

OCEAN SAND: PUTTING SAND ON THE OCEAN SUSTAINABILITY AGENDA

REPORT
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KEY MESSAGES

Sand is a fundamental feature of modern society –

Without sand, there would be no concrete, no asphalt, no glass and no electronics. Different types of sand and their derivatives are used in plastics, cosmetics, construction, land reclamation, fracking, beach replenishment and coastal defenses. Driven by industrialization, population growth and increased urbanization, sand demand has boomed. Aggregates (i.e., sand and gravel) are now the second most used natural resource in the world, second only to water, and the single most mined material. Globally, the consumption of aggregates has increased three-fold over the last two decades, reaching an estimated 40-50 billion tons per year – an extraction far quicker than the rate at which they can naturally be replenished.

Not all sand is the same – Naturally-occurring sand is eroded, deposited, and transported across the Earth's surface by physical processes, such as winds, water currents and tidal flows. Although available in large quantities, desert sand has a particular wind-weathered shape that prevents it from binding and makes it mostly incompatible with large-scale applications. Instead, sand mining takes place across the world with more angular aggregates dug from pits and quarries on land, dredged from riverbeds, or increasingly extracted from the marine and coastal environment as a result of declining inland resources. In this report, *ocean sand* refers to sand and gravel extracted from nearshore and offshore deposits, beaches, bays, lagoons, estuaries, tidal wetlands and coastal quarries, putting the emphasis on the broader coastal and marine complex social-ecological system in which ocean sand is embedded rather than the material's exact origin.

Sand in the ocean ecosystem – The marine and coastal environment is both a sink for sand delivered from rivers and an active source of sand, continuously subject to erosional and depositional processes, longshore currents, tides, waves and bio-erosion. Naturally-occurring sand acts as both a connector and a buffer at the land-sea interface, functionally linking the marine and terrestrial ecosystems while protecting the land and stabilizing the coastline in what is generally considered one of the most cost-effective climate mitigation strategies to enhance coastal resilience. It underpins island morphology, shapes the seabed, controls coastal erosion, offers

essential nutrients and maintains biodiversity through the formation of sand bars, beaches, dunes and other coastal landforms that support highly specialized biotic assemblages and provide habitat for a wide variety of species.

Sand in the ocean economy – Sand is not only an essential part of the ocean ecosystem, it also lies at the core of the rapid industrialization of the coastal and offshore environment. The ubiquitous dredging industry, equipped to excavate, transport and dispose of sand, possesses the machinery necessary to mine construction materials, reclaim land, deepen waterways and harbors, remove polluted sediments, replenish beaches, build coastal defenses, and support much of the infrastructure upon which offshore energy sectors depend. In doing so, dredgers not only interact with many ocean industries but also enable them, effectively creating new land where there was none and acting for the ocean economy as the epoch-making tractors did for the agriculture economy. Beyond highly mechanized excavation, sand is also an important component of artisanal and small-scale mining in coastal areas, providing alternative livelihoods and a vital source of income to coastal communities, often through undocumented and unregulated (sometimes illegal) activities.

Environmental impacts – By their very nature, dredging and coastal sand mining practices imply the relocation of large volumes of earth, resulting in critical habitat destruction, loss of biodiversity, sediment suspension, and changes in the bathymetry and topography of the seabed. This causes direct loss of organisms and disrupts entire food webs, leading to a decline in ecosystem functions and services, and a long-term loss of resilience to other stressors. Sand extraction is also a major driver of coastal erosion, accelerating the loss of protective features such as beaches, dunes and sandbars. This increases the vulnerability of the shoreline to floods and storm surges (including salinization of coastal aquifers) and puts at risk the integrity of coastal infrastructure and assets. Other widespread ecological impacts include noise and chemical pollution, transfer of invasive species, and greenhouse gas emissions. In some cases, it can take up to several decades to recover from damages to the ecosystem whereas other changes are irreversible.

For whom and at what cost? – Poor monitoring and weak governance result in numerous and often overlooked social consequences. The rights of local communities to land, water, and culture are often sidelined for mining and land reclamation projects they rarely benefit from. In many places across the world, sand mining profits accrue to only a few individuals while communities bear most of the costs, including displacement, loss of livelihoods, increased vulnerability to climate change, illegal practices, occurrences of crime, and destruction of cultural sites. Systemic gender inequities, economic coercion, and a lack of meaningful consultation with local stakeholders, further reinforce concerns of procedural inequity (i.e., whose voice is valued in the decision-making process) throughout the ocean sand value chain.

Diffused governance – No global agreement specifically exists to regulate or monitor the mining of ocean sand. The practice is addressed at multiple levels with varying effectiveness, including international, national and sub-national governance. Key international conventions and frameworks, such as the United Nations Convention on the Law of the Sea, the Ramsar Convention, and the London Convention/Protocol encourage conservation and provide guidelines to mitigate human impacts in the coastal and marine environment. Voluntary frameworks and initiatives also exist to promote responsible sourcing and transparency in extractive industries. Where regulated, national mining and environmental protection legislation creates the basic regulatory framework for sand extraction.

National governance typically involves the licensing and control of cross-border sand flow to deter unsustainable practices. In many cases, though, regulation falls under local authorities or communities at the sub-national level, including provincial authorities, traditional leaders and citizen committees.

Putting sand on the ocean sustainability agenda – Sand is climbing the global agenda, including through a surge in academic publications, an uptake in media coverage, and a series of high-level calls to action. Yet, on the ocean sustainability front, it remains a blind spot. Neither *sand* nor *dredging* is mentioned once in the texts of the United Nations Decade of Ocean Science for Sustainable Development, or in the High-Level Panel for a Sustainable Ocean Economy's guidance. A narrow lens on ocean sand as simply an 'aggregate' resource will miss the diversity of ways in which it forms the literal and figurative foundations upon which the future of coastal communities, biodiversity, and multi-billion-dollar ocean industries rest. Closing that gap will require a step-change in how ocean sand is understood and governed around the world, including: (1) building a holistic and systemic understanding of ocean sand; (2) developing and ensuring broad utilization of ocean sand monitoring tools; (3) embracing transdisciplinary research to inform policy and practice; and (4) fostering binding and voluntary governance mechanisms for ocean sand extraction and displacement.

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INTRODUCTION

The Anthropocene describes a new period where humans have become the dominant force of planetary change with profound impacts on the Earth's climate system and biosphere upon which our civilization depends¹. People, places, cultures and economies are connected across geographical locations, sectors and socioeconomic contexts, and actions taken in seemingly independent places affect distant yet interlinked systems in unexpected ways^{2,3}. Although rarely in focus and largely hidden from view, sand offers perhaps one of the most paradigmatic manifestations of this Anthropocene reality⁴.

More than one billion people live in coastal areas⁵, most of which are built and maintained by sand supplied from rivers and tidal currents. Sand is also a key driver of important geomorphological processes that underpin the shape and function of aquatic habitats and the ecosystem services humans derive from them⁶. Importantly, sand is continuously supplied by natural processes. Rivers convey around 11 billion tons of sand and other sediment from the continents to alluvial lowlands and coasts where sand is deposited⁷. In the ocean, sand from both river and ocean sources (e.g., from the erosion of coasts and reefs) is transported by currents and tides between source and sink areas, creating an ever-shifting substrate whose dynamics are critical for entire ecosystems^{8,9}.

Sand offers perhaps one of the most paradigmatic manifestations of the Anthropocene reality.

However, the unprecedented scale of human activities is changing natural sediment cycles and leading to rapid sand depletion^{10,11}. Global material stocks have expanded 23-fold since 1900, with sand and gravel accounting for the largest share of

primary material inflow¹². Driven by industrialization, population growth and urbanization, aggregates (i.e., sand and gravel) have become the second most used natural resource in the world, second only to water, and the single most mined material¹³. With applications as diverse as concrete, glass, electronics, asphalt, fracking and land reclamation (Figure 1), sand provides the foundation of modern society and accounts for most of the global Anthropogenic mass that now exceeds all living biomass¹⁴.

Global material stocks have expanded 23-fold since 1900, with sand and gravel accounting for the largest share of primary material inflow.

Globally, the consumption of aggregates has grown three-fold over the last two decades, reaching an estimated 40-50 billion tons per year¹⁵, and trends suggest continued increased demand, particularly in developing countries where rapid economic development requires strong growth in the construction industry^{16,17}. In Sierra Leone, for instance, the mining sector grew by over 20% in 2013 alone, partially due to the growth of glass manufacturing in neighboring Guinea, and issuing mining licenses has become the primary source of income for local authorities¹⁸. In Kenya, demand for sand extraction in rural areas is driven by the government's infrastructure-powered development program¹⁹ and similarly, in West Africa, infrastructural development is part of a regional strategy for poverty alleviation¹⁸.

While localized sand scarcities have emerged across the world²¹, sand remains a globally abundant resource and running out of it may be less of a

