (Lee et al., 2006; Lee & Khim, 2017). The introduction of exotic, often invasive species, alters the native biodiversity and ecosystem functions, posing a risk to the ecological balance. Over-exploitation and direct removal of species for food or materials, combined with industrial and agricultural runoff, introduce pollutants that degrade water quality and contribute to habitat loss. These pressures, often interacting in complex and unpredictable ways, compromise the health and resilience of these ecosystems (Lee & Khim, 2017).

Considering these challenges, the authors advocate for several restoration measures, supported by scientific knowledge. They emphasize the crucial role of biodiversity in maintaining ecosystem functions

and services, acknowledging existing knowledge gaps, particularly in understanding the response of ecosystems like mangroves to changes in species diversity. A deeper comprehension of ecosystem properties, such as, stability, and resilience, is essential for predicting recovery trajectories and the impact of human interventions. Long-term monitoring is vital for effectively assessing ecosystem recovery (Lee & Khim, 2017).

The authors argue for an ecosystem-level synthesis that addresses the productivity, resilience, and recovery of coastal ecosystems, forming the basis for tailored restoration strategies. They propose a multidisciplinary approach that integrates hydrodynamics, ecology, geomorphology, engineering, and social sciences, ensuring the preservation of the ecological foundation of services while accommodating multiple uses. Evaluating the socio-economic benefits of restoration options and incorporating them into project success assessments is crucial for selecting strategies that offer the most significant benefits to both local and wider communities (Lee & Khim, 2017).They suggest actions to lessen the impacts of ocean acidification, including pollution reduction, seaweed cultivation, seagrass restoration, and adapting human activities like fishing. These strategies aim to strengthen ecosystem resilience and sustain the provision of critical ecosystem services (Lee & Khim, 2017).

Overall, the authors call for multifaceted approaches to conservation considering the interconnectedness of ecosystem functions and the various drivers of change within coastal environments. These approaches should not only preserve biodiversity but also maintain and enhance the multifunctionality of ecosystems and thereby ensuring the provision of ecosystem services in the face of anthropogenic pressures (IPCC 2021 WPI, IPCC 2019 SR).

3 HYPOTHESES AND QUESTIONS FOR THE CASE STUDIES

In the pursuit of understanding the intricate dynamics between coastal ecosystems and biodiversity loss, our literature review has elucidated the paramount role of biodiversity in sustaining ecosystem services essential for human well-being and environmental equilibrium. The profound interconnectedness of social and ecological systems, as highlighted through various studies, underscores the urgency of addressing the multifaceted challenges posed by biodiversity loss in coastal regions. Within this context, the PRO-COAST project endeavours to explore and validate innovative frameworks and methodologies, informed by the integrative Social Ecological Systems framework (SESF) and grounded in the pioneering contributions of Elinor Ostrom, for the conservation and sustainable management of coastal ecosystems.

The development and application of hypotheses and research questions that resonate with the broader objectives of the PRO-COAST case studies are pivotal for advancing our comprehension of coastal ecosystem dynamics and formulating effective conservation strategies. These hypotheses and questions not only serve as a foundation for empirical investigation but also facilitate the engagement of local stakeholders in a co-creative process that enhances the relevance and applicability of research outcomes. Thus, the subsequent sections delineate a series of hypotheses and research questions, distinguishing those inspired by the extant literature from those prompted by the research gaps identified therein.

Hypotheses and Research Questions Derived from Literature

Hypotheses:

1. Enhanced biodiversity within coastal ecosystems directly correlates with increased resilience and provision of ecosystem services, such as carbon sequestration, storm protection, and support for fisheries.

2. Anthropogenic activities, such as urbanization, pollution, and overfishing, directly correlate with the degradation of coastal ecosystems and loss of biodiversity, subsequently diminishing the ecosystem services they provide
3. Participatory conservation strategies, including co-creation with local stakeholders, significantly improve the implementation success of biodiversity conservation projects by tailoring solutions to local contexts and enhancing community engagement.

Research Questions:

1. To what extent does biodiversity contribute to the resilience of coastal ecosystems against climate change-induced stressors?
2. How do specific anthropogenic activities impact the functionality and service provision of different coastal ecosystems across European regions?
3. How does the variation in biodiversity within coastal ecosystems influence their capacity to offer crucial ecosystem services, such as carbon sequestration and storm surge protection?
4. In what ways do participatory approaches, specifically the Bristol Approach and Extreme Citizen Science, impact the effectiveness and sustainability of conservation initiatives in coastal ecosystems?

Hypotheses and Research Questions Arising from Identified Gaps

Hypotheses:

1. The resilience of coastal ecosystems to climate change-induced stressors is significantly moderated by the socio-economic dynamics of the adjacent human communities, particularly their openness and readiness for ecological conservation.
2. Integrative management approaches that account for both social and ecological dimensions of coastal ecosystems yield greater benefits for biodiversity conservation and ecosystem service provision than those focusing on a single dimension.
3. Implementing advanced technological solutions for ecosystem monitoring and conservation, in synergy with traditional ecological knowledge (TEK), markedly enhances the efficacy of biodiversity preservation efforts.
4. Co-creation processes with local stakeholders, utilizing the Bristol Approach and the Extreme Citizen Science framework, lead to more sustainable and locally adapted conservation outcomes in coastal ecosystems.

Research Questions:

1. What are the critical socio-ecological factors influencing the success of biodiversity conservation projects in coastal ecosystems within EU and non-EU areas?
2. How can socio-ecological models be refined to better predict the impacts of socio-economic factors on the resilience of coastal ecosystems to biodiversity loss?
3. What are the most effective strategies for integrating advanced technological tools with TEK in the design and implementation of biodiversity conservation projects?
4. How do different coastal ecosystems respond to similar conservation interventions, and what does this imply for the scalability and adaptability of conservation strategies across different European coastal regions?

4 CONCLUSIONS

The literature review undertaken for the PRO-COAST project delineates a comprehensive examination of coastal ecosystems, elucidating the critical role biodiversity plays in sustaining ecosystem services essential for both human well-being and environmental health. Through this review, we've navigated the complexities of coastal ecosystems, ranging from mangroves and seagrass meadows to mudflats and North African lagoons, spotlighting the multifaceted ecosystem services they provide.

Key Findings and Insights

The synthesis of findings underscores biodiversity as the linchpin of ecosystem resilience, essential for the delivery of a myriad of services, including carbon sequestration, flood regulation, and support for fisheries and local economies. This review highlights the profound threats imposed by anthropogenic activities and climate change, from urbanization and pollution to habitat destruction, exacerbating biodiversity loss and thereby compromising ecosystem services.

Emerging from the studies are the intertwined fates of coastal ecosystems and human communities, where the health of these ecosystems directly influences socio-economic outcomes and vice versa. The imperative of adopting integrative management approaches that encompass both social and ecological dimensions has been prominently underscored, aligning with the project's focus on co-creation with local stakeholders and based on frameworks like the Social Ecological Systems framework (SESF).

Implications for Theory, Practice, and Future Research

Theoretically, this review reaffirms the critical need to perceive biodiversity and ecosystem services within the holistic framework of social-ecological systems, advocating for an interdisciplinary approach that bridges ecological science with social sciences. Practically, it calls for an urgent and adaptive response to conservation, emphasizing co-creation and participatory approaches that respect local contexts and knowledge.

Future research should prioritize identifying the critical socio-ecological factors that influence the success of biodiversity conservation projects, exploring the scalability and adaptability of conservation strategies across diverse coastal regions. Therefore, further investigation needs to be carried out to understand exactly how such specific anthropogenic activities affect ecosystem functions, so as to take targeted interventions.

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REPORT 2: DIRECT AND INDIRECT DRIVERS OF BIODIVERSITY LOSS IN COASTAL ECOSYSTEMS

1 INTRODUCTION

1.1 Scope of the document

This report represents a crucial component of the "A PROactive Approach for Communities to Enable Societal Transformation (PRO-COAST)" project, funded by the European Commission. Within the ambit of this endeavour, the literature review presented herein serves as a foundational bedrock, meticulously collating and synthesising existing scholarly work to illuminate the multifaceted drivers—both direct and indirect—of biodiversity loss within coastal ecosystems. This investigation traverses various societal levels, ranging from the micro to the macro, seeking to elucidate the entities responsible and the mechanisms through which they exert influence.

Rooted in the objectives delineated in the project proposal, our inquiry is anchored around a central question: What are the main direct and indirect drivers of biodiversity loss in coastal ecosystems (on the micro, meso and macro level of society)? This question not only guides our scholarly pursuit but also fosters a unique collaborative synergy between natural and social scientists. Through this interdisciplinary cooperation, we aim to compile an exhaustive list of triggers and drivers underpinning biodiversity diminishment in coastal regions, buttressed by a comprehensive literature review spanning both scientific domains.

Objectives and Research Questions

The primary aim of this document is twofold: to meticulously define the direct and indirect catalysts of biodiversity reduction in coastal ecosystems and to pinpoint the responsible actors and their modes of impact. By adopting a holistic approach that integrates insights from both natural and social sciences, the document endeavours to

Identify and categorize the myriad drivers contributing to biodiversity loss at the micro, meso, and macro societal levels.

Explore the intricate web of responsibility, examining both human and non-human agents and the mechanisms through which they facilitate ecological degradation.

Moreover, this literature review serves as a scaffold for the broader PRO-COAST project, setting the stage for subsequent case studies that will go deeper into the identified themes. It establishes a framework for understanding the complex interplay between societal actions and coastal ecosystem health, thereby guiding future research endeavours and conservation strategies.

Boundaries and Limitations

In acknowledging the scope of this document, it is paramount to delineate its boundaries and limitations explicitly. The review is circumscribed to literature that addresses the intersection of human activities and coastal biodiversity, focusing specifically on the drivers of biodiversity loss. While it encompasses a broad spectrum of methodologies and perspectives, ranging from empirical studies to theoretical models, the document does not claim comprehensiveness in covering all possible influences on coastal ecosystems. Instead, it aims to highlight predominant trends, identify significant gaps in current knowledge, and suggest directions for future research.

Furthermore, the report acknowledges the inherent complexities and uncertainties associated with predicting ecological responses to human interventions. It, therefore, adopts a cautious approach, emphasising the provisional nature of its conclusions and the ongoing need for adaptive management strategies in the face of evolving environmental challenges.

1.2 Methods

The methodology for conducting the literature review entailed a structured search of academic databases to gather comprehensive insights into the drivers of biodiversity loss in coastal ecosystems.

The literature search was conducted using three prominent academic databases: Web of Science, Scopus, and Google Scholar. These platforms were chosen for their extensive coverage of scientific and social science literature, offering a broad scope of peer-reviewed articles, conference proceedings, and books relevant to our research questions.

The search strategy employed a combination of keywords and Boolean operators to capture the multifaceted aspects of biodiversity loss in coastal ecosystems. The keywords used in the search were structured as follows:

- Topic Keywords: (biodiversity loss AND coast* ecosystem*)
- Driver Keywords: (direct drivers OR indirect drivers OR threat)
- Anthropogenic Impact Keywords: (anthropogenic OR human impact)
- Business and Supply Chain Keywords: (business actors OR private companies) AND (supply chain)
- Consumption Keywords: (consume*)

The asterisk (*) symbol was used as a wildcard to ensure the inclusion of all possible variations of the root word, thereby widening the search scope.

The initial query on the Web of Science database using the sequence “((biodiversity loss) AND (coast* ecosystem*)) AND ((direct drivers) OR (indirect drivers) OR (threat)) OR ((anthropogenic) OR (human impact)) AND ((business actors) OR (private companies)) AND (supply chain) AND (consume*))” resulted in 194 publications. In a second step for further selection, the abstracts of these 194 publications were reviewed in pairs and sorted according to their relevance to the topic. This review resulted in 86 usable papers. Another search was conducted on the Scopus database using the sentence “((biodiversity loss) AND (coast* ecosystem*)) AND ((direct drivers) OR (indirect drivers) OR (threat)) OR ((anthropogenic OR human impact)) AND ((business actors) OR (private companies)) AND (supply chain) AND (consume*))”. The result comprised 29 publications, of which 19 were selected for further use in the second step. To ensure adequate coverage, we extended the search to Google Scholar, but limited the results to the first 150 hits. Here, we were able to gain a further 45 publications.

In addition to the studies identified through the initial keyword search, we also considered relevant literature cited within these sources that was not initially captured in our database search. This snowballing technique allowed us to incorporate valuable studies that directly addressed our research themes but might not have been initially detected due to variations in keyword use or database indexing discrepancies.

The review did not restrict the inclusion of studies based on geographic regions or the year of publication. This decision was made to ensure a comprehensive understanding of the global and historical context of biodiversity loss in coastal ecosystems, recognizing that drivers and impacts can vary significantly across different locations and over time.

The search results from each database were carefully screened for relevance based on titles, abstracts, and keywords. Selected studies were then subjected to a full-text review to ascertain their contribution to understanding the drivers of biodiversity loss, the specific role of human activities, and the involvement of business actors and supply chains. This meticulous process ensured that the literature review was grounded in robust evidence and encompassed a wide range of interdisciplinary perspectives.

1.3 Structure of the report

The report, structured into three key chapters, provides an in-depth examination of biodiversity loss in coastal ecosystems, dissected through societal levels: micro, meso, and macro.

Chapter 2: Literature Review dives into the factors behind biodiversity loss, highlighting human impacts like habitat destruction, pollution, and the introduction of invasive species. It covers historical human interaction with coastal zones, recent policy efforts for conservation, and the critical role of the Social Ecological Systems framework in understanding these interactions. It also discusses current research trends, emphasizing the necessity of integrated conservation strategies that bridge ecological, social, and economic domains.

Chapter 3: Hypotheses and Questions for the Case Studies builds on the literature review to pose hypotheses and questions that could possibly guide the PRO-COAST project's case studies. It differentiates between established hypotheses and those emerging from identified research gaps, focusing on the impacts of human activities, climate change, and the efficacy of conservation strategies.

Chapter 4: Conclusion synthesizes the report's findings, stressing the importance of multi-faceted conservation approaches that blend local knowledge with scientific research. It underlines the urgent need for comprehensive and enforceable conservation strategies to mitigate biodiversity loss effectively in coastal ecosystems.

2 LITERATURE REVIEW

2.1 Background and Context

As humanity confronts the escalating crisis of biodiversity loss, coastal ecosystems emerge as critical fronts in the battle to preserve the planet's biological wealth. These environments, characterised by their dynamic interplay between terrestrial and marine realms, are not only bastions of biodiversity but also provide essential services to human societies. From safeguarding against climate change impacts to offering resources and recreational spaces, the value of coastal ecosystems is immeasurable. However, these same qualities render them particularly vulnerable to a spectrum of anthropogenic pressures and environmental challenges. Climate change is an additional accelerating factor in this context (IPCC 2021 WPI, IPCC 2019 SR).

Historical Context

The degradation of coastal ecosystems is not a phenomenon of the modern era alone but a consequence of centuries of human interaction with these fragile environments. Historically, coastal regions have been central to human settlement, commerce, and industry, given their strategic importance for trade, fishing, and agriculture. This longstanding relationship has, over time, led to significant alterations in coastal landscapes, often to the detriment of their natural structures and functions. The advent of industrialisation and the global population explosion have only accelerated these impacts, leading to unprecedented levels of habitat destruction, pollution, and resource depletion. In this context, Hopkins (2008) underlines the necessity for a transition from oil dependency to local resilience, emphasising the critical need for

communities to adapt and become more self-sufficient. His perspective is particularly relevant when considering the broader implications of such environmental challenges on societal structures and the potential for sustainable transformation.

Political and Policy Developments

In response to the growing recognition of these challenges, there have been concerted efforts at both international and national levels to address the plight of coastal ecosystems. Key political and policy developments include the adoption of international conventions such as the Convention on Biological Diversity (CBD) and the Ramsar Convention on Wetlands. These frameworks aim to galvanise global action towards the conservation and sustainable use of biodiversity. Within the European context, initiatives like the EU Biodiversity Strategy for 2030 (2020) and the Marine Strategy Framework Directive (MSFD) (2008) reflect a commitment to reversing biodiversity loss and achieving good environmental status of marine waters.

Defining Key Concepts

Central to our discourse is the Social Ecological Systems framework (SESF), which offers a comprehensive approach to understanding the interdependencies between human societies and ecological systems. Rooted in the seminal work of Nobel Laureate Elinor Ostrom, SESF underscores the complexity of social-ecological interactions and the importance of governance structures in managing common-pool resources. This framework is pivotal to the PRO-COAST project's methodology, guiding its holistic examination of coastal ecosystem dynamics.

2.2 Current Research Landscape

2.2.1 Overview of Existing Literature

Coastal ecosystems, including sandy beaches, dunes, rocky shores, mangroves, coral reefs, estuaries, and salt marshes, serve as dynamic interfaces between terrestrial and marine environments. These areas are not only biodiverse but also essential for ecological functions, offering resources, recreational opportunities, and protection against climate change for human societies. However, this biodiversity and productivity also render them vulnerable to human-induced pressures and climatic alterations.

Our literature review identifies numerous direct and indirect drivers contributing to the loss of biodiversity. These include the impact of population growth, habitat destruction, pollution, overexploitation, alteration of natural processes, and climate change-related phenomena such as rising temperatures, sea-level rise, and extreme weather events.

The reviewed studies have various focuses—some investigate specific threats like plastic pollution or overfishing, while others explore the impacts of a range of influences on particular regions. We will go further to see the unique communities of the coastal habitat and the critical roles that these include for nutrient cycling and energy transfer—all threatened by the burgeoning threats.

In examining the challenges, issues, and controversies surrounding conservation efforts, the review discusses multiple, often interacting threats, complicating the protection of these biodiverse and ecologically crucial areas. Notably, the analysis emphasises the gap between scientific understanding of the challenges facing these habitats and the adoption of effective conservation strategies.

There is a clear consensus within the literature on the necessity of adopting multi-faceted conservation strategies. These strategies must involve a synergy of local knowledge, scientific research, robust regulatory frameworks, and an expansion of protected areas. A collaborative approach is advocated for,

underscoring the need for integrated solutions that span governmental regulation, sustainable tourism practices, and active community involvement.

2.2.2 Recent Trends and Developments

The current body of literature reflects a growing recognition of the interconnectedness of coastal ecosystems and the multifarious impacts of human activities. From the escalating pressures of population growth and urbanization to the pervasive threats of climate change and pollution, researchers are increasingly adopting integrative frameworks that transcend traditional disciplinary boundaries. These trends underscore the importance of synthesizing knowledge across ecological, social, and economic domains to address the emergent challenges of conservation.

Recent methodological advances have facilitated a deeper understanding of the drivers of biodiversity loss. Landscape-scale analyses, coupled with remote sensing technologies, have allowed for the monitoring of habitat changes and species distribution patterns over time. Additionally, advances in molecular ecology are providing insights into the genetic diversity and resilience of coastal species. Participatory approaches, including citizen science and stakeholder engagement, have also gained traction, enriching the research with local knowledge and fostering community-led conservation efforts.

Theoretical developments in the field have been informed by the recognition of coastal ecosystems as socio-ecological systems. This has inspired a shift towards resilience thinking and adaptive management, emphasizing the capacity of these systems to withstand and recover from disturbances. The concept of ecosystem services has also been pivotal, highlighting the tangible and intangible benefits that humans derive from coastal biodiversity and the consequential socio-economic ramifications of its loss.

The field has witnessed a paradigm shift with the growing acknowledgment of the Anthropocene epoch, where human actions constitute the dominant environmental force. This has led to a reframing of conservation strategies, acknowledging the need for proactive and anticipatory approaches in the face of uncertainty. Moreover, the rise of interdisciplinary research clusters and collaborative networks is promoting a more holistic and concerted response to the conservation of coastal ecosystems.

2.2.3 Key Studies and Findings

Coastal regions function as the dynamic intersection between terrestrial and marine environments and are among the most diverse and significant ecosystems on our planet. They harbor a remarkable diversity of habitats and species. Examples of coastal ecosystems are sandy beaches, dunes, rocky shores, mangroves, coral reefs, estuaries and salt marshes. Each of these habitats supports unique communities of organisms adapted to the specific conditions of their environment (Suchanek, 1994).

The ecological complexity of coastal zones is further enhanced by the gradients of salinity and temperature, as well as by the influences of terrestrial and marine nutrient inputs (Vilas-Boas et al., 2021). Such environmental gradients create niches for a plethora of organisms, ranging from microscopic phytoplankton and zooplankton, which form the base of food webs, to a variety of fish, birds, mammals, and invertebrates (Medail & Quezel, 1997).

Amongst the significance of coasts for ecological functions they offer resources, recreational opportunities, and protection against climate change for humans. However, the very diversity and productivity that make coastal ecosystems invaluable also render them susceptible to human-induced pressures and climate change (McDougall, 2017, IPCC 2021 AR6 WGI, IPCC 2019 SR).

Our review of the relevant literature revealed a variety of indirect and direct drivers for biodiversity loss in coastal ecosystems. Coastal ecosystems are increasingly under pressure due to population growth and an increasing density of human populations residing in proximate areas (Doxa et al., 2017). Anthropogenic

activities impact these ecosystems in multiple ways including habitat destruction, pollution, overexploitation, and the alteration of natural coastal processes. Moreover, climate change poses a significant threat to these ecosystems by inducing higher temperatures, sea level rise, and more frequent occurrences of extreme weather events (Kennish, 2001, 2019, IPCC 2019 SR).

Each study within the literature review contributes to an understanding of biodiversity decline in coastal regions, yet they diverge in their specific areas of emphasis. Some papers concentrate on particular threats to biodiversity, whereas others investigate the impacts on regions from a range of influences. Our analysis begins by identifying the key direct and indirect factors contributing to biodiversity loss in coastal zones. We will then focus on specific regions, studying how they are impacted by a multitude of threats. Additionally, we will pinpoint key challenges, issues, and controversies surrounding conservation efforts. Finally, we will present strategies suggested for biodiversity conservation and identify existing research deficiencies.

The Impact of Population Growth on Coastal Ecosystems

As Earth's human population continues to rise, the strain on coastal ecosystems intensifies significantly. Coastal areas are highly attractive for living, tourism, and industry. As the population grows, the demand for residential and commercial development increases. This leads to habitat destruction, increased pollution, and alteration of coastal landscapes (Kennish, 2002). The construction of buildings, roads, and other infrastructure often leads to the loss of crucial habitats that protect against erosion and support biodiversity. Moreover, the surge in population heightens the demand for marine resources, leading to overfishing and resource depletion (Fraschetti et al., 2011). Pollution is another significant consequence of population growth. The accumulation of sewage, plastic waste, and agricultural runoff in coastal waters results in eutrophication, harming marine life and coral reefs (Kennish, 2002, 2019). Furthermore, coastal regions are on the frontline of climate change impacts, which are exacerbated by population growth (IPCC 2021 AR6 WGI, IPCC 2019 SR) . The increased density of people and infrastructure in these areas amplifies their vulnerability to sea-level rise, extreme weather events, and ocean acidification (Kennish, 2001, 2019). The phenomenon of "coastal squeeze," where natural habitats have no room to migrate due to urban development, is a direct result of expanding coastal populations (Luisa Martínez et al., 2014).

Plastic pollution

The review of literature reveals the multifaceted threat posed by litter, especially plastic litter to the biodiversity of marine and coastal ecosystems. It underscores how plastic pollution affects biodiversity not only in proximate locales such as beaches frequented for recreation but also in distant areas, like remote islands where plastic debris accumulates. This pollution stems from various sources, broadly categorized into land-based and ocean-based origins (Thushari & Senevirathna, 2020).

Land-based sources are the predominant contributors, accounting for over 75% of marine plastic pollution. These sources are closely linked to areas with high human activity, including urban, residential, and industrial zones. Factors such as freshwater runoff, residential waste, tourism, and harbor operations are significant contributors, funnelling plastics from terrestrial to marine environments through rivers and streams. Ocean-based sources, on the other hand, include activities related to commercial fishing, navigation, and the abandonment of fishing gear, all of which contribute to the marine plastic load (Andrady, 2011).

Beach litter, particularly plastics and polystyrene, serves as a direct anthropogenic driver of biodiversity loss in coastal ecosystems (De Francesco et al., 2018). Direct effects include the ingestion of plastics by wildlife, leading to internal blockages or poisoning, and entanglement in debris, which can cause physical harm, immobilization, or even death (Kennish, 2002; Thushari & Senevirathna, 2020). Indirectly, litter alters

natural habitats, affecting the availability of resources and the physical structure of environments where species live and reproduce. Litter, especially plastics, can persist in the environment for long periods, leading to long-term ecological impacts (Gall & Thompson, 2015).

The study by Lavers et al. highlights the profound impact of plastic debris on species distant from the initial pollution sources, focusing on hermit crab populations on remote islands. This research illustrates the extensive reach of plastic pollution, affecting wildlife in regions untouched by human habitation. On the Cocos Islands alone, it is estimated that around 508,000 hermit crabs perish annually due to entrapment in plastic debris (Lavers et al., 2020). The significant loss of hermit crabs underscores the broader ecological implications of plastic pollution. As these crabs play crucial roles in their ecosystems, including the decomposition of organic matter and enhancing nutrient cycling, their decline adversely affects soil fertility and overall ecosystem health (H. Lindquist, 2014)

Further exacerbating these challenges, plastic litter can act as a vector for the introduction of invasive species. Plastics floating in the ocean act as makeshift rafts, enabling organisms to traverse vast distances to new habitats. These hitchhikers may colonize areas where they have no natural predators, potentially unsettling local ecosystems. The introduction of non-native species can lead to competition with indigenous species for resources, predation on native species, and alterations to the structural integrity of habitats. This phenomenon not only exacerbates the challenges faced by already stressed ecosystems but also highlights the complex, interconnected nature of plastic pollution's impact across the globe (Thushari & Senevirathna, 2020).

Overfishing

Overfishing stands as a paramount threat to the biodiversity of marine and coastal ecosystems, directly and indirectly impacting various species. Research elucidates several mechanisms through which overfishing jeopardizes these ecosystems. The most immediate and direct consequence is the precipitous decline in the populations of targeted species. This effect is particularly pronounced in species with slow reproductive rates, such as sharks, rays, and other long-lived marine creatures, pushing them towards the brink of extinction (Dulvy et al., 2021). Overfishing can instigate trophic cascades by eliminating top predators like sharks, thereby disrupting the equilibrium of marine food webs. Such disturbances may lead to the proliferation of prey species, which in turn could excessively consume primary producers, undermining the biodiversity and health of the ecosystem. The alteration in species composition, spurred by overfishing, reshapes the dynamics of competition and predation, potentially fostering the dominance of a limited number of species, thereby diminishing biodiversity and altering the functionality of ecosystems (Eduardo et al., 2020).

Dulvy's 2021 study underscores overfishing as a critical threat to the survival of sharks, rays, and chimeras, noting a distressing increase in the threat level to these species, with 32.6% now facing the threat of extinction—an uptick from earlier assessments. The overexploitation of these species, affecting both pelagic and coastal zones crucial for their breeding, feeding, and migration, precipitates imbalances within marine ecosystems, including coastal habitats, with potential for wide-ranging ecological ramifications (Dulvy et al., 2021).

Despite existing conservation measures, sharks and rays continue to be overfished due to insufficient enforcement of regulations, lack of awareness, high demand for their products, bycatch, and the global nature of their trade, which complicates management (Dulvy et al., 2021). The slow reproductive rates of these species also make them particularly vulnerable to overfishing, as they cannot replenish their populations quickly enough to keep pace with the rate at which they are being removed from the oceans (Cortés, 2016; Dulvy et al., 2021).

Beach grooming

Another direct anthropogenic driver of biodiversity loss is beach grooming. Beaches are groomed primarily for aesthetic and recreational purposes to create clean, appealing sandy areas for tourists and locals. This involves removing debris, seaweed, and litter, and sometimes leveling the sand to make the beach more attractive and comfortable for visitors (Dugan, 2003).

Dugan and Hubbard demonstrate how beach grooming has led to a large-scale transformation of coastal strand ecosystems into unvegetated habitats. This process significantly reduces the abundance and diversity of native plants and alters physical and biological aspects of these ecosystems. The study shows that groomed beaches have wider unvegetated zones and significantly lower macrophyte wrack cover, which serves as a crucial habitat and food source for various macroinvertebrate species. The mechanical process of grooming not only removes this natural debris but can also disrupt the sand structure, affecting organisms living within the sand (J. E. Dugan & Hubbard, 2010; Gilburn, 2012).

Invasive species

Multiple papers highlight the escalating threat of invasive plant species on biodiversity of coastal ecosystems (Celesti-Grapw et al., 2016; Mancuso et al.,2023). Non-native plant species increase significantly in diversity and distribution. Examples of taxa are acacias and succulents (Celesti-Grapow et al., 2016). They threaten the natural ecosystems by outcompeting native flora for resources, altering habitat structures and functions, disrupting food webs, and changing soil chemistry (Richardson et al., 2000). These invasive species often have few natural predators in new environments, allowing them to proliferate rapidly and dominate landscapes. This leads to a reduction in biodiversity, affects the survival of native plants and animals, and can alter ecosystem services upon which humans and wildlife depend, such as water purification, flood regulation, and carbon sequestration (Mancuso et al., 2023). The drivers of the invasion of plant species include human activities that lead to habitat disturbances, climate change that can alter ecosystem conditions favouring invasive species, and globalization that facilitates the spread of species across regions, or the introduction of invasive species intentionally eg. for agricultural purposes (Lambdon et al., 2008b; Richardson et al., 2000).

The literature underscores the significant threat posed by invasive species to Mediterranean islands (Celesti-Grapow et al., 2016). Islands are particularly susceptible to invasive species, largely due to their unique ecological and geographical characteristics. Because of the isolation of island species, they are not adapted to cope with the pressures exerted by invasive species. Many island species occupy highly specialized niches due to the limited resources available. This specialization can make them particularly sensitive to changes in their environment (Elton, 2020; Lambdon et al., 2008a).

Additionally, the construction materials and design of marine infrastructure, such as seawalls docks, piers, and breakwaters, often create environments that are particularly conducive to the establishment of invasive species. Concrete structures, with their smooth surfaces, are especially prone to colonization by opportunistic and invasive species that thrive in man-made environments. These structures often lack the complexity and diversity of natural habitats, favouring the establishment of non-indigenous species over native ones (Bulleri & Airoldi, 2005).

Eutrophication

Human-induced nutrient enrichment, commonly known as eutrophication, is a process resulting from the excessive introduction of nutrients, notably nitrogen and phosphorus, into aquatic ecosystems. This influx primarily stems from agricultural runoff and sewage discharge (Johnson & Harrison, 2015). The surplus of nutrients promotes the rapid growth of algae, which can lead to several detrimental environmental effects. One of the immediate consequences of algal overgrowth is the depletion of oxygen levels in the water

body. When algae die, their decomposition consumes a significant amount of oxygen, which can lead to hypoxic conditions or "dead zones" where aquatic life cannot survive. This oxygen depletion not only affects fish and invertebrate populations but can also lead to broader ecosystem imbalances (Malone & Newton, 2020). Moreover, algal blooms can obstruct sunlight from reaching important underwater plant life, such as seagrass meadows. These plants rely on photosynthesis to produce energy and oxygen, and shading from dense algal layers can reduce their ability to thrive. Seagrasses are crucial for coastal ecosystems as they provide habitat and food for a wide array of marine organisms, stabilize sediments, and help to improve water quality (Scapin et al., 2018).

Eutrophication can also alter the composition of aquatic ecosystems by favouring species that thrive in nutrient-rich and low-oxygen environments. This shift can lead to trophic homogenization, where the diversity of food webs is reduced, and ecosystems become dominated by a smaller variety of species (Chihoub et al., 2020).

The threat to biodiversity is further explained by the example of copepod species. Copepod species play a crucial role in aquatic ecosystems as a key component of the zooplankton community. They serve as a vital link in the food web, transferring energy from primary producers, like phytoplankton, to larger predators (Beaugrand et al., 2003). Copepods are important in nutrient cycling, as they consume phytoplankton and are preyed upon by higher trophic levels, effectively recycling nutrients back into the ecosystem (Mitra et al., 2014). Their diversity and abundance make them essential for the health and stability of marine and freshwater ecosystems, supporting biodiversity and fisheries. Eutrophication affects the diversity of copepod species by favouring omnivorous copepods over specialists (Chihoub et al., 2020). Species homogenization of ecosystems is problematic because it leads to reduced biodiversity, making ecosystems more vulnerable to diseases, pests, and environmental changes. It can diminish the resilience of ecosystems to withstand stressors and recover from disturbances, leading to a loss of ecosystem services essential for human well-being, such as clean water, food, and climate regulation. Homogenization can also result in the loss of unique species and the genetic diversity necessary for adaptive responses to environmental changes (Levin et al., 2001).

Additional environmental pressures, including overfishing, coastal development, and climate-driven phenomena such as warming and acidification, intensify the effects of eutrophication. For instance, declines in large predatory fish populations have been shown to exacerbate eutrophication by weakening grazer control of algal biomass. This scenario, observed in the Baltic Sea, highlights a direct interaction between fishing pressures and the impacts of nutrient enrichment (Malone & Newton, 2020).

Lacking knowledge/ecological consideration in coastal infrastructure construction

The literature reveals that insufficient knowledge or disregard for environmental considerations in coastal infrastructure development can lead to biodiversity decline.

The concentration of populations along coastlines often necessitates extensive shoreline modification, which can severely alter or completely destroy natural shorelines, (J. E. Dugan et al., 2011). Furthermore, natural coastal habitats are increasingly being replaced with human-made structures such as ports, marinas, revetments, and breakwaters (J. E. Dugan et al., 2011). Traditional coastal infrastructure, characterized by its low surface complexity and non-natural composition, fails to provide the conditions necessary for the development of diverse biological communities (McManus et al., 2018). As a result, these artificial structures are frequently dominated by invasive species (Bulleri & Airoldi, 2005). Concrete, a material commonly used in coastal and marine construction, offers a particularly poor substrate for marine flora and fauna. Its widespread use is problematic due to its high pH levels and the leaching of

hostile compounds, which generally support low biodiversity and a high proportion of invasive species (McManus et al., 2018).

Additional stressors include the replacement of natural shorelines with artificial structures such as seawalls (Hou et al., 2022). These constructions compress the intertidal zone and diminish water retention capabilities, leading to reduced biodiversity in the coastal zone. The primary issues stem from the physical characteristics of artificial seawalls, such as vertical walls or steep slopes, which lack the complex features found in natural shorelines that nurture diverse biological communities (Chapman & Blockley, 2009).

The development of coastal infrastructure is often driven or intensified by tourism, which is increasingly concentrated in coastal regions. Tourism development in coastal zones often leads to an increased expansion of impervious land and, therefore, to habitat fragmentation and degradation. Furthermore, tourism facilities frequently choose locations on the borders of protected areas, which can affect wildlife and biodiversity (Lagarias, 2023). Often, economic profit is prioritized over sustainability concerns (Kousis, 2004).

Climate change

Climate change affects coastal ecosystems through a variety of impacts, including increased air temperatures, reduced precipitation, heightened intensity of precipitation events, severe droughts, and sea-level rise (IPCC 2021 AR6 WGI, IPCC 2019 SR). These changes contribute to a range of adverse effects such as coastal erosion and saltwater intrusion (Chilton et al., 2021). Such impacts can disrupt the ecological balance, affecting both marine and terrestrial species dependent on these ecosystems for survival, breeding, and food (Andreasen et al., 2001).

Within the literature sea level rise is considered one of the main threats to biodiversity. Sea-level rise poses a significant threat to various species for example through habitat destruction, or altered sediment composition (Dixon et al., 2023). As rising seas submerge habitats, essential habitats for numerous endangered species are lost. Consequently, this leads to diminished food sources and intensified competition for the remaining resources, exacerbating the survival challenges these species face (Lopez, 2015; Seney et al., 2013). Moreover, alterations in salinity and the flooding of freshwater habitats can severely impact the health and distribution of a wide range of coastal and marine species (Kingsford et al., 2016).

Benthic species for example which are crucial for nutrient cycling and energy transfer within aquatic ecosystems are vulnerable to environmental changes such as sea level rise (van der Linden et al., 2017; Wouters et al., 2018). Increased water levels can drown certain habitats, reduce the area of intertidal zones, and lead to saltwater intrusion. As habitats become submerged or altered, species must adapt, migrate, or face extinction, leading to changes in community structure and potentially reducing biodiversity and ecosystem functioning (Dixon et al., 2023).

Sea-level rise significantly endangers not just aquatic and semi-aquatic species but also terrestrial wildlife, such as the Florida Panther, the Loggerhead Sea Turtle, and the Marsh Rabbit. These species, each dependent on distinct coastal habitats, face unique challenges that underscore the complex nature of sea-level rise impacts. The Florida Panther, for instance, relies on upland forest habitats that can be fragmented or lost entirely as sea levels rise. Loggerhead Sea Turtles depend on beaches for nesting, which can be eroded or submerged, disrupting their reproductive cycles. Similarly, the Marsh Rabbit's salt marsh habitats are vulnerable to submersion and salinity changes, threatening their survival (Lopez, 2015).

Multiple pressures

While previously we have focused on single direct and indirect drivers for biodiversity loss, we will now focus on ecosystems threatened by multiple stressors.

In many papers scientists studied specific coastal regions identifying complex challenges, illustrating, that in most cases, coasts are not only threatened by one stressor, but by multiple (Suchanek, 1994).

The example of wetlands illustrates how ecosystems often are threatened by multiple factors. Wetlands are an integral part of coastal ecosystems. They include mangroves, salt marshes, and estuaries, lying at the transitional zone between land and water and are influenced by both marine and freshwater systems. Wetlands contribute to biodiversity by offering food, breeding grounds, and shelter. Additionally, they provide many ecosystem services such as water quality improvement and coastal protection (Dudgeon et al., 2006; Zedler & Kercher, 2005). The paper emphasizes that despite their critical importance, wetlands are among the most threatened ecosystems (Kingsford et al., 2016).

The alteration of upstream flow regimes through the construction of dams and water diversion for agriculture has a dual impact: it directly destroys or diminishes wetland areas and indirectly affects downstream wetlands through cascading effects on biodiversity and ecological functions. Development activities, including urban expansion, agricultural encroachment, and flood mitigation efforts, further exacerbate these impacts by altering natural flow patterns and leading to significant habitat destruction. Climate change adds another layer of complexity by altering hydrological cycles, which affects water availability, quality, and ecosystem health in wetlands, and creates conditions conducive to the invasion of alien species (Kingsford et al., 2016). The introduction of invasive species, often facilitated by human-altered flow regimes, reduces species diversity and affects the structural complexity of habitats, thereby impacting ecosystem processes and trophic interactions. Additionally, the accumulation of pollutants, such as pesticides, herbicides, and heavy metals, particularly through activities like irrigation, leads to further degradation of wetland ecosystems (Dudgeon et al., 2006; Kingsford et al., 2016; Zedler & Kercher, 2005).

Another example is Negril, a popular tourist destination in Jamaica. It is characterized by sandy beaches, coral reefs, seagrass beds, and mangroves (McDougall, 2017; Mcintyre, o. J.). These ecosystems provide habitats for a wide variety of species, they provide water filtration, coastal protection, mitigate erosion and buffer against the impacts of climate change and sea-level rise (McDougall, 2017).

The ecosystem is threatened by coastal erosion, climate change, and human activities such as tourism development, pollution, and inadequate waste management (McDougall, 2017). For instance, coastal development impedes natural beach dynamics and, combined with climate change, contributes to coastal squeeze, where species lose their capacity to migrate inland (Cambrollé et al., 2018; McDougall, 2017). This situation is worsened by sea level rise and increased storm intensity, which enhance the erosive forces acting on the coastline (Nicholls et al., 2007). The degradation of marine communities, including coral reefs, seagrasses, and mangroves, due to pollution and physical damage, further diminishes the coastline's natural defences against erosion (Orth et al., 2006). These ecosystems, which serve as critical buffers against storms and erosion, are weakened by human activities, leading to decreased coastal protection and increased vulnerability to erosion and storm damage (Orth et al., 2006; Ten Ham et al., 2006). Additionally, the alteration of natural water flows due to development and inadequate sewage treatment contributes to eutrophication, reducing water quality and further stressing marine ecosystems. The accumulation of nutrients in coastal waters from agricultural runoff and sewage discharges fuels the growth of harmful algal blooms, which can deplete oxygen levels in the water, causing dead zones and affecting marine life and biodiversity (Gray et al., 2002; Rabalais et al., 2009).

