

THE MANAGEMENT OF OFFSHORE SAND MINING: A SYSTEMATIC LITERATURE REVIEW

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Abstract: Sand mining is a global practice drawing increasing scrutiny because of its perceived negative environmental and social consequences. Understanding the scientific data underlying efficient management is essential in light of growing calls for stricter mining regulations. Sand demand is especially high in Asia and driven by rapid urbanisation and infrastructure development. Currently, an enormous amount of sand is extracted from offshore sources for use in reclamation and construction projects. This systematic literature review provides an overview and analysis of the extant body of knowledge in peer-reviewed literature on offshore sand management. Most of the literature focussed solely on the environmental impacts and effects of sand mining. Although sand mining is associated with various forms of environmental impacts and concerns, the cessation of sand mining may achieve some level of ecosystem recovery. Conversely, limited analyses on management suggest that offshore sand mining is primarily characterised by poor management practices, leading to environmental, social, and economic deprivation. The review concludes by highlighting several gaps in the literature, particularly the need for more emphasis on management and underscoring the necessity of establishing transparent governance processes to manage offshore sand mining effectively.

Keywords: Offshore sand mining, environmental management, governance, sustainability.

Introduction

Development and construction activities are increasing globally due to rapid development in many countries. According to Torres *et al.* (2021), construction aggregates, including sand, gravel, and crushed rock, account for most anthropogenic masses worldwide. Asia had the highest sand exploitation rate (Larson, 2018). Urbanisation and infrastructure growth, including significant dam investments (Torres *et al.*, 2021) are the main drivers of sand demand (Hugo, 2019; Hackney *et al.*, 2020). This is because sand is a raw material that is required in the production of a wide variety of products, including cosmetics, pharmaceuticals, glass, electronics, and concrete (Bendixon *et al.*, 2021; Pilkey *et al.*, 2023; Rangel *et al.*, 2023). By 2035, it is expected that there will be 5.6 billion urban dwellers worldwide, with Asian cities experiencing significant urban growth (UN-Habitat, 2021). The infrastructure of Asian

cities must be developed urgently and sand is a critical component of this development. As countries address these pressing climate change challenges, particularly rising sea levels, such demand will grow even stronger, with massive amounts of sand required for land reclamation and flood protection (Torres *et al.*, 2021). These events occur as a global crisis caused by sand scarcity emerges (Bendixon *et al.*, 2019; Anokye *et al.*, 2023; Jones, 2023; Pilkey *et al.*, 2023; Rangel *et al.*, 2023).

The United Nations Environment Program's (UNEP) 2019 Sand Governance Report (UNEP, 2019) highlighted the weak governance and research on sand mining. Scientific interest in sand has grown in recent years, with publications in science and nature moving beyond synthetic studies to begin dissecting sand in its granular form (UNEP, 2019).

Need for This Study

In this study, we examined peer-reviewed English-language literature from journals focusing on the management of offshore sand mining to identify the literature gap in offshore sand mining. In addition, we sought to understand the challenges and difficulties associated with managing offshore sand mining. Sand remains inexpensive yet an illegal resource needed to support global development. However, such rapid and chaotic development comes at a cost, which includes but is not limited to social tension, resource depletion, and environmental degradation (UNEP, 2019; Hernandez *et al.*, 2021; Pilkey *et al.*, 2023; Rangel *et al.*, 2023; World Economic Forum, 2023; Aziz *et al.*, 2024; Poonia *et al.*, 2024). The management of sand mining needs to be more closely linked to larger anthropogenic changes and the current governance challenges need to be addressed. Consequently, a thorough literature review will assist researchers in determining the research gaps in this study regarding offshore sand mining management.

Background

The deep sea consists of important natural resources that benefit people and the environment. However, these resources are in danger and face massive exploitation as seabed mining moves quickly and becomes a certainty (Jaeckel, 2020; Pilkey *et al.*, 2023; Rangel *et al.*, 2023). Over the years, a huge volume of offshore sand has been dredged and mined globally (Bendixen *et al.*, 2019; GESAMP, 2019; Bendixen *et al.*, 2021; Hernandez *et al.*, 2021; Pilkey *et al.*, 2023; Rangel *et al.*, 2023). The world is witnessing rapid urban development and expansion at a scale that has never been seen before (UNEP, 2019). Rapid development and urbanisation have resulted in an enormous increase in the demand for sand, which is the main element of asphalt and concrete, as well as a vital component of land reclamation (Asabonga *et al.*, 2017; UNEP, 2019; World Economic Forum, 2023). These have occurred for many years, and the amount of

sand extracted is much greater than the renewal rate (UNEP, 2014). Offshore sand was selected because it is rapidly depleting and becoming more expensive (Asabonga *et al.*, 2017).

Historically, diversion to offshore sand mining on the continental shelf has resulted from efforts to reduce landslides (Rona, 2008; Parr, 2008; Boughen *et al.*, 2010). The industry expanded widely during the 1970s, 1980s, 1990s, and the 2000s. Consequently, there were numerous issues regarding offshore sand mining such as marine mineral rights, beneath values price for minerals, lack of cost-effective qualifying technology, indecision concerning environmental effects, exertion of adopting mining externalities, weak management and policy implementation, and the non-appearance of a strong “social license to operate” in the sea floor environment (Earney, 2005; Boughen *et al.*, 2010; Petersen, 2016; Jaeckel, 2020; Bendixen *et al.*, 2021). However, until recently, these problems have remained prevalent and have yet to be addressed.

UNEP reported that nearly 85% of global mining activities are related to sand and gravel production. However, these activities, especially offshore mining are largely unnoticed and not effectively regulated (UNEP, 2019). After freshwater, it is widely known globally that sand is the next most oppressed natural resource (UNEP, 2019; World Economic Forum, 2023). Offshore sand is generally used for land reclamation projects, whereas river sand is used for construction because it is a core component of cement (GESAMP, 2019; Lim *et al.*, 2021; Jones, 2023; Mohamad, 2023).

Policymakers have overlooked the issues caused by offshore sand mining as a whole and they have continued to be unnoticed by society despite the mining of offshore volumes, demand and dependence on development, and negative impact on the environment (Asabonga *et al.*, 2017; Chua, 2019; UNEP, 2019; GESAMP, 2019; Hernandez *et al.*, 2021; Mahyuddin *et al.*, 2022; Dou *et al.*, 2023; Pilkey *et al.*, 2023;

Rangel *et al.*, 2023; Aziz *et al.*, 2024; Poonia *et al.*, 2024). Given this background, the following objectives are formulated for the study:

- (1) To identify research gaps about the management and sustainability of offshore sand mining.
- (2) To identify the challenges in managing offshore sand mining.

Review Methodology

This study utilised a systematic literature review to identify research gaps and limitations in offshore sand-mining management. Tranfield *et al.* (2003) proposed five stages to conduct a systematic literature review: Planning, identification and evaluation, data extraction and synthesis, reporting descriptive findings, and utilising the findings to guide research and practice.