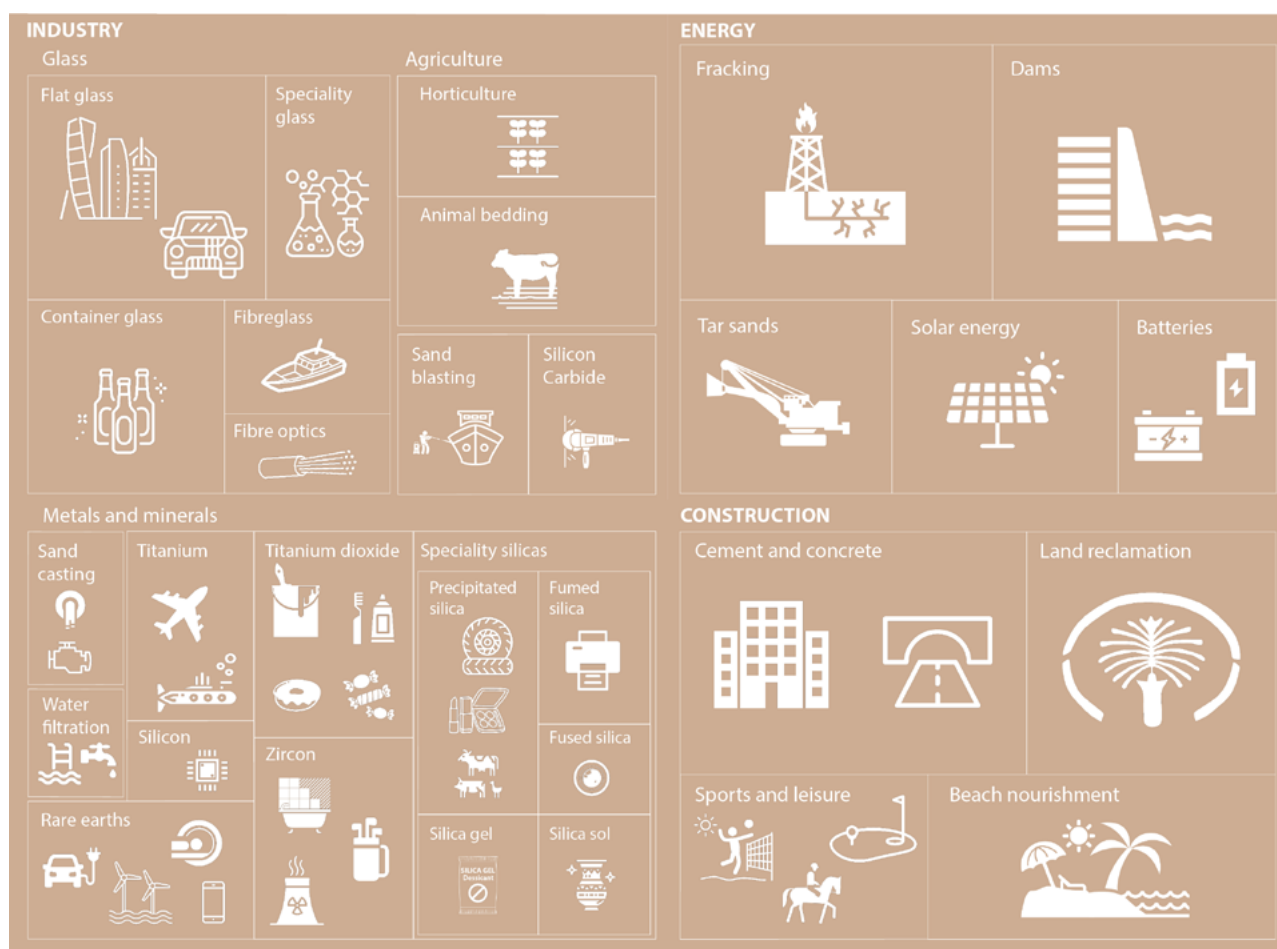


Figure 1. From glass to urban infrastructure, from dams to silicon chips, from land reclamation to solar panels, sand provides the foundation of modern society. Adapted from Pereira²⁰.

concern in the shorter term than the social, economic and ecological impacts of its extraction^{4,21,22}. Poor monitoring and weak governance result in numerous and often overlooked social-ecological impacts, including biodiversity loss, habitat modification, shrinking deltas, threats to marine fisheries, salinization of coastal aquifers, change in livelihoods, and occurrence of illegal activities^{8,21,23}. A recent analysis of the impacts of aggregate extraction on each of the 17 Sustainable Development Goals (SDGs) found major conflicts with most of them, including foundational ones such as SDG 14 (Life Below Water), SDG 15 (Life on Land) and SDG 16 (Peace, Justice and Strong Institutions)¹⁶.

Improving sand governance has been described as one of the most pressing resource issues of the 21st century, and even considered by some as a matter of national security²⁴. In 2019, the fourth United Nations Environment Assembly Resolution No. UNEP/EA.4/Res. 19 on Mineral Resource Governance recognized the challenges of sustainable sand management and called for improved knowledge and solutions. Yet it more often fits the description of a development mineral²⁵: “vital to economies and societies, but

invisible in many ways”²⁶. This is particularly true in the context of ocean industrialization and associated discourses around the blue economy, where the significance of sand and its supply chain has been largely absent despite lying at the core of it – both literally and figuratively.

This report aims to put sand on the global ocean sustainability agenda by highlighting its relevance for ocean risks and resilience. Not only is sand an essential component of the biophysical marine and coastal ecosystem, providing habitat and shoreline protection, but it also underpins the rapid expansion of human activities into the ocean²⁷, warranting more scrutiny on the sustainability and equity challenges associated with its extraction.

OCEAN SAND

The definition of sand varies according to size, density and composition, with various geotechnical standards in use across sectors. In the interest of streamlining the terminology, an expert group convened by the UN Environment Programme recently proposed to define sand as “a mineral granular material which does not stick together when wet and remoulded (i.e., non-cohesive) and where the combined weight of 50% of the particles is smaller than 4.75mm, with less than 15% of material smaller than 75 μ m”²⁸. Gravel is defined in similar ways but with a particle size between 4.75mm and 75mm. Sand and gravel are often considered together as aggregates, a term mostly associated with the end-use of the material for construction purposes.

Beyond physical and chemical characteristics, distinctions are made based on the source of origin. For instance, *river sand* refers to sand used from river channels, floodplains, estuaries and deltas, as

Here we introduce the notion of ocean sand to embrace a more holistic approach to the sustainability and equity challenges posed by sand mining in the marine and coastal environment.

opposed to *lacustrine sand*, extracted from lakes, or *marine sand*, derived from nearshore and offshore deposits, beaches, bays, and lagoons²⁸. Marine sand is more rounded than freshwater-sourced sand, largely

Aerial view of sand mining on John Obey beach, Sierra Leone²⁵⁸. Credit: Peter Yeung



available (e.g., global reserves of sand and gravel on continental margins are estimated to be two orders of magnitude greater than those of terrestrial supplies²⁹), and typically contains few contaminants or silt. One of its limitations for the construction industry is the presence of chloride, which can cause corrosion when used in reinforced concrete and requires large volumes of water to be washed. Other sources of sand for construction include land quarries and pits, crushed rocks, or recycled materials²⁸.

Extraction from active sand bodies results in changing rates of sand transport that are often crucial for ecosystem functioning and the livelihoods of communities who depend on them.

In contrast, active sand bodies are subject to modern erosional and depositional processes and are often characterized by dynamic sediment movement, as observed in the coastal and nearshore areas¹⁷. Extraction from active sand bodies results in changing rates of sand transport that are often crucial for ecosystem functioning and the livelihoods of communities who depend on them.

Here we introduce the notion of ocean sand to embrace a more holistic approach to the sustainability and equity challenges posed by sand mining in the marine and coastal environment. It encompasses sand and gravel extracted or mined from nearshore and offshore deposits, beaches, bays, lagoons, estuaries, tidal wetlands and coastal quarries. In doing so, it acknowledges the dynamic nature of interactions between sources and shifts the focus away from the actual material and its various technicalities towards the broader context it is embedded in, effectively recognizing ocean sand as an interconnected and dynamic complex social-ecological system at the land-sea interface.

An important distinction is made between *inactive* and *active* sand deposits. The former refers to sources of natural sand, such as quarries and pits, that are considered static and not influenced or replenished by present-day sedimentary dynamics.

Sand miners shovel sand into a truck on John Obey beach, Sierra Leone²⁵⁸. Credit: Peter Yeung



SAND IN THE OCEAN ECOSYSTEM

Sand in the coastal environment is naturally replenished from sediment transported downstream by rivers and distributed along the coastline⁷. It plays an important role in building new land and stabilizing the shoreline in the face of climate change and rising sea levels^{5,30,31}. In the tropics, sand comes from the breakdown of calcium carbonate shells and skeletons belonging to reef-living organisms (e.g., corals, mollusks, foraminifera), either by mechanical forces such as waves and currents or from bio-erosion caused by grazing organisms. Parrotfish in particular have been identified as major producers of island-building sediment, crunching through the reef framework as they feed and turning it into sand-grade sediment underpinning entire island morphology³². In the offshore environment, sand shapes the seabed topography and provides a substrate for benthic organisms to thrive upon, ultimately contributing to the broader food webs and natural balance of the surrounding marine ecosystem⁹.

Sand acts as both a connector and a buffer at the land-sea interface, functionally linking the marine and terrestrial environment while protecting the land against coastal erosion and severe weather events.

The continuous action of wind, waves and tides not only transports sand from shores further into the ocean (and vice-versa), but also results in the formation of sand bars, beaches, dunes and other coastal landforms with unique physical and ecological attributes³³. Sand acts as both a connector and a buffer at the land-sea interface, functionally linking the marine and terrestrial environment while protecting the land against coastal erosion and severe weather events³⁴. Sand dunes on the

southeast coast of India, for instance, are thought to have significantly reduced the impact of the 2004 tsunami by preventing flooding and saltwater intrusion in coastal aquifers³⁵.

The characteristics of different types of sand and tidal regimes create a wide range of dynamic habitats that support highly specialized biotic assemblages and play an important role in recycling nutrients, breaking down organic matter and pollutants, filtering and storing water, and maintaining biological and genetic diversity³³. The waters behind sand bars and barrier islands (i.e., long and narrow strips of sand parallel to the coast) can form tidal pools, lagoons, salt marshes and other wetlands rich in biodiversity. Sandy shores and coastal ecosystems are particularly important breeding and nesting grounds (e.g., for turtles and shorebirds) as well as nursery areas for juvenile fishes. Seagrass meadows, for example, are highly productive ecosystems providing nursery and feeding habitats for 20% of the world's largest fisheries^{36,37}. They trap sediments and excessive nutrients; store considerable amounts of carbon; protect the coast; control human, fish and coral diseases by reducing exposure to pathogens; buffer against ocean acidification; and support megafauna³⁷. A recent study also showed that seagrass meadows can act as 'sand factories', with seagrass epibionts (i.e., carbonate-producing organisms that live on seagrass leaves) delivering substantive quantities of carbonate sediment that is suitable for reef island building³⁸ – thereby reinforcing the importance of their conservation in the face of climate change impacts on low-lying islands.

Overall, sand is a critical component of the biophysical coastal and marine environment, supporting a wide variety of habitats and species while delivering key ecosystem services that, in many regards, can mitigate ocean risks³⁹. Yet it also lies at the heart of a rapid and unprecedented expansion of human activities in the coastal and nearshore environment²⁷, where sand is either extracted as a source of minerals or displaced from functioning ecosystems to enable ocean industries. Recognizing these dynamics and the actors behind them is essential for ensuring a sustainable and just ocean economy.