These threats are interconnected, as the degradation of natural barriers like coral reefs and seagrass beds increases the vulnerability of the coastline to erosion and pollution, which in turn can lead to further habitat loss and decreased biodiversity (McDougall, 2017; Rabalais et al., 2009; Shadrin, 2013, IPCC 2019 SR).

Cascading effects

The scientific literature we studied consistently illustrates the profound impact that the loss of a single species can have on an ecosystem, highlighting interdependencies among species and ecological processes (Dixon et al., 2023). Each species occupies a unique niche within the food web, serving as predator, prey, or both. Consequently, the removal of a species can precipitate a cascade of effects, leading to imbalances within the ecosystem. For instance, a decline in predator populations can cause their prey numbers to swell, potentially leading to overgrazing and subsequent vegetation damage (Mahanes et al., 2023; Paine, 1992). Species such as hermit crabs play a crucial role in nutrient cycling through the decomposition of organic materials. Their absence can impede this process, adversely affecting soil fertility and plant growth, which in turn impacts the broader food chain dependent on those plants (E. S. Lindquist et al., 2009).

Moreover, certain species are instrumental in creating or maintaining habitats that other species rely on for survival. Seagrass meadows, for instance, offer shelter to a diverse array of marine life; their deterioration can displace numerous (Scapin et al., 2018). The loss of even a single species can disrupt these complex interactions, leading to a decline in ecosystem function, resilience, and biodiversity. The literature provides numerous examples of this dynamic (Paine, 1992; Scapin et al., 2018). For example, seagrass meadows offer vital functions for various species but are threatened by eutrophication, macroalgal blooms, sediment disturbances, and direct mechanical destruction (Adriano, Chiara, & Antonio, 2005; Adriano, Chiara, Sonia, et al., 2005). These threats have led to a significant reduction in populations of pipefishes and seahorses that depend on seagrass meadows (Scapin et al., 2018).

Challenges, unresolved issues and controversies

Within the literature there are many challenges, unresolved issues and controversies described.

Coastal ecosystems, such as coral reefs, mangrove forests, and salt marshes, are highly vulnerable systems. Coral reefs for example depend on a narrow range of temperature and are susceptible to bleaching when water temperatures rise too high. Similarly, salt marshes are affected by changes in salinity levels and water flow patterns (Kennish, 2002). These ecosystems host a high diversity of species that are often highly specialized and interdependent (Ahnesjö & Craig, 2011; Vincent et al., 2011). This makes these ecosystems more vulnerable to disturbances, and the loss of a few species can have cascading effects on the entire ecosystem (Vasconcelos et al., 2007). Additionally, being at the interface between terrestrial and marine environments, these ecosystems are subject to impacts from both sides (Levin et al., 2001). For example, land-based activities can lead to increased sedimentation and pollution in coral reefs, while changes in sea levels and marine conditions can alter salt marsh dynamics (Kennish, 2001). These special ecosystems are challenging and slow to recover once damaged (Vincent et al., 2011).

The vulnerability of coastal ecosystems intensifies due to the substantial number of individuals residing in and visiting these regions, introducing additional complexity and conflict into conservation efforts (Doxa et al., 2017). The presence of large human populations increases pollution, accelerates habitat destruction, and heightens the demand for marine resources, exacerbating the threats to these ecosystems (Kennish, 2002; Vasconcelos et al., 2007). Additionally, the tourism industry, attracted by the natural beauty and biodiversity of these areas, often contributes to their degradation through activities that can physically damage habitats and disrupt ecological (Bulleri & Chapman, 2010).

Unfortunately, the extensive scientific literature documenting the multitude of anthropogenic threats to coastal ecosystems underscores that conservation strategies necessary to mitigate these pressures are far from universally implemented (Cambrollé et al., 2018; McDougall, 2017, IPCC 2021 AR6 WGI, IPCC 2019 SR). The volume of research highlights a critical gap between the understanding of human-induced challenges facing these vital habitats and the widespread adoption of effective conservation measures. Therefore, many scientists call for conservation actions within the scientific literature.

The presence of multiple, often interacting, threats complicate efforts to protect these biodiverse and ecologically crucial areas (Fraschetti et al., 2011). Anthropogenic drivers compound natural threats derived from climate change (see Kennish, 2002). Pollution, resulting from agricultural runoff, sewage discharge, and industrial effluents, introduces toxic substances into coastal waters, leading to eutrophication and harmful algal blooms. Coastal infrastructure development, including the construction of resorts, marinas, and sea walls, often leads to habitat alteration and fragmentation, further stressing these ecosystems (Bulleri & Chapman, 2010). Moreover, direct human activities such as overfishing and destructive fishing practices deplete marine resources and disrupt ecological balances (Eduardo et al., 2020). This situation is further complicated by the inherent challenges associated with managing transitional zones that are influenced by both terrestrial and marine factors. The convergence of these stressors on coastal ecosystems makes the task of implementing effective conservation measures particularly difficult. Despite the recognition of their vulnerability and the clear need for targeted action, the complexity and interconnected nature of the challenges at hand often hinder the development and execution of comprehensive management strategies (Fraschetti et al., 2011).

In numerous instances, conservation measures for coastal ecosystems have indeed been initiated; however, these efforts often fall short in scope or suffer from inadequate enforcement by relevant authorities (McDougall, 2017).

Furthermore, lacking scientific knowledge often hinders the implementation of effective conservation strategies (Hooper et al., 2005). As previously noted, these ecosystems are highly interconnected and complex, with the loss of key species triggering cascading effects throughout the system. Without a deep, systemic knowledge of ecosystem interdependencies and the specific requirements for the survival of various species, conservation efforts may not fully address the critical challenges or exploit the opportunities for resilience and recovery (Cambrollé et al., 2018).

In the case of Negrils Beach the threats to the ecosystem are attributed to a combination of ineffective governance, the pressures of tourism, and the lack of community engagement in conservation efforts. The paper details how these factors are responsible for environmental degradation in Negril:

Firstly, the government's ineffective policies and lack of enforcement have led to environmentally damaging practices such as sand mining in Long Bay, which exacerbates coastal erosion. Amendments to laws that undermine established environmental protections, such as allowing construction in setback zones and ignoring the carrying capacity of the barrier beach system, have further degraded the ecosystem (McDougall, 2017).

Secondly, the economic dependence on tourism has driven developments that neglect the environmental cost. The pursuit of tourist dollars has prioritized short-term economic gains over long-term sustainability, leading to harmful algae blooms, increased erosion, and a decline in water quality. Despite the economic incentives, less than half of the hotels in the Caribbean region have adopted environmental policies, indicating a significant gap in the integration of environmental conservation with business practices (Shah, 2011). And lastly, the lack of community involvement in planning and decision-making processes has been a barrier to effective conservation management. Although there have been efforts to engage the

community, such as the Negril Coral Reef Preservation Society's (NCRPS) engagement in environmental protection planning and zoning of the Negril Marine Park, challenges remain in achieving sustainable management of the ecosystem (McDougall, 2017).

Micro, meso and macro levels of society

The review does not explicitly delineate findings specific to the micro level, defined as individual or small group interactions and their direct impact on coastal biodiversity. However, it does indirectly reference micro-level activities through descriptions of behaviors contributing to habitat destruction, such as pollution (notably plastic pollution) and overexploitation of marine resources. Individual and small group actions, such as local fishermen engaging in overfishing or households contributing to plastic pollution, can be inferred as contributing factors at this level.

At the meso level, which focuses on communities, organizations, and institutions, the review highlights several key areas where meso-level entities influence coastal biodiversity. This includes the impact of coastal development and tourism, pollution from agricultural runoff and sewage, and the introduction of invasive species facilitated by human activities. Local governance and policies that fail to protect or actively harm coastal ecosystems (e.g., ineffective regulations or policies encouraging harmful coastal development) are critical at this level. The lack of community engagement in conservation efforts and the pressures from tourism development exemplify meso-level dynamics impacting coastal ecosystems.

The review also reveals substantial evidence of macro-level drivers affecting coastal biodiversity, including global climate change impacts such as sea-level rise, increased temperatures, and extreme weather events. Large-scale economic pressures leading to overfishing and the global proliferation of plastic pollution are also significant. Moreover, the broader economic and political frameworks that shape conservation efforts, international collaboration or conflicts over environmental policies, and the global nature of trade contributing to invasive species spread are highlighted as macro-level challenges.

Call for action

Our comprehensive review of the literature underscores the critical importance of adopting multi-faceted conservation strategies to address the pressing challenges of biodiversity loss and coastal ecosystem degradation. There is a consensus that conservation efforts require a variety of measures implemented at the micro, meso, and macro levels:

An essential component of these strategies involves integrating local knowledge with scientific understanding. This approach not only enhances the effectiveness of conservation measures but also ensures they are culturally and contextually relevant. It emphasizes the importance of participatory vulnerability analysis that considers social, cultural, environmental, economic, and political dimensions, highlighting the need for a deeper comprehension of ecosystem services. These services are multifunctional and require an understanding of chain reactions within ecosystems to ensure their effective protection (Fatorić & Morén-Alegret, 2013).

Furthermore, the literature calls for enhanced political willpower and cohesive actions across all governmental tiers. It emphasizes a multi-layered strategy that necessitates active collaboration among national, provincial, and local governments. This collaborative effort extends beyond governmental entities to include businesses and local communities, aiming to sustainably manage and rehabilitate vital areas like Negril's beaches (McDougall, 2017).

The documents also advocate for expert knowledge to guide management decisions, such as emphasizing ecological considerations in infrastructure planning (Perkol-Finkel et al., 2018). A comprehensive regulatory framework for coastal land use is highlighted as a crucial measure to mitigate ecological

impacts. Additionally, there is an urgent call for sustainable management and conservation strategies, along with expanding protected area networks to safeguard coastal biodiversity against the pressures of urbanization (Bulleri & Chapman, 2010; Doxa et al., 2017). Managing beach grooming practices and implementing educational programs about the ecological importance of natural beach debris and the role of native vegetation are suggested to foster public support for conservation efforts (J. E. Dugan & Hubbard, 2010).

Additionally, the literature underscores the critical importance of comprehending species interactions within ecosystems, particularly for forecasting the consequences of biodiversity loss on ecosystem services (Dixon et al., 2023). It advocates for an increase in quantitative research to ensure these habitats are accurately depicted in ecosystem assessments (Yuguda et al., 2022).

The interplay of environmental sensitivity, human activity, and economic interests in areas like Negril's Beach illustrates the necessity for integrated solutions. These solutions should encompass government regulation, sustainable tourism practices, and active community involvement to effectively tackle the environmental issues at hand (McDougall, 2017). Adaption and conservation strategies are above all a challenge for society as a whole (IPCC 2019 SR).

In conclusion, this review highlights the necessity of a collaborative approach to conservation that combines the strengths of local communities, scientific research, robust regulatory frameworks, and the expansion of protected areas. Such strategies are vital for addressing the complex challenges of biodiversity loss and ecosystem degradation.

Research gaps

The key findings of the literature review identify several research gaps and areas where further study is needed to address biodiversity loss in coastal ecosystems. These gaps span across various drivers of biodiversity loss and encompass both direct and indirect factors. In the following section, we will summarize the identified research gaps.

1. **Lack of Deep Understanding of Coastal Ecosystem Dynamics**: While the literature review highlighted the importance of coastal ecosystems and the threats they face, it also pointed out a gap in the comprehensive understanding of these ecosystems' dynamics. This includes the need for more detailed studies on the interactions between various drivers of biodiversity loss and their cumulative impacts on coastal ecosystems.
2. **Insufficient Knowledge on the Effects of Plastic Pollution**: Although the impact of plastic pollution on coastal biodiversity is recognized, there remains a need for more focused research on understanding the long-term ecological impacts of plastics, including microplastics, and effective strategies for mitigating these impacts.
3. **Inadequate Data on Overfishing Consequences**: Overfishing is acknowledged as a critical threat to coastal biodiversity, but there's a gap in specific knowledge about its broader ecological impacts, particularly the effects of trophic cascades and the decline in predator species on ecosystem health and functionality.
4. **Limited Insight into the Role of Beach Grooming**: The review identifies beach grooming as a direct anthropogenic driver of biodiversity loss, yet highlights a lack of comprehensive studies on its wider ecological impacts, especially on macrophyte wrack cover and macroinvertebrate species that depend on natural debris for habitat and food.
5. **Invasive Species Dynamics**: While the threat of invasive plant species is noted, there's a call for more detailed research into the mechanisms through which these species impact native flora and

fauna, disrupt food webs, and alter ecosystem services. This includes understanding the drivers of invasion and the conditions that favour invasive over native species.

6. **Consequences of Eutrophication**: The process of eutrophication and its impacts on aquatic ecosystems, such as hypoxia and the alteration of species composition, is well-documented. However, the review suggests a need for deeper investigation into the long-term effects of nutrient enrichment on biodiversity and ecosystem services.
7. **Effects of Climate Change**: The review emphasizes the significant threat posed by climate change to coastal ecosystems but points out a gap in comprehensive studies on the specific impacts of sea-level rise, temperature changes, and extreme weather events on biodiversity and habitat loss.
8. **Ecological Considerations in Coastal Infrastructure Development**: There's an identified need for more research on the ecological impacts of coastal infrastructure development, including the effects of artificial structures on natural habitats and the proliferation of invasive species.
9. **Integrated Conservation Strategies**: Finally, the review calls for more research into effective, integrated conservation strategies that address the multifaceted challenges facing coastal ecosystems. This includes the development of methods to incorporate local knowledge and scientific research, enhance political will, and ensure active collaboration among all stakeholders involved in coastal conservation.

In addition, the literature review has revealed a notable absence of references to environmental sociology, underscoring the need to incorporate environmental sociological perspectives into the analysis of coastal biodiversity. These perspectives should cover areas such as environmental attitudes and behaviors, the observation of social discourses, and the sociology of risk. Understanding the social dimensions, such as how societal values and norms influence environmental behaviors and the role of social movements and policy in shaping conservation efforts, is crucial for addressing the complex dynamics of biodiversity conservation in coastal areas.

The sociology of risk (Beck, 1992; Giddens, 1991, Lupton, 2013) holds particular relevance for this project due to its comprehensive exploration of several key themes that are crucial for understanding contemporary societal challenges. It considers risk perception, examining how individuals and groups, shaped by cultural, social, and psychological factors perceive and interpret risks. This aspect is vital for grasping the complex nature of how risks are conceived and assessed differently across various communities. Furthermore, the study of risk communication sheds light on the mechanisms through which risk-related information is disseminated and how diverse communication strategies influence public understanding and behaviors towards risks. The field also explores risk management and governance, offering insights into the organizational frameworks societies deploy to manage and mitigate risks through government policies, corporate practices, and community actions. Additionally, the analysis of social inequality and risk distribution is crucial, highlighting the uneven distribution of risks among different social groups, which often amplifies existing societal inequalities.

Moreover, the sociology of risk critically evaluates the concept of a "risk society," (Beck 1992) where the management of risk becomes a foundational principle of societal organization. This perspective is instrumental in understanding the transition towards new forms of social organization, governance, and lifestyle adaptations in the face of risk. By emphasizing the interplay between technological advancements, social structures, and cultural values, the sociology of risk significantly contributes to our comprehension of how societies navigate uncertainty and the potential adverse effects of future events. This multifaceted approach not only enriches our theoretical knowledge but also provides practical insights for addressing

the complex web of risks that characterize our modern world, making it especially pertinent to the objectives of our project.

Moreover, the inclusion of environmental psychology perspectives (Gifford, 2014; Steg at al., 2013; Bell et al., 2001) could provide additional insights, especially since this area is missing from the review. Environmental psychology examines the interplay between humans and their natural environment, focusing on how environmental perceptions, attitudes, and behaviors are formed and how they can be influenced towards more sustainable outcomes. Applying environmental psychology to the PRO-COAST project could enhance understanding of the psychological drivers behind behaviors impacting coastal biodiversity and inform the development of more effective conservation strategies.

Overall, addressing these research gaps and integrating sociological and psychological perspectives can enrich the understanding of the multifaceted challenges facing coastal biodiversity conservation. This approach will support the development of holistic and effective strategies to mitigate biodiversity loss and promote ecosystem resilience.

3 HYPOTHESES AND QUESTIONS FOR THE CASE STUDIES

The PRO-COAST project embarks on a critical journey to understand and mitigate biodiversity loss in coastal ecosystems, drawing upon a rich tapestry of existing research while also identifying new frontiers that demand exploration. Coastal ecosystems, vital to both ecological integrity and human well-being, are under increasing threat from a multitude of stressors. The initiative's foundation on the Social Ecological Systems framework positions it uniquely to tackle these challenges through a holistic lens that incorporates dynamic interactions between social and ecological subsystems. By engaging with local stakeholders across diverse European coastal regions, PRO-COAST aims not only to elucidate the complex drivers of biodiversity loss but also to co-create sustainable conservation solutions. This chapter delineates our investigative roadmap, outlining hypotheses and research questions both reaffirmed and newly proposed based on the extensive literature review conducted.

Tested Hypotheses and Research Questions

Hypotheses:

1. Human activities, notably habitat destruction, pollution, and overexploitation, are primary direct drivers of biodiversity loss.
2. Climate change, manifested through higher temperatures and sea-level rise, serves as a critical indirect driver, exacerbating the impacts of direct human pressures.
3. The spread of invasive species, facilitated by human activity, significantly disrupts coastal ecosystem structures, threatening biodiversity.
4. Threats to coastal biodiversity are not effectively counteracted due to the inefficient implementation and comprehensiveness of existing conservation strategies.

Research Questions:

1. How do increased human population densities directly impact habitat destruction and biodiversity loss?
2. What roles do plastic pollution and eutrophication play in coastal ecosystem decline, and how do these impacts vary regionally?

3. How do overfishing and the removal of key species lead to trophic cascades, and what measures can reverse these effects?
4. What is the comparative impact of climate change versus direct anthropogenic pressures on coastal ecosystems?

Emerging Hypotheses and Research Questions from Detected Research Gaps

Hypotheses:

1. Insufficient ecological consideration in coastal infrastructure design significantly exacerbates biodiversity loss.
2. A cumulative impact from simultaneous stressors, such as overfishing, pollution, and climate change, precipitates a rapid biodiversity decline beyond individual effects.
3. The effectiveness of conservation efforts in coastal ecosystems is significantly hampered by socio-economic constraints and inadequate stakeholder engagement rather than mere enforcement issues.

Research Questions:

1. How can coastal infrastructure be re-envisioned to support rather than diminish biodiversity, considering ecological principles?
2. Can the interaction of multiple stressors on coastal biodiversity be effectively modelled to predict and mitigate future trends?
3. What socio-economic barriers impede the implementation of effective conservation strategies, and how can these be overcome?
4. In what ways can stakeholder participation in conservation efforts be enhanced to ensure both ecological and social objectives are met?

To Address the Identified Research Gaps in Environmental Sociology and Psychology Within the Context of Coastal Biodiversity Conservation

Hypotheses:

1. Societal values and norms significantly influence individual and community behaviours towards coastal biodiversity conservation.
2. Environmental attitudes are positively correlated with proactive conservation behaviours in coastal communities.
3. Increased awareness and understanding of the sociological risks associated with biodiversity loss leads to greater community engagement in conservation efforts.
4. The perception of risk related to biodiversity loss in coastal ecosystems varies significantly across different social groups, influenced by cultural, socio-economic, and psychological factors.
5. Tailored and innovative risk and environmental communication strategies, deeply rooted in the cultural and social contexts of coastal communities, can significantly enhance public understanding and participation in biodiversity conservation initiatives.
6. Social inequality exacerbates the vulnerabilities of certain groups to the risks posed by biodiversity loss in coastal ecosystems, leading to a disproportionate distribution of the adverse impacts.

7. Psychological drivers, such as a sense of place and environmental identity, are key determinants of individuals' willingness to engage in biodiversity conservation practices.
8. Interventions based on environmental psychology principles can effectively change behaviours detrimental to coastal biodiversity.
9. Communities with a strong sense of connection to their local coastal environment are more likely to engage in conservation behaviours.

Research Questions:

1. How do societal values and norms shape individual and collective behaviours towards coastal biodiversity conservation?
2. What role do social movements and policy play in influencing conservation efforts and public attitudes towards coastal biodiversity?
3. How do environmental attitudes and behaviours differ among communities located in different coastal regions, and what factors contribute to these differences?
4. In what ways can the sociology of risk be applied to better understand and mitigate the challenges associated with biodiversity loss in coastal areas?
5. How can the concepts of the Risk Society be applied to understand the societal transformations required to address biodiversity loss in coastal ecosystems effectively?
6. How do various stakeholders (including local communities, policymakers, and businesses) perceive the risks associated with biodiversity loss in coastal ecosystems, and how do these perceptions influence their decision-making processes?
7. What are the most effective communication strategies for raising awareness and fostering meaningful engagement among diverse stakeholders regarding biodiversity conservation in coastal ecosystems?
8. How do governance structures and policies at the micro, meso, and macro levels affect the management and mitigation of biodiversity loss risks in coastal ecosystems?
9. In what ways do social and economic inequalities impact the distribution of risks and vulnerabilities associated with biodiversity loss in coastal ecosystems, and what measures can be taken to address these inequalities?
10. How do perceptions of coastal ecosystems influence individuals' behaviours and attitudes towards biodiversity conservation, and what are the psychological processes underlying these perceptions?
11. How do coastal communities perceive the risks associated with biodiversity loss, and how do these perceptions influence their attitudes towards conservation efforts?

Methodological Approach:

To explore these hypotheses and answer the research questions, a mixed-methods approach can be utilized, combining quantitative surveys to assess environmental attitudes and behaviors across different coastal communities with qualitative methods such as interviews and focus groups to gain deeper insights into the psychological and sociological dynamics at play. Additionally, case studies of successful conservation initiatives can provide practical examples of how environmental sociology and psychology have been effectively integrated into biodiversity conservation strategies.

This comprehensive approach will not only highlight the importance of integrating sociological and psychological perspectives into the conservation of coastal biodiversity but also offer actionable insights for developing more holistic and effective conservation strategies.

4 CONCLUSIONS

In concluding the present literature review on the drivers of biodiversity loss in coastal ecosystems and their implications for the PRO-COAST project, the synthesis of findings reveals a multifaceted issue encompassing a wide range of drivers at the micro (individual or small group activities), meso (community, organizational, institutional actions), and macro (global or regional processes) levels of society. These drivers include habitat destruction, pollution, overexploitation of resources, climate change effects like sea-level rise and increased temperatures, and the introduction and spread of invasive species. The complex interplay of these factors not only directly impacts the biodiversity and ecological integrity of coastal ecosystems but also indirectly affects human societies reliant on the services provided by these ecosystems.

The literature underscores the significant impact of human activities and underscores the urgent need for comprehensive and enforceable conservation strategies that integrate ecological, social, and economic considerations. The importance of adopting multi-faceted conservation approaches that are responsive to local contexts and inclusive of stakeholder participation is emphasized. These approaches should leverage scientific research, local knowledge, and robust regulatory frameworks to effectively mitigate biodiversity loss and ecosystem degradation.

Reflecting on the implications for theory, the findings from the literature review affirm the critical relevance of the Social Ecological Systems framework (SESF) in guiding the analysis and understanding of complex socio-ecological interactions in coastal ecosystems. The insights gained also have significant practical implications for the PRO-COAST project's approach to co-creating tools and policies for biodiversity conservation with local stakeholders. For future research, the review highlights the need to further explore the interactions of multiple stressors on coastal biodiversity, the socio-economic barriers to conservation efforts, and the potential for ecological considerations in coastal infrastructure development.

While the literature review has illuminated a plethora of factors driving biodiversity loss in coastal ecosystems, it has also revealed a notable gap: the majority of the examined papers include indicators which are predominantly social indicators, yet they often lack a comprehensive theoretical foundation from the social sciences. This absence is particularly conspicuous given that such theoretical approaches could greatly enhance our understanding of the underlying social dynamics at various levels. On the micro level, environmental sociology and psychology approaches could provide insights into individual attitudes and behaviours. At the meso level, they could offer a deeper understanding of organizational structures and functions, while on the macro level, they could elucidate the mechanisms of economic orders and political cultures.

Incorporating environmental sociological and environmental psychological approaches into the research framework could prevent the analysis from being a mere verification of indicators. Instead, it would allow for the development of theory-guided complex hypothesis models that offer significantly better explanatory potential. Such models are not only more adept at elucidating the multifaceted drivers of biodiversity loss but are also invaluable for the formulation of actionable recommendations. This shift towards a more theory-driven investigation would not only enrich the PRO-COAST project's analytical depth but also significantly enhance the practical relevance and impact of its conservation strategies, making it an essential consideration for future research and implementation efforts.

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REPORT 3: GOVERNANCE OF COASTAL BIODIVERSITY

1 INTRODUCTION

1.1 Scope of the document

More than half of the world's population lives in coastal zones (UNEP 2020). Multiple and heterogeneous economic actors which are directly and indirectly responsible for biodiversity loss also engage in coastal zones. These include fisheries, shipping and offshore energy companies, tourism and recreation firms, and residential developers (Schuster et al. 2019). Unsurprisingly, the management of coastal zones is often contested, and effective governance of these dual land and seascapes is challenging (Partelow et al. 2020). Effective governance of biodiversity conservation is assumed to lead to better socio-ecological outcomes (Kenward et al. 2011). Therefore, detailed understanding of what constitutes effective governance, how we can design this and how this relates to socio-ecological outcomes is required (Mitchell et al. 2015).

To address this and help Pro-Coast move forward with implementing its plans this knowledge report addresses the research question 'What do we know about the ways governance impacts on biodiversity conservation, including in coastal zones? It is prepared for the wider Pro-Coast team with the aim of contributing to the development of research design. Its contents are expected to facilitate the development of a core set of hypotheses and robust, evidence-informed, comparative methodologies for utilisation in the case-study contexts.

The basis for this report is the idea of the Social-Ecological Systems Framework (SESF) which can play a pivotal role in understanding governance in the context of coastal zones, especially given the complex interactions between human and ecological systems (Ostrom, 1990). The SESF allows researchers and policymakers to dissect these complex dynamics, offering insights into how governance impacts biodiversity conservation. The SESF emphasizes the importance of governance systems in shaping action situations, including rules, norms, and policies that guide interactions. In the context of coastal zones, where governance is often contested, the SESF's emphasis on understanding the governance system and its impact on biodiversity conservation is crucial. This framework allows stakeholders to map out the existing governance structures and identify areas where they can be improved or adjusted to better support biodiversity conservation.

The report provides a social science 'entry point' to considering governance in the context of coastal regions. This means understanding biodiversity loss – and the solutions to it - as political, economic, and social issues in addition to scientific or technical issues. To maximise the opportunities for learning, the report presents analysis of literature relating to governance of biodiversity in relation to forests, ancient woodlands, national parks, in the ocean (beyond national jurisdiction) in addition to in coastal zones. The report has been prepared by a critical economic geographer with prior expertise in public policy, business and human rights, and social policy, but who is firmly a non-expert in biodiversity or in environmental issues. Therefore, the report applies knowledge from the literature according to the authors' expertise; the report does not analyse scientific outcomes of coastal governance.

1.2 Methods

This report is based on a systematic review of the literature using the keywords "biodiversity loss," "governance," "change," and "sustainability". To expand and refine our search, we introduced additional keywords such as "organisational," "behavioural," "societal," and "governance" to encompass changes at

various analytical levels, including micro, meso, and macro (see glossary for definition of these terms). Searches were conducted on the Scopus database without restricting our search to a specific timeframe, thereby ensuring an expansive overview of the evolution of scientific discourse in this field over time. Our search criteria did not exclude any publication type and were confined to English-language publications relevant to social sciences and environmental studies. Employing a structured keyword search hierarchy, our initial query on the Scopus database using the sequence "biodiversity AND loss AND sustainable OR sustainability AND transformation OR change AND governance" yielded 86 publications. Subsequently, to refine our focus on the specific context of transformative change in relation to coastal ecosystems, we adjusted our search parameters to "biodiversity AND loss AND sustainable OR sustainability AND governance AND coastal OR ecosystem," resulting in 53 publications.

To ensure comprehensive coverage, we extended our search to Google Scholar and Web of Science, adapting the keyword order of precedence as per each database's specificities. Our selection criteria remained consistent across databases, with additional consideration given to specialised categories available on Web of Science, including Environmental Studies, Green Sustainable Science Technology, Ecology, Biodiversity Conservation, Geography, Economics, Urban Studies, Law, Political Science, Public Administration, Agricultural Economic Policy, Area Studies, Psychology, and Sociology.

This extended search in the context of coastal ecosystems on Web of Science using "biodiversity AND loss AND (sustainable OR sustainability) AND (transformation OR change) AND governance" brought to light 134 papers, while a narrower query focusing on "biodiversity AND loss AND (sustainable OR sustainability) AND governance AND (coastal OR ecosystem)" identified 92 papers. Furthermore, we scrutinized the first 150 papers on Google Scholar for each set of keywords, ranking them by relevance and cataloguing them with comprehensive bibliographic details, including keywords and citation counts, to foster an intricate understanding of the subject matter. Applying a semi-systematic or narrative review approach, our focus was on understanding the progression of research within the selected field and identifying relevant research traditions that inform the studied topic. We also ‘snowballed’ literature from key texts identified through the database searches.

We analysed the literature according to key themes and theoretical perspectives. This method enabled us to map the field of research, synthesize the state of knowledge, and identify gaps for further exploration. Additionally, thematic analysis facilitated the creation of an agenda for future research, guiding the development of evidence-based strategies for coastal biodiversity conservation.

1.3 Structure of the report

The report is structured in three main sections. The first addresses how ‘governance’ has been conceptualised in the biodiversity literature. The second part of the report takes a more discursive approach in discussing emerging themes within the literature which can be considered by the Pro-Coast team during the next phases of the project implementation. The third and final part of the report summarises the key findings with the aim of identifying the main research gaps in this field which Pro-Coast could usefully attend to. These sections also provide an overview of potential areas for research questions to be implemented by the case-studies, and potential and appropriate social science methodologies. Key terms are defined in the overarching glossary and in what follows.

2 LITERATURE REVIEW

2.1 Background and Context

This section first analyses how governance has been conceptualised within the literature at global, national, intergovernmental, sub-national and within market-based approaches. It attends to what we mean by 'governance' and briefly traces the evolution of the concept of biodiversity 'governance' in the literature.

We define biodiversity governance as referring to the formal and *informal* processes involved in decision-making, rule-setting, and enforcement within an organization or society (Armitage et al. 2020). As such, it is different from government (Karlsson-Vinkhuyzen et al. 2017) and may not even involve governments.Governance operates through laws, as well as social norms, and power dynamics within organized societies, facilitated by government, markets, or networks. It involves navigating collective problems and creating acceptable conduct and social order through interactions within and between formal institutions. Governance considers the actions of the state, as well as non-state actors like communities, the private sector, non-government organizations, and even research experts (Lemos and Agrawal 2006; Ostrom 2010). However, governance is not only 'top-down' in that governments make rules and the other actors comply; social science literature also considers 'bottom-up' governance from non-state actors as playing an important role (Vasconcelos et al. 2013).

Governance is also multi-scalar – by which we mean the different levels at which social, political, economic rules and norms are established, negotiated, and contested (Lockwood et al. 2010). Scales are considered as interactive and interconnected rather than in isolation. In other words, what happens at one scale may nevertheless be intertwined with and affected by what happens elsewhere. Consider for instance the example of Comino island in Malta, where localised governance activities (regulation, management, activism) are nevertheless linked with, for example, what happens in global capital markets in London, New York, Berlin via the owner of the IHG hotel chain implicated in the new development on the island.

Over the past three decades, biodiversity scholars have increasingly recognised that 1) analysis of humans and ecologies should be considered together (Folke et al. 2007; Olstom 2010), 2) that states' roles in declined vis. a vis. market-based approaches have risen in significance (Agrawal & Lemos 2007), and 3) that multi-level, adaptive, collaborative and networked forms of environmental governance are typically more common – and more effective - than top-down hierarchical models (Folke et al. 2007). We briefly outline the main conceptual / heuristic approaches utilised within the biodiversity literature to capture these aspects of governance. These approaches are inter-related rather than mutually exclusive and all draw on the ideas included within the 'socio-ecological system' (SES) which is outlined first.

The concept '**socio–ecological system'** (SES) (which underpins the Pro-Coast project) is utilised by biodiversity researchers to emphasise the artificiality of any perceived distinctions between society and the environment in everyday life as well as in policy (Folke et al. 2010). This is because humans are recognised as the main drivers of ecological systems changes (Folke et al. 2010). Socio-ecological systems are described as complex, adaptive, and ultimately interconnected systems at multiple scales (Ostrom 2010). SES is often utilised in the literature in the context of ecosystem services (ESS) which are defined as the benefits which humans acquire from ecosystems, either directly or indirectly (Gomez-Baggethun and Barton 2013). Benefits may be sustenance (food), economic, medicinal, or for human wellbeing (Millenium Ecosystem Assessment 2005). However, in recent years, SES has been increasingly critiqued because of its limited practical application, relative neglect of human agency incorporated into analyses of these models, and the neglect of considerations of power (Mitchell et al. 2015). Pro-Coast

aims to further develop the theory – and test the practical application of - the SES concept. This knowledge report is aimed at helping the team do this.

Multi-level governance (MLG) is an idealised model of expressing governance models that incorporate actors at international, national, local and community levels working together to share knowledge, including on good practices and experience-based knowledge to address sustainability issues (Kozar et al. 2019). Typically, this concept is used to refer to hierarchical decision-making structures. For instance, the International Partnership for the Satoyama Initiative (IPSI) is defined as an MLG as its governance model involves the sharing of learning and co-production of sustainability solutions within and by 314 member organisations from more than 22 countries, led by an elected Steering Committee and Secretariat (ibid.)

Increasingly, environmental governance scholars draw on the concept of **polycentrism** to capture the range of multiple actors and multiple scales commonly involved in biodiversity conservation (Lemos & Agrawal 2007; Ostrom 2010). Application of this theoretical lens recognises the role of vertical and horizontal networks of actors and institutions, the multiplicity of institutions, and actors, all of which are simultaneously operating at multiple interlinked scales and continually engaged in contestations and multiple self-adjustment (Ostrom 2010). These approaches are viewed as being a more inclusive – non-hierarchical - form of environmental governance, and approaches which might be better suited to the development of tailor-made solutions appropriate to the local context of conservation (Morrison et al. 2019). However, it could also be argued that polycentrism is simply a more empirically realistic way of viewing how multiple institutions and actors engage with each other.

Biodiversity governance scholarship also addresses **adaptive management**, broadly defined as 'learning by doing' (Kenward et al. 2011). Adaptive governance is characterised as a process to enhance resilience that uses continuous opportunities for iterative learning, adjusting responses to uncertainty, social conflicts, and complexity over time (ibid.). Key elements of this process include management structures and processes which incorporate feedback loops, networked policy and practitioner actors, and diverse stakeholders diversity (Chaffin et al. 2014). This however relates primarily to management strategies rather than the broader context of governance.

2.2 Current Research Landscape

2.2.1 Overview of Existing Literature

The Convention on Biological Diversity (CBD) commits the international community to sustainable development and the protection of the world's biodiversity. As such, much of the literature attends to implementation of its provisions by states (Lobo & Jacques 2017), as well as the relative failure of states to implement its provisions (Butchart et al. 2016; Buchanan et al., 2020). Scholars have advanced various explanations for the latter including unquantifiable and complex targets included within the CBD, a lack of ambition and insufficient awareness of the targets amongst states (Smallwood 2019). Others point to the lack of compliance mechanism and failure to adequately identify priority targets, thus allowing states to 'cherry pick' the 'low-hanging fruit' to implement whilst leaving the more challenging issues (Mace et al. 2018).

Governance by States

In general, substantial volumes of the biodiversity governance literature address the role of *states* in governing biodiversity, from states' roles in managing protected areas in land, in coastal zones, to mainstreaming environmental protection (including biodiversity conservation). The IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) categorises state biodiversity policies into four main types: legal, economic, social, and rights-based policies (IPBES 2018).

A full review of the literature pertaining to states' governance of biodiversity is beyond the scope of this report. Instead, we briefly emphasis the main areas of focus in the biodiversity governance literature as it pertains to governance by states: 1) Protected Areas; 2) Mainstreaming/ Policy Integration; 3) Community and Indigenous Community Governance, 4) Private and Public Private Governance, 5) Environmental Policy Instruments.

Protected areas: Protected areas (PAs) are a key tool in biodiversity conservationand are consistent with the CBD. The IUCN (International Union for the Conservation of Nature) defines PAs as: "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Lockwood et al. 2012). The global network of protected areas has increased in number and extent, now covering over 15% of terrestrial land (ibid.).. This is expected to increase further as the global Aichi Biodiversity Targets (2010) committed each signatory country to protect at least 17% of its terrestrial land area and 10% of its marine area by 2020 (Buchanan et al. 2020). The backbone of EU's green infrastructure policy is the Natura 2000 network of high conservation value areas, which currently covers over 18% of the European land area and almost 10% of the total EU marine area (over 550,000 km) (Salomaa et al. 2017). The sites are selected and proposed by the Member States.

Biodiversity scholars have shown that well-managed land-based PAs can be effective in conserving biodiversity, can reduce habitat loss and maintain species populations (Leverington et al. 2010; Watson et al. 2014), as well as provide a range of societal benefits (Stolton & Dudley, 2010). Broadly speaking, the consensus in the scholarship can broadly be summarised that deforestation outside PAs is greater than inside and that therefore in these contexts, PAs can be shown to have played an important role in conservation (Miller and Nakamura 2018). On the other hand, other scholars have found that PAs are often located in the wrong places to protect the greatest diversity (Jenkins et al. 2015; Wu 2018), including the Natura 2000 sites (Trochet and Schmeller 2013).. Moreover, land-based national parks may be targeted at preventing environmental degradation in general rather than specifically biodiversity which explain their limited efficacy in relation to the latter (Wu 2018). PAs may also be understaffed, underfunded and poorly managed (Wu et al. 2019), are often hampered by administrative conflicts and confused management goals and unclear decision-making structures (Wu et al. 2019; Probstl et al. 2023; Joly et al. 2017; Mihok et al. 2017), or lack financial incentives for compliance (Joly et al. 2017). To be successful, PAs require systematic planning at national level, alignment with international conventions and best practice, effective monitoring and a broader inclusion of stakeholders especially those around the parks (Wu 2018).

However, as Eklund and Cabeza note, comparability across the studies on PAs lack consistency due to a lack of clear definition or common conceptual approach to what is 'governance' or what is 'effectiveness' (2017). Furthermore, as PAs are established and managed within broader governance arrangements (Eklund & Cabeza 2017) within states, local areas and are affected by changes in global production networks (where MNCs are involved) ascertaining the contributory influences of local variations is empirically challenging. In other words, whilst the literature provides useful insights into specific case-study examples of governance of protected areas, we are not able to assume generalities across their entirety.

In addition to the terrestrial protected areas, more than 15,000 marine protected areas (MPAs) cover approximately 7% of the world's marine environment. Locally managed marine areas (LMMAs), in which nearshore waters are actively managed by communities, have been widely adopted across the tropical western Pacific, for example, as a way of achieving biodiversity conservation and fisheries management objectives simultaneously (Jupiter et al. 2014). Increasing the size and number of MPAs is often viewed

as a significant way of meeting ambitious biodiversity and sustainable development goals (Pendleton et al. 2018).

Overall, what we can say from the literature is that MPAs differ widely in objectives, the ecological and human structures in which they are situated, the degree to which they involve stakeholders, and how well their management and enforcement is resourced (Pendleton et al. 2018). Consequently, whilst there are noted specific successes reported in the literature in relation to strongly protected MPAs (e.g. Sala and Giakoumi et al. 2018; Gill et al. 2017), others point to ecological crises such as the mass bleaching of coral reefs in iconic MPAs due to the failure of governance (Johnson et al. 2022). Governance of MPAs is reported to be often notoriously weak as enforcement in marine areas is challenging (Kaplan et al. 2015). Therefore, ecological outcomes are generally improved where firm compliance measures are in place (Gill et al. 2017), including the provision of incentives for compliance (Kaplan et al. 2015). On the other hand, adaptive learning opportunities are lost because of poor data and poor monitoring of ecosystems (Probstl et al. 2023). This means that improving knowledge collation procedures and sharing this with the public could potentially increase buy-in at all levels, hence amplifying the opportunities for success (Joly et al. 2017).