(A) Planning

This study thoroughly summarises the extant literature on this topic, focusing on established and new critical factors. We aim to offer researchers a comprehensive review of previous studies on the management and sustainability

of offshore sand mining. Figure 1 illustrates the scope of this study. The approaches Moher *et al.* (2009) used in selecting databases for the review and methods. This involved the methods employed to identify and finalise the specific keywords on offshore sand mining (concept) and management (context) in four popular and widely used online databases such as Science Direct, Scopus, Springer, and Emerald. These four databases were chosen for their comprehensive coverage of offshore sand mining. The comprehensiveness of these databases for studies and papers covering a range of topics and subject areas ensures that this study can gather the necessary data to address the research questions. In addition, these databases also assist with the SLR process as most of these databases include features and tools designed specifically for SLR such as citation management, tagging, and exporting capabilities. Furthermore, these databases provide access to many academic journals, including some of the most prestigious and respected publications in various fields. Using multiple databases ensures a comprehensive, thorough, and unbiased review, thereby improving the quality and validity of research findings.

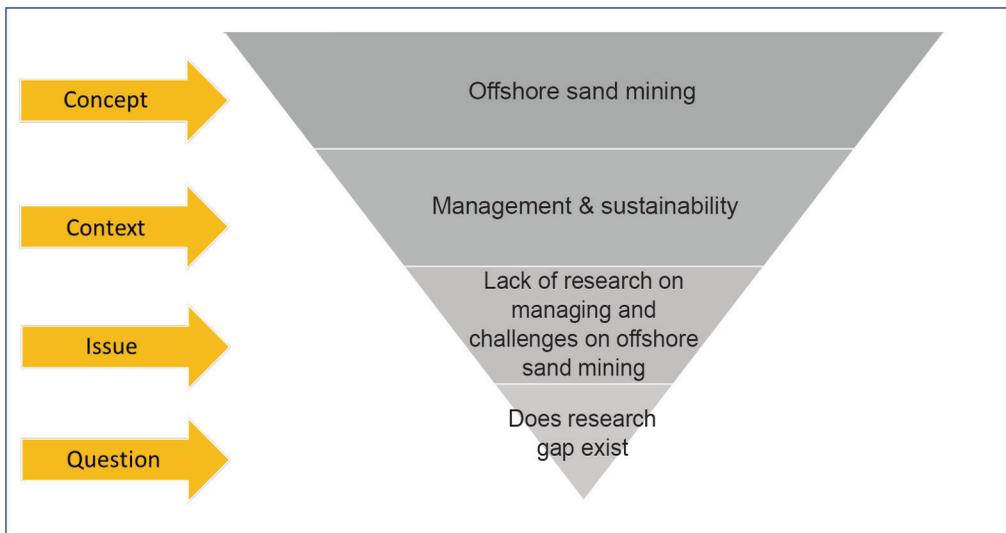


Figure 1: Scope of the review

(B) Identification and Evaluation

Keyword-based searches across scientific databases found 368 titles but there is a need to review the titles and abstracts to ensure that they are purely offshore sand mining management with no duplications. This step succeeded in identifying and obtaining 33 papers that were purely on the topic of offshore sand mining and management. Table 1 presents the information on the number of papers on the management of offshore sand mining that were searched using keywords and the number of papers selected accordingly. Additionally, the keywords used in this study covered both context and content.

Inclusion and Exclusion Criteria

As previously stated, four major online databases, which are Science Direct, Scopus, Springer, and Emerald were searched to collect relevant papers published between 1st January 2010 and 31st December 2023. Initially, 10 years of research papers were chosen for examination (2012 to 2022). In an effort to obtain more papers that discussed offshore sand mining, the coverage range was extended by three years, which is from 2010 to 2023. Furthermore, offshore sand mining management has not been the subject of many studies, which is why this period was chosen to collect pertinent and related studies that complement the research questions. The inclusion criteria for papers are that the papers need to be published in English within the time frame of 2010 to 2023 and the papers have to be peer-reviewed at conferences or in journals. On the other hand, the exclusion

criteria included unpublished work, books, and book chapters.

Keywords

We focused on offshore sand mining management and sustainability as the two main research areas. The search was expanded by adding additional keywords. It contained the following keywords: Offshore sand mining, management, governance, and sustainability. It was eventually set to a combination set that included all previously stated individual keywords. A detailed list of keyword sets used in this study is presented in Table 2.

Search Strategies

We studied the management and sustainability of offshore sand mines. Our strategy involves searching for papers in major online databases. Relevant papers published between 2010 and 2023, including conference proceedings, peer-reviewed papers, and dissertations were also collected. Using a combination of keywords, a search strategy was used to identify the papers discussing offshore sand mining about its management and sustainability (Table 2). However, there is a risk of publication bias due to the search strategy used in the selection process, which is based on the four identified keywords. This risk includes the inclusion of more keywords that will capture more papers on this subject. Therefore, future researchers may broaden their keyword selection to reduce the chance of missing pertinent articles.

Table 1: Number of papers on management of offshore sand mining

Detail	Number of Papers
Keyword-based search for papers on management in offshore sand mining (OSM)	368
Selected papers for this study	33

Table 2: Keyword combination sets

Individual Keyword Category		Combination Set				
1	2	3	4	5	6	7
Offshore sand mining	Management	Governance	Sustainable	Offshore Sand Mining + Management (OSM + M)	Offshore Sand Mining + Management or Governance (OSM + M/G)	Offshore Sand Mining + Management + Sustainable (OSM + M + S)
Offshore sand mining or marine sand mining or sea sand mining or coastal sand mining	Management or managements	Governance	Sustainable or sustainability	Offshore sand mining or marine sand mining or sea sand mining or coastal sand mining management or managements or governance	Offshore sand mining or marine sand mining or sea sand mining or coastal sand mining management or managements or governance	Offshore sand mining or marine sand mining or sea sand mining or coastal sand mining management or managements or governance and sustainable or sustainability

(C) Data Extraction and Synthesis

Papers from the four databases using the extraction method are depicted in Figure 2. Based on the primary databases, only offshore sand mining papers that were applied in nature and connected to management and sustainability were selected for further review with only 33 out of 368 papers were chosen for the final review.

This section describes the systematic review methodology that was used in the paper. A systematic review of selected studies was conducted following the PRISMA guidelines to address the research questions to ensure a transparent and evidence-based approach (Page *et al.*, 2021). Figure 2 provides a flowchart illustrating the study selection process using the PRISMA methodology. The sections that follow will go into detail about the study’s procedures and synthesis analysis.

(D) Reporting Descriptive Findings

Results

In Table 3, there were 19 countries/territories and seven regions, which were the focus of the 33 research papers included in this review. China had the most research (three papers), followed by Australia, New Zealand, and India, each with two papers. Table 3 lists other countries/territories and regions, each with one paper.

Figure 3 displays the percentage of papers based on the selected keywords. Bar graph displaying papers found through keyword searches using the terms OSM, OSM + M/G, and OSM + M + S, which are specified in Table 2. There was a total of 33 papers. Out of the total number of papers, 63% (21) were on OSM + M, 6% (2) were on OSM + M/G, and 9% (3) were on OSM + M + S.