SAND IN THE OCEAN ECONOMY

The Organization for Economic Co-operation and Development (OECD) defined the ocean economy as the “sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems”⁴⁰. Today, many ocean industries are growing faster than the global economy and providing the backbone of human development. Maritime transport represents 80% of global trade by volume and 70% by value; offshore oil and gas extraction accounts for 30% of total production; 1.4 million km of submarine cables carry over 99% of international telecommunications; and offshore wind capacity has increased 500-fold since 2000, with costs falling by nearly 70% over the past decade⁴¹. This Blue Acceleration²⁷ represents a new phase in humanity’s relationship with the ocean, marked by the rapid industrialization of the coastal and offshore environment⁴¹⁻⁴³ – a new ocean reality at the heart of which lies the shifting and extraction of sand.

Dredging in a nutshell

The ubiquitous dredging industry provides the machinery necessary to excavate, transport and dispose of materials from the seabed. In doing so, dredging not only interacts with many ocean industries⁴⁴ but also enables them, effectively orchestrating the mechanics of the ocean economy.

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Dredging activities are traditionally categorized into *mineral dredging* (the extraction of minerals with an economic value, including sand and gravel but also placer deposits of gold, diamond, titanium and tin); *capital dredging* (the creation of new civil engineering works such as port development and land reclamation); and *maintenance dredging* (the periodic removal of sediment to, for instance, enlarge and deepen existing waterways and harbor basins). *Remedial dredging* is a specific type of maintenance dredging that consists in removing contaminated sediment that poses a threat to people and the environment. Dredgers are broadly classified as either *mechanical* (remove material by mechanically scooping it from the sea floor) or *hydraulic* (use suction to remove the sediment and transport it through a pipe) with a range of more specific technologies under each category depending on the intended dredging area and the type of dredged material⁴⁵ (Table 1).

Grab dredger at work at Pier 35, San Francisco, USA. Credit: Dave R. via Flickr (CC BY-NC 2.0)



Driven by the expansion of human activities into the ocean, the sector has witnessed rapid growth over the last few decades: the carrying capacity of so-called 'mega' dredgers doubled within just ten years at the onset of the 21st century⁴⁶; installed power capacity on dredgers increased from 12,000 kW in the 1970s to over 44,000 kW in the early 2020s⁴⁷; and requisitions for new vessels stipulate sizes that are up to 150% larger than that of current vessels⁴⁸. The need to keep dredgers operating at all times to save costs creates a dynamic that encourages ever-larger projects, in turn stimulating further investment into fleet capacity⁴⁸. The industry is organized into open and closed markets, roughly half of the global market each, based on whether they are open to international competition (e.g., Europe and Latin America) or restricted to

domestic companies (e.g., USA and China, where only domestic companies can dredge). The open dredging market is highly concentrated, with the four largest companies controlling 95% of the market share (Table 2). Other major actors, operating both domestically and overseas, include China Harbour Engineering Company, the world's largest dredging company and a subsidiary of China Communications Construction Company, and Great Lakes Dredge and Dock, the United States' largest dredging contractor. According to the International Association of Dredging Companies (IADC), growth in the sector can be linked to five increasing global trends related to: (i) development and infrastructure; (ii) coastal protection; (iii) seaborne trade; (iv) tourism; and (v) energy demand⁴⁹.

Table 1. Common types of dredgers and their applications.

Dredger type		Description	Applications
Mechanical	Backhoe dredger	A versatile and powerful dredger with a mounted digger arm that scoops material onto a barge	Foreshore protection and dredging parts of harbors and access channels that are not easily accessible, especially when the seabed varies in depth and sediment type
	Grab/clamshell dredger	Like a crane or arcade claw machine, a clam-like device 'grabs' material, using cables to hoist it onto a barge	Precise dredging in waters of high or variable depths; dredging parts of harbors that are not easily accessible
	Bucket dredger	A stationary dredger using a chain of buckets to scoop soil and loose rocks which are then emptied onto a barge	Dredging for minerals and construction materials
Hydraulic	Trailing suction hopper dredger	Self-propelled dredger trails a suction pipe which pumps loose material into onboard storage areas (hoppers)	Construction and maintenance projects, such as port maintenance, beach replenishment, and land reclamation
	Cutter suction dredger	A rotating cutter head fragments hard material, pumping it into a suction pipe	Used when seabed is hard rock, for example in developing ports or dredging large access channels such as the Panama Canal
	Water injection dredger	Self-propelled dredger pumps water onto the seabed, suspending the sediment which is then swept away by currents	Harbor maintenance when seabed is of mud or fine sand; preferred for environmentally-sensitive projects

Table 2. The four largest dredging companies, headquartered in the Netherlands (NL) and Belgium (BE), account for 95% of the open market⁴⁹.

Company [HQ]	Dredging revenue (2021) in million euros	Percentage of total
Royal Boskalis Westminster N.V. [NL]	1,583	29.7
Dredging, Environmental and Marine Engineering [BE]	1,478	27.7
Jan De Nul Group [BE]	1,268	23.8
Royal Van Oord [NL]	727	13.6
Total (top 4)	5,056	94.8
Total (open market)	5,330	100



Fishers from the village Ribeira da Barca, Santiago, Cape Verde, turned to illegal sand mining after fish stocks plummeted. Men collect the sand with shovels from the bottom of the sea and fill the buckets that women carry to shore on their heads. Credit: Francesca Tosarelli. See full reportage at <https://www.francescatosarelli.com/sand-mining-in-cape-verde>

Aggregate and mineral mining

While attention has been rapidly and legitimately growing on the prospect of deep-sea mining and its associated challenges^{50,51}, shallow-water mining has long been taking place and remains an expanding sector that currently undermines global sustainability goals⁵². Aggregates play an increasingly important role in the construction sector and are today the most mined marine minerals. Countries such as Great Britain, Denmark and the Netherlands, for instance, have well-established dredging sectors that enable them to meet more than 20% of their construction needs for sand and gravel from marine aggregates^{29,53}. Likewise, the rapid economic development of coastal areas in China as well as large-scale island reclamation projects have raised the country's demand for marine sand by 30% annually during the last few decades⁵⁴ and transformed the Chinese dredging industry into the biggest in the world, with hundreds of vessels built over the past 10 years alone⁵⁵.

Although much smaller than aggregates in terms of tonnage extracted, coastal sand mining of heavy mineral sands provides many of the metals needed in high-tech applications. Two major economically important products include titanium (often the

In Cape Verde, fishers from the village Ribeira da Barca turned to illegal sand mining to be able to survive after fish stocks plummeted.

primary material of interest) and zircon (an important by-product)⁵⁶. Titanium is a key input for the aerospace, shipbuilding, medical, and chemicals industries whereas zircon is important for the ceramics, nuclear, and fiber-optics sectors⁵⁶. Coastal sand is also mined for iron oxides to be used in the steel industry⁵⁷. While large-scale coastal mining of heavy mineral sands began mainly in Australia in the late 1930s (driven by the need for metals in the defense sector during the Second World War), operations have since expanded to many countries, including South Africa, Madagascar, Senegal, The Gambia, India, and Vietnam, among others⁵⁶.

Sand is also extracted by artisanal miners⁵⁸. After farming and fishing, artisanal and small-scale mining is one of the most indispensable rural activities in the Global South⁵⁹, supporting 150 million people across 80 countries⁶⁰. While the true scale of artisanal sand mining remains poorly understood⁵⁹, it is known to take place in many countries around the world^{58,60,61}. In Jamaica, artisanal sand mining offered an important source of income following the devastating effects of Covid-19 on the arrival of tourists⁶². A similar pattern played out in Kenya, where many turned to artisanal sand mining following the collapse of the tourism industry^{19,63}. In Sierra Leone, too, sand mining provides vital income for increasing numbers of unemployed young men¹⁸, although such activities are often illegal, leaving miners vulnerable to state repression⁶⁴.

A recent analysis of 135 coastal cities with more than one million inhabitants revealed that 78% had pursued land reclamation since 2000.

In Cape Verde, fishers from the village Ribeira da Barca turned to illegal sand mining to be able to survive after fish stocks plummeted. They now depend on men collecting sand from the seabed with shovels and filling buckets that women carry to shore to be sold to sand truckers who capture most of the profits and use it for the construction industry in Santiago⁶⁵. A similar pattern is unfolding in the Rabaka community of Ikorodu, a coastal city in Lagos, Nigeria, where men are diving with buckets to gather sand from the seabed and load canoes before women sell it to truck owners. While considered a traditional occupation for many decades, these artisanal miners are now being pushed out of business by the mechanization of the sector and an influx of foreign contractors (**Spotlight 1**).

Land reclamation

In many rapidly-growing coastal cities, land scarcity is addressed through land reclamation. The process of creating new land by raising the elevation of the seabed, or pumping water out of wetland areas, has become a critical aspect of coastal development in the face of population growth, sea-level rise, and increasing economic dependence on the coastal zone^{49,66,67}. While it has been estimated that 3,370,000 ha of land has been added in coastal areas over the last 30 years⁶⁸, a recent analysis of 135 coastal cities with more than one million inhabitants revealed that 78% had pursued land reclamation since 2000, with the combined area of additional land reaching 253,000 ha (equivalent to an area the size of Luxembourg)⁶⁷. Singapore has increased its

An aerial photo of Eko Atlantic City in February 2018 near Lagos, Nigeria. The reclamation work required 91 million m³ of dredged sand for what has become one of the most expensive real estate locations in Africa. Credit: www.ekoatlantic.com



size by almost 25% since 1965 by filling the sea along its coast with sand, first exhausting its own foreshore resources in the early 1980s before starting to import sand from neighboring countries. Skyrocketing demand and rising environmental concerns led Malaysia, Indonesia, Vietnam, and Cambodia to successively announce export bans – with varying efficacy – in what constitutes a classic example of geographical displacement of ecological impacts^{24,69}.

Today, geopolitical power goes not only to those who control territory but to those who can manufacture it.

Land expansion is also driven by the real estate market^{70,71}, whose growth is strongly associated with land reclamation for residential and commercial use⁶⁷, including novelty islands in Dubai, Bahrain, Doha, and Panama City, as well as luxury gated havens such as Eko Atlantic City. This private development project in Lagos has now become one of the most expensive real estate locations in Africa, with 1,000 ha of land reclaimed from the ocean and protected by an 8.5-kilometer-long sea wall at a cost of US\$6 billion^{72,73}. The development of 17 artificial islands in Jakarta, by contrast, is primarily in anticipation of sea-level rise⁶⁷. Likewise, in the Maldives, the government recently announced a large-scale land reclamation project as part of a plan for coastline protection and tourism development (Spotlight 2), while the New Manila International Airport is moving ahead as the Philippines' most expensive infrastructure project, adding 1,700 ha of land to underpin what is predicted to become one of the busiest airports in the world (Spotlight 3). Overall, an estimated 70% of recent reclamation has occurred in areas identified as at high risk from extreme sea level rise by 2100⁶⁷.