As with terrestrial PAs, research into the 'effectiveness' of MPAs is mixed due to a lack of commonality of definition of 'effectiveness' (Pendleton et al. 2018). Studies on MPAs therefore contribute evidence on the governance of specific case-study examples and we know little about the efficacy of MPAs in general. Moreover, although the literature provides significant evidence of the ecological effects of MPAs within their boundaries, much remains to be learned about the social, political and economic effects of MPAs within coastal zones. In a global review of the literature of MPAs and terrestrial PAs, Oldekop et al. (2016) find that conversation benefits for biodiversity were highest when PAs also delivered positive socioeconomic outcomes for local people. However, we know little about what this constitutes nor how we generate this through governance. The literature provides us with some limited indications which the Pro-Coast team can build on.

For instance, biodiversity governance researchers conclude that more analysis is needed to address concerns about whether MPAs displace fishing efforts to outside waters, which, in turn, can simply displace impacts to other areas reducing biodiversity and fish abundance outside of the MPA. More evidence is also needed to assess whether the reduced access to resources within MPAs (for instance for fishers), at least in the short-term, can create social and economic inequities (Halpern et al. 2015), with unanticipated changes in human behaviour. For example, the emergence of hyper-competitive behaviour has been shown to occur in fishing communities that have been displaced by MPAs (Basurto et al. 2017). This means that some trade-offs are required. Whilst the trade-offs which are required for effective governance of MPAs are acknowledged in the literature (Halpern et al. 2015) they are seldom investigated empirically, nor are they placed in the context of other non-fisheries benefits of protection (e.g. shoreline protection, carbon storage, tourism, and recreation, etc.) (Pendleton et al. 2018).

Finally, given that over 60% of the ocean lies in areas that lie beyond national jurisdiction (ABNJ), which, given the increasing interest in seabed mining and other commercial interests, the issue of governance is even more challenging to unpack (Waagener 2020; Yadav & Gjerde 2020).

Mainstreaming: Over the past two decades, researchers and conservationists working within the SES framework have increasingly recognised that governance of biodiversity cannot be siloed into a 'science' matter distinct from other policy areas affecting human beings (Folkes et al. 2007). Addressing indirect drivers such as production and consumption patterns, trade, technological developments, and governance on different levels is particularly important for effective biodiversity conservation (IPBES 2019). Consequently, biodiversity governance researchers have paid significant attention to the issue of policy

integration, known as ‘mainstreaming’, formalised in the original text of the Convention on Biological Diversity (CBD) in 1992 and in subsequently communiques (Sandstrom et al. 2023). At its most basic level, mainstreaming means to move environmental issues from the periphery to the centre of (policy) decision- making (ibid). Internationally, National Biodiversity Strategies and Action Plans (NBSAPs) are the main instrument for mainstreaming biodiversity into different sectors at the national level to reach the global targets stipulated by the CBD.

However, mainstreaming has often not been reflected in conservation practice and conventional scientific and policy discourses and approaches which have tended to deal with ecological and social systems completely separately (Apostolopoulou et al. 2012). Sandstrom et al. (2023) identify at least three main reasons broadly underlying the difficulties of biodiversity mainstreaming within states: (i) insufficient political commitment, especially in relation to the lack of acknowledgements of the ecological, political, social and economic trade-offs (Singh et al. 2017; Razzaque and Lester 2020) ; (ii) a lack of enabling legal frameworks and policy mixes; and (iii) a need for governance arrangements for transformative change. These authors find that although many states pay lip-service to the concept of mainstreaming biodiversity, non-binding political commitments in combination with a lack of financial resources mean that the issue tends to be low down on the political agenda. Others emphasise the barriers arising out of dominant sector interests (Persson and Runhaar 2018), competing visions or a lack of a centralised vision which hampers policy coherence (Probstl et al. 2023; Karlsson-Vinkhuyzen et al. 2017), and a lack of sufficient attention to the local context (Hettiarachchi et al. 2014), or trade-offs required

Community-based governance and indigenous participation (IPLC): Over the past three decades, biodiversity governance researchers have increasingly attended to the role of indigenous and local communities (IPLCs) as pivotal stewards in conserving biodiversity (Agarwal et al. 2021). Researchers also increasingly centre ILPC engagement in formal global governance processes and dialogues as part of a rights-based approach to governance (e.g. Tengö et al. 2017; Armitage et al. 2020).

Involving local communities in governance can be more effective because these systems consequently draw on the lived and political realities of the people and communities affected by, adjacent to and directly reliant on biodiversity (Berkes 2007). Indigenous communities live in terrestrially protected areas and ecologically intact landscapes including boreal and tropical primary forests (Garnett et al. 2018). This is therefore a way to avoid the failures associated with ‘top-down’ government approaches which ignore the specific circumstances and needs of those most affected at the local level (Ostrom 2010). Studies indicate that adaptive management approaches that have integrated local communities in co-governance arrangements have been the most successful for terrestrial protected areas (Dawson et al. 2018). This facilitates continuous input from local communities rather than only relying on one-off consultations at the outset of activities. Others have shown that not only do Indigenous communities have a positive impact inside protected areas, their stewardship outside PAs harbours just as much biodiversity (Schuster et al. 2019). This shows that it may be that it is the contribution of the communities’ biodiversity preserving activities rather than the governance structures of the PAs which make them effective.

Indigenous peoples have sought to secure formal avenues for integrating their knowledge and value systems into the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (*IPBES*) (Tengo et al. 2017), a form of ‘bottom-up governance’. Over time, Indigenous peoples’ different ways of knowing and understanding human-ecological relationships have been recognised within formal global governance dialogues. For instance, Target 22 of the Kumming Montreal Global Biodiversity Framework (2030 Targets) explicitly calls for participation in decision-making by Indigenous peoples in

ways which respect their cultures and rights over land, as well as their traditional knowledge[1]. Participation in formal processes has amplified calls from Indigenous communities for their rights and appreciation by global governance actors of their 'ways of knowing' and understanding biodiversity stewardship (Tauli-Corpuz et al. 2020).

However, whilst their involvement is acknowledged as a necessary condition for successful conservation governance mechanisms, the literature also emphasises that to date the input of ILPCs has been sidelined or suppressed in mainstream conservation agendas (Zanotti & Knowles 2020). In practice, research of on-the-ground conservation initiatives often finds that the actual implementation of community collaboration is often piecemeal, tokenistic and masks power relations between the actors (Schuster et al. 2019). Moreover, some communities have often risked criminalisation precisely because their methods of conserving biodiversity conflict with those of powerful economic actors (Matulis & Moyer 2017), and there are often fundamental epistemological and ontological tensions between IPLCs and the 'outsiders' (including international NGOs) who come to advise on conservation of diverse landscapes (ibid.).

Private and public-private governance of biodiversity: In the past three decades, a growing number of studies have addressed the growing significance of market-based approaches to the governance of biodiversity (Negacz et al 2020). These include everything from voluntary standards and certification schemes (e.g. Fairtrade or Roundtable on Sustainable Palm Oil), regulatory price signals (e.g. eco-taxes), tradeable permits (carbon credits, or fishing quotas), conservation easements and concessions and new financial products like nature derivatives and weather insurances that mitigate the material risks of biodiversity loss (Anyango-van Zwieten 2021). Green financial products which centre the role of investors and international development agencies have also come to the fore. These include green bonds, green loans, equity funds that offer the potential of raising financial resources for green development projects and natural assets (e.g. marine protected areas and sustainable fisheries management) in exchange for a return to the investor after the contract period ends (Flammer et al. 2023). Together, these instruments and approaches are based on calculations that position biodiversity loss as a material risk to business profitability (Dempsey 2016). In other words, the economic impacts of biodiversity loss are front and centre.

Companies have also increasingly sought a political role in relation to biodiversity conservation in the context of corporate 'just transitions' agendas (Newell and Mulvaney 2013). In addition, global business coalitions which specifically call for action on biodiversity have emerged. For instance, "Business for Nature', which includes leading MNCs such as Unilever, Danone and Walmart, have issued demands that governments and business leaders take responsibility for halting biodiversity loss (Smith et al. 2019). Much of the global corporate activity on biodiversity has taken place in the margins of the various COPs, especially in the lead up to the 2030 agreement (McElwee et al 2020, Sandbrook et al 2020) showing the vastly increased significance of the private sector (net contributors to biodiversity loss) in shaping global narratives and policy positions on biodiversity loss.

However, the global context in which international business is increasingly engaged on the topic of biodiversity has shifted. Critics such as Buscher and Fletcher (2020) argue that the space for companies' political activities has been generated by international NGOs such as the International Union for Conservation of Nature (IUCN), World Wildlife Fund (WWF) and Flora and Fauna International (FFI). These organisations have adopted a position that companies would only engage in behaviour commensurate with conservation if it were not perceived to be in opposition to economic growth (Corson

[1] https://www.cbd.int/gbf/targets

& Campbell 2023). In other words, the leading mainstream conservation NGOs have sought to bring companies 'into the house' in the belief that changes can only be made effectively when they are on side.

On the other hand, other researchers have sought to show that individual businesses have begun to pay attention to biodiversity because of direct campaign pressure from consumers and NGOs, especially in relation to production of dramatically degrading commodities such as palm oil (Beck-O'Brien & Bringezu 2021; Boiral et al. 2018). Others have focused on companies' financial motivations, drawing a link between companies' public statements on biodiversity conservation and the ability of such firms to capitalise on future access to licenses and permits (e.g. for mining or fisheries), to access investments (Reale et al. 2019), to improve market share and increase legitimacy (Atupola & Gunarathne 2020; Anthony & Morrison-Saunders 2022). Vociferous critics of the appropriateness of market-based approaches have referred to these as the foundation for new forms of capital accumulation (Büscher & Fletcher 2020), and the commodification and neoliberalisation of nature (Pattberg et al. 2019). In other words, these critics allege that companies are utilising these opportunities to further profit without engaging in the necessary behavioural change to prevent further biodiversity loss.

Biodiversity scholars emphasise that this matters because global business increasingly is setting the terms of the international debate and evolving new norms on governance in ways which benefit them rather than biodiversity or indeed the most affected communities (Buscher and Fletcher 2020). For instance, Schumacher (2023) highlights that REDD+ (deforestation and forest degradation through reduced carbon emissions) has become an important instrument in global development policy. As bilateral aid institutions and international institutions like the World Bank increasingly fund projects and programmes to "prepare" countries for REDD+ this also means that inevitably states are being required as a condition of this funding to reduce funding on social welfare programmes hence contributing to the global neoliberal project (Schumacher 2023). Global business initiatives like The Economics of Ecosystem and Biodiversity, the Natural Capital Finance Alliance, and the Business and Biodiversity Offsets Programme have not only attracted and brought together potential investors but have also institutionalized neoliberal political rationality and apolitical explanations of biodiversity loss within conservation (Corson & Campbell 2023). Collectively, Dempsey (2016) argues, market-based approaches serve to reduce biodiversity to technical and financial 'rivets' and to therefore devalue biodiversity for non-financial / non-profitable reasons. In other words, corporate engagement has shifted the terms of the agenda.

At same time, studies of sector or country initiatives tends to show that the efficacy of geographically specific market-based approaches is limited (Ting et al. 2016; Reale et al. 2019; Boiral et al. 2018). Cocoa, palm oil, tea, capture fisheries can now credibly claim to certify (according to environmental standards) only around one-tenth of global production which partly accounts for its limited impacts (Van der Hern et al. 2018; Tayleur et al. 2017). Other limiting factors include the lack of land covered by certification (Beck et al. 2021; see also Van der Ven et al 2018), weak wording on standards and a lack of detailed measurements (Beck et al. 2021; Ting et al. 2016; Lammarent et al 2019), and gaps in implementation as companies often lack the technical expertise required (Anthony and Morrison-Saunders 2022; Boiral et al. 2018).

Others note that these individual and sector-based private governance models are not effective simply because they are not intended to be. Instead, they should be viewed in the context of 'greenwashing', a 'laundering' of companies' reputations to address external pressure at the lowest cost possible (Boiral et al 2018), or with the aim of obfuscating in response to unwelcome public attention rather than with the true aim of increasing transparency (Anthony and Morrison-Saunders 2022). Certification schemes are also often confusing for consumers (Boiral et al 2018), whilst access to certification schemes is disproportionately costly for smaller companies lower in MNC supply chains whilst the lead firms in Global

North countries reap the economic benefits (Anthony and Morrison-Saunders 2022). Consequently, such schemes may serve to further imbalance power relations between the dominant private players (such as the MNCs and international NGOs) at the expense of the local actors, especially indigenous communities (Ruysschaert 201).

Environmental Policy Instruments

Lastly in this section, a growing number of studies report on the efficacy of national and sectoral environmental policy instruments such as eco-taxes, 'green nudges' aimed at persuading consumers to purchase green products (e.g. electricity), and carbon offsetting projects/ trading. Liao (2018) divide these into three areas. Firstly, environmental policy instruments may include laws and policies which limit certain pollutants or methods to control the production process, thereby influencing the behaviour of producers. These are usually compulsory, and non-compliance sanctioned by means of administrative fines. In general, the literature shows that these can be effective in initiating more environmentally protective innovation within companies and contributing to environmental protection (Berguist et al. 2013).

Secondly, Liao (2018) outlines market-based approaches such as environmental subsidies, emissions trading, sewage charges, eco-taxes. Carbon pricing policy instruments are the most well-known in this category, in part driven by the 2015 Paris Agreement which prompted governments to consider stronger policies to achieve decarbonisation (Narassimhan et al. 2018). Carbon pricing instruments fall into three main sub-categories: 1) cap-and-trade (emissions trading systems ETS), carbon taxation, or hybrid which combine elements of both. However, existing studies of the efficacy of these, much like the studies of protected areas are geographically limited and lack common definitions of effectiveness which limits comparability (ibid.) Narassimhan et al.'s study of six jurisdictions found that no policy was alike which also hampered comparability. They report that certain attributes lend themselves better to certain national jurisdictions (e.g. auctions), whilst others worked well across all sites. Other more critical scholars argue that ETS approaches are rooted in neoliberal economic governance mechanisms which are too business-friendly and which consequently and frequently also tend to emphasise or require less stringent compulsory government environmental regulation as a political 'offset' (Wilson and Swyngedouw 2014; Castree 2008). This group of scholars also highlight that environmental degradation including biodiversity loss cannot be reduced to carbon nor the solution reduced to an economic problem (Bryant 2016). Scholars also challenge the use of carbon markets as ineffective mechanisms in any case to reduce greenhouse gas emissions (Andrew and Cortese 2013). However, the empirical evidence in the literature is limited.

Thirdly, Liao defines information-based instruments as informal (non-compulsory) environmental regulation. This may involve voluntary corporate reporting on environmental information by companies, for instance on sewage emissions, which enables stakeholder groups to exert social pressure on those responsible.

2.2.2 Recent Trends and Developments

This section delves into recent trends, methodologies, and theoretical perspectives in the field of biodiversity governance. With the emergence of fresh debates and voices, particularly in the wake of the Post-2020 Global Biodiversity Framework (GBF), there has been a call for a profound overhaul in the governance of biodiversity. As Corson and Campbell (2023) assert, conservation is undergoing an ontological and epistemic transformation, redefining the meaning of biodiversity, how it is understood, conserved, and by whom. This is therefore an ideal opportunity for the Pro-Coast team to make a significant difference. While the broad literature on SES governance frequently discusses the importance

of coordination and collaboration, exactly how it is achieved in the context of complex institutional arrangements remains underdeveloped (Lubell et al. 2014).

Drawing on the biodiversity governance literature, this section identifies and discusses three recent trends and developments that could be considered within the Pro-Coast framework. Firstly, it examines the notion of power in biodiversity governance, exploring how power dynamics shape decision-making processes and outcomes. Secondly, it delves into the role of knowledge in biodiversity governance, considering how different forms of knowledge are valued and incorporated into conservation efforts. Lastly, it explores a values-based approach to governance that integrates principles of justice, equality, and human rights into conservation strategies. These themes are discussed within the context of alternative theoretical approaches to biodiversity governance, including actor-network theory, and political ecology. We view these theoretical approaches as additive to the main overarching framework of SES rather than as replacements for it. By engaging with these theoretical perspectives, Pro-Coast can enrich its understanding of biodiversity governance and contribute to more effective and equitable conservation practices.

Power in biodiversity governance: Morrison et al. (2019) define power as the uneven capacity of different actors, both individuals and organizations, to influence the goals, processes, and outcomes of governance. However, traditional studies of biodiversity governance often overlook the multifaceted nature of power, focusing solely on formal structures of decision-making and resource allocation. This narrow approach fails to account for the deeper dynamics of power, including social capital, communication patterns, negotiation processes, and underlying networks (Biggs et al. 2012). Morrison et al. (2017) argue that this contributes to the failure of many biodiversity governance models, such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), which fail to address power imbalances inherent in land ownership, state control, and the economic dominance of multinational corporations (see also Gallemore et al. 2015; Sunderlin et al. 2015; Boelens et al. 2015).

Polycentric governance, therefore, should not be viewed merely as a structural solution to propose or as a diagnostic tool, but rather should be analysed as a complex system of diverse institutions, agencies, and social actors influenced by power-laden social relationships (Morrison et al. 2019). This includes three interconnected sources of power: decision-making power (legislate, allocate resources), pragmatic power (influence over day-to-day decisions), and framing power which includes discursive and epistemic issues, including the making of norms (Morrison et al. 2017).

Furthermore, in a different approach that draws on games theory, and in a study of water governance in San Francisco, Lubell et al. (2014) show the active engagement of over 100 policy institutions operating simultaneously, including collaborative partnerships, local and regional planning organisations and authorities and interest group associations. Complexity, they argue, is not only a hypothesis; it is the everyday reality faced by policymakers and resource users in socio-ecological systems (2014: 23). As such, an entire ecosystem of institutional conditions and plurality of interests, aspirations, and strategies amongst various actors and agencies can appear to manifest as an “ecology of games” (Lubell et al., 2017). In ‘power-games’, corporations and NGOs may act as pragmatic power brokers, acting as either enabling or constraining factors on effective biodiversity governance. Unpacking the relationships between different institutional actors facilitates insight into how multiple players, each mobilising and deploying different types of power, interact collaboratively and competitively to produce diverse social and environmental outcomes, including within internal government meetings, consultation processes and community protests. Policy scholars have thus usefully begun to explore polycentric systems as complex adaptive systems of interlinked games, which are not just structural but also functional (Berardo & Lubell, 2019).

Addressing these power imbalances is crucial as this has the potential to unlock new ideas, resources, and opportunities for scientists and practitioners involved in polycentric environmental governance (Kashwan et al., 2021). By shedding light on these dynamics, researchers can contribute to a more equitable and effective approach to biodiversity governance within polycentric systems.

Political ecology (PE) also offers a valuable qualitative theoretical lens for understanding the relationship between power, governance, and biodiversity. This approach views ecological conditions as the outcomes of formal and informal political processes. Scholars working in this tradition argue that environmental degradation is shaped by the political-economic organisation of labour and social relations of production under capitalism (Swyngedouw and Heynen, 2003; Blaikie and Brookfield 2015; Neumann 2009).

Like polycentrism, PE studies recognise the role of various actors, both state and non-state, in shaping governance arrangements, often leading to temporary and place-specific forms of governance (Cornea et al., 2017). However, the PE perspective additionally emphasises that social relations, economic constraints, wealth disparities, and structures of political power are significant factors which influence access to and control over natural resources (Neumann 2009; Robbins 2019). For this reason, biodiversity loss and environmental degradation are often linked to patterns of capital concentration, exemplified by what David Harvey termed "accumulation by dispossession" (Harvey 2003). As such, these studies tend to highlight that social and economic inequalities between different social groups drives environmental degradation (Swyngedouw and Heynen 2003; Swyngedouw and Kaika, 2014). For instance, PE studies have also shown that REDD+ schemes can result in resistance and eviction of forest communities, as well as increased militarization (Cavanagh and Benjaminsen 2014;Asiyanbi, 2016).

Furthermore, PE analysis emphasises the significance of neoliberalism as a hegemonic narrative and structure (Swyngedouw and Heynen 2003) and stresses the importance of considering historical processes such as colonisation, as well as geographical factors, in understanding contemporary biodiversity loss (Swyngedouw and Heynen 2003; Swyngedouw and Kaika 2000). In the other words, the past matters as much as the present.Perrault et al. (2015) summarise PE theoretical developments as having emerged from three commitments: a “theoretical commitment to critical social theory and a post-positivist understanding of nature”, a “methodological commitment to in-depth, direct observation involving qualitative research” (Perrault et al. 2015:7) and methodological plurality, and a “normative political commitment to social justice and structural political change” (Perrault et al. 2015:8). PE studies are thus frequently utilised to highlight how communities and social movements negotiate their rights to resources and how collective community action attempts to solve socio-environmental problems (Neumann 2009; Robbins 2019).

Knowledge and ideas in biodiversity governance: The process of knowledge production, including the questions asked, the methods employed, and the interpretation of results, is inherently shaped by social, cultural, political, and economic factors (Latour 1987). It is a form of power which can be utilised to enable or to constrain biodiversity loss and therefore, it is essential to critically examine scientific knowledge and the process of its production, including acknowledging the social and political contexts in which knowledge emerges (Law 1992). This recognition can allow for a more nuanced understanding of biodiversity issues and helps identify ways in which scientific knowledge can be used to address environmental challenges more effectively.

According to actor network theory (ANT), which emerged from science and technology studies in the 1980s, “knowledge is a social product” (Law 1992). Knowledge takes material form in written laws and rules, newspaper articles, embodied forms of knowledge (how to ‘do’ something, for instance guidelines) as well as in research outputs and statistics. ANT, as a theoretical approach, provides a ‘flat surface’ on which to empirically analyse the relationships between human and non-human inputs to networks (Bennett

2018). Knowledge (by which relationships and power are translated within the network) is the 'glue' that network actors utilise to mobilise resources, alliances and to construct different networks (Latour 1987; Roger et al. 2009).

In an example of its use in the biodiversity literature (and asa positive force in biodiversity conservation), Callon (2005) drew on ANT to explain how marine biologists in St. Brieuc Bay, France, convinced ('enrolled') local fishermen and scientific colleagues in an alliance to preserve the scallop population. Similarly, in a more contemporary example, Almazan-Casali et al. (2021) show how in Brazil's decentralized water management system, technocrats (técnicos) frequently mobilize what they present as 'apolitical' scientific information to increase regional decision-making capacity and policy implementation. By controlling the production and access to knowledge (e.g., climate forecasts) these technocrats were able to insulate decisions from river basin committee members and drive different agendas.

Others have increasingly sought to explore – and explain – how the ideas underpinning ecosystem services and 'green economy' (examples of market-based and neoliberal approaches) have come to appear hegemonic within global governance processes through ANT approaches. Pasgaard et al (2017) show how biodiversity scientists, NGOs and hired project consultants have shaped specific forms of environmental governance (Ecosystem Services, 'green economy') through the lens of ecological crisis narratives hence justifying market-based approaches (see also Büscher et al. 2012).

In a study of the role of biodiversity scientists within the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Wiegleb and Bruns (2023) show how the rising demand for policy-relevant knowledge by global institutions has catalysed the emergence of what they refer to as 'global boundary organisations' which operate at the 'science-policy' interface. They argue that the ways in which knowledge is produced within global governance structures such as IPBES tends to mask the social relations and uneven geographies of power, hence concealing significant inequalities in which marginalised peoples' knowledge, especially those located in Global South countries is crowded out and dismissed. This matters because whilst the hegemonic approach to understanding biodiversity governance lies in terms of preventing or mitigating biodiversity loss, an alternative paradigm is to see biodiversity degradation as the disruption of a harmonious relationship between humans and non-humans (Pickering et al. 2022; Turnhout et al. 2014). In other words, how a problem is defined, understood and narrated impacts on the specific type of governance solutions that are identified as well as who is involved in generating the solutions.

Social justice, equality, and human rights in biodiversity governance: The concept of inequality, whether social (e.g. gender, class), economic (e.g., income) or environmental (e.g., exposure to environmental risk, lack of access to ecosystems) has started to be acknowledged in the biodiversity governance literature and within global governance processes. Throughout the past two decades, biodiversity governance studies have drawn attention to the inequalities inherent in how biodiversity is managed and governed, most obviously through the racialised exclusion of Indigenous communities from land through protected areas approaches, referred to as 'fortress conservation efforts' (Tengö et al. 2017; Corson and Campbell 2023). Others have noted that community projects ostensibly established to advance IPLC rights and capitalise on their knowledge can often mask continued colonial power relations and patterns of dispossession and even concentrate wealth in the hands of the already wealthy (Büscher et al. 2012; Tauli-Corpuz et al. 2020). Market-based conservation approaches have therefore sometimes alienated communities from land and resource rights or led to what has been called 'green grabbing' (Corson and Campbell 2023). Moreover, within global governance processes, others have pointed to the disconnect between the international text which emphasises the importance of IPLC communities to biodiversity conservation and the 'on the ground' realities, including tokenisation, appropriation of IPLC agendas, the

militarisation of conservation (Kashwan et al. 2021b), and the exclusion of Global South activists and scholars from global dialogues (Agrawal et al. 2021; Corson & Campbell 2023).

In recognition of these socio-economic and political inequalities, a growing sub-field of literature aims to advance the values of justice, equality and human rights in biodiversity governance approaches. This ranges from the radical 'multi-species justice' approaches (emerging out of IPLC knowledge-based approaches) to international law (Fitz-Henry 2022) to global calls for conservation models which fight "overconsumption and exploitation of resources led by the Global North and its corporations" (Our Land, Our Nature Congress 2021[2]).

To combat these historical and contemporary inequalities, social justice has therefore increasingly moved to the centre of biodiversity governance. In some senses, a full circling and elaboration of socio-ecological relationships. On the political side, IPLCs and allies have challenged global targets, calling for a halt to protected areas that exclude IPLCs, reparations for historical expropriations, a commitment to rights-based approaches, and global economic reform (Corson and Campbell 2023). Within the literature, researchers have called for the incorporation of increasingly values-based approaches to governance to include the principles of equity and justice. For some, this can be looked at as 'convivial conservation', defined as "conservation outside of the capitalist box" through a combination of radical equity, structural transformation, and environmental justice approaches to governance (Büscher & Fletcher 2020: 202). On the other hand, Huntjens and Kemp (2022: 2) argue the case for what they refer to as a 'natural social contract' to support all of the environmental agendas, from circular economy to green transitions, including biodiversity protection: "A Natural Social Contract caters to calls for making society more fair, more equal and more sustainable, and is practiced and carried by (prefigurative) practices at various levels, based on values of responsibility that are gradually developed within the hybrid sphere and an alternative economy." Moreover, Ayambire et al (2022) call for what they refer to a 'working landscape' concept of governance which includes social – rather than only economic – wellbeing, and which fostering collective action, and which includes trust, equity in the elements of governance. This harnesses the broader EU agenda on furthering an Economy of Wellbeing, identified as a major theme during Finland's Presidency of the Council of the EU in 2021.

Overall, these new, diverse, and values-based approaches have been situated within debates about reforms of the global political economy and colonial legacies, to go beyond 'business as usual' approaches and to think more radically (Corson & Campbell 2023). In other words, a transformative governance agenda *(*see Knowledge Report 6), which can also be more effective in conserving biodiversity. As several biodiversity scholars have emphasised, at the very least, initiatives that fail to include affected communities in decision-making often fail to achieve their conservation objectives (Dawson et al., 2018b). Wagenaar (2022) goes much further in arguing that the protection and realisation of human rights depend on successful efforts to prevent biodiversity loss. In other words, an alternative way of framing the justification for preventing further biodiversity loss lies in maintaining and advancing human rights rather than only economic factors. For this author, the adoption in July 2022 of the new human right to a clean, healthy environment by the UN Human Rights Council thus presents an exciting prospect for the future of biodiversity governance. Environmental justice consequently moved to the centre of the human rights regime, or we could argue, was mainstreamed in human rights agendas. The report now moves to the third section.

[2] https://www.ourlandournature.org

3 RESEARCH GAPS AND QUESTIONS FOR THE CASE STUDIES

This section addresses the exploration of governance strategies aimed at preventing biodiversity loss within coastal ecosystems. Understanding how governance is operating at all scales and within different institutions as well as how to embark on more ecologically effective, socially just, governance approaches will be critical.

3.1 Ways governance impacts on biodiversity conservation

Hypothesis 1: Integrating Social Science Theories and Approaches Leads to More Effective Biodiversity Conservation Efforts in Coastal Zones

To test this hypothesis, the following research questions (RQs) should be addressed:

- **RQ 1.1**: How can the full range of affected communities be identified, along with the diverse ecological, social, economic, and political issues that impact them?
- **RQ 1.2**: What networks (horizontal, vertical, formal, informal) are involved in coastal zone governance, and what are the power dynamics within these networks?
- **RQ 1.3**: How does power (political, economic, normative, etc.) affect leverage and resistance within these governance networks?
- **RQ 1.4**: To what extent are marginalized communities included in identifying solutions and governance structures, and what impact does this inclusion (or lack thereof) have on biodiversity outcomes?
- **RQ 1.5**: How do sources of knowledge (formal and informal) contribute to biodiversity conservation, and who holds expertise and legitimacy in conveying knowledge?
- **RQ 1.6**: What social and economic inequalities exist within affected communities, and how do these relate to biodiversity loss and conservation?
- **RQ 1.7**: How do social and political values shape biodiversity conservation efforts in coastal zones, and how can these values be harnessed to promote conservation?
- **RQ 1.8**: What messages and communication strategies are most effective in obtaining "buy-in" from stakeholders, and what factors influence these communication strategies?
- **RQ 1.9**: What are the existing trade-offs in coastal zone governance, who decides on them, and how can they be adjusted to support biodiversity conservation?
- **RQ 1.10**: How can biodiversity concerns be mainstreamed into local regulations, and what is the role of business incentives in driving or mitigating biodiversity loss?

Hypothesis 2: Longitudinal Studies Provide Insights into the Long-Term Impacts and Resilience of Biodiversity Conservation Efforts in Coastal Zones

To examine this hypothesis, these research questions should be explored:

- **RQ 2.1**: What specific longitudinal studies can be conducted to assess the long-term impacts of governance on biodiversity conservation in coastal zones?
- **RQ 2.2**: What factors contribute to the resilience of biodiversity conservation efforts over time, and how do these factors vary across different case studies?

- **RQ 2.3**: How do different governance models affect biodiversity outcomes over the long term, and what lessons can be learned to improve future conservation efforts?
- **RQ 2.4**: How can trade-offs be managed over time to balance ecological, social, and economic outcomes while ensuring sustainable conservation?

Hypothesis 3: Understanding Power Dynamics and Voice Contributes to More Effective Biodiversity Conservation Efforts in Coastal Zones

This hypothesis can be evaluated by investigating these research questions:

- **RQ 3.1**: What power structures exist within coastal zone governance, and how do they influence conservation efforts?
- **RQ 3.2**: Which stakeholders have the most significant impact on biodiversity conservation, and how can their influence be harnessed to promote positive outcomes?
- **RQ 3.3**: What strategies can be employed to identify and address resistance among stakeholders, and how can more inclusive governance be achieved?
- **RQ 3.4**: What role does voice and representation play in coastal zone governance, and how does it impact biodiversity conservation?
- **RQ 3.5**: How can governance models be designed to avoid targeting low-hanging fruit (e.g., marginalized groups) and instead focus on stakeholders with significant leverage for conservation?

3.2 Case studies in PRO-COAST

Hypothesis 1: Integrating social science theories and approaches into identifying existing governance models in Pro Coast case-studies will contribute to more effective conservation efforts.

Proposed Research Questions (RQs):

- **Identifying Full Range of Affected Communities and Range of Issues:**
    - **Comino Island (EU CS1):** Tourism is significantly impacting the island through increased trash and waste, affecting local communities and their environment. To understand the full scope of this impact, it's crucial to identify stakeholders such as local business owners, community residents, and environmental groups like Friends of the Earth Malta (FoEM). This broader perspective will help in devising strategies to manage the negative effects of tourism on biodiversity and community health.
    - **Aquatina di Frigole (EU CS2):** Challenges in lagoon-sea management affect local communities engaged in fishing and tourism. Engaging with community members, local fishers, and tourism operators provides insights into the social and economic impacts on biodiversity.
    - **Arne Parish (Non-EU CS6**: Invasive species, particularly grey squirrels, are causing significant damage to trees, leading to broader ecological and climate-related issues. Addressing the impact of grey squirrels on local environments and residents is essential, as their destructive behavior negatively affects tree health and contributes to climate change. A critical solution involves replacing grey squirrels with native red squirrels, which can help restore balance to the ecosystem and promote healthier forests. This effort not

only benefits local farmers and residents but also contributes to broader biodiversity conservation and climate change mitigation goals

- **Mapping Networks and Stakeholder Relationships:**
  - **Strunjan (EU CS3):** Engaging the local community through citizen data science (e.g., Step Change APP) involves mapping stakeholders across various relationships—government, local residents, and scientific institutions. This mapping is crucial for understanding horizontal and vertical connections.
  - **Boka Kotorska Bay (Non-EU CS4):** The Chamber of Commerce leads the initiative, suggesting the need to map networks among business stakeholders, local authorities, and conservation groups. Understanding these relationships reveals the interplay between economic and conservation goals.
- **Role of Power:**
  - **Sligo (EU CS5):** Coastal community groups drive conservation efforts. Exploring the power dynamics within these groups and between them and local authorities informs the extent of influence and potential resistance to conservation measures.
  - **Corbu (EU CS9):** The absence of a supervisory body indicates a power vacuum. Analyzing the sources of power, such as construction companies, and their influence on development reveals underlying issues contributing to biodiversity loss.
- **Voice and Knowledge:**
  - **Comino Island (EU CS1):** Friends of the Earth Malta plays a critical role in amplifying the community's voice. Examining the sources of knowledge (e.g., community-driven vs. academic) and the degree of inclusion helps assess the extent of community involvement.
  - **Bergen (Non-EU CS7):** The University of Bergen engages in research on ghost fishing and plastic pollution. This case highlights the importance of academic knowledge in addressing biodiversity issues. Understanding who holds this knowledge and how it is disseminated informs broader conservation efforts.
- **Inequalities and Values:**
  - **Comino Island (EU CS1):** Addressing unsustainable agricultural practices requires considering economic inequalities among farmers. Investigating the impact of conservation efforts on social and economic structures provides insights into possible resistance or support.
  - **Boka Kotorska Bay (Non-EU CS4):** Uncontrolled fishing and recreational boating reflect economic incentives that may not align with conservation. Exploring how economic inequalities contribute to biodiversity loss informs strategies to engage the broader community.

Hypothesis 2: Longitudinal studies provide valuable insights into the long-term impacts and resilience of governance of biodiversity conservation efforts.

Proposed Research Questions (RQs):

- **Long-Term Impacts and Resilience:**

- **Aquatina di Frigole (EU CS2):** Poor management of the lagoon-sea connection has long-term effects on biodiversity. Longitudinal studies could reveal trends in biodiversity changes and evaluate the effectiveness of governance models over time.
- **Bergen (Non-EU CS7):** The impact of ghost fishing and plastic pollution on marine ecosystems warrants long-term observation. Studying these trends over time allows for the assessment of resilience and informs adaptive governance strategies.

Hypothesis 3: Effective understanding of power, leverage, and voice will contribute to more effective conservation efforts.

Proposed Research Questions (RQs):

- **Power, Leverage, and Avoiding Low-Hanging Fruit:**
  - **Arne Parish (Non-EU CS6:** With the growing issue of grey squirrels damaging trees, leading to adverse effects on biodiversity and climate change, the emphasis must be on identifying key stakeholders capable of driving effective change. Instead of targeting smaller-scale conservation efforts, the focus should be on addressing larger-scale impacts from grey squirrels on forest health and sustainability.
  - **Comino Island (EU CS1):** Transitioning to sustainable tourism practices necessitates understanding the power dynamics among tourism operators and regulatory bodies. Identifying leverage points among key stakeholders in the tourism industry, rather than focusing solely on smaller players, is crucial for effective conservation efforts.

In summary, integrating social science theories and approaches provides a comprehensive understanding of existing governance models and their impacts on conservation efforts. Understanding the dynamics of power, knowledge, and leverage is key to developing effective and sustainable strategies for biodiversity conservation. By mapping networks and assessing longitudinal impacts, the Pro Coast project can make informed decisions that contribute to the resilience and sustainability of biodiversity governance.

4 CONCLUSIONS

The landscape of biodiversity governance is complex and multifaceted, encompassing a broad spectrum of ecological, social, and economic considerations. From Marine Protected Areas (MPAs) to mainstreaming and community-based governance, each aspect plays a critical role in addressing biodiversity loss and promoting conservation.

The success of MPAs is highly contingent upon robust governance, clear objectives, and stakeholder involvement. Effective enforcement and adaptive learning are central to these protected areas achieving their ecological goals, but they often face challenges due to weak governance and inadequate resources. While some MPAs have demonstrated success, others have been marred by ecological crises, highlighting the variability in outcomes. Mainstreaming biodiversity into broader policy areas has gained traction, yet significant hurdles persist. Insufficient political commitment, inadequate legal frameworks, and the need for transformative governance approaches remain substantial obstacles. The importance of integrating biodiversity into wider socio-economic contexts is underscored by studies showing that conservation efforts yield better results when they align with positive socioeconomic outcomes for local communities. However, mainstreaming is often undermined by competing sectoral interests and a lack of coherence.

Community-based governance and indigenous participation have shown promise in achieving conservation goals by harnessing local knowledge and practices. Indigenous communities have demonstrated a positive impact on biodiversity within and outside protected areas, emphasizing the value

of engaging local stakeholders in governance. This approach contrasts with top-down governance models, which often fail to consider local needs and realities.

Market-based approaches to biodiversity governance, such as eco-certification and environmental policy instruments, have gained momentum but face skepticism and criticism. Critics argue that these approaches can lead to greenwashing and may not effectively address the root causes of biodiversity loss. The corporate influence on global conservation agendas has shifted the focus toward profit motives, raising concerns about the commodification of nature and the potential for reinforcing power imbalances. Recent trends in biodiversity governance reflect a growing recognition of the importance of addressing power dynamics, valuing diverse forms of knowledge, and adopting values-based approaches that prioritize justice, equality, and human rights. The need for a more holistic understanding of governance that encompasses formal structures and informal networks has become apparent.

To summarize, the governance of biodiversity requires a multi-faceted and adaptive approach. The challenges are significant, but there are also opportunities for innovation and collaboration. By acknowledging and addressing power imbalances, embracing local knowledge, and fostering inclusivity, the path to effective biodiversity governance can become more accessible. Ultimately, successful biodiversity governance will depend on a combination of robust governance, community engagement, and a commitment to aligning conservation goals with broader social and economic outcomes.

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REPORT 4: COMMUNITIES IMPACTED BY BIODIVERSITY LOSS AND THEIR ROLE IN BIODIVERSITY RESTORATION

1 INTRODUCTION

1.1 Scope of the document

According to recent IPCC report around 1 billion individuals will face heightened vulnerability to coastal hazards (i.e. escalating coastal populations, rising sea levels, flood risk and other coastal alterations) by 2050 (Intergovernmental Panel On Climate Change (Ipcc), 2022; Nilon et al., 2017). These risks are unfolding within a rapidly evolving global landscape influenced by climate change, ecosystem degradation, human activities, and the anticipated shifts in economic structures to align with the goals of the Paris Agreement. The unique challenges faced by coastal communities in the face of biodiversity loss underscore the urgent need for integrated conservation approaches. Engaging these communities in restoration efforts is crucial for sustainable outcomes. This report reviews literature to investigate how coastal communities are impacted by biodiversity loss, and the roles communities can play in biodiversity restoration. By synthesizing findings, the review aims to identify common themes, gaps in current knowledge, and emerging trends in the impact of biodiversity loss on human communities and their role in biodiversity restoration. This comprehensive analysis will contribute to the understanding of social-ecological systems (McGinnis & Ostrom, 2014) at the human community scale and aims to inform future research and policy development in the field of coastal biodiversity conservation and restoration.

This report emphasizes the importance of social impact through effective communication of knowledge and by providing low threshold offers on various social levels. In addition to augmenting the understanding of the intricate dynamics surrounding biodiversity loss and restoration efforts in coastal and marine communities, our research aims to investigate the transformative and adaptive changes taking place within these systems by providing insights into how community engagement in biodiversity conservation and restoration can be enhanced. It highlights the interdisciplinary potential of social science to facilitate behavioural change and societal transformation, for example the importance of enhancing social awareness, the effectiveness of community-led restoration, policy advancements that support community roles in conservation by engaging stakeholders, or technological innovations that empower communities in monitoring and restoring biodiversity. Furthermore, we endeavour to identify the barriers hindering advancement, and meticulously explore potential solutions to comprehensively address these challenges. By focusing on understanding social barriers, promoting socio-ecological transformation, leveraging interdisciplinary approaches, and ensuring social impact, it may be possible to contribute significantly to addressing environmental challenges. Additionally, this report underscores the need to consider biodiversity conservation in climate change mitigation efforts to safeguard our ecosystems for future generations.

