Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 19, No. 2, 2025

Strategic Significance and Sustainable Development Prospects of Offshore Sea Sand Resources in Guangdong Province

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Abstract: Against the backdrop of Guangdong Province's rapid economic development, the demand for construction materials continues to rise. Offshore sea sand resources, with advantages such as abundant reserves, concentrated distribution, and relatively convenient extraction, have become an essential material foundation for supporting regional engineering projects. In-depth research on the genetic mechanism and sustainable development pathways of offshore sea sand in Guangdong holds significant practical value. This paper systematically analyzes the strategic value of offshore sea sand resources in Guangdong's regional economic construction, elaborates on its genesis from the perspectives of geological processes, marine dynamics, and sedimentary environments, and identifies problems encountered in current development practices. Based on this, it proposes sustainable development pathways aimed at providing theoretical references and practical guidance for the scientific development and rational use of Guangdong's offshore sea sand resources.

Keywords: Offshore Guangdong; Sea Sand Resources; Genetic Mechanism; Sustainable Development.

1. Introduction

As the leading province in China's coastal economic belt, Guangdong has seen accelerated infrastructure construction, marine engineering development, and urbanization processes, leading to a dramatic increase in the demand for construction materials. Sea sand, as a vital component of concrete and other construction materials, is indispensable due to its abundant reserves, centralized distribution, and ease of extraction. Guangdong's vast offshore areas are rich in sea sand resources, and their rational development plays a crucial role in alleviating supply-demand imbalances, reducing engineering costs, and promoting regional economic development. However, the exploitation of sea sand is a double-edged sword; irrational extraction practices can easily trigger coastal erosion, marine ecological imbalance, and other environmental issues. Therefore, thoroughly investigating the genetic mechanisms of Guangdong's offshore sea sand, accurately grasping its formation patterns and distribution characteristics, and exploring scientific and effective sustainable development approaches have become key to ensuring rational resource utilization and marine ecological safety [1-3].

2. Strategic Value of Offshore Sea Sand Resources in Guangdong's Regional Economic Development

In the context of socio-economic development, the demand for various resources is rapidly increasing, especially for sea sand, as shown in Table 1. Sea sand is a critical raw material for building concrete and similar materials. Thanks to its stable physical and chemical properties and relatively low cost, it plays an irreplaceable role in many large-scale engineering projects. From bustling port constructions to massive cross-sea bridge developments, from rising skyscrapers to the assembly of complex marine platforms, sea sand is present in almost every project. Guangdong's adjacent offshore area is vast and, through long-term geological actions and marine dynamic sedimentation, has formed rich and concentrated sea sand deposits. This unique resource advantage provides a solid guarantee for the robust growth of the regional economy. Scientific and proper development of these resources can effectively reduce the cost of raw materials for construction, enhance construction efficiency, accelerate project timelines, and shorten construction periods. It can also drive the coordinated progress of related industries such as construction and marine engineering, create more employment opportunities, and generate economic benefits, thus playing a vital role in the continuous growth of Guangdong's regional economy.

Table 1. Strategic Value of Offshore Sea Sand Resources in Guangdong's Regional Economic Construction

Strategic value	Description
Abundant resources	The offshore area of Guangdong Province is vast. Through long-term geological processes and Marine dynamic deposition, the sea sand resources have large reserves and concentrated distribution, which provides a reliable resource guarantee for regional economic development
Reduce engineering costs	Scientific and appropriate development and utilization of sea sand resources can effectively reduce the cost of raw materials, improve the construction rate, speed up the project schedule and shorten the construction period
Promote related industries	The development and utilization of sea sand resources can promote the coordinated progress of construction, Marine engineering and other related industries, and generate more employment opportunities and economic results
Promoting economic growth	The rational development of sea sand resources plays a key role in the sustainable growth of regional economy in Guangdong province, and is an important support for regional economic development

3. Current Status of Offshore Sea Sand Resource Development and Utilization in Guangdong Province

3.1. Environmental Risks

The ongoing development of offshore sea sand resources in Guangdong Province has led to significant environmental concerns. Extensive sand extraction activities have drastically altered the seabed's original topography, disrupting the previously stable and diverse underwater landscapes. This disruption has initiated a cascade of environmental issues [4-5]. Coastal erosion has become increasingly pronounced, with once expansive and flat beaches gradually diminishing under constant wave action. In some coastal areas, beaches have entirely disappeared, adversely affecting local natural scenery and weakening the shoreline's ability to buffer against wave energy. Consequently, coastal regions face heightened risks from natural disasters such as storm surges. Furthermore, sand mining activities disturb the dynamic balance between seawater and groundwater, leading to seawater intrusion into coastal aquifers. This intrusion elevates groundwater levels and exacerbates soil salinization, rendering previously arable land infertile and significantly impacting agricultural productivity.