Land reclamation is also highly geopolitical, as phrased by journalist Vince Beiser: “Today, geopolitical power goes not only to those who control territory but to those who can manufacture it”⁵⁵. This is perhaps most notable in the disputed South China Sea, where unprecedented island-building efforts and dredging activities have been seen as gray zone warfare – a form of non-military action designed to exhaust the opponent without quite provoking open conflict^{74–76} (Spotlight 4).

Shipping and port infrastructure

Ports, channels, and other waterways are vital arteries of the ocean economy. Volumes of goods transported by container ships have quadrupled over the past 20 years and more than half of all internationally traded grain and fertilizer pass through at least one critical maritime chokepoint (e.g., Suez Canal, Panama Canal, Strait of Gibraltar) before reaching their destination⁷⁷. The grounding of the container ship the “Ever Given” and subsequent blockage of the Suez Canal in March 2021, for instance, is estimated to have cost between US\$6 and US\$10 billion a week⁷⁸, with knock-on effects on supply chains, including shortages and price volatility⁴¹. The dredging industry plays a crucial role in both constructing (capital dredging) and maintaining (maintenance dredging) these waterways, thereby enabling global seaborne trade.

The size and number of ports have also risen dramatically alongside the volume of goods moved from port to port⁶⁷. Reclaimed land is used for port extensions in over half of coastal cities, and much of China's recent overseas investment as part of the Belt and Road Initiative has been linked to port development^{67,79}. Overall, it has been estimated that capital infrastructure projects made up 38% of the dredging industry's turnover in 2021⁴⁹. However, few ports are naturally deep, requiring considerable dredging efforts to maintain or increase the depth of navigation channels, anchorages and berthing areas. Periodic maintenance dredging is thus subsequently needed to keep channels clear and safe for vessels.

As the ocean becomes more crowded and vessels grow larger, so does the reliance on dredging to ensure safe passage and the development of associated port infrastructure.

In the USA, for example, the Army Corps of Engineers coordinates over 200 dredging jobs a year, tasking National and Regional Dredging teams to maintain 40,000 km of navigation channels^{80–82}. In Australia, controversial dredging operations are taking place inside the Great Barrier Reef World Heritage Area, with dredging said to occur “24 hours a day, 7 days a week” in the port of Townsville to widen its shipping channel and allow access by larger ships⁸³.

As the ocean becomes more crowded and vessels grow larger, so does the reliance on dredging to ensure safe passage and the development of associated port infrastructure. Importantly, ports matter beyond just the shipping industry and are strategic hubs for virtually all ocean-based sectors, from fisheries and aquaculture to offshore energy and tourism. Offshore wind ports, for instance, provide the facilities necessary for manufacturing, storing, assembling and deploying wind turbines, and will have to significantly expand their area and deep-sea berths to keep pace with the projected growth in offshore wind capacity (e.g., from 3 GW of new offshore windfarm per year today to 25 GW by 2030 in Europe alone)⁸⁴.

Beach nourishment – the dynamic practice of adding large quantities of sand onto the beach to increase its width – has become a dominant climate adaptation strategy, widely used to stabilize the shoreline, build coastal and flood defenses, and support tourism.

Tourism and beach nourishment

Beaches, dunes, and sand bars are not only essential features of coastal resilience in the face of climate change⁸⁵, but they also offer important recreational opportunities. Coastal and marine tourism represents at least 50% of global tourism and constitutes the largest economic sector for most small island developing states⁸⁶. A recent study estimated that even under a moderate CO₂ emissions pathway (RCP4.5), sandy beach erosion from rising sea levels would lead to a 38% drop in Caribbean tourism revenue by 2100⁸⁷. As a result, beach nourishment – the dynamic practice of adding large quantities of sand onto the beach to increase its width – has become a dominant climate adaptation strategy, widely used to stabilize the shoreline, build coastal and flood defenses, and support tourism^{86,88}.

In the USA, more than 1.2 billion m³ of sand have been used for nourishment since the first large-scale project on Coney Island in 1923⁸⁹. The frequency of beach nourishment and the corresponding volumes of sand dredged have systematically increased over the past decades, with costs reported to be between US\$1 and US\$4 million per mile of shoreline⁹⁰. This dual purpose of tourism promotion and coastal protection has fed a ramping demand for sand, sourced both from coastal and offshore deposits. For instance, tourist beaches in Australia have been nourished since the 1970s using sand dredged from nearby estuaries and inlets, while Jamaica is using offshore sand to replenish beaches and maintain its tourism economy⁶². Paradoxically, the practice can also lead to reduced natural sediment input to the beach and higher rates of coastal erosion if the dredging site is too close to shore – an alternative often favored to minimize transport costs^{88,91}.

Offshore energy and infrastructure

The oil and gas sector is currently the largest ocean-based industry by revenue^{40,92}; more than 136,000 km of pipelines have been installed since the early 1950s²⁷; marine renewable energies are among the solutions with the greatest potential to reduce greenhouse gas emissions⁹³; and nearly all international telecommunications are carried via submarine fiber optic cables⁹⁴. Dredging plays a significant role in the installation and maintenance of these oil and gas platforms, wind turbines, pipelines, and other offshore infrastructure that must be stabilized and secured by flattening the seafloor⁴⁹. In the case of offshore wind farms, dredgers often level the seabed by removing up to 10 m of soft sediment^{95,96}; for hydrocarbon projects, it is common to instead create a platform of rocks⁹⁷. Similarly, sweeping the seabed is the first step before laying undersea pipelines and cables, before either flattening the seafloor, digging a trench, or constructing rock beds to reduce stress on the structure⁹⁸. Small quantities of marine sand and gravel can be used to cover submarine pipelines and cables⁹⁹ while navigational dredging is also important to ensure access routes for maintenance vessels to reach these offshore installations.

ENVIRONMENTAL IMPACTS

By its very nature, sand mining in the marine and coastal environment has severe consequences for the surrounding and interconnected ecosystems. The impacts are highly context-dependent, based not only on the location and method of extraction, but also on its purpose and broader regulatory context. Although the effects can be mitigated to some degree through effective regulation and management, negative impacts are inevitable. In some cases, it may take several years or decades to recover from damages to the ecosystem, whereas other changes may be irreversible. As far as policymakers are concerned, sand should be considered a finite resource. Every decision to allow its extraction thus acquires a greater significance and leaves behind a wide spectrum of potentially cascading impacts, disrupting functional ecosystems not only at the source of extraction, but

also through transport corridors and at the end-use destinations^{8,20}. While comprehensive reviews of direct and indirect impacts can be found elsewhere (see refs ^{8,9,88,99-103}), **Table 3** synthesizes some notable environmental effects from the extraction, deposition and use of ocean sand.

By its very nature, sand mining in the marine and coastal environment has severe consequences for the surrounding and interconnected ecosystems.

Turbidity plume in Fremantle Harbor, Australia. Credit: nearmap.com via Flickr (CC BY-SA 2.0)



Table 3. Examples of environmental impacts associated with the extraction and displacement of ocean sand.

Type of impact	Description	References
Habitat destruction	Land reclamation causes widespread ecological damage, including the loss of entire ecosystems such as vegetated coastal wetlands and coral reefs, ultimately resulting in a substantial decrease in ecosystem functions and services. The disturbance of spawning, nursery, and feeding grounds impacts many organisms. In the Persian Gulf, for instance, infill and dredging for waterfront developments and artificial islands have led to a decline in fisheries following the loss of coral reefs and seagrass beds. Likewise, sand mining in coastal areas causes the destruction of critical habitats such as beaches, dunes and tidal flats that provide food and shelter for many species at the base of the marine and coastal food webs, potentially triggering cascading impacts on higher trophic organisms. Beach mining and nourishment also affect the nesting sites of shorebirds and turtles, while changing sediment properties (and thus habitat suitability) beyond what coastal species have adapted to, with consequences for the densities of invertebrates that are important prey to shorebirds and crabs. Offshore, the removal of sand changes the bathymetry and topography of the seabed, creating deep holes with anoxic water inhospitable to marine life. Likewise, the dumping at sea of millions of tons of dredged sediment annually causes structural changes to seafloor habitat and increases water turbidity.	8-10,21,33,88,100,102,104-110
Biodiversity loss	Disturbance to marine and coastal habitats results in the direct loss of organisms as they become mechanically crushed, removed or buried in the process. Loss of benthic habitat usually leads to a net decline in benthic community biomass and diversity, along with a shift in species composition and changing population age structures due to selective mortality. A loss of 60% of the number of benthic species is generally observed within dredging sites, with up to 95% reduction in the number of individuals. Small and non-mobile organisms (e.g., microorganisms, corals, and fish eggs) are most at risk. These changes can disrupt entire food webs, result in long-term loss of biodiversity and reduce ecosystem resilience to other stressors.	8,9,102,112-115
Sediment suspension	Turbidity plumes created by dredging activities can extend over several kilometers and cause damages to receptor, feeding and respiratory organs of marine species. Increased turbidity results in a reduction of light penetration into the water column and lower energy production by photosynthetic organisms (e.g., smothering of corals and their symbiotic photosynthetic algae). Clouding also reduces visibility and may prevent fish from detecting their prey. Anoxic layers can form when fine sediment resettles, potentially leading to the formation of toxic hydrogen sulphide if organic matter becomes trapped. The release of sediment-bound nutrients, on the other hand, may lead to phytoplankton blooms. Dredging can also release toxic sediment-bound chemicals with dire consequences for the ecosystem, as recently suspected in the UK with an 80-95% decline in crab and lobster catches attributed to the release of pyridine. In Victoria Harbour, Hong Kong, dredging has been found to increase the bioavailability of toxic polycyclic aromatic hydrocarbons.	8,64,88,100,103,116-119
Coastal erosion	Sand extraction is a major driver of coastal erosion, either directly by mining protective features such as beaches, dunes and sandbars, or indirectly through physical changes to the near-shore seabed which alter coastal morphodynamics, including tidal currents, sediment transport, wave energy, beach drawdown and natural dune development. The removal of soil from dunes prevents the re-establishment of plant species, which accelerates erosion and can lead to changes in humidity, temperature, and wind. Coastal erosion is also accelerated by a reduced rate of sediment delivery from rivers due to upstream sand extraction and human-made dams that sequester sediments, ultimately posing a threat to the integrity of coastal infrastructure and assets. Beach nourishment itself can change the dynamics of natural forces such as wave patterns and shifting currents, sometimes with safety consequences. In the USA, for instance, increased swimming accidents have been linked to stronger rip currents following beach nourishment projects.	7,8,33,88,102,120-122
Exposure to floods and storm surges	Reduced shoreline integrity and stability (as well as loss of vegetation), increase the vulnerability of coastal areas to storms, flooding and sea level rise, putting at risk coastal infrastructure and assets. In Sri Lanka, for instance, the removal of sand dunes and reduced sediment replenishment from rivers due to sand mining are thought to have exacerbated the impacts of the 2004 tsunami.	8,85,112,123