1.2 Methods

In conducting our review on understanding the intersection of human communities and community engagement with biodiversity conservation and restoration, we structured our literature search to include Web of Science (WoS) alongside Scopus and focusing on the first 150 results from Google Scholar database. Our methodology employed precise search criteria, leveraging a combination of six pivotal keywords to align with our research topic i.e. ‘Community or Society' (coupled with ‘Coastal’ or ‘Marine’), 'Biodiversity' (coupled with 'loss' or 'restoration'), 'Social-ecological systems,' 'Transformative change,' 'Adaptive change,' and 'Barriers' (or 'solutions') across titles, abstracts, and keywords of articles, while

explicitly excluding references to plant communities unless associated with coastal or marine contexts. Initially, Web of Science yielded 13661 entries. Searches were conducted without restricting our search to a specific timeframe, thereby ensuring an expansive overview of the evolution of scientific discourse in this field over time. Our search criteria did not exclude any publication type and were confined to English-language publications. We then used a rigorous selection process, first applying a research area filter in WoS to exclude studies not related to the social sciences, and environmental studies and excluding review papers and books, then screening for relevance—based on topic congruence and abstract review—to narrow our pool to 36 papers. Due to a lower yield of relevant papers associated with 'Barriers' or 'Solutions,' these terms were excluded from the Scopus database search. Our initial query on the Scopus database brought to light 7017 papers. Then the same process was applied to Scopus results, which distilled the number to 64 relevant publications, focused human community engagement in coastal biodiversity contexts.

We analysed the literature according to key question and themes and theoretical perspectives of this report. Geographical focus was not constrained exclusively to coastal areas of EU countries. However, studies characterized by markedly different climatic conditions or environmental and social-economical contexts were systematically excluded to ensure the review's thematic coherence and applicability.

1.3 Structure of the report

This report is organized into several key sections to provide a stat of the art analysis of the impact of biodiversity loss on coastal communities and their role in restoration efforts. It starts with a "Literature Review" section that includes "Background and Context" to set the stage for understanding the topic. This chapter assesses current research, emphasizing the impact of biodiversity loss and the potential for community involvement in biodiversity restoration. It addresses biodiversity's role in ecosystem resilience, the valuation of ecosystem services, and the importance of integrating multidisciplinary approaches and community engagement in conservation and restoration efforts. The "Current Research Landscape" further divides into sub-sections: "Overview of Existing Literature," "Recent Trends and Developments," and "Key Studies and Findings," offering a deep dive into the state of research. "Hypotheses and Questions for the Case Studies" outlines the research framework for investigating the dynamic interplay between biodiversity loss and ecosystem service provision in coastal regions. It formulates the basis for examining real-world applications, aligning with the broader objectives to advance understanding and develop effective conservation strategies by presenting hypotheses and research questions, both derived from the literature review and identified research gaps. Finally, the "Conclusion" will summarize the report's findings, discuss their implications for theory and practice, and suggest directions for future research and the application to case studies.

2 LITERATURE REVIEW

2.1 Background and Context

The direct impacts of climate change on the ocean, such as elevated ocean temperatures, ocean acidification, sea level rise, sea ice melt and altered storm patterns, indirectly effect coastal social and ecological systems (Whitney & Ban, 2019). Furthermore, urbanization in biodiversity hotspots and escalating coastal populations leads to habitat destruction and reduced biodiversity, impacting ecosystem functions and human well-being (Nilon et al., 2017). Coastal areas, being at the frontline of environmental change, suffer significantly from biodiversity loss, which impacts not only their ecological but also social and economic stability. An interesting example is a multidisciplinary approach to unravel the intricate social-ecological challenges the coral reefs of Southwest Madagascar face amid climate change and

human activities (Bruggemann et al., 2012). Given the delayed impact of greenhouse gas concentrations on ocean warming, climate change effects are inevitable for centuries, underscoring the urgent need for adaptation at all scales, particularly through local and regional planning (Whitney & Ban, 2019). Recognizing coastal communities' unique position, there's a growing scholarly focus on how these communities are impacted by biodiversity loss and what roles they can play in biodiversity restoration. The imperative for enhanced community engagement (for example in Bergen, Norway (Bremer et al., 2022)) is rooted in the recognition that local communities possess invaluable traditional knowledge and have a vested interest in the sustainability of their environmental resources. Our report synthesizes findings from a wide review of research literatures which incorporate innovative approaches, stakeholder involvement, conceptual and integrated research methods, adaptation plans, and theoretical progress, and in some cases implement these approaches to unravel common themes, knowledge gaps, and emerging trends concerning the impacts of biodiversity loss on human communities and their participation in restoration efforts within coastal and marine environments. Emphasizing the pivotal role of coastal communities in biodiversity rehabilitation, the analysis strives to identify recurring patterns, areas lacking sufficient knowledge, and emerging trends to inform future research endeavours and policy formulation in the realm of coastal biodiversity preservation and restoration.

The urgency to address the complex challenges posed by climate change and biodiversity loss within coastal communities highlights the necessity for a multidisciplinary approach that integrates social, economic, and environmental perspectives, with the aim of accelerating sustainable ocean policy development (Britton et al., 2021). The reviewed papers underscore the critical need for transformative and adaptive strategies to enhance community engagement in biodiversity conservation and restoration (Bulkeley et al., n.d.). Adaptation actions for biodiversity restoration encompass strategies that mitigate adverse impacts and optimize the potential benefits of environmental changes, leading to enhanced social and ecological outcomes. They are commonly classified into 'hard' (e.g., engineering, infrastructure interventions), 'soft' (e.g., policy, governance, institutional changes), and 'ecosystem-based' (e.g., management, conservation, restoration) approaches (Whitney & Ban, 2019). Adaptive governance strategies underscore the importance of learning and flexibility in governance practices to effectively respond to environmental changes, as outlined in (Armitage & Plummer, 2010; Bohensky et al., 2010). Assessment, planning, implementation, and monitoring are considered as four distinct phases of the adaptation policy cycle to ensure comprehensive and effective adaptation strategies (Cabana et al., 2023). Concurrently, the concept of transformative change has gained traction, advocating for systemic shifts in how biodiversity conservation is approached and implemented, recognizing the limitations of traditional conservation practices in the face of escalating environmental challenges to promote sustainability (Koskimäki, 2021).

This report draws insights from a diverse array of studies including theoretical frameworks and analytical approaches to understand social-ecological systems (SES) dynamics for transformative sustainability change, and explores the impacts of biodiversity loss and the potential roles of communities in biodiversity restoration (Metcalf et al., 2015; Moore et al., 2014). Empirical evidence, such as that presented in (Avriel-Avni & Dick, 2019) underscores the complexity of community engagement in restoration activities and the factors influencing adaptive capacity in coastal communities. By examining SES adaptive and transformative changes, as well as identifying barriers and solutions, this study contributes to the development of more effective conservation and restoration policies aimed at enhancing coastal biodiversity preservation.

2.2 Current Research Landscape

2.2.1 Overview of Existing Literature

Recent studies have illuminated the complex challenges of addressing biodiversity loss and implementing transformative changes in coastal regions. Theoretical frameworks like Social Practice Theory and the identification of change agents offers nuanced approaches to socio-ecological systems with which to plan for transformations towards sustainability. This section synthesizes key methodologies, main findings, goals, and results from a range of studies to deepen our understanding of the complex dynamics of coastal ecosystems.

Methodologies across these studies vary from theoretical insights and conceptual models, analytical frameworks and participatory workshops to case studies (Nilon et al., 2017) and even predictive modelling. For example, Hamin et al. (Hamin et al., 2018) introduces an Adaptive Gradients Framework for assessing coastal adaptation solutions collaboratively. Similarly, (Mizrahi et al., 2020) develops a 'Livelihood Impact Potential Index' through field surveys to evaluate the socioeconomic effects of Marine Protected Areas (MPAs) on small-scale fishers. Findings emphasize holistic ecosystem management, integration of local and scientific knowledge, and the pivotal role of social-ecological transformations in fostering sustainable change.

The primary goal across these studies is to enhance the resilience of social-ecological systems to environmental changes while promoting sustainable management and conservation practices. Results demonstrate the effectiveness of integrated, stakeholder-driven approaches in achieving equitable outcomes. Notably, Britton et al. (Britton et al., 2021) highlights stakeholder engagement in formulating comprehensive ocean policies which consider marine issues' interconnectedness with human health.

The literature provides a broad understanding of socio-ecological dynamics in coastal communities, emphasizing human and natural systems' interdependence. A synthesis article by Whitney et al. compares diverse approaches to studying adaptive capacity, incorporating qualitative, quantitative, and participatory techniques (Whitney et al., 2017). Whitney and Ban in their recent study emphasize the multifaceted nature of SES and the necessity for governance frameworks that are flexible and inclusive of diverse knowledge systems (Whitney & Ban, 2019). Bruch et al. (Burch, 2010) underscore the necessity of reforming institutional frameworks, organizational culture, and policymaking processes to overcome barriers to climate action, addressing institutional path dependency as a barrier to local initiatives. Studies from England (Burch et al., 2014), the Netherlands (Uittenbroek et al., 2013), and British Columbia (Burch, 2010) highlight ways to overcome funding uncertainties and siloed thinking via ecosystem-based approaches within organizations and institutions to foster sustainable development trajectories.

Recent literature advocates for a multidisciplinary approach to comprehend and mitigate biodiversity loss impacts on coastal communities. For example, Bruggeman et al. and Findlater et al. shed light on the intricate interplay between human activities and marine ecosystems, advocating for sustainable community-led conservation efforts (Bruggemann et al., 2012; Findlater et al., 2022). Integrating ecological, social, and economic insights is recommended to foster sustainable community-led conservation efforts effectively (see Figure 2).

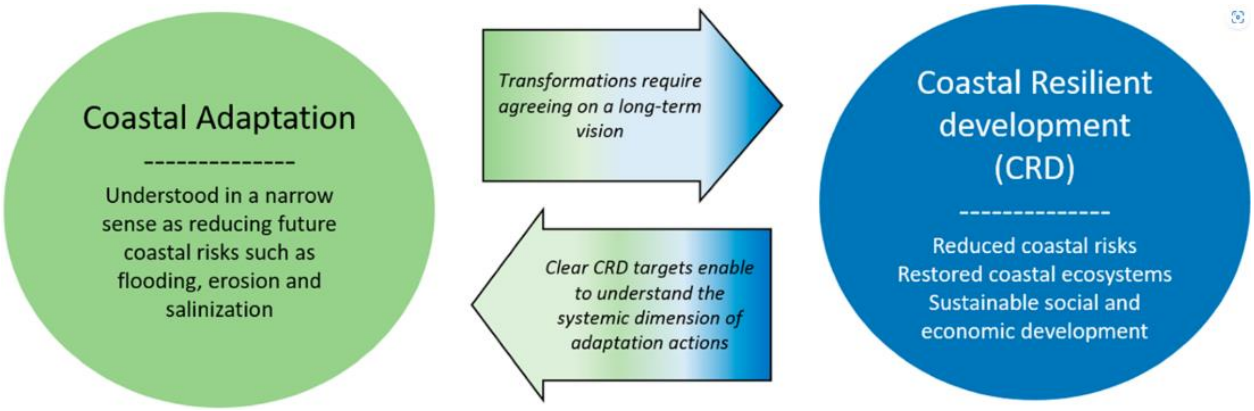

Figure 2: Enhancing coastal resilience with social transformations: transitioning from future coastal risks to holistic development with social sciences (Philippenko & Le Cozannet, 2023: 10).

By integrating ecological surveys, climate modelling, socio-economic assessments, and stakeholder interviews, Bruggemann et al. explore the resilience potential of high-latitude coral reefs as climate change refuges, despite the looming threats of environmental and anthropogenic stressors. The study underscores the vital interconnectedness of marine ecosystem health with broader socio-economic dynamics (or the relationship between biodiversity loss and community impacts), emphasizing socio-ecological resilience and integrated and adaptive management strategies as crucial elements in addressing challenges. Uittenbroek et al. emphasize the need to integrate climate adaptation into existing policy domains and the connection between adaptation science and crucial economic sectors to mitigate climate-related risks, using data from the Netherlands (Chung Tiam Fook, 2017; Uittenbroek et al., 2013).

Our categorization of papers on environmental challenges into common groups and subgroups reflects an interdisciplinary understanding of climate change, biodiversity conservation, and sustainable management. Drawing from sociology, ecology, and policy studies, the chosen categories align with societal goals for transformative change, stakeholder engagement, integrated research, adaptation strategies, and theoretical development. Table 1 shows some selected papers that are categorized based on thematic concentration and methodological approaches to address the complexities of environmental issues and propose inclusive and effective strategies for sustainability and resilience amidst global environmental changes. Some papers are classified into multiple groups concurrently.

These categories reflect a scientific approach to environmental conservation and adaptation in coastal regions. Adaptation Strategies and Resilience Building examines adaptive frameworks that enhance coastal resilience, including specific mechanisms to mitigate stressors and support recovery. Livelihoods, Vulnerability, and Socio-Economic Impacts analyzes how coastal communities' livelihoods and socio-economic factors interact with environmental changes. Stakeholder Engagement and Participatory Governance focuses on multi-stakeholder collaboration and community-led conservation and adaptation, emphasizing diverse actor engagement. Transformative Change and Systemic Approaches explores societal and ecological transformations, integrating global frameworks and policies for systemic change. Integrated Research and Interdisciplinary Methods promotes transdisciplinary research and knowledge integration, emphasizing ecosystem-based management. Theoretical Insights and Conceptual Models provides foundational theories, conceptual frameworks, and sociological perspectives to guide conservation and restoration. Together, these categories provide a holistic framework for addressing coastal conservation and resilience.

Table 1: Examples of selected research papers categorized by key themes in social-ecological resilience and adaptive strategies for coastal communities facing climate change and biodiversity loss.

Category	Subgroup	Papers listed in this group
Adaptation Strategies and Resilience Building	Adaptive Frameworks and Coastal Resilience	(Fedele et al., 2019; Findlater et al., 2022; Hamin et al., 2018; Whitney et al., 2017)
	Livelihoods, Vulnerability, and Socio-Economic Impacts	(Chin et al., 2019; Julsrud & Denstadli, 2020; Metcalf et al., 2015; Mizrahi et al., 2020; Wingfield et al., 2021)
Stakeholder Engagement and Participatory Governance	Multi-Stakeholder Collaboration	(Avriel-Avni & Dick, 2019; Britton et al., 2021; Burch, 2010; Esteve et al., 2018; Jacobson & Robertson, 2012; O'Donnell et al., 2018)
	Community-led Conservation and Adaptation	(Burnham et al., 2016; Flood et al., 2022; Hamin et al., 2018; Jansujwicz et al., 2021)
Transformative Change and Systemic Approaches	Societal and Ecological Transformations	(Bennett et al., 2016; Gillard et al., 2016; Koskimäki, 2021)
	Global framework and Policy Integration	(Bruggemann et al., 2012; Bulkeley et al., n.d.; Burch et al., 2014; Serrao-Neumann et al., 2023; Uittenbroek et al., 2013)
Integrated Research and Interdisciplinary Methods	Transdisciplinary Approaches and Knowledge Integration	(Arbo et al., 2018; Barnes et al., 2020; Szaro et al., 1998)
	Ecosystem-Based Management and Conservation	(McKinley et al., 2020; Vasseur, 2021)
Theoretical Insights and Conceptual Models	Theoretical Foundations and Conceptual Frameworks	(Moore et al., 2014; Tedesco et al., 2023)
	Sociological Perspectives on Environmental Change	(Gillard et al., 2016; Hossain et al., 2018)

2.2.2 Recent Trends and Developments

Recent studies underscore a growing recognition of the intricate interconnections between social and ecological components of socio-ecological systems. Academic collaboration fosters discussions on the convergence of social sciences, environmental science, and climate change, enhancing knowledge exchange (Philippenko & Le Cozannet, 2023). Emerging frameworks advocate for integrated approaches that leverage insights from social movements, socio-technical transitions, and social innovation theories (Koskimäki, 2021) to elucidate the mechanisms driving transformative change (Moore et al., 2014). An emerging focus in the literature revolves around SES theoretical framework as providing a foundational

framework for comprehending and addressing environmental challenges. This shift underscores the pivotal role of democratizing environmental governance, as evidenced in recent research (Britton et al., 2021; Bulkeley et al., n.d.). Central to this discourse is the articulation of adaptive and transformative strategies, essential for navigating the multifaceted challenges posed by biodiversity loss and climate change, particularly in coastal contexts. There is a growing emphasis on adaptive governance models capable of responding to the dynamic nature of social-ecological systems, advocating for flexible and inclusive conservation approaches, and moving away from rigid, top-down conservation models.

Recent work signals an increasing emphasis on incorporating local knowledge and promoting stakeholder engagement in conservation and restoration initiatives. For instance, (Jansujwicz et al., 2021) explore the potential of localized approaches to address governance gaps and enhance community involvement in conservation initiatives. The importance of participatory governance and stakeholder involvement in achieving sustainable conservation outcomes is further emphasized by Britton et al. and Hamin et al. (Britton et al., 2021; Hamin et al., 2018), reflecting a broader recognition of the contributions of local knowledge and community-led initiatives in restoration projects. Esteve et al. identify challenges to climate change adaptation such as low stakeholder acceptance and awareness (for example the lack of links between water users and the environmental groups and scientific community), and highlight the key role that can government can play in facilitating communication and sharing of knowledge (Esteve et al., 2018). Key to this is the harnessing of digital platforms and social media for stakeholder engagement and knowledge dissemination (Bremer et al., 2022).

In the field of Integrated Research and Interdisciplinary Methods, studies exploring adaptation strategies emphasize the significance of frameworks integrating socio-economic and biophysical perspectives (Hamin et al., 2018; Kingsford & Watson, 2011). The necessity for theoretical advancements incorporating social sciences into environmental research is emphasized as critical to grasp the complex dynamics of social-ecological systems. Research in this field emphasizes the importance of data integration to foster a holistic understanding of ecosystems by merging ecological, social, and economic data streams (Szaro et al., 1998). It criticizes current research practices which often compartmentalize diverse knowledge domains, suggesting a future research direction prioritizing methodological advancements to enable comprehensive ecosystem management. Furthermore, equitable scientific attention to all stages of adaptation knowledge is crucial for effective adaptation strategies (Cabana et al., 2023).

Work on Theoretical Insights and Conceptual Models reveals a complex landscape where communities' adaptive capacities, influenced by their social, economic, and natural capital, play a pivotal role in their responses to and mitigation of biodiversity loss impacts. A recent study highlights the critical role of human agency in climate change adaptation, through scenario planning and collaborative adaptation pathways planning in one locality – a small pool of participants in Australia over a 4-years period (Serrao-Neumann et al., 2023). Here again, a key trend is the shift towards interdisciplinary research methodologies aimed at bridging the gap between scientific inquiry and community-based conservation practices. Work in this field includes participatory action research and the integration of indigenous knowledge in conservation strategies (Barnes et al., 2020). Through participatory governance mechanisms, studies demonstrate how incorporating diverse voices, particularly those of local coastal communities, can enhance the efficacy and inclusivity of policy-making processes. This is vividly demonstrated by studies such as Fernández-Giménez et al. (Fernández-Giménez et al., 2022), which explore the dynamic roles of women in Spanish communities as custodians of tradition and agents of change, underscoring their critical contribution to fostering adaptive transformations within SES.

2.2.3 Key Studies and Findings

Key findings from various studies underscore the critical role of human agency, collaborative planning, and stakeholder engagement in crafting anticipatory adaptation responses to climate change and biodiversity loss. Notably, research in Southwest Madagascar explores the "wicked" nature of coral reef management, characterized by complex socio-ecological problems resistant to straightforward solutions (Bruggemann et al., 2012). Such complexity poses a significant barrier to formulating effective management strategies for coastal ecosystems, necessitating a nuanced and adaptive approach to address the multifaceted issues involved.

Addressing the need for governance systems that can adapt flexibly to environmental changes remains a critical area for further exploration (see also Report 3). While the importance of adaptability is recognized, additional research is required to identify the specific structures and mechanisms essential for enhancing adaptive capacity within coastal communities. Understanding how governance systems can evolve to meet the dynamic challenges posed by climate change is paramount for fostering resilience and sustainability (Armitage & Plummer, 2010). Emerging challenges include climate-induced migration, integrating gender equity, inclusion of disabled individuals, and religious and ethnic minorities into adaptation policies, and demand combining a justice-oriented approach with a clear economic vision outlining opportunities and constraints (Philippenko & Le Cozannet, 2023).

The transition from conceptual frameworks to practical strategies for achieving transformative and adaptive changes within coastal communities still presents a notable gap in current research. While new analytical frameworks offer insights into understanding deliberate attempts to lead social-ecological transformations such as highlighting the three phases involved in SES transformations by (Moore et al., 2014) (i.e. preparing for change, navigating the transition, and building resilience of the new trajectory of development), bridging remaining gaps between theory and implementation is crucial. Future studies should focus on translating theoretical concepts into actionable measures that can drive meaningful change and resilience in coastal regions.

Despite the demonstrated effectiveness of community-led conservation initiatives (Pelke & Simonn, 2023), further research is needed to evaluate their long-term viability and scalability. Investigating the factors that contribute to the success or challenges of community-led efforts is essential for informing future conservation practices and ensuring their enduring impact on biodiversity outcomes and climate resilience.

Addressing the acute vulnerability of coastal communities to climate change and biodiversity loss necessitates a comprehensive, multidisciplinary approach to enhance adaptive capacity through ecosystem resilience, infrastructural reinforcement, economic diversification, and inclusive governance. This includes a deep dive into educational initiatives, the role of social networks, and other non-traditional factors beyond infrastructure and economic support that can fortify resilience against the adverse impacts of biodiversity loss (Koskimäki, 2021). Understanding the holistic ecosystem of factors that contribute to adaptive capacity is crucial for developing robust conservation strategies that can effectively mitigate the challenges posed by climate change and biodiversity loss in coastal areas (Whitney et al., 2017).

3 HYPOTHESES AND QUESTIONS FOR THE CASE STUDIES

The review suggests several research questions future case studies. These could be used to guide inquiries which aim to delve deeper into the complex interplay between community actions, biodiversity restoration, and socio-ecological system resilience, providing a foundation for innovative case-study investigations in social-ecological science.

Role of human agency and stakeholder engagement

Hypotheses:

1. Enhanced integration of human agency and stakeholder engagement positively contributes to effective biodiversity restoration and conservation efforts.
2. Effective stakeholder participation is crucial for successful biodiversity conservation efforts.

Research Questions:

1. How does the integration of human agency and stakeholder engagement influence the success of biodiversity restoration initiatives in coastal environments?
2. What are the main obstacles hindering stakeholder participation in biodiversity conservation initiatives, and how can these barriers be effectively addressed to enhance conservation outcomes?

Barriers and enablers to transformative changes

Hypothesis:

Identifying barriers and enablers is crucial for implementing transformative and adaptive changes in coastal socio-ecological systems.

Research Question:

What are the key barriers and enablers that influence the successful implementation of transformative changes in coastal SES?

Socio-ecological feedback and adaptive strategies

Hypothesis:

Understanding how socio-ecological feedback mechanisms interact during transformative processes can inform improvements in adaptive strategies for future climate resilience.

Research Question:

In what ways do socio-ecological feedback mechanisms influence adaptive strategies in coastal communities facing environmental changes?

How can this knowledge be used to enhance future resilience efforts?

Community engagement and SES resilience

Hypothesis:

Community engagement in biodiversity restoration initiatives strengthens the resilience of coastal socio-ecological systems.

The literature in this field (Armitage & Plummer, 2010) points to a need for further empirical research to explore the mechanisms through which community engagement can be effectively mobilized and sustained. Future research should aim to address the identified gaps, particularly in understanding the dynamics of community engagement in diverse cultural and ecological contexts and developing methodologies to measure the impacts of such engagement on biodiversity conservation outcomes.

Research Question:

How does community engagement in biodiversity restoration initiatives impact the resilience of coastal socio-ecological systems and contribute to long-term sustainability?

The role of adaptive governance in restoration projects

Hypothesis:

Adaptive governance frameworks play a vital role in the successful implementation of biodiversity restoration projects in coastal areas.

Future studies should explore innovative ways to boost the adaptive capacities of coastal communities, particularly through policies that support community resilience through economic diversification, education, and sustainable resource management (Metcalf et al., 2015).

Research Questions:

To what extent do adaptive governance frameworks contribute to the effectiveness of biodiversity restoration projects in coastal regions, and how can these frameworks be optimized for better outcomes?

Bridging knowledge gaps and integrating indigenous knowledge

Hypothesis:

Integrating traditional ecological knowledge with scientific research is hypothesized to enhance the adaptability and resilience of coastal communities to biodiversity loss.

There is a need for more empirical research focusing on the mechanisms through which community engagement in biodiversity restoration can be enhanced, including the roles of governance, policy support, and education. In addition, the development of monitoring and evaluation frameworks to assess the effectiveness of adaptation strategies, coupled with advocating for adaptive governance that incorporates community participation and upholds traditional knowledge, is essential (Vasseur, 2021).

Research Question:

In what ways does the integration of traditional ecological knowledge with contemporary scientific approaches in conservation efforts influence the adaptive capacity of coastal communities?

Innovative assessment methodologies

Hypothesis:

Innovative assessment methodologies are essential for identifying transformative change leverage points in conservation strategies.

Future research directions call for deeper engagement with interdisciplinary methods, the expansion of participatory governance models, and the exploration of novel theoretical frameworks to better understand and address environmental challenges (for example (Gillard et al., 2016). Innovations may involve participatory action research, technology utilization for community engagement (e.g., citizen science apps), and interdisciplinary methodologies merging ecological science with social sciences to enhance community awareness and engagement in biodiversity restoration.

Research Question:

How can the integration of participatory governance models, interdisciplinary methodologies, and novel theoretical frameworks help identify leverage points to enable inclusive and transformative change in coastal biodiversity restoration?

4 CONCLUSIONS

The report has outlined the multifaceted challenges facing and avenues for addressing biodiversity loss and fostering transformative changes in coastal regions. Grounded in a diverse range of studies, it

underscores the interconnectedness of social and ecological components of socio-ecological systems, emphasizing the vital roles of coastal communities in restoration and conservation efforts. Central to this discourse is the recognition of human agency, collaborative planning, and stakeholder engagement as pivotal elements in formulating anticipatory adaptation strategies. We highlight the need for integrated, participatory approaches to conservation that not only aim to restore ecological integrity but also strive to enhance the socio-economic resilience of coastal communities. The adoption of adaptive, inclusive governance frameworks, underpinned by the integration of local knowledge and active stakeholder participation, emerges as a fundamental strategy in navigating the complexities of environmental governance.

Recent empirical evidence and theoretical advancements highlight the efficacy of community-led initiatives in biodiversity conservation and the necessity of bridging theoretical concepts with actionable measures. Furthermore, the analysis reveals gaps in current research, particularly in the areas of effective community engagement, governance models, and the integration of local approaches within broader conservation strategies. It further highlights the need for interdisciplinary research to develop innovative methodologies that can address these gaps, fostering a holistic understanding of SES dynamics and enhancing the adaptive capacity of coastal communities. Moreover, the importance of addressing direct and indirect climate change impacts on coastal ecosystems, alongside the socio-economic factors exacerbating vulnerability, is emphasised, advocating for an interdisciplinary approach that weaves together social, economic, and environmental perspectives.

In conclusion, this report advocates for a transformative shift towards sustainability and resilience in coastal ecosystems, grounded in the principles of social-ecological science. By fostering greater community involvement, leveraging interdisciplinary approaches and embracing adaptive governance, there is potential to significantly enhance biodiversity conservation and restoration efforts. The proposed future research directions, emphasizing the integration of social scientific insights and participatory methods, promise a pathway towards achieving more resilient and sustainable coastal ecosystems. This narrative not only contributes to the scientific understanding of coastal biodiversity conservation but also provides actionable insights for policymakers, practitioners, and researchers, underscoring the indispensable role of coastal communities in navigating the challenges posed by global environmental changes.

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REPORT 5: INFLUENCE OF DEMOGRAPHIC, COGNITIVE, AFFECTIVE, ATTITUDINAL, AND SOCIETAL FACTORS ON COASTAL BIODIVERSITY

1 INTRODUCTION

1.1 Scope of the document

Our review is underpinned by the overarching aim of elucidating the multifaceted drivers of biodiversity loss in coastal ecosystems at various societal levels – micro, meso, and macro – and the resultant implications for societal responsibilities and proactive measures for conservation.

Primary Objectives

The literature review seeks to:

Investigate the diverse roles of demographic, social, ethnic, religious, and gender aspects in shaping attitudes and actions towards coastal biodiversity conservation.

Assess how cognitive and affective factors affect attitudes and relationships with coastal biodiversity

Understand the broader implications of crises, particularly the escalating climate crisis and cultural and societal impacts

Research Questions

Guiding our inquiry are the following pivotal questions:

How do socio-demographic characteristics such as education, age, and gender influence attitudes towards biodiversity, and how do these attitudes vary across different social groups or milieus?

What roles do local actors, institutional dynamics, religious communities, and micro-political contexts play in promoting or hindering social-ecological transformation towards biodiversity conservation?

How do larger societal crises, particularly the climate crisis, alongside the broader social climate, political culture, and legal frameworks, impact organizational and individual commitments to biodiversity conservation?

Boundaries and Limitations

This report explicitly defines its boundaries to focus on coastal ecosystems, acknowledging the unique challenges and conservation strategies pertinent to these areas. While drawing upon a broad spectrum of literature, the review acknowledges the limitation in coverage due to the vastness of the subject matter and the dynamic nature of ongoing research. Additionally, the scope is confined to the exploration of societal influences on biodiversity, without delving into the biological or ecological mechanisms of biodiversity loss.

1.2 Methods

The methodology for our literature review was developed to gather comprehensive insights into the ways socio-demographic characteristics, education, gender, religion, conspiracy theories, anti-science sentiments, barriers, political contexts, social-ecological transformation, organizational factors, and discrimination impact biodiversity loss in coastal ecosystems. This approach aimed to unravel the intricate relationship between human society and the degradation of coastal biodiversity.

We conducted our literature search using three renowned academic databases: Web of Science, Scopus, and Google Scholar. These databases were chosen for their extensive coverage across the sciences and social sciences, providing access to a wide variety of peer-reviewed articles, conference proceedings, and books relevant to our study.

Our search strategy combined specific keywords and Boolean operators to capture the diverse factors influencing coastal biodiversity. We structured our keywords as follows:

Topic Keywords: ((biodiversity OR “coastal biodiversity”) AND ("socio-demographic characteristics" OR sociodemographic* OR Education OR Gender))

Additional Thematic Keywords: ((religion OR “religious communities”) OR (conspiracy OR anti-science OR personality) OR (barrier*) OR ("political context*" OR "social-ecological transformation" OR organisation* OR discrimination))

The asterisk (*) was used as a wildcard to include all variants of the root words, ensuring a broad search scope.

In addition to the primary search, we employed a snowballing technique to incorporate literature cited within the initially identified sources. This method allowed us to include important studies that might not have been detected initially due to keyword variations or differences in database indexing.

The initial query on the Web of Science database using the sequence “((biodiversity OR “coastal biodiversity”) AND ("socio-demographic characteristics" OR sociodemographic* OR education OR gender) AND ((religion OR “religious communities”) OR (conspiracy OR anti-science OR personality) OR (barrier*) OR ("political context**"** OR "social-ecological transformation" OR organization* OR discrimination)))” resulted in 245 publications. In a second step for further selection, the abstracts of these 245 publications were reviewed in pairs and sorted according to their relevance to the topic. This review resulted in 86 usable papers. Another search was conducted on the Scopus database using the sentence “((biodiversity OR "coastal biodiversity") AND ("socio-demographic characteristics" OR sociodemographic* OR education OR gender) AND ((religion OR "religious communities") OR (conspiracy OR anti-science OR personality) OR (barrier*) OR ("political context**"** OR "social-ecological transformation" OR organization* OR discrimination)))”. The result comprised 205 publications, of which 35 were selected for further use in the second step. To ensure adequate coverage, we extended the search to Google Scholar, but limited the results to the first 150 hits. Here, we were able to identify a further 19 publications.

We did not restrict our review based on geographic location or publication date to achieve a comprehensive view of the global and historical context of biodiversity loss in coastal ecosystems, recognizing that the drivers and impacts vary across different areas and times.

It is pertinent to note that the majority of studies encountered in our research predominantly address biodiversity in a broad sense rather than concentrating explicitly on coastal biodiversity. This generalization arises from a marked scarcity of studies specifically dedicated to the nuances of coastal biodiversity.

The process began with screening the search results by examining titles, abstracts, and keywords for relevance, followed by a detailed full-text review of selected studies. This ensured that each study included in our review contributed meaningfully to our understanding of the research themes, with a particular focus on the interaction between human activities, societal factors, and biodiversity loss.

This thorough and inclusive approach aims to offer a nuanced, evidence-based exploration of the societal influences on coastal biodiversity, integrating a wide array of interdisciplinary perspectives.

1.3 Structure of the report

The report, structured into three key chapters, provides an in-depth examination of the intricate relationships between human societies and coastal ecosystems, focusing on the socio-demographic factors and institutional roles that influence biodiversity conservation.

Chapter 2: Literature Review critically evaluates the conservation of coastal biodiversity, focusing on the interplay between human activities and marine ecosystems. It outlines key concepts such as Biodiversity and Social-Ecological Systems, highlighting the impact of socio-demographic factors like age, gender, and socioeconomic status on conservation efforts. The review identifies significant research gaps, notably the lack of studies specifically targeting coastal biodiversity, and underscores the importance of inclusive research methodologies and stakeholder engagement to effectively address these challenges.

Chapter 3: Hypotheses and Questions for the Case Studies builds upon the literature review to frame hypotheses and research questions targeting the influence of socio-demographic variables and institutional roles on biodiversity conservation. It explores the impact of individual traits and broader societal factors on conservation attitudes and practices, aiming to identify effective strategies for fostering social-ecological transformation. This chapter sets the stage for in-depth case studies by highlighting the need for collaborative, multi-level approaches to biodiversity conservation.

Chapter 4: Conclusion wraps up the report by underlining the significance of the findings and the urgency of filling research gaps in coastal biodiversity conservation. It advocates for collaborative, inclusive approaches that leverage both socio-demographic insights and local institutional involvement. The chapter stresses the need to apply these insights practically, aiming to enhance the effectiveness of biodiversity conservation efforts globally.

2 LITERATURE REVIEW

2.1 Background and Context

What are the challenges and strategies involved in the conservation of coastal biodiversity, against the historical, political, and socio-ecological dimensions that shape these efforts?

Historical and Political Context of Coastal Biodiversity Conservation

The endeavor to conserve coastal biodiversity is embedded within a complex historical and political milieu that has evolved over centuries. The interaction between human societies and coastal ecosystems has always been dynamic, with coastlines serving as hubs for settlement, commerce, and culture. Historically, coastal regions have been cradles of civilization, fostering a unique interdependence between human activities and marine and coastal biodiversity. This symbiosis, however, has been increasingly strained by industrialization, urbanization globalization, and climate change (IPCC 2019 SR) leading to unprecedented levels of biodiversity loss.

The political landscape governing coastal biodiversity has seen significant shifts, especially in the last few decades. Policies and frameworks at both international and national levels, such as the Convention on Biological Diversity and various EU directives, have been instrumental in steering the discourse towards sustainable management and conservation of coastal ecosystems. Moreover, the recognition of coastal zones as critical areas for biodiversity conservation in the face of climate change has catalyzed a plethora of initiatives aimed at mitigating biodiversity loss and enhancing ecosystem resilience.

Key Concepts and Frameworks

At the heart of the discourse on coastal biodiversity conservation are several key concepts and frameworks that facilitate a comprehensive understanding of the challenges and strategies involved in such endeavors.

Biodiversity: The term encapsulates the variety of life in all its forms and levels, including genetic, species, and ecosystem diversity. In coastal contexts, biodiversity not only contributes to the ecological resilience and functionality of these habitats but also underpins the socioeconomic well-being of communities through services such as fisheries, tourism, and coastal protection.

Social-Ecological System: Central to addressing the complexities of coastal biodiversity conservation is the Social-Ecological Systems framework, which emphasizes the interconnectedness of human and ecological systems. This integrative perspective, championed by Elinor Ostrom (2009) among others, provides a valuable lens through which the dynamic interactions between social systems and their ecological settings can be examined, thereby facilitating holistic and adaptive management strategies.

Diversity in Socioecological Contexts: Beyond ecological diversity, the Social-Ecological Systems framework also brings into focus the importance of social diversity—including demographic, ethnic, religious, and gender dimensions—within conservation efforts. This multifaceted diversity influences and is influenced by ecological conservation practices, affecting how different communities perceive, value, and engage with biodiversity.

Co-creation and Stakeholder Engagement: Recognizing the value of diverse perspectives and knowledge systems, co-creation processes involve stakeholders at all levels in the development and implementation of conservation strategies. Approaches such as the Bristol Approach and Extreme Citizen Science (ECS) framework exemplify how participatory methodologies can enhance the relevance, effectiveness, and sustainability of conservation initiatives.

Future Directions

The narrative of coastal biodiversity conservation is one of growing awareness, evolving methodologies, and increasing urgency. Historical experiences underscore the necessity of adaptive management approaches that can navigate the complex and often uncertain interactions between human and ecological systems. Politically, there is a continuous need for governance structures that are inclusive, equitable, and capable of integrating traditional knowledge with scientific innovations.

2.2 Current Research Landscape

2.2.1 Overview of Existing Literature

In the following, we aim to briefly outline the major themes, debates, and findings present in the current body of literature related to the topic.

Major Themes in the reviewed literature

Analytical Levels of Society: The discourse on biodiversity conservation can be structured across micro, meso, and macro levels of society, offering a differentiated understanding of how diversity influences conservation efforts at different societal strata. This analytical approach reveals the predominance of micro-level studies, often aligned with natural sciences research paradigms, and underscores the need for increased focus on meso- and macro-levels where sociologists and political scientists can contribute significantly to understanding larger societal and systemic factors in biodiversity conservation.

Age: Age is a complex determinant in biodiversity conservation, with older individuals often showing greater concern and support for conservation efforts as well as a greater tendency towards pro-environmental behavior. However, there is also some evidence indicating that younger demographics may

engage more actively in certain conservation activities. This variability underscores the need for further exploration of age's nuanced influence on conservation behaviors.

Intersectionality of Diversity and Conservation: The literature highlights the multifaceted nature of diversity, encompassing age, gender, socioeconomic status (SES), education, and personality traits, each playing distinct roles in influencing attitudes towards and participation in biodiversity conservation. This complexity points to the importance of adopting an intersectional lens to fully grasp the interplay between diverse societal factors and conservation outcomes.

Gender Dynamics: A critical theme emerging from the review is the significant role of gender in shaping conservation attitudes and behaviours. Studies reveal varying levels of concern, support for conservation strategies, and participation in conservation activities between genders, indicating the necessity to consider gender dynamics in designing and implementing biodiversity conservation efforts. While many studies highlight that women tend to show greater concern and support for conservation efforts than men, there is also contrasting evidence suggesting this is not a universal trend and warrants a more nuanced examination of gender roles in conservation.

Socioeconomic Status (SES): SES emerges as a pivotal factor, with its impact on conservation attitudes and behaviours manifesting in complex and sometimes counterintuitive ways. The literature points to a nuanced relationship between SES and environmental concern, suggesting that both lower and higher SES groups exhibit unique patterns of engagement with biodiversity conservation.

Educational Impact: Education is identified as a key determinant of conservation attitudes and behaviours, with higher levels of education generally correlating with more positive orientations towards biodiversity conservation. This finding underscores the potential of educational interventions in fostering pro-conservation attitudes and behaviours across populations.

Role of Religion and Spiritual Beliefs: Although less explored, the intersection of religion and biodiversity conservation presents a rich avenue for understanding how spiritual beliefs and practices influence conservation perspectives and actions. Preliminary findings suggest that religious and traditional spiritual communities can play a significant role in preserving biodiversity, particularly in contexts where these communities hold significant land or wield moral authority.

Debates and Divergences in the Literature

Effectiveness of Conservation Strategies: A recurring debate centres on the effectiveness of various conservation strategies and the role diverse societal factors play in shaping their success or failure. This debate reflects broader discussions on the need for adaptive, context-specific conservation approaches that account for the complex interplay of demographic, social, ethnic, religious, and gender factors.