In addition to these visible impacts, the removal of benthic habitats significantly disrupts the marine food chain, leading to biodiversity loss in some areas. Many marine organisms, such as shellfish and benthic invertebrates, depend on specific sediment conditions for survival, and the destruction of these habitats can result in long-term population declines. The cumulative ecological footprint of such extractions may impair the resilience of marine ecosystems, ultimately reducing the ocean's ability to recover from natural disturbances or human intervention.

3.2. Technical Bottlenecks

The desalination of sea sand is crucial for its widespread application in construction; however, current technologies face several limitations. Existing desalination methods are plagued by high costs and low efficiency, making sea sand less competitive compared to other building materials. The inefficiency of these processes fails to meet the rapid pace required for large-scale construction projects, thereby hindering the broader adoption of sea sand in the construction industry. Additionally, the extraction process suffers from a lack of advanced, environmentally friendly equipment. Traditional extraction methods are not only inefficient but also result in significant resource wastage and substantial damage to marine ecosystems. This inefficiency and environmental degradation impede the rational and effective utilization of Guangdong's abundant offshore sea sand resources [6-7].

Moreover, desalinated sea sand still faces skepticism within the construction sector regarding its mechanical performance and long-term durability. Without standardized testing and certification protocols, engineers are often reluctant to use sea sand in high-stakes infrastructure projects. At the same time, there is a scarcity of skilled technicians capable of operating and maintaining desalination equipment, further constraining its application. Overcoming these barriers requires not only innovation in technology but also better industry awareness and government support in forming a trusted regulatory environment for sea sand use.

3.3. Technical Vulnerabilities

The current state of sea sand extraction and utilization in Guangdong Province is further complicated by technical vulnerabilities. Inadequate regulatory frameworks and enforcement mechanisms have led to instances of illegal sand mining, exacerbating environmental degradation and resource depletion. The lack of standardized protocols for extraction and processing contributes to inconsistent quality in sea sand products, posing challenges for their use in construction. Moreover, insufficient investment in research and development hampers the advancement of more sustainable and efficient extraction and processing technologies. Addressing these technical vulnerabilities is essential for the sustainable development of sea sand resources in the region.

Additionally, poor coordination between regulatory bodies and local authorities often results in fragmented governance, where responsibilities overlap or are entirely neglected. For instance, while one agency may approve sand mining licenses, another may lack real-time access to monitor extraction activity or assess compliance with environmental regulations. This administrative disconnect leaves room for exploitation and hinders proactive risk management. There is also limited community engagement in monitoring or reporting violations, which weakens social oversight. Without an integrated, transparent governance structure, Guangdong's sea sand industry will continue to be plagued by loopholes that undermine both environmental integrity and sustainable resource planning.

4. Sustainable Development Pathways for Offshore Sea Sand Resources in Guangdong Province

4.1. Enhancing Sea Sand Extraction Intensity Control Plans

To ensure the long-term sustainable development of offshore sea sand resources in Guangdong Province, it is imperative to conduct comprehensive and in-depth research (see Figure 1). This includes a thorough assessment of the region's marine ecological carrying capacity to accurately determine the threshold levels for sand extraction activities. Understanding the reserves and distribution of sea sand resources is crucial for identifying areas with high resource concentration and extraction potential. Based on these assessments, scientifically sound extraction intensity indicators should be established to delineate clear boundaries for sand mining operations. Annual extraction limits for different sea areas must be defined, and strict planning and management protocols should be implemented to prevent over-extraction, which can lead to rapid resource depletion and irreversible ecological damage [8-9].

A dynamic adjustment mechanism for extraction intensity should be instituted, allowing for real-time monitoring and evaluation of ecological impacts, enabling timely modifications to extraction activities to align with environmental changes and ensure the harmonious coexistence of resource utilization and marine ecological preservation. In addition to environmental considerations, socioeconomic impacts should also be incorporated into extraction models, balancing industrial needs with ecosystem protection. Marine scientists, policymakers, and stakeholders should collaborate in creating an integrated decision-making

framework, supported by digital mapping tools and ecological risk forecasting systems. Such a framework could help respond swiftly to ecosystem feedback, minimize conflicts between resource development and conservation, and achieve adaptive governance in sea sand exploitation.

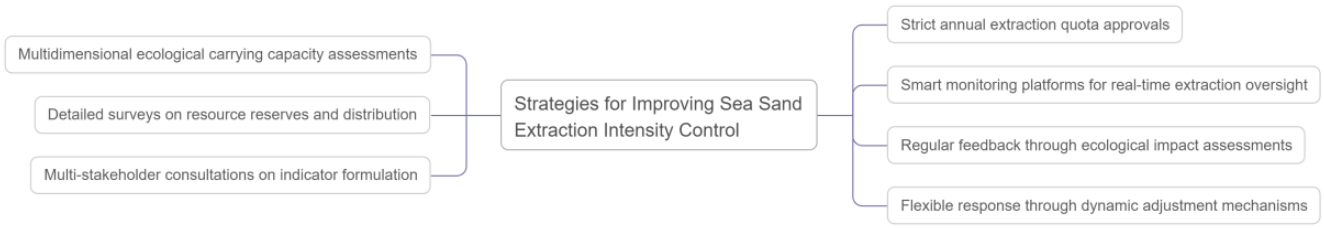

Figure 1. Strategies for Improving Sea Sand Extraction Intensity Control

4.2. Promoting Sea Sand Desalination and Comprehensive Utilization Technologies

Addressing the challenges of high costs and low efficiency in sea sand desalination requires concerted efforts from research institutions and enterprises. Increased investment in research and development is essential to explore the fundamental principles and processes of sea sand desalination. Research institutions can leverage their specialized teams and advanced laboratory facilities to innovate and optimize desalination techniques. Simultaneously, enterprises can provide practical platforms and funding, aligning technological advancements with market demands. Collaborative efforts should focus on developing cost-effective and efficient desalination technologies, incorporating new materials and streamlined processes to enhance the quality and stability of desalinated sea sand, ensuring compliance with construction standards [10-11].

Furthermore, expanding the applications of sea sand beyond traditional construction uses is vital. Exploring its potential in developing high-performance concrete and marine engineering structures such as breakwaters and revetments can increase the resource's value and promote its efficient utilization. Pilot projects could be launched to test novel applications, including eco-friendly coastal infrastructure and permeable pavement systems. At the same time, establishing technical standards and quality certification systems will help increase user confidence and accelerate adoption. Governments could also offer incentives such as tax breaks or subsidies to enterprises using desalinated sea sand, thereby encouraging greener construction practices and fostering a sustainable sea sand industry.

4.3. Establishing a Comprehensive Regulatory System for Sea Sand Extraction

Developing an all-encompassing regulatory framework for sea sand extraction is critical for sustainable resource management. Regulatory authorities should implement a robust system encompassing the entire extraction process, from application and approval to extraction management and product distribution. During the application and approval stages, thorough evaluations of applicants' qualifications, the scientific validity of extraction plans, and the feasibility of ecological protection measures are necessary to ensure compliance from the outset. In the extraction phase, advanced technologies such as satellite remote sensing and drone surveillance should be employed for real-time monitoring of sand mining activities. These technologies enable the detection and immediate cessation of illegal extraction operations.

Additionally, stringent oversight of sea sand transportation and sales is essential. Implementing a traceability system that records detailed information about each batch of sea sand, including its origin and the responsible extraction entity, ensures transparency and accountability, safeguarding the legality of sea sand sources. It is equally important to establish an open data platform where regulators, industry players, and the public can access real-time environmental and compliance data. Regular audits and third-party inspections should be institutionalized to deter malpractice. Furthermore, penalties for violations should be substantial enough to act as a deterrent, while incentives for compliance can motivate self-regulation. A balanced regulatory regime will not only curb illegal mining and resource abuse but also build trust among stakeholders.

4.4. Establishing a Cross-Regional Resource Allocation Mechanism

Given the disparities in economic development levels and sea sand resource distribution among coastal cities in Guangdong Province, fostering inter-regional cooperation is crucial. Cities should transcend administrative boundaries to collaboratively develop equitable resource allocation plans based on economic needs and actual resource availability. Establishing a regional sea sand resource trading platform can facilitate the integration and sharing of resource information, promoting market-driven allocation and enhancing utilization efficiency. Investments in transportation infrastructure, such as the construction and upgrading of ports, docks, and navigation channels, are necessary to improve the logistics of sea sand distribution.

These measures collectively ensure a stable supply of sea sand across the region, meeting the diverse demands of various localities and supporting their economic development objectives. Additionally, a unified digital monitoring system should be adopted to track the supply chain in real time, preventing illegal trade and ensuring data transparency. Policymakers could also consider forming a provincial-level coordination committee dedicated to resolving resource allocation conflicts, setting regional quotas, and streamlining logistics. By aligning environmental goals with development plans, cross-regional resource management can foster balanced growth, maximize the utility of available resources, and prevent overexploitation in areas with already vulnerable ecosystems.

5. Conclusion

Offshore sea sand resources in Guangdong Province serve as a vital material foundation for regional economic development. Their scientific development and rational utilization are integral to the sustainable advancement of the economy and society. This paper has analyzed the genesis

mechanisms of sea sand resources, highlighting the roles of geological processes, marine dynamics, and sedimentary environments in their formation and distribution. It has also examined the current challenges in resource development, including environmental risks, technical bottlenecks, and regulatory shortcomings. In response, the paper proposes sustainable development pathways encompassing enhanced extraction control, technological innovation in desalination and utilization, comprehensive regulatory frameworks, and cross-regional resource allocation mechanisms. Future efforts should focus on interdisciplinary research, policy optimization, and technological advancement to achieve a balance between resource development and marine ecological protection, thereby laying a solid foundation for the high-quality development of Guangdong Province.

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