Type of impact	Description	References
Groundwater contamination	The removal of beaches, dunes and sandbars can expose the groundwater to seawater, making it unsuitable for drinking and leading to severe reductions in agricultural productivity. The mining and processing of heavy mineral sands also risk polluting groundwater through toxic reagents and wet dredging.	8,56,88,124
Noise pollution	Noise generated during dredging activities has one of the widest frequency ranges amongst anthropogenic sound sources found in the ocean. While unlikely to cause physiological damage, it overlaps with the hearing ranges of most marine taxa and can lead to behavioral disturbances by disrupting the orientation, communication and feeding patterns of many species (especially mammals and seabirds).	9,101,106,125
Chemical pollution	Like any other vessel, dredgers may discharge bilge water and oily ballast. Anti-fouling paints used on the hull also impact bottom-dwelling organisms, such as clams and oysters. End-of-life disposal and shipbreaking activities involve hazardous material with serious safety and environmental implications.	126,127
Increased marine traffic	Dredging activities can lead to more traffic in the coastal zone, causing conflict with other marine users (e.g., large offshore areas being unavailable) and impacting wildlife. Collisions with marine mammals are possible but improbable given that operating dredgers are either stationary or moving at slow speeds.	99,101
Invasive species	Transfer of invasive species through the transport of sand (including the release of ballast water) and the movement of equipment.	128
Greenhouse gas emissions	Emissions from the burning of fuel by vessels and mining equipment, as well as the end-use of sand for concrete production, which accounts for about 8% of global carbon dioxide emissions. The loss of important carbon sink habitats, such as seagrass beds and mangroves, also reduces carbon sequestration.	20,99
Archeological and cultural damages	Damage and reduced access to archaeological and cultural sites through direct destruction, burial or other changes in the environment.	8,129

SOCIAL IMPACTS AND EQUITY CONCERNS

Rights to land, water, and culture

The adverse consequences of dredging and extracting ocean sand fall most frequently on poor, marginalized, and powerless groups^{21,56}. Their rights to land, livelihoods, water, and cultural sites often are sidelined for projects they rarely see the benefits of. Displacement and forced evictions are common, with for instance over 1,100 fisher families displaced for land reclamation in Indonesia¹³⁰ and 50,000 families at risk of displacement for the construction of Colombo Port City in Sri Lanka¹³¹. Forced evictions have occurred in the construction of a deep sea port in Myanmar¹³² and maintenance dredging of the Suez Canal⁴⁸. Overall, displacement was found to be a key point of contestation in a third of all heavy mineral coastal sand conflicts analyzed in a recent study⁵⁶. Dispossession can also involve the loss of cultural and sacred sites, such as tombs in Madagascar¹³³, ancient banyan trees in the Maldives¹³⁴, or aboriginal sites in Australia (Spotlight 5).

The loss of land often accompanies the loss of water supplies. In the Ranobe region of Madagascar, for example, sand mining for metals is currently depleting the local population's only water source by mixing ore with water into slurry (i.e., wet dredging) to facilitate the separation process¹³³. The mining and processing of heavy mineral sands also risk polluting groundwater through wet dredging and toxic reagents¹²⁴, making groundwater protection a central aspect of local opposition to such projects (e.g., sand mining for zircon in Senegal¹³⁵).

Together, dispossession and water pollution compound to generate one of the greatest inequities in the ocean sand supply chain: the loss of livelihoods associated with fisheries. Dredging damages marine ecosystems by churning up sediment, thus disrupting the seabed, reducing visibility, and smothering habitats^{106,136}. A decline in fish stocks has accompanied dredging in Cambodia¹³⁷; fish and shellfish catches have dropped dramatically following land reclamation projects in Indonesia^{130,138}; and the construction of a new airport in Manila has severely impacted local fisheries¹³⁹ (Spotlight 3). If fishers refuse to give up their livelihood they can be forced into dangerous situations, as is the case for the Bahraini fishers who began risking their lives by venturing illegally into Qatari waters after coastal development projects caused an 80% drop in their

earnings¹⁴⁰. Dredging can also release toxins from the sediment¹⁰⁶. Ongoing research into the UK's mass crustacean die-off in 2021 points towards the release of sediment-bound pyridine by dredgers, resulting in fishers' crab and lobster catches plummeting 80-95%¹¹⁶.

Together, dispossession and water pollution compound to generate one of the greatest inequities in the ocean sand supply chain: the loss of livelihoods associated with fisheries.

Beaches, dunes, and sandbars also play an important role in protecting farmland from saltwater intrusion⁸⁵. If disturbed or removed, severe reductions in agricultural productivity can ensue⁵⁶. This risk was central to the resistance to heavy mineral sand mining in Senegal¹³⁵ and Indonesia^{141,142}. Farmland is also at risk due to mining-induced soil erosion in the Gambia, where coastal sand mining was identified as one of the biggest threats to the country's environment¹⁴³. Where mining has occurred and the sites are left without restoration, flooded ditches attract mosquitoes and expose women who work in the fields to the increasing number of crocodiles¹⁴³. Overall, the livelihood impacts of sand extraction (Spotlight 1) are a primary cause of contestation in the vast majority of resulting conflicts⁵⁶.

Distributional equity

Distributional equity refers to how resources, costs and benefits are allocated or shared among people and groups¹⁴⁴. The previous section highlighted how the impacts and costs associated with dredging and extracting ocean sand are often displaced onto the most marginalized. But the benefits are also unequally distributed. Beaches, dunes, and sand bars all provide natural defenses against flooding and seawater incursion, making them important

for adapting to climate change⁸⁵. However, sand mining is degrading these natural features, rendering communities increasingly vulnerable^{141,145}. For instance, in Kerala, India, years of sand mining have led to a shrinking coastline and resulted in widespread displacement^{20,146–148}.

The depletion of these sources of sand reflects the prioritization of its use: the needs of the mining industry and real estate developers taking precedence over those of the local community for safety and secure livelihoods. Despite Cambodia's vulnerability to sea-level rise¹⁴⁹, much of the sand extracted there is used to expand Singapore's coastline^{137,150}. The case of Eko Atlantic City – the reclaimed coastal city built on 91 million m³ of dredged sand with a square meter valued at US\$1,720⁷³ – is another illustration of common resources being used to provide space and safety to the wealthiest¹⁵¹. The project has increased the vulnerability of ordinary inhabitants of Lagos, with locals identifying dredging as the driver of sea surges and soil erosion, and reporting that the city's sea wall deflects waves towards their shores¹⁵². Likewise, in the Maldives, a history of land mismanagement mixed with instances of corruption has resulted in the construction of private resorts and airport runways across many islands, at the expense of the Maldivian people and critical natural habitats^{153,154} (Figure 2) (Spotlight 2).

Procedural equity

How equitably benefits and impacts are distributed largely depends on whose voice is valued in the decision-making processes; in other words, procedural equity¹⁴⁴. Procedural inequities often stem from inequities in gender, access to information, and economic power. In many cases, projects begin with little, if any, meaningful consultation with local stakeholders^{48,135,137,142,155} (Spotlight 3). In the Maldives, for example, Fainu Island council only discovered plans to build an airport on the island once the project agreement was signed and funding allocated¹³⁴. Women are often excluded to an even greater extent, similar to what has been observed in other sectors¹⁵⁶. In both Myanmar and Indonesia, where shellfish collection represents a traditional source of women's income, women have found themselves consistently excluded from consultations despite being particularly affected by coastal dredging^{130,132}.

Even when consultations are held, the processes are often opaque, with stakeholders frequently complaining of a lack of transparency, or a rushed consultation period^{132,134,135,142,152}. If local stakeholders refuse to comply with the decision, it is not unusual for them to be arrested, harassed, assaulted, intimidated, or in the worst cases



Figure 2. Google Earth views of the Maafaru island in the Maldives, before (a) and after (b) the construction of a new airstrip. The island is a nesting site for the endangered green turtles (*Chelonia mydas*) that usually return to the same beach where they were hatched to lay eggs. In April 2019, a photo posted online by @naibuthuthu showing a turtle laying eggs on the island's new airstrip (c) went viral and sparked a debate about the environmental cost of land reclamation projects.

murdered^{132–134,138,139,141,143,145,157}. Economic coercion also distorts the power balance in decision-making. In some cases, local stakeholders are persuaded to comply by the prospect of jobs – although these promises may never be fulfilled^{132,135}. In Madagascar, villagers rejected the compensation offered for mining their lands, conscious that they would lose subsistence over the long-term¹³³. Economic coercion can also occur at the international level^{158–160}, with debt mechanisms forcing material extraction for export as a means of repaying loans¹⁶¹. While further analyses are required, it is worth noting that a third of the 21 countries where ocean sand conflicts have been reported¹⁶² are in a debt crisis.

OCEAN SAND GOVERNANCE

International governance

To date, no global agreement specifically exists to regulate or monitor the mining of ocean sand^{15,22}. Nevertheless, several international conventions and frameworks are relevant to ocean sand. The 1982 United Nations Convention on the Law of the Sea (UNCLOS), ratified by 168 parties, is one of them. In addition to granting coastal states sovereign rights over the exploration and exploitation of natural resources, both living and non-living, within their exclusive economic zone (Article 56), UNCLOS requires pollution reduction in mining, regulated through environmental monitoring both before and during ocean exploitation. It also commits states *“to protect and preserve the marine environment”* (Article 192) and *“to ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment”* (Article 194). The International Seabed Authority is then responsible for managing mineral resources outside of national jurisdiction. The management of some coastal ecosystems is guided by more specific conventions. The 1971 Ramsar Convention, for example, seeks *“the conservation and wise use of all wetlands”*¹⁶⁵. A specific resolution on extractive industries (Resolution X.26) was added in 2010 to encourage the Parties to evaluate extraction in wetlands using quantitative data and environmental impact assessments at each stage^{166,167}.