Methodological Approaches: The literature reflects a methodological diversity, with debates on the merits and limitations of quantitative versus qualitative approaches in capturing the nuances of how diversity influences conservation efforts. This methodological plurality highlights the importance of interdisciplinary research in providing a comprehensive understanding of the topic.

Policy Implications: There is ongoing discussion regarding the implications of diversity-related findings for policy formulation and implementation. Debates focus on how best to integrate insights on the influence of diversity into effective, inclusive, and equitable conservation policies and practices, especially in the face of global environmental challenges.

2.2.2 Recent Trends and Developments

This subsequent chapter seeks to elucidate the intellectual milieu from which these insights have emerged, setting the stage for a deeper appreciation of the nuanced interplay between diversity and environmental stewardship, particularly within coastal biodiversity contexts.

Emerging Trends, Methodologies, and Theoretical Perspectives

The burgeoning recognition of the profound impact of diversity on environmental conservation has engendered a paradigmatic shift towards embracing more inclusive and holistic research methodologies. This intellectual movement is marked by a heightened focus on understanding the intricate relationships between human societies and natural ecosystems, acknowledging the complex interdependencies that characterize coastal regions.

Quantitative Surveys and Advanced Statistical Analyses: The adoption of comprehensive quantitative surveys and sophisticated statistical techniques, such as hierarchical multi-level regression models, stands as a testament to the field's commitment to uncovering the subtle nuances of sociodemographic variables on conservation attitudes and behaviors. This methodological sophistication allows for a more granular understanding of the diverse factors influencing environmental engagement.

Interdisciplinary Research and Cross-sectoral Collaboration: A salient trend within the realm of biodiversity conservation is the move towards fostering interdisciplinary collaborations that bridge the natural sciences, social sciences, and humanities. This approach is indicative of a broader recognition of the need for collaborative efforts that transcend traditional academic boundaries, highlighting the importance of integrating diverse perspectives in tackling the complex challenges of coastal biodiversity conservation.

Theoretical Innovations: The theoretical landscape of biodiversity conservation research has been enriched by the integration of ecopsychology and social identity theory. Ecopsychology explores the psychological relationship between humans and the natural world, positing that a deeper emotional and cognitive connection to nature can bolster conservation efforts. Concurrently, social identity theory offers insights into how an individual's identification with certain social groups can shape their environmental attitudes and behaviours.

Protection Motivation Theory: The application of protection motivation theory to the context of biodiversity conservation provides a framework for understanding how perceived threats to biodiversity, coupled with coping appraisals, influence individual and collective actions towards conservation. This theory underscores the critical role of cognitive processes in shaping human responses to environmental challenges.

Socio-Ecological Models: Emphasizing the interconnectedness of human societies and ecological systems, socio-ecological models advocate for a holistic approach to conservation that considers social, economic, and environmental determinants. This perspective is particularly pertinent in addressing the multifaceted challenges of coastal biodiversity conservation. The intricate interplay between human activities and natural systems necessitates an integrative approach that incorporates Gender, Feminism, and Intersectionality Theories.

Theories related to gender, feminism, and intersectionality enrich our understanding of the role of diversity in environmental conservation. For instance, feminist political ecology, as outlined by Sylvester & Little (2021), provides a powerful lens through which to examine women's participation in agroecology, highlighting how gendered dynamics and intersectional identities shape conservation practices and outcomes. This theoretical perspective underscores the importance of acknowledging and addressing the

unique challenges and contributions of women, particularly in agroecological contexts, as integral to fostering sustainable environmental stewardship.

2.2.3 Key Studies and Findings

In the following sections, we aim to answer the questions mentioned in Chapter 1. We will address these questions by analytically separating society into micro-, meso-, and macro-levels of society. It should be noted that most findings pertain to the micro-level, likely because quantitative studies are predominantly situated here and align more closely with research approaches in the natural sciences. In contrast, the meso- and macro-levels tend to be domains of interest for sociologists and political scientists. The majority of the papers we discovered were within the realm of the natural sciences, which probably reflects the focus on the topic of "biodiversity." Along the micro-level, we will discuss the influence of age, gender, socioeconomic status, education level, and personality traits.

At the meso level, in our review biodiversity conservation encompasses themes such as cross-sectoral cooperation, the influence of tourism, the role of NGOs, sustainable business practices, participatory municipal decision-making, the contributions of religious and educational institutions, and the development of shared values to address conflicts and promote unified conservation efforts.

The papers contained the least discussion on the macro level, which is likely due to the scientific focus of the articles that less often consider a socio-critical perspective. The key themes of the papers we found at the macro level include the influence of wealth, language, and geography on the availability of biodiversity conservation data, the impact of personality traits at a societal level on environmental engagement, systemic approaches to enhancing nature connectedness, and the challenges and potential of educational approaches to promote biodiversity conservation.

Micro-level factors that contribute to the protection of biodiversity, including coastal biodiversity

Across diverse communities and contexts, the public can play a crucial role in the restoration and protection of biodiversity. Hence, the potential relevance of sociodemographic and other micro-level variables to biodiversity, perceptions thereof, and the implementation of strategies aimed at its conservation or restoration is a significant area of inquiry. Age, gender, SES, education, personality and religion stand out as plausible factors that may influence these aspects. Despite the importance of coastal biodiversity, studies specifically addressing this topic are scarce. Therefore, findings from research on other forms of biodiversity are incorporated in the following sections.

Age

A study conducted by Davison et al. (2023) delves into the factors influencing concern over marine biodiversity loss and the desire for more research into marine biodiversity protection among European citizens. Executed via a survey method involving 14,167 participants from 14 European countries, Davison et al. (2023) utilized hierarchical multi-level regression models to predict concern and support for research through sociodemographic variables. The analysis revealed a notable trend concerning age demographics. Older adults exhibited a heightened level of concern regarding marine biodiversity loss compared to their younger counterparts. This heightened concern among older age groups was further reflected in their stronger support for additional research into marine biodiversity protection. This finding is further supported by a study conducted by Liu et al. (2014) providing insights from nation-wide public surveys carried out in the United States. The study encompassed approximately 3000 respondents across three surveys conducted from 2004 to 2013, aiming to ascertain determinants of public environmental concern encompassing both general environmental awareness and specific issues such as pollution and

global warming. While no significant effect of age was observed in 2004, older citizens exhibited greater environmental concern in 2007 and 2013.

Attitudes and support for conservation may also vary depending on the specific conservation strategy in question. Bremner and Park (2007) conducted a study on public attitudes toward the management of invasive non-native species, which are recognized as one of the main threats to biodiversity. The study, carried out in Scotland with a sample size of 248 individuals randomly selected from the general public and thus relatively representative, utilized postal questionnaires. Generally, support for control and eradication programs was high. Notably, regression analyses revealed that older individuals, particularly those in the age group 45-54, demonstrated higher levels of support for control and eradication programs.

To evaluate the perception and attitudes of local forest users towards community forestry programs, Lucungu et al. (2022) conducted a study in three villages in Congo. The survey included 138 households, and it was found that respondents aged between 20 and 50 tended to have a more favorable perception of the local community forestry programs compared to younger and older respondents ($p < 0.10$). A study conducted by Datta et al. (2023) focused on assessing attitudes towards predators such as tigers and leopards. These attitudes, as well as human-wildlife cohabitation, play an important role for species conservation. The survey encompassed 345 households distributed across 10 forest villages in India. In this study, age did not have a significant impact on attitudes toward conservation.

Focusing on environmental behaviors including biodiversity protection, Bronfman et al. (2015) conducted a survey in a Chilean community. While they did not specifically report results for biodiversity protection, they found that the younger subjects tended to score lower across pro-environmental behaviors. Focusing on climate change-related behaviors rather than biodiversity specifically, Thaller et al. (2020) investigated climate-friendly behaviors in Australia across different age groups. In line with the finding by Bronfman et al. (2015), they found a positive association between increasing age and engaging in climate-friendlier behaviors, suggesting a potential alignment between age and environmental consciousness.

Contrastingly, Lucrezi (2022) explored public perceptions of marine environmental issues among coastal recreational users in Italy ($N = 202$) and found that younger individuals participated more in conservation activities. Similarly, Sakurai et al. (2016) investigated local residents' behavioral intentions for coastal conservation in Japan. In a questionnaire survey, younger residents were more likely to express willingness to make financial sacrifices for coastal conservation.

However, Ressurreição et al. (2012) found no significant effect of age on willingness to pay for prevention of marine species loss in surveys conducted in Portuguese islands and the Baltic Sea Gulf in Poland ($N = 747$). This suggests that age may not always be a significant factor in determining attitudes towards biodiversity conservation.

Several studies also assess the influence of sociodemographic factors on donation behavior toward biodiversity conservation. Eylering et al. (2022) investigated willingness to donate as well as actual donations towards the conservation of endangered bird species. Using the Protection Motivation Theory framework, which incorporates threat appraisal and coping appraisal as predictors, the study additionally examined how sociodemographic variables like age influences the outcomes. Through an online questionnaire administered to 579 German participants, the researchers assessed the impact of age on willingness to donate and actual donation behaviors. Actual donation behavior was measured as a percentage of the questionnaire reward, ranging from 0 to 2 euros. Contrary to the authors´ initial expectations, the findings revealed no significant difference in willingness to donate or actual donations between younger and older participants. Despite previous research suggesting age as a determining factor in donation behaviors, this study, utilizing multiple hierarchical regression analyses, revealed age to be

non-significant once theory-based constructs were considered. However, the study allowed a very narrow monetary range in actual donations and was confined to Germany, which may limit the results´ generalizability.

Applying the identical design and methodology as Eylering et al. (2022), Dörge et al. (2021) utilized the Protection Motivation Theory to forecast both willingness to donate and actual donations toward insect conservation, diverging from the focus on bird conservation. Expanding the model, Dörge et al. (2021) again incorporated various sociodemographic variables, including age. In a sample comprising 515 German participants, age emerged as a non-significant predictor of willingness to donate, yet exhibited a negative impact on actual donations. This result contrasts both with Eylering et al.´s (2022) findings and the expectation of willingness to donate preceding actual donations. Given the uniformity in methods, the study shares the same limitations as observed in Eylering et al.´s (2022) research. In a similar vein, Veríssimo et al. (2018) investigated potential factors affecting donations toward conservation campaigns in Australia. They examined the behavior of donors across 25 species-focused conservation campaigns organized by an NGO running in 34 stores over a span of 5.5 years and juxtaposed it with the age profile of residents living in the vicinity of the campaign sites. Analyzing real-life campaigns and donations, this method allowed for higher ecological validity. Like Eylering et al. (2022) but in contrast to Dörge et al. (2021), Veríssimo et al. (2018) did not find donors´ age to be associated with donation behavior. Furthermore, age did not exhibit a significant effect ($p < .05$) on willingness to make monetary contributions in a case study by Musa and Nadarajah (2023). In order to investigate willingness to pay for green tourism, the authors administered a questionnaire to 250 visitors of a Malaysian forest recreation area.

Apart from donations, the general public´s participation in conservation initiatives can also be an important lever for mitigating biodiversity loss. Méndez-López et al. (2019) examined the association between participation in conservation initiatives and several factors including community of residence, demographics, and socioeconomic characteristics. They collected data from 670 surveys across six rural communities in southeastern Mexico. The study identified the highest percentages of non-participation among the two youngest generations (aged 17-45), but noted that the specific participation rates of different age groups varied depending on the type of conservation initiative. Méndez-López et al. (2019) argue that young people´s low participation rates might reflect lower community involvement due to rural-to-urban migration.

Given the far-reaching consequences of agriculture on biodiversity and species conservation, farmers and their participation in sustainable practices play a crucial role and are thought to be influenced by socioeconomic factors. For example, cocoa agroforestry is one of the most effective nature-based solutions to address global change including biodiversity loss according to Kouassi et al. (2021). The authors hence investigated the willingness of cocoa farmers in the South-western Côte d´Ivoire to adopt cocoa agroforestry. Assessed through surveys and interviews, age was found to be a key determinant of cocoa agroforestry adoption. Older farmers exhibited a greater propensity for adopting agroforestry practices, with the highest likelihood observed among those aged 40 and above.

Yet, disparities in the valuation of ecosystem services do not appear to be the underlying factor behind age-related variations in engagement with sustainable practices. Based on an Australian online survey with 91 farmers, Page and Bellotti (2015) found that age did not have a significant impact on the perceived importance of ecosystem services.

As urban expansion is one of the drivers of biodiversity loss, residential strategies can also be an important means to enhance conservation. In their U.S. survey, Bowman et al. (2012) investigated conservation subdivision design and low-impact development as residential strategies for mitigating the negative environmental impacts of urban expansion ($N = 777$). They specifically examined residents´ valuation of

these strategies, measured through their willingness to pay for their implementation. The study revealed age to be a predictor, with older respondents showing a greater willingness to pay for the preservation of natural features such as streams with forested buffers.

In summary, age exerts diverse influences on biodiversity-related concerns, support for conservation strategies, and donation behaviors. Older individuals tend to exhibit higher levels of concern and support for conservation efforts, as seen in studies by Davison et al. (2023), Liu et al. (2014), Bremner and Park (2007), and Lucungu et al. (2022). They also seem to display more pro-environmental behavior (Bronfman et al., 2015; Thaller et al., 2020). However, for conservation activities, participation was higher among younger people (Lucrezi, 2022). The relationship between age and donation behavior or willingness to pay is inconsistent across studies too, with some showing older individuals' greater propensity to donate (Eylering et al., 2022) while others find no significant association (Ressurreição et al., 2012; Veríssimo et al., 2018). Additionally, age influences farmers' adoption of sustainable practices, with older farmers more likely to adopt such practices (Kouassi et al., 2021). The impact of age is nuanced and varies across different aspects of biodiversity conservation, suggesting the need for further investigation into its role.

Gender

Examining the determinants of concern about marine biodiversity loss and the desire for further research into marine biodiversity protection among European citizens, Davison et al. (2023) also assessed gender as a potential predictor of concern and support of research. Notably, gender emerged as a significant factor influencing these outcomes. Females demonstrated a heightened level of concern regarding marine biodiversity loss compared to males which translated into stronger support for additional research into marine biodiversity protection.

Regarding the impact of gender on broader environmental concern, Liu et al. (2014) also found a consistent pattern across the three surveys spanning the decade from 2004 to 2013 with women consistently demonstrating higher levels of environmental concern compared to men.

In contrast to that, Bremner and Park (2007) found gender to have a different effect on conservation attitudes. Support for a specific conservation strategy, namely management of invasive non-native species through control and eradication programs was assessed through a questionnaire. In a sample representative of the Scottish general public, support for control and eradication programs was higher among men. Similarly, gender played an important role for attitudes toward leopard and tiger conservation in the survey conducted by Datta et al. (2023) in India. Positive views on conservation of these species were common among men. Nevertheless, in their study of perceptions and attitudes of local forest users towards community forestry programs, Lucungu et al. (2022) did not find any effects of gender. Likewise, Bronfman et al. (2015) found no significant effects of gender on various environmental behaviors in a Chilean community, including biodiversity protection. However, Lucrezi (2022) noted that females were more likely to engage in pollution reduction efforts among coastal recreational users in Italy, indicating a gender disparity in environmental engagement.

Thaller et al. (2020), focusing on climate-friendly behaviors in Australia, observed reverse effects for conservation behavior and climate citizenship concerning gender. Female participants exhibited more conservation behavior, while male participants showed higher engagement in climate citizenship activities. The authors suggest that gender roles may influence the type of environmental behaviors individuals engage in, with women more inclined towards private conservation efforts and men towards more visible political actions.

Concerning willingness to pay for coastal bird diversity enhancements in UK coastal ecosystems, Boeri et al. (2020) identified gender as a significant factor. They found that respondents with the strongest preferences for biodiversity improvements and highest willingness to pay tended to be female.

In a study conducted in a coastal region of Japan, Sakurai et al. (2016) also found that females were more likely to express willingness to make financial sacrifices for coastal conservation efforts, further illustrating gender differences in environmental attitudes and behaviors.

Conversely, Ressurreição et al. (2012) did not find such an effect at an alpha level of .05. In their survey conducted in Portuguese islands and the Baltic Sea Gulf in Poland, women were not more willing to pay for prevention of marine species loss.

Among studies assessing the effect of sociodemographic variables on donations toward biodiversity conservation, Eylering et al. (2022) investigated willingness to donate and actual donations for the conservation of endangered bird species in Germany. They extended the Protection Motivation Theory framework by not only including age, but also sex. Based on the data gathered through the administered questionnaire and the subsequent donations made by participants, the results indicated that women were more likely to engage in actual donations compared to men. Interestingly, this effect was not observed for willingness to donate when other constructs of the theoretical framework were considered.

Similarly, Dörge et al. (2021) found gender to be a predictor of actual donations for insect conservation, with women donating more than men. However, no influence was observed on willingness to donate. Yet again, limitations concerning generalizability due the possible donation range and the sample should be considered.

Within their examination of real conservation campaigns and donation behavior in Australia, Veríssimo et al. (2018) tested the relationship between donations received by campaign sites and gender distribution of the surrounding area. Unlike Eylering et al. (2022) and Dörge et al. (2021), they did not find a significant association.

Concerning participation in conservation initiatives across rural communities in Mexico, the survey by Méndez-López et al. (2019) revealed that participation was higher among men than among women. They suggest that possible reasons for this could be organization structures, lack of time and women´s long working days in the communities investigated.

In their investigation of barriers encountered by women, James et al. (2023) discovered that women are underrepresented in leading solutions to urgent conservation challenges. Utilizing a staff survey administered at The Nature Conservancy, one of the largest NGOs, with a sample size of 904 individuals (nearly evenly distributed between men and women), they examined aspects pertinent to career development, contributions to research, and decision-making processes. The analysis revealed significant disparities between men and women across a majority of survey questions related to these domains. Specifically, men were found to exert greater influence over conservation and scientific decisions, while women encountered numerous obstacles in their conservation careers attributed to gender bias. Additionally, women reported heightened incidences of sexual harassment, discrimination, and concerns regarding retaliation in comparison to men. Furthermore, the study unveiled a tendency among men to overestimate gender equity within the conservation sector, perceiving it as more favorable for women than women themselves experienced. The study also highlights that women encounter barriers in conservation careers influenced by intersecting factors such as race, ethnicity, age, physical abilities, and geographic location. For instance, only a small percentage of respondents felt that women from outside the U.S. were well represented in science or conservation leadership roles. Women with intersectional identities reported experiences of unconscious bias and discrimination in their careers.

Similarly, women face gender-specific barriers to participation in acroecology. Sylvester and Little (2021) investigated the obstacles faced by women engaging in acroecology in Costa Rica, employing semi-structured in-depth interviews with nine participants. The findings illuminate pervasive challenges, with all participants citing machismo and microaggressions as significant barriers. Over half of the women detailed a "triple burden," characterized by disproportionate workloads across productive, reproductive, and community spheres, compounded by underpayment and undervaluation of women´s compared to men´s work. Financial constraints, particularly the high costs of agriculture, further hinder participation. Additionally, the study reveals nuanced variations in factors influencing participation, as several factors were perceived as supporting by some women, yet hindering by others. According to Sylvester and Little (2021), this emphasizes the dependency of barriers on specific contexts and intersectional realities.

For farmers´ valuation of ecosystem services, no gender differences are apparent. In their Australian survey, Page and Bellotti (2015) found that farmers´ gender did not have a significant impact on the perceived importance of ecosystem services.

Concerning residential strategies, the U.S. survey conducted by Bowman et al. (2012) showed that female respondents reported higher willingness to pay more for clustered housing, which is a feature of conservation subdivision design.

In conclusion, gender plays a significant role in various aspects of biodiversity conservation but its influence varies across different contexts. Studies such as those by Davison et al. (2023), Bremner and Park (2007) and Liu et al. (2014) reveal gender differences in concern for biodiversity loss and support for conservation strategies. Additionally, research suggests that women may be more inclined to donate to conservation efforts and more willing to pay for biodiversity enhancements compared to men (Boeri et al., 2020; Dörge et al., 2021; Eylering et al., 2022; Sakurai et al., 2016). Findings concerning pro-environmental behavior do not suggest a straightforward effect, with men and women reporting high levels of different kinds of behavior or no significant effects of gender (Bronfman et al., 2015; Thaller et al., 2020). However, gender disparities exist in participation in conservation initiatives, as noted by Méndez-López et al. (2019) and barriers identified by James et al. (2023) and Sylvester and Little (2021). Despite these differences, gender does not seem to influence farmers' valuation of ecosystem services (Page & Bellotti, 2015) or preferences for conservation subdivision design (Bowman et al., 2012). Overall, recognizing and addressing gender dynamics is crucial for promoting inclusive and effective biodiversity conservation efforts.

Socioeconomic Status

Within their previously referenced survey, Davison et al. (2023) explored SES as another potential sociodemographic factor shaping concern about marine biodiversity loss and the desire for further research into marine biodiversity protection among European citizens. Notably, SES emerged as a significant predictor of concern and support for research into marine biodiversity. Adults with lower incomes exhibited a heightened level of concern regarding marine biodiversity loss and stronger support for research into marine biodiversity protection compared to their counterparts with middle incomes. This finding contrasts with the authors´ expectation that higher SES would be positively associated with environmental concern.

Conversely, insights from Liu et al. (2014) suggest that SES is not a significant predictor of more general environmental concern. While SES predicted one facet of environmental concern (concern about global warming) in the 2007 study wave, this effect disappeared when entering additional variables into the regression model.

For attitudes toward conservation of predators, Datta et al. (2023) found associations between higher incomes and positive attitudes toward tiger conservation, but no association between income and attitudes toward leopard conservation. Looking at farmers´ valuation of ecosystem services, SES does not seem to have an effect. In their survey, Page and Bellotti (2015) found that Australian farmers´ income did not have a significant effect on the perceived importance of ecosystem services either.

Concerning environmental behavior in a Chilean community, Bronfman et al. (2015) found that subjects in the lowest SES group exhibited the lowest scores, suggesting a negative correlation between lower SES and environmental behaviors. Interestingly, an inverted U-shaped relationship was observed, with individuals with the highest SES scoring low across pro-environmental behaviors, too.

Boeri et al. (2020) investigated willingness to pay for coastal bird diversity enhancements in UK coastal ecosystems. They identified income as a significant factor, with respondents with lower incomes showing lower levels of willingness to pay and those with the highest incomes exhibiting the highest levels of willingness to pay for bird diversity enhancements. In a survey conducted in Portuguese islands and the Baltic Sea Gulf in Poland, Ressurreição et al. (2012) also found that income had a positive and highly significant effect on willingness to pay to prevent marine species loss. Similarly, Sakurai et al. (2016) identified a positive relationship between annual household income and willingness to make financial sacrifices for coastal conservation efforts among residents in a coastal region of Japan.

In their study examining willingness to donate and actual donations for the conservation of endangered bird species in Germany, Eylering et al. (2022) expanded the Protection Motivation Theory framework to incorporate SES alongside age and sex. Analyzing data collected from the administered questionnaire and subsequent donations, the findings revealed that SES, as measured by income levels, did not significantly influence willingness to donate once the constructs of the Protection Motivation Theory were considered. This finding contradicts the authors´ expectation that individuals with higher income would be more inclined to donate.

However, in line with this expectation, Dörge et al. (2021) found SES to be positively associated with willingness to donate toward insect conservation. Again, limitations concerning generalizability due the possible donation range and the sample should be taken into account.

In their study of Australian real-life conservation campaigns and donations towards these, Veríssimo et al. (2018) investigated the association between donations received and income levels within the areas surrounding campaign sites. Surprisingly, they found revenues per donor to be greater in lower-income areas, though the effect was small overall.

In their questionnaire study conducted in a Malaysian forest recreation area, Musa and Nadarajah (2023) found visitor´s willingness to pay for green tourism not to be significantly predicted by income at all.

The survey by Bowman et al. (2012) revealed that higher household incomes were positively correlated with certain environmentally friendly residential features, namely a greater willingness to pay for pervious pavers and rain gardens. However, it should be noted that their U.S. sample population skewed towards higher average household incomes, which may have implications for the generalizability of the findings.

In summary, socioeconomic status (SES) plays a diverse role in biodiversity conservation efforts. While some studies suggest that individuals with lower incomes exhibit heightened concern for biodiversity loss (Davison et al., 2023), other studies found negative associations between lower income and positive attitudes toward conservation and pro-environmental behavior (Datta et al., 2023; Bronfman et al., 2015) or no consistent association (Lui et al., 2014). While Dörge et al. (2021) and Eylering et al. (2022) report conflicting findings concerning the effect of SES on donations toward conservation, willingness to pay for biodiversity efforts tends to be higher among individuals with higher SES (Boeri et al., 2020; Ressurreição

et al., 2012; Sakurai et al., 2016). Surprisingly, Veríssimo et al. (2018) found greater donations for conservation campaigns in lower-income areas. Moreover, SES intersects with biodiversity conservation at a macro level, as demonstrated by Amano and Sutherland (2013), who found a higher availability of biodiversity data in countries with higher per capita GDP. Overall, understanding the interplay between SES and biodiversity conservation is crucial for developing effective and equitable conservation strategies.

Education

The impact of education on fostering positive attitudes and behaviors towards environmental conservation is significant, necessitating an in-depth understanding of its effects. Numerous studies have explored the influence of formal education levels on attitudes concerning biodiversity. There seems to be a consensus in the research community that higher levels of education correlate with more positive attitudes and behavioral tendencies that contribute to biodiversity conservation (Bravo-Monroy et al., 2015; Canavari et al., 2022; Lucungu et al., 2022). However, there is also some contradictory evidence that indicates that further research is necessary (Davison et al., 2023).

A study by Canavari et al. (2022) investigated factors that influence conventional farmers' decisions to adopt organic farming, focusing on the Pesaro-Urbino province in Italy. The study employed a questionnaire-based survey, assessing the impact of personal, professional, and contextual factors on farmers' intentions. From the 202 respondents 40% possessed a university degree, 8% had completed high school, 9% had a middle school diploma and the remaining 42% held a primary school diploma. Farmers with higher education levels showed a greater inclination towards adopting organic farming. These findings were in line with previous results (Ferreira et al., 2020; Liu et al., 2019) that education significantly shapes farmers' attitudes and decisions regarding sustainable farming practices.

Similarly, a study by Bravo-Monroy et al. (2015) focused on understanding the factors influencing farmers' decisions to adopt organic versus conventional coffee management practices in Colombia. The research utilized a combination of ethnographic techniques and quantitative methods to explore the predominant drivers of management adoption, revealing how farmers' perceptions, social identity, and the complexity of interacting factors influence their decision-making processes. Education, as a sociodemographic factor, was found to have a significant influence on the adoption of organic farming practices, with more years of formal education associated with a higher likelihood of adopting organic methods.

The main research question of Lucungu et al. (2022) (previously referenced in the foregoing discussion) was to assess the perception and attitude of local community members towards Local Community Forest Concessions (LCFC) in the Democratic Republic of Congo. Education emerged as a significant determinant: respondents with elementary, high school, and university education levels had a more positive perception of LCFC compared to those with no education, indicating that education positively influences the acceptance and support for community forestry initiatives. The authors suggest that, having a certain level of education could enable a better appreciation of the issues, challenges and opportunities arising from community forestry, particularly in the perspective of local development based on the use of forest resources (Lucungu et al., 2022).

In contrast to these results highlighting the importance of education for attitudes and practices supporting biodiversity conservation, the previously referenced study by Davison et al. (2023) about concern and support for research into the health impacts of marine species loss revealed divergent findings. The study found that individuals with a university degree expressed both lower concern over the loss of marine species and lower support for research funding into marine species protection. Davison et al. (2023) acknowledge that this finding is contrary to the Eurobarometer (2017) results which found that those with higher educational attainment were more concerned about the decline or extinction of species and habitat

in general and Gifford and Nilsson (2014) who also showed that higher educational attainment correlated positively with environmental concern. The authors demand that more research on concern about biodiversity loss, with a focus on marine specificity and human health, is needed to clarify this discrepancy.

A subcategory in the research on the impact of education on attitudes towards biodiversity concerns the willingness to donate to environmental causes related to biodiversity or the willingness to pay for ecosystem services. In this research, however, greater variability appears to exist in the impact of educational level. While some studies indicate that a higher level of education correlates with an increased willingness to donate (Bhandari & Heshmati, 2010; Carlesi et al., 2023; Musa & Nadarajah, 2023), other research has not found significant educational effects (Eylering et al., 2022). Lastly, some studies suggest that educational level may not impact actual donation behavior, but only influence the willingness to donate (Dörge et al., 2022; Veríssimo et al., 2018).

The study by Carlesi et al. (2023) aimed to investigate Italian households' preferences for deep-sea ecosystem services in the Mediterranean through a hypothetical discrete choice experiment. Educational level was assessed by categorizing the 800 respondents into three groups: low (elementary and middle school), medium (high school), and high (bachelor, master, or PhD). The results showed that formal education positively influenced willingness to donate to NGO initiatives for deep-sea protection: Respondents with a degree below high school had a negative preference for limiting the global temperature, while respondents with a bachelor's degree or above presented a favourable preference. The authors state that such differences highlight the critical role of education and knowledge generation in understanding the importance of deep-see ecosystem services.

With similar results, the study by Musa and Nadarajah (2023) (previously referenced in the foregoing discussion) aimed to determine visitors' willingness to pay for green tourism conservation at Bukit Larut, Malaysia. Educational level was assessed across categories: no formal education, primary school, secondary school, and higher education (certificate/diploma/degree/PhD). The results showed a positive correlation between educational level and willingness to pay, indicating that higher education levels significantly increased the likelihood of supporting green tourism conservation financially. The study concluded that most visitors are willing to pay for conservation, highlighting the importance of education in enhancing environmental awareness and the willingness to support conservation initiatives financially.

The study by Bhandari and Heshmati (2010) investigated tourists' willingness to pay for biodiversity conservation in Sikkim, India, focusing on socio-economic and site-specific factors. Using survey data analyzed through logistic and Tobit models, the research found that educational level significantly influenced willingness to pay. Higher education correlated with greater willingness to financially support conservation efforts. These findings suggest that targeting well-educated tourists could effectively generate conservation funds.

Different results were obtained by a study by Eylering et al. (2022) (previously referenced in the foregoing discussion). They explored factors influencing the German population's willingness to donate and actual donations towards bird conservation, integrating the Protection Motivation Theory with sociodemographic variables, knowledge about, and attitudes towards birds. Educational level was assessed through standardized categories from the federal statistical office ranging from "no degree" to "general qualification for university entrance". The educational level of participants did not influence their willingness to donate or their actual donations toward bird conservation. The authors acknowledge that these findings are contrary to previous studies that demonstrated that a higher level of education is associated with a higher willingness to donate toward bird conservation (Brouwer, van Beukering & Sultanian, 2008; Lundberg et al., 2019). One possible explanation that the authors gave was that these previous studies also included higher educational qualifications (e.g., attendance at a university or a university degree).

In a methodologically similar study, Dörge et al. (2022) (also previously referenced in the foregoing discussion) also applied the Protection Motivation Theory to examine the factors influencing the Germans´ willingness to donate and actual donations, this time focusing on insect conservation. The study used the same approach of assessing educational levels through standardized categories defined by the federal statistical office, ranging from "no degree" to "general qualification for university entrance". However, the findings of this study diverged in one aspect from those of Eylering et al. (2022) regarding bird conservation. While the educational level of participants did not affect their actual donations towards insect conservation, it had a significant impact on their willingness to donate. The authors see that as evidence for the frequently described intention-behavior gap. They suggest that some participants might have indicated a high willingness to donate to insect conservation due to social desirability because they did not expect the subsequent question to be an opportunity to actually donate.

A further previously referenced study by Veríssimo et al. (2018) underscores the point that the influence of education on actual donation behavior may differ from its effect on willingness to donate. The study examined the impact of various factors on donations, including campaign duration, species traits, and donor demographics, with educational level gauged using the Index of Education and Occupation score from Australian census data, which reflects the education and occupation status of the population around each campaign store. Contrary to their initial assumptions, the study found that most of the hypothesized factors, including educational level, did not significantly influence the amounts donated. This finding suggests that actual donor behavior may deviate from the predictions of theoretical models, further highlighting the complexities inherent in fundraising for conservation efforts.

Educational programs

Educational programs play a crucial role in promoting awareness and influencing behavior. Multiple studies have delved into the efficacy of such programs and interventions, ranging from online platforms (Sundaraja et al., 2022) and educational classes (Børresen et al., 2022) to digital games (Fjællingsdal & Klöckner, 2019), as well as the broader implications for environmental education within diverse contexts (Schüßler et al., 2019). These studies contribute to a nuanced understanding of the role of education in fostering environmental consciousness and pro-environmental behaviors.

The research by Sundaraja et al. (2022) aimed to assess if an online educational intervention on sustainable palm oil could influence Australian consumers' purchasing behaviors. The method involved randomly assigning 628 adults to one of three groups: an interactive educational website on palm oil, an existing educational video on sustainable palm oil, or a control condition with content unrelated to palm oil. Participants' knowledge, attitudes, and self-reported purchasing behavior were measured before, immediately after, and two weeks post-intervention. Results showed that while the interactive website and video increased knowledge and intention to purchase sustainable palm oil compared to the control, they did not significantly influence actual purchasing behavior at follow-up. The study highlighted a gap between intentions and actual behavior, suggesting the need for strategies beyond education to facilitate sustainable purchasing, like improving product availability and labeling.

Børresen et al. (2022) explored the effectiveness of an educational program in altering secondary school students' knowledge, attitudes, and views towards ecosystem services and biodiversity in Tanzania's Ngorongoro District. Through a pre-test/post-test design involving 180 students, the study demonstrated a significant improvement in students' understanding of ecosystem services, the importance of biodiversity, and the negative impacts of climate change, human population growth, and land use change after participation in the educational program. The program consisted of questionnaires, lectures, and posters to help students understand the value of natural resources, and develop knowledge and understanding to inform decision making processes about responsible environmental behaviors over a period of six weeks.

The findings suggest that such educational interventions can effectively enhance awareness and foster positive attitudes towards environmental conservation among students, recommending the inclusion of similar programs in school curricula to promote sustainable natural resource management.

The study by Robinson et al. (2019), conducted through a global survey of conservation practitioners, aimed to assess the need for social marketing skills, the demand and supply for social marketing training, and the barriers to receiving such training in the conservation sector. Results from 322 respondents across 71 countries revealed a significant lack of social marketing skills among conservation practitioners, with only 16.1% considering their skill level as expert or advanced. However, 61.5% reported the need for advanced or expert skills for effectiveness in their roles. Despite high demand for training, barriers such as lack of funds, time, and available courses hinder practitioners from acquiring these skills. The study underscores the critical gap between the need and the supply of social marketing training in conservation, highlighting the importance of developing accessible training opportunities to enhance conservation efforts.

The study by Fjællingsdal and Klöckner (2019) explored the educational potential of "Eco", a digital simulated ecosystem game, to promote environmental consciousness. The study employed a qualitative research method, conducting semi-structured interviews with seven participants who had experience playing the game "Eco." These interviews were analyzed to explore the educational potential of the game in fostering environmental consciousness among players. This small, focused group allowed for in-depth exploration of individual experiences and perceptions related to the game's impact on environmental awareness and behaviors. The study identified two main themes: game-based learning outcomes and barriers to immersion and learning. It found that while "Eco" can enhance some aspects of environmental consciousness by simulating ecosystem impacts and requiring cooperation, challenges like slow pacing and limited flow hindered learning. The game serves as a potentially effective tool for environmental education, suggesting future implementation strategies for leveraging its educational benefits. However, it is important to note that all seven participants were male. Therefore, the possibility of skewed research results due to gender differences cannot be eliminated.

The study by Schüßler et al. (2019) reviewed 248 environmental education interventions in Madagascar, assessing their effectiveness in promoting pro-environmental behaviors amidst challenges such as poverty and limited resources. The research question focused on whether environmental education can influence the pro-environmental behaviors of the Malagasy people and identified the key success factors. Using a structured literature search and data from various sources, the study found that despite the implementation of numerous environmental education programs, mainly by NGOs, their impact is limited due to factors like insecure funding, poverty-driven unsustainable decisions, and a lack of systematic evaluation. The study suggests improvements in environmental education practice by integrating local cultural contexts and ensuring sustainable funding mechanisms.

Educational interventions are important for fostering environmental consciousness and pro-environmental behaviors. Beyond the immediate impact of these programs, there is also some research dedicated to understanding the transmission of knowledge acquired from educational programs to broader communities. This line of inquiry is essential as it provides insights into how effectively the lessons learned within educational settings can be communicated and adopted by individuals in their daily lives, thereby amplifying the reach and impact of environmental education.

An example of this is the study conducted by Martini et al. (2014) which investigated the diffusion of yard care knowledge among homeowners within urban ecosystems, focusing on whether and how individuals share information learned from short-term educational programs with their neighbors, the factors influencing this diffusion, the specific yard care information shared, and the perceived barriers to

information transmission. Utilizing a mixed-method approach that included mailed surveys, small group discussions, and mailed information exchanges in the Minneapolis–St. Paul metropolitan area, the study found that approximately 34% of participants shared information with their neighbors within a one-month period. Factors positively associated with information sharing included participation in group discussions, individual social connectedness, length of home ownership, and having children in the household. The content of shared information primarily related to increasing grass height and reducing fertilizer applications. The study also identified spatial, temporal, and perceptual barriers to information sharing but suggested that overcoming some of these barriers is possible.

Education for Sustainable Development in teacher education

The education of future teachers on sustainable development is important because they play a pivotal role in imparting this essential knowledge to the next generation. As educators are tasked with preparing students to face and address global challenges, their competence in teaching about sustainability can significantly impact the effectiveness of Education for Sustainable Development (ESD). By equipping teacher candidates with the necessary skills, knowledge, and attitudes towards sustainability, educational institutions can ensure that future generations are better prepared to contribute to a more sustainable world.

The study by Brandt et al. (2022) investigates the development of ESD-specific professional action competence among teachers, focusing on the impact of teacher education courses at Leuphana University (Germany) and Arizona State University (USA). The research question explores how these courses support the development of knowledge, skills, and attitudes necessary for implementing ESD at the school level. Utilizing a mixed-method approach, the study identifies the factors that support or hinder pre-service teachers in achieving intended learning outcomes. The results indicate that both courses effectively increased students' competence in ESD, highlighting the significant role of personal, professional, social, and structural connections in influencing students' learning processes and outcomes. The study suggests that these elements should be considered in designing teacher education programs for sustainable development.

The main research goal of the study by Büssing, Schleper and Menzel (2018) was to identify the contextual and personality variables that are motivationally relevant for pre-service teachers' motivation towards teaching about the return of the wolf. The method used is a cross-sectional study with a self-completion questionnaire distributed among 120 pre-service biology teachers in Lower Saxony, Germany. The results indicate that protection motivation, attitudes towards wolves, and psychological distance are significant predictors of motivational variables like attitudes, enjoyment, and perceived behavioral control towards teaching. Protection motivation emerged as a strong direct predictor, while psychological distance showed a negative direct prediction. The study concludes that these factors should be considered in designing teacher education programs to effectively integrate education for sustainable development topics like biodiversity conservation into teaching.

The study by Richter-Beuschel & Bögeholz (2019) investigated the procedural knowledge of student teachers in Germany regarding sustainable development challenges, particularly in biodiversity and climate change. Utilizing a mixed-methods approach, including a Delphi process and a questionnaire assessing the effectiveness of solution strategies against expert benchmarks, the research aimed to identify differences in procedural knowledge among student teachers across various education levels (bachelor vs. master) and subjects (biology, geography, politics). Results showed significant gaps between the students' estimations and the expert benchmarks, indicating varied levels of procedural knowledge that did not consistently improve from bachelor to master levels or across different subjects. This

underscores the need for enhanced education strategies focusing on sustainable development within teacher education programs.

Impact of sociodemographic variables overall

Some of the studies mentioned also report the impact of sociodemographic factors altogether, which becomes evident when including them in the initial step of hierarchical regression analysis. Gender, age, education and income together accounted for a mere 1.1% of the variance in willingness to donate toward bird conservation, indicating minimal influence (Eylering et al., 2022). For insect conservation, the same variables explained a similarly low 2.2% of the total variance in willingness to donate and 0.8% of the total variance in actual donations (Dörge et al., 2021).

Personality

Personality traits can play a role in shaping our attitudes and behaviors towards nature and biodiversity. Research has shown that how we perceive and interact with the environment is also influenced by our individual differences (e.g. Martín et al., 2023; Milfont & Sibley, 2012; Soga et al., 2018). These personality characteristics not only determine our concern for the natural world but also our willingness to support efforts aimed at protecting it (e.g. Davison et al., 2023).