The studies were classified into two types: Conceptual and empirical. They comprised eight conceptual studies (24%) and 25 empirical studies (76%). Conceptual papers do not include the actual test results. Empirical studies, on the other hand, are composed of evidence-based research as well as inputs for testing and results. The percentage of papers by category

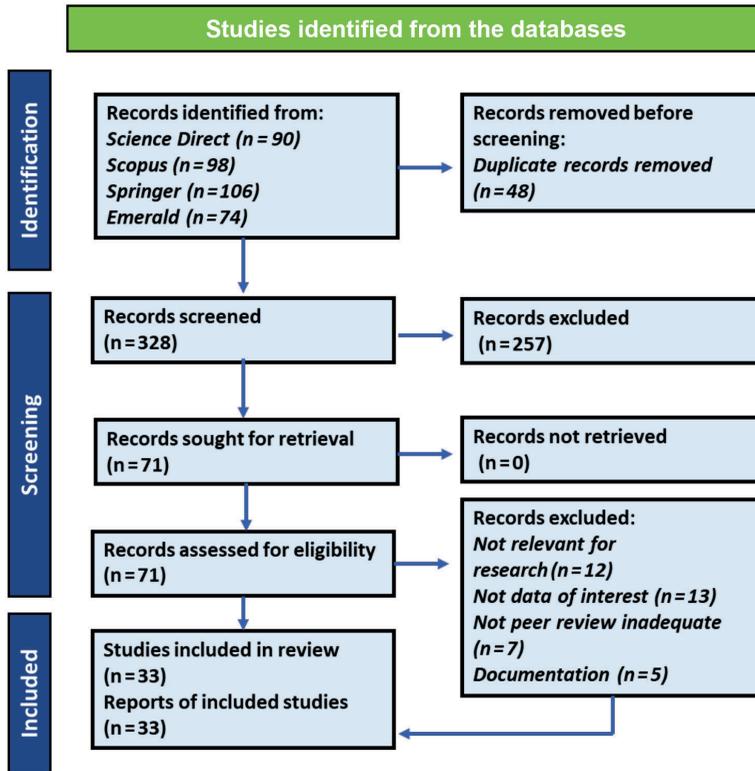


Figure 2: PRISMA flowchart for the process of the paper selection

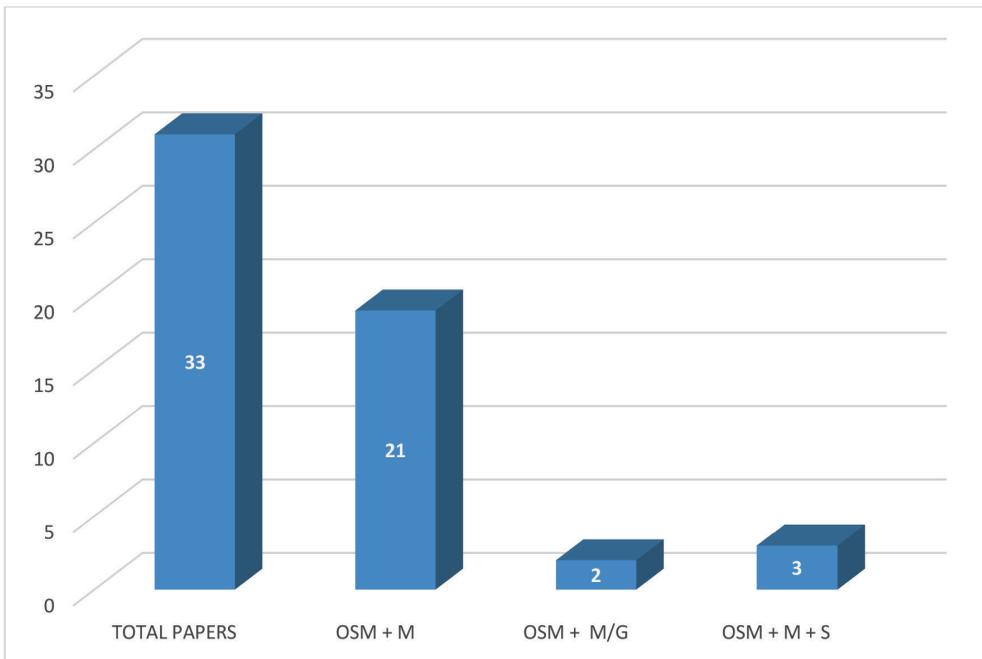


Figure 3: Papers by keyword search categories

Table 3: Numbers of papers by focus country/territories or region

Focus Country/Territory/Region	Number of Papers
Antigua and Barbuda	1
Australia	2
China	3
Fiji	1
Ghana	1
Guatemala	1
India	2
Israel	1
Japan	1
Korea	1
Malaysia	1
Namibia	1
Netherland	1
New Zealand	2
Nigeria	1
Pakistan	1
South Africa	1
Spain	2
Taiwan	1
Tanzania	1
Finland and Sweden	1
Atlantic Ocean	1
Wadden Sea (Denmark, Germany, and the Netherlands)	1
Europe	1
Caribbean	1
Black Sea	1
Global	1

is shown in Figure 4. Based on the 33 papers chosen, empirical research is more appropriate when the research is based on offshore sand mining because it includes research based on observation, experimentation, and verifiable evidence, as opposed to conceptual research, which includes abstract ideas and concepts.

Discussion

Table 4 shows papers on keywords combination number 5 that include OSM and management,

where it summarises the 21 papers on the management of offshore sand mining with data extracted from the databases as of 1 June 2024. The paper shows that offshore sand mining management is a complex and multifaceted endeavour that addresses various interconnected issues, such as Integrated Coastal Zone Management (ICZM), climate change resilience, sustainability, policy development, and best practice. Offshore sand mining that is responsible and sustainable must take an integrated, collaborative, and

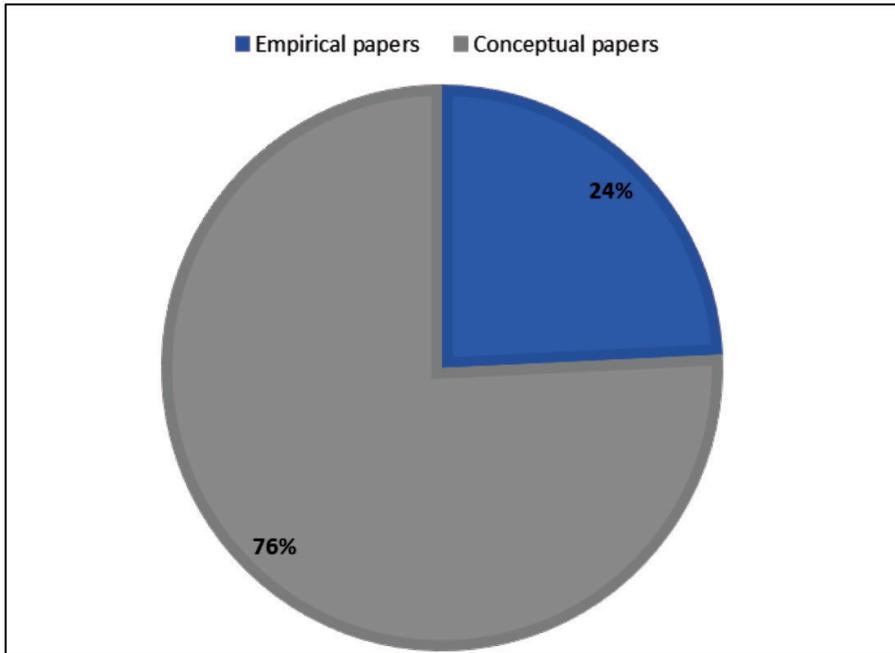


Figure 4: Percentages by paper type

Table 4: Summary of 21 papers on offshore sand mining and management

No.	Citation	Author	Factors	Key Findings
1	2	Mulder <i>et al.</i> (2011)	To improve the use of Integrated Coastal Zone Management (ICZM) in the Netherlands, as well as to ensure long-term conditions for flood protection and coastal function.	Many factors contributed to the inefficient application of the ICZM. The role of the government is crucial in employing the success of the ICZM.
2	22	Sakai <i>et al.</i> (2012)	To investigate the state of environmental and safety regulations in Japan’s suburban aggregate mines as well as their potential going forward.	The significance of expanding the supply of high-quality aggregate through research and development and effective extraction technologies and approaches.
3	32	Lodhia (2012)	To evaluate the risk of disasters caused by climate change in the coastal areas of Gujarat.	It is suggested that the stakeholder approach is the best strategy for coordinating the development of the coastal region, which has significant policy implications for the state of Gujarat.
4	24	Ye <i>et al.</i> (2014)	To comprehend the small number of Integrated Coastal Management (ICM) projects that were finished, continued, or deemed effective in China.	The overall positive outcome demonstrated that the ICM in Quanzhou could be regarded as a success, since the results of many ICM initiatives in China and other nations are not encouraging.

5	16	Johnson & Ericson (2015)	To explore how Sweden and Finland alter their mineral rights and control over mining corporations.	The involvement of the state in Sweden and Finland is examined historically in terms of mineral resource ownership, regulatory norms and control over mining, and ownership of state-mining and/or exploration businesses.
6	18	Ramsey <i>et al.</i> (2015)	To look into the present practices in Antigua and Barbuda and their effects on the ecology along the coast.	A more inclusive, all-encompassing management strategy was highly desired, and all questioned stakeholders indicated a willingness to engage.
7	39	Puente-Rodríguez <i>et al.</i> (2015)	To clarify the key components of a broad knowledge-practice interface framework in order to improve the management of knowledge in coastal zone management in the Wadden Sea area.	Sustainable development in coastal zones of the Wadden Sea area cannot be achieved just via scientific knowledge; instead, participatory knowledge and practices are becoming more and more necessary to enable the integration of many knowledge types (such as formal and informal knowledge) and the involvement of various stakeholders in order to improve integrated coastal zone management.
8	20	Kosyana & Velikovab (2016)	To study of the interface between science and policy in Integrated Coastal Zone Management (ICZM) in the Black Sea which is still in its early stages.	In the Black Sea area, striking a balance between human interests and the sustainability of natural ecosystems is far from being attained at this moment.
9	4	Sowunmi, <i>et al.</i> (2016)	To explore the effect of sand dredging on environmental efficiency of local fishermen in Nigeria.	Fishermen's environmental efficiency is negatively impacted by water turbidity in the research location.
10	53	Ellis <i>et al.</i> (2017)	To examine the limitations of existing best practices, scientific guidelines, and established environmental management principles in New Zealand.	Major revamp and full utilisation of the Environmental Risk Assessment (ERA) and Environmental Impact Assessment (EIA) in offshore mining in New Zealand
11	1	Lopez <i>et al.</i> (2017)	To comprehend the situation of coastal erosion, which has reached a disproportionate level, with around 70% of the shoreline eroding in Costa Blanca, Spain.	A legal error governing the division and regulation of authority among the several administrations on the Costa Blanca in Spain is the cause of the managers' lack of coordination.
12	11	Chen <i>et al.</i> (2019)	To investigate if coastal zone management can support the development of a better framework for coastal management in Taiwan.	In terms of integrated management in Taiwan, the practical application architecture is still in its early phases of implementation.

13	11	Kayhko <i>et al.</i> (2019)	To investigate how challenges with coastal management are caused by the abuse or misuse of marine and coastal ecosystems by both external and local players in Zanzibar, Tanzania.	Since the health of the marine ecosystem supports local livelihoods, various actors should be aware of and mindful of their impact on it in order to support the sustainable use of coastal and marine resources in Zanzibar, Tanzania.
14	3	Hasan <i>et al.</i> (2023)	To describe the regulatory obstacles that offshore sand mining faces, point out flaws in environmental impact studies, and make the case for tougher enforcement and more involvement from stakeholders in Malaysia.	It draws attention to important environmental issues and regulatory obstacles facing Malaysia's offshore sand mining sector. They point out shortcomings in the current regulatory framework, especially with regard to enforcement powers and Environmental Impact Assessments (EIAs). Stakeholder participation is highlighted as a crucial component, and suggestions are made to improve decision-making processes' inclusion and transparency.
15	7	Liu & Xing (2019)	To reconsider and reposition Integrated Coastal Zone Management (ICZM) in China.	Achieving complete management of the coastal zone in China requires the implementation of legislation and coastal zone planning.
16	12	Singh <i>et al.</i> (2021)	To improve community capacity and governance in order to handle issues with efficient law enforcement and guarantee the preservation, sustainable use, and management of marine and coastal resources in Fiji.	Though it is only partially evident through the employment of different tactics for managing coastal resources, rather than through overt declarations and actions, there is considerable evidence that ecosystem care is ingrained in PICs management history in Fiji.
17	8	Kong <i>et al.</i> (2021)	To explore the application of the Xiamen Model and an integrated coastal management system in China.	There is a necessity for monitoring systems, law enforcement's ability to apply integrated coastal management, and on-the-job training and courses in China.
18	2	Thom (2022)	To comprehend the functions of non-governmental organisations, integrated coastal zone management in Australia, and federal and state government coastal inquiries and committees.	The effects and cooperation of the functions and responsibilities of Australia's three levels of government in relation to coastal zone management are distinct.

19	26	Conde <i>et al.</i> (2022)	To conduct a thorough examination of the politics surrounding stakeholder involvement and identification at a global level, as well as a more critical examination of the definition and understanding of the seabed are essential to the implementation of planning strategies and policies.	There is a pressing need for greater consideration to enable more critical, fair, inclusive, and just approaches to the development and regulation of deep sea mining at the international level.
20	2	Callow <i>et al.</i> (2023)	To explore regulatory shortcomings and the significance of strong governance and regulatory monitoring in Australia's offshore sand mining activities.	The findings indicate significant ecological repercussions, including habitat destruction, altered sediment dynamics, and implications for marine biodiversity, as a result of weak regulatory control, with monitoring and enforcement gaps contributing to environmental damage. To successfully reduce these impacts in Australia, enhanced governance mechanisms are required.
21	30	Anokye <i>et al.</i> (2022)	To examine the positive and negative effects of sand mining on people's lives in Ghana's urban and rural areas.	It was found that sand mining has varying effects on land-based livelihood security in Ghana. Some block makers and truck drivers acknowledged favourable benefits of sand mining on their livelihoods. However, the majority of household respondents and other key informants reported that sand mining had negative consequences on their livelihoods.

adaptive approach that balances economic development, environmental protection, social equity, and cultural preservation. Major challenges include conflicting stakeholder interests, limited policy development and enforcement capacity, and rapid technological advancements exacerbating governance and sustainability concerns. Innovation, stakeholder engagement, knowledge-sharing, and continuous improvement can help navigate these complexities, fostering resilience, sustainability, and prosperity for marine ecosystems, coastal communities, and future generations.

Table 5 summarises the two papers that discussed offshore sand mining management or governance. The two papers (Ehlers, 2016; Taljaard *et al.*, 2019) emphasise the role

of governance and management and focus on the legislative frameworks that govern offshore sand mining, highlighting the need for environmental protection and the long-term use and protection of ocean resources. It also looks at the role of environmental protection and ocean conservation in offshore sand mining management, emphasising the importance of incorporating sustainable practices, regulatory compliance, and ecosystem stewardship into governance frameworks.

Meanwhile, the aspects of management and sustainability of offshore sand mining were examined in three papers and summarised in Table 6. Studies on the management and sustainability aspects of offshore sand mining to provide a comprehensive overview of current

Table 5: Summary of two papers on offshore sand mining management or governance

No.	Citation	Author	Factors	Key Findings
1	87	Ehlers (2016)	To strike a good balance between the usage and protection of the seas, particularly the necessity for global ocean governance.	Creating a comprehensive and sustainable ocean governance structure at the global level as soon as possible is critical to maintaining a healthy balance between using and conserving the oceans. The rising usage of the seas demands careful consideration, weighing varied user interests against environmental conservation. Achieving sustainable growth and sustaining equilibrium rely on effectively resolving these concerns.
2	26	Taljaard et al. (2019)	To evaluate legislative progress toward integrated environmental governance in South Africa, where a significant portion of the legal landscape (governing activities and developments that may have an impact on the coastal marine environment) is still fragmented among many sector-based government offices.	Effective implementation across all government departments in South Africa However, remains a major difficulty in most sectors, principally due to sectoral capacity limits.

practices, challenges, and opportunities, as well as examining the impact of community engagement, stakeholder involvement, and participatory approaches in offshore sand mining projects were reviewed and summarised.

(E) Utilising the Findings to Guide Research and Practice

The findings from the systematic literature review enabled the identification of several research gaps based on the paucity of suggestions from the extant literature. The research gap in offshore sand mining management is evident, evidenced by the scarcity of papers that specifically address management and sustainability issues compared to the predominant emphasis on environmental concerns. Furthermore, the lack of papers investigating the Malaysian context from a management perspective reveals a significant literature gap, particularly in regulatory frameworks, policy development, stakeholder engagement, and best practices tailored to local socioeconomic, environmental, and cultural contexts. Addressing these research

gaps is critical for improving understanding of offshore sand mining management challenges, opportunities, and strategies and fostering informed decision-making, capacity building, and collaborative efforts to promote sustainable and responsible offshore sand mining practices in Malaysia and worldwide. Three significant research gaps were identified from the systematic literature review which are presented in turn:

Research Gap 1: Offshore Sand Mining in the Context of Management and Sustainability

Only three studies as shown in Table 6 deal with offshore sand mining in the context of management and sustainability. Other papers that have been reviewed include management and sustainability elements; however, they also have elements that focus on other factors. Because of the limited number of papers that have discussed this topic, researchers should look into this new phenomenon further. The three papers that specifically discuss offshore sand mining management and sustainability are primarily concerned with guidelines and legislation

(Trop, 2017), stakeholder engagement between government bodies (Agostin *et al.*, 2015), and environmental management in the context of the environment (Marale, 2013).

Research Gap 2: Offshore Sand Mining Management and Sustainability in Malaysia

Only one paper on offshore sand mining is available in the context of Malaysian management, as detailed in Table 6. The research community, particularly in Malaysia needs to conduct more research on this topic, which is essential for more effective knowledge on this issue which is of pressing concern. Three of the analysed papers all focused on China while two papers each had India and New Zealand

as their respective countries of focus. Given Malaysia’s active offshore sand mining-related activities, more research is required in the context of offshore sand mining management and sustainability.

Research Gap 3: Offshore Sand Mining Paper Focuses

Table 7 details the 33 papers on offshore sand mining, with 12 articles focusing on the environmental aspects in terms of management, seven papers focusing on legislation, eight papers emphasising offshore sand mining management, and six papers looking into other aspects that are involved such as marine zoning, marine spatial planning, and others.

Table 6: Summary of three papers on offshore sand mining management and sustainability

No.	Citation	Author	Factors	Key Findings
1	8	Marale (2013)	To investigate the numerous coastal concerns and management techniques in India for effective environmental management and sustainable development in areas that have not received enough protection and are under stress.	The ecosystem-based management framework guides India’s costal management through strategies such as institutional strengthening, capacity building, policy planning, management plans for degraded areas, education, and awareness.
2	31	Agostini <i>et al.</i> (2015)	To describe the main processes that resulted in the creation of a draft marine zoning design for St. Kitts and Nevis.	The challenge of creating a common vision for the waters surrounding St. Kitts and Nevis was successfully accomplished by the stakeholders, who took into account a wide range of data and navigated challenging discussions regarding the sharing of ocean space. In order to maximise the utilisation of the marine space, stakeholders also developed a better knowledge of how to best combine their needs. Resource management calls for ongoing work and contributions; this is particularly true for marine zoning, where cooperation amongst management authorities is necessary to regulate the use of maritime space.
3	13	Trop (2017)	To investigate Israel’s regulatory, planning, and legislative frameworks for offshore protection.	The majority of UNCLOS and ICZM policy principles are firmly established in Israel regulatory frameworks, as evidenced by the principles and rules developed in Israel policy in relation to the fundamental ideas of pertinent international policies.

Table 7: Summary of 33 reviewed papers in terms of method, focus, and coverage of keywords

No.	Citation	Author (Year)	Method	Focus	Factor	Has the Paper Discussed about These Keywords?			
						Offshore or Marine or Coastal or Sea Sand Mining	Management or Managements	Governance	Sustainable or Sustainability
1	2	Mulder <i>et al.</i> (2011)	Qualitative	Management	To improve the use of Integrated Coastal Zone Management (ICZM) in the Netherlands, as well as to ensure long-term conditions for flood protection and coastal function.	X	X		
2	3	Lamarche & Clark (2011)	Qualitative	Environment	To examine the difficulty that national and intergovernmental organisations are currently facing in promoting the growth of mining activities while making sure that environmental sustainability in New Zealand is not jeopardised.	X	X		
3	4	Yang & Kang (2011)	Qualitative	Environment	To identify measures to lessen the environmental impact of the extraction process in order to boost its sustainability.			X	

4	22	Sakai <i>et al.</i> (2012)	Qualitative	Environment	To investigate the state of environmental and safety regulations in Japan's suburban aggregate mines as well as their potential going forward.	X	X
5	32	Lodhia (2012)	Qualitative	Management/ Stakeholder	To evaluate the risk of disasters caused by climate change in the coastal areas of Gujarat.	X	X
6	8	Marale (2013)	Qualitative	Environment	To investigate the numerous coastal concerns and management techniques in India for effective environmental management and sustainable development in areas that have not received.	X	X
7	24	Ye <i>et al.</i> (2014)	Qualitative	Management and Stakeholder	To comprehend the small number of Integrated Coastal Management (ICM) projects that were finished, continued, or deemed effective in China.	X	X
8	39	Puente-Rodriguez <i>et al.</i> (2015)	Qualitative	Zoning	To clarify the key components of a broad knowledge-practice interface framework in order to improve the management of knowledge in coastal zone management in the Wadden Sea area.	X	X

9	31	Agostini <i>et al.</i> (2015)	Qualitative	Zoning	To describe the main processes that resulted in the creation of a draft marine zoning design for St. Kitts and Nevis.	X	X	X
10	16	Johnson & Ericson (2015)	Qualitative	Management	To explore how Sweden and Finland alter their mineral rights and control over mining corporations.	X	X	X
11	18	Ramsey <i>et al.</i> (2015)	Qualitative	Management	Many activities in Antigua and Barbuda are currently being conducted unsustainably, with negative impacts on the coastal environment.	X	X	X
12	3	Hasan <i>et al.</i> (2023)	Qualitative	Management	To describe the regulatory obstacles that offshore sand mining faces, point out flaws in environmental impact studies, and make the case for tougher enforcement and more involvement from stakeholders in Malaysia.	X	X	X
13	20	Kosyana & Velikovab (2016)	Qualitative	Management	To study of the interface between science and policy in Integrated Coastal Zone Management (ICZM) in the Black Sea which is still in its early stages.	X	X	X

14	14	Palazon <i>et al.</i> (2016)	Qualitative	Environment	To assess the current situation of beach management along Spain's Alicante coast, paying particular attention to the connection between beach erosion and urban growth.	X	X	
15	4	Sowunmi <i>et al.</i> (2016)	Case Study	Environment	To explore the effect of sand dredging on environmental efficiency of local fishermen in Nigeria.	X	X	
16	87	Ehlers (2016)	Qualitative	Environment	To strike a good balance between the usage and protection of the seas, particularly the necessity for global ocean governance.	X	X	X
17	13	Trop (2017)	Qualitative	Legislative Guideline	To investigate Israel's regulatory, planning, and legislative frameworks for offshore protection.	X	X	X
18	53	Ellis <i>et al.</i> (2017)	Qualitative	Environment	To examine the limitations of existing best practices, scientific guidelines, and established environmental management principles in New Zealand.	X	X	
19	16	Gonzalez & Clifton (2017)	-	Management	To address the governance of marine resources in Guatemala, which has received scant attention this far.			X

20	187	Torres <i>et al.</i> (2017)	Qualitative	Environment	To examine how rising sand mining, commerce, and consumption present global sustainability issues.	X	X	X
21	1	Lopez <i>et al.</i> (2017)	Quantitative	Environment	To comprehend the situation of coastal erosion, which has reached a disproportionate level, with around 70% of the shoreline eroding in Costa Blanca, Spain.	X	X	
22	7	Liu & Xing (2019)	Qualitative	Management/ Zoning	To reconsider and reposition Integrated Coastal Zone Management (ICZM) in China.	X	X	X
23	11	Kayhko <i>et al.</i> (2019)	Qualitative	Marine Zoning	To investigate how challenges with coastal management are caused by the abuse or misuse of marine and coastal ecosystems by both external and local players in Zanzibar, Tanzania.	X	X	X
24	26	Taljaard <i>et al.</i> (2019)	Qualitative	Legislative	To evaluate legislative progress toward integrated environmental governance in South Africa, where a significant portion of the legal landscape (governing activities and developments that may have an impact on the coastal marine environment) is still fragmented among many sector-based government offices.	X	X	X

25	11	Chen <i>et al.</i> (2019)	Qualitative	Management	To investigate if coastal zone management can support the development of a better framework for coastal management in Taiwan.	X	X	X
26	12	Singh <i>et al.</i> (2021)	Qualitative	Management	To improve community capacity and governance in order to handle issues with efficient law enforcement and guarantee the preservation, sustainable use, and management of marine and coastal resources in Fiji.	X	X	X
27	3	Ullah <i>et al.</i> (2021)	Qualitative	Legislative/ Guideline	To review the implementation of the Marine Spatial Planning (MSP) in Pakistan.	X	X	X
28	2	Marin <i>et al.</i> (2021)	Qualitative	Legislative	To examine the gaps between Uruguay and Argentina's joint agreements and institutions, as there is a long history of binational fisheries management and maritime traffic organisation that do not include many other activity sectors that are subject to separate jurisdictions and regulatory instruments.	X		
29	8	Kong <i>et al.</i> (2021)	Qualitative	Legislative Guideline	To explore the application of the Xiamen Model and an integrated coastal management system in China.	X	X	X

30	2	Callow <i>et al.</i> (2023)	Qualitative	Management	To explore regulatory shortcomings and the significance of strong governance and regulatory monitoring in Australia's offshore sand mining activities.	X	X
31	30	Anokye <i>et al.</i> (2022)	Mixed Methods	Environment	To examine the positive and negative effects of sand mining on people's lives in Ghana's urban and rural areas.	X	X
32	26	Conde <i>et al.</i> (2022)	Qualitative	Environment	To conduct a thorough examination of the politics surrounding stakeholder involvement and identification at a global level, as well as a more critical examination of the definition and understanding of the seabed are essential to the implementation of planning strategies and policies. Enactment of policy and planning techniques.	X	X
33	2	Thom (2022)	Qualitative	Legislative/ Guideline	To comprehend the functions of non-governmental organisations, integrated coastal zone management in Australia, and federal and state government coastal inquiries and committees.	X	X

Table 8: Summary of challenges in managing offshore sand mining from the 33 papers selected

No.	Author (Year)	Title	Challenges
1	Trop (2017)	An overview of the management policy for marine sand mining in Israel Mediterranean shallow waters.	There is no national database for collecting relevant data on marine sand resources and no monitoring program in place.
2	Ullah <i>et al.</i> (2021)	Implementation of a marine spatial planning approach in Pakistan: An analysis of the benefits of an integrated approach to coastal and marine management.	The deployment of the MSP strategy along the CPEC coastal and marine zones is projected to promote long-term socioeconomic growth. There is a need for the country's policymakers, planners, and developers to adhere to the MSP (social, economic, and ecological) framework in order to reduce conflicts among users and between users and the environment that may arise as a result of the absence of maritime regulations and legislation.
3	Kong <i>et al.</i> (2021)	Overcoming the challenges of integrated coastal management in Xiamen: Capacity, sustainable financing and political will.	A lack of good managerial competence may make the implementation of Integrated Coastal Management (ICM) more difficult. This challenge emphasises the need for capacity-building and training programs to provide local staff and managers with the skills needed to properly plan and manage coastal areas and resources.
4	Thom (2022)	Coastal management and the Australian Government: A personal perspective.	The absence of both federal law and a dedicated national coastal office within the bureaucracy. Without a legislative framework and a stable national office, policies and programs become haphazard. The public service suffers from workforce turnover and efficiency dividends, exacerbating the issue. The availability of permanent technical advice system is not present.
5	Ellis <i>et al.</i> (2017)	Environmental management frameworks for offshore mining: The New Zealand approach.	There is limited scientific knowledge and advice on recommended practices for conducting an ERA, EIA, and EMP. In addition, there is a lack of best practices or governance structures that management and policy professionals must consider.

6	Maria et al. (2017)	Living with our backs to the sea: A critical analysis of marine and coastal governance in Guatemala.	Minimal attention has been given to the governance of maritime resources in Guatemala where a variety of institutional and structural restrictions impede conservation efforts. There is a need to empower local institutions for better governance to emerge in Guatemala.
7	Taljaard et al. (2019)	The legal landscape governing South Africa's coastal marine environment—Helping with the “horrendogram”.	The issues in South Africa's legal landscape managing coastal marine habitats include slow development at the municipal level, especially in smaller municipalities. There is an urgent need for increased capacity in comprehending complicated coastal dynamics. Furthermore, political buy-in is required, as is a more deliberate and collaborative governing style.
8	Chen et al. (2019)	Beyond sectoral management: Enhancing Taiwan's coastal management framework through a new dedicated law.	Various stakeholders may have competing interests and claims regarding the usage of coastal resources. This can result in disagreements and legal difficulties, as witnessed in the case of the aforementioned beach resort construction. The evaluation of the application of ICZM principles might be difficult.
9	Agostini et al. (2015)	Marine zoning in St. Kitts and Nevis: A design for sustainable management in the Caribbean.	Moving from concept to implementation will necessitate a robust governance system and financial strategy.
10	Marín et al. (2021)	So far and so close: Opportunities for marine spatial planning in the Southwest Atlantic Ocean.	In relation to marine spatial planning, overlaps and interferences were discovered in the clusters of transportation, fishing, and cables and pipelines.
11	Puente-Rodriguez et al. (2015)	Strengthening coastal zone management in the Wadden Sea by applying “knowledge-practice interfaces”.	Failing to consider the long-term perspectives of various players engaged in various behaviors and failing to integrate information across concerns and geographical areas.
12	Ye et al. (2014)	Evaluating the performance of Integrated Coastal Management in Quanzhou, Fujian, China.	In contrast to the performance of ICM in many other nations in the literature, this element has frequently performed poorly and has not always been “the key” to success in China due to its top-down administrative strategy.
13	Hasan et al. (2023)	Regulatory challenges in managing offshore sand mining in Malaysia: Insights and recommendations.	The inadequate legal frameworks now in place in Malaysia for the efficient management of offshore sand mining, together with the absence of transparency and consultation in the decision-making processes are among the major obstacles that have been identified.

14	Kosyana & Velikovab (2016)	Coastal zone-Terra (and aqua) incognita-Integrated Coastal Zone Management in the Black Sea.	The lack of clear and quantitative relationships between pressures and impacts, the gaps in and lax enforcement of laws and policies, and the management of coastal zones based on “learning after observing terrible repercussions” are all examples of scientific ignorance.
15	Koyhko <i>et al.</i> (2019)	The role of place-based local knowledge in supporting integrated coastal and marine spatial planning in Zanzibar, Tanzania.	Insufficient spatial information about marine and coastal habitats and their sociocultural values makes it difficult to integrate a wide range of marine activities into the decision-making process for spatial planning.
16	Ramsey <i>et al.</i> (2015)	Integrated Coastal Zone Management and its potential application to Antigua and Barbuda.	A effective strategy must be driven by the government, but stakeholders must also be willing and committed to participate.
17	Torres <i>et al.</i> (2017)	A looming tragedy of the sand commons.	Insufficient involvement from the government and the requirement to update the regulations.
18	Lopez <i>et al.</i> (2017)	Alicante coastal management for sustainable development.	Beach administrators’ capacity to effectively oversee and maintain the beaches is hampered by their lack of cooperation and expertise. A lack of cooperation amongst various authorities also contributes to the underfunding of beach services and maintenance.
19	Palazon <i>et al.</i> (2016)	Evaluation of coastal management: Study case in the province of Alicante, Spain.	The study discovers that the managers in charge of the upkeep and services of the beaches in the province of Alicante do not work together well. A legal error governing the authority of each administration is the cause of this lack of coordination.
20	Sakai <i>et al.</i> (2012)	Study of present situation and future prospect of environmental and safety measures in suburban aggregate mines in Japan.	Concerns about the environment, growing raw material costs, and dwindling economically viable resource supplies are the problems Japan has with regard to aggregate resources. There is a growing market for high-grade aggregates and high-strength concrete, which emphasises the need for safe, effective, and environmentally responsible resource extraction.
21	Mulder <i>et al.</i> (2011)	Current challenges in coastal management in the Netherlands: Examples of pilot projects.	The government’s limited and minimal involvement in Integrated Coastal Zone Management (ICZM) implementation poses a challenge.

22	Lamarche & Clark (2011)	Enabling the management of offshore mining through improved understanding of environmental impacts—a New Zealand perspective.	Not every stakeholder has been invited to participate in the development of any protocols related to offshore mining management.
23	Yang & Kang (2011)	Energy evaluation of the marine sand extraction for aggregate supply for the construction of the Pusan new port in Korea.	According to the study, extracting marine sand may be a feasible option in terms of yield; but, in order to improve the process' sustainability, steps must be taken to lessen the extraction's negative environmental effects. The challenge lies in more comprehensive understanding of policy goals concerning aggregate supply for Korea's building industry, additional emergency assessments of alternate aggregate production methods are needed.
24	Conde et al. (2022)	Mining questions of “what” and “who”: Deepening discussions of the seabed for future policy and governance.	Difficulties with Jurisdiction: Regulating mining operations on the deep seabed is complicated by the International Seabed Authority's (ISA) and coastal states' differing jurisdictions. There are concerns regarding the efficient management and control of mining operations in overlapping areas due to this division of jurisdiction. Challenges with Stakeholder Engagement: There is still a lack of research on the identification and acknowledgement of stakeholders. Environmental Impact Assessment Difficulties: In order to comprehend and lessen these effects, thorough Environmental Impact Assessments (EIAs) must be conducted. Nonetheless, there are difficulties in defining the parameters and process of EIAs. The evaluation procedure is made more difficult by the participation of stakeholders in the EIA process and the inclusion of ecosystem-based methodologies. Challenges with Policy and Governance: Developing frameworks for policies and governance necessitates answering basic inquiries about stakeholders and the seafloor. The way that mining policy is approached is influenced by various conceptualisations of the seabed such as considering it to be a geological, economic, or biological system.

25	Sowunmi <i>et al.</i> (2016)	Sand dredging and environmental efficiency of artisanal fishermen in Lagos state, Nigeria.	Inadequate incorporation and involvement of artisanal fishermen into official programs that were conducted in Lagos, Nigeria.
26	Ehlers (2016)	Blue growth and ocean governance-how to balance the use and the protection of the seas.	Lack of clear regulation - The issue of who is in charge of ocean governance, international bodies such as the International Seabed Authority or individual governments enforcing their sovereign rights.
27	Johnson & Ericson (2015)	State ownership and control of minerals and mines in Sweden and Finland.	Lack of stakeholder engagement - The governance system may benefit from the involvement of non-governmental and civil society stakeholders.
28	Shalimi <i>et al.</i> (2021)	Coastal resource management and tourism development in Fiji Islands: A conservation challenge.	The experiences of the past must be actively incorporated into ongoing updates to mineral plans. In both countries' mineral policies, we think the state's position as the owner or controller of the mineral resources and as the regulator of mining and exploration activities has to be addressed more in-depth. In addition, we think that Sweden and Finland, which have experienced state ownership and control in all the methods covered in this article with overall success, ought to share and tell other nations and international organisations about this as well.
29	Callow <i>et al.</i> (2023)	Offshore sand mining and its environmental impacts: An Australian perspective.	Local communities collaborate to execute coastal resource management, as demonstrated by the Fiji Locally Managed Marine Area (FLMMA) Network. The government should integrate this model network into its management of coastal systems since it fosters cooperation between local coastal communities, governments, the private sector, non-governmental organisations, and scientific groups.
			There are no adequate regulatory structures in Australia for offshore sand mining. They highlight the lack of participation from the local population and stakeholders in decision-making processes, as well as the necessity of stricter restrictions to properly offset environmental damage.

30	Marale (2013)	Strategies for coastal ecosystem management in India.	<p>The socioeconomic features of coastal areas exhibit a spectrum of situations between two extremes: A small number of areas seeing noteworthy economic development as a result of urbanisation and industry; and backward and depressed areas, sparsely populated and lacking in resources. These conditions are present in a regional scenario marked by mass poverty, underdevelopment, and environmental degradation.</p>
31	Anokye et al. (2022)	Sand mining and land-based livelihood security in two selected districts in the Central Region of Ghana.	<p>Because local government areas differ from one another, it is important to interpret the data carefully before generalising to the entire nation.</p>
32	Liu & Xing (2019)	Analysis of China’s coastal zone management reform based on land-sea integration.	<p>There are shortcomings in the current legislation and rules and how to make sure they support the objectives of coastal zone management. It is advised that a special “Coastal Zone Management Act” be introduced in order to establish a legislative framework for the all-encompassing management of the coastal zone.</p>
33	Lodhia (2012)	Risk and management of climate induced disasters in coastal Gujarat in India.	<p>Limited data relevance: Satellite imagery from the years 1989 to 1999 was used to create Gujarat’s Coastal Zone Management Plan (CZMP). This raises questions about how well the CZMP was implemented utilising out-of-date data in the present decade.</p> <p>Absence of local participation: There was a dearth of local involvement in the CZMP at both the planning and execution stages.</p> <p>The lack of participation from multiple stakeholders, including local governments, communities, the media, and environmentalists resulted in disputes in Gujarat’s coastal regions and impeded the efficacy of the strategy.</p> <p>Inadequate attention to coastal disasters: The CZMP did not sufficiently handle coastal emergencies. Data gaps and a lack of knowledge about the possible hazards of disasters in the coastal region existed. This made it more difficult for the plan to efficiently reduce and manage these risks.</p> <p>Bias towards economic development: Modifications to the Coastal Zone Regulation Act suggest that the original goal of protecting the coastal environment was superseded by a bias towards economic expansion. This implies that the plan gave economic development a higher priority than the preservation of coastal resources.</p>

Thus, it demonstrates that the gap identified here on offshore sand mining is appropriately less studied, particularly studies on its management and sustainability aspects. In light of this, it is of the utmost significance that further research be conducted in this area. Table 7 presents all 33 papers thoroughly discussed in the paper with summary information about each paper, including its focus and highlighted contributing factors. It also displays the paper relationship based on the keywords entered. It is important to highlight that only three reviewed papers discussed the keywords offshore, management, and sustainability.

The challenges gleaned from the 33 reviewed papers are succinctly presented in Table 8. This paper presents some challenges encountered when dealing with offshore sand mining. The challenges summarised in Table 8 are relevant to the research objective of identifying challenges in offshore sand mining. This analysis therefore bridges the gap related to the subject and some challenges have been explored in previous research on matters regarding the management of offshore sand mining.

Challenges in Managing Offshore Sand Mining

- (1) A summary of challenges in the management and sustainability of offshore sand mining is presented in Table 8. Based on the information provided, offshore sand mining management challenges can be identified. Numerous challenges are outlined in the selected papers. The four significant challenges that emerged from earlier research are provided below.
- (2) Weak governance: Inadequate sand legislation and a complex regulatory framework in the government contribute to weak governance when dealing with offshore sand mining. There are gaps in understanding how offshore sand mining is managed, including its application, amount of extraction, and guidelines (Marale, 2013; Guanqiong *et al.*, 2014; Agostin *et al.*,

2015; Kosyana & Velikovab, 2016; Ellis *et al.*, 2017; Gonzalez & Clifton, 2017; Singh *et al.*, 2021; Zafar *et al.*, 2021; Thom, 2022; Callow *et al.*, 2023; Hasan *et al.*, 2023).

- (3) Stakeholder cooperation: Seven papers presented the challenges related to stakeholder issues. The actors involved in offshore sand mining activities are diverse, responsibility and cooperation are lacking. Stakeholder involvement is often a key factor in determining the success of Integrated Coastal Management (ICM) in many countries (Archer, 1988; Imperial *et al.*, 2000; Ernoul, 2010). Furthermore, the involvement of all stakeholders is critical for managing sustainable sand-mining activities (Lamarche & Clark, 2011; Lodhia, 2012; Guanqiong *et al.*, 2014; Rodrigue *et al.*, 2015; Cooper & Yates, 2015; Marin *et al.*, 2021; Singh *et al.*, 2021; Callow *et al.*, 2023; Hasan *et al.*, 2023).
- (4) Lack of knowledge: Lack of scientific knowledge and limited guidance on best practices for conducting and managing offshore sand mining activities result in environmental degradation, economic loss, and negative impacts on community livelihoods (Kosyana & Velikovab, 2016; Ellis *et al.*, 2017; Kayhko *et al.*, 2019).

Lack of data on sand resources: Data on sand resources are lacking in many major countries, which has contributed to the lack of a comprehensive national and global database, exacerbating these issues and impeding evidence-based management efforts (Trop, 2017; Kayhko *et al.*, 2019).

Future Research

- (1) This review proposes alternative theoretical underpinnings such as investigating the moderating effects of offshore sand mining management and sustainability, which have underpinned the existing research. Future research should be conducted in the following areas.

- (2) Future research should examine offshore sand mining from the perspective of imports and exports from countries to gather data on sand resources, which would benefit the emerging global data sand supply system.
- (3) The effects on the physical and biological environments are frequently cumulative and difficult to quantify and assess. Sand extraction affects the entire network of ecosystem services and flow. Future studies should focus on quantifying and mapping such effects.

While many studies have focused on the negative effects of offshore sand mining, there is no doubt that offshore sand mining is beneficial for developing countries (Ashraf *et al.*, 2011; GESAMP, 2019). Therefore, it is recommended that the benefits of offshore sand mining be explored.

Conclusions

Based on the systematic literature review, few researches have been conducted on the management and sustainability of offshore sand mining. Previous research has not adequately explained how management and sustainability work or provide the best tools to address offshore sand mining. Consequently, the literature on offshore sand mining management is in its early stages and may require further investigation. The management of offshore sand mining is critical to the nation and every country that manages offshore sand mining. Offshore sand mining sustainability provides additional benefits such as improving existing processes, introducing new business models, and establishing new service channels to modernise services.

This study addresses two issues. First, this study discovered gaps in managing offshore sand mining mines. Second, challenges are associated with the management of offshore sand mining. This study contributes to a better understanding of offshore sand mining management by investigating its underlying factors. In this interdisciplinary study, we focus on offshore sand mining. The implications

presented herein provide researchers and the public with relevant research and educational references. This study also assists scholars in providing directions. The limitations of this study highlight the challenges faced in research on offshore sand mining management. This study revealed a gap in offshore sand mining management and sustainability, the community was asked to conduct additional research to fill this gap.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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