As well as regulating the extraction of ocean sand, other international agreements address the disposal and trading of sand. The 1972 London Convention and 1996 London Protocol, of which over 90 countries are signatories, specify physical, chemical, and biological criteria that need to be met for dredged material to be dumped at sea, including regular environmental monitoring, the dilution of contaminants, and a lack of potential conflicts with other marine activities¹⁶⁸. Indeed, 80-90% of the hundreds of millions of tons of material dumped at sea every year consists of unusable and sometimes contaminated dredged material from the maintenance of harbors and waterways⁹⁹.

From a trading perspective, sand import bans are currently being used to sanction North Korea, with UN Security Council Resolution 2397 imposing a

sectoral ban on *“earth and stone”*, in effect prohibiting North Korea from supplying, selling, or transferring sand, directly or indirectly, from its territory or by its nationals or using its flag vessels or aircraft¹⁶⁹.

Other voluntary frameworks exist as well, such as BES 6001 and the Extractive Industries Transparency Initiative (EITI). BES 6001, defines a Framework Standard for the Responsible Sourcing of Construction Products through which actors in the value chain can have the responsible sourcing credentials of a wide range of materials assessed and certificated¹⁷. The EITI, meanwhile, encourages value chain transparency – from the awarding of extraction rights to public benefit – in order to strengthen accountability. Since its launch at the 2002 World Summit on Sustainable Development, over 50 countries have agreed to the voluntary EITI Standard. While the initiative has succeeded in increasing revenue transparency, it has had little detectable impact on public empowerment^{170–172}.

To date, no global agreement specifically exists to regulate, or monitor the mining of ocean sand.

Finally, there are several more geographically-specific conventions, with at least 15 regional conventions existing to regulate human impacts in the coastal and marine environment¹⁰². For example, the Protocol on Integrated Coastal Zone Management (ICZM), adopted by signatories of the Barcelona Convention in 2008, provides specific guidelines for seabed mining in the Mediterranean Sea. In particular, the Protocol requires signatories to conduct preliminary risk assessments, define sustainability indicators for use in monitoring, and prohibit extraction if ecosystems are at risk^{102,163,173}. In addition, two EU Directives make mention of marine extraction, encouraging Member States to share environmental spatial information¹⁶³.

National governance

National-level governance tends to involve the distribution of licenses or permits for sand extraction and the control of cross-border sand flows, in accordance with national legislation. In the UK, the seabed is owned by The Crown Estate which licenses marine aggregate extraction and reviews it every five years. To access these rights, commercial actors must first identify an area of interest and then submit a tender bid to the Estate^{53,174}. Instances of particularly strong governance include Israel, where commercial extraction permits are distributed by the Ministry of Environmental Protection, subject to detailed environmental assessments and monitoring, archaeological supervision, and the condition of long-term public benefit, such as preventing coastal erosion or protecting antiquities¹⁶³. A lack of national legislation, by contrast, can lead to unfavorable outcomes; in Uganda, for example, the constitution's explicit exclusion of sand and construction materials from mineral governance has been suggested to fuel illegal sand mining¹⁷⁵.

National ocean sand governance is increasingly taking the form of export bans, as can be seen playing out in South East Asia. As part of an ambitious land expansion program, Singapore reclaimed over 3,000 ha of land between 2000 and 2020 with plans to open the world's largest container terminal by 2040^{67,176}. However, this growth has been heavily dependent on substantial sand imports from neighboring countries¹⁷⁷. In 2002, Indonesia announced a temporary export ban following the disappearance of 24 sand islands in its waters and instituted a permanent ban in 2007^{10,178}. Malaysia, Cambodia, and Vietnam have also implemented bans, citing the environmental consequences of dredging^{176,177}. It is questionable how effective these measures have been, however, given large quantities of sand continue to flow to Singapore from all four countries^{179,150}.

Sub-national governance

In many cases, sand extraction is regulated at the sub-national level, either by local authorities or communities. In India, for example, sand is considered a 'minor' mineral by the Constitution and thus leases are regulated by State governments (although illegal sand mining is addressed by the National Green Tribunal)¹⁸⁰. Similarly, in the USA, governance varies between states. Sand mining in California was unregulated until 1960 whereupon the State Lands Commission began issuing leases; control of these leases has since passed to the U.S. Army Corps of Engineers, which imposes maximum mining restrictions for environmental protection¹⁸¹. And in Kenya, although large-scale extraction is governed nationally following the 2016 Mining Act,

it falls to Country Governments to manage artisanal sand mining¹⁹. But sub-national governance also carries its own issues. In Vietnam, the delegation of licensing to provincial authorities in 2005 was accompanied by a dramatic leap in sand mining activities as authorities used it as a means to raise revenue¹⁸². Insufficient local resources often also prevent adequate monitoring, as in Kenya and Jamaica^{19,62}.

In many cases, sand extraction is regulated at the sub-national level, either by local authorities or communities.

Africa offers several examples of community governance. In Ghana, it falls to local traditional leaders to regulate coastal sand mining, a method that appears to successfully balance the needs of community members. Following complaints from fishers and local tourism operators, for example, some local Chiefs decided to ban commercial sand mining, making exceptions for community construction projects¹⁸³. Meanwhile, user rights in Kenitra, Morocco, belong to local ethnic groups who manage sand as a commons (although ultimately overseen by the Ministry of the Interior)¹⁸⁴. By contrast, citizens of Makueni County, Kenya, claimed greater control over sand extraction following anti-mining protests, resulting in the creation of the Sand Conservation and Utilization Authority under the 2015 Makueni County Sand Conservation and Utilization Act – the first and only county in Kenya to regulate sand. Now half of all revenues for sand extraction are put towards restoration and conservation; the sites for sand mining are decided by citizens; there is a sub-national export ban on sand; and a license threshold of two tons ensures communities can still access sand for local construction projects^{17,19,185}.

LOOKING AHEAD

Ocean sand forms the literal and figurative foundations upon which the future of coastal communities, biodiversity, megacities and billion-dollar industries rest. While awareness about the centrality of sand to human development and well-being is growing, guiding ocean sand use and governance in a more sustainable, equitable and responsible direction will be a major challenge of this century, requiring a step-change in how ocean sand is understood and governed around the world.

One aspect of this challenge is the ubiquity of sand and dredging activities in the ocean economy: crucial for both local livelihoods and virtually every ocean-based industry; increasingly linked to international trade flows and geopolitics tensions; and an attractive and accessible resource distributed across areas that are tightly controlled and areas in which no such mechanisms are in place. As a result, displacement of ocean sand extraction into regions with limited governance and enforcement mechanisms has deepened inequities and, in some instances, left coastal communities stripped of their natural coastal defenses and even more vulnerable to climate change impacts. A narrow lens on ocean sand as simply an 'aggregate' resource that can drive national infrastructure development will miss these dimensions of justice, the diversity of ways in which ocean sand underpins local livelihoods, as well as all the benefits that it provides as a natural buffer and foundation for marine ecosystems.

Building a holistic and systemic understanding of ocean sand must therefore become a key priority for sustainable ocean management and coastal development planning. Indeed, ocean sand remains a striking blind spot in existing processes. The High-Level Panel for a Sustainable Ocean Economy, for instance, published guidance on achieving 100% Sustainable Ocean Management, and while it covers traditional industries such as ocean energy, tourism and fisheries, dredging goes unmentioned¹⁸⁶. Likewise, the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) is well on its way and yet neither *sand* nor *dredging* is mentioned once in hundreds of pages of official documents, including the full implementation plan, call to action, progress reports and operational guidelines¹⁸⁷⁻¹⁸⁹. Addressing these gaps will require broadening the awareness of stakeholder groups traditionally involved in ocean planning.

The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) is well on its way and yet neither sand nor dredging is mentioned once in hundreds of pages of official documents.

Developing and ensuring broad utilization of ocean sand monitoring tools is another urgent priority. Satellite imagery is already being used to monitor sand mining activities in river systems and provide robust estimates of volumes extracted¹⁹⁰. In the seafood sector, analyses based on vessels' automatic identification systems have provided revolutionary ways of tracking fishing efforts, including instances of illegal activities¹⁹¹⁻¹⁹⁴. The upcoming *Global Marine Sand Watch* that was recently announced by UNEP/GRID-Geneva as part of their Global Sand Observatory Initiative¹⁹⁵ aspires to take a similar approach and ultimately allow the near-real-time monitoring of dredging vessels across the world. Expanding this toolbox can help not only capacity building and enforcement activities, but also voluntary action by stakeholders seeking to develop guidelines and best practices to demonstrate their responsible use of ocean sand. Emerging research to 'fingerprint' sand based on its composition provides a further example of innovation to monitor the sand supply chain and support potential traceability and certification schemes¹⁹⁶.

A step-change in the level of transdisciplinary research on ocean sand is needed to inform policy and practice. Key research frontiers include shedding light on the various actors along the ocean sand value chain (e.g., companies, traders, financiers, insurers, and regulators) to identify effective incentives that can improve accountability and leverage transformative change¹⁹⁷. A dialogue on how sustainability is understood and operationalized within the dredging sector is also necessary, as large dredging companies stand out by their absence in global ocean sustainability initiatives

and associated commitments. For instance, none of them are members of the UN Global Compact, the UN Ocean Stewardship Coalition, or signatories to the Sustainable Ocean Principles¹⁹⁸. Profitability, which sometimes is treated as a proxy to convey the “sustainability” of the sector, appears to be the main lens used to gauge the likelihood of business continuity¹⁹⁹, as opposed to a focus on the limits of anthropogenic pressure the ocean ecosystem can sustain before its ability to support coastal communities and economies is undermined^{200,201}.

Finally, binding and voluntary governance mechanisms for ocean sand use need to be further explored and tested for efficacy. The absence of a global agreement that explicitly addresses sand mining and associated dimensions of monitoring (transparency) and regulation (accountability) represents a significant gap in global sustainability governance, and one that is likely to be exacerbated by the rapidly growing demand for ocean sand as well as its distribution across jurisdictions and areas of strong and weak governance²⁰. Importantly, such mechanisms will need to be accompanied by effective implementation and enforcement tools. In many instances, it will be incumbent upon developed countries to support the necessary institutional capacity building and strengthening in developing countries for these governance mechanisms to be successful. Considerations also need to include impacts on other ocean-based industries⁴⁴.

For instance, a case study in Korea that simulated direct and indirect damages to commercial fisheries from marine sand mining estimated US\$1.5 million worth of cumulative damages due to recurring mining over a period of five years within a single district^{20,202}. Taking a systems view on ocean sand also means recognizing that its governance will not be bound to the marine system only, but also involves parts on land and in inland waterways (e.g., river sand mining upstream and the construction of large dams critically reduce the natural influx of sand to the coast^{7,203}).

Some heartening signals are emerging that sand is climbing the global agenda, including a surge in academic publications, an uptake in media coverage, and a series of high-level calls to action such as the 2019²⁰⁴ and 2022²⁰⁵ UNEA resolutions and 2020 IUCN World Conservation Congress motion²⁰⁶. The establishment of UNEP/GRID-Geneva’s Global Sand Observatory, with the ambition to promote sustainable practices, lead monitoring innovations, and foster a dialogue on sand governance, is another encouraging step. Now is the time to build the scientific knowledge base, holistic understanding, and fit-for-purpose tools to ensure that ocean sand is a driver of resilience rather than risks. Now is the time to put sand on the ocean sustainability agenda.

Dredging vessel working on Palm Jumeirah in Dubai, United Arab Emirates. Photo: Richard Schneider via Flickr (CC BY-NC 2.0)



SPOTLIGHTS

Spotlight 1 The consequences of mechanized sand mining on women in Lagos

By Esther Olubukola Adedeji

For many decades, manual sand mining has been a traditional occupation of the Rabaka community in Lagos state, Nigeria. Skilled male divers fill buckets of sand from the bottom of the lagoon and load them onto canoes. Women generally stockpile this sand for sale to truck drivers, earning about a thousand naira per day (less than US\$2), unless they own a canoe, which allows them to employ divers and stockpilers of their own.

This traditional method of sand mining sustained livelihoods for decades by balancing sand harvesting with what the environment could sustainably provide. However, it took only a few years for mechanization to take over. Foreign men arrived in the region and began using powerful mechanized dredgers and tractors to load the trucks, extracting tons of sand within a few hours and rapidly pushing the manual sand miners out of business. Although the resulting environmental degradation and complaints from citizens led to the former governor of Lagos state banning sand mining in some areas, these activities have continued illegally.

The consequences for the communities have been enormous, particularly for women who are now losing access to this source of livelihood without a viable alternative. Many women have resorted to other activities, including harvesting mangroves for sale as firewood; collecting and selling plastic bottles from the lagoon; and unregulated fishing.

Fishers' livelihoods are further threatened by mechanized sand mining: noise pollution and habitat destruction reduce their catch while dredging machinery destroys fishing nets, sparking conflicts between the fishers and miners. For the men of Rabaka, it has also been difficult to find alternative employment on the mechanized platforms since the workforce is primarily composed of foreigners or men from other neighboring communities. While monitoring and control of the mechanized dredging operations are needed and still lagging, efforts are underway to develop sustainable livelihood pathways for the women affected.



Men in the Rabaka community of Ikorodu, a coastal city along the Lagos Lagoon, Nigeria, collect sand from the bottom of the lagoon and load it onto canoes (a). Once brought ashore, women transfer the sand into stockpiles ready for sale (b). The recent arrival of mechanized dredgers (c) has pushed women out of the sand mining business and into alternative livelihoods such as fishing (d), harvesting mangroves for firewood (e), or collecting and selling plastic bottles (f). Credit: Esther Olubukola Adedeji

Spotlight 2 Lost paradise? The Addu Atoll land reclamation project

The Maldives, situated near the equator in the Indian Ocean, are famous for their white sandy beaches, clear turquoise water, and flourishing coral reefs. The islands are often referred to as a paradise on Earth, with tourism providing a major source of income alongside fishing. Maintaining conditions that attract tourists is therefore key as alternative livelihoods are few and 98% of the country's exports and 71% of its employees are directly linked to its biodiversity¹⁵³. The nation is also considered to be among the most vulnerable to climate change impacts, with over 80% of the land area less than one meter above mean sea level²⁰⁷. Increasing severe weather events and rising sea levels are contributing to shoreline retreat and increased coastal erosion, ultimately putting the very existence of the islands at stake^{208,209}.

In Addu, the Maldives' second most populated area, the government announced a large-scale land reclamation project to improve the economy through new land for commercial, industrial and residential development²¹⁰. Financed through a US\$800 million credit line from the EXIM Bank of India, an estimated volume of 5.6 million m³ of ocean sand needs to be dredged to reclaim 194.2 ha of land, including the construction of three new islands (29.4 ha) to accommodate 4-star resorts²¹¹. The sand will be taken from the bottom of the lagoon in the middle of the Addu Atoll, home to 25,000 people and a protected UNESCO Biosphere Reserve since 2020^{212,213}.

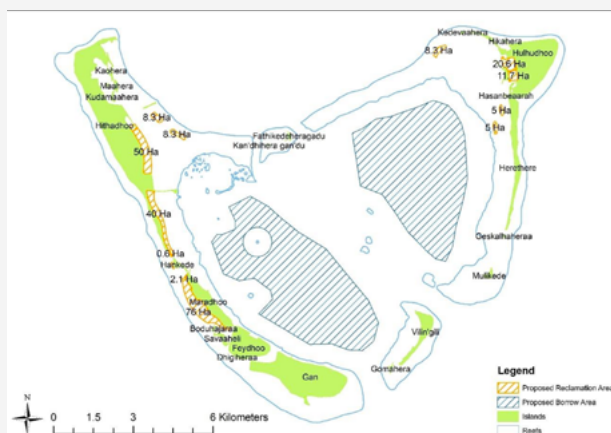
Local environmental agencies have raised major concerns about the social-ecological impacts of the project and want to halt it. The latest environmental impact assessment (EIA) shows that 26% of the atoll lagoon will be impacted²¹¹, including biodiverse ecosystems such as coral reefs and seagrass beds, home to over 1,200 species of fish, including several endemic species, as well as dolphins, turtles and manta rays²¹³.

The project is expected to bury 21 ha of corals, 98 ha of seagrass meadows (thereby losing a large portion of potential carbon sequestration from the lagoon), and release sediment plumes in the water that will dramatically impact fish populations. The irreparable damage to marine ecosystems will, in turn, negatively affect the people who depend on them for fishing, tourism, and other recreational activities²¹. In addition to the environmental impacts, there are also growing equity concerns, with fears that the local community will be sharing the costs, but unlikely to benefit from the gains. Promises of solving housing issues (which contributed to the project's public support) risk remaining unfulfilled while new resorts and high-end businesses emerge.

The Mayor of Addu City has admitted that approving the project was difficult but necessary, highlighting the need for providing land and economic development to the next generation while trying to minimize inevitable environmental damage. The Maldives Government did not prevent the project either, despite the conclusions of the EIA²¹⁴ and a court case stating the project will cause irreversible damage to the environment and future generations – in stark contrast to Article 22 of the Maldivian Constitution: *“The State shall undertake and promote desirable economic and social goals through ecologically balanced sustainable development and shall take measures necessary to foster conservation, prevent pollution, the extinction of any species and ecological degradation from any such goals”*^{215,216}

The Dutch dredging and marine construction company Van Oord – one of the world's largest, with revenues surpassing €727 million from dredging activities alone – is in charge of the project. They are quick to emphasize that the project involves working with local interest groups, the use of sustainable techniques to minimize fossil fuels, and the reallocation of coral prior to execution²¹⁷. The dredging director forecasts that similar tasks will become more common in the era of climate adaptation. Yet, one of the most pressing concerns of this project is that it may trigger erosion in other islands of the atoll, as observed in previous reclamation work in the Maldives^{153, 211, 218}.

A joint letter signed by multiple NGOs highlights the hundreds of millions of dollars projected for the loss of ecosystems as a consequence of the Addu reclamation²¹⁶. Investing in land reclamation and coastal geoengineering is increasingly seen as a way for small island states to enhance economic development and adaptive capacity in the face of climate change. But the solution to one problem can be the cause of another, ultimately raising the question: land reclamation for whom and at what cost?



A map of Addu Atoll with the initially proposed reclamation and dredging areas²¹⁹. The area of the borrow locations has since then been reduced by 73.6%, with three new islands instead of the five originally planned²²¹. Credit: Environmental Impact Assessment²¹⁹.

Spotlight 3 Runaway risk: The New Manila International Airport

In its report 'Runaway Risk', Global Witness, an international non-governmental organization that works for a more sustainable, just and equal planet, reports on how Dutch companies will profit from a new Philippines airport project being built at a high cost to communities and the environment¹³⁹. The New Manila International Airport, a US\$15 billion mega-development project, is the Philippines' most expensive infrastructure project to date. It required the Dutch government to issue its largest-ever insurance policy, valued at €1.5 billion, via the privately-held export credit agency Atradius Dutch State Business (Atradius DSB)²²⁰. By the end of 2022, dredging giant Royal Boskalis Westminster N.V. had already delivered more than one-third of the material needed to build the huge sandbank²²¹. This is also Boskalis' biggest project ever, with 1,700 ha of land expected to be developed for the new facilities²²².

While both Boskalis and Atradius made statements celebrating the project's social and environmental credentials, the report suggests otherwise. It points out the failure to screen for severe human rights risks and implement international standards such as the OECD guidelines to address environmental and social risks^{139,223,224}. Quite notably, the project received a go-ahead nearly two years before it even had an environmental clearance certificate^{225,226}. The local population was not initially informed about plans to build an airport, effectively denying them a Free, Prior and Informed Consent process. Many residents felt compelled to abandon their homes, citing concerns for their safety after company representatives reportedly came every day accompanied by armed soldiers²²⁷. The compensation process too has been highly contested. In one of the villages, 700 families were displaced and reportedly only half of them received compensation¹³⁹. Thousands of fishermen have been denied access to the communal fishing grounds on which they depend for

their livelihoods, and local communities now struggle to catch enough fish for a healthy diet^{227,228}.

From a climate and environmental perspective, the project is set to further enhance the vulnerability of the local population in what is already one of the most at-risk countries. An estimated five million people are exposed to flooding within Manila Bay, and this will likely rise to 12 million by 2040¹³⁹. Mangrove forests, a crucial carbon sink and flood mitigation solution, were cut down to make way for what is scheduled to become one of the top three busiest airports in the world^{224,225,229}. The project also encroaches on an area identified as a 'strict protection zone'^{224,228}, while disrupting the East Asian-Australasian Flyway, a critical corridor for more than 50 million migratory birds, which includes the most threatened or near-threatened species of any of the world's migratory routes²³⁰⁻²³⁴.

The first impact assessment could find no threatened wildlife species and simply concluded that *"there is a high possibility that the birds will be affected but due to their highly mobile nature they can transfer to other areas"*²³⁹. The second risk assessment, conducted to appease financiers, did find seven Key Biodiversity Areas within a 50 km range of the project. However, since it had received an environmental clearance certificate, work had reportedly already begun and Atradius DSB subsequently insured the project six months after the second impact assessment was completed^{224,231}. The report concludes by underscoring the need for mandatory corporate accountability²²⁴ and calling on legislators in the European Union to ensure that people and the planet are put before profit. In January 2023, Boskalis' CEO threatened to move its headquarters away from the Netherlands in response to a new corporate social responsibility act that would strengthen human rights and environmental regulations²³⁵.



Aerial view of the New Manila International Airport under construction. The dredging works are moving ahead to develop an estimated 1,700 ha of new land. Credit: rexDroneTV.

Spotlight 4 The geopolitics of sand: Dredging in the South China Sea

Sand has become a contested resource amid rising tensions in the highly strategic South China Sea. Fishing in the area employs 3.7 million people and provides nearly 12% of global catch²³⁶; it is a major node in the network of undersea telecommunication cables; its seabed contains large oil and gas reserves²³⁷; and an estimated one-third of global shipping – about US\$3.4 trillion in goods in 2016 – passes through the region each year²³⁸. As a result, territorial claims and sovereign rights over the sea's natural resources are disputed by China, Vietnam, the Philippines, Malaysia, Brunei, and Taiwan^{239,240} – and sand is no exception.

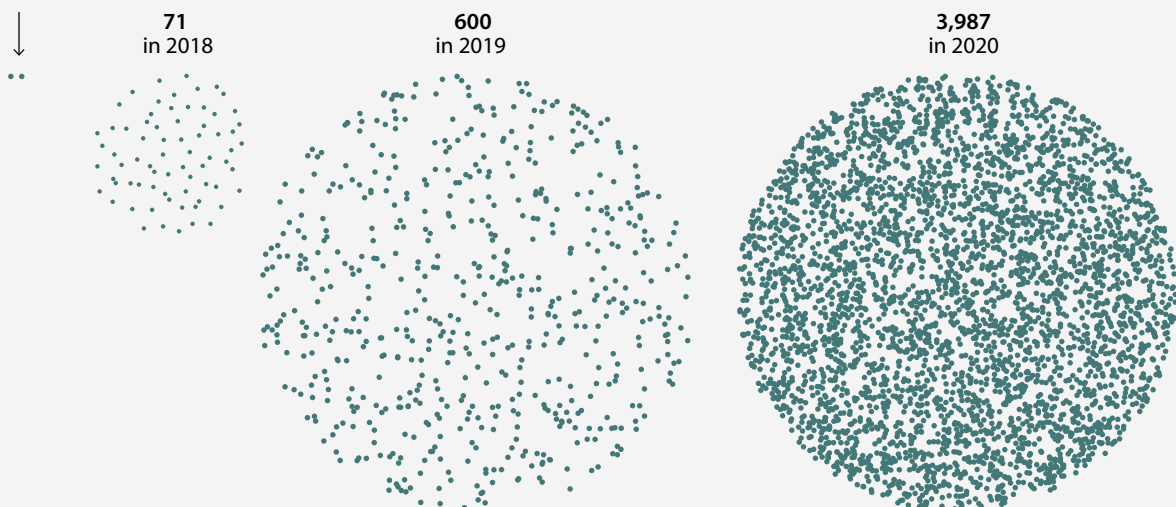
China is the world's largest producer and consumer of sand by a substantial margin, making headlines in 2015 for using more cement in three years than the USA did in the entire 20th century²⁴¹. Its vast aggregate consumption mostly stems from the construction of buildings and infrastructure²⁴². Yet recent environmental regulations over the period 2017–2019 led to the closure of almost 30,000 Chinese aggregate mines²⁴³, triggering a sand deficit in nearly a third of the country and possibly underlying China's considerable appetite for ocean sand. In early 2020, activities related to illegal sand mining by Chinese vessels were reported in the Formosa Banks, an ocean shoal area situated in the southern portion of the Taiwan Strait, where vessels were estimated to draw up to 100,000 tons of sand each day. Dredging also led to a souring of the relationship between China and the Philippines after reports emerged of Chinese vessels illegally mining black sand from the northern coast of the Philippines along with the construction of artificial islands for military purposes²⁴⁴.

Here, sand takes on geopolitical importance. Over the past decade, Chinese dredgers in the South China Sea have been engaged in unprecedented levels of land

reclamation and island-building efforts⁷⁶. As one author writes, “in addition to bolstering China's negotiating position in the South China Sea maritime disputes by virtue of their very existence, the islands also provide logistical support for China's rapidly expanding coast guard, its maritime militia, and Chinese-flagged fishing vessels used in furtherance of Beijing's diplomatic goals”²⁴⁵. Remote sensing data suggests that the artificial islands are often militarized for strategic importance and equipped with infrastructure such as wind turbines, helipads, and harbors^{74,76}. Meanwhile, Vietnam is mobilizing its own dredging fleet as part of a similar, though smaller, island-building counter-campaign in the region. Last year, Vietnam expanded its island area by roughly 170 ha^{246,247}, adding to a long history of Sino-Vietnamese tensions flaring up periodically as disputes over oil and gas exploration or fishing²⁴⁸.

Further to sand's use in construction, the very act of dredging itself can in some situations be considered ‘gray zone warfare’ (i.e., non-military action designed to exhaust the opponent without quite provoking open conflict)⁷⁵. This is the case, for instance, in the Matsu Islands which are among the region's many contested territories – in this case administered by Taiwan, and simultaneously considered by China as part of its sovereign territory. In 2020, nearly 4,000 Chinese sand dredgers and associated vessels were expelled by Taiwan, a 560% increase from 2019²⁴⁹. The sand dredgers serve dual purposes: collecting a valuable resource, while also exhausting the resources of the Taiwanese coast guard that is seeking to drive them away. As in other areas, the extraction of sand has been seen to harm marine life, shrink beaches, and alter coastlines. Such illegal dredging also hinders the maintenance of underwater cables and intimidates residents and tourists^{136,249}.

TWO VESSELS
expelled in 2017



The annual number of Chinese sand-dredging and transport vessels entering Taiwan-controlled waters has surged over recent years. Source: Taiwan's Coast Guard; bathymetry data from GEBCO 2019 grid. Graphics by M. Hernandez/Reuters²⁴⁹.

Spotlight 5 What comes after the sand mine? The case of Minjerribah, Australia

Minjerribah, the aboriginal name for North Stradbroke Island, Australia, is the second-largest sand island in the world. The Quandamooka people are the officially recognized traditional owners of the island. Its landscape is characterized by sand dunes covered by old forests, important freshwater lakes and unique wetland areas home to many threatened bird species. By 2015, half of the island was recognized as a national park²⁵⁰. The place is a popular holiday resort located ca. 30 km from Brisbane and home to approximately 2,000 people.

Industrial sand mining on the island has a long history starting back in the 1950s when sand was mostly mined from beaches. In the later stages, mineral sand was extracted from the center of the island for rutile, zircon and silica. Sibelco Australia, a large privately-owned international mining company with its headquarters in Belgium and revenues close to €2 billion²⁵¹, began operations on the island in 2009²⁵², following in the footsteps of its subsidiary Unimin Australia which had started mining silica already in 2001. By 2018, 43% (11,500 ha) of the island was under Sibelco's mining tenure of which 9,000 ha had been mined, with 500,000 tonnes of mineral sand extracted annually^{253,254}.

Strong local opposition to sand mining by the Quandamooka people and mainland environmentalist groups emerged primarily due to the destruction of culturally important archaeological aboriginal sites and concerns for the island's ecosystem and important freshwater resources. The permanent partial drainage of lake Kounpee in 1987 and the 100,000 L oil spill that severely contaminated the Amity swamp in 1991 are still in the community's memory. Dredging itself is a high-impact form of resource extraction, destroying its immediate environment by leveling sand dunes, removing vegetation, and creating a deep dredge pond²⁵⁵. Yet the perception of industrial sand mining among islanders eventually got more positive. The much-improved rehabilitation of sand dunes against erosion

and the perception of the company as a major job provider (despite employing only about 5% of the island's inhabitants) likely contributed to this shift²⁵².

In 2011, the Queensland Government passed the North Stradbroke Island Protection and Sustainability Act which set 2019 as the end date for sand mining. After a government change in 2012, the ban on sand mining was lifted but reinforced again in 2016 with the North Stradbroke Island Protection and Sustainability and Other Amendment Acts wherein the government also expressed the intention to make 80% of the island a national park. They published the *Economic Transition Strategy* and announced the *worker assistance scheme* to support former mining employees to transition into alternative careers. The closure of the sand mines became highly politicized, with polarizing media coverage dividing the local community. This was furthered by Sibelco's active campaigning for an extension of mining licenses. Islanders on both sides expressed their anger at being used by 'mainlanders' for political advantage. The disconnection between islanders and the Queensland government can be illustrated by their diverging views on what a sustainable transition of the island entails: while the state's future vision centers around economic development, the islanders are inspired by a more holistic approach focusing on social equity and ecological sustainability²⁵⁶.

Despite their different views, Sibelco Australia, the Queensland government and the Quandamooka people eventually signed a shared statement of intent for the rehabilitation of the sand mines in December 2019²⁵⁷. The transition process into a post-sand mining community is by no means completed (rehabilitation is expected to continue until 2025) nor perfect, but it emphasizes the importance of involving all parties in the decision-making process and the value of clarifying what different actors associate with sustainability and social responsibility.



Australian Conservation Foundation (ACF) members unfurl a banner protesting sand mining on Minjerribah/North Stradbroke Island, August 2013. Credit: ACF

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