The previously referenced study by Davison et al. (2023) investigated the variation in concern and support for research into the health impacts of marine species loss across Europe. The study found that out of the Big Five personality dimensions, openness, conscientiousness, and agreeableness were significant positive predictors of concern for marine species loss and support for research into marine species protection. Individuals with more open, conscientious, and agreeable personalities exhibited more concern and support. No significant effects were found for extraversion or neuroticism. The research underscores the importance of engaging especially individuals who are low in openness, conscientiousness and agreeableness in communications surrounding marine biodiversity.

Similar results about the effects of openness, conscientiousness, and agreeableness were found by the research of Milfont and Sibley (2012). Their goal was to examine the associations between the Big Five personality traits and environmental engagement at both individual and societal levels. The research aimed to explore whether specific personality traits could predict an individual's or a nation's engagement in environmental conservation behaviors and attitudes across three studies. Study 1 analyzed individual-level associations between the Big Five traits and the value of "protecting the environment" in New Zealand, finding agreeableness, conscientiousness, and openness most predictive of environmental values. Study 2 extended this to examine self-reported past behavior regarding electricity conservation, again in New Zealand, reinforcing the importance of the same three traits for environmental behavior. Study 3 broadened the scope to the country level, correlating aggregated Big Five personality traits with environmental engagement indicators using cross-cultural data about the distribution of the Big Five personality traits in various countries. This part of the study found that nations with higher scores in openness, extraversion, and to a lesser extent, agreeableness and conscientiousness, exhibited greater environmental engagement, highlighting the influence of national personality profiles on environmental policies and attitudes.

However, another study that investigates the relationship between the Big Five personality traits and attitudes towards biodiversity came to different results (Soliño & Farizo, 2014). Their goal was to analyze how the Big Five personality dimensions influence consumer preferences for an environmental program concerning forest management in Spain. The method employed involved the use of a discrete choice experiment and the implementation of the Big Five Inventory-10 (BFI-10), to gauge personality traits of the participants. This approach allowed for the examination of the role of personality in shaping preferences

for different attributes of the proposed environmental program, such as biodiversity, employment generation, risk of forest fires, and the presence of certified products incorporating natural resin. The results revealed that personality traits indeed influenced preferences for the environmental program. However, the findings for the individual personality dimensions partially diverged from those of Davison et al. (2023) and Milfont and Sibley (2012). In the study of Soliño and Farizo (2014), openness and extraversion had a positive effect on the preferences for the environmental program, indicating that individuals scoring high in these traits were more likely to support the program. Conversely, agreeableness and neuroticism had a negative effect, suggesting that those with higher scores in these dimensions were less inclined to favor the program.

The research conducted by Monteiro et al. (2023) focused on exploring the relationship between the Big Five personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism), Dark Triad personality traits (narcissism, Machiavellianism, and psychopathy), environmentalism, and the mediating role of social dominance orientation. The study aimed to determine if individuals with higher levels of Dark Triad traits exhibit lower levels of environmentalism due to their higher tendencies towards social dominance orientation. 305 participants were assessed using several scales measuring environmentalism, the Dark Triad traits, Big Five personality traits, and social dominance orientation. Environmentalism, in this context, refers to attitudes, behaviors, and actions aimed at protecting and preserving the natural environment. Social dominance orientation is a personality trait that reflects an individual's preference for inequality among social groups, with a higher social dominance orientation indicating a greater preference for one's own group to dominate others or for hierarchy in general.

In contrast to the study of Davison et al. (2023), Milfont and Sibley (2012) and Soliño and Farizo (2014) who found a significant effects ofpersonality traits, the research of Monteiro et al. (2023) indicated that none of the Big Five factors were found to be relevant or significantly correlated with environmentalism in the context of this study. This finding suggests that the traditional personality traits encompassed by the Big Five model did not play a direct role in predicting environmental attitudes and behaviors among the participants.

The results of Monteiro et al. (2023) revealed, however, that among the Dark Triad, psychopathy showed a significant negative correlation with environmentalism. Additionally, social dominance orientation was found to be moderately negatively correlated with environmentalism. A key finding was that the direct negative effect of psychopathy on environmentalism disappeared when controlling for social dominance orientation, indicating a complete mediation effect. This suggests that the relationship between psychopathy and environmentalism is mediated by social dominance orientation, with those high in psychopathy traits tending to exploit the environment for personal gain due to their higher social dominance orientation.

The study by Martín et al. (2023) showed that next to psychopathy other personality traits might be even more important. Their study aimed to explore bystanders' reactions to animal abuse in relation to psychopathy, empathy towards people, and empathy towards nature. They utilized a sample of 409 individuals from the Canary Islands, assessing responses to hypothetical scenarios of animal abuse or environmental law violations through questionnaires measuring psychopathy, empathy, and the likelihood of intervention or reporting the abuse. Psychopathy, especially the callous-unemotional traits aspect of psychopathy, characterized by a lack of guilt or remorse, emotional inexpressiveness, coldness, insensitivity to others' feelings, and disregard for one's own performance in tasks, has been previously linked to animal abuse behaviors (Rock et al., 2021). Empathy towards people refers to the ability to experience an emotional response similar to that of another person as well as to the rational ability to understand what other people feel. Empathy towards nature measures how individuals emotionally

connect with and understand nature and its elements, including animals and plants. Empathy with nature was more strongly related to reactions against animal abuse than empathy with people or psychopathy traits. The study suggests that understanding the psychological factors influencing reactions to animal abuse can enhance informal social control mechanisms against such abuse, highlighting the importance of empathy with nature over other traits.

Personality traits not only shape our attitudes towards biodiversity and animal welfare but also influence our connection with nature and the environment. In today's rapidly changing world, understanding the interplay between individual differences and our relationship with the natural world can be helpful in the fight against biodiversity loss. As urbanization increases and digital media becomes more prevalent, research focusing on the factors that influence our experiences of nature and how these experiences can be nurtured and expanded is vital.

The study by Soga et al. (2018) investigated the factors influencing children's direct experiences of nature, focusing on the roles of opportunity (urbanization and time pressure) and orientation (nature relatedness, screen-based media inclination, and family attitudes towards nature). The authors state that a lack of experiences of nature is one of the fundamental obstacles to halting global biodiversity loss. Understanding what drives and limits children's direct experiences of nature is therefore increasingly important. Nature relatedness was measured as emotional connectedness to nature and consists in an individual's connection to the natural world and concerns cognitive, affective, and physical connections to nature (Nisbet, Zelenski & Murphy, 2009). Utilizing a large-scale questionnaire administered to 5801 children in Tochigi, Japan, they found that the frequency of children's nature experiences as positively associated with their personal nature relatedness and their family's nature orientation. Degree of urbanisation had significant negative influences on the frequency of direct experiences of nature. Time pressure and grade level showed no significant impact. The authors underscore the importance of both opportunity and orientation in promoting children's engagement with nature, suggesting that multifaceted approaches are required to combat the "extinction of experience" with nature.

Richardson et al. (2020) explored the application of "pathways to nature connectedness" on a societal scale, identifying leverage points for enhancing human-nature relationships. The study investigates how sensory contact, emotion, meaning, beauty, and compassion can foster closer connections with nature. Nature connectedness describes an individual's relationship with nature (Mayer & Frantz, 2004). The construct covers how we think about nature, our affective relationship with nature and the extent to which we see ourselves as part of nature. Nature connectedness matters because it brings benefits for both humans and nature; it is a factor in improved mental wellbeing and increased pro-environmental and pro-nature behaviours. By analyzing interventions across various societal scales, from individual activities to cultural programs and urban design, the authors provide recommendations on enhancing nature connectedness at a societal scale through system characteristics and leverage points. These recommendations emphasize the need for a multi-faceted approach to enhance nature connectedness across societal systems, leveraging deep shifts in values and goals, redesigning institutions, disrupting negative feedbacks, and implementing supportive policies and infrastructure.

In conclusion, it can be observed that the influence of various aspects of individual personality on attitudes toward biodiversity remains somewhat ambiguous, characterized by contradictory findings. While some research suggests that traits such as openness to new experiences, conscientiousness, and agreeableness may be associated with positive environmental attitudes (Davison et al., 2023; Milfont & Sibley, 2012), other studies have failed to find significant correlations or have highlighted the significance of different personality characteristics (Martín et al., 2023; Monteiro et al., 2023).

Research gaps related to the micro-level of society

The literature on the impact of sociodemographic variables on coastal biodiversity presents several notable research gaps, hindering a comprehensive understanding of this complex relationship. One significant gap is the scarcity of studies specifically dedicated to coastal biodiversity. Numerous investigations delve into biodiversity in other contexts, and some findings, such as relationships between sociodemographic variables and general attitudes towards biodiversity or general willingness to donate, may be transferable to coastal biodiversity to some extent. However, especially findings on more specific contexts may lack applicability or generalizability to coastal ecosystems.

Moreover, a substantial portion of existing research originates from regions outside of Europe, which introduces a challenge in extrapolating findings to European coastal environments due to variations in sociodemographic composition, ecosystem characteristics, species composition, legislative frameworks, cultural differences and policy implementations. As a result, insights gleaned from studies conducted in non-European contexts may not accurately reflect the dynamics at play in European coastal regions.

Although sociodemographic factors are frequently incorporated into biodiversity studies, they often serve as peripheral variables rather than the central focus. This is particularly evident in the case of age and socioeconomic status. Furthermore, the lack of theoretical frameworks guiding research efforts in this domain seems to contribute to a predominance of exploratory studies over hypothesis-driven investigations. As a consequence, there is a scarcity of predictive models and theoretical insights into the mechanisms underlying the impact of sociodemographic variables on coastal biodiversity, attitudes toward biodiversity and environmental behavior. Especially in light of partially contradicting findings regarding the influence of age, gender and SES, theory-driven research may offer clarity by untangling the various effects.

In addressing these research gaps, future studies should examine coastal biodiversity within a European context, employing theoretical frameworks in order to understand the intricate relationships between sociodemographic variables and ecosystem dynamics. By bridging these gaps, researchers can foster a more comprehensive understanding of the factors shaping coastal biodiversity, facilitating informed conservation and management initiatives aimed at preserving these critical ecosystems for future generations.

Contradicting findings for age, gender and SES

Furthermore, the call for incorporating qualitative research methods becomes evident as a means to gain a more nuanced understanding of how education influences biodiversity attitudes . According to Carlesi et al., 2023, Davison et al., 2023 and Lucungu et al., 2022, qualitative studies offer the potential to delve deeper into the intricacies of individual and collective perceptions, allowing for a richer exploration of the underlying psychological, cultural, and socio-economic factors that drive attitudes towards biodiversity.

In examining the research gaps within the domain of how education influences attitudes towards biodiversity as well as the willingness to donate, the authors highlight that a comprehensive understanding necessitates a broader examination of contexts (Canavari et al., 2022), economic conditions (Bravo-Monroy et al., 2015; Davison et al., 2023) and the integration of trans-national data (Carlesi et al., 2023; Davison et al., 2023). These studies collectively suggest that the interplay between educational experiences and attitudes towards biodiversity is complex and deeply intertwined with local conditions and broader socioeconomic factors.

The synthesis of findings from several studies also underscores a research gap regarding the influence of educational level on the willingness to donate toward biodiversity conservation. While studies like those conducted by Carlesi et al. (2023), Musa and Nadarajah (2023), and Bhandari and Heshmati (2010) suggest a positive correlation between higher education levels and an increased willingness to financially

support conservation efforts, contradictory evidence from Eylering et al. (2022) and Dörge et al. (2022) indicates that educational level may not always directly impact donation behaviors or intentions. This discrepancy points to a complex relationship between education and conservation support, suggesting that other factors, such as attitudes, knowledge specificity, or even the type of conservation effort, might mediate or modulate this relationship. Consequently, there is a clear need for further research to disentangle these effects and to clarify under what conditions, and to what extent, educational level influences individuals' willingness to contribute financially to biodiversity conservation. Such research is essential for developing more effective strategies for fundraising and engagement in conservation initiatives, particularly in light of the varying results from existing studies.

An additional research gap concerning the impact of education on the willingness to donate exists in the limitation of assessing willingness to donate through a single item, which may not fully capture the nuances of behavioral intentions (Dörge et al., 2023; Eylering et al., 2022). Future studies are recommended to employ multiple items for a more comprehensive assessment of behavioral intentions.

The study of Veríssimo et al. (2018) focusing on actual donor behavior underscores a valuable opportunity for future research to foster partnerships between academics and NGOs. The authors highlight that such collaborations would grant academics access to extensive real-world data, ensuring their research remains practically relevant. Conversely, NGOs would benefit from the sophisticated analytical capabilities and theoretical insights of academic researchers, creating a symbiotic relationship that enhances both the practical applications of research findings and the effectiveness of NGO initiatives in the field.

In studies on educational programs, there appears to be a research gap regarding the broader examination of contexts as well (Martini et al., 2014; Sundaraja et al., 2022). Sundaraja et al. (2022) suggest for example that the COVID-19 Pandemic could have had an influence on their results. Additionally, research on educational programs in general and on the education of future teachers in particular underscores the necessity for adopting longitudinal study designs. According to Brandt et al. (2022) and Richter-Beuschel and Bögeholz (2019), such approaches are crucial for making clearer statements about changes and about the impact of educational interventions over time.

The impact of individual personality dimensions on attitudes towards biodiversity is not fully understood yet, characterized by conflicting research findings. While some studies suggest that traits such as openness to experience, conscientiousness, and agreeableness may be positively associated with pro-environmental attitudes (Davison et al., 2023; Milfont & Sibley, 2012), others have found no significant relationships or have highlighted the role of different traits (Martín et al., 2023; Monteiro et al., 2023). This inconsistency might stem from variations in study designs, cultural contexts, or methods of measuring environmental attitudes. As such, the direct influence of personality traits like neuroticism, extraversion, conscientiousness, and even agreeableness and openness on biodiversity attitudes requires further investigation to disentangle these complex relationships and understand the underlying mechanisms driving these associations.

Additionally, Monteiro et al. (2023) acknowledge that in their study about the dark triad personality traits the potential influence of social desirability bias wasn't accounted for. Especially in research about more aversive personality traits, like psychopathy, social desirability could have a skewing influence on the results. Furthermore, they suggest that future research should aim to incorporate more diverse and representative populations, taking into account factors such as education level, ethnicity, and socioeconomic status. Lastly, examining the impact of more complex aversive personality traits, such as sadism, greed, and spitefulness, alongside implementing behavioral assessments of environmental actions, could provide deeper insights (Monteiro et al., 2023).

Meso-level factors that contribute to the protection of biodiversity, including coastal biodiversity

Within the complex world of protecting our planet's biodiversity, the meso-level stands out as a crucial area where different groups—government agencies, non-profits, and local communities—come together to make a real difference.

At the meso level, it can generally be summarized that measures to protect biodiversity can only be implemented within the framework of networks with different stakeholders. Looking at different social groups and stakeholder levels reveals the need for cooperation from different perspectives.

In the area of tourism management, for example, Csete and Szécsi (2015) showed that responsibility is not clearly assigned to one authority, moreover government, population and local authorities were seen to be responsible together.

Further Martini et al. (2017) accentuate the need “of bottom-up processes for the co-creation of sustainable tourism offers” (Martini et al., 2017, p.1). Tourists also usually have no emotional connection to their vacation destination. They have no overview of the local landscape and social development, which can lead to them being less mindful of nature. "Educational tourism” (Bhuiyan et al., 2010) is therefore an important concept for encouraging external people to adopt a sustainable lifestyle at their vacation destination.

NGOs often take on a mediating role at the meso level. As membership is voluntary, the intrinsic motivation of members is high. In order to enforce certain protective measures, communication and the linking of various groups involved are predominantly used. However, NGOs often also take on corrective work if areas, animals or plants in need of protection have been forgotten in official decisions (Olive & Penton 2018).

With regard to the economic perspective in the private business sector, it is clear that sustainable products and processes must be promoted. Tenders and regulations must place greater emphasis on the sustainability aspect (Martin et al., 2022; Guerra & Gonçalves, 2023).

At municipal level, the issue of participation is the main topic of discussion in the literature (Bravo-Monroy et al., 2015; Brooks, 2016; Ewane, 2023) .If different actors are involved in decision-making processes at municipal level, it is easier to implement joint projects or sustainable processes in society. Trust in institutions also plays a decisive role here (Lucungu et al., 2022). The greater the trust in state institutions, the greater the likelihood of participation on the part of civil society. The lack of financial resources for the implementation of sustainable and nature conservation projects is a common problem in many communities. Here it is recommended to do persuasive work, to invest anyway, but at the same time to train municipalities to apply for external sources of funding (Nordstrom et al., 2002). It is also the task of the municipal level to ensure that smaller groups are heard and to clarify priorities in decision-making processes, as Alexander et al. illustrate: “Development of inclusive community consensus on landscape dependencies should be undertaken before lucrative tourism ventures and land allocations are advanced in competition to the needs of more vulnerable and often voiceless sectors of a community.” (Alexander et al., 2018).

On the one hand, religious communities offer value-based ideas of sustainability and closeness to nature. On the other hand, they must also be considered at the meso level as landowners and as their own network. Educational institutions such as schools or universities are important because they can also convey values and thus ensure the longevity of protective measures over several generations. Experience-based learning plays a role here, as does the teaching of philosophical paradigms such as eco-humanism (Aloni & Veugelers, 2023).

Impact of Religion or Religious Communities

From a natural science perspective, it seems initially perplexing to discern a connection between religion and biodiversity. Additionally, there are a scant number of studies in the research landscape that explore this connection. Religion is often categorized under the keyword of traditional knowledge or traditional religion.

In relation to the Christian Orthodox Church, Votrin (2005) provides a comparative analysis of the attitudes towards biodiversity conservation between the Russian Orthodox Church and the Ethiopian Orthodox Church. Both churches are described as “excellent bridgeheads for promoting sustainable development” (Votrin, 2005,p. 18). He notes that religious communities are often the landowners of vast hectares of land and points out that especially within the monasteries of the Ethiopian Orthodox Church, a substantial number of endangered species and plants are preserved (Votrin, 2005: 14). Moreover, Votrin (2005) argues that religious institutions and priests are regarded “as moral authorities” (Votrin, 2005: 18), and he expands on this idea by stating, “the transformation of nature begins with the transformation of the soul” (Votrin, 2005, p. 17).

In another vein, a study investigated the interactions between religion and perceptions of conservation within the specific case of Community Resource Management Areas (CREMA) in Western Ghana (Murray & Agyare, 2018). Utilizing a mixed-methods methodology with quantitative surveys at both national and local levels, in conjunction with focus-group interviews, the authors explored the link between religion, education, nativity, and perceptions of conservation. Religiosity is categorized according to Christian tradition and traditional religions. Drawing upon previous studies (Adu-Gyamfi, 2011; Awuah-Nyamekye, 2014; Hens, 2006; Jimoh et al., 2012; McPherson et al., 2016; Ntiamao-Baidu, 1991; Saj et al., 2006), traditional religion incorporates various religious and spiritual beliefs, spiritual laws, and taboos, as well as spiritual entities connected to nature. The hypothesis of the article posits that religious identity influences perceptions of conservation efforts (Murray & Agyare, 2018). The scope of the study was confined to Christian and traditional religious identities, thereby excluding Muslim or hybrid religious identities (Murray & Agyare, 2018: 6). The results demonstrate “consistent differences between Christians and Traditionalists” (Murray & Agyare, 2018: 7-8), with Christians showing a higher educational level and a more open-minded attitude towards new conservation methods. Conversely, focus groups clarified that Christians were less connected to nature and “tend to be firm in their beliefs and resistant to traditional teachings” (Murray & Agyare, 2018: 10). Traditionalists were found to be more intimately connected to and dependent on natural resources, yet they occasionally regard conservation efforts as a divine rather than a human responsibility. Additionally, there was a notable “distrust of external ideas” and skepticism towards external organisations. The authors recommend a deeper exploration into the role of religion within conservation areas and emphasize the importance of considering existing religious or spiritual perspectives. Future research should aim to address the “changing religious landscape” (Murray & Agyare, 2018: 12), given that hybrid forms of religious and spiritual beliefs were prevalent in the studied area. Parallel findings were also reported in studies by Adeyanju and Bulkan (2022) and Kosoe et al. (2020).

Another pivotal work highlights the importance of considering spiritual and moral values in advancing conservation efforts, featuring a case study in South Africa (van de Water et al., 2023). The objective of the study was to develop a Theory of Change that balances ecological and social needs. Employing mixed methods data from interviews, workshops, and surveys, the authors identified four different types of trade-offs “by considering both secular and sacred principles” (van de Water et al., 2023: 10). Especially since conflicts involving sacred aspects cannot be readily addressed through secular arguments, a solution was found in embracing a shared philosophical value known as Ubuntu, which emphasizes interconnectedness and the principle of generosity. Traditional religious frameworks for the practice of biodiversity

conservation, various religious attitudes are also noted for producing different perspectives on biodiversity or, more broadly, on the relationship between humans and nature.

For instance, diverse religious worldviews, such as the concepts of intelligent design or creationism, can lead to beliefs that perceive God's plan in negative natural phenomena (Reiss, 2009).

Another dimension of the interplay between religion and biodiversity is evident in various social religious movements, often grouped under the term "religious environmentalism" (Koehrsen et al., 2022). In their article, Koehrsen et al. (2022) illustrate that the nexus of religion and ecology gives rise to a variety of inter- and intra-religious tensions. Tomalin (2004) examines religious environmentalism in India and highlights how, depending on the context, these movements can sometimes forge undesirable political coalitions.

In conclusion, the significance of the religious dimension in the implementation of biodiversity protection is multifaceted. Firstly, it is possible that traditional religious knowledge, which encompasses specific notions about biodiversity conservation, exists locally. Secondly, as religious communities or institutions often possess significant landholdings, they become crucial legal stakeholders. Thirdly, these communities offer diverse interpretations of the relationship between humans and nature. When different local communities hold transcendental views about humans and nature, this diversity can precipitate conflicts in the execution of ecological conservation initiatives. Such conflicts are further exacerbated when secular and sacred expectations collide.

Conflicts in the implementation of biodiversity conservation measures are particularly evident at the meso level when conflicts of objectives arise between the groups, mutual trust is lacking or the respective motivations for change are mutually exclusive, as can be the case, for example, between secular and sacred motivations. In order to bridge group differences, it can be helpful to develop shared values or philosophies to guide joint decision-making processes. However, like any value or philosophy, this always entails the risk of it being exploited for power politics or developing into an ideology.

Macro-level factors that contribute to the protection of biodiversity, including coastal biodiversity

Global Biodiversity Conservation Challenges: Wealth, Language, and Geography

Amano and Sutherland's (2013) study reveals how wealth, language, geographical location, and security intricately influence global biodiversity conservation efforts. Their analysis reveals significant biases in the availability of conservation data, predominantly favoring countries with higher GDPs, more English speakers, closer proximity to database host countries, and higher levels of security. This trend underscores a misalignment between data availability and areas of high biodiversity need.

The research underscores the critical need for expanded scientific education, communication, and collaboration, particularly targeting countries that are economically disadvantaged, have fewer English speakers, and are remote from Western nations that host major global databases. The inclusion of conflict-ridden regions highlights the complex challenges of conducting and disseminating scientific research in such contexts.

Through hierarchical partitioning, the study demonstrates that the aforementioned barriers contribute both independently and jointly to spatial variations in biodiversity data availability. This suggests that addressing these barriers could significantly advance global biodiversity conservation efforts. The approach advocates for a more equitable distribution of resources and emphasizes the importance of fostering a globally inclusive scientific community. A research gap thus lies in exploring how these barriers directly impact conservation outcomes and the efficacy of interventions designed to mitigate biodiversity loss. Further

research could also investigate strategies for overcoming these barriers, enhancing data collection, and facilitating greater international collaboration in biodiversity conservation.

Moreover, the study points out the poor correlation between biodiversity data availability and actual biodiversity richness, indicating a pressing need to realign conservation efforts towards regions in dire need of attention. This misalignment risks misallocating conservation resources, highlighting the need for a more strategic approach to global biodiversity conservation.

Macro-Level Societal Personality Traits

A study by Milfont and Sibley (2012) delves into the intricate relationship between personality traits and environmental engagement at the societal level, specifically examining the impact on coastal biodiversity protection. Their research underscores the pivotal roles of Agreeableness, Conscientiousness, and Openness to Experience in fostering environmental concern and actions. By exploring these personality traits at a country-level, Milfont and Sibley contribute significantly to our understanding of how societal dispositions towards environmental preservation, particularly concerning coastal biodiversity, can be influenced by the collective psychological attributes of its members.

The study suggests that societies characterized by higher aggregate levels of Agreeableness, Conscientiousness, and Openness may exhibit stronger commitments to environmental conservation efforts. This finding is paramount in the context of the macro level of society, where broad-scale social structures and norms govern individual and collective behavior towards biodiversity protection.

By integrating psychological dimensions into the discourse on biodiversity conservation, Milfont and Sibley's (2012) work provides a compelling argument for the necessity of aligning societal attitudes with conservation goals. Their analysis not only enriches the literature on environmental psychology but also offers practical insights into leveraging societal traits to enhance environmental stewardship and protect coastal biodiversity. While the study significantly contributes to understanding how personality influences environmental attitudes and behaviors, it leaves room for investigating the mechanisms through which personality traits impact specific environmental actions. Moreover, the study’s focus on national samples from New Zealand suggests a research gap in examining these relationships in a broader array of cultural contexts, which could provide insights into cross-cultural variations in the influence of personality on environmental engagement.

Systemic Leverage Points for Enhancing Nature Connectedness

A research paper by Richardson et al. (2020) ventures beyond the conventional focus on individual and local interventions to enhance nature connectedness. It introduces a systemic approach, incorporating the pathways to nature connectedness—sensory contact, emotion, beauty, meaning, and compassion—into the fabric of societal structures, policies, and practices. This broadened perspective is pivotal for fostering a profound and sustainable relationship between humans and nature.

At the macro societal level, the study underscores the profound impact of environmental crises, notably the climate crisis, on both organizations and individuals. It argues that societal climate, political culture, and legal frameworks play a significant role in shaping the actions of organizations and individuals towards the environment. Employing the pathways to nature connectedness as a theoretical framework, the paper proposes systemic changes across different societal echelons to mitigate these crises' effects and promote a more symbiotic human-nature relationship.

The findings and discussions presented are particularly relevant to exploring how crises affect organizational and individual actions at a macro level and the influence of societal climate, political culture, and legal frameworks on these dynamics.

While the paper provides a novel perspective on integrating the psychological construct of nature connectedness with systemic societal changes, it also highlights several research gaps that warrant further exploration: 1.) empirical evaluation of proposed interventions: There is a need for empirical research to assess the effectiveness of the suggested interventions and systemic changes in enhancing nature connectedness. This includes evaluating the impact of these interventions on biodiversity protection and their role in facilitating societal transformation towards sustainability. 2.) measurement and metrics: developing and refining metrics for measuring nature connectedness at the societal level could provide clearer insights into the progress and effectiveness of interventions. This would help in tracking changes over time and adjusting strategies accordingly. 3.) Cross-Cultural Validity and Adaptability: The paper's recommendations are based on a framework that may have cultural-specific elements. Research into the cross-cultural applicability of the pathways to nature connectedness can uncover universal and culturally unique aspects, enhancing the global applicability of the approach. 4.) Interdisciplinary Approaches: Further research could benefit from an interdisciplinary approach that combines insights from psychology, environmental science, sociology, and policy studies. This could lead to a more holistic understanding of the complex interactions between humans and nature. 5.) longitudinal studies: Long-term studies are needed to understand the enduring effects of systemic changes on nature connectedness and environmental outcomes. This would provide valuable data on the sustainability and long-term impact of these interventions.

The Macro-Level Impact of Educational Approaches on Biodiversity Conservation

Schüßler et al. (2019) provide a comprehensive review of educational approaches to encourage pro-environmental behaviors in Madagascar, a biodiversity hotspot grappling with the twin challenges of poverty and environmental degradation. This paper delves into the intricacies of implementing Environmental Education (EE) in a context where about 80% of the population lives below the poverty line and relies heavily on dwindling local resources. Through a thorough analysis of 248 EE interventions, the authors illuminate how EE can foster pro-environmental behaviors and delineate the formidable obstacles it encounters, using the case study of Lake Alaotra.

At the macro level, the findings underscore the pervasive influence of crises, particularly the worsening climate crisis, on organizations and individuals. The social climate, political culture, and legal framework are elucidated as pivotal factors in shaping organizational and individual actions toward environmental conservation. The study reveals that despite the potential of EE to promote biodiversity conservation, its effectiveness is severely curtailed by challenges such as insecure and insufficient funding, poverty-induced unsustainable decisions, and the overarching issue of a lack of empirical research on the interventions' effectiveness.

Research gaps highlighted include the need for comprehensive empirical evaluation of EE interventions to assess their real-world impact on enhancing nature connectedness, biodiversity protection, and facilitating societal transformation towards sustainability. Additionally, the development of metrics for measuring nature connectedness at the societal level is identified as crucial for evaluating the progress and effectiveness of interventions.

Research gaps: The absence of theory

Overall, we have observed that many studies lack theoretical frameworks. They tend to be conducted more in the spirit of testing individual or multiple hypotheses, for which suitable indicators are then selected. An exception is made for feminist and environmental psychological theories, which are mentioned above. This is regrettable, as a more theory-driven study could also be very fruitful for practice. Here, we would like to make some suggestions. Environmental sociology has some theoretical approaches

that are interesting. The sociology of risk, particularly as conceptualized by Ulrich Beck (1992) and further developed by Anthony Giddens (1990), provides a critical framework for understanding the complex interactions between society and the environment in the context of biodiversity loss, especially in sensitive areas such as European coastal regions. This theoretical perspective sheds light on how societal structures, technological advancements, and global economic pressures contribute to environmental degradation and biodiversity loss, while also examining the societal responses to these challenges.

Beck's notion of "risk society" suggests that modern industrial societies are characterized by the proliferation of risks, many of which are global and complex, such as climate change and biodiversity loss. These risks are not only environmental but also social, as they require collective action and changes in policy and behavior to mitigate. In European coastal regions, one can observe the manifestations of these risks in the form of habitat destruction, pollution, and overfishing, all of which contribute to the loss of biodiversity.

For example, the encroachment of urban development along coastlines, driven by economic growth and the desire for coastal living, often leads to habitat loss for numerous species. Pollution from agricultural runoff, industrial discharges, and plastic waste further degrades these habitats, affecting both terrestrial and marine biodiversity. Overfishing, driven by both local consumption and global seafood markets, depletes fish stocks and disrupts marine ecosystems.

The sociology of risk can help explain why, despite the known risks to biodiversity and the environment, actions to address these issues are often delayed or insufficient. Factors such as economic dependence on industries like fishing and tourism, conflicting interests between conservation efforts and development projects, and the global nature of environmental problems contribute to the complexity of managing and mitigating these risks. Additionally, the perception of risks—how they are understood by different societal groups, policymakers, and the public—plays a crucial role in shaping responses to environmental challenges.

Giddens's concept of "reflexive modernization" suggests that societies are capable of reflecting on the environmental consequences of their actions and can pursue more sustainable paths. However, the application of this concept in the context of European coastal regions requires navigating complex political, economic, and social landscapes, where local actions are often intertwined with global environmental issues.

Theories of social inequality provide a crucial lens for understanding the social dimensions of biodiversity loss. Bourdieu’s analysis of social and cultural capital demonstrates how dominant groups are able to manipulate environmental policies to favour their interests, often exacerbating biodiversity decline (Bourdieu, 1986). The theory of intersectionality, developed by Crenshaw, is particularly insightful in showing how overlapping social identities—such as race, class, and gender—intersect to affect individuals' exposure to environmental risks. This framework allows for a more nuanced understanding of how different communities experience biodiversity loss uniquely, highlighting the compounded vulnerabilities faced by those who are marginalized on multiple fronts (Crenshaw, 1989). By applying these theories, we can better understand the inequities that drive and are driven by the degradation of natural environments.

Social capital theory, as explicated by scholars such as Putnam, Coleman, and Bourdieu, provides another robust framework to analyze the social dimensions of biodiversity loss. Putnam's notion of social capital focuses on the role of networks, norms, and trust in fostering cooperation among community members, which can be instrumental in collective efforts to address biodiversity decline (Putnam, 2000). Coleman’s interpretation highlights social capital as a resource that individuals can leverage, suggesting that community education and awareness are crucial for mobilizing responses to environmental challenges

(Coleman, 1988). Bourdieu's approach views social capital as a power resource within a social field, elucidating how various social groups, based on their access to economic, cultural, and social capital, may differentially impact biodiversity conservation efforts (Bourdieu, 1986). These theoretical perspectives collectively emphasize the importance of social interactions and resource distribution in influencing environmental outcomes.

Micropolitics in environmental governance refers to the use of power by individuals or groups within organizations to push their agendas, which can significantly affect biodiversity conservation strategies. Internal power dynamics within environmental organizations or governmental bodies can lead to prioritization of certain policies over others due to personal interests or power struggles, potentially compromising effective biodiversity conservation (Cleaver, 2000).

Bounded rationality addresses the limitations in decision-making processes due to limited information, time constraints, and the cognitive limits of individuals. In the context of biodiversity conservation, decision-makers may not fully appreciate the complexities of ecological systems or the long-term consequences of biodiversity loss, leading to inadequate or ineffective policy measures (Gigerenzer & Selten, 2001).

Improving decision-making processes in biodiversity conservation requires enhanced transparency, better information dissemination, and increased collaboration across various levels of governance. Such improvements help mitigate the negative impacts of micropolitics and bounded rationality, ensuring more effective conservation strategies are implemented.

Another possibly fruitful theoretical strand is Critical Theory, developed by Theodor Adorno and Max Horkheimer (1947), providing a unique lens through which the protection or non-protection of biodiversity can be analyzed. This theoretical framework, part of the broader Frankfurt School tradition, critiques the ways in which societal structures, driven by capitalist economies and instrumental rationality, lead to environmental degradation. The core argument of Critical Theory is that enlightenment, which promised liberation through reason, has instead resulted in the domination of nature and society by economic interests.

One of the pivotal contributions of Critical Theory to understanding biodiversity conservation is its critique of the instrumental rationality that characterizes modern industrial society. This rationality prioritizes efficiency, quantification, and control, leading to the exploitation of natural resources without regard for ecological balance or the intrinsic value of non-human life. From this perspective, biodiversity loss can be seen as a consequence of the capitalist system's relentless drive for expansion and profit, which often overrides environmental concerns.

Critical Theory also emphasizes the role of culture and ideology in shaping human interaction with the environment. The culture industry, as discussed by Adorno and Horkheimer, manufactures consent for the capitalist system, promoting consumerism and materialistic values that contribute to ecological destruction. This aspect of Critical Theory can help explain why efforts to protect biodiversity are often overshadowed by economic development goals and consumerist lifestyles.

However, a significant limitation within many scientifically oriented studies of biodiversity loss is the absence of a comprehensive model of societal critique. While these studies might adeptly identify and quantify the ecological impacts of human activity, they frequently do not address the underlying societal, economic, and cultural forces driving these impacts. Critical Theory fills this gap by providing a framework that links environmental issues to broader societal dynamics, suggesting that meaningful solutions to biodiversity loss must address the root causes of environmental degradation: the capitalist mode of production, the prioritization of profit over ecological and social well-being, and the pervasive influence of consumer culture.

To effectively apply Critical Theory to the protection of biodiversity, interdisciplinary approaches are necessary. These approaches should combine the insights of Critical Theory with ecological science and environmental sociology to develop comprehensive strategies for conservation that address both ecological and societal dimensions.

Another research gap we observe pertains to psychological dimensions. Although several psychometric scales such as the Big Five or Psychopathy are mentioned in studies, there is a lack of a personality model that has a broader theoretical background. Besides the classical research on authoritarianism, which is based on psychoanalytic principles, psychodynamic approaches are also required. These approaches deal with why people, for example, deny climate change or, conversely, commit themselves to averting the damages and catastrophe. Concepts from psychodynamics, such as defense mechanisms, are suitable here. They can explain why people react in certain ways to threatening actions or how they cope with fear. As explored by Kari Marie Norgaard (2017), emotions such as guilt, fear, and hopelessness play significant roles in how individuals process the reality of climate change. These emotions can lead to forms of "implicatory denial," where people recognize the threat of climate change but fail to integrate this knowledge into their lives or to take action. Understanding these psychodynamic factors can help in developing strategies that address the emotional and psychological barriers to climate action. For a more detailed exploration, you might find the analysis provided by Kari Marie Norgaard (2017) on the sociology of climate inaction insightful.

3 HYPOTHESES AND QUESTIONS FOR THE CASE STUDIES

In the subsequent sections, we articulate hypotheses and research questions designed to be employed within the case studies, aligning with their broader objectives. These hypotheses and questions may prove beneficial in the development of the case studies; at the very least, they are intended to contribute to the discussion. We have maintained the division into micro, meso, and macro levels of society, differentiating between hypotheses and research questions that have emerged in reviewed studies and those that, in our assessment, arise from identified research gaps.

Hypotheses and research questions related to the micro-level of society

Hypotheses and Research Questions derived from presented findings

1. *Age and Biodiversity Conservation*: Older adults exhibit heightened concern and support for marine biodiversity protection, suggesting a generational perspective on environmental stewardship.
    - **Hypothesis**: Older individuals possess a stronger intrinsic value for biodiversity, leading to greater support for conservation efforts.
    - **Research Question**: How does the perceived value of biodiversity vary across different age groups, and what implications does this have for engaging younger populations in conservation efforts?
2. *Gender and Environmental Concern*: Gender plays a significant but varying role for biodiversity conservation, i.e. women and men tend to engage in different kinds of pro-environmental behavior.
    - **Hypothesis**: Gender differences in environmental concern are mediated by variations in socialization and cultural expectations regarding care for the natural world.
    - **Research Question**: What role does gender play in shaping attitudes toward biodiversity conservation, and how can gender-inclusive strategies enhance conservation outcomes?

3. *Socioeconomic Status (SES) and Support for Biodiversity*: Individuals with lower SES exhibit heightened concern for biodiversity loss, challenging assumptions that environmentalism is a luxury of the affluent.
    - **Hypothesis**: Economic vulnerabilities increase the salience of biodiversity loss due to a closer dependence on natural resources.
    - **Research Question**: How does socioeconomic status influence perceptions of and responses to biodiversity conservation, particularly in contexts of economic precarity?
4. *Education and Environmental Awareness*: Higher levels of education correlate with more positive attitudes toward biodiversity conservation.
    - **Hypothesis**: Educational interventions that incorporate biodiversity education can significantly enhance conservation efforts by fostering a deeper understanding of ecological interdependencies.
    - **Research Question**: What specific educational approaches are most effective in promoting pro-biodiversity behaviors and attitudes across diverse societal segments?

Hypotheses and Research Questions Evolving from Research Gaps

1. *Micro-Level Social Dynamics and Biodiversity*: The influence of micro-social dynamics, including family structures and local community norms, on biodiversity conservation is understudied.
    - **Hypothesis**: Local social dynamics significantly influence individual and collective engagement in biodiversity conservation.
    - **Research Question**: How do micro-level social dynamics within communities affect the implementation and success of biodiversity conservation projects?
2. *Intersectionality in Biodiversity Conservation*: Research often overlooks the intersectional nature of identity factors (e.g., race, ethnicity, gender, age, SES) in shaping attitudes toward biodiversity.

Hypothesis: Intersectional identities influence perceptions and egagements with biodiversity conservation in complex ways that are not fully captured by examining sociodemographic variables in isolation.

- **Research Question:** How do intersecting identities shape individuals and collective attitudes toward and engagement in biodiversity conservation efforts?

3. *Cultural and Spiritual Values in Biodiversity Conservation*: The role of cultural and spiritual values in shaping biodiversity conservation efforts is underexplored, particularly in coastal ecosystems.
    - **Hypothesis**: Cultural and spiritual values play a critical role in shaping local communities' attitudes and behaviors toward biodiversity conservation.
    - **Research Question**: How can cultural and spiritual values be integrated into biodiversity conservation strategies to enhance community engagement and project success?
4. *Bounded Rationality in Decision Making:*
    - **Hypothesis:** Limitations in decision-making due to bounded rationality result in inadequate biodiversity conservation policies.
    - **Research Question:** How can decision-making processes be improved to better incorporate ecological complexities and long-term impacts in biodiversity conservation?

5. *Psychological Dimensions of Environmental Engagement*: The psychological dimensions influencing environmental engagement, including environmental identity, personality traits, and affective factors, are not well understood in the context of biodiversity conservation.
    - **Hypothesis**: Psychological dimensions such as environmental identity and emotional connection to nature significantly influence engagement in biodiversity conservation.
    - **Research Question**: What psychological factors most strongly predict pro-environmental behaviors and attitudes toward biodiversity conservation, and how can these be leveraged in conservation strategies?
6. *Parental Rearing*: The path between parental rearing styles and personality traits which are linked to the engagement in the protection of biodiversity are not well enough researched.

Hypothesis*:* The link between parental rearing styles and personality traits significantly influences an individual's engagement in the protection of biodiversity. Specifically, children raised in authoritative parenting environments, characterized by warmth, support, and structured guidance, are more likely to develop personality traits such as openness to experience and conscientiousness, which in turn enhance their propensity to engage in biodiversity conservation efforts.

Research Question: How do different parental rearing styles impact the development of personality traits such as openness and conscientiousness in children, and how do these personality traits mediate the relationship between parental rearing and individual engagement in the protection of biodiversity?

Hypotheses and research questions related to the meso-level of society

Hypotheses and research questions derived from presented findings

1. *Stakeholder Networks and Biodiversity Conservation*: The necessity of networks with various stakeholders (government agencies, NGOs, local communities) for implementing biodiversity protection measures has been recognized.
    - **Hypothesis**: Effective biodiversity conservation at the meso-level requires a collaborative network approach that integrates various stakeholders' efforts.
    - **Research Question**: How do stakeholder networks influence the success of biodiversity conservation initiatives, and what factors facilitate or hinder effective collaboration?
2. *Tourism Management and Biodiversity Protection*: The impact of tourism on biodiversity conservation efforts, highlighting the role of education and sustainable tourism.
    - **Hypothesis**: Sustainable tourism initiatives, especially those incorporating educational components, can significantly mitigate negative impacts on biodiversity.
    - **Research Question**: What are the most effective strategies for integrating sustainable tourism practices that protect biodiversity while engaging tourists in conservation efforts?
3. *NGOs as Mediators in Biodiversity Conservation*: NGOs often mediate between various groups, playing a critical role in advocating for forgotten areas or species in need of protection.
    - **Hypothesis**: NGOs' mediating role and their capacity to link different groups are crucial for addressing gaps in official biodiversity conservation efforts.
    - **Research Question**: In what ways do NGOs contribute to bridging gaps in biodiversity conservation, and what challenges do they face in this mediating role?

4. *Economic Perspectives and Biodiversity Conservation*: The necessity for the private business sector to adopt sustainable practices for biodiversity protection.
    - **Hypothesis**: Greater emphasis on sustainability in business practices and regulations can lead to improved biodiversity conservation outcomes.
    - **Research Question**: How can economic policies and business practices be aligned to support biodiversity conservation goals?

Hypotheses and Research Questions Evolving from Research Gaps

1. *Participatory Decision-Making at the Municipal Level:* The literature highlights the importance of participation in decision-making processes for successful biodiversity conservation.
    - **Hypothesis**: Enhanced participatory decision-making processes at the municipal level lead to more effective and inclusive biodiversity conservation initiatives.
    - **Research Question**: How can participatory decision-making processes be optimized to include diverse community perspectives in biodiversity conservation planning?
2. *Role of Educational Institutions in Long-Term Biodiversity Conservation*: Schools and universities are pivotal for instilling values and knowledge necessary for long-term conservation efforts.
    - **Hypothesis**: Educational institutions play a critical role in ensuring the longevity of biodiversity conservation efforts through value-based and experiential learning.
    - **Research Question**: What educational strategies and programs are most effective in cultivating long-term commitment to biodiversity conservation among students?
3. *Conflict Resolution in Biodiversity Conservation*: Conflicts of objectives and lack of trust between groups can hinder biodiversity conservation at the meso-level.
    - **Hypothesis**: Developing shared values or philosophies can facilitate conflict resolution and enhance cooperation in biodiversity conservation efforts.
    - **Research Question**: What approaches can be employed to resolve conflicts and foster mutual trust among different stakeholder groups involved in biodiversity conservation?
4. *Influence of Religious Communities and Landownership on Biodiversity*: Religious communities can offer unique perspectives on sustainability and nature, influenced by their roles as landowners and network participants.
    - **Hypothesis**: The involvement of religious communities and their stewardship of land can positively influence biodiversity conservation efforts.
    - **Research Question**: How can religious communities be effectively engaged in biodiversity conservation, considering their dual role as value-driven entities and landowners?
5. *Social and Cultural Capital I:*
    - **Hypothesis:** Dominant social groups leveraging their social and cultural capital in policy-making exacerbate biodiversity loss by prioritizing economic interests over conservation.
    - **Research Question:** How can policy-making be structured to mitigate the influence of dominant groups and better support biodiversity conservation?
6. *Social and Cultural Capital II:*

- **Hypothesis**: High social capital within communities enhances cooperation and effectiveness in biodiversity conservation efforts.
- **Research Question**: How can communities increase their social capital to improve biodiverity conservation outcomes?

7. *Micropolitics in Environmental Governance:*
   - **Hypothesis:** Micropolitics within environmental organizations lead to prioritization of personal or group interests, undermining effective biodiversity conservation.
   - **Research Question:** What mechanisms can be introduced to reduce the negative impact of micropolitics on biodiversity conservation strategies?

Hypotheses and research questions related to the macro-level of society

Hypotheses and research questions derived from presented findings

1. *Effectiveness of Environmental Education (EE) Against Economic and Environmental Crises**:*** Schüßler et al. (2019) explored the implementation challenges of EE in a poverty-stricken context, emphasizing the potential of EE in fostering pro-environmental behaviors despite significant obstacles.

- **Hypothesis**: Environmental education can mitigate the adverse effects of economic and environmental crises on biodiversity conservation by promoting sustainable behaviors and values.
- **Research Question*:*** How can environmental education programs be adapted to effectively promote biodiversity conservation in contexts heavily impacted by economic and environmental crises?

Hypotheses and Research Questions Evolving from Research Gaps

1. *Incorporating Sociology of Risk in Biodiversity Conservation Strategies*: Given the pervasive influence of global risks, such as climate change, on biodiversity, understanding societal perceptions and responses to these risks is crucial.
   - **Hypothesis**: A deeper understanding of risk perception and communication strategies can enhance the effectiveness of biodiversity conservation efforts by aligning them with societal risk responses.
   - **Research Question**: How do societal perceptions of environmental risks influence individual and collective actions towards biodiversity conservation, and what strategies can effectively communicate these risks to promote proactive conservation actions?
2. *Critique of Economic Order and Biodiversity Conservation*: Drawing on Critical Theory, the capitalist economic order's emphasis on growth and consumerism is critiqued for its role in biodiversity loss.
   - **Hypothesis**: The capitalist drive for continuous economic growth and consumerism fundamentally conflicts with the goals of biodiversity conservation, leading to the exploitation and degradation of natural environments.
   - **Research Question**: How does the capitalist economic model, characterized by growth imperatives and consumerism, undermine biodiversity conservation efforts, and what alternative economic approaches could support sustainable interactions with nature?

3. *The Role of Cultural and Ideological Factors in Biodiversity Loss*: Critical Theory emphasizes the role of culture and ideology in shaping environmental interactions, suggesting that societal values and norms influence conservation efforts.

    - **Hypothesis**: Prevailing cultural and ideological frameworks that prioritize materialism and human dominion over nature contribute to biodiversity loss.
    - **Research Question**: How do cultural and ideological factors, particularly those promoting consumerism and a disconnectedness from nature, affect societal engagement in biodiversity conservation, and what interventions can foster a cultural shift towards greater ecological consciousness?

4. *Interdisciplinary Approaches to Biodiversity Conservation*: The absence of a comprehensive societal critique in biodiversity research points to the need for interdisciplinary approaches that integrate ecological science, sociology, and economics.

    - **Hypothesis**: Interdisciplinary approaches that combine ecological science with sociology of risk and Critical Theory can provide a more comprehensive understanding of and solutions to biodiversity conservation challenges.
    - **Research Question**: What interdisciplinary strategies, combining insights from ecological science, sociology of risk, and Critical Theory, can effectively address the multifaceted challenges of biodiversity conservation, particularly in addressing the root societal causes of environmental degradation?

4 CONCLUSIONS

The culmination of our literature review under the aegis of the PRO-Coast project illuminates the intricate nexus between diversity—demographic, social, ethnic, religious, and gender aspects—and the cognitive and affective dimensions that significantly influence biodiversity conservation, with a keen focus on coastal biodiversity. The exploration, structured across micro, meso, and macro societal levels, unveils the nuanced contributions and impediments various forms of diversity present to the conservation of coastal biodiversity.

Key Findings and Insights

The examination highlights, predominantly at the micro-level, the pivotal role sociodemographic factors such as age, gender, socioeconomic status, and education play in shaping perceptions, attitudes, and behaviors toward coastal biodiversity conservation. Older adults, for instance, display a marked concern and support for marine biodiversity protection, underscoring the importance of engaging this demographic in conservation efforts. Gender dynamics reveal that women sometimes exhibit heightened environmental concern and a tendency to make greater donations towards conservation, , but often face barriers to participation in the field of conservation Socioeconomic status emerges as a double-edged sword, influencing both concern for biodiversity loss and the capacity for financial support of conservation initiatives. Education, meanwhile, consistently enhances environmental awareness and support for biodiversity conservation across diverse contexts.

At the meso and macro levels, the interplay of organizational, communal, and societal dynamics with biodiversity conservation efforts comes to the fore. Cross-sectoral cooperation, the role of NGOs, sustainable business practices, and the influence of religious and educational institutions highlight the importance of collaborative efforts in promoting unified conservation initiatives. Macro-level analysis further

underscores the impact of global socioeconomic factors and societal attitudes shaped by collective personality traits on biodiversity conservation efforts.

Implications for Theory, Practice, and Future Research

The insights derived underscore the imperative for theoretical frameworks that encapsulate the multifaceted influences on biodiversity conservation. The findings advocate for an integrated approach, combining quantitative and qualitative methodologies to comprehend the complex interdependencies fully. Practically, this review emphasizes the necessity of inclusive conservation strategies that account for the diverse demographic, social, and economic fabrics of communities. It calls for bespoke engagement strategies that harness the unique strengths and address the specific challenges presented by different demographic and social groups.

For future research, this review identifies pivotal gaps and opportunities. The scarcity of studies specifically focusing on coastal biodiversity within Europe and the need for a theoretical grounding in environmental sociology are significant voids. Further exploration into the roles of age, gender, socioeconomic status, and education, underpinned by robust theoretical models, is essential for developing nuanced understandings and effective conservation strategies.

In our analysis of biodiversity conservation studies, a notable observation is the general neglect of the macro social level, primarily due to the absence of a humanities perspective in the majority of these works. This omission is particularly significant given the valuable societal critique offered by disciplines like sociology. For instance, the sociology of risk, as conceptualized by Ulrich Beck and further elaborated by Anthony Giddens, provides an essential framework for understanding the complex interplay between society and the environment, especially relevant to the sensitive ecosystems of European coastal regions. These sociological perspectives highlight how societal structures, technological advancements, and economic pressures contribute to environmental degradation and biodiversity loss. Yet, many scientific studies on biodiversity fail to incorporate these critical views, focusing instead on testing specific hypotheses without a robust theoretical foundation. This approach overlooks the potential insights that sociological theories, including Critical Theory developed by Theodor Adorno and Max Horkheimer, can offer. These theories critique the capitalist systems and instrumental rationality that lead to the exploitation of nature, underscoring the importance of addressing not just the ecological but also the societal roots of biodiversity loss. Integrating these critical sociological perspectives could significantly enrich our understanding and approach to biodiversity conservation.

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Bridging this foundational understanding to future research, this review identifies pivotal gaps and opportunities. The scarcity of studies specifically focusing on coastal biodiversity within Europe and the need for a theoretical grounding in environmental sociology are significant voids. Further exploration into the roles of age, gender, socioeconomic status, and education, underpinned by robust theoretical models, is essential for developing nuanced understandings and effective conservation strategies.

In light of these future directions and the identified research voids, in our our analysis of biodiversity conservation studies, a notable observation is the general neglect of the macro social level, primarily due

to the absence of a humanities perspective in the majority of these works. This omission is particularly significant given the valuable societal critique offered by disciplines like sociology. For instance, the sociology of risk, as conceptualized by Ulrich Beck and further elaborated by Anthony Giddens, provides an essential framework for understanding the complex interplay between society and the environment, especially relevant to the sensitive ecosystems of European coastal regions. These sociological perspectives highlight how societal structures, technological advancements, and economic pressures contribute to environmental degradation and biodiversity loss. Yet, many scientific studies on biodiversity fail to incorporate these critical views, focusing instead on testing specific hypotheses without a robust theoretical foundation. This approach overlooks the potential insights that sociological theories, including Critical Theory developed by Theodor Adorno and Max Horkheimer, can offer. These theories critique the capitalist systems and instrumental rationality that lead to the exploitation of nature, underscoring the importance of addressing not just the ecological but also the societal roots of biodiversity loss. Integrating these critical sociological perspectives could significantly enrich our understanding and approach to biodiversity conservation.

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REPORT 6: WAYS THAT TRANSFORMATIVE CHANGE HAS BEEN UTILISED TO HALT COASTAL BIODIVERSITY LOSS

1 INTRODUCTION

1.1 Scope of the document

Biodiversity is the cornerstone of healthy ecosystems, supporting the well-being of both human and non-human life forms (Chivian & Bernstein, 2008). However, despite localized conservation successes, the global biodiversity crisis persists, with biodiversity declining at an alarming rate (Leclere et al., 2018; McRae & Böhm, 2021). This concerning trend has led scientists to label the current era as the 'sixth extinction wave' within the Anthropocene epoch (Dirzo et al., 2014). Addressing this crisis necessitates more than just incremental improvements to traditional conservation approaches; it demands transformative change, characterized by fundamental, system-wide reorganization across various societal dimensions (IPBES, 2019). Consequently, there are urgent calls for transformation in biodiversity conservation to tackle the growing challenges of the Anthropocene (IPBES, 2019; Fouge et al., 2020). Transformation is understood as a substantial, profound, and fundamental change, which requires a paradigm shift in how we relate to and manage the environment (IPBES, 2019; Blythe et al., 2018, Brown & Neill, 2013). A range of possible approaches have been suggested to pursue this transformation (Büscher & Fletcher, 2019).

The ‘transformative turn’ is echoed across a wide range of environmental discussions, and a rich body of work has emerged under the banner of ‘transformations to sustainability (Scoones, 2020; Schneidewind & Augenstein, 2016; Feola, 2015; Temper et al., 2018; Patterson et al., 2017). Closely linked to ongoing discussions of related concepts such as sustainable development, transitions, and resilience, this growing field of social science inquiry aims to understand the dynamics of transformation and to harness the ‘momentum building around the possibility for paradigm shifts at multiple levels’ (Blythe et al, 2018 p.1207). While biodiversity is at times considered in transformations to sustainability literature, a specific focus on biodiversity conservation (“halt of biodiversity loss”) is currently lacking. This is partly because the concept of transformation presents something of a paradox for conservation, which, as the term implies, has historically sought to resist rather than promote particular forms of change (Büscher & Fletcher, 2020; Marris, 2013).

In this paper, our primary focus is to provide a comprehensive analysis of how transformative change has been harnessed to mitigate coastal biodiversity loss. Coastal ecosystems are among the most biodiverse and economically valuable ecosystems on the planet, yet they are also highly vulnerable to human-induced pressures (IPCC, 2019). Our aim is to delve into the diverse array of strategies and mechanisms employed to halt the degradation of coastal biodiversity through transformative initiatives.

To achieve this goal, we undertake a thorough examination of existing literature, case studies, and examples where transformative approaches have been implemented in coastal regions. By scrutinizing these findings, we endeavor to uncover the underlying principles, drivers, and conditions that contribute to the success of transformative interventions in coastal biodiversity conservation.

Understanding the complex challenges facing coastal ecosystems requires a framework that recognizes the intricate relationships between social and ecological systems. The Social Ecological Systems Framework (SESF) offers a comprehensive and integrative approach, treating social and ecological systems with equal depth. As the most advanced and widely used framework for studying complex social-

ecological systems (SESs), SESF can guide our exploration of transformative change in biodiversity conservation.

SESF defines SESs as social systems in which some interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units. The framework's origins can be traced back to the work of Nobel Laureate Elinor Ostrom, whose last contribution to the SESF's revision was published in 2014. In the center of the SESF, Ostrom places "focal action situations," where actors' interactions produce outcomes. These focal action situations are the arenas where transformation occurs, as multiple actors work with various resource units to create outcomes. This process is governed by a governance system that establishes rules and regulations for actors within the SES.

The SESF encompasses related ecosystems (ECO), resource units (RU), governance systems (GS), and social, economic, and political settings. It acknowledges the dynamic nature of these relationships through multiple feedback loops that connect different parts of the framework.

By incorporating the SESF, we can analyze how transformative change can address coastal biodiversity loss in a holistic manner. This framework enables us to understand the role of governance, actors, and resource units, as well as the interconnectedness of social, economic, and ecological factors. In doing so, we can identify best practices and innovative approaches to conservation that are both effective and sustainable.

Through this comprehensive exploration, we aim to offer valuable insights, lessons learned, and best practices for policymakers, conservation practitioners, and stakeholders involved in coastal biodiversity conservation efforts. By understanding the effectiveness of transformative approaches in halting coastal biodiversity loss, we can better inform future strategies and initiatives aimed at safeguarding these invaluable ecosystems for generations to come.

In the following, we examine how transformative change to halt biodiversity loss is currently conceptualized in academic literature, identifying the proposed goals and means of transformative change.

1.2 Methods

In our report designed as semi-structured literature review, we explore the utilization of transformative change as a strategic approach to mitigate coastal biodiversity loss. Recognizing the urgent need for innovative solutions in the face of unprecedented threats to coastal ecosystems, we delve into existing literature on conservation strategies. Our review examines how transformative change has been employed to counteract the decline of coastal biodiversity, identifying, and analysing various approaches, policy frameworks, and innovative strategies that have shown efficacy in fostering positive outcomes for coastal ecosystems.

To gather relevant literature, we utilized keywords such as "Transformative Change," "Coastal Biodiversity," "Conservation Strategies," "Ecosystem Restoration," "Innovative Approaches," and "Halt Biodiversity Loss" across multiple databases, including SCOPUS, Web of Science, and Google Scholar. Through this search, applying the combination of "Biodiversity AND loss AND (sustainable OR sustainability) AND (transformation OR change)," we identified a total of more than 300 papers. After implementing our exclusion criteria, which included selecting papers with comparable definitions of transformation, focusing on coastal areas, and excluding those that solely presented practical case reports, we arrived at a final sample of 82 papers. To ensure the inclusion of grey literature, we conducted a search on Google Scholar using the same keyword combination as utilized in SCOPUS and Web of Science. We meticulously examined the first 150 search results on Google Scholar, as beyond this point, the relevance and quality of the papers diminished significantly. This thorough search process resulted in

a final sample of 134 papers. By employing this comprehensive approach, we aimed to capture a diverse array of studies from both ecological and social science disciplines, thus facilitating a thorough exploration of the topic at hand.

Applying a semi-systematic or narrative review approach, our focus was on understanding the progression of research within the selected field and identifying relevant research traditions that inform the studied topic. We collected data in the form of descriptive information, such as authors, years published, topic, or type of study, or in the form of effects and findings- beside the form of conceptualizations of a certain idea or theoretical perspective. Importantly, we put huge emphasis on aligning this data gathering with the purpose and research question of this review. Two independent researchers were involved in the procedure to identify and analyse the final sample of papers.

This approach allowed us to synthesize diverse perspectives and methodologies, providing a nuanced understanding of the complexities surrounding transformative change in biodiversity conservation. Utilizing thematic analysis, we identified, analysed, and reported patterns within the literature, discerning key themes and theoretical perspectives. This method enabled us to map the field of research, synthesize the state of knowledge, and identify gaps for further exploration. Additionally, thematic analysis facilitated the creation of an agenda for future research, guiding the development of evidence-based strategies for coastal biodiversity conservation.

Overall, our semi-structured literature review contributes valuable insights to the broader discourse on biodiversity conservation and sustainable coastal management. By synthesizing diverse perspectives and methodologies, we provide a comprehensive overview of transformative change in biodiversity conservation, laying the groundwork for future research and practice in this critical field.

1.3 Structure of the report

After presenting the scope of this report and its' method, the report outlines the background and context of transformative change in biodiversity conservation, delving into the historical and political landscape that has shaped the discourse over time. This historical exploration sets the stage for a deeper understanding of the complex issues at play and the challenges that lie ahead. Afterwards, the report provides an overview of the key definitions to clarify foundational terms and concepts. Through a comprehensive examination, it highlights the close relationships between key terms and their interconnections within the interdisciplinary field of biodiversity conservation.

Moving forward, the report provides an overview of existing literature, drawing from a diverse array of disciplines and themes. Notably, it underscores the crucial role of social science in this domain, emphasizing the need for a holistic approach that integrates ecological, social, and political perspectives. It identifies key themes and debates that permeate the literature, offering insights into the multifaceted nature of sustainability discourse. These themes serve as guiding principles for the subsequent discussion, shaping the trajectory of the report's analysis.

Embedded within the discussion are key theoretical concepts and methodologies that underpin transformative change in biodiversity conservation. These concepts provide a theoretical framework for understanding the mechanisms driving change and the factors influencing conservation outcomes. Methodologies employed in investigating biodiversity conservation range from quantitative analyses to qualitative assessments, offering diverse perspectives and approaches to research.

Afterwards, we show the identified gaps and unresolved issues in the field, paving the way for future research and inquiry. These gaps serve as focal points for exploring new avenues of investigation and

advancing the collective understanding of transformative change in biodiversity conservation. Research questions emerge from these gaps, guiding the direction of future inquiry and exploration.

In a final synthesis, we align these research questions with the case studies of PRO-COAST, showcasing how this project addresses gaps in the field and contributes to the advancement of knowledge. By examining the case studies through the lens of identified gaps and research questions, the report illustrates the practical implications of transformative change in biodiversity conservation to inform and shape the future of biodiversity conservation efforts.

2 LITERATURE REVIEW

2.1 Background and Context

2.1.1 Historical and Political Context

The historical and political context surrounding the topic of transformative change in biodiversity conservation is complex and multifaceted, shaped by a combination of socio-economic, environmental, and political factors over time. Several key events and developments have influenced the discourse and practices in this field:

Colonialism and Conservation: The roots of modern biodiversity conservation can be traced back to the era of colonialism when European powers established protected areas to safeguard natural resources for exploitation and recreation (Agrawal, 1997; Domínguez & Luoma; 2020). This approach to conservation often involved the displacement and marginalization of indigenous communities, laying the groundwork for conflicts over land and resources that continue to impact conservation efforts today.

Emergence of the Conservation Movement: The late 19th and early 20th centuries saw the emergence of the conservation movement, driven by concerns over the depletion of natural resources and the loss of biodiversity (Van Dyke et al.; 2020). Influential figures such as John Muir and Theodore Roosevelt advocated for the preservation of wilderness areas and the establishment of national parks, laying the foundation for modern conservation practices (Callicott; 2008; Van Dyke et al.; 2020)

The Rise of Environmentalism: The 1960s and 1970s witnessed the rise of the environmental movement, fueled by growing awareness of pollution, habitat destruction, and species extinction (Mitchell et al.; 2014). This period saw the establishment of landmark environmental legislation such as the Endangered Species Act and the creation of organizations like the Environmental Defense Fund and Greenpeace, which advocated for stronger protections for biodiversity (Zelko; 2013).

The Convention on Biological Diversity (CBD): Adopted at the Earth Summit in Rio de Janeiro in 1992, the CBD represents a significant milestone in international efforts to conserve biodiversity (Chandra & Idrisova; 2011). The treaty aims to promote the sustainable use of biological resources, ensure equitable sharing of benefits, and conserve ecosystems and species. The CBD has played a central role in shaping global conservation policy and fostering collaboration among nations [108].

The Anthropocene Paradigm Shift: The concept of the Anthropocene (Lorimer, 2015), which recognizes the profound impact of human activities on the Earth's ecosystems, has led to a paradigm shift in conservation thinking. Rather than viewing humans as separate from nature, the Anthropocene paradigm emphasizes the interconnectedness of human and natural systems, prompting calls for more integrated and adaptive approaches to conservation (Lorimer, 2015).

Critiques of Traditional Conservation Approaches: In recent decades, there has been growing recognition of the limitations of traditional conservation approaches, which often prioritize the protection of pristine

wilderness areas over the needs and rights of local communities (Berkes, 2014; Haller & Galvin, 2008; Gavin et al.; 2015). Critics have highlighted the social injustices and conflicts perpetuated by top-down conservation interventions, leading to calls for more inclusive and participatory approaches (Reed; 2008; Keahey; 2021).

The Rise of Critical Social Science Perspectives: Critical social science perspectives have gained prominence in conservation discourse, challenging the underlying power structures and assumptions of mainstream conservation practices (e.g. Massarella et al., 2021). Scholars and activists have highlighted the need to address issues of social inequality, environmental justice, and cultural diversity in conservation efforts, leading to a greater emphasis on interdisciplinary and community-based approaches (Sanbrook et al., 2013; Balmford et al., 2021; Montana, 2021; Massarella et al., 2021).

Overall, the historical and political context surrounding transformative change in biodiversity conservation reflects a complex interplay of social, economic, and environmental factors. Key events and developments have shaped the evolution of conservation practices and policies, while ongoing debates and critiques continue to inform efforts to address the interconnected challenges of biodiversity loss and environmental degradation.

2.1.2 Theoretical definitions and concepts on transformation

In the following, an overview of the theoretical definitions and understandings of transformation, transformational change, and transformational adaption is provided highlighting key debates within the fields of ecological and social sciences. This conceptual groundwork informs the subsequent exploration of transformational change and adaptation to halt coastal biodiversity loss.

Adaptation and Transformation

In the context of climate change, the Intergovernmental Panel on Climate Change (IPCC) defines adaptation as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities” (IPCC, 2013, p. 785). This definition underscores the proactive response to risks by addressing exposure and vulnerability (IPCC, 2012). Vulnerability comprises sensitivity (or susceptibility to harm) and a lack of adaptive capacity or resilience (IPCC, 2013, 56). While exposure often drives disaster losses for high-intensity events like hurricanes, vulnerability plays a more significant role in lower-intensity events such as coastal flooding.

Adaptive capacity, on the other hand, refers to the preconditions enabling adaptation (Gallopín, 2006). It encompasses the ability to live with uncertainty, foster diversity, experiment with different knowledge types, and learn (Folke et al., 2003)). Adaptive capacity relies on access to human, financial, and technological resources and can diminish over time due to repeated coping mechanisms and risk accumulation (Satterthwaite, 2007, Reckien et al., 2017). Adaptation, in a broader sense, involves responding to new information or changing conditions and is essentially a process of change or innovation (Nelson, 2011), closely related to concepts of transformation.

While transformation has long been discussed in climate mitigation discourse, its role in adaptation is relatively recent. The IPCC defines transformational adaptation as “fundamental qualitative change... often involving a change in paradigm and may include shifts in perception and meaning, changes in underlying norms and values, reconfiguration of social networks and patterns of interaction, changes in power structures, and the introduction of new institutional arrangements and regulatory frameworks” (IPCC, 2012, p. 465). This definition aligns with other perspectives characterizing transformational adaptation as a reconsideration of human-environment relations, leading to the long-term sustainability of transformed systems (Karki, 2017, Pellinger, 2010).

Transformational adaptation involves the adoption of new techniques or technologies at a larger scale and intensity, novelty to specific regions or systems, shifts in locations, and fundamental changes to political economies or addressing root causes of vulnerability (Garschhagen, 2018; Gillard et al., 2016). It represents a reinvention of systems and people with new relationships, modes of organization, and networks (Kates et al., 2012, O'Brien, 2012; Feola, 2015).

Transformational adaptation represents a paradigm shift in how societies approach climate change adaptation, emphasizing a fundamental qualitative change in social systems and their interactions with ecological systems. This kind of adaptation involves significant changes, often at a larger scale, with new techniques, technologies, or shifts in location. It may include reconsidering human-environment relations, reconfiguring social networks, changing power structures, or introducing new institutional arrangements and regulatory frameworks.

Integrating the SESF into the understanding of transformational adaptation provides a comprehensive framework to explore these changes (Ostrom, 1990). The SESF views social and ecological systems with equal depth, focusing on interactions between humans and biophysical or non-human biological units. Central to the SESF are "focal action situations," where actors interact to produce outcomes. These interactions are governed by rules defined within a governance system. The framework's dynamic nature, characterized by multiple feedback loops, allows for a holistic examination of adaptive capacity and vulnerability.

In transformational adaptation, SESF can illuminate the relationships between social, economic, and ecological factors. It reveals how governance structures and action situations contribute to vulnerability and adaptive capacity, providing a roadmap for fundamental changes in adaptation strategies. This framework underscores the importance of understanding the interconnectedness of human and ecological systems in addressing climate change and fostering long-term sustainability.

By applying the SESF to transformational adaptation, stakeholders can better understand how to reshape social networks, reorganize institutions, and implement innovative practices. This understanding is crucial for developing adaptive strategies that address root causes of vulnerability and promote the resilience and sustainability of both human and ecological systems.

Debates Within Transformation Scholarship. This section delves into key debates within the literature on transformational adaptation, including its definition, relationship to resilience, process versus outcome, incremental versus transformational change, and capacities approaches and agency. Given the interdisciplinary nature of the field, diverse perspectives are expected, but acknowledging this diversity is crucial for advancing discussions (IPBES, 2019).

Relationship between resilience, adaptation, and transformation: Early discussions distinguished adaptation from transformation, with adaptation referring to changes to protect or safeguard a system and transformation involving system change when adaptation was not feasible (Pelling et al., 2014, O'Brien, 2012). However, recent scholarship has broadened conceptions of adaptation to include transformation, categorizing adaptation as either incremental or transformational (Kates et al., 2012). These distinctions have significant implications for adaptation policy and implementation, necessitating attention to evolving concepts and their applications (Kasdan et al., 2021).

Debates also revolve around the relationship between resilience and transformation. *Resilience approaches* encompass adaptability and transformability, emphasizing the dynamic nature of socio-ecological systems (SES) and the need for frameworks to safeguard social development and well-eing within planetary boundaries (Rockström et al., 2009). However, some argue that resilience frameworks

can hinder transformation by reinforcing existing structures, leading to unsustainable adaptation strategies (Pelling, 2010; Ribot 2011; Eriksen et al., 2015).

Process versus outcome: Another debate centres on whether transformation is viewed as a process or an outcome (Pelling et al., 2016). Some see transformation as an ongoing process involving interacting units at multiple levels, characterized by continuous learning (Kates et al., 2012; O'Brien, 2012). However, transformation can also be unintentional, triggered by emergent processes or external actors, making defining outcomes challenging (Wolfram et al., 2019). The distinction between transformational and transformative adaptation lies in the former being the actions leading to a transformation and the latter being the transformation itself (Lonsdale et al., 2015).

Similarly, *transition and transformation* are often used interchangeably, but they stem from different scholarly traditions (Feola, 2015; Pelling, 2010; Foxon et al., 2009). Transition refers to fundamental societal change, while transformation describes also shifts in human-environment interactions and feedbacks (Hölscher, 2018). Some scholars view transformation as a type of transition, while others distinguish between them as processes versus outcomes (Pelling et al., 2016; IPBES, 2019).

For transformation, the SESF is particularly valuable in exploring deeper changes within social and ecological systems. It can illustrate how shifts in human-environment interactions lead to altered feedback loops and new paradigms in societal behaviour and environmental management. By focusing on the interconnectedness of social and ecological components, the SESF allows for a comprehensive view of transformation, encompassing changes in norms, values, power structures, and social networks.

Incremental versus transformational change: The debate over incremental versus transformational change questions whether incremental adaptations can accumulate over time to become transformational (Kates et al., 2012; Termeer et al., 2017; Rickards & Howden, 2012). While some argue that incremental adaptations are essential for transformational change, others emphasize the need for truly novel innovations to catalyse transformation (Schot & Geels; 2008).

Capacities approaches and agency: Critiques of SES and socio-technical transitions frameworks highlight their emphasis on system structure over individual or organizational agency (Wolfram et al., 2019; Foxon et al., 2009). While adaptive capacity frameworks aim to overcome these limitations, debates persist over whether such approaches are suitable for analysing transformation. Some argue for the inclusion of transformative capacity, which encompasses the ability to disrupt existing systems and create viable alternatives (Wolfram et al., 2019; Moore et al., 2018).

In summary, understanding transformational adaptation requires navigating diverse perspectives on its definition, relationship to resilience, process versus outcome, incremental versus transformational change, and capacities approaches and agency.

2.2 Current Research Landscape

2.2.1 Overview of Existing Literature

The current body of literature on sustainability around transformational change spans various disciplines and addresses a range of interconnected themes and debates. Major themes include the recognition of planetary boundaries, the sustainability of corporate practices, the impact of transnational land deals (TLDs), and the interlinkages between fisheries, aquaculture, and agriculture sectors.

The concept of planetary boundaries, introduced by Rockström et al. (2009) and further elaborated by Whiteman et al. (2013), emphasizes the need to define safe operating limits for humanity within Earth's systems. These boundaries encompass critical environmental processes such as climate change,

biodiversity loss, and the nitrogen cycle, highlighting the interconnectedness of ecological systems and the risks associated with exceeding these boundaries. In the realm of corporate sustainability, Whiteman et al. (2013) argue for closer integration between corporate practices and the natural sciences to address complex ecological challenges. They emphasize the importance of systemic research to measure companies' impact on ecological processes and advocate for governance and institutional reforms to promote sustainability.

In 2016 Vandergeten and colleagues shed light on the sustainability implications of transnational land deals (TLDs), revealing social, economic, and environmental challenges associated with these transactions. Despite economic benefits for investors and host governments, TLDs often result in negative outcomes for local communities and biodiversity, underscoring the need for improved land governance and equitable land distribution. Blanchard et al. (2017) explore the interlinkages between fisheries, aquaculture, and agriculture sectors in the context of global food security and biodiversity conservation. They highlight the need to address trade-offs among Sustainable Development Goals, particularly in countries facing challenges in both fisheries and agriculture sectors under climate change. The authors advocate for context-dependent strategies that prioritize effective governance, improved management practices, and innovation in food production to promote sustainability.

Further, the reviews by Whiteman and colleagues (2013) and Rockström and colleagues. (2009) laid the groundwork for understanding sustainability from a systemic perspective by introducing the concept of planetary boundaries. Whiteman et al. argued for closer integration between corporate sustainability practices and the natural sciences, emphasizing the need for systemic research to measure companies' impact on ecological processes. Meanwhile, Rockström et al. (2009) proposed nine planetary boundaries that define safe operating limits for humanity within Earth's systems. They highlighted the interconnectedness of these boundaries and the risks associated with transgressing them, particularly in relation to climate change, biodiversity loss, and the nitrogen cycle. Blanchard et al. (2017) explored the interlinkages between fisheries, aquaculture, and agriculture sectors in the context of global food security and biodiversity conservation. They emphasized the need to address trade-offs among Sustainable Development Goals, particularly in countries facing double jeopardies in both fisheries and agriculture sectors under climate change. The authors called for context-dependent strategies that prioritize effective governance, improved management and conservation practices, and innovation in food production to reconcile trade-offs and promote sustainability.

While these reviews offer valuable insights into sustainability challenges across various sectors, they do not specifically address strategies for halting coastal biodiversity loss. Coastal ecosystems are particularly vulnerable to anthropogenic pressures, including habitat degradation, pollution, and overexploitation of marine resources. Given the critical role of coastal biodiversity in supporting ecosystem services and livelihoods, there is a need for focused research and transformative strategies aimed at conserving and restoring these ecosystems. Closing this gap will require interdisciplinary collaboration and targeted interventions to address the unique challenges facing coastal areas.

In the last decade, numerous reviews have provided valuable insights into various aspects of environmental conservation, climate change, and sustainability. These reviews have covered topics ranging from climate research advancements to transformative conservation initiatives and governance approaches. However, despite the breadth of literature, there remains a notable gap in the exploration of transformative strategies specifically targeted at halting coastal biodiversity loss. Reviews such as Martin and colleagues (2022) synthesized findings in climate change research, emphasizing the multidisciplinary nature of the field and the need to overcome structural barriers to accelerate mitigation efforts. While their review offers comprehensive insights into climate-related challenges, it does not specifically address

strategies for coastal biodiversity conservation. Similarly, Scheffran (2023) focused on the geopolitical dimensions of environmental challenges in the Anthropocene era, advocating for cooperative governance and sustainable climate protection. While the review discusses important governance approaches, it does not delve into transformative strategies for coastal biodiversity conservation. Fougères et al. (2022) discussed transformative conservation initiatives aimed at countering biodiversity loss and climate change. They highlighted the importance of political mobilization and power dynamics in catalyzing transformation processes. However, their recommendations did not specifically target strategies for halting coastal biodiversity loss.

Irvine-Broque and Dempsey (2023) evaluated corporate-led approaches to managing the impact of business on biodiversity, emphasizing the role of financial mechanisms. While their analysis contributes to understanding financial drivers of biodiversity loss, it does not specifically explore transformative strategies for coastal biodiversity conservation. De Koning et al. (2023) examined the role of landscape-oriented partnerships in transformative change for biodiversity conservation, emphasizing integrative governance approaches. However, their analysis did not focus on strategies tailored to address coastal biodiversity loss. Day and Cramer (2022) discussed the transition to regenerative farming practices as a means to address environmental challenges in agriculture. While their review touches on broader conservation issues, it does not specifically explore strategies for coastal biodiversity conservation. Finally, Ziegler et al. (2022) explored social innovation's potential to address drivers of biodiversity loss across various land use sectors, emphasizing participatory governance and nature-based solutions. However, their analysis did not specifically target transformative strategies for coastal biodiversity conservation.

Overall, while each review contributes valuable insights within its respective field, there remains a gap in the literature regarding transformative strategies specifically aimed at halting coastal biodiversity loss.

2.2.2 Recent Trends and Developments

Recent trends and developments in the field of transformative change to halt biodiversity loss have been influenced by a growing recognition of the urgent need for action. Several key papers have contributed to shaping the current discourse and guiding research agendas in this domain.

The IPBES Global Assessment: The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment provided a comprehensive analysis of the state of global biodiversity. It underscored the alarming rates of species extinction and habitat loss, highlighting the urgent need for transformative change in biodiversity conservation (IPBES, 2019). The report emphasized the importance of integrating diverse knowledge systems, including indigenous and local knowledge, into conservation efforts, signalling a shift towards more inclusive and holistic approaches. While IPBES has historically been instrumental in assessing knowledge and raising awareness of biodiversity loss, its current mandate also includes the assessment and support of transformative change processes (Gustaffson & Hysing, 2022). This perspective asserts that this new role necessitates IPBES to embody key elements of transformative agency, essentially redefining its identity as a transformative agent. While this transformation presents opportunities for organizational innovation, such as advancing public reasoning and ensuring scientific autonomy, it also invites critique. There are concerns about the potential risks of undermining IPBES's credibility, relevance, and legitimacy, as well as challenges in balancing governmental power within the organization.

The Luc Hoffmann Biodiversity Revisited Report: This report contributed to the discourse on transformative change by advocating for radical shifts in global political-economic structures to address biodiversity loss (Environment UN, 2019). It emphasized the need to challenge entrenched systems that drive ecological

crises and called for alternative models of development and governance that prioritize environmental sustainability and social equity.

The Nature Needs Half and Half Earth Proposals: Proposals such as "Nature Needs Half" and "Half Earth" have gained traction in conservation circles, advocating for significant increases in protected areas to safeguard biodiversity (Wilson, 2016; Locke, 2014). These proposals reflect a vision of transformative change grounded in the preservation of wilderness areas and the separation of humans from nature, echoing historical conservation paradigms. However, they have also sparked debates about the feasibility and equity implications of such large-scale conservation efforts.

The Emergence of New Conservation Paradigms: A shift towards new conservation paradigms, such as the "post-wild" approach, has gained momentum in recent years (Lorimer, 2015; Marris, 2013). This paradigm recognizes the interconnectedness of humans and nature in the Anthropocene era and promotes coexistence and adaptive management strategies. It emphasizes the need to integrate conservation goals with development objectives and engage local communities in conservation efforts.

Calls for Justice and Equity in Conservation: There has been a growing emphasis on justice and equity in biodiversity conservation, with calls for transformative change to address historical injustices and power imbalances (Temper et al., 2018; Büscher, et al., 2017). The concept of "just transformations" has gained prominence, advocating for environmental justice and equitable outcomes for both humans and nonhumans. This trend highlights a shift towards more inclusive and socially conscious approaches to conservation.

Integration of Social Science Perspectives: There is increasing recognition of the importance of integrating social science perspectives into biodiversity conservation efforts (Bennett et al., 2015). Critical social science inquiry has emerged as a valuable tool for understanding the socio-political dimensions of conservation challenges and identifying pathways for transformative change (Sandbrook et al., 2013; Chua et al., 2022; Massarella et al., 2021). This trend reflects a broader shift towards interdisciplinary approaches that recognize the complex interplay between social, economic, and environmental factors in conservation. The Social-Ecological Systems Framework (SESF) offers a structured approach to understand the integration of social science perspectives into biodiversity conservation, providing insights into the interactions between human and ecological systems. The framework treats social and ecological systems with equal importance, allowing for a comprehensive examination of the complex dynamics that characterize conservation challenges.

The discourse surrounding transformative change in biodiversity conservation is increasingly urgent, as human-driven impacts continue to threaten global biodiversity at unprecedented rates (IPBES 2019; EU Environment, 2019). Scholars have warned of potentially catastrophic consequences, including flooding, erosion or species extinction underscoring the need for profound shifts in conservation practices to address the challenges of the Anthropocene era (EU Environment, 2019). This imperative calls for a paradigm shift in how humans interact with and manage the environment, with an emerging emphasis on achieving sustainability through transformative measures [Blythe et al., 2018; Brown et al., 2013).

Critical social science perspectives have emerged as key drivers in this discourse, challenging conventional conservation approaches and questioning the power structures that underpin them (Sandbrook et al., 2013; Chua et al., 2020; Massarella et al., 2021). These perspectives advocate for a more holistic understanding of the complex interplay between social, political, economic, and environmental factors (Büscher, 2014; Mabele, 2020). In particular, critical social science inquiry highlights the importance of politicizing and pluralizing debates, as well as identifying transformative alternatives to dominant conservation models (Büscher & Fletcher, 2018). The SESF complements these perspectives

by highlighting the interconnectedness of social, economic, and environmental factors. It helps to identify how human activities impact ecosystems, and conversely, how ecological changes influence social systems.By placing focal action situations at the centre, the SESF aligns with the critical social science focus on understanding power dynamics, social norms, and governance structures that drive conservation outcomes. It allows for the examination of how various stakeholders interact within governance systems and how these interactions lead to particular outcomes.

Recent proposals for transformative change in biodiversity conservation have proliferated, yet critical exploration of how such change is conceptualized remains lacking (Büscher & Fletcher, 2019). Drawing on transformations to sustainability scholarship, scholars have outlined various goals and means of transformation (Scoones et al., 2020; Scheidewind & Augenstein, 2016). Three overarching conceptualizations of transformative goals emerge: the restoration of pre-human wilderness, recognition of human-nature interdependence in the Anthropocene, and the pursuit of justice for both humans and nonhumans (Temper et al., 2018; Büscher et al. 2017; Shoreman-Ouimet & Kopnina, 2015).

Proposed approaches to achieving transformative change include strengthening governance systems and policy frameworks, shifting values and behaviours at local and global scales, and integrating diverse knowledge systems (Mace et al., 2018; Leclère et al., 2020). However, many dominant framings of transformative change primarily focus on top-down interventions, such as strengthening policy mechanisms and improving enforcement of regulations (UN Environment, 2019; Secretariat of the Convention on Biological Diversity, 2020). While there is growing recognition of the need for behavioural and societal shifts, transformative change in values and behaviours remains a central theme in both academic and policy-oriented literature (Nienaber et al., 2020; Secretariat of the Convention on Biological Diversity, 2020; Schultz, 2011).

Critical social science inquiry plays a crucial role in this discourse by challenging the status quo, questioning assumptions, and highlighting unintended consequences and injustices caused by conventional conservation interventions (Moros et al., 2020; Kiwango et al., 2015). By politicizing and pluralizing debates, critical perspectives open up opportunities for radical, transformative alternatives (Blythe et al., 2015; Chua et al., 2020; Massarella et al., 2021). These alternatives challenge the existing global capitalist political economy and promote structural shifts towards a more equitable and convivial conservation paradigm (Büscher & Fletcher, 2019; Feola, 2020; Escoba 2015).

The SESF can be used to explore the pathways for transformative change in biodiversity conservation. As scholars have warned of potentially catastrophic consequences due to human-driven impacts, the SESF provides a framework for exploring transformative solutions. It can map out the resource units and governance systems that need transformation to address issues like flooding, erosion, and species extinction. This framework offers a way to examine how shifts in governance and social practices can lead to more sustainable conservation models.

In conclusion, addressing the challenges posed by the Anthropocene and achieving sustainability in biodiversity conservation require transformative change guided by interdisciplinary collaboration and a commitment to justice, trust, and equity (IPBES, 2019; Fougères et al.,2020). Critical social science perspectives offer valuable insights into navigating this complex terrain and shaping a more sustainable future (Blythe et al., 2015; Chua et al., 2020; Nienaber et al., 2021). However, there remains a need for greater attention and resources directed towards social science, particularly critical social science, to foster meaningful and lasting transformations in biodiversity conservation.

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provides a framework for exploring transformative solutions. It can map out the resource units and governance systems that need transformation to address issues like flooding, erosion, and species extinction. This framework offers a way to examine how shifts in governance and social practices can lead to more sustainable conservation models.

Overall, recent trends and developments in the field of transformative change to halt biodiversity loss reflect a growing recognition of the need for radical shifts in conservation paradigms and governance structures. These trends underscore the importance of integrating diverse knowledge systems, promoting justice and equity, and engaging with social science perspectives to foster more effective and inclusive conservation efforts.

2.2.3 Key Studies and Findings

The following section is structured to align the theoretical perspectives, methodologies, and key themes with the three levels: micro, meso, and macro. Firstly, the underlying theoretical perspectives of the reviewed papers are discussed within the context of these three levels, providing a foundation for understanding the conceptual frameworks guiding biodiversity conservation efforts. Secondly, an overview of the methodologies employed in the reviewed studies is provided, with each methodology categorized according to its application at the micro, meso, or macro level. Subsequently, the key themes that emerged from the papers regarding transformation to halt biodiversity loss are presented, organized along the micro, meso, and macro levels to provide insights into how conservation efforts operate at different scales. This structured approach allows for a comprehensive understanding of biodiversity conservation efforts regarding transformation.

I. Theoretical perspectives to explore transformative change to halt biodiversity loss.

(1) Governance and Institutional Dynamics: At the micro level, studies such as Geldmann et al. (2013) focus on the internal dynamics of organizations involved in biodiversity conservation, highlighting the importance of adaptive governance mechanisms and stakeholder engagement within protected areas management. Similarly, Kunyanga et al. (2011) explore governance structures within research institutions, emphasizing the need for institutional reforms to address challenges in implementing sustainable agricultural practices. *At the meso level*, Baldwin-Cantello et al. (2023) advocate for transformative governance and policy innovations, highlighting the role of NGOs and governmental agencies in shaping conservation policies at the community and organizational levels. Raar et al. (2020) examine accountability concepts within organizational frameworks, shedding light on meso-level dynamics of stakeholder engagement and policy innovation. *On the macro level*, studies like Fastenrath et al. (2020) and Jones et al. (2018) explore scale and scalability in conservation efforts, illustrating macro-level implications of scaling up solutions globally and planning for regional recovery of ecosystems. While these papers provide insights into governance and institutional dynamics across different levels, there's a gap in the application of methodologies specifically tailored to the micro level, where individual behaviors and organizational dynamics play a crucial role.

(2) Social-Ecological Systems Analysis: Hill et al. (2015) and Boronyak and Jacobs (2022) adopt a social-ecological systems (SES) approach to understand interactions between human societies and ecosystems. *At the micro level*, Hill et al. (2015) examine impediments to achieving conservation targets, focusing on individual perceptions and behaviors within local communities. Boronyak and Jacobs (2022) explore pathways to coexistence with large carnivores *at the meso level*, emphasizing the role of communities and organizations in integrating human well-being with conservation objectives. *On the macro level*, while there is a lack of specific studies mentioned in the provided text, social-ecological systems analysis inherently considers interactions at larger scales, including governance structures and policy frameworks that

influence conservation efforts. However, further research may be needed to explicitly address social-ecological dynamics at the macro level.

(3) Transformative Governance and Policy Innovation: Baldwin-Cantello et al. (2023) and Raar et al. (2020) advocate for transformative governance and policy innovations across different levels. While these papers highlight the importance of paradigm shifts in governance frameworks, there's a gap in addressing specific methodologies applied at the micro level to understand individual perceptions and behaviors within organizations and communities.

(4) Scale and Scalability: Fastenrath et al. (2020) and Jones et al. (2018) explore scale and scalability in biodiversity conservation efforts. *At the micro and meso levels*, there's limited mention of studies focusing on spatial and temporal scales or scalability of interventions. However, these concepts are inherently interconnected with governance and institutional dynamics, as highlighted in previous sections.

(*5) Complexity and Uncertainty:* Levin et al. (2020) and Morf et al. (2023) grapple with complexity and uncertainty in biodiversity conservation and environmental governance. While these papers emphasize the need for adaptive management approaches and scenario planning, there's a lack of explicit mention of methodologies applied *at the micro level* to address individual behaviours and perceptions contributing to uncertainty (Nienaber et al., 2023; Nienaber et al., 2021). Further research integrating micro-level methodologies with complexity and uncertainty frameworks could enhance understanding and decision-making in conservation efforts.

In conclusion, the exploration of theoretical perspectives across micro, meso, and macro levels provides valuable insights into the dynamics shaping biodiversity conservation efforts. While existing studies offer significant contributions, further research focusing on micro-level methodologies and explicitly addressing social-ecological dynamics at the macro level could enhance the effectiveness of conservation strategies.

II. Methodologies to investigate biodiversity conservation through transformational change.

(1) Quantitative Analysis: Several papers utilize quantitative methods to examine biodiversity conservation, focusing on different levels of analysis. For example, Shen et al. (2020) conduct spatial analysis to understand the relationships between ecosystem services and social-ecological drivers in the Beijing-Tianjin-Hebei region, emphasizing a macro-level perspective. Similarly, Ford et al. (2022) employ quantitative techniques to study the drivers and environmental outcomes of protected area downgrading and degazettement in Cambodia, contributing to a meso-level understanding.

(2) Qualitative Research: Qualitative research methods are commonly employed to explore perceptions and social dynamics in biodiversity conservation, often focusing *on the micro and meso levels*. Bacha et al. (2021) investigate public perceptions of climate change in Pakistan's Swat Valley region, highlighting a micro-level analysis. Meanwhile, Boronyak and Jacobs (2023) utilize qualitative interviews to explore pathways for coexistence with dingoes across Australian farming landscapes, offering insights at the meso level.

(3) Case Studies: The use of case study approaches provides in-depth insights into specific biodiversity conservation initiatives, offering nuanced understandings *at various levels*. Enaruvbe et al. (2019) conduct a case study on armed conflict and mining-induced land-use transition in Liberia's Nimba County, contributing to a *micro-level* understanding of local environmental challenges. On the other hand, Chaudhary et al. (2022) undertake a regional assessment of protected areas in the Hindu Kush Himalaya, providing insights at *the meso level*.

(4) Policy Analysis: Several papers employ policy analysis methods to examine governance mechanisms and policy interventions in biodiversity conservation, often operating *at the meso and macro levels*.

Turnhout et al. (Year) explore evolving expectations and practices of REDD+ in the post-Paris Agreement era, contributing to a macro-level understanding of international policy frameworks. In contrast, Raar et al. (2020) conduct a theoretical analysis to re-steer accountability concepts toward incorporating biodiversity management, focusing on a meso-level perspective.

(5) Interdisciplinary Approaches: Many papers adopt interdisciplinary approaches, combining quantitative and qualitative methods to address complex environmental challenges *across multiple levels*. For example, Hill et al. (2015) apply a social-ecological systems analysis to identify impediments to achieving biodiversity conservation targets, providing insights at both micro and meso levels. Similarly, Molinario et al. (2020) investigate forest cover loss drivers in the Democratic Republic of Congo using interdisciplinary methods, offering a comprehensive understanding at multiple levels. However, some methodologies, such as quantitative analysis, are less prevalent at the micro level, indicating a gap in research focused on individual behaviors and perceptions in biodiversity conservation. Adding references like Geldmann et al. (2013) and Ostrom and Cox (2010) could further enrich the discussion on governance and institutional dynamics, providing additional insights at the macro level.

By integrating these methodologies and considering multiple levels of analysis, researchers can develop more robust strategies for addressing biodiversity conservation challenges and fostering sustainable outcomes. While interdisciplinary approaches offer comprehensive understandings, addressing gaps in methodologies at the micro level could further enhance our understanding of individual behaviours and perceptions in conservation efforts.

III. Key themes across the papers that address transformative change to halt biodiversity loss.

(1) *Governance Transformation*: At the micro level, Aguiar et al. (2021) discuss transformative governance approaches linking forest restoration to human well-being, highlighting individual perceptions and decision-making processes. Raar et al. (2020) propose re-steering accountability concepts at the meso level, emphasizing organizational restructuring to align with conservation goals. However, there's a gap in explicit mention of methodologies tailored to the micro level, focusing more on conceptual frameworks and policy analysis.

(2) *Social-Ecological Resilience*: Hill et al. (2015) delve into social-ecological systems analysis at the micro level, examining impediments to biodiversity conservation targets and individual perceptions within local communities. Boronyak and Jacobs (2023) explore pathways for coexistence with wildlife at the meso level, emphasizing organizational and community dynamics. While social-ecological systems analysis inherently considers interactions across scales, there's a need for explicit research focusing on macro-level governance structures influencing resilience strategies.

(3) *Ecosystem Services Optimization*: Benra et al. (2019) and Shen et al. (Year) investigate ecosystem services optimization at different levels. Benra et al. (2019) examine non-native tree plantation expansion, providing insights at the micro level into land management practices. Shen et al. (Year) conduct spatial analysis, offering a macro-level perspective on spatial patterns of ecosystem services. However, there's limited mention of studies explicitly addressing meso-level governance mechanisms influencing ecosystem services optimization.

(4) *Climate Change Integration*: Bacha et al. (2021) and Levin et al. (2020) address climate change integration in biodiversity conservation efforts. Bacha et al. (2021) explore public perceptions of climate change at the micro level, focusing on individual attitudes and behaviors. Levin et al. (2020) consider climate considerations in deep-sea resource extraction at the macro level, emphasizing global climate policies. Yet, there's a gap in research specifically targeting meso-level institutional responses to climate change impacts on biodiversity conservation.

(5) *Community Engagement and Indigenous Knowledge*: Aguiar et al. (2021) and Boronyak and Jacobs (2023) highlight community engagement and indigenous knowledge integration. Aguiar et al. (2021) discuss transformative change in forest restoration at the micro level, emphasizing local community involvement. Boronyak and Jacobs (2023) explore coexistence with wildlife at the meso level, considering indigenous knowledge systems. However, there's a need for more studies bridging micro-level community engagement with meso-level organizational structures for effective conservation practices.

(6) *Interdisciplinary Collaboration*: Enqvist et al. (2017) and Chaudhary et al. (2022) underscore the importance of interdisciplinary collaboration in biodiversity conservation. Enqvist et al. (2017) discuss interdisciplinary approaches at the micro level, focusing on individual behaviors and perceptions. Chaudhary et al. (2022) explore stewardship in biodiversity conservation at the meso level, emphasizing collaborative efforts. However, there's a gap in research explicitly integrating interdisciplinary approaches across micro, meso, and macro levels for comprehensive conservation strategies.

In conclusion, organizing biodiversity conservation research according to micro, meso, and macro levels provides a comprehensive understanding of the complex dynamics shaping conservation efforts. While many studies highlight the importance of governance transformation, social-ecological resilience, and community engagement, there's a need for more interdisciplinary collaboration and explicit methodological approaches tailored to each level. By addressing these gaps, future research can enhance the effectiveness of biodiversity conservation strategies and contribute to sustainable environmental stewardship across all levels of society.

IV. Challenges, Controversies, and Unresolved Issues in Transformative Change for Biodiversity Conservation

The research domain of transformative change for biodiversity conservation presents several key challenges, controversies, and unresolved issues, indicating areas where further investigation is needed:

Limited Long-Term Monitoring: A significant challenge is the lack of long-term monitoring in evaluating the effectiveness and sustainability of transformative interventions. While short-term outcomes may show success, longitudinal studies are essential to understand the long-term impacts and resilience of these interventions over time.

Understudied Social Equity Implications: Despite the emphasis on transformative governance and community engagement, there is a lack of research on how these initiatives affect marginalized or vulnerable communities. Understanding the social equity implications of transformative change is crucial to ensure equitable outcomes for all stakeholders.

Neglect of Indigenous and Cultural Perspectives: Indigenous knowledge systems and cultural perspectives are often overlooked in biodiversity conservation efforts. Incorporating indigenous voices and traditional ecological knowledge into transformative approaches is essential to respect local values and customs.

Insufficient Evaluation of Trade-Offs and Synergies: While some studies acknowledge trade-offs and synergies between biodiversity conservation and other societal goals, there is a lack of comprehensive assessments. Further research is needed to quantify and evaluate these interactions, particularly in sectors such as agriculture, infrastructure, and economic development.

Underrepresentation of Developing Regions: Much of the existing literature on transformative change focuses on developed countries, neglecting the challenges faced by developing regions. Research in developing countries is vital to address the global biodiversity crisis comprehensively.

Inadequate Integration of Climate Change Adaptation: While recognizing the importance of integrating climate change adaptation into biodiversity conservation efforts, there is a gap in systematically evaluating

its effectiveness. Future studies should explore synergies between biodiversity conservation and climate change adaptation strategies.

Limited Stakeholder Engagement Research: Collaborative efforts among diverse stakeholders are essential for transformative change in biodiversity conservation. However, there is a gap in research assessing stakeholder perceptions, interests, and capacities for transformative action.

*Unresolved Issues and Controversies***:** One unresolved issue is the scalability and replicability of transformative interventions across different contexts. While there is substantial literature on theoretical frameworks and case studies, there is a lack of implementation research evaluating the scalability and replicability of these interventions.

Additionally, controversies may arise regarding the prioritization of conservation goals and the allocation of resources. Balancing competing interests and priorities requires careful consideration and stakeholder engagement to ensure equitable and sustainable outcomes.

Addressing these challenges, controversies, and unresolved issues is crucial for advancing transformative change in biodiversity conservation. By highlighting gaps in the existing literature and identifying areas for further research, we can develop evidence-based strategies to effectively halt biodiversity loss and promote ecosystem resilience.

3 HYPOTHESES AND QUESTIONS FOR THE CASE STUDIES

The hypotheses and research questions in this section are centred around the exploration of transformational change strategies aimed at halting biodiversity loss within coastal ecosystems. With increasing environmental pressures and human activities threatening coastal biodiversity, understanding the mechanisms of transformational change becomes paramount for effective conservation and sustainable management. Through a comprehensive examination of hypotheses and research questions, this section delves into the potential pathways, drivers, and outcomes of transformative initiatives in coastal conservation. By elucidating these inquiries, researchers endeavour to uncover novel insights, identify key leverage points, and catalyse actionable interventions to safeguard coastal biodiversity for future generations.

3.1 Transformative Change for Biodiversity Conservation

Hypothesis 1: *Integrating social science into transformative change initiatives enhances the effectiveness and sustainability of biodiversity conservation efforts.*

Research Questions:

1. What are the key social factors influencing the success of transformative change initiatives in biodiversity conservation?
2. How do cultural perspectives and indigenous knowledge contribute to the design and implementation of effective conservation strategies?
3. What role do stakeholder perceptions, interests, and capacities play in shaping the outcomes of transformative interventions?
4. How can community engagement and participatory approaches be optimized to foster ownership and long-term commitment to conservation goals?

5. To what extent does the equitable distribution of benefits and resources contribute to the success of transformative change efforts in biodiversity conservation?

Hypothesis 2: *Longitudinal studies provide valuable insights into the long-term impacts and resilience of transformative interventions in biodiversity conservation.*

Research Questions:

1. What are the long-term effects of transformative change interventions on biodiversity conservation outcomes?
2. How do these interventions contribute to the resilience of ecosystems and their ability to adapt to environmental changes over time?
3. What factors influence the sustainability of transformative initiatives, and how do they evolve over the long term?
4. What lessons can be learned from successful long-term monitoring efforts in biodiversity conservation, and how can they inform future conservation strategies?
5. How do socio-economic dynamics and governance structures influence the long-term success of transformative change initiatives in biodiversity conservation?

Hypothesis 3: *Effective integration of climate change adaptation strategies enhances the resilience of biodiversity conservation efforts in the face of environmental challenges.*

Research Questions:

1. How can climate change adaptation be integrated into transformative change initiatives to enhance the resilience of biodiversity conservation efforts?
2. What synergies exist between biodiversity conservation and climate change adaptation, and how can they be leveraged to achieve mutual benefits?
3. What are the barriers to integrating climate change adaptation into biodiversity conservation strategies, and how can they be overcome?
4. To what extent do climate change adaptation measures contribute to the long-term sustainability of biodiversity conservation efforts?
5. How can social science approaches inform the design and implementation of climate change adaptation strategies within transformative change initiatives for biodiversity conservation?

3.2 Case Studies in PRO-COAST

These hypotheses and research questions align with the broader objectives of the case studies by emphasizing the importance of integrating social science perspectives, conducting longitudinal studies, and integrating climate change adaptation strategies into transformative change initiatives for biodiversity conservation. By addressing these questions, the case studies aim to generate actionable insights and evidence-based recommendations to enhance the effectiveness and sustainability of biodiversity conservation efforts in their respective regions.

Three Key Takeaways for PRO-COAST Case Studies

Leveraging Social Science for Effective Conservation: Integrating social science theories such as the Social Cognition Theory and the Theory of Planned Behaviour can significantly enhance the design and implementation of biodiversity conservation strategies. For PRO-COAST, this means understanding the

role of stakeholder perceptions, indigenous knowledge, and community engagement in driving transformative change. Effective stakeholder involvement can lead to broader ownership and commitment to conservation goals. Considering equitable distribution of benefits among stakeholders also plays a crucial role in the success and sustainability of these efforts.

Longitudinal Studies for Insight and Resilience: Longitudinal studies provide valuable insights into the long-term impacts and sustainability of transformative conservation initiatives. PRO-COAST case studies can benefit from examining how different conservation measures contribute to ecosystem resilience and adaptability over time. Exploring socio-economic dynamics and governance structures can reveal factors that influence the success of transformative change initiatives in biodiversity conservation. Procedural approaches, like the Transtheoretical Model or the Behavioural Change Model by Nienaber (2020) based on Kotter (2012), can help understand the progression and adaptation of these initiatives.

Integrating Climate Change Adaptation for Resilient Conservation: Climate change adaptation is crucial for enhancing the resilience of biodiversity conservation efforts. PRO-COAST can focus on integrating climate change adaptation into its transformative change initiatives to address environmental challenges. This requires understanding how social science approaches can inform climate change adaptation strategies, fostering both adaptability and sustainability in conservation. Attitudinal changes, driven by cognition, affect, and past behaviours, can be key to successful integration, supporting a holistic approach to biodiversity conservation that acknowledges the interconnectedness of climate change and ecosystem health.

4 CONCLUSIONS

This review revealed several key findings and insights regarding the utilization of transformative change to halt biodiversity loss, as well as the implications of these findings for theory, practice, future research, and the case studies. Understanding the drivers of behavioural change, including knowledge, attitudes, and social norms, is crucial for designing effective interventions in biodiversity conservation efforts. Rigorous evaluation of transformative interventions, such as community engagement programs and technological solutions, is essential for assessing their effectiveness and sustainability. Socio-economic factors, such as incentives and livelihood opportunities, play a significant role in shaping behavioural change efforts and must be integrated into conservation strategies (Hofeditz et al., 2017). Effective governance structures and policy frameworks provide enabling environments for promoting sustainable behaviours and achieving long-term conservation goals. Community involvement and stakeholder collaboration are vital for the success and sustainability of biodiversity conservation initiatives, as they foster ownership and collective action.

Further, the Social-Ecological Systems Framework (SESF) provides a robust lens to understand and implement transformative change in biodiversity conservation. As this review reveals, transformative change requires a multi-faceted approach, encompassing behavioural shifts, effective governance, and community collaboration. The SESF integrates these elements by examining how human and ecological systems interact and affect each other. The SESF is structured around focal action situations, where interactions among actors lead to particular outcomes. This aligns with the findings that underscore the importance of understanding drivers of behavioural change in biodiversity conservation. Knowledge, attitudes, and social norms are central to SESF's social components, reflecting the need to consider these factors when designing interventions. By examining the rules, governance structures, and resource units within the SESF, practitioners can identify how these elements contribute to or inhibit behavioural change.

The findings contribute to the advancement of theoretical frameworks in understanding behavioural change, governance structures, and the role of socio-economic factors in biodiversity conservation.

Practitioners can utilize the insights to design and implement more effective interventions, tailored to local contexts and incorporating community engagement and stakeholder collaboration. The identified gaps in the literature highlight areas for further research, such as long-term monitoring, social equity considerations, and the integration of climate change adaptation into conservation strategies. The case studies provide practical examples of transformative change efforts and offer valuable lessons learned for policymakers, practitioners, and researchers.

In conclusion, this report underscores the significance of transformative change in halting biodiversity loss and promoting ecosystem resilience. By integrating insights from theory, practice, and case studies, the report contributes to a deeper understanding of the mechanisms driving behavioural change and the factors influencing conservation outcomes. Moving forward, it is essential to continue building upon these findings, fostering interdisciplinary collaborations, and developing evidence-based strategies to address the global biodiversity crisis effectively.

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ANNEX - GLOSSARY

Term	Definition
Anthropogenic Impact	*Discipline: Environmental Science* Definition: The influence exerted by humans on the natural environment, which encompasses a wide range of activities, including pollution, deforestation, habitat destruction, and climate change, leading to significant alterations in ecosystem dynamics and biodiversity. Reference: Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science, 277*(5325), 494-499.
Biodiversity Loss	*Discipline: Biology/Environmental Science* Definition: Biodiversity loss refers to the decline in the number and variety of the species within a specific ecosystem, biome, or across the globe. This phenomenon primarily includes the extinction of species and the loss of genetic diversity within species. Additionally, while environmental degradation can indirectly influence biodiversity by altering habitats, its direct relationship to the reduction of species variety necessitates a nuanced understanding Reference: Wilson, E. O. (2020). *Half-Earth: Our Planet's Fight for Life*. Liveright.
Climate Change	*Discipline: Environmental Science/Climate Science* Definition: Long-term alterations in temperature, precipitation, wind patterns, and other aspects of the Earth's climate system. Primarily driven by human activities such as burning fossil fuels and deforestation, climate change significantly impacts natural and human systems worldwide. Reference: IPCC. (2014). Intergovernmental Panel on Climate Change. (2014). *Climate change 2014: Synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri & L.A. Meyer (eds.)]. IPCC.
Coastal Ecosystem	*Discipline: Marine Biology/Ecology* Definition: Diverse, dynamic environments found at the interface between land and sea, characterized by their unique biological, physical, and chemical components. They include mangroves, coral reefs, salt marshes, estuaries, and sandy beaches, playing crucial roles in coastal protection, carbon sequestration, and supporting marine life. Reference: Alongi, D. M. (2020). *The Energetics of Mangrove Forests*. Springer.
Coastal Environment	*Discipline: Geography/Environmental Science* Definition: The interface zone between land and ocean, encompassing a variety of ecosystems, geographical features, and human interactions. It is affected by

	marine processes (such as tides, waves, and sea level changes) and terrestrial influences (including river flows and land use), making it a key area for biodiversity and human livelihoods. Reference: Small, C., & Nicholls, R. J. (2003). A global analysis of human settlement in coastal zones. *Journal of Coastal Research*, 584-599.
Conservation Strategies	*Discipline: Conservation Biology* Definition: Methods and plans implemented to preserve ecosystems, species, and genetic diversity, including protected areas, habitat restoration, and species recovery programs. Reference: Sutherland, W. J., Pullin, A. S., Dolman, P. M., & Knight, T. M. (2004). The need for evidence-based conservation. *Trends in Ecology & Evolution, 19*(6), 305-308. https://doi.org/10.1016/j.tree.2004.03.018
Direct Drivers of Change	*Discipline: Ecology* Definition: Immediate factors influencing ecosystem dynamics and biodiversity include land-use change, natural resource extraction, pollution, and climate change. These elements directly alter the structure and functioning of ecosystems, affecting their processes and the variety of life they support. . Reference: Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press.
Ecological levels	*Discipline: Ecology* 1. Micro Level: This level revolves around the interactive system based on the individual, at local scale, where drivers are energetic and behavioural, within the limits allowed by the morpho-functional characteristics of the organism. A population of organisms of the same species also belongs to this level; the population characteristics are defined by the average characteristics of the individuals belonging to that population. The personality of individuals is a diversity that plays a relevant role at the micro level. This level is very much similar to the human micro level, as it is defined by development, relations, and interactions with other organisms. 2. Meso level: The ecological “meso” level deals with ecosystems. Biodiversity levels targeted are defined around communities, intended as assemblages of different organisms belonging to different species. A community can relate to very different spatial units, depending on whether it is considered a bacterial assemblage on a substrate, or a patch of rainforest, or an urban area. Biodiversity within a community is measured and expressed as α diversity (while β diversity is the diversity recorded among different communities). Relationships such as prey-predator; parasite-host; commensal etc. emerge at this level. Landscapes are characterized by the interaction of biodiversity and geodiversity; they include different ecological patches. Diversity in landscapes is measured as ϒ diversity, including diversity over the range of different conditions (e.g. the diversity measurable along the full extension of a mountain slope).

	3. Macro level: The macro-level refers to systems of ecosystems, on a scale from regional/continental to global, where drivers are thermodynamics and evolution. On such a large scale, genetic flows patterns define metapopulations, i.e. different populations connected over distance, through a range of different mechanisms. The macro level does not relate strictly on spatial distance, though it involves climatic and historical frames. Ecoregions Biogeography looks for the explanation of current diversity patterns at macro scale and through a historical lens (including past eras, but also modern times e.g. for the spread of invasive species). Reference: Odum, E. P. (1971). *Fundamentals of Ecology* (3rd ed.). W.B. Saunders Company.
Ecosystem Resilience	*Discipline: Ecology* Definition: The capacity of an ecosystem to resist damage and recover quickly from disturbances or changes, ensuring the preservation of essential structures, processes, and feedbacks. Reference: Holling, C. S. (1973). Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4*, 1-23. https://doi.org/10.1146/annurev.es.04.110173.000245
Ecosystem Service	*Discipline: Environmental Economics/Geography* Definition: The benefits humans derive from ecosystems, which include provisioning services (e.g., food and water), regulating services (e.g., flood and disease control), cultural services (e.g., spiritual and recreational benefits), and supporting services (e.g., nutrient cycling, which underpins the production of all other ecosystem services). Reference: Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... & Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253-260.
Environmental Stewardship	*Discipline: Environmental Ethics* Definition: The responsible use and protection of the natural environment through conservation and sustainable practices to enhance ecosystem resilience and human well-being. Reference: Chapin, F. S., Power, M. E., Pickett, S. T., Freitag, A., Reynolds, J. A., Jackson, R. B., Lodge, D. M., Duke, C., Collins, S. L., Power, A. G., & Bartuska, A. M. (2011). Earth stewardship: science for action to sustain the human-earth system. *Ecosphere, 2*(8), 1-20. https://doi.org/10.1890/ES11-00166.1
Eutrophication	*Discipline: Ecology/Environmental Science*

	Definition: Eutrophication is a condition in water ecosystems that arises when they are enriched with excessive amounts of nutrients, primarily nitrogen and phosphorus. This enrichment often results from human activities and leads to an overgrowth of algae and phytoplankton. The resulting dense plant growth disrupts normal ecosystem functioning, adversely affecting water quality, fish populations, and overall biodiversity. Reference: Malone, T. C., & Newton, A. (2020). Eutrophication and its effects on coastal ecosystems. *Environmental Science and Policy for Sustainable Development, 62*(5), 18-29. https://doi.org/10.1080/00139157.2020.1767372
Habitat Destruction	*Discipline: Environmental Science/Ecology* Definition: The process in which natural habitat is rendered unable to support the species present; this is the primary cause of biodiversity loss. Habitat destruction can result from a variety of human activities, including agriculture, mining, logging, and urban development. Reference: Dugan, J. E., & Hubbard, D. M. (2010). Loss of Coastal Strand Habitat in Southern California: The Role of Beach Grooming. *Estuaries and Coasts, 33*(1), 67-77. https://doi.org/10.1007/s12237-009-9239-8
Indirect Drivers of Change	*Discipline: Sociology/Political Economy* Definition: Underlying societal factors that affect ecosystems and biodiversity through complex socio-economic processes and governance structures. These include economic growth, population dynamics, technological change, cultural values, and policy frameworks. Reference: Geist, H. J., & Lambin, E. F. (2002). Proximate causes and underlying driving forces of tropical deforestation. *BioScience, 52*(2), 143-150.
Integrated Coastal Zone Management (ICZM)	*Discipline: Environmental Science* ICZM is a strategic, holistic, and adaptive process aimed at achieving sustainable management of coastal zones. It encompasses the entire cycle from data gathering, through planning and decision-making, to management and monitoring, ensuring the involvement and cooperation of all stakeholders. ICZM strives to balance environmental, economic, social, cultural, and recreational goals within the boundaries of natural dynamics, emphasizing the need for integration across various policy domains, sectors, and both terrestrial and marine spaces. Reference: CEC Communication 2000/547 ICZM. (2000). Integrated Coastal Zone Management. European Environment Agency. Retrieved from

	https://www.eea.europa.eu/help/glossary/eea-glossary/integrated-coastal-zone-management
Invasive Species	*Discipline: Ecology* Definition: Non-native species introduced to new environments where they establish, proliferate, and spread, often outcompeting native species and disrupting ecosystems. Their presence can lead to significant ecological, economic, and health consequences. Reference: Richardson, Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: Concepts and definitions. *Diversity and Distributions,* *6*(2), 93–107. https://doi.org/10.1046/j.1472-4642.2000.00083.x
Levels of Society	*Discipline: Sociology and Economics* 1. Micro Level: The micro level of society focuses on individual or small group interactions and social processes. It examines the behaviors, perceptions, and actions of individuals within their immediate social contexts. This level often explores interpersonal relationships, communication patterns, attitudes and individual identity formation within small settings such as families, workplaces, or friendship circles. Studies at the micro level might investigate topics like socialization, personal identity development, or the dynamics of small group interactions. The mirco level encompasses not only the micropolitical dynamics and power plays within organizations that can impede goal achievement but also the critical relationships with key stakeholders and the nuances of internal governance. 2. Meso Level: The meso level bridges the gap between the micro and macro levels, focusing on intermediate-sized units such as communities, organizations, institutions, and subcultures. This level examines how these units organize social interactions and how they influence, and are influenced by, individuals and larger societal forces. Meso-level analysis might explore the roles of educational institutions, religious organizations, small businesses, and community groups in shaping social norms, values, and behaviors. 3. Macro Level: The macro level of society looks at the largest-scale social processes and structures that transcend individual and local contexts. This level includes the examination of societal-wide trends, wider governance structure, societal climate, political culture and global crises, institutions, and systems such as the economy, political systems, education systems, and cultural norms. Macro-level analysis seeks to understand how these large-scale phenomena influence individuals, groups, and smaller social units. Topics of interest at this level might include the study of social stratification, global economic trends, political revolutions, cultural shifts and crises. Reference:

	The definition is an adapted consensus definition by Alexander Yendell, David Herbert, and Ann-Marie Nienaber, tailored for the PRO-Coast project.
Nature-based Solutions (NbS)	*Discipline: Environmental Science* Definition: Actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. Reference: Hall-Spencer, J. M., & Harvey, B. P. (2019). Ocean acidification impacts on coastal ecosystem services due to habitat degradation. *Emerging Topics in Life Sciences, 3*(2), 197–206. https://doi.org/10.1042/ETLS20180117
Plastic Pollution	*Discipline: Environmental Science* Definition: The accumulation of plastic objects and particles (e.g., plastic bottles, bags, and microbeads) in the Earth's environment that adversely affects wildlife, wildlife habitat, and humans. It is a significant component of marine debris and poses challenges to marine health and biodiversity. Reference: Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin, 62*(8), 1596-1605. https://doi.org/10.1016/j.marpolbul.2011.05.030
Resilience	*Discipline: Ecology/Sociology* Definition: The capacity of a system, whether ecological or social, to absorb disturbance and reorganize while undergoing change, so as to retain essentially the same function, structure, identity, and feedbacks. Reference: Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society, 9*(2).
Sea Level Rise	*Discipline: Climate Science* Definition: An increase in the global average sea level caused by the expansion of sea water as it warms and the melting of ice over land. It poses significant threats to coastal habitats, human settlements, and biodiversity. Reference: Nicholls, R., Wong, P., Burkett, V., Codignotto, J., Hay, J., McLean, R., ... & Saito, Y. (2007). Coastal systems and low-lying areas. *Faculty of Science - Papers (Archive)*. https://ro.uow.edu.au/scipapers/164
Social-Ecological Systems (SES)	*Discipline: Environmental Sociology/Political Ecology*

	Definition: A holistic approach to understanding the complex and interdependent relationships between human societies and their environment. SES frameworks emphasize that ecosystems and human societies are inextricably linked, with changes in one affecting the other. This perspective is critical for devising sustainable management and conservation strategies in coastal regions. SES emphases that humans must be seen as a part of, not apart from, nature. References: Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*(5939), 419-422. Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change, 16*(3), 253-267. https://doi.org/10.1016/j.gloenvcha.2006.04.002
Social-ecological Transformation	*Discipline: Sociology/Political Science* Definition: Significant, long-term changes in the interactions between society and ecosystems, aimed at sustainability and resilience in the face of environmental challenges. This concept encompasses shifts in governance, economic systems, social values, and technologies to foster a harmonious relationship between human societies and the natural environment. Reference: Olsson, P., Folke, C., & Hughes, T. P. (2008). Navigating the transition to ecosystem-based management of the Great Barrier Reef, Australia. *Proceedings of the National Academy of Sciences, 105*(28), 9489-9494.
Socio-Demographic Factors	*Discipline: Sociology* Definition: The characteristics of a population, including age, gender, education level, income, and ethnic background, which influence individuals' behaviors, attitudes, and access to resources. Reference: McMichael, A. J. (1999). Environmental and social influences on emerging infectious diseases: Past, present and future. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 354*(1384), 1047-1058. https://doi.org/10.1098/rstb.1999.0481
Sustainable Development	*Discipline: Political Science/Economics* Definition: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs, integrating economic, social, and environmental objectives. Reference: World Commission on Environment and Development. (1987). *Our common future*. Oxford University Press.
Sustainable Management	*Discipline: Environmental Management*

	Definition: The practice of managing natural resources and human activities in a way that ensures the long-term viability and health of ecosystems and communities. Reference: Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., & Noble, I. (2013). Sustainable development goals for people and planet. *Nature, 495*(7441), 305-307. https://doi.org/10.1038/495305a
Transformative change	*Discipline: Environmental Science/Ecology/Political Science* Transformative change is defined in line with previous work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services approved by its Plenary, as a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values, needed for the conservation and sustainable use of biodiversity, good quality of life and sustainable development. References: IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. E. S. Brondizio, J. Settele, S. Díaz, & H. T. Ngo (Editors). IPBES secretariat. https://doi.org/10.5281/zenodo.3831673 Intergovernmental Panel on Climate Change. (2018). *Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. https://www.ipcc.ch/sr15/
Urbanization	*Discipline: Urban Studies and Environmental Planning* Definition: Urbanization describes the process by which rural areas transform into urban areas, characterized by a significant increase in population density within cities or towns, expansion of urban infrastructure, and a shift from agricultural-based economies to manufacturing, services, and technology. This transformation often leads to profound changes in land use, habitat fragmentation, increased demand for resources, and significant environmental impacts, including air and water pollution, heat islands, and loss of green spaces. Urbanization poses challenges for sustainable development, requiring innovative approaches to urban planning, housing, transportation, and energy to ensure resilience, sustainability, and quality of life in urban environments. Reference: United Nations, Department of Economic and Social Affairs, Population Division. (2018). World Urbanization Prospects: The 2018 Revision. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf