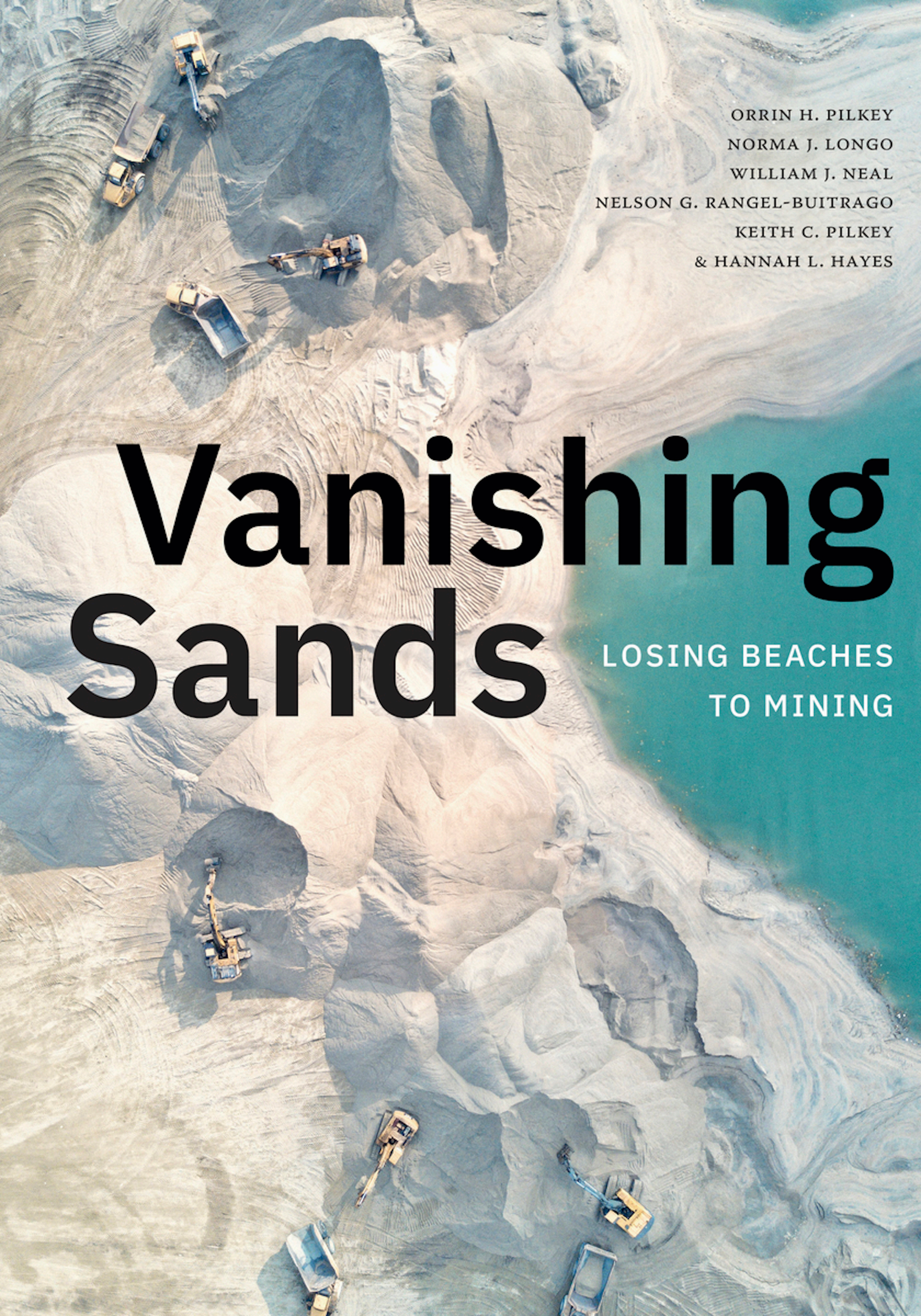

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Vanishing Sands

LOSING BEACHES TO MINING

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IN GRATEFUL RECOGNITION OF THE SANTA AGUILA FOUNDATION'S SUPPORT OF OUR PAST RESEARCH AND PUBLICATIONS, AS WELL AS THE FOUNDATION'S GOOD INFLUENCE ON GLOBAL COASTAL MANAGEMENT, ALL ROYALTIES FOR *VANISHING SANDS* WILL BE ASSIGNED TO THE FOUNDATION.

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This book was a true team effort and brought together a group of people who had a previous history of cooperative research, authorship, and editing, as well as strong ties of family and friendship. In the course of this effort, we had not only the concerns of COVID-19 but other difficulties and losses that deeply affected our family of writers and editors.

WE DEDICATE THIS BOOK TO THREE SPECIAL PEOPLE:

First, to the memory of Claire Le Guern, who passed away as this book was going to press, in recognition of her years of inspiration, guidance, and friendship, especially during our research and writing for this book, as well as for all the years we worked together through Coastal Care.

Second, to the memory of Cameron Pilkey, son of Keith, grandson of Orrin, who passed away during this time. His loss was unexpected not only to the immediate family but to those of us who had followed his growth from child to manhood.

Third, to the memory of Nelson "Yeyo" Williams Rangel Diaz, father of Nelson Rangel-Buitrago, known to us through Nelson as his inspiration.

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PREFACE

BEACHES AND COASTAL DUNES ARE AMONG THE MOST DYNAMIC OF NATURE'S ENVIRONMENTS

—worked on by waves, storms, surf-zone currents, wind, and even ice in the winter. Beaches and dunes occupy a place in coastal space that moves up and landward with sea level rise, or down and seaward if sea level falls. Beginning with Neolithic people and then the Phoenicians and Romans, humans have interfered with these natural processes by blocking waves and currents with hard structures to hold the shore in place, in order to protect valued property placed next to the shore.

Today, we continue this compulsion to hold the dynamic ocean shoreline in a static position with the same ineffective techniques, such as dredging channels and building bigger and better seawalls and groins, to protect property (e.g., tourist facilities, ever-bigger houses, refineries, and infrastructure) that could have been placed in less hazardous positions. Globally, most of this modern activity is driven by the tourism industry and the attraction of permanent seaside residency. The resulting boom in urban-suburban development has grown to the very edge of beaches, often atop dunes. And this construction is based largely on one man-made material: concrete.

The two key ingredients for concrete are cement and aggregate. Cement is produced from limestone, and the production process releases huge amounts of CO_2 into the atmosphere, contributing to global warming. Aggregate is sand and gravel, and often only sand is needed. But just any sand won't do to produce reliable concrete. Quality concrete aggregate must meet a specific set of criteria (e.g., composition, texture). The demand for high-quality sand has grown exponentially with global population growth, creating sand shortages. So, the problem is more precisely that *there is a global shortage of sand suitable for concrete*. Shortages, of course, lead to higher costs, so why not go to the nearest beach or coastal dune to get suitable sand with angular grains for free? You can't beat that for a bargain!

And therein lies the problem — robbing the sand from beaches and coastal dunes. Most of us have heard the old joke about the smuggler at the border. A young boy appears at the border pushing a wheelbarrow full of sand. The border guards are suspicious that the boy is a smuggler. They paw and prod the sand but find nothing. Over the following days, this scene is repeated again and again, but the guards find nothing. The punch line is that the boy was smuggling wheelbarrows! But now there's a twist on the story: the boy is smuggling sand — and it is no longer a joke. Raids on sand resources are now a global activity, utilizing both child labor and impoverished citizens as sand miners, in a business ruled by organized crime that has graduated from wheelbarrows to dump trucks to shiploads of sand crossing international boundaries. All this happens at the expense of the storm protection furnished by beaches and dunes that also are the basis of a huge global tourist industry.

Part of the evolution toward this modern free-range attitude regarding sand resources traces back to the traditional perception of beaches as public lands. Beaches, like waterways and the ocean itself, have been regarded as the public common, and mirroring those water bodies, beaches too are now part of the "Tragedy of the Commons." This nineteenth-century concept was brought back into focus by Garret Hardin in the 1960s. *The tragedy of the commons is a situation in a shared-resource system where individual users, acting independently according to their own self-interests, behave contrary to the common good of all users by depleting or spoiling the shared resource through their collective action* (Hardin 1968).

Beach mining parallels the story of the village green, once available to all for grazing their livestock, but the collective overgrazing destroyed the green.

Beaches and coastal dunes have always supplied sand for local use (e.g., the sandbox for the kids; some sand for improving the garden soil; making a beach volleyball court away from the beach). The extracted sand volumes ranged from sand buckets or wheelbarrows to small pickup truck–loads. But starting in the late twentieth century, driven by coastal development, the big guys stepped in all over the world with excavators, bulldozers, front-end loaders, and dump trucks. And of course, large-scale mining immediately created a litany of environmental, social, and economic damages. In particular at the shore, the impact was the degradation and loss of beaches and dunes — the first step in killing the proverbial goose. No more golden eggs from tourism after the loss of the drawing cards of scenic and recreational aesthetics.

What follows is a pattern of decline with loss of local economies, loss of natural storm protection, and loss of offshore resources (e.g., fisheries, reefs). The push for sand resources has become so great that even more damaging corruption and crime has resulted. Within the first twenty years of the twenty-first century, the devastating impacts of sand mining on beaches and coastal dunes, as well as on rivers, have reached crisis proportions.

We are beginning to feel the negative outcomes familiar to us from other boom-bust resource raids, like deforestation, gold-rush ghost towns, and coal-mining wastelands. The passing of John Prine during our research for this book reminded us of his "Paradise," a song about the devastating environmental impacts of strip-mining by Mr. Peabody for coal in Kentucky. The parallel of global losses of the "Paradise" of beaches and coastal dunes led us to coining the following:

Daddy, won't you take me to the shoreline sands
Down to the beaches and dunes to play
Well, I'm sorry my child, but you're too late in asking
The Sand Miners have hauled them away

The beaches, the dunes, and river plains too
To build high rises, highways, and places to stay
But for those who still come for Sand, Sea, and Sun
They'll just have to limit their play

No Sand for castles, forts, or volleyball courts
No beach to stroll by the bay
No Scotch Bonnet shells, or bonfire rapport
The Sand Pirates have stolen our Paradise away!

We hope this book will be a contribution to increasing resistance to the mining of beaches, dunes, and rivers, and to conserving these public commons. We suggest some solutions, including use of existing alternative inland sources of sand. Perhaps the cost of such sand sources is higher than beach-mined sand, but in comparison the environmental cost will be much less.

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ACKNOWLEDGMENTS

Significant recognition of the coastal sand-mining problem has already been publicized by Coastal Care (coastalcare.org), and their extensive website is an important source for public education in regard to this issue. We especially express our appreciation to Claire Le Guern who, working with Coastal Care, pointed out significant beach-mining examples for us, supplied many photographs, and provided valuable critical editing comments.

We also express our immense gratitude and sincere thanks to Olaf and Eva Guerrand-Hermes who formed the Santa Aguila Foundation (SAF) and founded Coastal Care. They have been tremendous supporters who also supported the spectacular and award-winning documentary *Sand Wars*, by director Denis Delestrac, who aptly brought attention to the global shortage of sand and the politics of mining.

Geologists Andy Coburn, Andrew Cooper, Gary Griggs, Joe Kelley, Hal Wanless, and Rob Young were important sources of local beach stories and information about beach mining. We express our hearty thanks to them and to numerous other colleagues and friends who have shared their experiences and photographs, and who were willing to share ideas and local observations.

We also gratefully acknowledge Representative Pricey Harrison (D-NC) for her steadfast support of our books over the years. Last but definitely not least, we express our gratitude to two of our ever-patient IT specialists, Andy Minnis and Katheryne Doughty.

In addition to the six coauthors' past experience with coastal processes, coastal management, and international field travels, we originally planned to visit various beach-sand mining hot spots (e.g., Singapore, Morocco, Barbuda, Jamaica, The Netherlands). But the COVID-19 virus scrapped those plans. However, our collective global experiences provide a strong background to address sand-mining issues.

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WHO'S MINING THE SHORE?

CH.01

In fall 1995, Duke University's research vessel *Cape Hatteras* was sampling off the north shore of Puerto Rico, near the town of Arecibo. The goal of the cruise was to learn how river sediments from a recent major flood on the Arecibo River were distributed on the beaches and on the narrow shelf (three-fourths-mile-wide). The ship's eight-man crew and ten scientists and marine geology students spent twenty-one days doing closely spaced coring of the sea floor, while the vessel swayed gently with the swells as they moved inexorably toward the beach. The sampling was always in clear sight of the shore and the traffic on the coastal highway.

It was a hard-working but pleasant cruise in calm weather, taking twenty-foot-long cores of sediment in pipes that were vibrated into the sea floor. During breaks we would occasionally watch whales surfacing nearby and try to identify them from a whale catalog that described specific individuals based on various body markings, particularly scars from bites and scratches.

In clear sight, for all twenty-one days, except Sundays, a sand-mining operation steadily removed chunks of the large, vegetated sand dune that lined the shore. Lines of dump trucks awaited their turn to move into range of a backhoe plunging into the sand and coming up to dump its load into the truck. It was clear, even to an offshore audience, that the loss of this dune was removing a protective line of sand that could defend the island's major east-west highway and some buildings from future storms.

After the cruise was completed, some of the science crew drove out to the mining site and were disheartened to see a sign, posted nearby on

FIG 1.1 A child playing on a beach in Morocco not far from dump trucks being loaded with sand—a striking contrast. Is this a sign of the future? Photo © Lana Wong—Coastal Care.

a coconut palm, proclaiming that removal of sand from the dunes was strictly prohibited.

Upon further investigation, it became apparent that mining beach sand for construction purposes has a long history in Puerto Rico and on most Caribbean islands. In the 1950s, the San Juan Puerto Rico International Airport was built largely with fill from the nearby Piñones Beach and dune system—another protective beach and dune system removed. For years, sand mining has gone on around the community of Isabela, also on the north coast of Puerto Rico.

Clearly, the mining has increased the rate of erosion of beaches that are critical to the all-important tourist industry and the recreational and commercial fishing industries. Adding to the beach erosion problem in Puerto Rico are small sand-trapping dams on the rivers as well as sand mining operations in these same rivers that lessen or even halt the flow of fresh sand to the beaches.

Oceanographic studies have located three large, shallow underwater sand deposits off various parts of Puerto Rico that could be mined by dredging without immediate impact on nearby developed shorelines. These are off Cabo Rojo on the southwest corner of the island, Isabela off the northwest corner, and the largest of these sand bodies, Escolla de Arenas off Vieques Island, just off the east coast of Puerto

Rico (see chapter 8). However, considering the distance, the costs, and equipment required, it is both cheaper and easier to drive a truck to the beach nearest the construction site and load it up with sand.

In September 2018, the impact of beach and dune mining along the shores of Puerto Rico came home to roost. As Hurricane Maria devastated the island, much of the coastal damage was intensified by the absence of the sheltering effect that the mined-away dunes would have provided to a number of places along the north shore. Waves and high water penetrated inland in places once protected by high, vegetated dunes.

The Puerto Rican story is being repeated all over the world. We are removing coastal sand, and beach-sand sources, at the very moment that we need these landforms the most. Sea level is rising now at an accelerating rate, and storms are intensifying; both are expected results of global climate change and, in particular, the warming of the oceans. Along many thousands of miles of sandy shorelines around the world, beaches and especially dunes offer critical, though temporary, protection from both storms and the rising sea. Moreover, loss of beaches and coastal dunes is a blow to the world's tourist industry. What is driving this coastal sand-mining boom? Sand has many uses, but sand aggregate for concrete is the need that is driving the exponential increase in sand mining (figure 1.1).

SAND: A LIMITED RESOURCE

In just over two decades, sand went from being a local product—with transport to the site of use economically unfeasible beyond thirty miles—to a commodity with global trade, explains Susan Froetschel, managing editor of Yale Global Online: "Fast-growing economies and a growing middle class in Asia, particularly China, fuel demand for sand even as environmental concerns and permitting requirements limit supplies. Nations and communities that want to restore beaches, or expand territory as is the case in Singapore and China, often eye low-cost sand in nearby nations with ample supplies and fewer regulations" (Froetschel 2017).

Although intuitively it may seem otherwise, sand is not a limitless resource. In fact, by some measures, less than 5 percent of the world's supply of sand can be used for concrete. The problem is that in order for sand to be useful for industry, it must be located reasonably close to the place where it is needed, and the individual grains must be irregular in shape to make strong concrete. Beach sand grains are usually uniform in size and irregular in shape; the deposits are close by to most of the coastal development around the world, and it's easy and cheap to mine. Just drive a dump truck and a backhoe to the beach or to the dune behind the beach, and you can get all the sand you need — until it's gone. All of this has led to the mining rush to the beaches.

As it turns out, the assault by storms and sea level rise on sandy coasts is far less damaging than the assaults by humans who are mining the beaches and coastal dunes. Beaches left to Nature may change shape, size, and location, but they will always be there as climate and sea level change. But mining may permanently remove both the beaches and the coastal dunes, especially where mining has removed all sand down to the bedrock as in some parts of Morocco (figures 1.2A and 1.2B).

Pushback on beach-sand mining comes from several directions. *Sand Wars*, a spectacular, award-winning documentary by director Denis Delestrac (2013), follows contractors, builders, smugglers, and sand mafia who are all part of widespread, largely illegal, global operations that are mining beaches, dunes, and rivers. The film makes a strong case for the need to halt mining of the world's beaches and coastal dunes in this time of great need of sand for construction purposes (concrete). The corruptive influence and environmental damage of the sand-mining industry and the violence of the sand mafias described in the documentary are stunning. *Sand Wars* may have provided the inspiration and data for the 2019 United Nations report "Sand and Sustainability" (UNEP 2019).

The website for the Coastal Care organization provides a gold mine of information concerning a global range of topics including beach-sand mining, sea level rise, shoreline retreat, armoring, plastic pollution, and climate change. The stated goal of the organization is to raise people's awareness about the ongoing decimation of beaches, with emphasis on sand mining. Much of the information and many illustrations in this volume come from coastalcare.org. Both *Sand Wars* and Coastal Care are supported by the Santa Aguila Foundation.

Vince Beiser (2018), in his book entitled *The World in a Grain*, informed the nonbureaucratic world that there is a huge global shortage of sand used mostly for construction purposes. Because of this, there are sand black markets, sand mafias, and sand thieves, as well as governments that have fallen over the issue of sand mining. Beiser sounded an alarm that must be heeded.

Joyce Msuya, acting executive director of the United Nations Environment Programme, puts it this way: "The problem is that we have

FIGS 1.2A & 1.2B Large sand-mining operations in Morocco.

FIG 1.2A The end result of mining. A large-scale sand mine slowly destroying a typical high coastal dune that lines the Atlantic Coast of Larache, Morocco. Photo © Lana Wong — Coastal Care.

FIG 1.2B Eventually this site will look like the rocky beach south of Larache. A few miners remain at and beyond the low-tide line cleaning out sand from crevices. Ironically, many of these mining sites are removing beach sand to construct facilities for tourists who come to enjoy the beach. On such shorelines, tourism and the ecology are dead and gone. Photo © SAF — Coastal Care.

been exceeding easily available sand resources at a growing rate for decades. . . . Even though these materials are the second largest resources extracted and traded by volume, after water, they are one of the least regulated in many regions. Increasingly sand is being produced through environmentally damaging extractive processes in sensitive terrestrial, riverine and ocean ecosystems" (UNEP 2019, xi).

Unfortunately, there is no better (or cheaper) source of sand just the right size for construction than a nearby sandy shoreline. As usual, there is a fly in the ointment. To use sand from the ocean or beach, you must thoroughly wash it to remove all vestiges of salt before it is used in concrete. Salty sand does not affect the concrete per se, but it will corrode steel reinforcing rods encased in concrete. Salty sand has created a crisis in Shenzhen, China, where inspections have revealed that at least fifteen buildings under construction used salty sand, which is illegal in China. Among these buildings is one that was intended to be the second-tallest building in the world. Because the buildings could eventually collapse years down the road, China halted construction, at least temporarily (Huifeng 2013).

The June 24, 2021, disastrous collapse of the Champlain Towers South condominium in Surfside, Florida, the cause of nearly one hundred deaths, has forced a sudden rush of attention to the problem of salty sand in concrete (Goodell 2021). Clearly there were multiple causes of this collapse, but one of the suspected problems was the use of beach and dune sand in concrete. The condo, like many shorefront buildings in Florida, was located a few feet from the base of the nearby ocean-facing dune. Degraded reinforcing rods (rebars) were reported to be visible in some of the lower parts of the building, a degree of degradation that would take decades to form in this forty-year-old building. Salt could have been contributed to the concrete by other means:

- Storm overwash
- Salt spray from the nearby surf
- Super high (King) tides
- Underlying porous limestone containing sea water

The Surfside condo collapse tells us that not only should beach sand mining be prohibited, but if such sand is used, it must be thoroughly washed. The requirement for washing should be closely enforced worldwide. The Champlain Towers South collapse is a warning that shorefront construction of any building may be a fool's errand. Buyer beware!

FIG 1.3 Beach-sand mining in Portugal. In this case, the sand is being mined from a very wide beach created by a large jetty or rock wall perpendicular to the beach that traps sand on its updrift or upstream side, much like a river dam. Just like a dam, the downdrift or downstream beach side (not shown here) is missing a lot of sand, and that shoreline is rapidly eroding. If the beach were to need nourishment, sand could be removed from upstream and placed on the downstream side of the jetty, or sand could be brought in from inland sources. Photo by William Neal.

In Sierra Leone, Africa, as many as twenty or more dump trucks line up side by side, each surrounded by three or four men with shovels to quickly demolish the upper beach and dune. In Morocco, fleets of dump trucks are destroying the massive dunes that line the Atlantic coast, removing as much as two hundred full truckloads a day (see chapter 9). In Portugal, sand trapped on the updrift sides of two jetties at the Rio de Aveiro and Rio Mondego is being mined, while the beaches on the downdrift sides of the jetties are eroding rapidly and could desperately use the mined sand (figure 1.3).

Flash ahead a few years from the Puerto Rico cruise, and one of us was traveling around the shorelines of several Hawaiian islands looking at the beaches. Leading the trip was Professor Chip Fletcher, a coastal geologist from the University of Hawaii. At one stop, we saw a mysterious, huge depression in the dune sand, perhaps ten-by-fifteen-feet wide and three-feet deep. Now, we had seen lots of holes on beaches everywhere that were dug by various animals like sea turtles and ghost crabs as well as, of course, by kids who dug small pits in the beach. But nothing like this hole had we ever seen.

A day later on another beach, we spotted another hole of similar dimensions, also in the dunes close to the high-tide line. This one was different, however. There were obvious tire tracks around the pit, a clear indication that the pit had been mechanically excavated, the sand taken away by a dump truck.

On many beaches, we have spotted what we now call foxholes, ephemeral depressions in the beach or dune, the size of a pickup truckload. On the Pacific shoreline of Colombia, we saw a man filling up a horse-drawn wagon with beach sand. The man was using the sand to make ornamental concrete blocks, and he explained that the high tide refilled the holes daily. For him there was no net loss of sand. On the same beach, an elderly man, partially buried in the sand, explained that he did so to cure his arthritis. Since the sand contained some radioactive monazite sand grains, who knows?

In Uruguay, geologist Rob Thieler witnessed a young man filling a horse-drawn wagon with beach sand, and in Sumatra, wheelbarrows were being used (figure 1.4A). On Majuro Atoll in the Marshall Islands, we observed a boy, perhaps ten or twelve years of age, struggling to push a wheelbarrow to the beach where he gathered sand for his father who was building a new home (figure 1.4B).

Flying over the beach fronting the premier beach resort in Ecuador, the Hotel Splaris 25, we witnessed a backhoe loading beach sand immediately in front of the hotel building into a dump truck. In a magazine advertisement from the 1960s, a US automobile manufacturer illustrated the hauling capacity of a new model of dump truck being loaded with sand from a beach at Nags Head, North Carolina.

Not all sand stealing is done on a dump truck or even a wheelbarrow scale. In 2019, a French couple took fourteen plastic jars of spectacularly white sand from Chia Beach in Sardinia, Italy. Taking sand from this famous white-sand beach is illegal, and the couple faced a possible fine of $3,000 and six years in prison (Giuffrida 2019). The discovery of sand stolen by the French couple was unusual only in that it was a larger volume of illicit sand than usual. Apparently, the word didn't get out, and again in Sardinia, in 2020, another tourist was fined more than $1,000 for stealing 4.4 pounds of sand. Local officials at the time said fines ranged from "Sardinian Sand Theft" 3,550 depending on the amount stolen (DiDonato and Kolirin 2020; BBC 2020b).

FIGS 1.4A & 1.4B Examples of small-scale sand-mining operations.

FIG 1.4A Sand mining is done on many scales. Gravel mining on a wheelbarrow scale in Sumatra. Photo © Andrew Cooper.

FIG 1.4B Here in Uruguay a horse-drawn wagon is being filled with sand. Photo © Robert Thieler.

At nearby Olbia airport, bag checks are routinely carried out seeking stolen sand, and over the past ten years, about ten tons of sand, much of it in half-quart bottles, have been seized. With the help of geologists, the sand is returned to the same beach from which it was stolen. Locals at Stintino, another popular beach in Sardinia, are so protective of their beach sand that they have even mulled over banning towels because towels can carry a lot of sand when wet. In Bermuda, the airport has a special security station where bags are searched for beach sand—the beautiful pink sand for which the island is famous. If discovered, it is immediately confiscated.

On Etretat Beach in Normandy, France, an estimated three hundred to four hundred kilograms of pebbles are removed from the beach each year, in spite of signs stating that removal of pebbles is strictly forbidden. The pebbles are valued for use in gardens and decorative walls. On the beach, the gravel is valued because the deposits protect the base of the coastal cliffs, with buildings on top, from erosion. A sign on another Normandy pebble beach notes, "To take one single pebble away would put our shore in danger."

In April 2020 on Zahara de los Atunes Beach near Cádiz, Spain, a very strange form of beach management was carried out. In response to the coronavirus pandemic, a day before Spain allowed children out of six weeks of lockdown, local officials sprayed 1.2 miles of the beach with a bleach solution to make it safer for children's play. That was the end of any living thing on or in the sand, and of course the beach was even too dangerous for children's recreation. A local official, Agustín Conejo, apologized (*BBC News* 2020a).

On St. Lucia Island in the Caribbean, in an effort to keep individuals away from a beach where sand was commonly taken, a sign declared that a number of rattlesnakes had been released near the beach. Whether the rattlesnakes were for real or not, beach visitation and sand stealing were most likely reduced.

Another strange sand-stealing incident occurred in July 2008 at Coral Springs, Jamaica. In a single night, perhaps five hundred dump truck–loads of pristine white beach sand were spirited away to two other beach resorts. Prime Minister Bruce Golding took a personal interest in the sand theft and arrests were made, but charges were dropped when a key witness became unavailable, reportedly due to death threats (Gayle 2011). Forensic scientists used neutron activation analysis to identify sands from the resorts on the receiving end of the stolen sand.

Beautiful white beaches also line the Isle of Tiree in Scotland, which wind surfers called the Hawaii of the North. Midnight sand thieves have hauled away tons of the lovely sand several times in the dark of the night.

In Northern Ireland as early as the 1990s, R. W. G. Carter, David Eastwood, and Philip Bradshaw noted that "small scale sand removal (loads of 0.5 to 10 tonnes) is a persistent environmental problem on beaches within Areas of Outstanding Natural Beauty in Northern Ireland" (1992, 95). They estimated that in 1990 about five thousand to six thousand tons of sand and gravel were "drawn" from eleven beaches in their study area, and they estimated that as much as 80 percent of the shoreline erosion was due to the mining (95). Geologist Andrew Cooper (1997, pers. comm.) recalls that at Portstewart, Northern Ireland, some years ago, a local farmer maintained he had rights to take sand from the beach, so the locals started a resistance group. Every time he came onto the beach with a tractor and trailer, a group of locals blocked the exit with their cars, keeping him trapped there for several hours; he soon stopped.

The problem is worldwide. Sand mining on shorelines is going on in at least eighty countries and on six continents. Most mining of sand from beaches and dunes is probably illegal across the world. It certainly should be. We can't imagine that there is a coastal government anywhere that doesn't recognize the protective and economic value of beaches and dunes. However, enforcement is highly variable and often nonexistent. Money speaks.

One of the largest volumes of sand mined from the ocean in recent years was obtained from the sea floor off the Spratly Islands in the South China Sea. The Spratlys are a cluster of eighteen small islands and more than one hundred coral reefs and cays with a somewhat disputed ownership by the Philippines, Malaysia, Vietnam, and Taiwan. Rather suddenly, new islands have arrived within the Spratlys—islands made of sand dredged up from the shallow seafloor and pumped up on top of coral reefs. These are seven artificial Chinese islands largely built in just two years, more than 500 miles (805 km) from the Chinese mainland. On these islands, China has built ports, airstrips, radar facilities, and numerous buildings, all of which are designed to extend China's military influence and their Exclusive Economic Zones of 200 miles (322 km) into new waters (Sutton 2020). Much to the concern of India, China is also intending to build new islands in the Indian Ocean (Ryapolova 2020).

A strange sand-mining operation was discovered in 2020 by two CNN Business reporters operating in Hong Kong. Lucas Kuo and Lauren Sung discovered a gathering of 279 ships just off the port of Haeju, North Korea. It turns out that this was a shallow water sand-mining operation. This wasn't a simple operation of dredging sand and then steaming off to a new location where the sand was needed. Instead, the operation involved dredging sand, then moving the sand by barge to a second vessel, which then steamed off with its sand load to ports in China. The latter ship was never a North Korean flagged ship but was instead usually registered to China or smaller countries. Apparently between May 2019 and the end of that year, North Korea sent a million tons of sand to China (Berlinger 2020).

It turned out that the operation with the vessel-to-vessel sand transfer was a violation of the UN sanctions on North Korea. Having ships registered in other countries transporting the sand was intended to hide the country of origin of the cargo. So, the illegality of sand commerce extends well beyond the mining operations.

Sand is both a common export and a common import for various countries around the world. The values of exports and imports of sand from all sources are listed in chart 1.1. While these numbers are from 2018, they are likely still roughly in proportion to 2020 numbers.

HOW AND WHY SAND MINING IS DONE

There are four types of coastal beach- and dune-sand mining.

Construction Sand Mining

This is the big one. This type of mining involves complete removal of massive volumes of sand for construction purposes, typically for concrete. It is the most damaging kind of mining. Usually this involves dump truck–scale mining, but it can also involve, as noted above, pickup trucks, donkey carts, and even wheelbarrows.

Mineral-Sand Mining

In this type of industrial-scale beach and dune mining, the goal is extraction of particular minerals from the sand that occur in concentrations usually ranging from 2 to 10 percent of the total sand volume. Commonly mined minerals in beach and dune sand include magnetite (source of iron), ilmenite and rutile (sources of titanium), zircon (source of zirconium), garnet (source of abrasive sand), monazite (source of uranium, thorium, and rare-earth elements), and gold. In Sierra Leone,

CHART 1.1 WORLD'S TOP EXPORTERS AND IMPORTERS OF SAND FOR 2018

Top Sand Exporters	
1. United States	$513 million
2. Netherlands	$201 million
3. Germany	$148 million
4. Belgium	$137 million
5. Australia	$101 million

Top Sand Importers	
1. Singapore	$366 million
2. Canada	$293 million
3. Netherlands	$152 million
4. Belgium	$143 million
5. United Arab Emirates	$112 million

Data from Lauren Kyger, "Wave of Global Sand Trade May Be Depleting Beaches," *TradeVistas*, September 6, 2019.

Namibia, and South Africa, beaches are mined for diamonds, but the concentrations of diamonds are far less than 1 percent.

Separation of the minerals from beach sand involves taking advantage of the fact that most of the desired minerals are much heavier than quartz and feldspar, the common major components of many beach sands. Thus, they are often separated from sand or other minerals by centrifuging, or mixing in a medium-density fluid in a process in which the heavies sink and the lights float, leaving behind much of the original volume of sand. Magnetite can also be separated from sand by its magnetic properties.

Ideally, mineral-sand mining can be much less damaging than mining for concrete aggregate, which can lead to complete removal of beach and dune sand. After ore minerals are removed from the sand, the remaining volume can be returned to the beaches and dunes, allowing their protective role against storms and shoreline retreat to continue.

However, in several instances, this replacement has not been done. For example, in Nagonha, Mozambique, serious storm damage occurred after mineral-mining destroyed inland dunes that were not replaced after mineral extraction (see chapter 9).

Heavy-mineral mining in beach sand is a burgeoning industry, and extraction of rare-earth elements (e.g., lanthanum, europium, tantalum, and erbium) in monazite sands leads the way. Monazite is a rare-earth phosphate of highly variable composition. Rare-earth elements (REE) are used in cell phones, computers, and many other applications.

Ancient coastal sands containing these heavy-mineral deposits are just as valuable as present beach and dune deposits. Early sand-mining operations in central Florida took place in such ancient deposits. At the time of this writing, controversy was swirling around a proposed mining operation in the Trail Ridge deposits of Georgia that could potentially have detrimental effects on the famous Okefenokee Swamp.

AD HOC MINING

The third and usually the least damaging category is small-scale, nonindustrial mining carried out by individuals, usually illegally. Sometimes called artisanal mining, ad hoc mining is widespread, occurring in about eighty countries and employing thousands of people. Some of the so-called miners are hobbyists, while others may be supplementing their income or eking out a living.

Commonly in ad hoc mining, the sought-after mineral, such as native gold, is a minor part of the beach and dune sand. The problem with gold is that extracting the element from a separated concentrate usually involves using either mercury or cyanide, exposure to which can lead to serious health problems for those involved in the separation process. The mercury or cyanide also can pollute the environment. Other mined, ad hoc minerals include a variety of gemstones such as garnets, epidote, rutile, emeralds, and even diamonds.

BEACH NOURISHMENT

The fourth major type of coastal mining is taking sand to rebuild beaches, to provide a recreational beach, and to protect shorefront development and infrastructure. Commonly, sand is dredged from the adjacent continental shelf and pumped up onto the beach, essentially creating an artificial beach. Sometimes sand is trucked in to the beach from an inland source, and sometimes bulldozers simply move sand from the lower beach to the upper beach and dune in a process called *sand scraping*. As a rule, artificial beaches fail to simulate natural conditions, and their rate of loss by erosion is much greater than that of natural beaches. Sand lost from an artificial beach, usually because of storms, is lost in a seaward direction and spread out in thin layers over the continental shelf, no longer in thick deposits that can be mined for beach nourishment. In other words, just like construction sand, nourishment sand cannot be used more than once.

SEA LEVEL RISE

Rising sea levels and the resulting damage are two major reasons that we should stop coastal sand mining. The level of the sea is rising at an ever-accelerating rate. A multiauthored 2021 *Scientific American* article notes that the climate emergency has arrived (Ripple et al. 2021). The year 2020 was one of the warmest years ever; record-setting forest fires occurred in the western United States and Australia; temperatures exceeding one hundred degrees Fahrenheit occurred in Siberia; Atlantic hurricanes caused $46 billion in damage; and floods and landslides forced twelve million people to leave their homes in South Asia. Among the strongest indications of increasing sea level, visible to coastal dwellers, are lines of dead trees along the seaward margins of the coastal plain. The trees are killed by saltwater intrusion, or the roots may be drowned by rising freshwater tables pushed up by rising sea water. Another prevalent sign of rising seas is the sunny-day flooding (sometimes called nuisance flooding) occurring when the highest high tides are pushed even higher by sea level rise that has already occurred. King tides, the highest of these so-called sunny-day floods, can be particularly damaging, especially where the natural protection from dunes is long gone due to mining or development. In most affected communities, these tides are announced in local papers because they are more than just a nuisance. Periodically flooded streets are a hazard, services may be disrupted, businesses may need floodproofing, access to cars may be difficult, and property values sink.

A summary of recent studies in *Science* magazine indicates the acceleration of sea level rise is real and is probably on the order of 4.8 millimeters per year (figure 1.5). This latest estimate includes satellite data that is not affected by fluctuations in the level of land areas. The acceleration is assumed to be caused mainly by the recent rapid melting observed in the Greenland ice sheet. The level of the sea is expected to

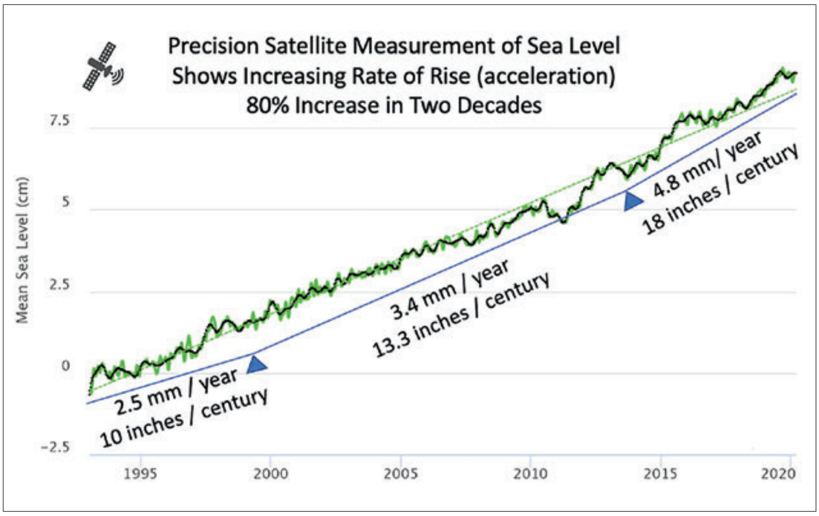

FIG 1.5 Generalized sea-level curve for the quarter century from 1995 to 2020 published by John Englander. The data are from open-ocean satellite observations and clearly show a significant acceleration (>doubling) in the rate of sea level rise. The observed rates of ice sheet melting in both the Arctic and Antarctic indicate that this rise of the sea will continue to accelerate. Sea level rise is a major factor behind the increased environmental impact of beach and coastal dune mining (e.g., coastal erosion) and is a driving force in the abandonment of coastal settlements. Graphic from John Englander, *Moving to Higher Ground: Rising Sea Level and the Path Forward* (Boca Raton, FL: Science Bookshelf, 2021). Data points from CNES, LEGOS, CLS www.aviso.altimetry.fr/msl; trendline overlay by Rising Seas Institute/John Englander. Courtesy of John Englander.

be three or four feet higher than at present by 2100. The maximum rise could be six feet or more.

On gently sloping coastal plains, such as those that line the eastern United States and Gulf coasts, a single foot rise in sea level can, in theory, push back the shoreline a couple thousand feet. In fact, on the Outer Banks of North Carolina the slope is so flat that a one-foot rise could, in theory, push the shoreline back two miles.

As the sea rises on a natural sandy shore, there will always be a beach of some sort, but it will have moved landward. Since it takes time for sand to blow or wash ashore and accumulate, the new beaches and dunes that form along the new shoreline landward of today's position will likely be smaller than present-day beaches and dunes.

Efforts to hold shorelines in place with seawalls and beach nourishment (which in essence is a form of mining) are costly and are done primarily to protect shorefront development. A problem is that hard structures such as seawalls do not address the processes that cause shoreline erosion; thus, erosion continues and may even speed up after wall emplacement. Seawalls can effectively hold back the sea for a while, but the price is the eventual loss of the beach. When beach communities become beachless, tourist dollars disappear, much like the protective dunes did.

Storms, working in conjunction with sea level rise, make the prohibition on mining protective coastal sand dunes and beaches all the more important. The 2020 Atlantic hurricane season shattered many records, reflecting the major global intensification of storms. Global warming of the ocean, a response to atmospheric warming, is the principal villain. In 2020, twelve hurricane landfalls exceeded the old record of nine in 2016. For the first time since record-keeping began, Category 5 storms have occurred in the Atlantic Ocean for five straight years:

2016	Matthew
2017	Irma and Maria
2018	Michael
2019	Dorian and Lorenzo
2020	Iota

The change in hurricanes is reflected in these big five variations:

- increasing intensity
- increasing frequency
- increasing size
- moving slower (extending time of hazard)
- increasing rapidity of change from tropical storm to hurricane

IMPACTS OF BEACH AND DUNE MINING

Sand mining in coastal regions and describing the extreme damage it causes to coastal processes, to nearshore landforms, and to the ecosystem is the major point of this book. Beach and dune mining are greatly increasing the potential impacts of sea level rise on a global scale. The sea-level-rise response (and hence the impacts of mining) of different shoreline types will vary depending on many factors, including the slope of the land (greater erosion rates on flatter land surfaces); the size of sand grains on the beach; typical wave energy (measured by wave height); the frequency and magnitude of storms; the size of dunes; and the volume of the natural incoming sand supply.

Sea level rise and the ongoing intensification of storms will significantly magnify the impacts of beach and dune mining described here.

BIODIVERSITY

Extensive habitat loss for globally important species both onshore and offshore is inevitable. Loss of beaches and dunes affects various ecosystems, nesting and spawning areas, and food sources, especially those of shorebirds, sea turtles, and surf-zone fish that depend on the sand in one way or another for their continued existence.

The Awaaz Foundation and Bombay Natural History Society (2013), the former founded by environmental activist Sumaira Abdulali of Mumbai, state that sand mining is a largely unacknowledged but major threat to biodiversity, particularly in beaches and rivers, in many parts of the world. These two organizations have encouraged governments and the United Nations to perform studies and research on the detrimental effects of sand mining on coastal and riverine ecosystems and biodiversity. They also relate that an international protocol on sand mining is needed, as no coherent policies are currently in place.

Nelson Rangel-Buitrago, a coauthor of this book, explains that dune-sand mining can be threatening to the very existence of plant species. The endemic La Hierba de El Tabo dune plant (*Astragalus trifoliatus*), found on the Las Cruces dune system (Valparaiso region—central Chile), has a limited range. As a consequence, it is seriously threatened and in danger of extinction because of dune mining which in Chile is perfectly legal.

Further, an unsettling ecological consequence of illegal sand mining, pollution, and development is the possible extinction of a rare species of Acacia tree, the *Vachellia bolei*, in southern coastal India (Kumar, Kathiresan, and Arumugam 2019). A separate report by Matt Davis (2019) decries the effects of sand mining on wildlife. The gharial crocodile in India, for instance, is on the brink of extinction, partially due to sand-mining practices that have destroyed its nesting sites, and the Ganges River dolphin appears in danger of extinction, as well.

BEACHFRONT PROTECTION

Beach and dune mining–related damage to beachfront development includes loss of protection from storm waves and tidal flooding and from extreme events like exceptional storm surges and tsunamis.

SALINIZATION AND WATER QUALITY

The loss of dunes may alter the freshwater table, allowing salt pollution of the freshwater supply due to seawater intrusion (salinization). Sand mining can cause the accelerated penetration of saltwater inland to make agricultural and timber lands along the shoreline, especially along the shores of bays and lagoons, useless for farming. As an example of the effects of saltwater intrusion, salinization of groundwater has made at least 25 percent of North Carolina's Hyde County agricultural land adjacent to Pamlico Sound useless and has contaminated a number of freshwater wells. Life in the sea is also disturbed by beach and dune mining, which can increase water turbidity in the near-shore ocean and affect filter-feeding organisms.

EROSION RATES

Land loss rates related to mining will increase on both developed and undeveloped shorelines, threatening infrastructure such as transportation systems, pipelines, wastewater treatment systems, communication systems, and farm lands. On purely natural undeveloped shorelines, beach erosion means shoreline retreat and land loss, but beaches and dunes, while changing in shape and size, will always be there on sandy shores.

TOURISM

Mined beaches and dunes cause the loss of quality tourism and coastal aesthetics, leading to a strong negative economic impact on local communities. For instance, in Morocco, sand mining has stripped some beaches of sand, leaving behind beachless rock outcrops. Because of this, tourism has drastically changed for large segments of the Moroccan shoreline.

CORRUPTION

Beach- and dune-sand mining, which is commonly illegal, has had a corrupting effect on many local governments. Among other things, this has resulted in the emergence of local sand mafias, who sometimes resort to violence to protect alleged mining rights. Resistance to antimining laws is especially strong in India and Southeast Asia. Corruption begets corruption at all government levels, and corruption in the sand-mining business begets violence, which we will explore in chapter 4.

BEACH INFRASTRUCTURE

Sand mining can also damage or destroy seawalls, breakwaters, and groins. Alternatively, removal of beach and dune sand can lead to a need for hard stabilization, such as seawalls, the use of rubble, or sandbags, further damaging beach aesthetics and touristic value, and further disrupting natural beach processes.

SAND — A NONRENEWABLE RESOURCE

Mathematicians at the University of Hawaii calculated there are 7 quintillion, 500 quadrillion grains of sand on earth (Krulwich 2012). Although intuitively it may seem otherwise, sand, at least useful sand, is not a limitless resource. The following chapters explore the many aspects of sand mining's impact on beaches and coastal dunes, including problems that may seem too far from the shore to matter. In addition, solutions are sought to the quandary posed by this resource that seems so abundant yet is limited by its properties to high-demand uses and that is essentially nonrenewable and subject to unsustainable current mining activity.

SAND

CH.02

Earth's Most Remarkable Mineral Resource

Sand is found almost everywhere on the globe, and we can't get along without it. We interact with sand in many ways, particularly on beaches and coastal dunes where this resource is much appreciated by all. We play on beach sand, and we rely on coastal dunes to protect our housing and amusements that are (foolishly) built next to shorelines. Unfortunately, the world is now using fifty billion tons of sand a year, far more than the rate of replacement by natural processes. Because a shortage of sand useful for construction exists globally, we attempt to alleviate the shortage by taking ever-increasing amounts of sand from rivers, ocean beaches, and dunes.

Sand on beaches and coastal dunes comes from a number of sources. Ultimately, sand at the coast gets there by rivers that flow to the sea, but it is more complicated than that. On a mountainous coast like California, sand flows directly from a river to the beach. Sand-trapping dams on California rivers often lead quickly to a cutoff of the sand supply to beaches and a rapid increase in the rate of shoreline erosion. Erosion of bluffs on rocky coasts and erosion of material originally brought to areas by glaciers, as found in the northern hemisphere, are also major sources of beach sand.

On coastal plains of the East Coast and Gulf Coast of the United States, most rivers flow into quiet bays and lagoons rather than directly to the beach. Tidal currents may bring some of that sand from the bay to the ocean shoreline, but much of the sand deposited by rivers into quiet waters may be incorporated into the beach only when flushed out by flooding, or when sea level rise causes the shoreline to move landward and catch up with the sand stored in the bay. In other words, California rivers contribute sand to the beaches on a daily basis, but coastal-plains beaches may capture their river sand only after a long period of time has passed.

Once sand makes its way to the beaches, a whole new set of processes takes over. Sand is moved up and down beaches by longshore currents formed when breaking waves hit the shoreline at an angle, carrying sand laterally from beach to beach. For example, along the southeastern US Atlantic shoreline, summer currents generally carry sand from south to north. In the winter, the dominant direction reverses as winter winds and waves change direction, causing sand on beaches to move predominantly from north to south. Storms often remove sand offshore from beaches, and big storms can carry sand completely across the continental shelf. Or beach sand can be lost onshore by wave overwash or to the dunes by the action of winds. Sometimes fair-weather waves bring sand back to the beach from offshore. The processes of beach and dune evolution are complex and highly variable on different beaches.

The sand supply to beaches around the world has been reduced, largely due to activities of humans. On rivers, dams capture sand as it moves downstream, and the mining of river sand, a very damaging process, reduces the sand supply to beaches (see chapter 5). Mining beach sand almost inevitably causes erosion problems on adjacent beaches. On St. Lucia Island in the Caribbean, a river delta is being mined to obtain sand for a horse racetrack, and the mining has reduced the sand supply to adjacent beaches, causing serious erosion. There are a thousand stories around the world with the same plot.

Sand is a size term, independent of mineralogy or shape. Beach sand is made up of a wide variety of mineral grains that have weathered out of rocks exposed to the atmosphere, usually from source rocks many miles from the shoreline. On most US beaches, as well as along the coasts of Africa and much of South America, the dominant mineral is quartz, but on Caribbean Island beaches, shell and coral fragments may be the dominant sand-sized component. On volcanic islands, sand-sized fragments of black lava rock may dominate the beaches.

MINERALOGY OF BEACH SAND

The two most common minerals in the crust of the earth are quartz and feldspar, both formed at high temperatures. Feldspar is a mineral group made up of ten different aluminum silicate species with the addition of some combination of potassium, calcium, and sodium. Quartz is a clear, colorless, glass-like mineral with the simple chemical composition of silicon dioxide (SiO_2). Although feldspar is more abundant overall than quartz in the earth's crust, the reverse is usually true in beach sand. This is because feldspar sand grains are less resistant than quartz to weathering of source rocks, and its grains may also break up during transportation by rivers, wind, and ice from the source to the beach. Feldspar breaks on planes of cleavage along which fracturing can occur. Quartz has no such cleavage planes and is a very hard and chemically stable mineral. While feldspar grains can appear as white, pink, gray, or darker colors, quartz grains (normally colorless) in beach sands often can be yellow-brown in color due to iron oxide staining the grain surfaces. Generally, in beach sands, feldspar and quartz are very difficult to distinguish with the naked eye.

The sand derived from the source rocks starts out as a wide variety of minerals. As the sand is slowly, over thousands and even millions of years, transported by rivers to the coast, some of the minerals disappear as a result of breaking up (abrasion) and, even more important, by chemical destruction (weathering) of the individual grains. By the time the sand reaches the beaches, especially after long transport from continental interiors and across wide coastal plains as in North and South America, the relative abundance of minerals is completely reversed, and the color usually changes from dark to light as quartz grains become dominant.

The original minerals from the source rocks (other than quartz and feldspar) that survive the trip to the beach commonly make up less than 5–10 percent of the total grains on the beach and rarely up to 50 percent. These mineral grains are sometimes concentrated into black-colored sand layers on beaches, often mistaken for oil spills. These layers are made up of heavy minerals, so-called because they are mostly heavier than the more abundant quartz grains. On the beach, the black, heavy sand is separated from the light minerals by the sorting action of both winds and wave swash that moves the light quartz grains, leaving the darker, heavier sand concentrated into distinct layers. The black color is often due to relatively high concentrations of the minerals magnetite and ilmenite.

Occasionally the patches of heavy mineral sands on beaches may be so well segregated from quartz grains by winds and waves that the patches at the surface of the beach are dominated by a single mineral. Garnet and rutile concentrations may produce a red-to-purple sand, while epidote and olivine produce green sands. Papakolea Beach, the famous green sand beach on the Big Island of Hawaii, is made up of olivine, a volcanic mineral. In this case, the entire beach is green, not just a heavy mineral patch. This beach requires a hike to get there — and removing even small samples of sand from this beach and some other unique beaches in the world is illegal (Love Big Island 2021).

Some components of beach sands are economically valuable minerals, including ilmenite and rutile, which contain titanium (mined in Queensland, Australia); monazite, which contains rare-earth elements (Orissa Beach, India); magnetite, a source of iron (West Coast of North Island, New Zealand); and garnet, used in sandpaper (Tamil Nadu, India). A number of these minerals, when larger than sand size, are precious stones used in jewelry, including epidote, garnet, rutile, staurolite, topaz, tourmaline, and zircon. Native gold is found in some beach sands (Nome, Alaska), but because the particles of gold are soft, they do not travel far from gold-bearing rocks. Diamonds are a rare component of some beaches located near diamond-bearing rocks (Namibia).

The relative weight of minerals is measured by specific gravity which compares the mineral weight to water, which is given a value of 1. Anything with a specific gravity of less than 1, such as wood, floats. Everything with a specific gravity greater than 1 sinks. Specific gravities of sand grains are a factor determining how they react to beach processes. Specific gravities are listed in tables 2.1 and 2.2.

HEAVY MINERALS AT WAR

Heavy minerals, because of their large variation of mineral species in typical beach sands, are fingerprints in the sand that tell its source. In fall 1944, Japanese unmanned balloons began flying into western US forests. The balloons transported incendiary bombs that were intended to start fires wherever they landed. Many of the balloons reached the Pacific Northwest, although others were scattered from Hawaii to Michigan and from Northern Mexico to Alaska. In total, six thousand balloon bombs were sent across the Pacific.

A number of forest fires were started, and a special crew of smoke-jumpers was organized to meet the new threat. The crew was an all-black paratrooper unit, the first of its kind.

TABLE 2.1 COMMON LIGHT MINERALS IN BEACH SANDS WITH SPECIFIC GRAVITY OF 2.7 OR LESS

Mineral	Color
Mica	
Muscovite	clear, shiny, sparkly
Biotite	black, shiny
Quartz	clear, gray-brown, yellow stains
Feldspar	
Plagioclase feldspar	light-to-dark colors
Orthoclase feldspar	light color, some pink-to-red
Shell fragments	various colors

Based on wind patterns, it was correctly assumed that the balloons were from Japan. But wartime censorship required that no publicity be given to the threat so the Japanese would not know the success of their balloon endeavor. As a result of the secrecy, on March 5, 1945, a Sunday school class on a fishing trip near Coos Bay, Oregon, ran across one of the balloons and began examining it. The bomb exploded, killing five youngsters and the wife of the minister. These were the only human casualties of the Japanese balloon attacks.

The ballast used in the balloons was sand, the character of which (wave-rounded shell fragments) indicated it was a beach sand. There were no coral fragments, indicating it was probably from the north of Japan. The sand contained no minerals that characterized granite fragments and instead was dominated by volcanic minerals. With the added information gained from microorganisms in the sand, the source was narrowed down to two Japanese beaches. Aerial reconnaissance found the culprit, a hydrogen factory on one of the two suspected beaches, and subsequent bombing wiped the facility out, so ending the Japanese fire-balloon program (Crelling 2015).

FINGERPRINTING SAND SOURCES

The methods used in World War II to trace the origin of ballast sand in the Japanese balloons could also be used to trace the origin of construction sand. Erik Klemetti (2020) suggests that the time has come to start

TABLE 2.2 COMMON HEAVY MINERALS IN BEACH SANDS (HEAVIER THAN QUARTZ)

Mineral	Specific Gravity	Color
Water	1.0	
Quartz	2.0	Clear, gray-brown, yellow stains
Feldspars	2.6	Light-to-dark colors
Amphiboles	2.9–3.6	Dark green, black
Epidote	3.4	Yellow-green, green
Garnet	3.5–4.3	Red, pink, purple
Ilmenite	4.8	Black
Kyanite	3.6	Gray, blue
Magnetite	5.1	Black
Monazite	6.0	Reddish brown
Olivine	3.3–4.5	Green
Pyroxene	3.0–4.0	Dark green, black
Rutile	4.3	Red, black
Sillimanite	3.4	Colorless, white, gray
Staurolite	3.8	Brown
Topaz	3.5	Clear, gray, yellow, blue
Tourmaline	3.0–3.5	Black, green, pink
Zircon	4.6	Colorless, brown
Gold	19.0	

fingerprinting sand sources, legal and illegal, and building data bases that can be used to track illegal mining. Such tracking could be done from loose sand samples as well as from concrete samples (Geological Society of America 2020).

Heavy Minerals as Detectives

Using sand for forensic purposes must be done carefully by experts in the field. A few years back, a teenager in Hillsborough, North Carolina, was arrested for breaking into a house and robbing it. A study by a police laboratory determined that the sand and mud from the floor of the house matched exactly the sediment on the youth's shoes. That was true enough. However, a geologist from the University of North Carolina testified that the same sandy mud with the same sand-size minerals was found locally over hundreds of square miles. The young man was freed.

THE SIZE AND CHARACTER OF SAND

Grain Size

Grain size is perhaps the single most important descriptive characteristic of sand grains. Size is described by either the mean, mode, or median size of all the grains in a sand sample. Commonly, sand-grain size distribution is measured by using sieves of varying sizes of mesh or screens. The size scale known as the Wentworth scale shown in table 2.3 is used to describe size categories (Wentworth 1922).

The variations in size of sand are due to two things. First, the original size of the grain that weathered out of the parent rock many miles away from the beach is important. Source rocks of preexisting sediments (sedimentary rocks) can be made of fine-to-coarse sand, while igneous granites and metamorphic gneisses may have large or small sand-size crystals that will weather out to become sand grains. Lava may furnish few and typically tiny grains, while sediments deposited by glaciers may range in size from mud to huge boulders.

The second factor that determines grain size on beaches is the nature of the process that carried the sand to the beach. Along much of the US East Coast (mid-to-south Atlantic) and the Gulf of Mexico shorelines, the sand ultimately comes from relatively slow rivers cross-

TABLE 2.3 THE WENTWORTH SCALE OF SEDIMENTARY PARTICLE SIZE INCLUDING SAND GRAINS

Class	Size in millimeters	Description
Boulder	>256	too big to carry
Cobble	64–256	bigger than grapefruit
Pebble	4–64	skipping size
Granule	2.00–4.00	peas
Very coarse sand	1.00–2.00	lentils
Coarse sand	0.50–1.00	very coarse sugar
Medium sand	0.25–0.50	granulated sugar
Fine sand	0.125–0.25	fine sugar
Very fine sand	0.0625–0.125	super-fine sugar
Silt	0.0039–0.0625	dust
Clay	<0.0039	invisible grains

SOURCE: Wentworth 1922.

ing a flat coastal plain. Therefore, beach sands there tend to be fine to coarse, with few particles as coarse as pebbles, except for shells (figure 2.1). Cobbles and even boulders are brought directly to the beach from fast-moving mountain streams or from the collapse of coastal cliffs. Along the Maine coast, glaciers during the Ice Age extended to and beyond what is now the shoreline, and they left behind a great variety of materials on the beach, ranging from clay to boulders.

The difference in size of beach and dune sands is another example of the importance of the power of the process that transports sand to its site of deposition. Dune sand is transported and deposited by wind. Sand on beaches is deposited and worked on primarily by ocean waves and currents, and to a lesser extent by wind. The forces of ocean waves are more powerful than the wind alone and can move larger grains, so wind-blown dune sand is invariably finer grained than sand on the adjacent beach.

FIG 2.1 All the materials on beaches are not sand grains. Waves and currents sometimes concentrate shells in patches called shell hashes like this one on Shackleford Banks, North Carolina. Sometimes shelly beaches are created by beach nourishment activities that dredge up sediment that is coarser or finer than sand-sized particles. Shelly beaches do not make good swimming areas and tend to discourage use by tourists but not shell hunters. Photo by Norma Longo.

SORTING

Sometimes called grading, sorting is another important measure of sand character and is a measure of how widespread the different sizes of individual sand grains are in a single sample. Dune sands tend to be very well sorted, while the grain sizes of beach sands are, as a rule, more variable or not as well sorted.

ROUNDING

Surprisingly perhaps, the shape of individual sand grains plays an important role in determining how the sand will be used. In the construction business, grains that are irregular in outline are preferred in concrete mixes because the grains will contact one another and lock together to make a stronger concrete.

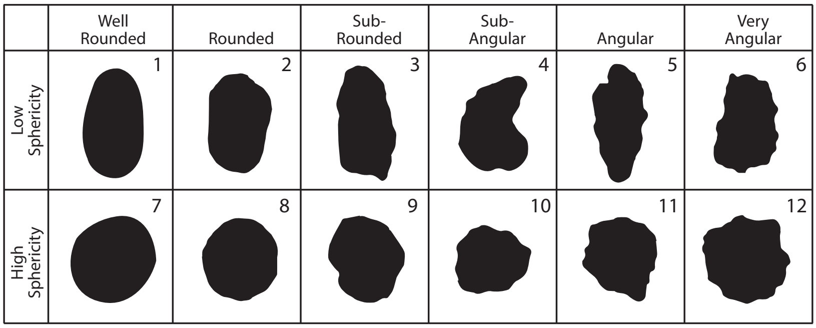

FIG 2.2 The Powers Roundness Scale provides a visual basis for determining both roundness and sphericity of sand grains. Roundness is a measure of the smoothness of the edges of a sand grain. Sphericity is a measure of closeness to a sphere shape. The grain in the upper right corner is the most angular, and the grain in the lower left corner is the most spherical, as well as most rounded. Source: United States and Canada Obsidian Source Catalog, http://www.sourcecatalog.com/terminology/terminology.html. Modified from Powers 1953.

Roundness is defined by the curvature and smoothness of the edges and corners of grains. The roundness is generally determined by comparison of grains with charts showing grains with a range of roundness based on the Powers Roundness Scale (figure 2.2), named after the geologist who formulated it (Powers 1953). Abrasion reduces sharp corners and edges, rounding the grains. So, well-rounded grains reflect a long history of abrasion.

SPHERICITY

Sphericity is defined as the extent to which a particle resembles a sphere. Note that a grain can be well rounded without being spherical. Sphericity is measured by comparing grains with a standard silhouette chart showing standard degrees of sphericity.

The original shape of a sand grain as it weathers out of the mother or source rock usually plays the major role in determining sphericity. As noted, roundness or the smoothness of corners is more a function of abrasion as a grain bounces up against other grains during transportation. Sand-size grains are assumed to round faster by wind abrasion than by abrasion in water because water provides a cushioning effect of grain-to-grain contact that is absent for grains suspended in the wind. The assumption that all desert sands have high roundness and high sphericity is based on the idea that these sands have been in the desert for so long geologically that they are at the ultimate endpoint of wind abrasion (figures 2.3A and 2.3B).

OTHER DESCRIPTIVE TERMS

Turbidity (muddiness) is a measure of the amount of *fines* (silt and clay) in a sand sample. *Solubility* is a measure of the potential for some particles to dissolve over time in water. Carbonates, such as fossil shell fragments and salts, are often susceptible to dissolution, but quartz is insoluble in most geologic environments. Silica sand refers to sand made up mostly of quartz with very little turbidity. Manufactured sand is made from crushed rock and is very angular. Clinker refers to kiln-baked, lime-based aggregate particles. Other related terms used by engineers to describe sand grains include *grain roughness*, *circularity*, and *cylindricity*.

PEBBLES, COBBLES, BOULDERS

The term *beach* conjures up images of long, sandy coastal reaches, but beaches can be composed of coarser sizes — gravel (usually pebble sizes), cobbles, and even boulders. Beaches made of cobbles and boulders are found in New England, where the Ice Age glaciers dumped their loads, and along the West Coast, where mountain streams bring big particles directly to the beach in floods.

These coarse materials are themselves valuable resources. Their concentrations on beaches in some locales, plus available coastal access, have led to their mining since the earliest days of sailing ships. Pebbles and cobbles are widely used in landscaping to line patio and walkway borders and flower gardens, among many other things. Boulders may be close at hand to build shore-hardening coastal engineering structures. Some of the earliest seawalls, revetments, and groins were simply piles of boulders or cobbles. In New England, breaking waves and even the wind in big storms can pick up and throw cobbles and pebbles landward against beachfront buildings, like shot from a cannon.

Early sailing vessels used large cobbles as ballast. Ships traveling from the Old World carried ballast and then left it ashore in the Americas where the stone was found to be useful in paving streets or in build-

FIGS 2.3A & B
Microscopic comparison of desert dune and beach sand (photos are not at the same scale).

FIG 2.3A Well-sorted desert sand from the Gobi Desert. Close examination of the photo indicates that almost all the grains are well rounded, and a smaller but still high percentage are highly spherical, which is believed to be typical of desert sand grains. Highly spherical sand grains make weak concrete. There is a universal assumption that all desert sand grains are spherical and thus are useless for concrete aggregate. This seems geologically unlikely, so perhaps in the future some desert sand will be useful for construction. Photo © Siim Sepp, via Wikimedia Commons, CC BY-SA 3.0.

FIG 2.3B Beach sand from near Puerto Vallarta, Mexico. These sand grains are clearly more angular and less spherical than the grains of sand from the Gobi Desert. This poor-to-moderately-sorted beach sand is much more suitable for concrete aggregate than the desert sand because irregular grains tend to lock into one another and make a stronger concrete. Superior grain shape is the principal reason that beach, coastal dune, and river sand are in demand. Photo by William Neal.

ing construction. The freed-up space on the ships from ballast removal made way for the valuable cargoes they carried back to their home ports. Piles of discarded ballast rocks have been found in marshes, on some lagoon beaches, and on the continental shelf along the US East Coast, and some found in Georgia's salt marshes have actually been used as home sites. The composition of discarded ballast cobbles provides geologic clues to the shipments' ports of origin.

Just as sand does on beaches and dunes, pebbles, cobbles, and boulders on and near beaches play an important part in coastal evolution.

SAND USES: WHY THERE IS A GLOBAL SHORTAGE

Everyone, whether they recognize it or not, is in almost constant contact with sand or the products made from sand in their daily lives (see chart 2.1). The most common of all sand-based materials is concrete, but other less-apparent materials also depend on sand. For example, the petroleum for our fuel is often extracted by use of fracking sands, construction mortar contains sand, the landfill some buildings sit on is likely to be sand, and the computer chips in our electronics are based on silica sand. In all of its various forms, sand is something we cannot exist without, just as we can't exist without honeybees!

SAND-USE VOLUME NUMBERS

The global volume of sand use is around fifty billion tons annually. Most of this is used in concrete. And a real shortage of sand for construction purposes exists. For this reason, the sand from rivers, beaches, and coastal dunes is now a prime source of sand for construction, even though this often damages the ever-important tourist industry, diminishes the storm protection provided by these coastal sand bodies, and destroys large ecosystems.

At best, most of the volume estimates listed below are approximations or even orders-of-magnitude numbers. There are wide variations in estimates from different sources. Suffice it to say that the volume of sand used by humans each year is immense.

World Aggregate—40 billion tons per year, mostly for concrete (both sand and gravel)

US Aggregate—970 million tons in 2018

CHART 2.1 SAND USES, LARGE AND SMALL

Aquaria

Artificial islands (Dubai, South China Sea) **

Asphalt

Beach nourishment **

Brick manufacturing

Computer chips

Concrete and other construction uses **

Equestrian sand

Fracking **

Geotextile seawalls

Glass manufacturing

Golf courses

Highway nonskid surfaces

Landfills (Singapore, Boston, New York) **

Metal casting

Mortar

Railroad (improve traction)

Recreation (volleyball, sandcastles, etc.)

Road construction

Sand casting (foundry sand)

Sandbags (floods, erosion, military)

Sand blasting

Solar panels

Water filtration

**Very large volumes

Beach Nourishment Sand in the United States (total over five decades)—1.275 billion cubic meters or about 1.912 billion metric tons

Concrete—10 billion tons produced in the United States every year

Concrete Sand—globally more than 8 billion tons per year

Sand Use Globally—all uses, perhaps 50 billion tons of sand annually

Landfill Sand—Artificial islands in Dubai amounted to more than 350 million tons. Other large landfilling and land-building projects include those in Singapore, Hong Kong, China, and various coastal cities (New York and Boston). Note that these projects are primarily coastal and/or offshore in the marine environment—all impacting beaches, directly or indirectly.

Fracking—In 2014, 95 million pounds of frac sand were used in the United States. Typically, about 2,500 tons (1,600 million cubic meters) of sand are used in a single gas-well development project.

THE BIG USERS

AGGREGATES

More sand is used for concrete aggregate than for any other purpose. *Aggregate* is a generic term for crushed rock, sand, and/or gravels in concrete and asphalt, which can be subcategorized by formation process (natural or manufactured), composition, and grain size distribution. Sandy gravels also are commonly used for gravel roads. Manufactured aggregate is created by crushing rock or concrete debris or other wastes from industry. Sintered (heated) bauxite is sometimes used as a sand substitute in aggregate.

BEACH NOURISHMENT

Globally, artificial nourishment of beaches is the main engineering response along eroding ocean shorelines. America's reliance on such nourishment is well documented in terms of the amounts of sand used since the mid-twentieth century and the sand sources used. (See chapter 8.) Artificial beach construction and maintenance are used to slow down erosion, protect beachfront buildings, and provide recreational beaches; but as the sea level rises, beach nourishment will become prohibitively costly.

FRACKING

Hydraulic fracturing (fracking) involves pumping some combination of loose sand, water, a viscous gel, and other chemicals down a deep well at high pressure for the purpose of opening up fractures in reservoir rocks, especially shales, that hold gas and oil. The fractures allow the escape and eventual capture of oil and natural gas. Accurate estimates of the volumes and tonnage of materials (including noxious chemicals) used in fracking suffer from the operational secrecy of the oil and gas industry. Amounts of sand used in fracking can be estimated from industrial statistics and from volumes of sand extracted at source-rock mines. Between 1990 and 2012, 119 million metric tonnes of sand were used for fracking in the United States, at an average rate of 5.4 million metric tonnes annually. Each shale gas well on average used around 2,500 tons (1,600 million m^3). Wells not drilled in shale sometimes use as much as 1,500 tons of sand (975 m^3), and large shale gas wells may use as much as 25,000 tons of sand (16,250 m^3) (Blum 2017; Rowell 2014).

Particles used in fracking are called proppants. Sand is by far the most common proppant, but ceramic beads—quartz grains treated with resin, bauxite, and a variety of other materials—are also used. The petroleum industry prefers grains shaped like spheres for fracking of gas-bearing shales. Such grains work better than irregular-shaped grains because these will flow through rock fractures with the fracking fluid more easily than irregular-shaped grains. So, presumably desert sand will do fine for fracking.

High-silica sand (sands with almost exclusively quartz grains) is generally considered the best for frac sand. Low turbidity and strong resistance to crushing (quartz sand grains are the best in this regard) are also important. In the United States, major suitable sands (spherical and 99 percent quartz) come from the Ordovician St. Peter Sandstone in Minnesota, Illinois, Arkansas, and Missouri. The Cambrian age Jordan Formation is another major source. Both formations are widespread through the Midwest. These ancient sandstones reflect millennia to millions of years of reworking in a variety of environments with abrasion that removed nearly every mineral except the quartz grains and wore them down into their state of roundness and sphericity. Because the transportation costs are the principal cost of sand, new sources for mining fracking sand are being developed near drilling locations, usually within a few tens of miles. In all cases, most sand used in construction, and often in fracking, is the nearest, cheapest sand.

Fracking has greatly increased the amount of natural gas production in the United States but at an environmental price. Risks of fracking include ground- and surface-water contamination, and even the triggering of earthquakes.

DESERT SAND

In a global sense, there is no shortage of sand on Earth. Many billions of tons of sand exist in the world's great deserts including the Sahara, Gobi, Sahel, Kalahari, and Atacama deserts. The Sahara alone covers an area larger than the size of the continental United States, but this desert sand is too distant from most construction sites to be economically feasible for use in concrete.

Also, a widespread assumption is that desert sand is useless for concrete because it is too spherical and too fine (small). "The concrete and reinforced concrete industry has refrained from using desert sand. The reasons for this are the rounded form of the particle, its grading [sorting] and its chemical composition" (Neumann and Curbach 2018, 1).

In Dubai, desert sand has been observed to make lousy sand traps in golf courses because the well-rounded and spherical grains allow golf balls to sink in the sand traps! For one local Dubai golf course, sand was obtained from North Carolina. The Burj Khalifa building in Dubai, the world's tallest, used sand imported from Australia in its concrete rather than the nearby, abundant desert sand. Volleyballs also behave differently in desert sand.

There is some physical evidence that concrete made with spherical grains is not as strong in certain regards as concrete made with more angular grains. In one investigation, a concrete aggregate made of spherical dune grains was compared with a concrete with aggregate of angular, crushed sand grains. The compressive and tensile strength of the spherical sand concrete was reduced by 50 percent compared to that of the angular aggregate concrete (Neumann and Curbach 2018, 2).

Clearly, the angularity of desert sand needs investigation. A company seeking sand for concrete should investigate the sands at various dune sites within reasonable distance from the construction site and choose the site with the least spherical sand. The widely held, questionable, and global belief in the uselessness of desert sand as concrete aggregate has led to considerable research effort into finding a replacement material and undoubtedly led to intensified mining of beach and coastal dune sands.

Note that not all dune sands are created equal. Coastal dunes are derived from the adjacent beaches and have virtually the same ultimate source and history as the beach sand. Desert dunes usually occur in dune fields or sand seas (ergs) that have endured for long periods during which persistent reworking (abrasion) has occurred, producing different characteristics in texture and composition compared to coastal dunes.

The belief in the supposed negative aspects of the use of desert sand for concrete is based on the following assumptions: (1) all desert sand is too spherical, and (2) therefore, regardless of desert source, location, or history, it is useless for concrete, and (3) desert sands are more or less globally uniform in sphericity. But these broad assumptions are geologically unsupportable. Desert sands from different locations most certainly will have different life histories, ages, source areas, and climate, especially wind conditions and unequal time spans in terms of abrasion history and achieving high roundness values. These variations are likely, considering the vast size of many deserts. John Crelling (2015), a professor at Southern Illinois University, showed a clearly angular quartz sand from the Jordanian desert. We strongly advise that desert sand not be thrown out altogether and that users of sand in the desert prospect for the desired shape.

Meanwhile, some nations are eyeing the potential to exploit new sand resources. The presence of large deposits of potential construction sand in front of the retreating glaciers along the shores of western Greenland has been widely publicized. Rachel Fritts (2019) quotes University of Copenhagen geologist Minik Rosing, saying Greenland could be a promising source because "the environmental consequences are likely to be low, governance standards are high, and there will be likely co-benefits for indigenous people" (n.p.). But much of this sand has a high silt content (glacial flour requiring washing), and it also is a very long distance from most construction sites. All of this leaves us with the fact that alternatives to sand are needed.

ALTERNATIVES TO BEACH SAND

There is no question that viable alternatives to and substitutes for sand do exist already, although all are more costly than easily mined beach or dune sand. These alternatives include crushing of rock, concrete, and glass to make them a reusable resource as well as the use of fly ash left behind after waste incineration. Fly ash is already being used in some places in making concrete and aggregate and for land reclamation. Bottom ash is used in concrete blocks and also in land reclamation. Imagine how much sand could be made from concrete slabs from demolished buildings. At Laguna Beach, California, a glass-to-sand machine is used to turn bottles into sand suitable for golf course bunkers and for beach nourishment. On a visit to Antigua, we observed lava rock being ground up to create sand. In addition, innovations in the construction industry allow increases in materials efficiency and environmental performance using, for example, geopolymer concrete. This type of concrete uses a different cement binder that significantly reduces the carbon footprint compared with that generated by the use of Portland cement as a binder, an important consideration in this time of global climate change (Whitaker and Holland 2019).

A research team from the Imperial College of London claims to have developed a new material (Tam et al. 2020). This type of concrete uses a cement binder called Finite that can be made from desert sand (Block 2018). This new binder is secret at this point, but supporters claim that it "may hold the key to the next Gulf economic miracle" (Gornall 2019)—(after oil), as desert sand solves the global sand shortage problem.

Another research team from the Banerjee Lab at Texas A&M University has devised a new form of concrete using soil. Their motivation was to provide a substitute for cement in concrete to reduce the amount of CO_2 produced in the manufacture of cement. Their new concrete is still in the design phase, but in the initial experiments, clay from someone's backyard was combined with a water-repellent additive made from beets and sodium silicate as a binder. The soil concrete has the advantage of avoiding transport costs and reducing energy-intensive production steps besides vastly reducing CO_2 emissions. It will probably find use in small buildings (but not skyscrapers) and in buildings in remote, inaccessible sites; and it could reduce the need for sand (Rocheleau 2020).

Some industries are already researching turning waste materials into resources. Rio Tinto and Lafarge Canada have developed a sand substitute that is made from aluminum-smelting waste that normally goes to landfills. The companies believe they will be able to produce a million tons of concrete a year in their facilities in Bath, Ontario (Spencer 2020). And Brazil-based Vale S.A. Mining announced in 2020 that its Pico Block plant, a research and development facility, will manufacture more than sixty different construction products, including structural concrete blocks and sealing blocks. The feed stock is the sandy, high-silica tailings from Vale's ore processing. In the future, the annual thirty thousand tons of waste tailings may be turned into pre-molded products, rather than going into useless waste piles or in holding areas behind dams (Bailey 2020).

Along 0.3 miles (500 m) of Manila Bay in the Philippines is a new beach made up of crushed dolomite rock (calcium magnesium carbonate). Dolomite, like limestone, is a softer mineral than quartz or feldspar. But the wave energy in the bay is relatively low, so the amount of sand loss by abrasion in the surf will be small. The new beach is controversial, but we see no particular problems with a carbonate beach in this location. The claim from opponents that the dolomite may contain mercury and lead is probably baseless. Ironically, Manila Bay is already so polluted that swimming from the beach is prohibited (Steffen 2020).

Marina di Pisa, a beach near Pisa, Italy, has been repeatedly nourished with scrap marble chips from a nearby marble quarry (figure 2.4). The chips make a fine pebble beach, and best of all, the pebbles are low cost.

Professor John Orr of Cambridge has found that plastic waste, when cleaned and crushed, can be used as an alternative for sand aggregate in concrete and could replace 10 percent of the sand in a concrete mix. He estimated that in India alone, the use of plastic could save 820 million tons of sand annually (Wade 2018; Thorneycroft et al. 2018).

THE OTHER SIDE OF THE STORY

Concrete, the main sink of sand worldwide, serves people in a multitude of ways. It is not an exaggeration to say that concrete is the very foundation of modern progress and development. Because sand is commonly about 25 percent of concrete, it is fair to say that sand should share the blame or the credit for how people are served by concrete. However, as always seems to be the case, there is another side to the story; there is always a price to be paid.

Jonathan Watts's article “Concrete: The Most Destructive Material on Earth” (2019) makes the case for the other side of the story. Like any good thing used in excess, more problems can be created than solved. One widespread impact of concrete is that it forms an impermeable surface that prevents rainwater from soaking into the earth. This effect is a major reason globally for flooding that, in cities, increases as development spreads over an ever-widening area. The spectacular case

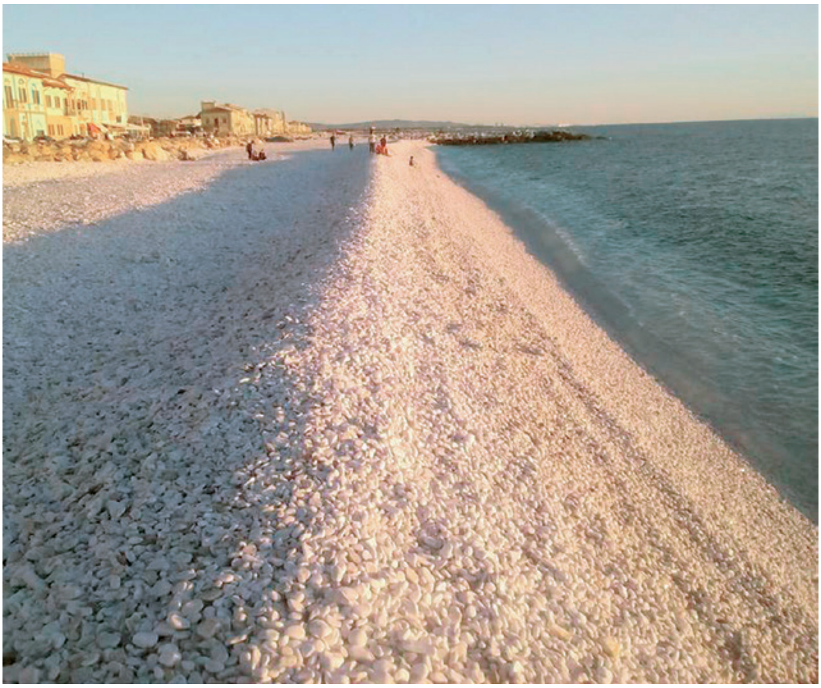

FIG 2.4 The pebble beach near Pisa, Italy, is a unique one that uses unusual materials for frequent nourishment. A nearby marble quarry furnishes a supply of scrap marble chips. A gravel beach may not be as comfortable as a sand beach, but it will do just fine because the chips are furnished at cost, and the beach is a good temporary buffer against sea level rise. Photo © Andrew Cooper.

of flooding caused by the 2017 Hurricane Harvey in Houston, Texas, is a case in point.

Another problem (besides the overuse of the sand resource) is that the manufacture of Portland cement used to harden a mixture of sand and aggregate to make concrete produces between 4 and 8 percent of the world's carbon dioxide emissions. Furthermore, 10 percent of the world's industrial water is consumed for making concrete, and in arid regions, concrete production strongly impacts local water supplies. Concrete also adds to the heat-island effect in cities by absorbing atmospheric heat (although to a lesser degree than dark asphalt).

In some countries, such as Japan, China, and Brazil, there seems to be a strong correlation between the volume of concrete and the amount of corruption, a reflection of the way construction companies often work in corrupt political atmospheres.

Immediately after World War II, Japan's construction industry depended heavily on concrete to repair the extensive war damage. The wave of construction, defined as progress, created infrastructure at a very rapid rate — politicians were judged by the amount of new development they could bring home. Large bribes became common as the construction companies smoothed the way for more concrete use. Soon rivers were lined with concrete, as were lakes, marshes, roads, roadcuts, bridges, and tunnels; and massive seawalls lined the ocean shores. The ubiquitous and largely unneeded layers of concrete covering roadcuts were particularly frustrating to geologists who use roadcuts to study Earth's history.

The pattern followed by Japan after recovery from war destruction was (1) construction for social development, followed by (2) construction as an economic necessity (employment, etc.), and then (3) construction for greed and political expediency. China and Brazil have followed Japan's example, and India and Indonesia may not be far behind.

China today puts Japan to shame in regard to the extent of concrete use, because it uses almost half of the world's concrete and has followed the same three-step process noted above to get there. A *Guardian* article pointed out that since 2003, China "has poured more cement every two years than the US managed [to pour] in the entire 20th century" (Hawkins 2019). To his credit, President Xi Jinping has recognized the huge excesses of China's development and has approved some projects to restore Nature (such as on riverbanks and forests). Furthermore, S*outh China Morning Post* journalist Ji Siqi (2021) noted that "as prices of the natural materials surge," China is crushing granite rocks to create an artificial sand for use in concrete.

Brazil puts the whole world to shame. One construction company alone, Odebrecht, paid bribes to 415 politicians and twenty-six political parties (Campos et al. 2021). Paulo Maluf, ex-mayor and governor of São Paulo, was found guilty of receiving US$334 million in bribes during his four-year reign between 1993 and 1996 and reportedly skimmed US$1 billion, the last largely from the construction of a giant elevated expressway (TBR Newsroom 2020; Watts 2019).

The problem of removing sand from beaches, dunes, and rivers for use in concrete could be partially solved by more efficient development using construction techniques and alternative materials that require less natural sand and concrete. But can the problem ever be solved in the face of the widespread demand for construction fueled in part by the world's increasing population?

SINGAPORE SAND BANDITS

CH.03

Sitting on Asia's Sandpile

Not many airports can claim the distinction of being a destination in and of themselves. But Changi Airport in Singapore boasts a massive nature-themed retail and entertainment complex known as Jewel, which drew in over fifty million visitors within six months of its 2019 opening. In addition to the accoutrements one would expect at an international airport, such as restaurants and retail shopping, Jewel features the Shiseido Forest Valley, a massive indoor garden spanning five stories that contains over nine hundred trees and sixty thousand shrubs. Jewel's Canopy Park includes a 164-foot-long glass-bottomed bridge and combines multiple gardens with leisure amenities. The centerpiece of the massive structure is the Rain Vortex, the world's tallest indoor waterfall, which funnels recirculated water up to let it drop 130 feet from the massive glass-paneled ceiling.

Changi Airport sits atop land that was reclaimed from the sea. This reclamation included filling in 490 acres of swampland and the construction of canals to drain water from three rivers. The massive landfill and seafill project created 2,100 acres of reclaimed land. Singapore is a city-state that gained its independence from Britain in 1963 and declared itself the independent Republic of Singapore, breaking off from its much larger neighbor Malaysia in 1965. Since its inception as an independent nation, Singapore has embarked on an aggressive expansion of its land, expanding its acreage by 25 percent through land reclamation projects, creating land where water once was. Singapore initially used home-sourced materials for land reclamation projects, but being such a small, wealthy country with limited natural resources, it increas-

FIG 3.1
Reclaimed land along the east coast and Katong area of Singapore, October 1971. Since gaining independence in 1965, Singapore has increased its land mass roughly 25 percent through land reclamation. Photo by Mazlan Badron. *The Straits Times*. © SPH.

ingly turned to importation of sand from neighboring countries to feed their hunger for expansion through both land reclamation and construction (i.e., materials for concrete). Since 1965, Singapore has added an astounding sixty-five square miles to its territory, mainly by importing sand from other countries. In addition to the airport, Singapore's iconic Marina Bay Sands hotel and casino and the Port of Singapore were built over reclaimed land.

Singapore is made up of Mainland Singapore, or Singapore Island, as well as sixty-two additional islands, some of which have merged as a result of land reclamation. With all the land reclamation projects, many seaside properties lost their close adjacency to the beach. For instance, Raffles Hotel's address is One Beach Road, but the shoreline, which was once next to this hotel, is now barely visible through the high-rise buildings built on reclaimed land (figure 3.1).

Singapore's wealth stems from its position as a financial center, as well as from shipping and manufacturing. The Singaporean government believes future economic growth depends in large part on land expansion. Singapore's insatiable sand appetite fuels both horizontal growth through land expansion via reclamation using sea sand and vertical growth using river and estuary sand for the nonstop construction of high-rises (figure 3.2).

Phase One of the massive Tuas Mega Port was completed in late 2021, and upon completion of the entire project, which is expected by 2040, Tuas Mega Port will be the world's biggest container terminal. Just the first phase of this project used approximately 88 million cubic meters of materials to reclaim an area equal to the size of 383 soccer fields. Singapore has started on Phase Two of the project, the largest of the four phases (Abdullah 2021). Samantha Boh (2016) explained that Phase Two will involve reclamation of approximately 956 acres and require the installation of 222 caissons, large airtight containers that will serve as the foundation for the wharf structure, each ten stories high and weighing up to 15,000 tonnes (16,534 tons).

After exhausting their own supplies of sand, Singapore, a country of 5.8 million people crammed together on an area of only around 280 square miles (725 km^2), turned to importing sand from neighbors. In the ten years preceding 2016, Singapore was the world's number one importer of sand for five of those years. According to a 2017 article in the *World Atlas*, the Observatory of Economic Complexity named tiny Singapore as the world's largest importer of sand, importing 13 percent of the entire world's sand imports (Sousa 2017). As Singapore expanded importation, multiple South Asian countries responded by banning the exporting of sand. Often these bans have been ineffective, as sand smuggling remains a problem. Also, official numbers on exactly how much sand has been imported are difficult to come by, and this is further complicated by the lack of distinction made between the importation of sea sand and the importation of river and estuary sand. The amount of sand reported by countries to have been exported often conflicts with the amount reportedly imported by Singapore.

According to Lin Derong (2017), almost all of Singapore's reclamation projects have been headed up by three government agencies—the Housing and Development Board, the Jurong Town Corporation, and the Port of Singapore Authority. These agencies employ contractors, usually Japanese, Dutch, Belgian, or Korean, to source the cheapest supplies of sand. Joshua Comaroff (2014), writing in *Harvard Design Magazine*, notes that Singapore considers the details of sourcing to be confidential and a matter of national security. In response to queries from the nongovernmental organization (NGO) Global Witness (2010, 29) about Singapore's role in the sand trade, Singapore responded that "the import of sand to Singapore is done on a commercial basis. The Singapore government is not a party to any agreement or contract for the import of sand." This is indeed a convenient confidentiality and, coupled with the use of foreign contractors to acquire sand, acts to re-

FIG 3.2 The wooden unpainted buildings in the massive architectural model of Singapore's central district represent future projects. Reclaimed land is viewed by Singapore as essential for continued growth and as a way to protect the island from sea level rise. This interactive model is on display at the Singapore City Gallery. Photo © SAF — Coastal Care.

move Singapore from responsibility for illegal mining and environmental degradation of its South Asian neighbors by sand mining. This also helps preserve the reputation of Singapore as a noncorrupt state.

By employing various layers of contractors, Singapore can obfuscate its own responsibility and role in the corruption and destruction of the environment of other Asian countries. In effect, it can declare, "How were we to know?" Ironically, this preserves Singapore's reputation as one of the world's greenest cities. Singapore is Asia's Greenest City, sitting atop the *Asian Green City Index* (EIU 2011), a measurement of the environmental performance of Asian cities. However, Singapore also sits literally atop sands that were obtained to the detriment of the environment and economy of other South Asian countries, and in a manner that contributed to political corruption in those countries.

MALAYSIA

Initially, Singapore turned to its closest neighbor, Malaysia, as a source for sand. These countries are physically connected by the one-kilometer-long Johor-Singapore Causeway and the Malaysia-Singapore Second Link, a 1.9 kilometer bridge completed in 1998. Singapore's dual needs for sand (for reclamation and construction) are exemplified by this project. Singapore constructed a checkpoint on their side of the bridge atop forty-eight acres of reclaimed land, and the bridge itself used some 1.9 million cubic feet of concrete in its construction.

Singapore's next-door neighbor has served as a major source of sand, stone, and gravel for decades, with trade having started in 1989. In 1997, sand exports to Singapore were banned, ostensibly to protect the Malaysian environment, but this ban was illusory and did little to stop the flow of sand from Malaysia into Singapore. Malaysia told UN Comtrade that Singapore bought a total of US$58 million worth of sand, stone, and gravel between 1997, the first year of the ban, and 2002; Singapore, however, admitted to spending over ten times that on sand from Malaysia — US$595 million during that same period. Malaysia's ineffective ban was officially (and temporarily) lifted in 2017 to allow exports of sand on a case-by-case basis (e.g., a 2017 sand shipment to India, noted in chapter 5).

How ineffective was the ban? Well, Singapore reported an astounding US$2 billion in imported sand, stone, and gravel from Malaysia between 2007 and 2016. In what has become a pattern, the official sand export numbers from countries sending material to Singapore are often much lower than what was actually sent to Singapore. One factor complicating matters is that there often is no distinction made between sand, stone, and gravel imports.

Just how much sand was illegally exported from Malaysia to Singapore is anybody's guess. For instance, for the year 2008, Singapore claimed to have imported 3 million tons of sand from Malaysia while Malaysia's official figures showed 133 million tons of sand were sent Singapore's way. In January 2010, Malaysian officials arrested thirty-four civil servants, charging them with accepting bribes and sexual favors to facilitate the sand smuggling to Singapore (Associated Press 2010). Speaking to the *Telegraph* in 2010, former Malaysian Prime Minister Dr. Mahathir Mohamad claimed that seven hundred trucks per day crossed from Malaysia to Singapore carrying sand (Henderson 2010). In January 2010, drivers walked away from thirty-seven trucks loaded with sand and parked on the causeway connecting the two countries

FIG 3.3
"Singapore Desert." Singapore's mammoth sand reserve safely stored behind security fencing in Tampines underscoring the importance of imported sands to Singapore's continued growth. Photo © Lin Derong, 2018.

when they learned of a customs operation on the Singapore side. Notably, these figures and anecdotal stories of smuggling sand took place well after Malaysia declared a blanket ban on exports of sea sand. Mahathir banned the exportation of sea sand when he was prime minister in the 1990s. Indonesia joined Malaysia in banning sand exports in 2007, resulting in a slowdown in construction in Singapore and a big jump in sand prices.

Singapore responded by releasing sand from its national reserves. Sand is so vital to Singapore's economic growth and expansion that they constructed three large stockpiles of sand, making up a national reserve of sand which can be released to counter rising prices or shortages in supply (Lin 2011). Seletar stockpile is next to Seletar Aerospace Park and Seletar Military Camp. The Tampines Avenue 10 stockpile is located adjacent to former sand quarries (figure 3.3). And the Palau Punggol Timor is a reclaimed island dedicated to the processing of sand. Part of Singapore's northeastern coastline reclamation project in 1985–90 — a stockpile site, a processing plant, and an aggregate-receiving terminal surrounded by tall security fences — sits atop what was once the sea.

Since the shortage of sand in 2007, and in response to various countries banning sand exports, Singapore has diversified its sources of sand, tapping new countries from which to import materials. Malaysia relaxed their ineffective ban in 2017 and, according to UN Comtrade data, in 2018 Singapore imported sixty-five million tons of sand from Malaysia at a cost of US$347 million, reportedly accounting for 97 percent of Singapore's total sand imports for that year. Upon temporarily returning to power, Prime Minister Mahathir banned the exporting of sea sand and tightened regulations on river and estuary sand exports in 2018. However, this time the ban did not slow construction in Singapore. For instance, the massive Tuas Mega Port project continued unfazed by the ban because Singapore had stockpiled a huge amount of sand solely dedicated to the project. Singapore had not only diversified their sources for sand, but it had also stockpiled massive amounts of the natural resource in the three national reserves of sand mentioned above (figure 3.4).

INDONESIA

As Malaysia tightened its hold on its sand resources, Singapore increasingly turned to Indonesia as a source of sand. Sand dredging for export in the waters off Riau Province for export started in 1979, when three companies received permits to dredge sand. A 2001 report by *Down to Earth* noted that by 2001 there were more than three hundred companies licensed to operate in Riau. Because of the profits to be made in exporting sand, illegal sand mining there was also rampant. *Down To Earth* (2001) also reported that illegal sand mining was allegedly controlled by a cartel of three Singaporean-backed companies, supplementing the legal operations to supply sand to Singapore. Local communities were provided compensation for the loss of fishing grounds, but this was well below what they were earning from fishing. The dredging reportedly resulted in increased erosion, damage to water quality, and the actual disappearance of a few small islands.

In October 2001, angry villagers commandeered a sand-mining vessel in the Durian Strait and took it to a jetty where other villagers boarded the ship. A crew member opened fire, dispersing the villagers, but in doing so he killed a thirty-six-year-old man (*Down To Earth* 2001). In July 2002, the Indonesian Navy deployed two warships to capture seven dredgers carrying foreign flags operating off the province of Riau. Among the detained ships that were supplying sand to Singapore

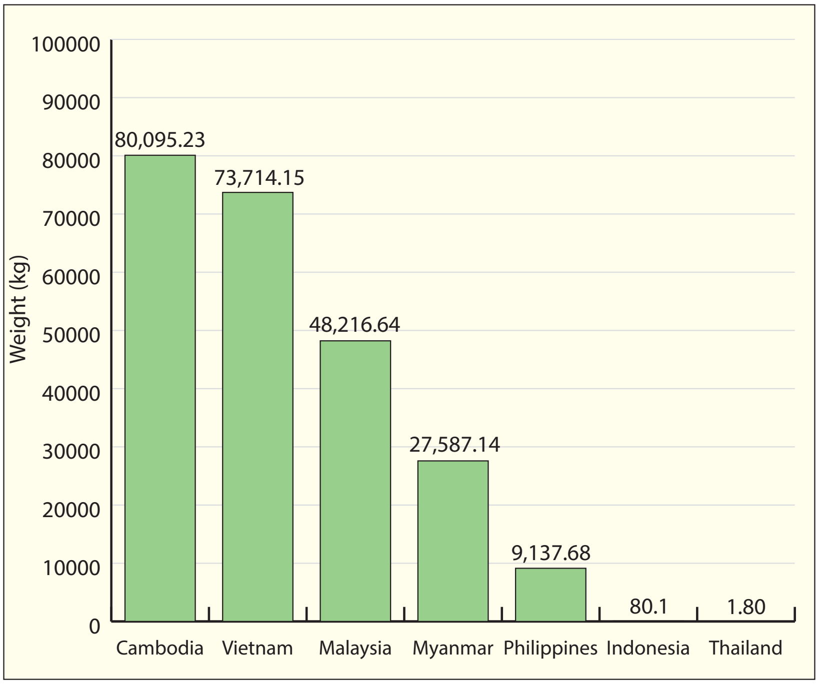

FIG 3.4 This chart shows Singapore's 2008–2017 sand import figures derived from United Nations' Comtrade data. Exact figures on the amounts of sand Singapore has imported are difficult to discern as the reported figures from the exporting countries often do not match Singapore's reported numbers. Courtesy of the ASEAN Post; data from UN Comtrade, DESA/UNSD (United Nations International Trade Statistics Database, Department of Economic and Social Affairs/Statistics Division).

was the *Vasco da Gama* (a Belgium-registered ship), the world's biggest hopper dredger. Shots were reportedly fired. The ships were detained for months, accused of stealing Indonesia's sand. This conflict led to Indonesia instituting a ban on sand exports to all countries in an effort to curb rampant mining and reduce environmental degradation (Kog 2006, 3).

As mentioned previously, bans on exportation of sand appear to be ineffective, and this was indeed the case with Indonesia's 2003 ban. Between 2003 and 2006, Singapore reported purchasing a total of US$388 million worth of stone, sand, and gravel from Indonesia. That same period marked a slowdown in imports from Malaysia, so it appears Singapore replaced the annual amount of sand that was previously coming from Malaysia with sand from Indonesia during this period. A 2014 UNEP (UN Environment Programme) report on global sand mining noted a shortfall of 120 million tonnes (132 million tons) between Indonesia's reported exports versus Singapore's reported imports for the years 1995 and 2013 (Peduzzi 2014).

How damaging has sand mining been to Indonesia? In addition to the typical destruction of the habitat of bottom-dwelling creatures and the damage to water quality, some Indonesian islands have disappeared to the dredgers. Chris Milton (2010) reported that dredging near the Singapore-Indonesia border caused Nipah Island to disappear underwater in 2003, with only a few palm trees now marking its location. A 2010 Grist article in the *New York Times* mentioned that since 2005, twenty-four small Indonesian islands disappeared as a result of erosion caused by illegal sand mining. An estimated two dozen small Indonesian islands disappeared since 2005 due to sand extraction and at least two thousand Indonesian islands are at risk of disappearing if dredging continues unchecked (*Down To Earth* 2016). It doesn't take a detective to ascertain that the sands of those islands and their beaches now most likely reside across the Singapore Strait in Singapore, helping to sustain one of the world's wealthiest economies.

VIETNAM

So, what could Singapore do to counter these bans and to keep the sand flowing into their country? They expanded their import sources throughout Southeast Asia. One of the countries that supplied sand was Vietnam. Then, in 2009, Vietnam announced a ban on sand exports to Singapore. How effective was this ban? A 2018 article in *Asian Correspondent* reported that between 2009 and 2016 Singapore reportedly bought US$756 million worth of stone, sand, and gravel from Vietnam. During that same period, Vietnam reported just US$126 million in sales to Singapore (Banergee 2018). Why was the sand ban ineffective? An investigation by the Vietnamese newspaper *Tuổi Tre News* (2017c) suggested that a 2013 change in regulations to allow some businesses to export sea sands resulted in large volumes of dredged sand heading to Singapore. In 2017, reporters from the paper *Tuổi Tre News* (2017a) tracked ships carrying Vietnamese sand to Singapore. The ships were supplying sand for a land reclamation project to expand the area of Singapore's Tekong Island from 657 to 3,310 hectares.

In an article posted on the blog *Failed Architecture*, authors Robert John and William Jamieson (2020) point out that Singapore's growth depends not only on sand extracted almost entirely from other countries in the region but also on foreign labor, adding that the complex supply chains and networks of subcontracting deliberately obscured from view and hid the true costs of Singapore's urban growth model. After some countries banned sand exports, Cambodia became a willing partner with Singapore for roughly a decade. In 2019, Comtrade data showed that Singapore sand, gravel, and stone imports from Cambodia rose from none in 2006 to US$24.5 million in 2008. Between the end of 2007 and the beginning of 2009, 124 dredging companies obtained licenses, with the largest share of the concessions owned by two senators in the ruling Cambodian People's Party, H. E. Mong Rethhy and H. E. Ly Yong Phat.

In a 2010 report titled "Shifting Sand," the NGO Global Witness noted that some of the sand dredging licenses bore the stamp of a Singaporean official in the Phnom Penh embassy in Cambodia. You may recall that Singapore reportedly told Global Witness that these contracts were private: the "Singapore government is not a party to any agreement or contract for the import of sand" (29). Global Witness notes that while boasting the "most advanced policies for environmental sustainability in the region" (3), Singaporean government agencies were sourcing sand through companies with ties to high-level Cambodian officials, whose operations appeared to ignore environmental and social safeguards in Cambodia. The lack of transparency and corruption also deprived Cambodia of tax revenue from the sand sales. Sand dredging licenses were allocated in rivers and estuaries along Cambodia's coast, including some protected areas that are home to endangered species such as the dugong, a mammal similar in appearance to Florida manatees. On one day alone, Global Witness documented nine dredging vessels within a protected area, and this was after Cambodia banned sales of sand to Singapore. The effects of dredging have been particularly hard on local fishermen, with fish and crab harvests plummeting. In the Koh Kong area, an informant told Global Witness that the fish catch had declined by 50 percent after dredging operations commenced in the area.

What happens to a small Cambodian fishing village when the fish and crab populations plummet due to dredging? Filmmaker Kalyanee Mam set out to answer that question and more in her excellent, short documentary *Lost World* (Mam 2019). Mam traveled to the island of Koh Sralao where sand had been dredged among the mangrove forests since 2007. Mam notes that she "observed firsthand what happens when the foundation of a community falls apart. First the land gives way, then the people, and soon, the entire fabric of a culture and identity is lost." She notes that the demise of fishing and crabbing catches was related to the dredging and that loss of income had resulted in many residents leaving the island. Thus, the dredging disrupted the livelihoods of the locals and threatened their very way of life. Speaking to *Reuters*, Louk Pou, a fisherman from Koh Sralao revealed that before the dredgers arrived he used to earn more than fifty dollars a day fishing for crab, but his income dropped to less than ten dollars a day after fish and crab stocks plummeted following widespread dredging. Pou also reported that seven beaches disappeared because of sand mining, adding, "They're just gone and the people can't enjoy them anymore" (Arsenault 2016). Thus, not only has the local fishing industry been devastated by sand mining, but the potential for future beach-related tourism has been dashed.

Over a ten-year period, per UN Comtrade data, at least eighty million tonnes of sand (eighty-eight million tons) from Cambodia were sold to Singapore. John and Jamieson (2020) observed that the village of Koh Sralao, the setting for Mam's *Lost World* film, was particularly hard hit, noting that extraction was wanton and often occurred without required environmental impact assessments. The dredging resulted in such a decline in fish, crab, and shrimp catches that fishing communities that could expect to bring in 150 kilograms per day before were now reduced to a catch of just 10 kilograms. With their livelihoods threatened, more villagers went into debt to pay for supplies and equipment. All told, 25 percent of the village, which was made up of approximately three hundred households, had to leave to find work elsewhere; many of these villagers were women who had to leave their traditional livelihoods to work in factories.

"Never before have I witnessed the uprooting and displacement of land itself," Mam told *Atlantic* magazine. "It is already enough to be removed from one's land," Mam said. "It is another thing entirely to have one's land removed as well" (Mam 2019). The *Lost World* film ends with Mam marveling at the visitors and plants found in the biodome at Changi Airport, Singapore's Jewel, taking in the spectacle of the artificial natural wonders built on reclaimed land made possible from massive sand importation from throughout Southeast Asia.

Local residents protested the dredging-related devastation and, along with the NGOs such as Mother Nature and Global Witness, waged an international campaign to draw attention to the plight of Cambodia at the hands of the dredgers. Finally, the Cambodian government banned sand exports in 2017. But, as noted above, these bans are often ineffective. Plus, they certainly haven't slowed Singapore's insatiable sand appetite, and the country continues to look for other sources of sand in Southeast Asia.

Compelled by the bans to seek out new export sources for sand, Singapore has turned to other countries, including the Philippines, Myanmar, Australia, and Bangladesh. In Myanmar, farmers blame the dredging of rivers for increased erosion, but the government counters that the environmental damage has been minimal and that the rivers need to be dredged to clear the waterways of silt. The farmers' complaints are complicated because the government and the dredging companies can also point to climate change and other factors as the cause of erosion. In an *Ear to Asia* podcast (Clarke 2020), Dr. Vanessa Lamb, a geographer at the University of Melbourne whose research interests include sand studies, pointed out that the demand for sand in Myanmar is driven externally by Singapore's needs but internally by an increased demand for sand for construction purposes. Economic sanctions in Myanmar were lifted when the country transitioned from military to civilian rule in 2011. And what happens to sand mining enterprises when the country once again sinks into chaos as of 2021?

It now appears that Singapore has set its sights on the sands of Papua New Guinea. Writing for EMTV, scott Waide (2020) reported that a Singaporean company was working to get approval to mine a fifty-kilometer stretch of beach on the North Coast of Madang, Papua New Guinea. This beach includes nesting grounds for endangered leatherback turtles. Mas Kagin Tapani group (Makata), a local NGO dedicated to preserving these nesting areas, has requested more information from the government on the environmental impacts of the project. Some locals have also expressed their concern over the potential mining project. However, Waide reports that sand mining remains largely under the radar in Papua New Guinea and stresses that the lack of understanding of the economic and social impacts puts communities at risk of making poor decisions that could result in widespread environmental destruction. A March 1, 2021, press release from the Turtle Island Restoration Network stated that the Singaporean company withdrew its application for a sand-mining exploration license across 51 kilometers of protected habitat for endangered leatherback sea turtles, due to Makata's grassroots efforts (Turtle Island Restoration Network 2021).

Inevitably, Papua New Guinea will grasp the hard-learned lessons from the other Asian countries that initially welcomed sand exports to Singapore and other countries only to later ban the practice. At risk are not only the environmental destruction related to sand mining but also the disruption to the livelihoods of villages that bear the brunt of increased erosion; the loss of fishing habitats; the loss of economic benefits from the sales of sands; and even the possible disappearance of whole islands. An additional concern would be the potential corruption of local and national politicians who may turn a blind eye to the negatives of legal and illegal sand mining if they can somehow get in on the profits from it.

GREEN OR GREED?

Sitting perched atop its piles of sand taken from throughout South Asia is the wealthy city-state of Singapore. Singapore can claim the title of Asia's greenest city but only by turning a blind eye to how their insatiable appetite for legal and illegal sands is causing corruption and destruction in an ever-widening arc throughout South Asia.

CH.04

THE SANDS OF CRIME

Mafia, Sand Robbers, and Law Benders

From Jamaica to Morocco to India and Indonesia, sand mafias ruin habitats, remove whole beaches by truck in a single night and pollute farmlands and fishing grounds. Those who get in their way—environmentalists, journalists or honest policemen—face intimidation, injury and even death. **NEIL TWEEDIE, 2018**

While the sand mafias operate as smugglers, "key personalities—lawmakers or retired soldiers—hand out permits allowing them to over-exploit deposits, without respect for quotas" (Moroccan, environmental activist to Mekouar). **HAMZA MEKOUAR, 2019**

THE GREAT SAND RUSH

Gold, black gold, diamonds, illicit drugs, and sand all have something in common. Aside from the important attribute of extraordinary value, all but the drugs have finite quantities. That sand is available only in finite quantities sounds unbelievable, considering that the Earth has so much sand; but the demand for sand is outstripping the supply, and much of the Earth's sand is not usable—so the sand rush is on!

Throughout history, critical, scarce, or high-value natural resources have generated rushes or booms, such as the gold and silver rushes, the oil and uranium booms, and the lust for diamonds. Getting water rights and new farmland for settlement in the United States spurred mad dashes. Unfortunately, these historic trends have been accompanied by the evils of illegal mining or drilling, false land claims, conscription and child labor, poaching, and violence, including murder. For many of us, this is the stuff of western movies, or stories about the 1849 California Gold Rush, the Oklahoma land rush of 1889, or the 1901 Spindletop in Texas, and the 1920s Oklahoma oil booms.

Such booms or surges continued through the twentieth century and persist into the twenty-first century with a wide variety of new mining areas and oil prospects coming on the scene. Unfortunately, the related illegalities, violence, and atrocities are still occurring, particularly in the numerous second- and third-world countries on at least three continents. For the last fifty years, lost in the noise of a variety of other conflicts and controversies, the most critical raid of all on a natural resource has taken place — sand mining. Most large sand-mining operations in the United States have been legal (overlooking the fact that operations have been controversial, sometimes political, and usually environmentally destructive), but in much of the world, such mining has not been legal and is often gang or guerrilla controlled. In the process of scratching out tons of sand or specific minerals derived from sand deposits, many factors come into play: inhumane working conditions; destruction of agricultural lands, forests, and water supplies; displacement of local cultures; conscription work; and last but not least, child labor (see chapter 9).

SAND MAFIAS

As the scale of sand mining has evolved from a cart-load of sand stolen during a midnight raid on a beach to giant operations of unlawful mining of beaches, dunes, rivers, and estuaries with back hoes and dump trucks (figure 4.1), the term *sand mafia* has come into wide use. Illegal sand miners and their cohorts are the sand mafia and can be in collusion with organized groups or companies, leading to corruption and graft. Sand mafias operate globally, typically affecting countries that tend to depend on their beautiful beaches for tourism.

Filmmaker Denis Delestrac spent time in Morocco while shooting *Sand Wars*, a documentary about the global sand trade and its environmental impacts. David Roos (2017) quotes Delestrac who said, “The sand mafia [in Morocco] is the second most powerful criminal organization in the country. We saw people with shovels taking every last

FIG 4.1 Sand miners in Tangier, Morocco, taking sand by the truckload from the beach and dune system. Photo © Lana Wong — Coastal Care.

grain of sand from the beach. Where a few years ago you used to have a very thick and white beach, now you have this lunar landscape. It's devastating."

Various authors, including Christian Hellwig (2015), note that the places being affected the most by global sand theft include Indonesia, India, Mexico, Cape Verde, Malaysia, Jamaica, New Zealand, Kenya, Morocco, South Africa, South and Central America, and the many tiny island states in the Indian and Pacific oceans and the Caribbean Sea. In India, where the sand mining mafia is prevalent, the Konkan coast south of Mumbai has several beaches that are completely devoid of sand (R. Singh 2015).

Sand mining, also called sand harvesting — sometimes permitted, sometimes illicit — is widespread. As with any commodity, supply and demand are the driving forces. Since construction and development have increased so significantly, particularly in India, Indonesia, and Singapore, the need for sand is greater than ever (see chapter 3). In a practical sense, because the demand is greater than the legal supply, illegal mining activities increase, along with the associated corruption.

Notably, if supply is to meet demand, illicit mining is seen by some as a necessary evil. Illicit implies extraction that is either unlicensed (i.e., illegal) or permitted mining where the extraction process breaches restrictions agreed upon by a mining license issued by the authorities (i.e., extralegal) (Mahadevan 2019).

Complicating the sand business even further is that illicit sands are often exported, as in Southeast Asia where parts of Singapore are built of other countries' sand resources (see chapter 3). Islands in the Pacific and the Caribbean have had their landscapes mined away to feed the demands of other nations — corrupting local governments as well as the natural habitat.

As one writer has observed, "Current legal frameworks are not sufficient, and 'sand mafias' comprising builders, businessmen and dealers in countries such as Cambodia, Vietnam, India, Kenya and Sierra Leone regularly flout existing laws" (Chandran 2019). But what exactly constitutes a sand mafia?

Consider the different meanings of the word *mafia* for a moment. Selwyn Raab (2016), author of *Five Families: The Rise, Decline, and Resurgence of America's Most Powerful Mafia Empires*, explains that the term *mafioso* or *mafia* member, in Sicily, referred to someone who was suspicious of centralized authority. There was no criminal attachment at first, but at some point, the Sicilians banded into groups and became known as private armies, or mafie, who forced landowners to pay for protection and eventually developed into a violent criminal organization. Raab notes that the term *mafia* derived from a Sicilian-Arabic slang expression that means "acting as a protector against the arrogance of the powerful" (14). On the other hand, the sand mafias seem to be aligned with (not against) the powerful that include crooked officials and construction magnates. The sand mafia members themselves are the criminal bands. So, the term *mafia* in relation to the illegal sand mining seems to be a polyseme with a different meaning than the original.

A 2013 lawsuit filed by a government-supported advocacy group in India provided a working definition of what a typical sand mafia there consists of: "The illegal trade is driven by the unholy nexus between contractors, politicians, trade union leaders, panchayat (local officials) and revenue officials and corrupt policemen" (Mahadevan 2019).

In other words, a variety of people profit from illegal sand mining. In addition to those entities, Rollo Romig included local laborers, construction companies, people who own the trucks and earth movers;

genuine mobsters who, in some places, organize the miners and offer extra muscle; the suppliers who act as middlemen between the mafias and the real estate developers; and officials who accept bribes (Romig 2017, 44).

Clearly, government officials should not be above the law, but the sand mafias often appear to have beneficial, symbiotic relationships with their local officials. In this book, we have chosen to refer to the controlling groups as mafia in the loose sense to mean any organized group using extortion and other criminal methods to control a particular resource, locally or regionally.

Another description claims that "the word *mafia* derives from the Sicilian adjective *mafiusu*, which, roughly translated, means 'swagger,' but can also be translated as 'boldness' or 'bravado'" (ET Bureau 2018). The boldness of the sand mafia, widely reported in the media, is evident. They are protecting or defending in violent ways the construction boom and the mining of sand. Numerous brutal episodes involving the exploitation of this natural resource have been reported in the press, incidents in which violence was perpetrated upon journalists, police officers, administrators, activists, and communities (see appendix A).

Regardless of the particular definition, the groups basically are sand robbers, sand thieves, sand smugglers, and their associates (figure 4.2). Some are also killers. To defend their purported right to take sand, they often intimidate, harm, or kill people who try to stop them.

Mahadevan writes that sand mafias are also connected to land mafias, but "only the 'beach sand mafia' . . . deals routinely with overseas business partners and therefore represents a fusion of transnational and organized crime" (2019, 2). For instance, rare-earth minerals "smuggled from Tamil Nadu are destined for foreign markets, primarily North America and Europe" (5).

NOT ALL MAFIAS ARE THE SAME: ITALY VS. INDIA

Considering the criminal aspects of the sand-mining business, Aunshul Rege and Anita Lavorgna (2017) undertook an extensive document analysis of organized resource-related crime in Italy compared to illegal sand mining in India, both of which were found to be connected with the construction industry. These are environmental crimes because they remove natural resources and adversely affect the environment in both the short term and the long term. The authors describe organized crime groups in Italy called ecomafias, managed by already

FIG 4.2 A miner, who is part of the sand mafia system, is stealing sand from a beach near Mumbai, India. Sand mafias are found in many countries where they control illegal sand mining interests, often with violence. In this photo, the miner threatens the photographer, Denis Delestrac, the writer and director of the documentary film *Sand Wars.* Photo © Denis Delestrac.

existing organized crime groups that rely on kinship ties and personal relationships. Their mining is not of sand, per se, but of soils they dig up for use by the construction industry that also may be tied to the crime groups. The resulting holes are then illegally filled with waste, sometimes nuclear waste, trash, toxic materials, or other pollutants. The ecomafia activities are primarily found where Italian mafias originated, in the southern Italy regions of Puglia, Campania, Calabria, and Sicilia; but other groups are found in central and northern Italy (Rege and Lavorgna 2017).

Similarly, the researchers found that in India the illegal sand mining also is carried out by sophisticated organized crime groups; but then they point out that the illegal operations are geographically dispersed, with no evidence of any familial or personal connections between them. Their connections are business and profit driven and include contractors and politicians (Rege and Lavorgna 2017).

INDIA: HOTBED OF BLACK-MARKET SAND

Ashwin Aghor et al. (2012), in a *Down To Earth* article, tell of "the murky business of sand mining" and list twelve known illegal mining hot spots in India: Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Bihar, Uttarakhand, Nagaland, and Madhya Pradesh. Mining in most of these states is of river sand, with only Odisha and West Bengal noted to have coastal involvement with mineral mining—Odisha's coastline has deposits of ilmenite, garnet, sillimanite, rutile, zircon, monazite, magnetite, and pyriboles, but ilmenite and sillimanite are those found in West Bengal's beach sands.

Besides the states listed above, a different account specifies several other Indian states where illegal sand mining was booming, including Haryana, Goa, Rajasthan, Chhattisgarh, Orissa, plus Uttar Pradesh (Singh et al. 2015). Asha Sikarwar, a Morena-based social activist in Madyha Pradesh, reveals that "almost every family in the villages here owns a tractor trolley and a gun. Mining is the only source of livelihood. The community is so united that the entire village comes together to attack us if we try to stop them" (Aghor et al. 2012).

Even though India has governmental guidelines for legal sand mining, the country has been at the forefront of events involving black-market sand mining, with increased media coverage of mafia incidents drawing attention to the issue in the last decade or so. Reports show that some law enforcement units are understaffed, and others are in cahoots with the sand criminals. Mahadevan's *Sand Mafias in India* (2019) is grim reading; the author notes that in Bihar, a province with a conspicuous gun culture, cumulative killings associated with illicit sand mining and mafias now total several hundred.

Some estimates suggest that India's black market for sand-mining commerce employs over thirty-five million people and is worth over $100 billion a year, including both coastal and inland mining. That would make India the biggest participant in a global, illicit sand trade that could be worth a global total of up to $600 billion a year (Roughneen 2017). Money is the gold at the end of the rainbow for all those involved in the illegal business, mafia or not.

The sand mafias work with construction companies to lower the cost of sand and increase construction profit margins. In India, the Union Environment Ministry guidelines consider sand a minor mineral, and its mining falls under state jurisdiction, which means that corruption does not need to travel as far up the power ladder as it would if the national government were in charge of its regulation. This jurisdictional separation makes it easier for sand mafias to bribe corrupt officials at the state or local level, making illegal sand mining profitable for everyone involved: miners can get paid for their work and officials can be paid to ignore crimes (Yogesh 2018).

Many people from India's rural agricultural areas migrate to cities in search of work, only to become part of the cheap labor force there. Mahadevan (2019) points out that politicians and wealthier urbanites were "delighted to have a large, submissive workforce for menial jobs. So were crime lords in mega-cities like Mumbai, who could recruit the more ambitious and hot-blooded among these rural immigrants, to serve as street-level muscle for various kinds of racketeering" (n.p.).

Such a labor force supports sand mafias and can be viewed as a socioeconomic path to a better life for workers. Certainly, sand-mining jobs can alleviate poverty and put food on the table. Miners get a small wage, but it's likely more than they would receive from other types of employment such as farming or fishing. That they are well paid is a misconception. Some think truckers who move the sand from the mining area to the consumer earn good money, but a sand transporters association official, who was interviewed at Mlolongo, Kenya, by Simon Muthomi and colleagues (2015), denied the allegation that they are the main beneficiaries of sand harvesting:

> People think that we get a lot of money from selling sand and that we are millionaires. On the contrary, we face many challenges and what we make in profits is very modest. We have loans to pay, we have to pay the bribes demanded by the police and county administrators, and we pay county levies and salaries. Apart from these, there are frequent lorry breakdown because of poor maintenance of road and our drivers disappear with daily collection. Sometimes flashflood destroys out vehicle and some other times sand harvesters burn our vehicle. Tell me, with all these expenses, what is left for us? (141)

In the real estate market and construction business in Mumbai and other growing Indian cities, for example, money can be earned, but most goes to the upper echelons in the businesses (Mahadevan 2019). Clearly, sand mafia employees at the lower echelon provide muscle. However, sand mining has brought success to those at the top, especially the managers and organizers, who are now able to send their children to college, earn enough to build a better house than a small hut, or accomplish various practical goals. Sometimes they may cease their mining occupation if their economic goals are fulfilled, but that may be the exception rather than the rule.

A former sand miner told Rollo Romig (2015) that he "started sand mining around 2002, to raise money for a new business." Once he achieved that goal (and a new house), he then stopped mining as an occupation. This miner set out with a purpose and fulfilled it by working in a labor-intensive, sometimes dangerous, field that might have been either legal or illegal at the time.

Without a doubt, laws are often ignored. Countries that allow legal mining of beach sands are still plagued by the illegal, unlicensed, and unauthorized black-market sand trade. A rough estimate by Indian revenue officials indicated that illegal miners have been extracting close to six hundred truckloads of sand a day, sometimes using suction pumps and heavy machinery, while in other places using divers with plastic or metal buckets (Yeshwantrao 2010). Regardless of the method, the state loses revenue when proper mining procedures are not followed and royalties are not paid to the state.

Tom Lasseter and Rakteem Katakey (2014) recount that one state official, Rajender Singh, director of industries, among the state's most senior officials in charge of mining, said, "It's unreasonable to expect small-time miners to meet national requirements for environmental approvals," and he made the point that without the informal sand-mining trade, "construction activities would have come to a stop." The construction magnates rely on the criminal trade (the informal sand-mining trade) — the environment be damned.

We find it hard to think of the world's sand resources nearing extinction, but sand is replenished in the natural environment at an infinitesimally slow rate compared to the massive amounts of sand being mined. Remembering that the world's vast deposits of desert sand are considered unusable for concrete because of grain shape (see chapter 2), sand consumption for construction projects around the world is rapidly diminishing the amount of readily available and useable deposits of sand. Inevitably sand mining continues. Vince Beiser (2015) states in *Wired* that India "hides hundreds, most likely thousands, of illegal sand mining operations. Corruption and violence will stymie many of even the best-intentioned attempts to crack down." Besides being associated with the mining of sand, violence and corruption also surround the mining of another valuable resource — diamonds.

THE ENDPOINT OF SAND CRIME: BLOOD DIAMOND PARALLEL

Like sand mining, diamond mining causes environmental degradation, but diamond mining also has brought murder and definite mayhem—civil war—to some African countries, such as Sierra Leone, Liberia, and others, initiating the label "blood diamonds." Brilliant Earth (2019) reports the following about blood diamonds: "Diamond mining is plagued by shocking violence, from killings to sexual violence to torture. Often, rebel groups are responsible for this violence. But governments and mining companies also commit atrocities in Africa's diamond fields, frequently in countries that are not at war." Will sand end up being called *blood sand* like a commenter to Erik Brown's (2018) article remarked?

The sand mafias are making a name for themselves in India and Africa, and lawlessness has been penetrating other locales where sand is the prize. As with blood diamonds, the ultimate evidence of the seriousness of the illegal side of sand mining is the growing record of violence toward, and murders of, those who stand up for the law and the environment or who are victimized participants in the crime webs. The brief review below of some of the victims in various parts of the world should sound the same kind of alarm as that for the traffic in drugs, blood diamonds, poached ivory, smuggled gold, and other illegal materials.

SAND MAFIA GLOBAL VIOLENCE

MEXICO

An environmental activist from Tabasco, José Luis Álvarez, who fought illegal mining and also fought to preserve the habitat of howler monkeys, was murdered in Chiapas. An environmental official, Miguel Pérez, said, "This is abominable, he was a nice person, his fault was to fight against the illegal extraction of sand" (*Mexico News Daily* 2019). On several occasions, Álvarez had denounced the illegal extraction of sand and stones from the Usumacinta River, and he had asked authorities for protection after receiving death threats, but none was provided. Pérez said that messages threatening Álvarez's family and other environmentalists were left with his body. The *Mexico News Daily* stated that "Álvarez is the first environmental activist from Tabasco to be murdered, but 125 environmentalists have been killed in Mexico in recent decades, according to the international NGO Global Witness" ("Environmental Activist Who Fought" 2019). Clearly, brave activists need the benefit of protection but often do not receive it.

KENYA

In Kenya, police corruption was discussed in an interview that Muthomi and colleagues conducted on March 13, 2015, with the driver of a sand-hauling lorry who was based at Mlolongo: "When they stopped me, (Administration Police) I refused to give them a bribe. They were very angry with me for this. They shot at my lorry and eventually managed to burst three tires. I however did not stop which made them to shoot directly at me. Somehow I managed to escape. When I reported the matter to the senior officers, my case was dismissed because the involved police officers argued that I had stolen sand from the river and I was escaping" (2015, 142).

That driver was probably lucky, for on the night of December 20, 2015, three Kenyan truck drivers were viciously attacked. Beiser (2017) reported that police told a local newspaper that the men were loading their trucks with sand when attacked; two were burned to death and a third was shot with arrows by a mob of local youths.

SOUTH AFRICA

In 2003, a Xolobeni family was attacked, and a headman from the village of Mpindweni, Mandoda Ndovela, was shot dead, "allegedly after criticizing proposed Xolobeni dune mining" (Washinyira 2016a). Tariro Washinyira's report also mentions that police found no evidence connecting the headman's murder to the mining proposal, though the case was still being investigated as of 2016; some years later, John G. I. Clarke (2020) related that the shooting remained "unsolved despite the clear evidence of unnatural causes." Furthermore, along with a "spate of shootings after heated meetings" about the mining project in Xolobeni, a sixty-one-year-old woman was stabbed, and later two journalists were attacked (Pearce 2017).

Washinyira's (2016a) story notes that conflict in Xolobeni had been smoldering for at least ten years and periodically burst into flames. People were scared because terrorists were banging on doors, shooting guns, and otherwise intimidating residents of the coastal villages. Because of fear of more vicious attacks, some villagers and their children were sleeping in the forests or fields for safety.

One antimining activist, Sikhosiphi "Bazooka" Rhadebe, was assassinated on March 22, 2016—shot dead at his home in Pondoland, South Africa, by two men posing as police. Accounts published by Human Rights Watch (2020) and African Defenders (2020), the latest as of June 16, 2020, report that no arrests had been made in the case.

The yearslong feud has been between those who are opposed to the mining and those who are in favor of the mining. Fred Pearce (2017) writes, "The opponents don't say the mining companies directly killed Rhadebe. But they do say the mining plan, and the creation of companies like Xolco, has created an atmosphere in which some members of their own community, eager to profit from future mining, have become violent." If the terror agents continue their violence, more deaths could happen. Villagers (residents of the coastal Amadiba villages that are affected by the mining company's plans) seem to recognize this. One of the elders is quoted as saying, "These gangsters used to be good children before they were offered money." Another one said, "They will kill us first before they start mining. We are Pondo; we are prepared to die for our land. Even in the past, our ancestors chose land and ignored a bag of money they had been offered for this same land" (Washinyira 2016b).

More recently, the situation there may have improved. Zelda Venter (2018) reports that in November 2018: "It was joy and jubilation for the Xolobeni community on Thursday as the Gauteng High Court, Pretoria, ruled that consent must be given by communities living on ancestral land before government can give the go-ahead for mining rights. The Department of Mineral Resources cannot issue a mining right without the consent of the affected people in terms of existing legislation, Judge Anneli Basson ruled" (n.p.).

Ideally, these environmentally important areas will remain safe from further mining schemes and violence.

INDONESIA

Violent incidents related to sand mining occurred in 2015 in East Java, Indonesia. Two farmers, sand-mining protesters—Salim Kancil, fifty-two, and Tosan, fifty-one—protested against sand-quarrying activities on Watu Pecak Beach. They were attacked by a group of people in Selok Awar-Awar subdistrict, Pasirian district, becoming victims of collective assault (Boediwardhana 2015). Tosan and Kancil were "dragged from their homes, beaten, stabbed, and left for dead on the road. 36 people were arrested for the attack" (HRD Memorial 2022). Kancil died and Tosan was left in critical condition. Kancil's death was reported to be the first case of an environmental activist being murdered in East Java (Boediwardhana 2015).

VIETNAM

Asia One reported on extensive illegal mining of sand in Vietnam, writing,

> Rampant illegal exploitation has been posing major challenges for law enforcement bodies. . . . The country has 824 licensed sand and gravel mines and about 90 authorised projects of river-bed dredging.
>
> However, Deputy Minister of Public Security, Senior Lieutenant General Lê Quý Vương, said the police had detected more than 4,300 violations in more than 8,000 inspections in the past year. The violations involved nearly 3,000 people and more than 1,000 facilities and equipment were seized. Criminal proceedings were only initiated in two cases. (*Asia One* 2017)

Furthermore, the report states that violence accompanied some of the illegal activities and some activities were protected by corrupt officials.

INDIA

Still, India has the most well-documented examples of the violence of sand mafias, probably reflecting a free and abundant media, compared to other countries. Most reported sand-related murders in India appear to target journalists and environmental activists but sometimes law or other public officials. For instance, in Madhya Pradesh, a fifty-year-old deputy forest ranger, Subedar Singh Kushwaha, was "stationed at a check post on National Highway 3 to curb illegal excavation of sand from the Chambal riverbed, and was killed at around 8 a.m. Friday while inspecting vehicles coming from the riverside" (Tomar 2018).

He was run down by a sand-carrying tractor trolley. Methods of murder in the fight for valuable and diminishing sand supplies have been varied and include shootings, beatings, burning, and killings by tractor trolley, motorcycle, or SUV.

Sand mafias have injured hundreds and killed dozens of people in recent years, with victims including a twenty-two-year-old activist who was hacked to death, a journalist who was burned to death, and at least three police officers who were run over by sand trucks (Beiser 2017).

Some killings by the sand mafia and the sand-mining industry have taken place when people have attempted to stop the mafia from removing sand illegally from their lands. But, in the village of Manimala in India, the villagers themselves have been mining the river sand and have created problems of their own, as their river eventually shrunk to a trickle and a few puddles, with "the stone steps now leading to a gouged-out ravine of pale boulders baking in the sun" (Romig 2017). Would those villagers be called sand mafia if they had simply been trying to earn a few rupees for buying food or using the sand for projects at their own homes, as artisanal miners? Not likely.

Illegal sand miners can be a small, disorganized group or even a single person, so-called artisanal miners — all struggling to make money to support their families, sometimes just to survive. One man told Samantha Hawley (2017b), an ABC News correspondent, "I get a little extra money, that is why I do it. Everybody does what they do for their stomachs."

In one incident, a social and environmental activist named Brijmohan Yadav alerted authorities about suspicious activity near his home village on the riverbeds of two rivers — the Betwa and Ken rivers in Bundelkhand, Madhya Pradesh. Miners were trespassing on his family's land, but when he reported them, he started receiving intimidating threats and being attacked. Within a few days of his filing a police complaint, a gang of men went to his house and threatened to kill him if he did not withdraw the charges. Yadav went into hiding, saying, "I am in danger. . . . My family is in danger. . . . The sand mafia is very strong" (Paul 2015).

Sand Mafias in India, Mahadevan's 2019 report, is subtitled *Disorganized Crime in a Growing Economy*, so it's not a secret society like the Mafia. Some call the sand mafia "organized," and some call it "disorganized." Regardless of their organizational skills, they cause problems, not only to the environment but also to many people.

In their news bulletin, the South Asia Network on Dams, Rivers and People (SANDRP) published extensive information about sand mining, saying,

> Tamil Nadu is home to one of the most dreadful sand mafia operations anywhere in the country. Since 2003, as many as five officers with the police or revenue department have been found dead under mysterious circumstances after they decided to go after the sand mafia. The most

> recent death was that of S Jagadish Durai, a constable with the Special Branch who was found with his head crushed in a village at the banks of the river Nambiyar in May of this year. (Ananth 2018, n.p.)

Tamil Nadu is only one state in India dealing with illegal sand mining and those hired to protect the process and the sand loads themselves. But if some policemen get killed, others have benefitted from associations with the mafia. Saji P. Thomas said, "There are policemen who have built beautiful houses thanks to sand mining" (Romig 2017, 45). Another man, Jagbir Nagar, was asked if they fight the police. "If there are a lot of police and only a few men, then we run," he said. "If the police are few and the men are many, then we get into it with them. We fire shot for shot" (Romig 2017, 48).

A report from the Centre for Science and Environment (2020) highlights some of the problems brought about by the network of sand miners in Kerala and Tamil Nadu: "This network operates so far outside the legal boundaries that in the last ten years there have been numerous reports of the blatant murders of revenue officers. This type of organized, indiscriminate mining could be the death note not just for revenue officers, but also for ecological systems, habitats, and livelihoods."

Sand mafia participants are in the news regularly because stealing sand and defending that theft are prevalent activities. Sand is India's gold. As noted, the demand for sand and its potential for helping someone make a living create the conditions that trigger activities of the sand mafia groups.

To investigate the situation in person, Samantha Hawley traveled to central India with a film crew to see the sand mafia in action in 2017. The news team knew it was dangerous to be there, but they made it out safely after encountering the criminals who were hauling sand out from a site in trucks. Hawley points out that those she calls "accidental activists," who try to stop the illegal sand-mining operations, have been "beaten, maimed and in some cases murdered" (Hawley 2017b). Two brave souls Hawley writes about are Akaash Chauhan and Sumaira Abdulali. The environmental activist Sumaira, who campaigns around her country against illegal sand mining and the sand mafia, was beaten and hospitalized for her work trying to save Kihim Beach near Mumbai, and her car was nearly rammed off a bridge at one point. After she was attacked in 2004, she set up a network for protection of environmental activists in India.

The dreadful story of the Akaash Chauhan's father, Paleram Chauhan, tells how he had been active in trying to save "communal village lands from being entirely stripped of sand by illegal mining" (Hawley 2017b) and how he was attacked in his own home, shot, and killed by some sand mafia members. Meanwhile, Akaash is carrying on his father's work, and Sumaira continues with her activism, travelling around the country researching illegal sand-mining activities, despite threats against her (Hawley 2017a).

Since as early as 2003 to the present, accounts of injuries and deaths by sand mafias abound on the internet, and the mafia's activities have not ceased. The Committee to Protect Journalists (2018) states that Sandeep Sharma, a reporter for the News World television channel, was murdered after exposing "alleged police corruption and illegal sand mining." ("Sandeep Sharma" 2018). *India Today Web Desk* (2018) reported that Sandeep Sharma had earlier approached the police with complaints that his life had been threatened due to his sting operation showing police accepting bribes. ("Madhya Pradesh Journalist Murder" 2018) A 2018 CCTV video actually shows thirty-five-year-old Sharma being run over, with him on his motorbike disappearing underneath a truck on a road in the Bhind district of Madhya Pradesh.

In a *NewsClick* article regarding the number of cases of violations related to mafia sand mining, S. Yogesh relates:

> The officials at Department of Mines and Geology have registered 16 cases daily related to Sand Mafia in Karnataka from 2015–2017. As many as 12,318 cases were booked during this period, all of them mentioning illegal sand mining, transportation, storage, and use of filter sand. The numbers here explain the scale of operation the Mafias are running in the state. . . . In 2017, Maharashtra accounted for almost 40 percent of illegal mining in India, highest in the country. Between 2015–16, 30,979 cases on illegal sand mining were registered in Maharashtra alone. (2018, n.p.)

This article goes on to describe the grisly deaths of several individuals who apparently had been working to expose the sand mafia and their activities.

Sandhya Nair (2019) reports on an impromptu police raid on the sand mafia near Mumbai. A police superintendent, Gaurav Singh, who was travelling one night with Constable Dinesh Patil, stopped their vehicle to question the driver of a truckload of sand who told them the source of the sand. They went to check it out at Virar, Mumbai, and question other equipment drivers; and when Patil "tried to stop a fleeing truck, the driver, instead of paying heed, forged ahead. Patil would have been run over had he not jumped aside in the nick of time." In this particular case, charges were brought against the driver and others, and some equipment was seized by the police.

But currently, as noted above, India's legal system may not be charging all of the violent criminals because some officials are looking the other way, as the Awaaz Foundation and the Bombay Natural History Society (2013) emphasizes in their "Application for Inclusion of Sand Mining in the Agenda of the Convention of Biodiversity."

Notably, the Global Initiative Against Transnational Organized Crime report by Mahadevan (2019) states,

> Although there is insufficient data to reach a definitive conclusion, from media reports it appears that hoodlums working for the sand-mining contractors routinely threaten and injure, but rarely kill, women. Those instances where a deliberate killing is suspected involve male journalists, farmers and activists. In this manner, the mafias try to avoid attracting the attention of women's-rights groups. (17)

Nevertheless, Rajesh Kumar Singh (2015), while investigating violent incidents in the Indian state of Uttar Pradesh, discovered that two women were sexually assaulted by the musclemen of a kingpin while they were working in a field. The reason given was that their families had refused to give up their land near the Betwa River to facilitate sand miners' access.

Even though people may be opposed to the mafia's acts, they are forced to be quiet. One of Rajesh Kumar Singh's interviewees said, "It is better to be silent than dead" (2015). But some local officials and individuals are standing up against illegal operations. In the western state of Maharashtra, the Daund revenue officials cracked down on the illegal sand mining by setting fire to twenty-three boats used by the sand mafia and seizing ten suction pumps they used for illegal dredging along the Bhima River ("Pune: Crackdown on Sand Mafia," *Times of India* 2020).

Some areas, such as NOIDA (New Okhla Industrial Development Authority) near Mumbai, have created a Special Mining Squad to inhibit illegal sand mining in their area ("Grains of Despair" 2020). It may or may not be successful.

Commonly in India, coastal sand mining is occurring regardless of Coastal Regulation Zones that have been set up (figures 4.3A and 4.3B). One lone woman, Jazeera, protested when she discovered the sand mafia was removing sand from a beach near her hometown in Kerala on the west coast of India (Suchitra 2013). Every time she protested "the rampant exploitation of the seashores of the Neerozhukkumchal

FIGS 4.3A & 4.3B Mined beach and dune sand is often stored in bags, easing transportation to sites where the sand is needed, especially for construction. Both images © Denis Delestrac.

FIG 4.3A Bags filled with beach sand in the Maldives.

FIG 4.3B Bags filled with beach sand in Mumbai, India.

beach in Kannur because of illegal sand mining by the local sand mafia," she was beaten up (Nithya 2013), but mining persisted. She eventually stopped protesting (Devasia 2014).

SAND MINING: OCCUPATIONAL AND ENVIRONMENTAL HAZARDS

While the sand mafia attack and sometimes kill opponents, many young miners lose their lives in diving operations while working in creeks and rivers. These deaths also should be attributed to the sand mafia, for operating under unsafe conditions. In the case of Vasai Creek in Maharashtra, India, "75,000 men, many from India's poorest areas, were risking their lives and health by spending up to 12 hours a day diving 12 metres into pitch-black waters with iron buckets to fill with sand" (Srivastava 2018). The investigation reported by Roli Srivastava and Ed Upright (2017) found that some of these divers were dying, but the police denied there had been deaths of miners in the creeks. "We have registered cases of theft of sand and also violations of environmental norms but there are no cases ever of drowning," said S. D. Jadhav, a senior police inspector with the local police station, when asked about the deaths. Other workers at Vasai Creek said deaths go unreported, with hundreds of boats in the creek nightly, and they only find out when the body of a drowned diver floats to the surface a day or two after disappearing, or they find it buried on the creek bed.

Srivastava and Upright (2017) also report that India's national association of real estate developers, Confederation of Real Estate Developers' Associations of India (CREDAI), denied that manual mining even takes place and maintained that a local sand-mining association dismissed any risks. "This work has been going on for over 150 years. This is traditional work and is good physical exercise for those who do it," said Bhagirath Ramchandra Mhatre, who heads the Bhiwandi Taluka Reti Utpadak Sanghatna, an association of sand businessmen in Thane in the Maharashtra state of western India. "There are no grievances, no pain in this work. . . . They are like fish under water," he said, adding that workers are reluctant to wear gloves or masks as they find it uncomfortable (Srivastava and Upright 2017).

WHAT ABOUT THE UNITED STATES?

Indigenous Americans used coastal and riverine sediments, but sand mining goes back only to European settlement in the United States on a small scale. In the southeast United States, there are extant colonial buildings as well as ruins of structures that Spanish and British settlers built using tabby concrete. They burned oyster shells to make lime and mixed it with sand, water, ash, broken pieces of shells, and whole oyster shells to make the tabby concrete for walls. Yes, there's probably some beach sand in that mix. Lauren Sickels-Taves (2016) states that the sand was always from a local body of water, and any sand from salt water was washed clean of salt before making the tabby mixture.

Oren Morton ([1920] 1973) recorded that river sand was being collected to make the mortar for building a meeting house in Virginia: "A supply was brought from that watercourse in sack-loads, each horse in the train carrying a girl as well as a sack. An armed escort was in attendance" (174). Even though the girls may have been the primary reason for the guards, the value of the sand was important. All things of purported value have required guards and protection — protection from theft and maybe even murder. In the United States, violence and murder took place during the 1849 Gold Rush in California, during the twentieth-century Oklahoma oil boom, and even more recently during another oil boom in North Dakota.

In the United States, past sand-mining operations have left their scars on the landscape and also account for some beach and dune losses. While sand-mining violations may be less common in the United States than in some other countries, illicit mining beyond permits or licenses, local raids on dune deposits or sand bars, and sand being stolen from construction projects are known to occur. Particularly, violations of permits for mining offshore sand deposits for use in beach replenishment projects have occurred (see chapter 8).

NO END IN SIGHT?

Money is the element that is creating havoc in every case. Times and places may change, but going for the gold — money in whatever denomination of the country involved — is the driving force behind sand mining and sand-mining mafias. These groups don't hesitate to engage in violence and murder to intimidate everyone from individual landowners to government officials and environmentalists who try to block their illegal activities. And who will prevent it? No one, apparently—the demand for sand won't ebb while booms in building continue. Ultimately, pressure must come to bear from citizens for officials to no longer tolerate criminal activity associated with illegal sand mining.

As noted earlier, the battle lines against such crimes will require increased awareness of the extent of mining and associated violence, creation of new global protocols, enforcement of existing regulations, and management of economic incentives. When all is said and done, however, substitute materials must be found to replace our diminishing sand resources.

SAND RIVERS TO THE BEACH

CH.05

Choked Flow

The beach is a river of sand. **ANONYMOUS**

Complex principles and processes are often summarized in a simple expression or truth. The axiom *The beach is a river of sand* has been used as a teaching tool by coastal scientists since at least the 1960s. The expression is the standard for describing the lateral movement of sand and gravel on beaches. If you're standing on a beach, the sand at your feet came from somewhere else, and it's on the way to a new location every day, whether measured in inches, feet, or miles. The movement is offshore, onshore, and especially alongshore (shore parallel). Even on a pocket beach in a closed cell, bounded by headlands, the collective sands move back and forth parallel to the shore. So, this simple truth, "The beach is a river of sand," provides a quick picture of why groin fields or jetties (walls that cross the beach) act the same as a dam on a river, blocking the sand flow to the next downdrift position, depriving adjacent beaches of sand. This lateral flow of sand on a beach is called longshore drift. And just as river flow is referred to as downstream and upstream, beach sand movement is referred to as downdrift and updrift.

But beach sands come from other ultimate sources—erosion of the bluffs and cliffs at the back of the beach, or from erosion and biodegradation of offshore rocks and reefs, and from rivers and streams for most of the world's beaches. So, a new premise can be added: "The sand river feeds the beach." Choke the rivers and the beaches will starve. Just as a jetty on a beach blocks the downdrift movement of sand, river dams block the movement of sediments downstream. And sand taken from a river is likewise a minus for downdrift sand supply.

Even in a natural wild river, the journey of an individual pebble or grain of sand is long and arduous, with many stops along the way from its sources to the river mouth. However, much of that sand reaches the delta, and ultimately the sea, to form beaches. Mining river sediments removes sand and gravel before it ever reaches a beach, adding greatly to sand deficiency on beaches.

River-sand mining is an overwhelming problem in its own right, exclusive of sediment supply to beaches. The purpose of this chapter is not to dig into those specific negative aspects of mining. Two reports and a video are recommended for understanding the global scope of the demand for sand and the multiple impacts of river-sand mining. The World Wildlife Fund (WWF) report, "Impacts of Sand Mining on Ecosystem Structure, Process and Biodiversity in Rivers" (2018), is easily accessible and important for public awareness. In contrast, D. Padmalal and K. Maya's (2014) book *Sand Mining* is a bit more technical, but it provides considerable detail of the numerous impacts of river-sand mining and gives an extensive bibliographic background. Although the latter draws heavily on associated problems in India, the authors also provide a world view of such impacts in a dozen other countries. The video *Illegal Sand Mining Is Ruining These Countries' Ecosystems* by *VICE News* (2021) illustrates river-sand mining's vast area of damage to the largest deltaic riverine system in the world (Bangladesh), the extent of illegal sand mining in Asia, and the associated violence. Chart 5.1 summarizes the impacts of sand mining in rivers on associated riverine environments as well as the impacts of loss of sand supply to the coast.

RIVERS: SEDIMENT SUPPLIERS—IMPORTANT OR NOT?

In a classic global study of 280 small mountain rivers, J. D. Milliman and J. P. M. Syvinski (1992) posed two parts to the question, "What is the sediment flux to the sea?: (1) how much sediment do rivers carry, and (2) how much escapes seaward past the land and estuary environments?" (540). Their conclusion was not surprising—"We don't know" (540)—but 20 percent of the world's land area is drained by small rivers, over ten thousand of them. Often these small, high-gradient streams coming out of coastal mountain ranges are major contributors to local beaches. In a broad sense, one would think the bigger the river, the greater the sediment input, and although the four hundred biggest rivers in the world drain 80 percent of the land area, not all of these rivers are major carriers of coarse sediment to the sea (i.e., sand and gravel).

Milliman and Syvinski were attempting to approximate natural sediment loads, and they examined the many natural controls such as geology and climate on sediment production and transportation, as well as changes induced by humans. Climate is a difficult one to estimate because occasional big storms will carry more sediment from hillsides and down rivers than decades of normal rainfall. Such runoff and flood events may cause most of the sediment transport that's included in average annual sediment discharge calculations. Milliman and Syvinski also noted that because of human modifications to rivers and drainage basins, many of the numbers given in their paper were already out-of-date by the time of publication!

In trying to estimate rivers' volume of sediment delivered to the coast, general calculations do not always factor in the really incredible catastrophic events that generate record-breaking rainfall and floods. Hurricanes are particularly notorious for voluminous rainfall, both in the immediate areas of landfall as well as inland. These catastrophic inland events are major sediment producers into the sand flow to the coast. For example, north of Lynchburg, Virginia, in 1969, Hurricane Camille produced over twenty-five inches of rain in a five-hour period, a catastrophe that came without warning and killed more than two hundred people. This event is memorialized by a historical marker along US Highway 29. The catastrophe was restricted to rural areas and narrowly missed the cities of Lynchburg and Charlottesville. Garnett P. Williams and Harold P. Guy (1973) reported that the Camille rainfall event was three to four times greater than an expected hundred-year event (i.e., an event having a likelihood of 1 percent in any given year). Centuries worth of sediment was carried down every little wash and gully and collected into the James and other rivers, to combine with sediments already in the streams, and then within hours, these sediments were flushed out to sea nearly 150 miles (241 km) away. The Williams and Guy report discusses the amounts of sediment carried, and the associated land surface features such as cones of sediment at the base of gullies where they enter the valley floor, helping to explain earlier field observations that the authors couldn't interpret. Although such catastrophic events are rare, their importance is significant with

CHART 5.1 IMPACTS OF RIVER-SAND MINING

Channel

EROSION AND SCOUR

Widening and deepening (altering flow conditions)

Undercutting of bridge abutments and pilings; collapse

Undercutting of water intakes/outfalls, utility crossings

WATER-LEVEL FLUCTUATIONS

Increase both flooding and lower water levels

Impact fisheries, agriculture, and water supply

Exposure of water intakes/outfalls, utility crossings

Banks

EROSION

Loss of land, roads, buildings, infrastructure, and cemeteries

Loss of flood-protection structures (e.g., levees, bulkheads)

Lowers water table reducing water supply (agriculture and domestic)

Increases turbidity (decreased water quality; loss of fishery)

DEPOSITION

Fouled water intakes, navigation loss

Floodplain

DECREASED FLOODING

Loss of natural soil replacement by flood cycles

Lowering of water table, loss of irrigation water supply

Land-use loss (e.g., reduced agriculture)

INCREASED FLOODING

Land-use loss (particularly agriculture)

Increased losses and damage to buildings, roads, infrastructure, and cultural sites

Delta

LOSS OF SEDIMENT SUPPLY

Erosional retreat of delta front without sediment renewal

Loss of delta beach fronts (sediment starvation)

Permanent flooding of subaerial delta (no sediment to maintain elevation)

INCREASED VARIATION IN WATER LEVELS

Increased/decreased flooding frequency and max high and low flood levels
Alteration of distributaries and landforms (fishery and agricultural losses)

Beaches

Loss of sand supply increases rate of beach retreat, disappearance, and land loss

Habitats

Losses associated with all of the above (impacts water quality, breeding environments, fisheries, aquaculture, and recreation)

respect to moving sediment to the coast. And we should not be misled by using the term *rare*.

Hurricane Camille's 1-in-1,000-years rain event joins a list of similar events in global drainage basins, including those that occurred during 2020, and those that will happen tomorrow. Climate change tells us that hurricane frequency and intensity are increasing, so it isn't just the coast that should be preparing for the next catastrophic storm. Statistical probabilities (e.g., a 1-in-100-years flood) have proven to be poor guidelines for planning, and the statistics are changing as the climate changes. The next Camille, Katrina, or Sandy is just over the horizon.

Coarse sediment load (sand and gravel as opposed to mud) is more impressive in high-gradient streams, but big rivers are important too. At the end of the great Ice Age when the sea level was lower, the melting ice created great sediment-choked sluiceways. These ancestral streams became today's great rivers, such as the Missouri, Ohio, and Mississippi Rivers, as well as the rivers that formed the valleys of today's Chesapeake Bay, Delaware Bay, and Hudson River. These rivers brought copious amounts of sediment to what are now the coastal plains and out onto the continental shelves. As the sea level rose with the final melting away of the ice sheets, river gradients were lowered, and natural sediment discharge declined. At the new coastlines, waves and winds reworked the earlier sediment deposits to become mainland or barrier-island beaches and dunes, and these shorelines advanced landward across the continental shelves with the rising sea level. The sea level rise also had the effect of creating river landforms upstream, such as floodplains and channel fill — the old deposits that are now exploited by miners for their sands and gravels.

Today's sand and gravel deposits in these areas are looked on as resources, but they are not replenishable resources and are subject to depletion like any other nonrenewable resource such as coal, petroleum, gold, and diamonds. Surprisingly though, over the millennia, humans have gone from being contributors to river sediment load to the present as overconsumers. Prior to the beginning of widespread agriculture and deforestation about 2,000 to 2,500 years ago, global sediment discharge was probably only half as great as at present. But as land clearance and agriculture proliferated, river sediment load increased as erosion increased. So, in effect, humans temporarily were responsible for increasing river-sediment delivery to the coast. However, humanity also developed a reliance on rivers, using them as water resources, transportation routes, food, and even for the sediments, the last particularly in recent history. And then came dams!

> There Charon stands, who rules the dreary coast.
>
> **VERGIL, *AENEID*, FIRST CENTURY BC**

If there were a mythical god who prevented sand from crossing from land to the seashore via rivers, he'd have a hard time matching what humans have accomplished in just over a century. Since the nineteenth century, this human reliance on rivers and river sediment has produced two major impediments — dams as well as sand and gravel mining — that effectively prevent river sediment from reaching the coastal areas of critical need. While both activities have occurred well back in human history, the rapid increase in dam construction began in the late nineteenth century and continued through the twentieth century, driven by engineering capabilities, flood-control requirements, water supply needs, and hydroelectric power generation. Dams grew bigger and better but without a parallel growth in knowledge of the resulting long-term impacts of altering rivers, including changes in habitats, landform evolution, and changes in erosional and sediment-trapping behaviors. Estimates vary, but globally the number of dams today is on the order of forty-five thousand. Probably around the same time as the accelerated rate of dam building, the industrial revolution spurred the mining of rivers and associated landforms: their channels, floodplains, estuaries, and deltas. The industrial revolution even affected gold mining. Ground sluicing is an ancient way of mining river-bank sand and gravel deposits for gold, but in the mid-1800s, gold mining became mechanized, big-time, with hydraulic mining, particularly in the California gold fields. The so-called waste sand and gravel were left behind, some of which was subsequently mined for concrete aggregate and other uses.

Current losses of river sand to beaches are magnified by these two impediments—dams and the mining of river sediments. The combined driving forces of the need for construction aggregate and the energy requirements for associated urbanization and tourism developments continue to be perceived as more important than the known impacts of dams and mining. For example, between 2007 and 2013, four of the top-ten hydroelectric generating dams in the world became operational in China: Three Gorges, Xiluodu, Xiangjiaba, and Longtan—dams that will negatively influence their downstream environments.

Sand mining within the drainage basins of rivers flowing to the sea now occurs in every coastal country and even in areas of large lakes, such as the Great Lakes of North America. Over the last century, dams have been the first focus for recognizing coastal sand loss, while the focus on river-sand mining is more recent, reflecting the exponential growth in demand for sand.

RIVER DAMS: THE FIRST FOCUS

Herodotus (circa 442 BC) is credited with recognizing (what the Egyptians surely knew a millennium earlier) that if the annual Nile River floods were to cease, the delta and fertile Nile floodplain would fail. Yet, throughout history, the damming of streams and rivers for mills, water supply, and later for flood-control and hydroelectric generation would continue to escalate. There is no measure of how greatly this history of dam growth has impacted beaches, but certainly by the 1950s there was a global recognition that dams cut off critical sediment supply to downstream flood plains, deltas, and beaches. In the United States, the small dams on California's high-gradient streams flowing to the coast were at the top of the list for cutting off sand supply to beaches and accelerating coastal erosion.

Old Herodotus was proven correct, right there in Egypt where twentieth-century dams did a job on the Nile Delta. Patrick McCully's *Silenced Rivers* notes,

> Over the last millennium the Nile has reached the Mediterranean through two distributaries — the Rosetta and Damietta Promontories — which have built their own "sub-deltas." The most severe erosion has been on the western side of Rosetta Promontory which retreated by nearly six kilometres between 1900 and 1991, washing out to sea a lighthouse and a resort and flooding coastal villages. A replacement lighthouse built one kilometre inland in 1970 is now "offshore a long distance away from land." Before the closure of the High Dam in 1966 the rate of retreat was around 20 metres per year; by 1991 the annual rate had accelerated to 240 metres. (2001, 33–35)

This retreat of the delta front is largely due to the reduction of fine sediment, silt, and clay reaching the delta surface as well as the shoreline front. The Aswan Dam traps 98 percent of the Nile's sediment, and the loss of the silt fraction to the delta floodplain has had a serious effect on Egyptian agriculture. Now farmers use fertilizers which can have disastrous effects on river and offshore fisheries.

Similarly, decreased sediment discharge for almost every great river (e.g., Colorado, Mississippi, Magdalena, Danube, Ebro, Niger, Zambesi, Indus, Ganges, Mekong, etc.) continues to starve their associated deltas, associated barrier islands, and beaches. The Akosombo Dam on Ghana's Volta River has contributed to the loss of the delta's sandy beaches and increased the erosion rates of the delta-front and shorelines of neighboring Benin and Togo by around 33–50 feet per year (10–15 meters per year).

Dams on smaller rivers with high sediment loads provide even more spectacular examples of sediment-supply loss to beaches. The large number of studies as well as media coverage of associated controversies of California dams provide examples that are repeated globally (figure 5.1).

In regard to southern California beaches, Gary Griggs notes,

> In addition to providing most of California's drinking water, the state's rivers and streams also provide about 75% of our beach sand. . . . The total amount of beach sand now trapped behind all of California's coastal dams totals about 200 million cubic yards, or a line of dump trucks bumper to bumper stretching completely around the world nearly four times. . . . In California, the San Clemente Dam on the Carmel River, Gibralter Dam on the Santa Ynez River, Matilija Dam on the Ventura River, and the Rindge Dam on Malibu Creek are now completely full of sediment and no longer serve any purpose. . . . Combined, these 4 dams have trapped 2.8 million dump truck loads of sand that can end up on

FIG 5.1 The removal of the San Clemente Dam near Monterey, California, in 2015, revealed that the impoundment was filled with sands and gravels that had accumulated behind the dam over a period of about ninety years. The fill rendered the dam useless and presented a flood and surge hazard if the dam failed. A good guess is that most of the fill was hauled away, rather than being reintroduced to feed the downstream channel and ultimately the shore. Photo © Luke Gianni, California American Water.

> the downstream beaches. . . . Google "dam removal" to see some of the dam removal projects that have already been accomplished. (Griggs 2014)

An earlier California study by Douglas Sherman, Kamron M. Barron, and Jean T. Ellis put similar information in terms of cubic meters of sand lost per meter of shoreline:

> Sediment impoundment data were obtained for 28 dams and more than 150 debris basins in the watersheds of eight rivers: the Santa Ynez, Ventura, Santa Clara, Los Angeles, San Gabriel, Santa Ana, San Dieguito, and San Diego. The cumulative effect of these structures is the impoundment of more than 4,000,000 m^3/yr of sediment. This is equivalent to a potential deprivation of beach sand of roughly 3 m^3/yr per m of shoreline in the five southern California coastal counties. (2002, 662)

Negative effects of dams go beyond downstream sediment loss, and upstream and downstream impacts of dams are virtually the same as those of sand mining, with a few additions (see chart 5.1). Dams create a false sense of security, encouraging development on the valley floors downstream and along the shorelines of the reservoirs created by the dams. In May 2020, two dams on a tributary of the Saginaw River in eastern Michigan washed out after heavy rainfall runoff. No lives were lost, but thousands were evacuated, houses were lost, and lake-front property owners now look out on a mudflat. The strong likelihood is that the dams may not be replaced, and the finger-pointing lawsuits will occupy court time for several years. The former lake-front properties lost their value in just a few hours. Modern history has numerous examples of dam failures where the downstream populations were not as lucky.

On a grander scale in Brazil, a major fish kill was reported by Luna Gámez (2020) — six tons of dead fish appeared in the Teles Pires River, about a year after a similar event with thirteen tons of dead fish. Both events were due to a hydroelectric dam operation, bringing to light a host of violations by the operating company, including infringement on the rights of Indigenous people and revealing that hydroelectric dams are not always as green as we think in terms of alternative energy. In Brazil's tropics, dam construction requires the removal of all vegetation cover prior to flooding of the land by the resulting reservoir. In this example, the company cleared only 30 percent of the cover, resulting in a layer of rotting vegetation in the bottom waters of the lake, causing oxygen depletion, the emission of greenhouse gases, and likely more fish kills in the lake, upstream and downstream. Study of another hydroelectric dam reservoir in the Amazon, where vegetation was not removed, revealed that gas emissions were eleven times greater than at an equivalent thermoelectric plant. The report notes a similar situation in French Guiana with double disasters contributing to global warming, namely, dead rivers and loss of the rain forest (Gámez 2020).

Progress comes slowly, but unlike in China and Brazil, the enthusiasm for new dams in the United States and a few other parts of the world has waned. Dam removal is becoming more common, including the elimination of ineffective dams due to sediment backfilling (e.g., California); the removal of obsolete mill or hydroelectric dams (e.g., Michigan); and the major removal of two dams on the Elwha River in Washington State, the 210-foot Glines Canyon and 105-foot Elwha dams.

The 2014 completion of the latter project has significantly restored the beach and natural ecology. The salmon fishery and beach clams of particular importance to local Native Americans should recover as well. Today the Elwha River runs free from the mountains of Washington's Olympic National Park to the Pacific's Juan de Fuca Strait, once again bringing sand to the beaches. This Elwha River restoration is an important experiment in determining how natural habitats and sediment flow recover after dam removal. Similar dam removals are planned for the Klamath River in California (figures 5.2A and 5.2B).

Another big US experiment began in 1996 in an attempt to restore some aspects of natural habitat within the Colorado River's Grand Canyon. Sand bars and river beaches within the river's great canyon were being lost or overgrown, sometimes by invasive species. Major water releases from the Glen Canyon Dam were conducted to flush sediment downstream, wash out some of the overgrowth, and restore fish habitat and sand-bar campsites for rafters. The results for river-beach and sand-bar restoration, native species recovery, and improved recreational aspects were good enough to establish a planned program for more such water releases (Harder 2001).

The qualifier here is that not a single grain of sand moved by this experiment would make it to the Colorado River's delta and ocean beaches because Hoover Dam is the next downstream trap, with six more such chokeholds beyond. The good news is that the truth, "Downstream sediment flow is as important as water flow," has been recognized—a recognition of Sand Rights (see appendix B).

RIVER-SAND MINING: THE SECOND FOCUS

While dams have historically been the focus as the culprits of cutting off river-sediment supply to the coast, another rapidly growing, double-threatening trend was occurring—river sand and gravel mining. Many of us remember the swimming holes down by the river—usually the county gravel pit for road materials, or perhaps a small operation of a private aggregate company. Nothing too large, and certainly not of any concern, even in terms of loss of fertile cropland. But as the demand for aggregate and sand in general has grown, especially since the 1950s, so too has river-sand mining—in the floodplains, in the river's sand bars, and in the river-channel floors.

Just as river sand is a number one source for beach sediments, river environs globally are the number one source of mined sand—the latter canceling out the former, which is bad news for global beaches.

But why river sand as opposed to other sand sources? Preferable aggregate properties and economics are the answers. Strictly speaking, river sand and gravel are not as well sorted as beach sand within their size categories, but they are usually well washed in the sense that the currents that deposited this coarse sediment also washed away the finer silts and clays (the mud). Typically, both the sand and gravel have a mix-

FIGS 5.2A & B
Changes at the mouth of the Elwha River, Washington, before and after the removal of the upstream dam.

FIG 5.2A Before the removal of the dam, there was loss of adjacent beaches and a Native American shell-fishing ground in the nearshore. Photo © SAF — Coastal Care.

FIG 5.2B After the upstream dam was removed, sand once again was flushed down the river to build adjacent beaches and restore the sand-delta habitat. Photo © Ian Miller of Washington Sea Grant, Jonathan Felis of the US Geological Survey (USGS), and Neal and Linda Chism of Light Hawk.

ture of grain shapes, tending to be more angular than well-rounded desert sand, and thus better suited for concrete. And river sands are free of the salt problem associated with marine sands that require washing, or else the requisite reinforcement rods in concrete are weakened.

Rivers' sand and gravel deposits frequently are close to areas where construction aggregate needs are the highest, such as rapidly developing urban areas and developing industrial sites including oil fields, such as those found along the Niger River in West Africa. Because floodplains often are underlain by extensive, thick river deposits, there is an ample supply for ongoing mining operations. Good volume, quality aggregate, less extensive transportation, and lower processing costs all add up to potential big profits for the mining company.

Like trying to estimate how much sediment natural streams deliver to the coasts each year, calculating how much river sand is mined annually is nigh impossible, but it is not an exaggeration to say tens of billions of tons (yes, billions with a *b*). Imagine trying to determine the amount of sand mined in southeast Asia's Mekong River that flows through six different countries, none of which have an accurate idea of the sand volumes lost legally, let alone illegally.

To date, few studies have been published that attempt to give data on specific sand volumes lost, and those few are full of qualifications. For example, Doan Van Binh, Sameh Kantoush, and Tetsuyi Sumi (2020) allude to quantifying sand loss due to sand mining versus dam blockage on segments of the Tien and Hau Rivers that are part of the Mekong River system. They based the study on "licensed sand-mining volume" (5) which averaged 1.7 million cubic meters per year over a ten-year period, with the qualification that the number may be too small because "sand mining operators tend to report lower amounts to reduce their fees" (12) for licenses. The authors give no estimate of illegal mining volumes but imply they are significant.

In addition to downstream sand-supply loss, dams and sand mining both cause riverbed incision; that is the erosion and cutting down of the river channel, causing more detrimental effects downstream (see chart 5.1). The noted threat to infrastructure by sand mining can be life threatening. Vince Beiser (2017) notes, "Sand mining caused a bridge to collapse in Taiwan in 2000, and another the following year in Portugal, as a bus was passing over it; 70 people were killed. Another bridge collapse in India in 2016 that killed 26 may have been caused by sand mining" (n.p.). He also note that "a 1998 study found that each tonne of aggregate mined from a California river caused $3 in infrastructure damage—costs that are borne by taxpayers. In Ghana, sand miners have dug up so much ground that they have exposed the foundations of hillside buildings, putting them at risk of collapse" (n.p.).

In comparing dams and sand mining, Binh, Kantoush, and Sumi (2020) conclude that if mining of the entire Vietnamese Mekong Delta were at a level of 7.75 million cubic meters per year, sand mining would be responsible for approximately 15 percent of the incision. So, in the Mekong Delta, dams are still the main culprit for both choking off sand and channel incision, but mining is gaining.

Mette Bendixen et al. point out that "this extraction of sand and gravel has far-reaching impacts on ecology, infrastructure and the livelihoods of the 3 billion people who live along rivers" (29).

They go on to say, "Most of the trade in sand is undocumented. For example, between 2006 and 2016, less than 4% of the 80 million tonnes of sediment that Singapore reported having imported from Cambodia was confirmed as exported by the latter. Illegal sand mining is rife in around 70 countries" (30).

This example reminded one of the authors of a story told many years ago by an American geologist working in Portugal where he tried to get data on how much sand volume had been approved for legal mining from a particular river versus volumes of sand sold. He was told to mind his own business (i.e., "go back to your country").

Breaks in the supply chain is a concept to carry over to river sands and beaches. Just as tariffs, political unrest, or pandemics can lead to breaks in the supply chains for manufactured goods, mining river sediments breaks the sand stream going to the shore. If there is a warehouse full of parts, manufacturing will continue for a while, but it ultimately ends when the supply inventory is exhausted. Because some river systems have large amounts of stored sand and gravel, a mining operation here or there on the river isn't regarded as depleting Nature's warehouse. But neither a single mine nor an entire river basin has inexhaustible aggregate deposits.

Look country-by-country online, and the number of examples of little-to-big-to-massive operations is staggering (Coastal Care 2020b). And they are found from the heads of rivers to their mouths. A massive sand-mining operation in the Puna Tsang Chu River, Punakha, Bhutan, is next to the Himalayas, far from the Ganges Delta, but it's the head of the sand supply chain (figure 5.3A). The sands of today's beaches in the Indian Ocean had their origins in similarly faraway locations. In the lower Tatai River of Cambodia, small operators from little boats to small barges have dredged sand from the riverbed to feed small processing plants or have sent it by barge directly to the river mouth to go onto sea-going barges—Singapore bound (Gray 2011) (figure 5.3B). And Chinese mining companies covet the black magnetite sand found at the very river mouth next to the beach near Aparri, Luzon, Philippines, as ore for steel. *Australia Network News* (2013) reported that eighteen Chinese miners were apprehended for illegal sand mining in a restricted zone. As the network commented, "Under Philippine Law, it is illegal to extract any minerals within 200 metres (656 feet) of a beach." These Chinese miners lacked work permits and were mining sand that clearly was an immediate sand supply for the beach; in addition, they were building a processing plant at the beach. In both Cambodia and this latter example, the battle to circumvent regulations continues, a common line of reasoning being that the river channel is being dredged to deepen for navigation or improved flow. *Australia Network News* went on to say that the mining firms are "often operating in collusion with local government officials."

Associated negative impacts from sand mining were noted earlier (see chart 5.1); however, there are related problems that may not be implied by that list. For example, mining operations often divert channels or place barrages to change drainage patterns for the convenience of mining. Landforms are destroyed, as are the livelihoods of the local population (agriculture, fishing, navigation). Pollution is commonly associated with and from mining. Sulayman Hossain (2021) provides a well-illustrated report on the impacts of illegal sand mining from the Jamuna River in northern Bangladesh. Urbanization drives the need for "raw gold" (sand), and the river dredging has destroyed ancestral farmlands, wetlands, and rice paddies and has also changed the course of the river, expanding the land loss—allowed by local authorities who are ignoring court writs to stop. Bangladesh, one of the most populous countries on earth with a coast in desperate need of sediment, is rapidly losing coastal sand sources to both urbanization and mining.

Chapter 4 highlighted sand mafias, underscoring that such illegal mining activities are an outgrowth of socioeconomic conditions, rarely providing any long-term benefits to local communities. Many of the examples given were associated with river-sand mining as well as with coastal environments. Even outsiders can fall victim to such operations. An example of an unintended consequence of illicit river-sand mining occurred on the Beas River in the northern India state of Himachal Pradesh. In June 2014, a group of university students on holiday went down a mining road to the river where miners were filling bags with sand. The students had travelled a long way on a hot journey, so they jumped in to enjoy the cool river water. But then, most of them

FIGS 5.3A & B River-sand mining operations.

FIG 5.3A Sand is mined from a large sand bar in the midstream (just beyond photo area) of the Puna Tsang Chu River, Punakha, Bhutan, and stored in a loading area from which the sand is moved by truck to a processing plant. The riverbank is scarped by erosion because mining changes the river channel position. Photo © SAF—Coastal Care.

were washed away and drowned because, shortly after they entered the river, the dam upstream was opened to let water and sands flow out into the river from the Larji Dam Reservoir. Perhaps this was only a sand-mining-related tragedy, but Tom Lasseter and Rakteem Katakey (2014) wrote that speculation was that the dam operators and the sand looters were working together, so that the miners would have more sand to collect as sediment behind the dam was washed downstream.

And such mining impacts are not restricted to third-world countries. Look at American rivers and estuaries. Matthew Rozsa (2021), reporting on an article in the science journal *Geophysical Research Letters*, notes that one in three US rivers has changed color since 1984 in response to sediment loading from various causes including mining and

FIG 5.3B A small sand-processing plant on the bank of the Tatai River, Cambodia. Small boats and dredge barges off-load sand that will be trucked or barged to the river mouth for export on sea-going barges. In 2011, the destination was Singapore. Photo © Robert Tyabji Hoorob, Creative Commons CC BY-NC-ND 2.0.

pollution. Mining can both decrease the coarse-sand load and increase fine sediment in suspension, the latter creating yellow and brown rivers (Gardner et al. 2021). Even in the United States, those old swimming holes in the floodplain often became landfill sites, above and in the water table. Many such sites are now undergoing environmental pollution cleanup and land-restoration measures that often cost more than the value of the original mined aggregate. Agricultural nutrient runoff has caused algal blooms that are toxic and given rise to green rivers and green plumes in lakes, including Lake Erie, threatening municipal water supplies.

The age of coronavirus (COVID-19) increased focus on how disease spreads. Sand mining is no exception inasmuch as mining creates areas of standing, often stagnant, water. In Kerala, India, virus outbreaks, such as the Nipah virus, may be associated with such environmental disruption. Damayanti Datta (2018) notes, "Kerala is particularly vulnerable to infectious zoonotic diseases . . . since the 1970s: from Bird Flu to Swine Flu, SARS to MERS, Ebola to Zika and finally the Nipah outbreak" in 2018. In 2017, a *Science* magazine article noted that sand mining's stagnant pools were potential spawning grounds for *Anopheles sp*. mosquitos, the vector of malaria, in such areas as Iran, Ethiopia, and Eritrea (Torres et al. 2017; Kindu et al. 2018).

THE LESSONS TO BE LEARNED

Perhaps the irony of river-sand mining, as well as an illustration that sand is a nonrenewable resource, is the following quote from an article by Nikhil Menon (2018): "Almost exactly a year ago, a ship laden with over 56,000 tonnes of sand from Malaysia docked at Tuticorin port in Tamil Nadu. It was the first imported consignment of river sand to arrive in India."

Imagine: India, a world leader in sand-mining production, was reduced to begin importing river sand. This event is a harbinger of what countries should expect when the ravenous hunger for sand exceeds the supply. Our river barges and cargo ships now haul sand instead of coal—and nations compete to export what underlies their very landforms. The double irony here is that there are beaches in Malaysia that need sand, while Malaysian sand is being exported! And even political boundaries (rivers) that straddle sand deposits are in question. Indeed, *Sand Wars* may become more than just a term for internal struggles.

Progress in gaining control over sand mining is too slow. Like dam removal, the United States leads in some respects in banning or limiting certain kinds of sand mining (e.g., beaches and dunes), but river-sand mining still flourishes. Some countries have banned the exportation of sand but continue to mine their own rivers for internal use. And a number of countries, such as Australia and China, have banned the mining of their own beaches but then import sand mined from beaches, coastal dunes, and rivers in other countries without such restrictions.

Some countries propose or present legal solutions, with talk of studies to control mining, but they are still in denial as to the magnitude of the problems. For example, India still relies on cost-benefit analyses that rarely account for costs outside of the mine area, or the long-term cumulative costs that will occur well after the mining is over. Sustainable sand mining and sustainable sand management continue to be unsustainable points of view and are unrealistic because the resources are nonreplenishable.

To close the loop, recall that we began with the truth: "The beach is a river of sand." And in looking at dams and river-sand mining, more truths can be stated that ought to have some influence on how rivers are managed, for they are combined resources of water, sediment, and processes that need maintenance rather than blind exploitation.

TRUTH: The sand river feeds the beach.

TRUTH: Downstream sediment flow is as important as water flow.

This truth underlies the concept of sand rights (see appendix B).

TRUTHS: Sustainable sand mining or sustainable sediment management are oxymorons because in most cases river sands are derived directly or indirectly from very old deposits.

River-sand deposits took centuries to millennia to millions of years to accumulate and are not replaced upon being extracted (i.e., nonrenewable resources are not sustainable). Similarly, periodic releases of large volumes of water from behind dams to flush out valley sediments does not achieve an equilibrium in sediment delivery to the coast.

TRUTH: Local populations rarely benefit from dams or river-sand mining.

In particular, in third-world countries, others derive the profits, whether from legal or illegal sand mining, while paying low wages to locals, and then leave environmental ruin behind, unfit for fishing or agriculture.

TRUTH: So-called cost-benefit analyses supporting river-sand mining projects do not take into account the true costs of the cumulative negative impacts of the mining (see chart 5.1).

In some countries, the permitting of legal river-sand mining is based on cost-benefit analysis, where benefits must outweigh the costs for approval. But it is rare indeed, if ever, that a project looks at more than just local costs. The effects of a mining project upstream, downstream, medium-term, and long-term, as well as whether there will be enforcement of stipulations, monitoring of projects, sources for financing such requirements (and how), and similar questions, are ignored. Every project is local, but regionally the cumulative effects of multiple projects can be synergistic in terms of negative effects.

FINAL TRUTH: The need for sand from rivers, beaches, and coastal dunes must be significantly reduced, requiring changes on many fronts, such as regulations and enforcement, more efficient architectural design and construction techniques, and substitutes for sand and gravel aggregate. (See chapter 10.)

BARBUDA AND OTHER ISLANDS

CH.06

Lessons from the Caribbean

When picturing the Caribbean, idyllic beaches are often conjured. Perhaps one imagines crystal blue waves lapping on soft, white sands. Whatever the Caribbean connotes, it is unlikely to stir images of beaches as sites of destruction. Nevertheless, the Caribbean is a hot spot for the extractive practice of sand mining. Caribbean beaches have been increasingly mined to support construction booms and tourism development across the region. In particular, Barbuda, the smaller half of the twin-island state of Antigua and Barbuda, has become a cornerstone of the sand-mining market in the Caribbean by exporting sand to nearby islands. With no tariffs on sand importation, some countries opt to source sand from abroad to preserve their own beaches (Parker 2002).

Available sand resources and the impacts of sand mining are a function of geology, politics, mining practices, and past mining activity. Each of these is considered in view of the future of the beaches and coastal dunes of Barbuda and other Caribbean Islands.

GEOLOGY OF BARBUDA

Barbuda is a tiny piece of the Caribbean Plate in the global puzzle of plate tectonics. The Lesser Antilles Island chain formed due to the subduction of the westward-moving North American Plate beneath the eastward-moving Caribbean Plate. The Antilles are a chain of large volcanoes formed near the plate boundary, some of which are still active (e.g., Montserrat and Martinique). These volcanoes, including the predecessors of Barbuda and Antigua, emerged above sea level. Barbuda's volcanic seamount was probably underwater during most of its history, but its top was shallow enough for coral reefs to grow some five to twenty million years ago. These reefs formed limestones that are now exposed on the island.

During the Pleistocene (the Ice Age), water was locked up in continental glaciers, so sea level was as much as 400 feet (122 m) lower than today. The most recent rapid melting of the ice caps began around eleven thousand years ago, accompanied by sea level rise. By the time Columbus sailed into this so-called New World, the rate of sea level rise was very low, Barbuda was emergent, and its size was much smaller but stable. During this time, a veneer of coastal sand (beach ridges, dunes) was deposited over the older limestones of the low-lying island. Sea caves and other erosional features cut the old reef limestones.

While nearby Antigua has a maximum elevation of over 1,300 feet (nearly 400 m), most of Barbuda's elevation is low (less than 25 feet [7.6 m]) with a highland reaching about 200 feet (60 m). Consequently, the coming sea level rise and future storm surges will cause serious land inundation. Topographic landforms protecting the island interior are generally lacking, and the sedimentary veneer is essentially a nonrenewable resource that is easily eroded. So, Barbuda can afford neither any loss of older sand deposits nor the loss of present beaches and dunes to sand mining or development.

THE POLITICS OF BARBUDA

Separated by less than 40 miles (64 km) of sea, the islands of Antigua and Barbuda, former British colonies, merged to form a sovereign state in 1981. Antigua and Barbuda have a combined coastline length of 95 miles (153 km).

Despite sharing mutual statehood and similar environmental challenges, the sister islands are starkly different in notable ways. In terms of population, approximately 96,000 people reside in Antigua, while only 1,800 live in Barbuda. This imbalance translates into Antigua carrying significantly more political influence and representation in Parliament.

The islands have distinct land-tenure systems. Antigua boasts a freehold system, where private ownership rules. Barbuda operates under communal land tenureship, meaning that Barbudan inhabitants and their descendants collectively own the island. Communal land ownership can be traced back to colonial rule (Sluyter and Potter 2012).

The British Crown leased Barbuda to the Codrington family from the late seventeenth century to the late nineteenth century. While Antigua was used for plantation agriculture, Barbuda's landscape was better suited for cattle ranching, which enslaved Africans carried out. To develop a system of open-range livestock herding, the Codringtons chose not to build fences. Economic activity and land management from this period would shape later land use and perceptions of ownership. After slavery in British territories was abolished in 1834, Barbuda continued cattle ranching and kept the communal land system. Cattle ranching, the original economic justification for communal land tenureship, was abandoned around island independence in 1981, but Barbudans maintained their land ownership system (Sluyter and Potter 2012). Though communal land ownership was codified in 2007 under the Barbudan Land Act (BLA), a group of speculators, primarily Antiguan politicians and foreign investors, have been trying to convert Barbuda to private ownership since Antigua and Barbuda formed a sovereign country (Sluyter and Potter 2012). Opening Barbuda lands for purchase by non-Barbudans is seen as necessary by proponents to cultivate a flourishing tourism market.

A decision to repeal the BLA was made days after Barbuda was struck by Hurricane Irma in 2017 when Barbudan politicians were unable to be present to vote in the Antiguan-dominated Parliament (Gould and Lewis 2018). However, this repeal has been met with fierce opposition. Barbudans claim that the move to privatize communal land is an infringement on land rights and a practice of *disaster capitalism*. The conflict over land tenureship continues to be a source of social and political tension between the sister islands. Currently, the BLA is being examined in the Eastern Caribbean Supreme Court.

The difference in land tenureship between Antigua and Barbuda also influences the islands' differing economic models. Antigua's economy is primarily centered on tourism, with financial services being the second-largest source of revenue. Research carried out by Kenneth A. Gould and Tammy L. Lewis (2018) demonstrates that Barbuda's largest sources of revenue are remittances and subsidies from its more prosperous sister island. Barbuda also offers some tourism, usually in the form of boutique luxury experiences. The island was a favorite destination of Britain's Princess Diana.

However, this destination's popularity may change in the next few years as Barbudan land could be opened for purchase to non-Barbudans depending on the Eastern Caribbean Supreme Court ruling on Barbuda land tenureship. Foreign investors, including Hollywood actor Robert

De Niro, are eager to acquire land to build resorts (Gould and Lewis 2018). Communal land tenureship has left much of the island undeveloped, and much of its beauty has been preserved by barring foreign development. However, the remaining pristine environment and largely untouched land appeal to investors who see the island as an untapped, lucrative opportunity in the tourism industry. Since Barbuda faces economic challenges, particularly after Irma left the island in shambles with slow reconstruction efforts, investing in tourism is often presented as a solution. But, given the lack of tourism as a real economic opportunity, sand mining is commonly practiced across the island. However, because of its illegal status, sand mining is not officially recorded as a source of revenue for Barbuda.

To contextualize the sand-mining dilemma in Barbuda, recognizing the contributing factors that foster the practice of mining is necessary. Lack of economic opportunity and government oversight, the presence of beaches, a soaring construction industry, weak enforcement, lenient punishment, and tensions between sister islands collectively make it possible for sand mining to endure.

HISTORY OF SAND MINING IN BARBUDA

Since the advent of large-scale sand removal in the twentieth century, construction has been the main driver of sand mining. Tourism has changed the landscape in the Caribbean. Development became even more concentrated in coastal areas following the influx of tourists from the 1970s onward. Compared to other islands in the Caribbean, Barbuda hosted tourists only at a modest scale. The island has remained comparatively less developed, with only a few resorts constructed since the 1970s. Barbuda did not experience the same tourism-triggered construction boom as the other islands, which left Barbuda in a position to become an important sand exporter for the Caribbean. Compared to its sister island Antigua, Barbuda suffers from a lack of economic opportunity and diversification. As a result, sand mining was adopted and quickly became a cornerstone of the Barbudan economy. Sand mining in Barbuda began in 1976 (Brown 2013). Reports published as early as the mid-1990s express the dangers of sand mining.

Various operators, large and small, have carried out sand mining on Barbuda. Barbudaful (2020), a community website, claims that the Barbuda Council, government ministers, American investor Dave Strickland, international banker Bruce Rappaport, numerous civilians, and

several mining companies have all mined Barbudan sand. Depending on the scale of operation, sand mining requires pickup trucks (most commonly) or industrial construction equipment, such as backhoes. Using pickup trucks to haul mined sand is so commonplace that these vehicles have become the standard for measuring sand volumes, reports Hendren Parker (2002) in the national climate change report on Antigua and Barbuda. A cubic yard of sand is roughly equal to one pickup truck–load, and a typical dump truck–load is 10 to 16 cubic yards (figure 6.1). This report also indicates that sand mining is primarily carried out on interior dunes in Barbuda by digging large pits, but that beaches are also sites for mining operations.

FIG 6.1 An excavator removes sand from a Barbudan beach to be hauled away by dump truck, often to a barge that will transport the sand to Antigua or other Caribbean islands. Photo courtesy of *Antigua News Room.*

CURRENT STATUS OF SAND MINING IN BARBUDA

Passed in 1952 by the government of Antigua and Barbuda, the Beach Protection Act (BPA) is a piece of legislation that prohibits sand mining unless a permit has been issued at the discretion of the Ministry of Works (Parliament of Antigua and Barbuda 1993). Initially, the BPA only applied to the island of Antigua. Barbuda was exempt from sand mining prohibition until an amendment to the BPA was passed in 1993. The Ministry of Works and the Barbuda Council, a council of eleven elected officials in charge of managing internal affairs in Barbuda, are the agencies responsible for the enforcement of the BPA.

The Department of the Environment states that illegal sand mining in Barbuda carries a prison sentence of up to one year, a fine of $370, and seizure of the vehicle used for mining. This lenient punishment does not effectively deter mining. Offenders can easily pay off the penalty if they mine enough sand, since the sale of one cubic yard (0.8 m^3) of sand pays upward of $200, reports NBC *News* (2008).

In interviews from research carried out by Vashti Ramsey, Andrew Cooper, and Katherine Yates (2015), two officers of the Barbuda Council expressed that illegal sand mining remains prevalent and that the destruction of beaches is one of the greatest threats to the island's store of natural resources. In part, sand mining is still widely practiced because the BPA is enforced infrequently, likely because of corruption.

Today, the construction industry on Barbuda and other Caribbean islands still galvanizes sand-mining demand. The 2017 hurricane season is responsible for the most recent spike in sand mining. The hurricanes left Barbuda in shambles. Many former residents are moving back to the island and are forced to salvage the remains of their homes or start fresh. Sand for concrete is necessary for both the repair of existing structures and the construction of new buildings. This dilemma foreshadows the Sisyphean cycle Barbuda faces moving forward: beaches and protective dunes are mined to support construction mostly on Antigua. But then new storms will strike and wreak more damage due to the mining, and then ever-more sand must be mined to supply sand to rebuild structures lost from the latest storms. Clearly, this cycle cannot continue ad infinitum. In fact, the accelerating sea level rise that is now occurring at the same time that storms are intensifying may soon halt this cycle.

The extraction of sand is not sustainable and will ultimately leave Barbuda even more vulnerable in the already arduous battle against climate change. While sand mining creates an array of consequences for the island, residents need shelter. Citing a lack of adequate disaster relief, some Barbudans see sand mining as the only viable, albeit problematic, route to rebuilding their homes.

Allegations of corruption and greed surrounding sand mining are longstanding. Don Schanche (1989b) reported in the *Los Angeles Times* that former Prime Minister Vere Bird refused to stop sand mining after the Barbuda Council requested for the practice to end. In fact, Bird's son, Lester Bird, and two Antiguan Cabinet ministers co-owned the sand mining company that was digging in Barbuda. Barbudans disapproved of sand mining on environmental and economic grounds; Barbuda was receiving little money in exchange for its sand. According

FIG 6.2 A barge that transports sand from Barbuda. Dump trucks can drive onto the barge and dump their loads. Photo © Desmond Brown, via Coastal Care.

to Hilbourne Frank, a Barbudan member of Parliament (MP), Barbuda only received an average of $2,000 per barge of sand. At the same time, the mining company charged Guadeloupe and other islands upward of $28,000 per barge of sand (Schanche 1989b) (figure 6.2). Undeniably, Barbuda sees little financial return for its valuable resource.

ENVIRONMENTAL IMPACT OF MINING

While specific impacts of sand mining depend on the unique characteristics of the ecosystems, all sites experience coastal erosion; whether it is from the removal of sand onshore, nearshore, from nearby dunes, or rivers (to a lesser extent)—all have an impact on the erosion of the shoreline.

As a Small Island Developing State (SIDS), Antigua and Barbuda endures unique environmental, economic, and social constraints that undermine sustainable development. In a report published by the UN's Natural Disaster Risk Reduction Program (Global Facility for Disaster

Reduction and Recovery 2017), the islands are recognized for frequently being caught in the destructive paths of hurricanes and tropical storms and are especially vulnerable to rising sea levels. Further, the relative remoteness and limited resource base of Antigua and Barbuda make it challenging to cope with the impacts of natural disasters. In addition, since Barbuda lays relatively low with little elevation, much of this elevation (dunes) has already been removed by sand mining.

Barbuda's struggles as a SIDS were evidenced by the devastating Hurricane Irma that struck the island in 2017. The Global Facility for Disaster Reduction and Recovery reports that Irma is the strongest Category 5 storm on record in the Eastern Atlantic Ocean. The eye of the storm passed directly over Barbuda, causing severe flooding, and in large part because of the lack of dunes due to the mining, the storm destroyed more than 90 percent of the island's buildings. Barbudans became climate refugees overnight—all 1,700 residents were evacuated to Antigua in the wake of Irma. When residents began returning to Barbuda weeks after the storm, they found that the Antiguan government had attempted to craft a private airstrip, using precious machinery that could have been used to help the residents recover from the storm (Boger and Perdikaris 2019). Instead, the Antiguan government used the equipment to build an airstrip for tourism development. Four years later, Barbuda remains a shell of its former self. This is, in part, due to a lack of economic resources. Financing reconstruction efforts is a costly endeavor. According to Barbudan residents, rebuilding efforts have been almost nonexistent, so hundreds of Barbudans remain in Antigua.

There are other non-disaster-related impacts of sand mining as well. A 2008 Associated Press article noted *NBC News'* coverage of sand mining across the Caribbean and reported that illegal sand miners damaged a freshwater aquifer in the process of digging a 23-foot-deep (7 m) crater. The mining operation exposed the aquifer to saltwater and manure from cows and donkeys. In an article from *Dominion Post* by Suzanne Elliott (2019), Jason Hubbart notes that there are eight thousand donkeys on Barbuda and that it is illegal to kill them. Barbudan marine biologist and environmentalist John Mussington, referenced in the NBC article, claims this pollution left the aquifer completely useless. Sand mining effectively hamstrung an invaluable source of freshwater for Barbuda. Salinization and contamination of the aquifer ultimately reduced the amount of drinkable water on the island available for people and livestock.

Freshwater aquifers in Barbuda had previously been damaged by sand mining on multiple occasions. The *Los Angeles Times* reported in 1989 that the sandpit excavated by former Prime Minister Bird's son, Lester Bird, exposed a freshwater aquifer (Schanche 1989b). Sand-mining operations in this area had already destroyed a sisal farm and scrubby vegetation, an essential source of food for pigs and deer. Evidently, there has been concern over the environmental perils of sand mining for decades. How developers intend to supply an increasing number of tourists with an adequate freshwater supply is unclear. As reported in the *Dominion Post* mentioned above (Elliot 2019), Jason Hubbart assessed the island's freshwater supply. Already in 2018, he points out, the island's residents were dependent on bottled water, for two to three dollars per bottle.

Loss of wetlands also has proved to be an enduring consequence of sand mining in Barbuda. Palmetto Point, a coastal area located in the Codrington Lagoon National Park, is a designated site of Wetlands of National Importance (Global Legal Action Network 2020). After Antigua and Barbuda signed on to the Ramsar Convention, an intergovernmental treaty that promotes conservation and responsible use of wetlands, Palmetto Point was established as the only Ramsar site for the twin-island state.

Despite the area's protected status, mining has continued in Palmetto Point. The *Antigua Observer* (2017a, 2017b), the national newspaper, reported the issue to the public and cited warnings from the Department of Environment and John Mussington over the destructive nature of sand mining. According to Mussington, miners removed sand from Palmetto Point in such colossal quantities that back-beach areas are now at sea level. Palmetto Point has lost nearly all biodiversity and is at increased risk of flooding during storms. Mussington also expressed concern that defying the Ramsar Convention through the continued practice of sand mining will establish a pattern of disregard for environmental commitments made via international treaties.

In addition to wetlands, coral reefs are another type of marine ecosystem harmed by sand mining. The United Nations Environment Programme (UNEP) reports that coral reefs are among the victims of excess sedimentation in the Barbudan context (2008). A national report published by the Convention on Biological Diversity (2020) indicates endangered coral reefs surround Barbuda with the largest concentration located off the western shores in the Codrington Lagoon. Recognized by the US Environmental Protection Agency (n.d.) as a primary stressor for coral reef habitats, sedimentation essentially suffocates corals by cutting off their ability to feed, grow, and reproduce. Sediment does not have to settle on coral reefs directly to cause harm, however. An over-abundance of suspended sediment raises water's turbidity, or murkiness. A team of marine scientists reports in *Marine Pollution Bulletin* that high turbidity, a sign of poor water quality, is detrimental to coral reefs (Bessell-Browne et al. 2017). Most corals depend on photosynthetic algae as suppliers of nutrients and bright pigmentation. Sediment blocks sunlight from reaching coral habitats, making it impossible for the algae to photosynthesize and support the survival of corals (National Ocean Service, n.d.). This is seen in coral bleaching, the process by which corals lose their vibrant colors due to algae being unable to produce nutrients.

Despite occupying less than 1 percent of the Earth's surface, coral reefs are hosts for 25 percent of ocean species (Knowlton and Ocean Portal Team 2018). Their reputation as biodiversity hot spots has earned coral reefs the title of *rainforests of the sea*. In addition to protecting biodiversity, coral reefs shield shorelines from powerful wave activity and contribute economically by supporting tourism and fishing. For these reasons, protecting such invaluable ecosystems is of utmost importance.

The Intergovernmental Panel on Climate Change (IPCC) reports that coral reefs are under fire from several stressors, including ocean acidification, ocean warming, and overfishing (IPCC n.d.). Barbuda cannot singlehandedly eliminate all threats against their coral reefs, considering global patterns of emissions drive acidification and warming. However, by stopping local sand mining operations, coral reefs will be less vulnerable to sedimentation.

THE FUTURE OF THE BEACHES OF BARBUDA

In part, sand mining is practiced in Barbuda because of an economic vacuum. With few other viable sources of income available, the practice of mining will likely endure. This dilemma of sand mining in Barbuda is part of a wider discussion on Just Transitions. According to the International Labour Organization (ILO), Just Transitions is a framework that seeks to ensure that livelihoods are protected as economies shift away from unsustainable production. Generally, the concept is applied in the context of climate justice (ILO 2015). In Barbuda, a Just Transition would mean stopping sand mining while creating sustainable employment opportunities, particularly for those who would suffer the loss of jobs and income from the end of mining.

The sand in the hourglass is running out. Sand mining is destroying Barbudan beaches to the point of no return and no tourism. To echo the words of John Mussington, "Barbuda is digging itself off the planet" (Brown 2013).

OTHER CARIBBEAN ISLANDS

There are notable commonalities across the island states and territories in the Caribbean. Perhaps most concerning is that the region is characterized by severe environmental precarity in the wake of natural disasters induced by climate change, particularly the anticipated intensification of storms. Low-lying islands are still reeling from the damage of the particularly devastating 2017 hurricane season. The combination of environmental vulnerability and the general lack of economic resources and diversification makes a recovery an arduous journey for the region. Removing massive quantities of sand via mining and dredging, common practices across the Caribbean, has left shorelines completely exposed and exacerbates the destruction by hurricanes.

The following examples show the widespread nature of Caribbean islands' struggles with sand mining. The islands noted below exemplify the varying impacts of destroying beaches, including public health issues, loss of biodiversity, interference with agriculture, economic loss, infrastructure damage, and increased vulnerability to climate change.

PUERTO RICO

Puerto Rico is an unincorporated US territory and archipelago in the eastern part of the Greater Antilles with a coastline of 311 miles (500 km). In the 1940s Puerto Rico began Operation Bootstrap, an economic model that emphasized exports as a driver of industrialization (Toro 2013). Operation Bootstrap was implemented to quickly mitigate poverty and modernize Puerto Rico's economy by replacing agriculture with industry. There is no consensus as to whether Operation Bootstrap was successful. Proponents cite that living standards have drastically improved, while critics worry that Puerto Rico is highly dependent on US government assistance. Operation Bootstrap ushered in a new era of construction and development in the 1960s and 1970s, which subsequently led to sand mining, according to US Geological Survey geologist Rafael Rodriguez (2017). Additionally, building hotels to support the growing tourism market is associated with sand mining.

While sand mining is illegal today, the US Geological Survey (USGS) expresses concern that the black market for sand is too powerful for legal regulations to stop mining effectively. Andrea Handler Ruiz and Rojeanne Salles O'Farrill (1988) discovered from a mining impact assessment that miners still mine sand in Puerto Rico on a scale of front-end loaders and dump trucks. Such an illegal operation on frontal dunes on the North Coast near Arecibo, Puerto Rico, was described in chapter 1. Pedro A. Gelabert (n.d.), an environmental scientist researching the impact of sand extraction in Puerto Rico, reports that sand is mainly extracted from beaches and coastal dunes. Still, alluvial floodplains and some rivers are also popular mining sites. There is an enticing financial incentive to mine sand. Research carried out by geologists David Bush, William J. Neal, and Chester Jackson (2009) on coastal vulnerabilities in Puerto Rico highlights a case where a resort owner charged a mere fifty cents per dump truck–load of sand, which could be resold at much higher prices or be cheaply used for construction purposes.

This same research paper revealed that decades of unchecked sand extraction are responsible for the severe coastal erosion Puerto Rico is experiencing today. While erosion is inevitable and naturally occurring, sand mining accelerates this phenomenon and creates pressing issues. The beaches of the Piñones were nearly wholly destroyed to build the Luis Muñoz Marín International Airport, located just outside of San Juan. The shoreline receded at an alarming rate and experienced frequent washovers. Artificial dunes were constructed to replace sand lost from mining, but these later were destroyed by storms and caused ecological issues when the new sand washed into inland forests.

A lot of development, such as power lines, sanitary infrastructure, buildings, and fiber optic cables, is located along coasts. Bush, Neal, and Jackson (2009) also reported that some of the structures on Puerto Rico's coasts are partially composed of aggregate derived from the very beaches they occupy. Paradoxically, these structures are vulnerable to coastal erosion, which is largely caused by the mining that supplied sand to construct these buildings in the first place. Other aspects of mining Puerto Rico beaches are discussed in chapters 1 and 8.

Coastal erosion poses a major threat to Puerto Rico's economy because economic activity is chiefly concentrated in coastal areas. The tourism industry is particularly at risk — the loss of beaches means fewer visitors, which translates to less revenue. Further, manufacturing, the backbone of Puerto Rico's economy through Operation Bootstrap, could be endangered by worsening coastal erosion. Manufacturing is responsible for 45 percent of GDP as reported by the Foundation for Puerto Rico (2019). The loss of manufacturing plants, mostly located in coastal areas, would be devastating and would likely send Puerto Rico into an economic tailspin.

The 2017 hurricane season provided an ominous glimpse into the future for Puerto Rico and the wider Caribbean. Coastal erosion from sand mining (described in chapter 1) coupled with Hurricane Maria left coastal homes completely exposed to later storms by erasing the beaches and dunes that separated the sea and houses. Environmental journalist Irina Zhorov (2018) reported that Rosa Elena Mastache Dominguez, a fourth-generation Puerto Rican, lost her family home built on the black sand beaches in La Boca on the northern coast due to Hurricane Maria. With little beach remaining to protect the houses in La Boca from storm waves, many residents lost their homes. Residents constructed small crude rock revetments to support what remained of their houses, though this is technically illegal now that building on beaches has been banned in Puerto Rico. However, enforcement is negligent, and since the storm was not classified as a federal disaster, residents were ineligible to qualify for aid.

Coastal flooding is not a singular issue in Puerto Rico or elsewhere; Mastache Dominguez stated that homes will likely be destroyed again after rebuilding efforts. This dilemma is further investigated in the book *Sea Level Rise: A Slow Tsunami on America's Shores* (Pilkey and Pilkey 2019), in which the authors suggest that nationally, the surge of climate refugees seeking reprieve from encroaching seas and natural disasters will be one of the most significant challenges of the twenty-first century.

BRITISH VIRGIN ISLANDS

The British Virgin Islands (BVI) is a British overseas territory located east of Puerto Rico in the Leeward Islands of the Lesser Antilles. The BVI has a total coastline of 50 miles (80 km), and sixteen of the fifty islands are inhabited.

As a tax haven with beautiful, white sand beaches, the BVI is an attractive destination for businesses and tourists alike. The Convention on Biological Diversity (2020) claims that while offshore financial services and tourism are integral to the economy, these sectors rely on development and construction, which in turn encourage sand mining. The loss of beaches via mining is especially concerning for the tourism industry. Yacht charters, boating, and scuba diving are the most popular activities, all of which depend on healthy beaches (Joint Nature Conservation Committee 2017). With much of the BVI economy hinged upon beaches, protecting them and stopping mining are of utmost importance.

The BVI has its own laws as a separate legal jurisdiction from the United Kingdom. Today, sand mining is illegal in the BVI. However, the penalty for mining, the obvious presence of illegal mining, and the level of enforcement against mining are all unclear. The Conservation and Fisheries Department's Environmental Monitoring Unit is responsible for the surveillance of environmental use (Convention on Biological Diversity 2020). This department seeks to deter sand mining and other harmful environmental practices. However, the Royal Society for the Protection of Birds, a UK-based NGO, claims enforcement against sand mining is nonexistent. Indeed, existing governance networks are not sufficient to stop the unsustainable extraction of sand.

While the BVI appears to have allocated resources to quell sand mining, this practice essentially went unchecked in the past. Many beaches are now shells of their former selves (Gore 2011). This beach loss is mainly due to the construction boom of the 1980s and 1990s. Gillian Cambers (1997) reported on behalf of UNESCO that during this period, the government regularly issued sand-mining permits to both small- and large-scale operations. Locals with trucks and commercial dredging schemes were allowed to mine sand, which caused enduring ecological consequences. The United Nations Caribbean Environment Programme report on sea turtle recovery (Eckert, Overing, and Lettsome 1992) states that accelerated sand mining destroyed the beaches of Fat Hogs Bays and Josiah's Bay, leaving the shores unsuitable for leatherback and hawksbill turtles to nest. In a press release on illegal sand mining, BVI information officer Berta McKelly Adams (2017) reported that the BVI Ministry of Natural Resources, Labour and Immigration also cited mining as a threat to turtle populations. Because of sand extraction, beaches on the island of Tortola also underwent drastic reductions in size. Between 1989 and 1990, two-thirds of these beaches lost 20 percent of their area (Eckert, Overing, and Lettsome 1992).

Coastal erosion proves to be one of the worst consequences that the BVI contend with after decades of sand mining. The UNEP (2019) report "Sand and Sustainability: Finding New Solutions for Environmental Governance and Global Sand Resources" states that coastal erosion is caused by the removal of sand and vegetation and raises the risk of flooding by destabilizing banks that act as natural barriers against surging waters. After Hurricane Irma hit the BVI in 2017, there were spikes in floods across the islands. Floods not only threaten recovery efforts in terms of rebuilding infrastructure that the BVI lost but also pose major public health risks. Floods can carry water-borne illnesses and cause water pollution. Following the 2017 hurricane season, the BVI Department of Disaster Management (Kanyuck-Abel 2020) started building three flood-resilient smart communities and replanting mangroves to contend with future storms. Mangroves are not only a source of carbon sequestration, but they also protect shorelines. However, they do not provide swimming beaches. This decision by the BVI government to restore mangrove forests is prudent but will prove futile if sand mining continues unabated. The UNEP (2008) cautions that high levels of sedimentation, a direct consequence of sand mining, can cause loss of mangroves.

GRENADA

Situated northeast of Venezuela, Grenada is a country made up of seven islands with a coastline of 75 miles (120 km). Grenada's demand for sand continues to rise with the construction of new infrastructure and buildings (Coastal Care 2013). Bolstering the construction industry through sand mining comes at the expense of the environment and the tourism sector.

In addition to ecological degradation, sand mining also threatens the nation's cultural heritage. In Carriacou, an island of the Grenadines and dependency of Grenada, rampant sand mining has compromised several archaeological sites. Such sites are crucial sources to understanding how previous island populations contended with natural disasters.

In 2003, a team of archaeologists led by Scott Fitzpatrick (2012) documented the impact of sand mining on archaeological sites in Carriacou. During the seven-year study, the archaeology team determined that sand mining was responsible for the loss of numerous cultural remains and soils, as well as for shrinking the coastline by a meter annually. Eventually, the unchecked sand mining eroded a cemetery (figure 6.3). Due to damage to the cemetery and other archaeological sites, Prime Minister Tillman Thomas outlawed sand mining in 2008.

Following the 2013 election, newspaper *Now Grenada* (2016) reported that the new government lifted the ban on sand mining with

FIG 6.3 A graveyard in Carriacou washes away due to severe coastal erosion caused by sand mining. On many Caribbean islands, graveyards close to the shore are threatened by shoreline retreat. Photo © Scott Fitzpatrick.

the intention of mitigating construction costs. The *Grenada Informer* (2016) published that the Gravel, Concrete and Emulsion Production Corporation, a construction materials supplier, was granted exclusive rights to sand mining on the main island of Grenada. While the corporation pledged to remove sand in an environmentally conscious manner, they overmined Conference Bay, causing salt water to penetrate into a freshwater lagoon. This contamination of fresh water particularly affected farmers who saw reduced yields in their harvests. The government intervened to stop sand mining and to replace lost sand, but Gravel, Concrete and Emulsion waited a mere eighteen months before resuming operations. During this hiatus, illegal sand mining became increasingly popular, with trucks frequently spotted hauling sand overnight.

Today, illegal sand mining continues to plague Grenada's beaches. The penalty for sand mining is a fine of US$5,555 or a two-year prison sentence. However, if enough sand is stolen, the profits can outweigh the fine for mining. Enforcement of sand protection laws also appears to be selective. In *The Last Beach*, Orrin Pilkey and Andrew Cooper (2014) reported that journalist George Worme was arrested in 2012 for

FIG 6.4
Sand-bearing barge off Grenada. The barge is not self-propelled but is guided by a tug. This common mode of transportation is used worldwide to transfer sand from one island to another including to Singapore from other countries or islands. Photo © SAF — Coastal Care.

taking four buckets of sand from a Grenada beach. Some have accused the government of arresting Worme, who often wrote about the alleged corruption of the Grenada government, as a political move, while turning a blind eye to larger-scale sand mining (figure 6.4).

SAINT VINCENT AND THE GRENADINES

Comprising thirty-two islands, nine of which are inhabited, Saint Vincent and the Grenadines (SVG) are in the southern part of the Lesser Antilles with a coastline of 52 miles (84 km). Similar to other Caribbean islands, SVG should be considered a cautionary tale regarding the perils of sand mining.

With a steady increase in the number of commercial and residential properties being built per year in SVG, the construction industry is the key driver of sand mining. The World Bank (2019) report "St. Vincent and the Grenadines: First Fiscal Reform and Resilience Development Policy Credit" states that the majority of development and infrastructure is located in coastal areas, which are at risk in the face of natural disasters. However, the hazardous placement of buildings has forced the government to take a stronger stance against sand mining in an effort to bolster climate resilience. The World Bank report also expresses that as of 2018, sand mining is partially banned with a phasing-out process expected to culminate in a total ban in the next few years.

This decision was made after years of unbridled mining—residents hauled more than one hundred truckloads of sand per week from beaches, according to the US Agency for International Development (USAID) (2010) report on sand mining in SVG. During the current stages of the phasing-out process, the Buildings, Roads and General Services Authority (BRAGSA) and licensed private truck owners are allowed to mine sand in limited quantities from the runoff of the Rabacca River at Richmond Beach. Additionally, security is posted at the Brighton, Diamond, Dripp, and Richmond beaches to deter illegal mining. The St. Vincent national newspaper, the *Vincentian*, published an article citing concerns among different stakeholders, including local property owners and USAID, that the government was too sluggish in implementing interventions against sand mining and that these ongoing mining efforts would worsen beach erosion (Browne 2017).

Sand mining can rapidly change the appearance of beaches, which is detrimental to the tourism industry. The World Travel and Tourism Council (2015) demonstrated that tourism is a pillar of the SVG economy, employing nearly 20 percent of the national workforce and contributing 20 percent of the country's GDP. Due to consistent growth of tourism over the years, significant investments are being made in this industry. However, such investment and reliance on tourism could be fruitless pursuits if the beaches of SVG lose their aesthetic appeal. The latter will push tourists to opt for destinations with more conscientious beach management.

In addition to economic repercussions, there are also long-term ecological impacts associated with sand mining. The USAID (2010) documented such consequences in the report titled "Sand Mining in St. Vincent: Impacts and Options." At the Richmond, Brighton, and Diamond beaches, for example, sand mining was responsible for the loss of coastal forests and scrubland. Removing dunes cleared a path for the sea to reach inland habitats, which were rife with biodiversity. Ultimately, the salt water obstructs soil formation and destroys woodland trees, effectively maiming the ecosystem. Species that seasonally migrate to SVG also are vulnerable to sand mining. Turtles used to regularly nest on the shoreline shared by the Diamond and Brighton beaches. Today, turtle nesting in this area is a rare occurrence due to habitat loss and extensive beach destruction.

MONTSERRAT

Another island in the Lesser Antilles, not far from Antigua and Barbuda, is the active volcanic island of Montserrat. Part of the British Overseas Territories (BOT), this island's 25-mile (40 km) coastline is mostly rugged, rocky, eroded volcanic deposits but with some beautiful small beaches. The island's fame is due to major eruptions in 1995 and 2010 that buried and destroyed the major towns and development on the southern half of the island and forced thousands of inhabitants to flee the island. Many have never returned, in part because the southern half of the island is an exclusion zone to mitigate more losses to eruptions. These disasters have inflicted a repeated cycle of economic hardship, just as hurricanes have on the sister islands.

Prior to the 1995 and 2010 events, beach-sand mining was more widespread, but the combination of losing equipment and access to mining sites in the exclusion zone shifted operations to the northwestern part of the island. In addition, growing concern over the loss of beaches was resulting in new regulations. Nevertheless, after each major loss of towns and the airport in 2010, resettlement required redevelopment with a renewed local demand for aggregate.

The Montserrat Mining and Quarrying Industry (Oxford Policy Management 2011) report brings to light several aspects of this transitionary time. Only one active beach mine was in operation at that time, and the mining operation had shifted to the Belham Valley. More inland sand resources were then exploited, primarily volcanic sands brought down rivers and streams off the volcanoes. Some of that sand was destined for the beaches as natural replenishment.

As on other islands, sand from Montserrat was and remains an important export. By 2007, annual production was 170,000 metric tonnes (>187,000 tons), but after the January–February eruption event in 2010, production dropped to 30,000 tonnes (~33,000 tons). The 2011 Oxford Policy Management report highlights the economic competition that exists in the sand business and includes a map and data on the exporter competitors. Montserrat sand exports have been sent to Anguilla and Nevis as well as to other markets. Competitive sand exporters in the wider subregion to various markets as named by the USGS include Dominica, Guyana in South America, and the Dominican Republic. Statistics for sand exports in 2009 from the Dominican Republic were 20 million tonnes (22 million tons), from Barbados a half million tonnes (~551,000 tons), and from St. Kitts and Nevis 223,000 tonnes (~246,000 tons). Little has changed since the 2011 Oxford Policy Management report, and local controversies continue over coastal sand mining in Montserrat as well as the other Caribbean islands noted as sand exporters.

The Oxford Policy Management report also highlights the flaws of the regulatory approach as a solution to sand mining. Regulatory laws are passed with inconsistent definitions (2011). For example, agreement could not be reached on defining the term *minerals*, and directions for enforcement and penalties were vague. More than one governmental agency has authority over the environment, resources, and the related infrastructure, and when no one knows *who is responsible*, the door is open to management indecision and even corruption. Regulations are passed without funding for enforcement, monitoring of projects, or providing training for staff. The report notes the lack of available personnel with proper environmental training or sufficient expertise for management planning and enforcement. So, regulations fail because failure is built into their design.

CARIBBEAN BEACHES — LAST CALL FOR CONSERVATION

Across the Caribbean, sand mining proves to be a common and deadly practice. Despite growing awareness of its harmful impacts, illegal sand mining persists. In large part, this is a governance issue. Transparent and efficient monitoring of sand extraction needs to be developed, and enforcement of punishment for those who commit illegal mining must be consistent. Additionally, institutions responsible for overseeing illegal sand mining need to create a more robust and localized policy to address the mining. As a generally economically deprived region, the Caribbean may be unable to achieve these tasks on its own, so financial help from international sources will be necessary. At the global level, investing in alternative and sustainable resources instead of sand is critical. The world is using its finite supply of sand at a much faster rate than beaches can replenish.

Examples from different Caribbean islands demonstrate that sand mining is also a symptom of tourism-dominated economies and lack of economic opportunity. Tourism relies on construction, which creates a demand for sand mining. Illegal mining will endure if viable economic alternatives are not established. Diversifying economies to include sustainable industries would help eradicate sand mining, though this is much easier said than done. Ultimately, sand mining requires treating the economic and social drivers that facilitate the practice. Governments may wonder “How can we afford to save beaches?” but the real question is, “How can we afford to lose beaches?”

CH.07

A SUMMONER'S THIRTEEN TALES

South America's Coastal Sand Mining

Like its sister continent, North America, South America's long shoreline is characterized by virtually all types of coasts, beaches, and coastal dunes. Similarly, much of the continent's shoreline is impacted by increasing tourism, rapid development, and a corresponding demand for sand aggregate. Unlike North America, however, South America's coast is shared by eleven developing countries with diverse political systems and philosophies of coastal management. As a result, diverse mining activities, especially river- and beach-sand mining, have been erroneously promoted to achieve successful economic development.

The United Nations Environment Programme (UNEP) has warned about future sand shortages and collateral impacts in South America due to the high extraction rates of sand from rivers and coasts. Sand has been one of the most accessible natural resources, and sand mining has grown in direct proportion to the insatiable demand for the construction of housing, tourism infrastructure, and public works such as roads and highways. Despite these warnings, many governments (e.g., Brazil, Colombia, and Chile) consider sand mining an optimal source of employment and support for the new infrastructure. In theory, sand mining has been promoted as supporting the construction of new schools, hospitals, roads, and other infrastructure. In reality, such promotion has proven false and has been more beneficial to political and economic self-interests rather than to the public at large. River- and beach-sand mining have been largely uncontrolled and have impacted both natural and socioeconomic ecosystems (i.e., individuals, populations, and communities). In some cases, the impacts to the environment, as well as to the economy and politics, are irreversible.

Although coastal South American countries have regulations related to mining, most lack specific laws for sand mining and do not require procedures for monitoring, mitigating, and repairing the adverse collateral effects. Some countries (e.g., Colombia) do not have legal definitions for beach sand mining environmental liability or recovery cost requirements for environmental damage.

Faced with fuzzy or nonexistent regulations, post–mining operation recovery is not required or is minimal and naïve, such as planting nonnative species in areas previously exploited. For example, Adriana Gracia, Nelson Rangel-Buitrago, and Paola Florez (2019) report plantings of the African species, *Calotropis procera*, to stabilize dune systems located on the central Caribbean coast of Colombia. Few post-mining monitoring and remediation actions are taken because no one is held responsible and there is no required funding for recovery. In addition, like in the rest of the world, much of the sand mining is illegal, and profits are even used to sponsor internal conflicts as well as criminal activities.

History does repeat itself, and throughout South America the history of damage due to mining can be found going back to colonial times with the inland mining of mineral deposits. However, beach- and river-sand mining are leaving more than scars; this modern mining is destroying the coastal amenities that are the very reason for development. The so-called hotel rows of many of these countries are or will soon be on beachless shores, and the tourist cash cow will move to a beachier pasture. The remaining citizens will inherit a lost economy along with destroyed fisheries, polluted water sources, and lost farmland.

Borrowing from a *Sting* album cover, and following Geoffrey Chaucer's "The Summoner's Tale," this chapter's title refers to thirteen examples from eight countries that provide a picture of South America's sand-mining problems relative to the coast. Each example calls out specific situations of economic and environmental loss, corruption, and shortfalls in coastal management.

ATLANTIC COAST

ARGENTINA — THE BUENOS AIRES COAST

The Buenos Aires province coast is a 746-mile (1,200-km) reach on the Atlantic Ocean between La Bahía de Samborombón in the Rio de la Plata estuary (north) and the mouth of the Río Negro (south). Until the 1870s, the region was known as El Mullún, a Mapuche word meaning "coastal place." The Mullún was characterized by coastal cliffs interspersed with wide, sandy beaches and well-developed dune systems with vegetation. By 1870, after European immigration, the area had become one of the most human-altered regions in all of Argentina. So much so that this important coastal strip lost most of its original characteristics — Mullún is now part of history.

One of the factors responsible for these extreme alterations was beach- and dune-sand mining. Silvia Marcomini and Rubén López (1999; 2006) studied two coastal sectors: Miramar and Nutria Mansa Creek, and San Antonio Cape and Necochea. In both cases, sand mining generated a significant increase in coastal erosion, landscape degradation, and related impacts.

The sand mining was driven by developmental construction along the Buenos Aires coast. Urban development demanded large quantities of sand for concrete; this sand usually was extracted from beaches, dunes, and cliffs along the same coastal strand. At least ten extraction sites for sand were situated along the Buenos Aires coast. These beach-dune sand mines supplied coastal municipalities, providing raw material to nearby towns such as General Lavalle, Dolores, Maipú, Ayacucho, Balcarce, Tres Arroyos, and Bahía Blanca. The Bonaerenses (the people of Buenos Aires) chose sand for concrete over sand for beaches and dunes (figure 7.1).

In the case of Miramar and Nutria Mansa Creek, on a coastal strip just over a mile in length (1,800 m), two extraction points were located over beaches and foredunes at the mouth of Nutria Mansa Creek, and over the Miramar-Mar del Sur dune field, directly affecting a coastal area of about 240,000 square yards (200,000 m^2). According to Marcomini and López (1999; 2006), the resulting erosion rate reached 5 feet per year (1.54 m/yr) and generated a loss of sand volume of about 196,000 cubic yards (150,000 m^3). The indirect effects of the sediment supply loss extended for up to 22 miles (35 km) to the northeast.

ARGENTINA — RESERVA COSTA ATLÁNTICA DE TIERRA DEL FUEGO: HOW MINING INTERESTS THWART THE LAW

The Reserva Costa Atlántica de Tierra del Fuego is a Natural Área in Tierra del Fuego Province, Patagonia. The large reserve's 143-mile (230-km) coast extends from Cabo Nombre (Cape Name) north of San Sebastian Bay to the mouth of the Ewan River. Designated a Natural Reserve in 1992, the area is also a Western Hemisphere Shorebird Re-

FIG 7.1 Sand mining along the Buenos Aires, Argentina, coast. Beaches provide raw material for construction, and the city skyline reflects the demand for aggregate sand. But this shouldn't be at the expense of loss of the beach. Photo courtesy of Federico Isla.

serve Network Site (WHSRN) and became a Provincial Protected Natural Area in 1998. The reserve is considered a Wetland of International Importance under the Ramsar Convention and in 2005 was designated as an Important Area for Bird Observation and Conservation.

According to WHSRN (Clay 2017), in 2017 this reserve held 42 percent of the Hudsonian Godwits' global population (*Limosa haemastica*) and has significant numbers of White-rumped Sandpipers (*Calidris fuscicollis*), Patagonian-breeding species such as the Rufous-chested Dotterel (*Charadrius modestus*), the Two-banded Plover (*Charadrius falklandicus*), and the threatened Magellanic Plover (*Pluvianellus socialis*). However, this reserve is best known as the wintering site for the B95 (*Calidris canutus*, or Moonbird), the world's most famous Red Knot that was originally banded near the city of Río Grande in 1995. Clearly, this reserve is a world-class natural ecosystem. Surely no one would allow any sand mining in such an important area of the world. Think again!

Despite all the above, during the 1980s, diverse mining companies were authorized to develop beach-sand extraction activities, specifically on the Río Grande city coast. After the nature reserve's creation, beach-sand mining was gradually restricted, but it was never com-

FIG 7.2 Sand mining on Reserva Costa Atlántica de Tierra del Fuego, Argentina. During the 1980s, diverse mining companies were authorized to develop beach-sand extraction activities, specifically on the Río Grande city coast (the capital). After the creation of the Tierra del Fuego reserve, beach-sand mining was gradually restricted but was never completely banned. Photo courtesy of Tabaré Barreto.

pletely banned. Federico Isla (2014) reported that the adverse effects of this activity were and are still noticeable. Sand mining generated significant coastal erosion, changed the intertidal environment, and reduced bird habitat and food sources (figure 7.2).

The mining activity was supposed to have ended by 2019, but the companies continued to operate. Coastal erosion damage increased and destroyed a house whose owner filed a complaint through the courts. In May of that year, the courts definitively ordered the government to cease sand-mining activities. In 2020, a bill proposed to change the limits of the reserve. The proposal was to divide the reserve into three parts, allowing sand mining in the two intermediate areas. If this law had been approved, not only would it have opened the door for environmental destruction due to sand mining, but legally it would have set a detrimental precedent in terms of modifying the limits of a protected area to allow mining.

After all concerns were expressed by local, national, and international stakeholders, the Provincial Legislature of Tierra del Fuego sent a bill to the Argentine Natural Resources Commission in support of maintaining the reserve's integrity and creating an integrated coastal management plan. The bill also required a coastal mitigation plan for those reserve coastal areas where sand had previously been mined.

Thanks to the multiple expressions of concern, in this case, coastal sand-mining activities were banned — it is progress, but not yet an outright ban on coastal sand mining. Other areas, both coastal and rivers, are still being mined after the completion of environmental impact assessments that were done legally. Illegal mining has yet to be stopped. And although Argentina's deep recession in the late twentieth century slowed the economy and the rate of urbanization, the development trend is still upward. The sand mining debate in Argentina is not over.

BRAZIL: STEALING SAND IS NOT A SCALE PROBLEM

Brazil, with an ocean shoreline of 4,654 miles (7,491 km), is no exception to the rule, and sand mining of beaches and dunes is common. Sand mining is a very lucrative business. The country's annual mining revenues can reach US$1.5 billion (Gonçalves and Braga 2019).

Under Brazilian law, illegal sand mining constitutes two crimes. The first refers to the stealing or illegal possession of the country's heritage (Federal Law 8,166, of February 8, 1991). The second is the commission of an environmental crime (Article 55 in the Environmental Crimes Law — 9,605/1998).

However, sand mining is an activity that takes advantage of existing legal loopholes. Sand extraction can be considered illegal when it violates the Mining Code, which sounds good. However, this same code legalizes sand extraction in two ways: (1) when the sand is used for construction purposes, whose operating license is the direct responsibility of the municipality, or (2) when sand is used for industrial purposes, with the mining concession granted by the Mines and Energy Ministry.

Due to the vast Brazilian coastline, law enforcement can be a complicated task. Any person who needs sand and who has a shovel can go to a remote site, disregard legislation, and extract sand, leaving a trail of destruction wherever it may be. There are records of such illegal activity in all coastal regions of the country, encompassing all states. And sand extraction from beaches and dunes is a problem that occurs on all scales — large or small — including, for example, multinationals developing mines, and the small, local borrow pits mined by small groups or individuals with a horse cart or a wheelbarrow.

On a grand scale, the most famous example is from the municipality of Maricá, located about 15.5 miles (25 km) eastward from the

Guanabara Bay in Rio de Janeiro. Sand extraction from this coast began during the 1950s with the arrival of Portuguese business people who had many projects on their minds, one of them being glass production. After searching for the best place in the Rio de Janeiro state, they decided to locate the new industry in the São Gonçalo area. But the perfect raw-material sand site was in Maricá. The solution here was simple: they bought land and then destroyed all the original vegetation from dunes and beaches and began mining Maricá's sandbank.

Sand extraction has completely changed the entire Maricá area. Beaches and dunes that in the recent past were known for their outstanding scenery no longer exist. On the contrary, huge craters can be seen in many areas. The local population calls these craters Maracanã (the biggest soccer stadium in the world) due to the colossal dimensions of the holes left by the mining.

In one case, a massive hole remained with only a narrow wall separating the entire mine depression from the sea. Needless to say, storm wave action disrupted this barrier in two places, allowing flooding and washover that further affected the inner sand slopes' stability, causing slumping/sliding as documented (Muehe and Valentini 2003). Off-roaders frequently use the resulting coastal topography for four-wheeler ATVs and motorcycles, resulting in additional damage to the barrier beach, steepening the slopes, and increasing back-beach susceptibility to storm waves. The region is subject to significant erosion and flood risks due to this combined action of severe storm waves and off-road vehicle activity.

On a smaller scale, the leading players are the Carroceiros (a Portuguese word designating wagon drivers). Their origin dates from colonial times, and they are both an old and continuing problem that negatively affects the environment and traffic safety. Carroceiros' operations occur along most of the Brazilian coast (as well as in Caribbean areas). One can easily find areas where, daily, a single Carroceiro can extract between fifteen and twenty-five cartloads of sand, for example, at Barra de Jangada, Pernambuco, or Vila Velha, Espírito Santo (figure 7.3).

The modus operandi is simple: at any time of day (preferably at night), Carroceiros enter the target area, destroy and remove all the existing vegetation, and steal sand. They enter and leave the site without restrictions until they either exhaust it or complete their project where the sand was needed—moving on to the next prospect.

According to the Environmental Police, Carroceiros perpetrate three types of crime: theft of property belonging to the country, which can result in up to five years in prison; an environmental crime, which

FIG 7.3 Bags of sand awaiting transport line the back-beach along Brazil's Pernambuco shore. Carroceiros mined along the length of this beach, removing vegetation as well as the back beach and low dune line. These thieves enter and leave beaches without restrictions, exhausting the easily removable sand, and then move on. Photo by Nelson Rangel-Buitrago.

can yield up to a year of imprisonment for those who extract mineral resources without a license; and animal abuse, which can result in up to three years' imprisonment. Most Carroceiros are aware of the crimes that they have committed but plead that they have no other means of living and need to extract sand for survival income.

BRAZIL: NÃO QUEREMOS MINERAÇÃO EM SÃO JOSÉ DO NORTE (WE DO NOT WANT MINING IN SÃO JOSÉ DO NORTE)

São José do Norte is a Brazilian municipality with more than 62 miles (100 km) of beaches, located in extreme southern Rio Grande do Sul, surrounded by the Atlantic Ocean and the Lagoa dos Patos. This poor municipality is located over dunes and sandbanks and is inhabited by fishermen and small farmers. This area is ranked as an extremely high to very-high priority area of the Coastal and Marine Zones in terms of habitat and biodiversity.

In 2002, a titanium mining project for beach and dune sand (Projeto Retiro) was presented as a solution to the region's poverty problems. The promoters of this project supposedly calculated reserves of 531.2 million tons of ore, with about 17 million tons of heavy minerals, and a turnover of around 13.75 million cubic meters. The total size of the enterprise's investments was to reach 500 million Reals (approximately US$120 million), and it aimed to generate six thousand direct and indirect jobs, as well as 70 million Reals (US$16 million) in tax revenue. The operation was to be the only site in Brazil for extraction of titanium and zircon.

But such rosy predictions are common to all large-scale proposed projects, and promoters do not publicize negative impacts to the economy or the environment. In this case, farmers and fishermen said that the titanium mine would mean the end of the production of various vegetables and agroecological output, with a reduction in the quality and commercial value of agricultural and fishery products. They expressed concern about water quality and damage to the groundwater supplies of the region.

In February 2019, the movement Não queremos mineração em São José do Norte (We do not want mining in São José do Norte) presented, in a public hearing at the City Council of São José do Norte, a proposal to amend the law dealing with the territorial ordering of the municipality, the municipal development policy, and urban expansion. The Permanent Commission accepted the proposal for Education, Health, Social Action, Services, Public Works, and the Environment, and forwarded it for a plenary vote. The vote took place in April 2019, and seven votes passed the amendment. In May 2019, the mayor signed a new law banning mining in the municipality. At the time of this writing, the project is stopped. This important decision protects fishers, small farmers, and the environment!

SURINAME: TOURISM, COASTAL PROTECTION, AND TURTLES ARE BETTER THAN SAND MINING

Three small countries are centrally located on the central north coast of South America: Guyana, Suriname, and French Guiana. The coastline of Suriname is 240 miles (386 km) long. Suriname is chosen here for a case-study example, but coastal sand mining is a potential problem for the other two countries as well as for Venezuela, on Guyana's western border. For example, Guyana competes with various Caribbean islands' sand exporters.

Suriname's Braamspunt beach is an example of an open-coast chenier in the Guianas, developed between the mouths of two rivers, the

Maroni and Suriname. This beach is in the Commewijne District of Suriname's westerly point and is a former military outpost that is now a fishing village and nature reserve. The Suriname capital, Paramaribo, is located just 10 kilometers south of this coastal site.

Braamspunt beach is reported by Edward Anthony (2016) to be characterized by well-sorted medium sand with median grain-size values of 400–560 micrometers. The percentage of sand-sized, shelly material (carbonates) is highly variable, from 4 percent to over 40 percent, and is not detrimental to the commercial value of the sand. This carbonate component reflects preferential density sorting and concentration within the dominant quartz-sand matrix. The overall estimated sand stock of Braamspunt beach is about 745,500 cubic yards (570,000 m^3) of sand. These properties and the volume translate into a perfect location for sand mining.

Commercial sand mining has been carried out in several areas along the Suriname coast, notably on Braamspunt beach, which also is an important tourist spot of the country, and an important nesting area for the leatherback sea turtle (*Dermochelys coriacea*) and the green turtle (*Chelonia mydas*). In addition, Braamspunt serves as a natural breakwater that provides protection for the 250,000 people who live in the capital city from rising sea levels and storm surges.

Diverse environmental institutions such as the World Wildlife Fund, Conservation International Suriname, Green Heritage Fund Suriname, and the Suriname Hospitality and Tourism Association are seriously concerned about this natural area because the Ministry of Natural Resources has permitted sand mining at Braamspunt, despite reports such as Anthony's (2016) that advised not to do so.

Sand mining's deleterious effects to the subsisting beach's integrity are well documented by Anthony (2016), including reduction of beach area available to bird and turtle nesting and loss of the beach's sediment supply. Loss of beach also results in loss of the storm-surge and wave-buffering capacity. In addition, conservationists fear that nesting sea turtles will be disturbed by collateral effects of sand mining, such as by bright lights and loud noises.

The total collapse of Braamspunt beach is likely to have damaging feedback effects (irreversible change with no possibility for resilience). The east-bank cape at the mouth of the Suriname River has the potential to be severely eroded back by several kilometers, most likely exposing the estuary and the waterfront of Paramaribo to direct Atlantic waves.

Sand-mining prohibition and thus preservation of the beach are essential to dissipate the waves impinging on the east bank of the river mouth. The back-beach mangrove wetlands can thus be protected and the cape morphology on this bank maintained. These effects have a significant bearing on the role of Braamspunt beach in coastal protection for the human population, as well as that of turtles.

The organizations noted above have urged the Ministry of Natural Resources to immediately stop the excavations at Braamspunt, emphasizing the following points (Pool n.d.) :

1. No mining on land used by legally protected and/or endangered species for nesting or habitat.
2. No mining during the nesting season of the sea turtles, from the start of the nesting season through July and until the baby sea turtles come out of their nests in September.
3. No mining where the seashell deposits have a direct coastal defense function. Braamspunt, the natural breakwater, is essential as a coastal defense for Paramaribo North.

Suriname's environmental institutions hope to work out a sustainable solution that will be both economically and environmentally beneficial to all who depend on Braamspunt's continued existence.

PACIFIC COAST

CHILE: THE PUTÚ FIGHT

Mining in Chile, whose coastal length is 3,999 miles (6,435 km), is a serious matter. This country's economy is firmly based on exploiting its natural resources, and the general mining sector is one of its pillars. For example, Salazar et al. (2010) note that copper exports alone represent more than one-third of all national income. And although mining is widespread throughout the country, most mining in Chile is concentrated in the Norte Grande region spanning most of the Atacama Desert. Chile's mining products include copper, gold, silver, molybdenum, iron, coal, and, more recently, sand from beaches and dunes.

Rangel-Buitrago, Contreras-López, Martínez, and Williams (2018) note many examples of harmful operations related to beach-dune sand extraction along this lengthy coastal strip. The most famous case was known as "The Putú Fight."

The Putú Beach-Dune system is located around 14 miles (22 km) north of the city of Constitución, in the Maule Region. The Putú system covers 23.5 miles (38 km) along the entire beach length and forms a natural barrier that separates the town of Putú from the sea. This environment on its own impacts local climatic conditions such as rainfall and temperatures, serves as a natural barrier against tsunamis, and is important in recharging the area's aquifers. This area also includes wetlands that concentrate 40 percent of the 240 faunal species in the Maule Region, and it is home to hundreds of migratory birds.

Clearly the area is of great importance in terms of biodiversity as well as from an environmental point of view (i.e., water resources, storm protection). However, the area is also ideal from a mining point of view due to its elevated mineral concentrations. The magnetic fraction concentrates (magnetite and ilmenite) from Putú beach make up 20–60 percent per sand sample. The sand has an average iron (Fe) content of 40.5 percent, with 8.5 percent titanium dioxide (TiO_2). With a possible average thickness of 6 meters over 20 square kilometers, a volume of 120 million cubic meters has been estimated for the area by Aconcagua Resources (2007). In addition, Pleistocene deposits left behind by a higher sea levels hold the promise of substantially larger in-place resources; in addition, a further potential exists below the gravel bed beneath the modern beach and dune sands—a prospector's dream!

In 2010, a Chilean subsidiary of an Australian mining company obtained the concession and the right to exploit the area. They signed an agreement with a Chinese company to exploit other minerals such as lithium, titanium, vanadium, and iron found in the same place. An amount of 823 million tons of iron was estimated to be in the sands distributed along all the extensions of the beach, dunes, and wetlands.

The speed with which the state granted the mining concession aroused the Putú residents' suspicions. In response, the community of Putú mobilized, forming the Maule Mataquito Defense and Conservation Group to protect the area and its natural resources. However, the threats from extraction failed to cease. In January 2017, the Maule Mataquito Defense and Conservation Group received a grant to film a documentary about the socioenvironmental conflicts around extractive industries in the dunes and wetlands of Putú. This successful documentary was reported by Global Greengrants (2017), and the documentary was used as evidence of the harmful impacts of sand extraction and to educate local communities about the threats mining poses to the region. Then, late in the same year, Putú's residents received news of a huge victory. After a long process of citizen organizing and empowerment, inhabitants of the area learned that the dunes and wetlands had officially been designated as a protected Nature Sanctuary, and sand mining was now banned.

CHILE: SAND MINING VS. ENDEMIC SPECIES — THE HIERBA DE LAS CRUCES CASE

In the early twentieth century, on the Litoral de Los Poetas (Coast of Poets), Valparaiso, central Chile, several shipwrecks occurred off the coast of El Tabo municipality. According to locals, survivors erected wooden crosses over the beaches and dunes, renaming the area Las Cruces (The Crosses).

The beaches, dunes, and wetlands surrounding the coast of Las Cruces are called Gota de Leche (Drop of Milk). This sector covers 280 hectares and is the largest dune field in the Valparaíso region. It is also home to diverse vegetation (233 species) and fauna (82 species), including birds (71 species), reptiles (5 species), mammals (4 species), and amphibians (2 species). Adding to this eco-importance, the area contains a unique world vegetation treasure: *Astragalus trifoliatus Phil*. (*Linnaea* 28: 681.1856), also known as Hierba de Las Cruces or Hierba El Tabo. This *Leguminosae* is small, with thick leaves and a purple and violet flower, and has a particular set of characteristics. It is endemic to this place, living only along the Gota de Leche dunes. This isolated occurrence is because the plant has adapted to the area with exceptionally long, downward root systems to tap the groundwater of the dunes. The plant has adapted to the moisture and salt of the coast, and to this day, no one has been able to get the plant to reproduce in greenhouses.

And now this unique plant is in critical danger of extinction, along with the area's beach and coastal dunes, because of sand mining. The sand extraction is to supply the demands from aggregate sales companies. These companies mine the area and truck the sand away to construction, glass, and real estate operations (figure 7.4). In addition to the imminent danger posed by urban and suburban construction, off-road vehicles, particularly motorcycles, are doing great damage to the beach and dunes.

Many local organizations are trying to safeguard the dunes, animals, and plants from sand mining. However, all of them have a powerful common enemy: the ex-mayor of El Tabo.

The principal company in charge of sand extraction from the dunes is the El Tabo ex-mayor's family business. Although the company does not have permission to work in the area and violates many environmental laws by doing so, it regularly extracts sand, endangering the whole sector. Up to 2020, this sand mining had caused the destruction of at least 11 percent of the entire area (approx. thirty hectares), with half a

FIG 7.4 Sand extraction on the shores of Gota de Leche, Chile. Beach- and dune-sand mining supplies the demands from sand sales companies that fill needs for aggregate, glass, construction, and property development. Photo courtesy of Salvemos Gota de Leche.

million cubic meters of sand stolen. This environmental damage generated about US$28 million in profits for the ex-mayor's family business.

This case was denounced on national television and became famous. Thanks to the media coverage, local authorities decided to suspend the mayor from his position and stop the sand-mining activities. However, this has not been enough, and mining activities continue as usual, due to the absence of any law or a special status that provides for the strict protection of the area. Local organizations are currently compiling information to request the status of Nature Sanctuary for this vital area of the central Chilean coast.

PERU: MINING THE ROCKY COAST OF BAYÓVAR, PIURA

Peru has an ocean shoreline of 1,500 miles (2,414 km). In South America, coastal mining activities are impacting not only beaches and dunes but also other coastal environments such as coastal hills and cliffs. The Bayóvar mine, located in the Sechura Desert of Peru's Piura Region, is a case in point.

Started in 2010 by the Peruvian government, Bayóvar represents one of Peru's largest phosphate reserves. This mining project has an estimated life of twenty-seven years with reserves estimated at 238 megatonnes (234,000,000 long tons; 262,000,000 short tons) of ore. Annual production can reach 3.9 million metric tonnes (3,800,000 long tons; 4,300,000 short tons) of phosphate concentrate at a minimum grade of 29 percent of phosphorus oxide (P_2O_5) (INGEMMET 2008).

The project encompasses an important coastal sector and includes a phosphate concentrating plant, an access highway (35 km), a 5-kilometer conveyor in the dock, drying and storage facilities for loading, a port with the capacity to ship 7.9 metric tonnes per year, and a desalination plant. All these facilities occupy an area of 8,500 hectares. This mining project is causing the loss of landscape, aesthetic degradation, exposure to unknown or uncertain complex risks such as radiation, and socioeconomic impacts (i.e., human rights violations) for the entire region.

Fishers and artisanal shellfish workers have carried out intense riots opposing the project from the time of its inauguration. These riots generated many injuries and a couple of deaths. The protesters claim that the public hearing in which the environmental impact study was supposed to have been presented was annulled.

According to the mining company in charge of the project, which is also in charge of the environmental monitoring, impacts on the ground are minimal, and the effects on air quality (in terms of the generation of particulate matter) are also minimal, except during quarrying and road building. However, local inhabitants are experiencing firsthand that impacts are higher than those predicted and presented in the environmental study.

Similarly, this area's population along with the authorities oppose the exploitation of new uranium deposits discovered in the mining project's area of influence. They fear an increase in environmental and health impacts as well as potential destruction of fishing and livestock activities.

However, the project is already well underway, and local authorities warn about the multiple latent social conflicts in Piura Province. This situation is a ticking time bomb. The community has focused on two aspects: (1) banning the surface and easement contract for the communal territory and (2) attempting to convert the area to an intangible sector, preserved in its natural state, in order to save it. Locals emphatically reject the company's intervention in environmental monitoring and accuse it of being both the judge and the villain of this situation. As some would say, "We shouldn't let the Fox guard the Chicken House."

Peru: Pequedragas — A New Way to Steal Sand from the Coastal Environment

The familiar Peque-Peque is the world-famous and picturesque type of boat that navigates the Amazon River waters. These small, artisan canoes navigate the entire river basin, connecting remote sites and even serving as a tourist attraction.

Although these canoes appear to be flimsy, they can accommodate the miners' machines to dredge the banks of sand and other sediment from the bottom of the rivers, deltas, and estuaries. Despite their size, these boats have enough room for the robber's most critical tools: the dredge and the motor. The space that remains is used for miners to live, with food, fuel supplies, and hanging clothes on the open deck.

Information about the use of pequedragas in mining dates from at least around 2010, first along the Amazon River for gold mining operations, but this mode of extraction was adopted quickly along other rivers and proved to be well suited for sand mining. Just as in other parts of the world, river mining often reduces sand supplies to beaches, leading to shoreline erosion. The use of these boats expanded along the coast of Peru, as well as into Ecuador and the Pacific coastal zone of Colombia.

Peruvian law bans the use of pequedragas for dredging and for sand extraction. This ban is part of the legislative Act 1100 published by the Peruvian government in 2012. This regulation prohibits dredges and other similar devices in watercourses, rivers, lakes, lagoons, oxbow lakes, water bodies, wetlands, deltas, or estuaries.

But along some parts of the Peruvian, Ecuadorian, and Colombian Pacific coast, groups of illegal miners have managed to elude the law, easily escaping with their stolen sand from the different coastal environments.

Ecuador: The Quest for the Exotic Black Sands

Ecuador has five provinces adjacent to the Pacific coast with a total ocean shoreline length of 1,390 miles (2,237 km): Manabí, Esmeraldas, Santa Elena, Guayas, and El Oro. In all of these provinces, the beaches and dunes have metallic minerals, and where the sands have high concentrations of these specific minerals, they are prime targets for mineral mining. In fact, along the coasts of three of the five provinces (Manabí, Esmeraldas, and Guayas), exploration and mining of these heavy-mineral deposits is underway.

The Mining Regulation and Control Agency from Ecuador (ARCOM)

FIG 7.5 Black-sand mining on Mompiche Beach, Ecuador. These sands are composed of the ore mineral ilmenite ($FeTiO_3$), iron-titanium oxide, a primary source of titanium. Removal of the beach will result in accelerated erosion of the wave-cut bluff at the back of the beach. Fallen vegetation at the back of the beach shows that the bluff is already eroding. Photo courtesy of La Casa Mompiche.

identified and assigned permissions for eight sand extraction sites in beach areas where gold, iron, and titanium are sought. Of these eight beaches, the ones that receive the most attention are El Ostional beach and El Mirador beach. Both are located in Playa Negra, Mompiche, Esmeraldas Province, in the north of the country (figure 7.5).

These beaches' attractiveness for mining lies in the composition of their exotic black sands that derive their color from the ore mineral ilmenite ($FeTiO_3$), an iron-titanium oxide. This mineral is a primary source of titanium which is used in metal alloys as well as in paints, printing inks, fabrics, plastics, paper, food, sunscreen, and cosmetics.

And as with mining for metal-ore minerals, extracting massive amounts of sand is rife with problems to local economies and the environment. The citizens of Mompiche have such concerns. A binational company created by Ecuador and Venezuela has leased 4,100 hectares of a coastal area with potential for mining. This area includes the towns of San Gregorio and Bolívar y Muisne and borders the Refugio de Vida Silvestre Manglares Estuario Río Muisne (Wildlife Refuge Manglares Estuario Río Muisne). The Wildlife Refuge is also rich in metal minerals that mining interests covet, which generates pressure on officials to grant exceptions to environmental restrictions.

Different environmental organizations and NGOs have expressed their concerns over the negative coexistence of coastal ecosystems and sand-mining projects. These organizations have proof that mining activities outside the leased area granted by ARCOM are affecting the protection and regulation of the ecosystems inside and outside of the Wildlife Refuge. According to these organizations, sand extraction has taken place in banned areas, which justifies the urgent halt of all extractive activities in the region.

As of 2020, the Environmental Ministry of Ecuador oversaw analysis of the feasibility of expanding the Wildlife Refuge Manglares Estuario Río Muisne over the area affected by mining, which is also located to the south of the Galera-San Francisco Marine Reserve. This would create a unique and larger protected area where these activities would be entirely prohibited.

Although some sand mining concessions have been suspended and others are in the environmental authorities' sights, more and more conflicts will likely arise between communities, the environment, and the extractive industry in Ecuador. The above case is an example of Ecuador's commitment to different mining forms in support of the economy. Can this historic tide be turned back in favor of the environment and tourism based on conservation of beaches and dunes?

CARIBBEAN COAST

COLOMBIA: THE GUERRILLAS' SAND MAFIA

Playona-Acandí Fauna and Flora Sanctuary is one of Colombia's newest Natural National Parks. This park is located on the Uraba Gulf, in the Department of Chocó, on the Caribbean coast, and it is a vital area for hawksbill and leatherback turtles' survival.

In December 2013, the declaration for these 26,232 hectares of sea and 7.5 miles (12 km) of beaches to be a protected area came as a Christmas present for the Choco region and for Colombia. This declaration was aimed at watching over and protecting a unique turtle species, the leatherback (*Dermochelys coriacea*), the largest marine turtle in the world, and this area was designated as a most important breeding site in the Western Caribbean. This sanctuary is also home to the fourth-largest subpopulation of this species, after those in Gabon (Africa), Guyana, and Trinidad and Tobago. In addition, the sanctuary is home to a myriad of other plants and animals.

But now this unique world site is threatened by illegal groups' influence, the sand mining mafias. (Such mafias are discussed in detail in chapter 4.) To the locals, the symbol of the problem is the backhoe. And the penalty for getting in the way of these beach-sand thieves is violence and even threats of death. An anonymous local fisherman stated: "They pass through and destroy everything in their path, including the nests. They also interrupt turtle egg-laying; each turtle takes more than two hours to lay its eggs."

And the actual sand mining is not the only problem. The machines' movements compact the sand and create areas of roughness on the beach surface. Even if a nest survives the sand extraction, hatchlings cannot reach the surface or cannot get to the sea and die trapped in or on the beach.

Sand mafias take advantage of beach characteristics, in this case, the beach length. Playona beach—which is located near two other beaches (Playón and Chilingos)—is at least 7.5 miles (12 km) long. With low (almost no) surveillance by the Armed Forces. Using the dense equatorial rainforest as a shield, the backhoe excavators penetrate the beaches and mangroves, mainly at night, stealing sand and then escaping to the collective territory of the Cocomasur (an ethnic minority), where the most significant environmental degradation can be found.

These activities are done without environmental licenses and are part of the many illegal activities promoted by the Dissidences de las

Fuerzas Armadas Revolucionarias de Colombia (FARC) (guerrilla fighters who did not accept the peace agreement signed in 2016), as well as by criminal gangs associated with the drug business. According to the Colombian police, these illegal groups can earn up to 20,000 million Colombian pesos per year (US$6 million) for this type of activity along the Chocó coast, as well as in other coastal departments located on the Colombian Pacific coast.

COLOMBIA: THE CURE IS WORSE THAN THE DISEASE

Nelson Rangel-Buitrago, Allan Williams, and Giorgio Anfuso (2015; 2018) note that over the last fifty years, coastal erosion has become a severe problem, increasing in magnitude and dominance along the 1,581 miles (2,545 km) of Colombia's Caribbean coastline. About 50 percent of this critical area is undergoing severe erosion problems related to a multiplicity of factors, including development too close to the shoreline, that then is perceived as in need of protection by shore-hardening structures that cut off the sand supply to the beaches. Now, the added factor of the cumulative effects of past and present sand mining has become a concern: not only are beaches and coastal dunes being mined (as in the past) but now also rivers are being mined. Sand mining in rivers reduces sand delivery to the coast (see chapter 5), adding to beach-sand depletion. The Magdalena River delta has been a storehouse of sand for the coast, but here too, the river-sand supply reaching the coast is no longer sufficient to offset sediment losses due to coastal erosion. Erosional coastal retreat and the associated economic losses are the new norm.

Extraction operations have been documented along the entire coast, and their magnitude is related to the proximity of inhabited areas. Remote areas are more attractive to sand thieves than urban areas where illegal activities are more likely to be reported to, or discovered by, local authorities (figure 7.6).

Rangel-Buitrago, Williams, and Anfuso (2015) note that sand mining activities along this coast have caused a reduction of sand supply, disrupting the beaches' natural stable equilibrium. And the indiscriminate sand extraction has led to a lack of available sand for replenishing the beaches after they are washed away. In some places, coastal erosion rates reach over 80 feet per year (25 m/yr). Due to annual coastal erosion, many families lose their properties, giving rise to several adverse impacts, including loss of livelihoods.

The most common culprit is the sand and gravel demand for construction purposes. Just as in other areas of the world, sand mining be-

FIG 7.6 Sand mining destroyed this beach along the Cordoba Department shore of Colombia's Caribbean Coast. Two children walk hand in hand across a sandy mud flat of what was a sand beach. In the background is a low ridge of sand, bulldozed landward from the mining activity. Photo by Nelson Rangel-Buitrago.

came more important in the 1990s as Colombia's Caribbean coast saw a steep increase in urbanization. Long-distance transport of river sand is expensive, so mining was focused on coastal areas (figure 7.7).

Beach and coastal dune sand also is stolen by sandbagging, which is used to mitigate the coastal erosion process. Locals try to prevent erosion and hold back the sea by using local sand to fill sandbags that are then used to build small, low-cost seawalls and groins. This common practice offers no more than a very short-term solution, and the first big storm overtops and redistributes the bags, adding to the loss of beach aesthetics while contributing to the erosion and sand loss. Yet repeatedly we see sandbagging used to address erosional hot spots along the coast. This approach is global (e.g., Africa, North America's Great Lakes, the US Carolinas) and has the same fail rates along all high-energy coasts.

Of course, if little bags are good, bigger bags are better, and bigger offers more so-called protection. So, the use of giant bags and tubes is sometimes encouraged as a coastal erosion management practice, but like all hard structures, they produce no new sand, they do not respond

to the forces that cause beach erosion, and they disrupt sand supply to other parts of the coastal cell. Ultimately seawalls, whether massive concete structures or sand bags, destroy beaches (figure 7.8).

Regardless of the sand's final use, sand mining threatens severe short-term and long-term environmental damage. Sand mining is undermining Colombia's Caribbean beach tourism, which is a driving force behind the area's economy. Therefore, future regulations and decisions concerning sand mining on Colombia's Caribbean coast should consider the need to provide future generations with high quality, healthy beaches and dunes. The long-term economic potential of healthy, beautiful beaches is huge, but such an economy depends on extensive efforts to preserve the beaches now.

FIG 7.7 Sand mining on the Caribbean Coast of Colombia. Sand mining became more important in the 1990s as Colombia's Caribbean Coast saw a steep increase in urbanization, even in remote areas. Mining is focused on coastal areas, preferably on river mouths. Photo by Nelson Rangel-Buitrago.

TRINIDAD AND TOBAGO: CLOSE AND CHEAP SAND

Lying off the northern coast of Venezuela are the islands of Trinidad and Tobago. A study of Tobago's beaches, developed by Junior Darsan, Christopher Alexis, and Jason Barton (2013), found that beach mining tied with coastal erosion (a related problem) as the second-most pressing coastal problem. (First place went to sewage and litter.)

Darsan, Alexis, and Barton (2013) reported that in all of Trinidad and Tobago, sea-sand and river-sand mining are common and can be considered as traditional but harmful practices. Sand and gravel are mainly used for building construction and paving roads. The rate of construction and infrastructure development on the islands has accel-

FIG 7.8 Throughout South America, sandbagging is common both for means of small operators handling illegal (or legal) mining and transport (*left photo*), and for convenient construction units for building low-cost groins and seawalls (*right photo*) that are generally ineffective. In the background of the photo on the left, one can see a common small-scale mining operation in Colombia, with multiple piles of sand dug from pits in the back beach, low dunes, and overwash fans. Photos by Nelson Rangel-Buitrago.

erated since 1980, with a parallel escalation in the sand-mining industry. Beach mining in Tobago has been particularly common, including on the beaches of Crown Point, Kilgwyn, Lowlands, Milford Road (Scarborough), Bacolet (Minsky Bay), Hope, King Peters, Richmond, Kendall, Goldsborough, Turtle Beach (Courland Bay), Black Rock, and Back Bay. Locals also have witnessed the destruction of Richmond Bay, Goldsborough, Kilgwyn, and other notable small bays that became vulnerable to mining because they had vehicular access, making their beaches easy prey for the backhoes, trucks, and vans of miners and sandbaggers.

Turtle Beach, located in Courland Bay, was the first area to be hard-hit as development kicked off in the late 1970s in the western part of Tobago. This mining led to significant beach erosion.

Sand mining in Tobago is a money issue. No alternative source will ever be as cheap as beach sand. One truckload of beach sand only costs TT$100 and TT$200 to transport (total about US$44). So the global story repeats itself: when someone needs sand, they will get it from the nearest beach (close and cheap). If such sand mining is not banned, Tobagonians will continue taking small quantities of sand from their own beaches unmindful of the long-term impacts.

Tobagonians are not the only ones responsible for beach-sand mining. Some multinationals are doing their job as well. This is made possible because the Ministry of Energy and Energy Industries, which is responsible for regulating mining activities, and the Commissioner of State Lands, the enforcement agency, have virtually abandoned their mandates, allowing sand extraction at will.

There is always an economic price to pay for sand mining, but an island that allows beach-sand mining is committing economic suicide. Tobago is now developing at such a pace that beach mining is reaching a point of no return. Environmentalists have been crying out for a solution to this problem for decades. Once beach mining is stopped, sand demand will force the private and public sectors to work together to find an alternative source.

Guyana has offered to negotiate a trade of Tobago gravel for Guyanese sand. And Trinidad apparently has enough sand to supply Tobago for the short-term future, but their supply of sand is also finite. Neither of these two choices is a solution—instead, new problems are created elsewhere!

SOUTH AMERICA: A DIFFERENT CONTINENT, SAME PROBLEMS

In South America, beach-sand mining has generated a string of complications that include environmental destruction, social polarization, violence, loss of governmental credibility, corruption, compromised economies, and social impacts. The prophecies of the benefits from sand mining have left locals on the short end of the stick—false profits.

Sand-mining incomes are addictive, perhaps because in theory they represent easy earnings. However, the dependence on sand-mining revenues has generated severe economic problems along these coasts as well. For example, when mineral prices have fall, there is a subsequent and drastic reduction in employment and profits. Also, the mining approach does not generate productive chains; it employs very few workers, usually at low wages; and it is not a decadal sustainable economic driver at any given location. Further, illegal mining robs the state by not paying taxes, and the citizen taxpayers wind up paying for post-mining restoration.

There is another problem, not usually visible. Because the revenue is distributed only among regions where sand mining occurs, a deep inequality in the distribution of investment resources is generated. In each area, resource distribution favors the provinces and districts where mining activity is carried out, so inequality deepens. In essence, beach-sand mining, or river-sand mining, is an exclusionary activity.

Inequality is the first step in creating serious conflicts. The inequitable distribution of resources expands social and economic gaps, revealing a lack of institutions' capacities. These phenomena in turn exacerbate corruption and prevent the laying of foundations for reforms and modernization.

Coastal sand mining is a bad development strategy, and the growing list of both scientific studies and media reports provides information highlighting the many problems it creates. The thirteen case studies presented in this chapter make it clear that beach-sand mining is a bad business in South America. But where in the world is it not?

A DIFFERENT KIND OF SAND MINING

CH.08

Legal but Destructive

In recent years, another kind of sand mining has been taking place in the United States as beachfront development has exploded. Thousands of buildings have jammed up against the US barrier-island shorelines. The former mom-and-pop beach cottages of the 1950s and 1960s, which were one-story buildings on stilts, are no more. These have been replaced by large, three-story buildings, primarily designed to produce rental income, or, worse yet, by high-rise condos, apartments, and hotels, many of which are twenty or more stories high. In cities such as Miami Beach, Fort Lauderdale, Daytona, Marco Island, Destin, and many others, there is no realistic possibility of moving these big structures back from a retreating shore. But bedroom communities and coastal megacities aren't the only beachfront structures. Tourism infrastructure, power plants (including nuclear), wastewater plants, oil refineries, and miles and miles of highways, all lie in the high-hazard coastal zone, no longer protected by natural dunes and beaches.

The point is that as beachfront development has blossomed and as sea levels continue to rise, the effort to hold the shoreline in place and protect shorefront buildings will only intensify. One method is to build some form of hard structure such as a seawall. But seawalls eventually destroy beaches. Because preservation of a beach is essential for keeping the tourists coming, beach nourishment, the pumping in of newly mined sand from offshore, likely will continue to be the perceived solution, as is already the case for the US East Coast. However, sand mined and then placed on a beach is always very costly and always temporary. The sand eventually will be lost, usually spread out by storms in a thin layer on the adjacent continental shelf, and such thin layers of sand cannot be dredged up a second time.

We have learned that the driving causes of most beach problems are overdevelopment and poor coastal management. If no buildings crowded the shoreline, there would be no need for shoreline armoring, beach nourishment, or beach scraping. The threats to the beach fauna and flora or the recreational quality of the beach would not exist. And there would be no erosion problem requiring mined replenishment sand. No buildings, no erosion problem.

Keeping in mind that the term *mining* involves the movement of earth resources (e.g., material of value such as gems, ore, or aggregate sand, taken from a deposit to another site for use), the replacement of beach sands (beach nourishment) falls into the category of mining, and it is legal, permitted mining. The following accounts describe other legal sand-mining operations (these for construction sand) in North America.

UNITED STATES

MONTEREY BAY, CALIFORNIA, THE LAST BEACH SAND MINE

Closed in 2020, CEMEX Lapis Sand Plant was the last beach and dune sand mine operating legally on a beach in the United States. The mine was located in the southern portion of the 30-mile (48-km) Monterey Bay shoreline within the town of Marina in Monterey County, California. Strangely enough, the mining site was part of a National Marine Sanctuary where many restrictions are in place, such as no jet skiing and no drilling for oil. In addition, this is the most-visited shoreline reach in central California. Mining beach sand was decidedly out of place here.

Over the years, as many as six sand mines were operating along the southern Monterey Bay shoreline, taking sand directly from the beach. This type of beach-sand mining was halted by 1959 to be replaced by the use of offshore draglines that obtained sand from the shoreface, or inner continental shelf. The shoreface, extending to a depth of 30 feet (9 m) or so, is actually part of the beach, a surface over which sand is exchanged back and forth, to and from the beach (figure 8.1). As a consequence, there is little difference between mining the visible beach and mining the submerged shoreface. In either mining situation, the sand supply to adjacent beaches, furnished by longshore wave transport, is reduced and shoreline erosion is increased.

FIG 8.1
Closed in 2020, the CEMEX Lapis sand mine along Monterey Bay, California, was the last legal beach-sand mine in the United States. Sand washed over the sand spit at high tide or during storms and into the pond behind the spit and was eventually removed by a dredge. Photo © Gary Griggs.

The long-term average of the annual shoreline erosion rate on southern Monterey beach is about 4 feet (just over 1 m) per year, the highest erosion rate in the state. According to Coastal Engineer Edward Thornton, the rate in 2000 was close to 7 feet (about 2 m) per year due to the impact of the mine (Schmalz 2016a). Thornton predicted that shutting the mine could result in a shoreline advance as much as 3 feet (less than 1 meter) per year. Geologist Gary Griggs noted in November 2020 that the area of shoreline recovery would be limited but should be measurable over time (Ogasa 2020). However, the fact that the sea level is rising made the closing of the mine all the more important because the shoreline needs all the sand it can get to reduce the rate of beach retreat.

The CEMEX Lapis Sand Plant occupied a site at which beach-sand mining began in 1906. The plant employed a very unusual and even creative technique of sand extraction. In 1965 a dredge pond was excavated immediately behind and adjacent to the beach. The idea was that waves at high tide would push sand into the pit where a permanently stationed, floating sand dredge would pump sand into nearby dump trucks. The plant moved 150,000 to 200,000 cubic meters (twenty thousand to thirty thousand dump truck–loads) of sand each year, a major loss of sand from the beach. If the mine hadn't been there, it is likely that some of the sand would have gone into dune construction and been used to reduce the rate of erosion on adjacent beaches (Melius 2017).

A decades-long battle ensued between the plant owners and mining opponents, led in significant part by the Surfrider Foundation, geologists Rob Young and Gary Griggs, and attorneys from the Stanford Environmental Law Clinic (Melius 2017). Local media support included the *Monterey County Weekly*, which contended that the mining operation had been illegal from its beginning in 1965 (Schmalz 2016b). Support by local citizens was apparent when in August 2016, fifty coastal advocates descended upon a California Coastal Commission meeting to support the closing (Schmalz 2016a).

On July 13, 2017, the California Coastal Commission unanimously voted to accept a long-negotiated agreement to shut the mine down by December 31, 2020, ending a 114-year span of Monterey Bay beach mining. The good news is that the CEMEX site will be restored and will be open to the public (Surfrider Foundation 2017).

SAN FRANCISCO BAY: MINING THAT IMPACTS THE BEACH

There is an additional sand mining problem in California — this one in San Francisco Bay. This is not a beach-sand mining operation along the open ocean as was the case of the CEMEX mine on Monterey Bay. Instead, it is a seventy-year-long, bay-floor mining operation that ultimately affects the open-ocean shoreline by cutting off the sand supply, much like river-sand mining can affect beaches. Perhaps the mining's impact is less visible than the Monterey Bay CEMEX project because the open-ocean connection is not obvious to the casual viewer. The sand in San Francisco Bay originates in the Sierra Nevada Mountains and moves through the Sacramento–San Joaquin Delta to eventually wash into the bay and thence to the ocean. The mined sand from the bay is used primarily for concrete.

Evidence based on US Geological Survey studies indicates that some of the sand that tidal currents carry out from San Francisco Bay under the Golden Gate Bridge are deposited on Ocean Beach, near the mouth of the bay (Steimle 2018). The recent increase in erosion rates of Ocean Beach may be in part attributable to loss of beach-sand supply as a result of the mining in the bay (as well as to sea level rise).

In the article by Susie Steimle (2018), Gary Griggs is quoted: "It's sort of like a bank account, there's stuff going in and stuff going out; we know what happens when more is coming out from bay mining than is coming in." Changing the bottom contours of a bay by dredging may also change wave patterns striking the shorelines of the bay. Waves coming across relatively deep holes would experience less friction with the bay floor and would be larger and more energetic than usual upon striking the shore, a process that would add to the erosion rate of bay shorelines.

On October 31, 2018, the California Court of Appeals issued a ruling that allowed the bay mining to continue (Steimle 2018). It was the second time that opponents lost in an attempt to halt San Francisco Bay mining. The case involved the California State Land Commission that favored the mining versus San Francisco Baykeeper Inc. (2018), an environmental group headed up by Sejal Choksi-Chugh. The group has long been opposed to bay dredging. The mining lease held by Lehigh Hanson Inc. will come up for renewal in 2023, which will offer another opportunity to try to halt the mining and consequent Ocean Beach erosion.

SAND FOR THE BIG CITY

One of the largest sand-mining operations in the US was along the North Shore of Long Island. The operation lasted from 1865 to 1990, and by the time it closed it had furnished 200 million tons of sand to build New York City. Much of the sand came from the area that locals call Sand Alley along Hempstead Harbor, around 17 miles (about 27 km) east of Manhattan. The sand was primarily derived from glacial deposits and some younger dune and beach deposits (Shodell 1985; Welland 2009). These sands were poorly sorted and, according to legend, made very strong concrete for many of the city's famous buildings, including the Empire State Building, the Chrysler Building, and the World Trade Center.

CANADA: THE CANADIAN MINING SCENE

There have been many small, beach-mining operations along Canada's shoreline on both sides of the continent and on the shores of the Great Lakes. The sands of Prince Edward Island (PEI), Canada's smallest province, have an unusual and famous red color due to the presence of abundant iron in the source sandstone that is eroding to furnish the beach sand. At Basin Head, the sands are white and are known as singing or barking sand from the noise emitted from shuffling steps made by beach goers (Black 2020).

In 2009, provincial Environment Minister Richard Brown declared that on Prince Edward Island a direct link exists between coastal erosion and mining of beach sands for use in making concrete. At that time, the province ended commercial sand mining on PEI beaches (*CBC News* 2009). Mining here has consisted of front-end loaders that wait for low tide before heading to the beach to excavate sand that is dumped into large dump trucks. Most of the mining occurs in the spring at four different PEI locations including Gascoigne Cove (*CBC News* 2008). The minister noted that the holes left behind will eventually fill with sand but at the price of causing sand loss and erosion elsewhere. According to local activists, people have left the area because of the noise, erosion, and overall degradation caused by the mining (*CBC News* 2009). Nonetheless, in recent years there has been a strong movement afoot, led by Member of Parliament Bobby Morrissey, to resume beach mining. Currently sand is obtained by clearing harbors, and this sometimes results in shipping delays that would not happen if sand were coming directly from beach mining, according to Morrissey (McCarthy 2019).

In western Newfoundland along Route 430, south of Port au Choix, one can see evidence that beaches and dunes were mined away, probably in the late 1950s, to build the highway that was completed in 1962. All that remains between the road and the sea is a poorly vegetated bedrock surface, bounded by a narrow, rocky shore — neither wide sand beaches nor foredunes have formed in the six decades following the mining (figure 8.2).

BURYING AND BULLDOZING BEACHES: COASTAL MANAGEMENT TOOL OR PROPERTY PROTECTOR?

BEACH NOURISHMENT

The two major approaches to beach mining for coastal management are beach nourishment and beach scraping. Beach nourishment or replenishment involves mining large volumes of sand from outside sources, then transporting and distributing the sediment to and on the beach, with costs on the order of one-to-twenty million dollars per mile of shoreline. A typical beach-scraping operation moves less sand for smaller distances and might cost on the order of $100,000 per mile, requiring only a bulldozer or some sort of front-end loader. Beach nourishment usually involves an offshore dredge, barges, and/or long

FIG 8.2 A featureless surface is all that remains from a mined-out gravel mine near Avalon, Newfoundland, Canada. Most Canadian beach mining takes place in rural areas and thus has limited impact on tourist beaches. Completely flattening the beach and dune, as has happened here, destroys the ecosystem and removes any storm-surge protection for roads or buildings adjacent to the beach. Photo © Joe Kelley.

pipelines to deliver the sand to the beach, plus bulldozers on the beach to spread the new sand. Nourishment can also be achieved with dump trucks, bringing in sand mined from an inland source, which is also spread using heavy equipment. The resulting artificial beach, whether pumped ashore or trucked in, is still faced with the same storms, waves, currents, and rise in sea level as the once-natural beach. And artificial beaches often respond differently to these processes, for example, sometimes experiencing extreme scarping (figure 8.3). So, nourishment sand is eventually lost, often irretrievably, offshore, along shore, or onshore. The loss of sand may occur gradually over multiple years, or it may occur almost instantly in a single storm.

Often on a newly replenished beach, the first evidence of offshore loss of sand is the formation of an offshore sandbar, usually at wading depth, visible because waves break on it. Or a significant storm can take beach sand for miles out onto the continental shelf. Such long-distance sand transport was documented by studies carried out after hurricanes struck beaches in both Georgia (Gayes 1991) and Texas (Hayes [1967]

FIG 8.3 A two-to-three-foot erosion scarp in 2019 on the nourished beach at Nags Head, North Carolina. Scarps such as this one indicate rapid erosion and are far more common on replenished beaches because such beaches erode much faster than natural ones. Erosion scarps can be more than ten feet high and dangerous to unaware beach strollers. Photo © Margaret Miller Growe.

1974). In all cases, offshore loss of sand eventually results in a thin, widespread layer of sand.

Alongshore sand loss occurs when waves strike the shoreline at an angle, causing sand to be transported laterally. This process often occurs after both scraping and nourishment, and sand is lost from the target beach to adjacent beaches or into bays or inlets. In significant storms, beach and dune sand is moved onto the adjacent upland by waves, helped along by the rise in water level due to storm surge, forming overwash fans on land. Such landward sand transport is an important part of the barrier island migration process. However, rows of buildings block such transport and cut off the island's sand supply that is needed for migration. Onshore winds commonly add sand to beachfront dunes while offshore winds reverse the process and add sand to the beach. Dunes are important natural sand reservoirs for beaches during storms. And while beach nourishment projects often include artificial dune construction, artificial piles of sand do not make a natural dune.

The first nourishment project in the United States was a 2-mile-long (3 km) Coney Island, New York, beach in 1923, followed by a shorter nourishment in 1936, costing $4 million and $2 million, respectively, in 2018 dollars. However, nourishment did not become a widespread engineering approach in the United States until the 1960s, and somewhat later in Europe. Although Germany's first such beach project was in 1951, Italy's in 1969, and The Netherlands' in 1970, beach replenishment now is practiced worldwide.

According to records kept by the Program for the Study of Developed Shorelines (2020) at Western Carolina University, in 1963 there were twenty-three replenishment projects in the United States, and by 2005 the number had jumped to forty-four. This program's latest data base contains records of 1,243 million cubic yards (950 million m^3) of sand placement, covering 2,300 miles (3,700 km) of US shoreline and costing over $9 billion. Approximate total sand volume of beach nourishment in the lower forty-eight states is over 1.3 billion cubic yards (1.05 billion m^3). State-by-state volumes (cubic meters) of total sand used in beach nourishment over several decades, as recorded by the Program for the Study of Developed Shorelines, are shown in chart 8.1.

Nourishment is a process that must be repeated again and again in order to keep functioning beaches in place. Nourished beaches on the US Mid-Atlantic Coast typically last for two to three years, while Florida's east coast beaches last for seven to nine years. A few replenished beaches have lasted for a decade or more, mostly depending on the wave energy. A Miami Beach nourishment lasted for more than a decade, primarily because the Bahama Banks, offshore from Miami, reduce the area over which waves can be generated, hence reducing the size of the waves striking the beaches. Other nourished beaches have lasted for only a short time and then disappeared in a single storm.

Ideally, nourishment sand should be identical to the native or original beach sand. Good quality sand is not only important from an ecological standpoint but also from the standpoint of recreation. Unfortunately, there are global nourishment-sand quality problems. First, good quality sand deposits are not limitless, and nearby sources for some nourishment projects are becoming exhausted. Second, because of dwindling sand supplies and increasing costs, poor-quality sand (gravelly, rocky, muddy, shelly) is often being pumped up on many beaches around the world. The worst of these on the US East Coast was a nourished beach on North Topsail Beach, North Carolina, which contained cobbles and even a few boulders; and muddy sand was pumped up on Atlantic Beach, also in North Carolina.

Source areas for nourishment sand can be problematic, as was the case in New Jersey in 2007. The US Army Corps of Engineers used offshore sand from an ammunition dump site used during World War II,

CHART 8.1 US BEACH NOURISHMENT EPISODES (#) AND SAND VOLUMES (YD^3)

Washington (11)	1,211,570
California (343)	350,848,751
Texas (68)	6,798,369
Louisiana (40)	78,673,785
Mississippi (25)	30,955,443
Alabama (12)	16,625,400
Florida (495)	273,356,209
Georgia (11)	11,321,818
South Carolina (84)	59,964,694
North Carolina (265)	135,418,546
Virginia (66)	34,830,155
Maryland (35)	16,102,318
Delaware (107)	22,257,819
New Jersey (338)	206,390,689
New York (124)	95,245,021
Connecticut (37)	6,150,772
Rhode Island (13)	258,080
Massachusetts (42)	4,017,353
New Hampshire (7)	1,870,000
Maine (17)	777,818

SOURCE: Beach Nourishment Database, Program for the Study of Developed Shorelines, Western Carolina University, Cullowee, North Carolina, accessed March 2, 2022, www.beachnourishment.wcu.edu.

FIG 8.4 Ordinarily, a mud-nourished beach would be considered a failed project. In 2018, mud was poured on purpose onto Goleta Beach in California, in an emergency case. A mudflow had smashed into the city of Santa Barbara after forest fires removed stabilizing vegetation from nearby mountain slopes. The mud (with toxins, like oil) had to be removed from the city streets, and the beach and ocean provided a convenient dumping site. Photo © Vanessa Lytle.

resulting in the deposition of sand on a New Jersey beach that included seven hundred live rounds of munitions! Vacationers digging in the sand found the munitions, but fortunately no one was injured (Parry 2018). Beaches have also been used as emergency dumps, such as occurred during clean-up after forest fires and the resulting mudflows in California (figure 8.4). In the New Jersey and North Carolina cases, the problem with the nourishment sand was due to inexcusably poor exploration of the sediment-source area. Thorough exploration is necessary to find suitable nourishment sand, but this adds to the cost of the beach maintenance and for that reason is sometimes skipped in planning.

In the search for new sand sources for east Florida beaches, the Bahama Banks as one possible source area have received a lot of attention as they are a mere ninety miles offshore from Miami. As it turns out, Miami-Dade and Broward counties in south Florida are out of useable sand, which makes the Bahama Banks look most attractive (Grabar 2017). Sand mined from an inland source would cost twice the amount of that dredged from offshore. Already, sand from South Andros Island, Bahamas, is being mined to produce sand for Fort Lauderdale beaches. The mining process is causing erosion of South Andros beaches, the center point of local tourism. But South Andros, a lightly populated island that holds little political sway with the government in Nassau, is unlikely to be able to stop the mining.

Off North Carolina, the three capes, Hatteras, Lookout, and Fear, each have shoals with large volumes of sand extending across the continental shelf for distances up to 40 miles (nearly 65 km). Diamond Shoals are off Cape Hatteras, Cape Lookout shoals extend off Cape Lookout, and Frying Pan shoals are off Cape Fear. Coastal engineers are hungrily eyeing these shoals as sand sources for future beach nourishment, but so far, environmental concerns, including the impact that mining would have on wave patterns and changing the shape of the shoals, have kept sand miners away.

Three similar deposits occur off of Puerto Rico. Escollo de Arenas is a 3.5-mile-long (6 km) sand and gravel bar extending to the north off the northeast corner of the island of Vieques, a short distance from the main island of Puerto Rico. This sand and gravel body is estimated to contain 90 million cubic yards (69 million m^3) of material, a potential site of construction aggregate that could ease the mining pressure on Puerto Rico's beaches and dunes. The sand shoal off Cabo Rojo is almost as large as the Escollo de Arenas, but the oft-mined offshore Isabela deposit is much smaller (Rodriguez 2017).

THE POLITICS OF BEACH-NOURISHMENT MINING

> Blessed are the millionaire beach property owners
> for they shall inherit the beach.
> ***PENSACOLA NEWS JOURNAL*, DECEMBER 8, 2019**

Politics center on money, of course—that is, who pays and who benefits. In the United States, the federal government is typically responsible for much of the cost of beach nourishment, ranging from 65–100 percent. State funding is commonly 20–25 percent, and individual homeowners often pay only 10 percent. Often, home owners on the beachfront are required to pay a larger sum than the owners of homes farther back from the beach, which makes sense, but the point is that both federal and state taxpayers are subsidizing 90 percent of homeowners' protection of beachfront property and related recreational costs.

As sea level rises, the potential cost of beach nourishment increases proportionately as the stability of the nourished beaches decreases. The magnitude of this problem is illustrated by the North Carolina beach situation. The state has a total open-ocean shoreline of 325 miles (523 km), and about 150 miles (255 km) of them need (and want) beach nourishment. The total cost of nourishing all 150 miles (255 km) would come close to a billion dollars, and that's just for the first installment of temporary beaches.

The main political forces demanding nourishment or scraping are beachfront property owners seeking the preservation of their investments. Increasingly, in the United States, one should ask, "Why should I, as a taxpayer not living on or near the beach, pay for beach alteration? I wasn't imprudent enough to build a house or a high-rise on a retreating beach." Beachfront property owners, usually wealthy and influential, insist that the real justification for nourishment is a good recreational beach for the public. Yet public access to these government-funded beaches is often restricted by lack of adequate parking spaces and widely spaced access paths—public funded but not so public.

One way to look at beach nourishment and mining costs is that government (federal, state, and local) is subsidizing coastal development with beach replenishment money and in a real sense is costing taxpayers double because such funding encourages more coastal development at a time when storms are expected to intensify and sea levels are expected to rise at an accelerated rate. And taxpayers pay the bill twice! Communities around the country have spent billions of dollars nourishing beaches, which ultimately encourages people to rebuild houses after every major hurricane instead of moving back away from the edge of the sea. These areas then are insured under the subsidized National Flood Insurance Program, and are declared emergency areas after each big storm, with even more federal and state monies poured into these high-risk zones. And the latter usually includes more funding for another round of beach nourishment. Good money after bad.

THE INTERNATIONAL NOURISHMENT SCENE

Over much of the world, as is apparent from this book, extensive beach, dune, and nearshore mining is carried out for construction purposes. An impressive, but impossible to accurately quantify, portion of this effort is carried out illegally. In the United States, relatively small amounts of coastal sand are now used for concrete, and probably most

CHART 8.2 THE WORLD'S LONGEST BEACHES

Praia do Cassino, Brazil	150 miles
Padre Island, Texas	135 miles*
Ninety Mile Beach, Australia	90 miles
Cox's Bazar, Bangladesh	75 miles
Playa Novillero, Mexico	70 miles
Ninety Mile Beach, New Zealand	50 miles
Virginia Beach, Virginia	35 miles
Long Beach, New Jersey	28 miles
Muizenberg, South Africa	25 miles
Stockton Beach, Australia	20 miles

* length before artificial inlet was constructed

of this mining is small scale and illegal. By far the largest volume of mined coastal sand in the United States (more than 1.3 billion yd^3) is used in beach and dune nourishment. Beach nourishment in one form or another is carried out all over the world, and everywhere the process is costly. As a consequence, nourishment is primarily a first-world tool for responding to the ubiquitous erosion problem. Chart 8.2 is a list of the longest beaches in the world, many of which have been nourished over part of their length.

Vale do Lobo Beach in the Algarve of Portugal is one of the country's most popular tourist beaches, but its experience with replenishment was a big disappointment. The much-heralded 1999 nourished beach was intended to raise the beach by 6 to 10 feet (2 to 3 m) over a width of about 260 feet (80 m), along a distance of nearly a mile (1,400 m). The volume of sand used was around 915,000 cubic yards (700,000 m^3) and the cost was about 3.2 million Euros. The new Vale do Lobo Beach was completed in the first week of January 1999. The very first storm that struck the beach that same year removed almost the entire beach (Neves 2020).

An American nourished beach had an even worse record than the Portuguese one. In the early 1970s, a small nourishment project was being carried out in the vicinity of the high wave energy shoreline of Cape Hatteras, North Carolina. A storm occurred while the beach sand was still being pumped up. Most of the sand and some of the dredge pipes were lost at sea, and the project came to an end.

Japan has a long history of creating sea-walled coasts, but on Kashima Beach, about 37 miles (60 km) east of Tokyo, the choice was to nourish the beach. It turned out to be a quite unsuccessful beach project. Kashima Beach is also a high wave energy shoreline, and care was not taken to find suitable beach sand. Instead, the sand added was very muddy, making it undesirable as a tourist beach. To add to the problem, boulder groins were emplaced to try to hold the beach in place, but these created very strong and dangerous rip currents. The recreational beach and public safety were traded to hold the shore in place.

A Lincolnshire beach nourishment project is the largest nourishment project in the United Kingdom, and it certainly is a more successful project than the Portuguese Vale do Lobo nourishment endeavor. For twenty-five years, the Lincolnshire beach has been protecting almost thirty thousand homes and nineteen thousand static caravans along about 12 miles (20 km) of shoreline. Annually, about 520,000 cubic yards (400,000 m^3) of sand is sucked up by a hopper dredge that then brings the sand close to the beach and pumps it ashore. The sand is usually obtained from a location about 12 miles (19 km) offshore at a typical project cost of 6 million pounds (over US$8.3 million) (The Flood Hub n.d.). But read "annually" as "eternally," and ask, "From where will the continued, needed funding come as the rates of sand loss increase in a higher sea level?"

The 3-mile-long (4.5 km) beach at Nice, France, on the French Riviera, is a gravel beach that was nourished with a total of 730,000 cubic yards (558,000 m^3) of sediment between 1976 and 2005. The beach is strongly embayed, so lateral loss of gravel was nonexistent. The beach during this time maintained a more or less constant width. Most of the loss of gravel occurred in an offshore direction due to a very steep inner continental shelf or shoreface. Generally, gravel beaches tend to be steeper than sand beaches, and tourists sometimes complained that the beach at Nice was so steep they had to crawl out of the ocean (Penketh 2014). For that reason, the beach was flattened and widened annually by bulldozer every summer to benefit tourism. But the widening forced the outer edge of the beach to be closer to the steep shoreface, facilitating rapid loss of gravel from the outermost beach (figure 8.5).

In the Caribbean, beach-centered tourism in Barbados has influenced beach nourishment initiatives in an area of about three-quarters

FIG 8.5 This pebble beach at Nice, France, is very steep. Every spring the beach is flattened to encourage tourism, and each year the portion of the beach that was extended seaward by bulldozers is lost to erosion. So, beach nourishment is an annual affair. Photo ©kov09, Creative Commons CC BY-SA 2.0.

of a mile (1.2 km), which includes two beach nourishment projects that will cost US$3 million (BD$6 million) and US$2 million (BD$4 million), respectively. These unusually short projects are located in areas with high investments in tourism facilities and where maintaining a recreational beach supports extensive economic activities.

BEACH BULLDOZING OR SCRAPING

According to Francesca Russello Ammon (2016), the bulldozer, once a wartime weapon, became the key machine of post–World War II reconstruction and subsequently led to the global culture of landscape clearance. The bulldozer became a key player in clearing space for housing, interstate highways, urban renewal, infrastructure, and all things related to coastal development. Now, bulldozers are so widely used at the shoreline that the machine itself is virtually a shoreline process.

Beach bulldozing, or what's called beach scraping, is another form of beach mining. Unlike sand mined for use in concrete, the sand in beach scraping is used in close proximity to where it originally had come to rest after a long geologic journey from the mountains to the sea. Beach scraping has been called by some a poor-man's beach nourishment, and that's a fitting name because, at best, this process is a short-term fix, if it is effective at all. However, beach scraping is perhaps the most common process in the world used for combating shoreline erosion.

Beach scraping, which moves sand from the low-tide region to the high-tide zone of the beach, is actually a form of beach erosion in the long run. Most commonly such scraping is used to repair storm damage, but such repairs are temporary. After Hurricane Sandy in 2012, much of the 110-mile (160 km) stretch of the South Shore of Long Island's beach was scraped.

Beach sand scraping isn't always met with local satisfaction. In 2005, property owners in Broad Beach, Malibu, California, used bulldozers to remove sand from what was considered to be the public beach and then piled it up against the dune to protect their homes. The sand removal significantly narrowed the public's beach. The state's Attorney General accused the community of interfering with public access to the beach and of sand theft.

Oscar Munoz, former CEO of United Airlines; David Brown, CEO and president of Web Com; Chris Aitken, managing director of the financial services company UBS (Union Bank of Switzerland); and Margaret Conolly all have something in common (Murphy 2018). They all own costly beachfront houses at Ponte Vedra Beach, south of Jacksonville, Florida, and all violated the state's beach management regulations. After attempting to protect their homes with an artificial dune formed by beach scraping, in clear violation of state regulations, they were fined a total of $234,000 for damaging the public beach (figure 8.6). Their beach-mining episode had definite financial consequences.

The two principal beach alterations produced by sand scraping are (1) formation of a raised upper beach, intended to protect the dune by bulldozing added sand to the front or toe of the dune, and (2) construction or repair of an actual frontal dune. The two are closely related and sometimes indistinguishable.

PROTECTING THE DUNE BASE

This process steepens the beach, reducing friction or drag on the approaching waves as they come ashore on the outer beach. This, in effect, increases the size of the breaking waves. Thus, bigger waves will break farther up on the back beach, which has negative effects. The shoreline's erosion potential is actually increased, and the recreational dry-beach width is usually decreased.

FIG 8.6 The scraped beach and dune on Ponte Vedra Beach, Florida. Sand was bulldozed up from the lower beach to elevate the upper beach, in order to provide storm protection for private homes. The problem is that this process narrows the public's beach. The property owners responsible for the scraping were fined $234,000 by the state. Photo courtesy of the Florida Department of Environmental Protection.

Clearly, the beach response to sand scraping varies from location to location and from beach to beach, depending on many factors that include wave energy (wave height), storm frequency, the nature of aeolian (wind) transport, and even the grain size of the sand. For example, the scraped-up pile of sand at the base of the dune is less tightly packed than the sand on the natural beach, and under the right wind conditions such sand piles are highly vulnerable to wind erosion.

Almost certainly, in the short run, scraped sand piles on the upper beach should temporarily reduce rates of shoreline retreat during most wave conditions. However, under storm conditions the situation changes. A study of a scraped beach on Topsail Island, North Carolina, found that the amount of sand lost from the scraped beach in 1989, during Hurricane Hugo, was larger than the sand loss on adjacent natural beaches (18 vs. 12.9 m^3 of sand removed per meter of shoreline length) (Wells and McNinch 1991).

Engineers in South Australia experimented by shaping elongated sand bodies with scraped sand on the upper beach. They came up with three types of sand bodies designed primarily to reduce sand loss from wind: a single ridge, a double ridge, and a dike. The ridges were small bodies of sand with pointed tops, and the dike was larger and flat-topped. The double ridge seemed to reduce wind erosion the most. (Smyth and Hesp 2015). Although this may have been a prizewinning-worthy creative approach to saving sand in place, to our knowledge this design has never been applied beyond the experimental stage.

CREATING A NEW DUNE

The second and more common product of beach scraping is construction of a new or refurbished dune line, intended to protect buildings adjacent to the shore. But, as noted above, scraped sand is not as firmly packed as natural dune sand and is more easily blown or washed away. The new dune sand will eventually either be washed inland by storm waves, eroding the dune during a big storm, or moved by longshore currents to adjacent beaches. Just like nourished beach sand discussed earlier, scraped-sand dispersal will not provide significant sand volumes for future scraping or nourishment projects.

Beach scraping is widely applied in the communities within, but not part of, New York's Fire Island National Seashore. Within the National Seashore, scraping is not allowed. These adjacent scraped and unscraped beaches provide an interesting contrast. In general, the National Park Service's philosophy is to let Nature roll on without benefit of interference by humans.

According to the National Park Service (2019), artificial sand dunes produced by scraping actually increase the rate of sand deposition in downdrift beaches, potentially decreasing their erosion rate. This effect most likely is because the artificial dunes erode more rapidly than natural dunes. The Fire Island communities' dunes are commonly lowered in summertime to improve the sea view and then rebuilt in time to face the waves and winds of winter, a most unusual mode of sand management at the shoreline.

Charles Peterson, Darren H. M. Hickerson, and Gina Grissom Johnson (2000) performed studies on Bogue Banks, North Carolina, and came to some important conclusions regarding artificial dunes relative to sand scraping, as follows:

- Scraped sand dunes, under conditions of onshore winds, sustained substantial loss of dune sand by wind erosion.
- Sand fences were superior to scraping in protecting dune-vegetation plantings and reducing sand loss by wind.

- Dunes created by scraping also reduced the volume of longshore transport of sand to adjacent beaches.

This last conclusion is the opposite of the Fire Island, New York, study and illustrates how different shoreline environments have differing processes of evolution related to wind, wave, and storm frequency variables. This is a truth of the shoreline that is overlooked (or covered up?) by those who promote various systems or procedures to combat shoreline erosion. Buyer beware when the salesman says, "It worked in New York, so it's bound to work here."

Grooming or raking of beaches is akin to scraping, except scraping usually digs deeper than raking. The objective of beach grooming is to clean up refuse (plastic, cigarette butts, glass) from the beach and provide a fresh attractive beach surface without footprints, holes, and sand castles. Beaches may be groomed seasonally, weekly, daily, and even two or three times a day. In a study of beaches between Santa Barbara and San Diego (the more frequently groomed beaches in California), scientists noted the managed (raked) beaches had 88 percent fewer individual animals, 63 percent less biomass, and many fewer species.

On beaches in northern Dublin, Ireland, the material from beach scraping piled up on the upper beach is full of trash, including plastics, wipes, and sanitary products, plus organic marine material such as seaweed. Apparently, the problem is that the scraping is done by front-end loaders. The conclusion was that manual litter picking was the best means of cleaning trash from beaches, to be done before scraping.

BEACH MINING KILL ZONES

A fundamental question when looking at the shore is, "Why do we aspire to coastal living, then destroy the amenities that draw us to the shore?" Beach nourishment produces excessive environmental damage. Charles Peterson and Melanie Bishop (2005) summed up the impact as follows: "Nourishment can bury shallow reefs and degrade other beach habitats, depressing nesting of sea turtles and reducing the densities of invertebrate prey for shorebirds, surf fishes and crabs" (887). Obviously, the new sand buries and kills just about every living thing. The abundance of seabird flocks seen feeding around ongoing nourishment projects, taking advantage of the myriad of organisms exposed, is an indication of the extent of degradation of the nearshore fauna on the adjacent continental shelf. But then for a few years after the sand has been emplaced, alert bird-watchers will note the lack of swooping and wading shorebirds, a reflection of the lack of invertebrate prey living in the new sand.

Whether a small-scale scraping or a large-scale beach nourishment project, the entire beach and nearshore marine ecosystems are temporarily disrupted or destroyed, with recovery periods measured in multiple years to decades. A myriad of microflora and microfauna live in the pore spaces of sandy beaches, and their loss is reflected in the noted disruption of the food chain, obviously affecting birds, nearshore fish, and invertebrates (Schooler, Dugan, and Hubbard 2019). The impact of moving great volumes of sediment, whether by mining, dredging, or trucking, results in obvious impacts such as sand slurries and turbid waters. The fauna and flora of beaches do recover, but usually require more than three years to do so. By then, of course, engineers are planning renourishment and a new, artificial, critter-killing beach.

The significant impact of beach nourishment caused by changing the grain size of the beach sediment may not be noticeable to humans, but atypical grains are of particular concern to nesting turtles and birds. To avoid interrupting life cycles of these larger beach animals, the added sands should be comparable to the animals' native nesting sand. Also, the timing of scraping, dumping, or raking of sand on the beach all must be planned around the animals' biological needs. Farther away from the beach, the dredge-depression impacts on the continental shelf also are not seen or noticed by the beach aficionado (i.e., the marine dredge hole or landward sand pit is out of sight and out of mind).

Unfortunately, required planning is often ignored, especially because sand scraping usually is seen as an emergency pre- or post-storm procedure and is carried out without planning or concern in terms of resource management. Most states require permits for scraping and bulldozing, but the emergency mentality trumps planning. Some third-world countries employ unplanned techniques for beach management and may not consider the detrimental effects on habitat.

Impacts from scraping and grooming pale in contrast to those from large beach nourishment projects. Probably the most extensive (and useful) studies of biological impacts due to nourishment have been carried out by Peterson and colleagues (Peterson et al. 2000; Peterson et al. 2005; Peterson et al. 2006). In studies of North Carolina beach nourishment projects, he found that change in grain size relative to the original size and high shell content of the new sand were critical factors affecting the abundance of coquina clams, mole crabs, ghost crabs, and shore birds.

And in a survey of previous investigations of biological impacts, Peterson and colleagues (2006) found serious problems with the science of many of the studies. This was a reflection of the political nature of beach nourishment funding and the need to downplay the biological impact of nourishment, such as change in benthic populations, so as not to sully the funding for the proposed project. Among the guilty parties in this biased science is the US Army Corps of Engineers (USACE), an agency that understandably may favor projects because the agency requires such projects for its survival.

With regard to beach habitat, it is clear that mining beaches to protect houses and maintain tourism is counterproductive because of the profound biological impacts, particularly the disruption of nesting and the food chain for invertebrates, shellfish, shore birds, and surf fishes. Inadequate long-term monitoring of such projects has created a perceived uncertainty about the biological impacts of beach scraping and nourishment. This tends to allow such mining to continue. The uncertainty includes poor documentation of the impacts of mining the sand sources on the continental shelf, particularly at the dredge sites. Even more significantly, altering beach and dune shapes mechanically has provided a false sense of security with regard to coastal hazards and has encouraged intensified development including the increased number and size of beachfront buildings.

Beach nourishment projects require pre-project environmental studies, but the USACE track record for issuing permits seems to be more strongly influenced by studies on the cost-benefit ratio—namely, the ratio of the lowest bidder and the highest property value. Generally, these government (taxpayer)-funded projects have not required post-project monitoring of habitat damage and recovery either in the area mined offshore or on the nourished beach. Where a few short-term monitoring studies have been conducted, the results have been taken as so-called proof that future projects in other areas will obtain the same results, that is, results from one study area are assigned to another project. But at the shore, the truth is that no two shoreline/marine systems are the same, and this fundamental concept is being ignored.

IMPACTS ON OFFSHORE TOPOGRAPHY

Now we must revisit the unique problem of offshore dredging (mining). Dredging sand from the shelf takes every organism, large and small (sometimes including turtles). If the dredge site is a sand ridge, such as that off Nags Head, North Carolina, the sand can be obtained over a relatively small area as the dredge digs deep into the ridge. But some-

FIG 8.7 Oil-rich Dubai has constructed the world-famous Palm Jumeirah islands using ninety-four million cubic meters of sand dredged from the Persian Gulf. The dredging suspended fine sediment in surrounding waters and killed the local ecosystem, including living coral reefs. View from the International Space Station. Photo by Expedition 10 Commander Leroy Chiao, 2005, NASA.

times when the layer of useful sand is thin, it is necessary to vacuum a large area of the sea floor, a most damaging impact on the ecosystem, as was the case in a Myrtle Beach, South Carolina, project. Some North and South Carolina shrimp fishermen have complained that dredging for beach nourishment seriously damages their fishery.

In Dubai, sand mining has posed different challenges. Here, fine sediment from the dredging operations to make the famous Palm Islands in the Persian Gulf has done permanent damage to the local coral reefs and the ecosystem (figure 8.7). Active coral reefs were buried and killed when the artificial islands were created, starting in 2000.

Dredge mining sites change the offshore topography and can modify incoming wave patterns, creating new hazards. A great irony of dredging sand for beach nourishment is that the quality sand sources are in nearby offshore bars, estuaries, bays, and tidal deltas, and when these environments are modified by dredge mining, the results affect fisheries and cause alterations of wave and current patterns that may shift erosion forces to new coastal locations.

A stunning example of this problem occurred off Grand Isle, Louisiana, where a dredge-hole depression that was too close to shore actually changed wave patterns and wave height so as to greatly accelerate the erosion of the newly nourished beach.

In addition, dredging actually makes a significant contribution to global climate change. The floor of the ocean, which makes up 70 percent of the Earth's surface, stores more carbon than all the soils on land. Disturbance of the sea floor by dredging and dragging trawler nets releases carbon that eventually is turned into carbon dioxide. A coauthor of a study published in *Nature* (Sala et al. 2021) declared to Megan Rowling (2021), a Thomson Reuters Foundation climate correspondent, that carbon emissions from trawler fishing are comparable to those emitted by aviation. Adding dredging to the equation, both activities (trawling and dredging) would likely release more CO_2 to the atmosphere than the total amount of CO_2 released by aviation. (See also Fox 2021.)

THE END POINT OF BEACH ALTERATION

All beach scraping and beach nourishment projects require repeated applications, and each subsequent nourishment has a shortened life expectation, especially in a time of rising sea levels and intensified storms. A range of short-term, negative impacts due to beach mining have been documented, but the double indemnity is that our society has now been set up for long-term disasters at the shoreline. Wide swaths of development face moving or destruction and abandonment within the next half-century.

Clearly, finding required quantities of quality nourishment sand is becoming increasingly difficult and more costly. Artificially adding sand to a beach or dune in the long run is basically throwing it away because beach processes eventually send most of it seaward. Rising seas will make the need for sand even greater, and public concern about spending excessive sums of money to save the property of irresponsible, wealthy people will escalate. Meanwhile, nourishment and beach scraping only delay the inevitable retreat from the shore. Why not end this type of sand mining and direct the money for use in a different kind of beach management, such as moving buildings back from the beach, while raising or demolishing others?

AFRICA SANDS

CH.09

Desert Abundance—Coastal Dearth

Africa is the prime example of the aggregate-sand paradox discussed in previous chapters. One-third of the continent is covered by desert. Keeping in mind that much of any given desert's floor may be bedrock, salt flats, or gravel cover, nevertheless, tremendous volumes of sand exist in dunes, flats, and valley fills. This sand abundance is found in at least nine recognized deserts in Africa (Safaris Africana 2020), including three of the world's largest: Sahara, 3.6 million square miles (9.2 million km^2) over twelve countries; Kalahari, 359,000 square miles (930,000 km^2) over three countries; the Karoo, 154,000 square miles (400,000 km^2) in South Africa; and six others, including the Namib that has the highest sand dunes at more than 980 feet (300 m) in relief. Portions of these deserts extend to the coasts of the Mediterranean Sea, the Atlantic, the Indian Ocean, and north along the Red Sea. But all of this sand is said to be unsuitable for concrete aggregate!

At the same time, Africa is on the economic rise, and construction of new buildings and roads is underway in many places, especially in coastal cities and tourist resorts. Ever more aggregate-quality sand is needed for this development, and coastal sand has that quality. So, in spite of all the desert sand, the mining of Africa's beaches and coastal dunes has become a big business. Like much of the world, African countries have very little effective regulation of such mining, and illegal mining is dominant in almost every country that borders an ocean or sea (figure 9.1). And, to repeat a pattern, sand mining in Africa's rivers is like that of other continents, cutting off vital sand supplies to coastal environments.

FIG 9.1 Africa's long coastline is crowded with many countries, each with differing approaches to coastal management and to beach-sand mining, in particular.

The governments of most countries in Africa recognize the value of beaches, if only because of their critical basis for tourism, yet only a few governments effectively support limiting beach and dune mining. Almost every African coastal nation seems at one time or another to have unsuccessfully outlawed sand mining.

One reason (besides corruption) for the widespread illegal sand mining in African countries is that mining is a major source of income for thousands of the poor and those otherwise unemployed. Often, mining is more lucrative than available, traditional employment. For example, some farmers have given up agricultural pursuits and turned to mining. So many of the miners are children that mining negatively affects their education at both the primary and secondary level (Taylor

2017). Mining also has strong negative effects on coastal ecosystems, including raising the rates of shoreline erosion, eliminating natural protection from storm surge (wide beaches, foredunes, mangroves), and in turn, accelerating the loss of attractions for the tourism industry.

Some African sand is exported to the rest of the world. For instance, Australian mining in South Africa is expanding in response to strong sand-mining regulations back home. In the north of Africa, in addition to its local use, Moroccan sand is exported, with about a billion dollars' worth of sand being shipped out of the country each year, much of it to Spain.

As noted in chapter 5, a significant portion of African sand mining also is carried out in rivers and has a negative impact on beaches by eventually reducing the sand supply to coasts. In addition, river mining increases the erosion of nearby riverbanks, causes damage to infrastructure, and especially threatens bridges (see chart 5.1).

The methods of beach- and dune-sand mining vary considerably. Top-of-the-line mining methods are often employed in Morocco, where front-end loaders scoop sand directly from the Atlantic coastal dunes and load it into waiting dump trucks. More commonly, as in Sierra Leone, lines of dump trucks on the beach are surrounded by three or four men with shovels who fill up the truck with sand (figure 9.2), shovelful by shovelful. In Zanzibar, workers, usually women, wade out and fill baskets with river, lagoon, or ocean sand and carry their loads ashore on their heads. In other regions, burros are used to carry sand, particularly when the slope at the back of the beach is steep. In several places in Morocco, burros with sacks of sand on their backs struggle up steep scarps to a flat surface where front-end loaders and trucks await the sand. In small, illegal operations, wheelbarrows are widely used, as are horse or donkey carts, to haul the loot.

African desert dune sand (not coastal dune sand), such as in the 3.6 million-square-mile (9.2 million km^2) Sahara Desert, the largest accumulation of sand in Africa by far, is rarely used for construction purposes. Desert sand is thought to be poor aggregate for concrete because the grains are too spherical. This shape reflects their long abrasion history due to grain collision during transport by wind. As stated in chapter 2, this widespread assumption that all desert sands are too spherical, and thus useless for concrete aggregate, is both unfounded and geologically unlikely. Desert sands have widely varying histories, and some are more spherical while others are more angular. What is sorely needed are field studies of desert sand grains — sand-shape prospecting if you will—to find desert sediments that meet aggregate criteria.

FIG 9.2 A long line of dump trucks in Sierra Leone being filled with dune sand. Sierra Leone, like many African countries, hopes to develop a tourist industry based on their beautiful beaches, an ambition that is not helped by beach- and dune-sand mining. Photo © Tommy Trenchard.

Politics plays many roles in African sand extraction. One unusual example where a mining controversy wasn't driven solely by economics or environmental concerns was the export of sand from Western Sahara. This disputed territory in northwestern Africa is partially controlled by Morocco. Coastal sand from Western Sahara went to replenish Mogan Beach (Playa de Mogán) in the Canary Islands. This replenishment project was not controversial because of the sand quality, the color, or grain shape but because the sale of the sand was thought to have aided Morocco in its opposition to the independence movement of the Saharawi Arab Democratic Republic that was seeking governance of Western Sahara. In the fall of 2020, the Trump administration gave US recognition to Morocco's claim on Western Sahara, apparently in return for Morocco's normalization of relations with Israel. Further conflict between Morocco and Western Sahara over sand resources is likely.

The following overview of beach and dune mining in Africa focuses first on three countries, each of which provides a somewhat different view of the mining activities and related problems. (1) Morocco probably mines the largest volume of beach and coastal dune sands compared to any other country in Africa. (2) In contrast, Mozambique illustrates the problem of controlling the mining activities of a contractor from a foreign country. (3) Sierra Leone, a country recovering from a vicious civil war, puts profits now ahead of long-term economic development on the coast by allowing or tolerating extensive beach-sand mining. The mining is destroying the specific resources needed to develop the tourism potential of their coast.

Following the discussion of these three countries, a brief summary of beach mining activities is presented for nineteen other coastal African countries. With such a survey, it becomes obvious that Africa remains a pot of gold, a sand supermarket for non-African countries such as China and Australia.

MINING MOROCCO

Morocco has a total ocean-shoreline length, including Western Sahara, of 2,945 miles (4,740 km) bordering both the Atlantic Ocean and the Mediterranean Sea. This country and territory form the northwestern corner of the African continent. Morocco is a parliamentary constitutional monarchy with a king (Mohammed VI), a prime minister, and no fewer than thirty-two political parties (can you imagine?). In 2015, the Parliament Littoral Act was passed, which prohibited mining of beaches and dunes, with a few exceptions.

Morocco has vast and large coastal sand dunes, especially along the lengthy Atlantic shoreline. Unfortunately, the amount of sand needed for construction in Morocco also is very large and is predicted to grow rapidly. In 2015, Morocco required forty-five million tons of sand per year. In 2020, the projection was that sixty million tons of sand would be needed. As a consequence, sand mining often removes dune sand all the way down to the bedrock. A conservative estimate is that half of the sand used in construction in Morocco was mined illegally, and that illegal mining of beach and dune sand costs the government $1.1 billion in unpaid taxes each year (Quérouil and Viguerie 2015).

Coastal sand mining in Morocco is widespread. Not surprisingly, a driving force is the proximity of the sand resources to construction demand — for the coastal towns, cities of rapid development, and inland construction. From north to south, these towns, each with nearby major beach or dune mines, include Tangier, Asilah, Larache, Mohammedia, Kenitra, Rabat, Casablanca, Safi, Essaouira, Agadir, and Dakhia.

One especially large market for Moroccan beach sand is Spain—particularly Spanish companies. An article by Abdelkader Abderrahmane (2021) notes that Moroccan sand is widely used for construction of hotels and restaurants in southern Spain. Unfortunately, the quantity of sand in transactions with Spanish companies is usually undeclared, adding to the difficulty in regulating any sort of control of beach mining and raising serious questions. For example, do these Spanish construction companies thoroughly wash the salty beach and dune sands they are using? If the Moroccan sand used for concrete is not carefully washed to remove salt, we might expect a tragic situation to occur, comparable to the collapsed condominium in Surfside, Florida.

The United Nations Environment Programme (UNEP) published a 2019 report entitled "Sand and Sustainabiity: Finding New Solutions for Environmental Governance of Global Sand Resources." This UN report may have been inspired by *Sand Wars*, the documentary film by Denis Delastrac, which in turn is based partly on research and publications from Coastal Care. Coastal Care and the documentary conclude that the insatiable demand for sand now poses "one of the major sustainability challenges of the 21st century" (UNEP 2019, 9), and meeting it will require improved control of the mining process by governments. The UNEP report uses Morocco as the special case study on sand mafias, drawing attention to the problem of illegal sand mining on Moroccan beaches. The report spotlights the shoreline between Safi and Essaouira, an airline distance of 63 miles (101 km), noting that illegal mining has "transformed some beaches into rocky landscapes" (UNEP 2019, 7; Eliason 2019).

Near Larache, Morocco, all dune and beach sand has been removed along a long stretch of shoreline to the south. Dunes as high as 200 feet (60 m) have disappeared here. Now a new sand-mining operation, undoubtedly illegal, continues with the removal of the remaining sand at and below the low-tide line. Young men, including boys as young as eleven, stand knee-deep in the ocean, shoveling sand into bags. These workers are on the job eight hours a day, six days a week, and many are skipping school in the process. Some have been drowned by strong wave activity during storms. The bags they fill are then loaded up on donkeys that carry the sand up the steep back-beach to temporary piles from which it will later be carried away by dump truck (Beiser 2018; Delestrac 2013).

Along this shoreline, where sand remains near Larache, bulldozers mine three days a week. According to a *VICE News* article entitled "Trucks and Children are Sucking the Beaches of Morocco Dry"

(Quérouil and Viguerie 2015), there are hundreds of trucks on this beach (Monday through Wednesday), each truck making up to three trips loaded with sand. On other days, entrepreneurs (actually looters) move in and mine the dunes, using the shovel-and-donkey technique. On nearby Monica Beach, near West Mohammedia, only a single coastal sand dune remains to afford minor storm protection.

Asilah, an important tourist community in Northern Morocco, is located 20 miles (32 km) by air north of Larache. Between 2012 and 2014, the construction of homes, hotels, and resorts reached a peak. At the same time, coincidentally, mining of the nearby beaches also reached a peak. What better way to lower the cost of concrete than to take sand from the beach only a few hundred meters away? It was possible to fill bags with sand, put the bags on carts, and wheel them to nearby construction sites. Again, previously unemployed young men were the main laborers. Of course, this process destroyed the very reason (the beach) the new homes and hotel were being built there.

By 2020, sand mining had slowed down considerably in Asilah, leaving behind a lot of exposed rocks and ruined beach. In addition, a number of beachfront buildings were left exposed to erosion because the protective dune was gone. In recent years, small-scale beach nourishment has been carried out on some Asilah beaches to help the tourist industry, but this is a temporary measure at best.

Between Agadir and Essaouira lies Imsouane, the famed surfing beach and the town of the same name. In 2017, *Forbes* called Imsouane Beach one of the world's most beautiful beaches (Bloom 2017). Two years later, Surfrider Foundation Maroc (2019) published a video showing bulldozers mining sand on the beach. Until then, Surfrider said this beach had been spared from "plundering operations," widespread on other beaches. The National Ports Agency (ANP) denied the mining operation existed, saying that what was going on was sand removal designed to clear access to the port and to improve working conditions for fishers.

But the Surfrider video tells the real story. The ANP was being deceptive. The Surfrider's international organization had once again stepped in to preserve a beautiful beach — one that attracts as many as a hundred thousand surfers and other tourists each year. The fact that a government agency, the ANP, is in cahoots with the miners is discouraging. But the success of the Moroccan Surfrider chapter, founded in 2010, bodes well for the future of Morocco's beaches.

Just like beach- and dune-sand mining itself, the quality of much of the construction that required the sand to make concrete was un-regulated by the government. One view is that the lax regulation by the government is in some way related to an attitude generated by the Arab Spring, inspired by Mohamed Bouazizi, the Tunisian street vendor who set himself afire in 2011.

Abdou Khouakhi, a Moroccan oceanographer quoted by Matthew Greene (2016), notes, “It is important to look at beaches as part of a wider ecosystem that offers a valuable environment and habitat for many species of fauna and flora. The possible consequences of sand mining are not confined to shores, but may spread to estuaries and other habitats such as dunes and marshes that have significant relationships to the ocean.”

Unless the sand mining is finally regulated by the Moroccan government, the future will include gradual loss of more and more beaches, less and less protection for buildings, and an impaired tourist industry that depends on the beach. All of this as the seas rise and storms intensify.

SAND MINING AND THE FATE OF NAGONHA, MOZAMBIQUE

Mozambique, a former Portuguese colony in southeastern Africa, lies between South Africa and Tanzania. The country is slightly less than twice the size of California. Large portions of its 1,535-mile-long (2,470 km) shoreline on the Indian Ocean are lined with wide beaches and dune fields, and 115 beautiful sandy barrier islands line 563 miles (906 km) of the coast. The Zambezi and Limpopo rivers are the main sources of beach sand. Ilmenite, a source of titanium, and monazite, a source of tantalum (a rare-earth element), are considered to be major natural resources of the country, and both are obtained by coastal sand mining.

The mining of coastal dune sand in northern Mozambique is a clear example of the damage that heavy-mineral mining can do to natural coastal processes, affecting the lives and livelihoods of local people. This is especially true where there is a combination of a corrupt, or at least uncaring, government and an irresponsible foreign mining company (often greasing the skids with favors to the authorities in the host country).

Haiyu Mozambique Mining Co., Lda, a Chinese firm, mined the coastal sand dunes in Mozambique’s Nampula Province about 2 miles (3.2 km) north of the small fishing village of Nagonha. The village with a population of 1,300, housed in 236 huts, was perched atop the large coastal dune field with a clear and beautiful view of the Indian Ocean. The minerals sought by the mining company were mainly ilmenite ($FeTiO_3$ — source of titanium) and zircon ($ZrSiO_4$ — source of zirconium). These minerals are contained in the heavy-mineral or black-sand fraction of the dune sand, usually constituting less than 5–10 percent of the sand (Carvalho et al. 2014; Goswami 2018).

The company claimed to have obtained a concession for the purpose of mining not construction sand but heavy minerals. Amnesty International (2018) found that the company failed "to fulfil legal requirements for acquisition of *the right to land use and development* (DUAT)" and failed to conduct the required environmental impact assessment (11). No pre-mining environmental plan or controlled sand-disposal program had been developed, setting up the tragedy that followed.

As so often happens with no government oversight, profit prevailed as the driving force of the mining operation. The cheapest way to dispose of unwanted "waste" sand after removal of the desired ore minerals was to dump it onto and into the adjacent wetlands and channels that connected the lagoons to the sea, without regard for the environment, the fishing culture, or the safety of the local population.

On Saturday morning, February 7, 2015, after a very heavy rainfall, a flash flood rammed across the dunes forming a new cross-dune channel that extended right through the village! The flood washed 48 houses out to sea and damaged 173 other homes. About 290 people were left homeless. Village elders said that such a flood had never occurred before.

A two-year investigation by Amnesty International (2018) found that the flood event was entirely caused by the company's practice of dumping waste sand behind the dune and altering local drainage patterns. This waste fill reduced the ability of the marshes to hold floodwaters and, more significantly, blocked the two natural channels (inlets) that occasionally drained floodwaters flowing from behind the dune ridge to the sea. This destroyed the wetlands once used as a water source for villagers and livestock and as a source of food and medicinal plants. The healthy environment that local people once enjoyed was lost, sealing the fate of Nagonha.

Satellite images indicated that 335,000 square yards (280,000 m^2) of wetland, north of the village, had been destroyed by the sand cover. With the usual drainage blocked, the formation of a new channel and the resulting destruction of the village became a certainty. Clearly the sand from which the heavy minerals had been separated should have been used to reconstitute the source dunes that were destroyed by the mining operation, and the wetlands should have been protected rather than used for the waste dump.

Haiyu has denied responsibility for the disaster, and they initially refused to compensate for the damage they had caused to Nagonha (*Africa Times* 2018). Backing the company, the Chinese Foreign Ministry said that Amnesty International's observations are "irresponsible remarks targeting China" and have "not the slightest credibility to speak of" (Goswami 2018). The flood that destroyed the village was simply an act of Nature.

However, in April 2015, the company proposed to pay US$90 to each household that was missing a house, plus US$400 to repair the local mosque (Goswami 2018). This pittance was considered to be a very inadequate offer. Amnesty International noted that the 2015 flood should have been the catalyst for regulatory action by the government, but no such action has occurred. Perhaps better rules would not have mattered as Amnesty found that the company had failed even to follow existing domestic law to which it had agreed. "This is a classic case that highlights the struggles that poor communities face when big corporates ride rough shod over their rights and governments fail in their duty to protect the most vulnerable," said Deprose Muchena, Amnesty International's Regional Director for Southern Africa (AT Editor 2018). Unfortunately, his statement is true, and Nagonha-type losses will be repeated again and again unless the international community speaks out against irresponsible mining practices.

There may, however, be a light at the end of the tunnel for beach- and dune-sand mining in Africa. Management of mining activities can be done correctly, as has been shown on the Zululand Coast in South Africa, where dune mining for minerals is handled more responsibly. There, after removal of the heavy minerals, the tailings are replaced on the dune and molded back to the approximate original dune shape. Next, a soil cover is spread on the dune surface, which is then revegetated. This is a model for what should have been done in Nagonha.

TINY SIERRA LEONE, A VICTIM OF WAR

Sierra Leone is a tiny country, with only 30 miles (48 km) of Atlantic coastline. Famous for its diamond mining, it is squeezed between Liberia to the south and Guinea to the north. It has spectacular coastal landscapes with coconut palms and rain forest coming down to the beaches.

Sierra Leone also has perhaps the most serious and damaging beach-sand mining activity in Africa. For example, on Hamilton Beach, 5 miles (8.5 km) from the capital, Freetown, up to twenty trucks can be seen lined up and being loaded (by shovels) with sand. Often Sierra Leone mining involves making concrete blocks right on the beach.

Ironically, the intense mining of beaches started with the end of the civil war that began in 1991 and ended in 2002 (Kanu 2013). The war was a spillover from adjacent Liberia and was led by American-educated Charles Taylor's National Patriotic Front of Liberia. Taylor's group furnished arms to the Revolutionary United Front rebel army that confronted the Sierra Leone Armed Forces in the civil war. Ultimately, more than fifty thousand people died, and half a million were displaced in this tiny country. Property damage was extreme, and the postwar rebuilding effort led to the intense beach-sand mining activity that has characterized the country ever since.

The old part of the town of Grand-Lahou and the lighthouse there were destroyed by erosion. The town was relocated 10 miles (16 km) inland, a good example of managed retreat. Serious property damage directly due to the mining has occurred in the village of Lakka, where numerous buildings, or their ruins, are found on the beach. Ironically, the remains of the destroyed buildings now act as a crude, irregular seawall, slowing down the erosional retreat of the beach (figure 9.3). The villages of Tokeh, Lumley, and Aberdeen are also threatened by erosion due to mining.

The village of Bureh Town used to be the beach of choice for Freetown residents, but no more—because of the mining. There was hope for John Obey Beach and the nearby village as tourist destinations, but mining and the noise of trucks have also diminished their future prospects. An orphanage run by nonprofit OrphFund was moved back from the beach because of shoreline erosion. Kollehh Bangura, head of the country's EPA, characterized sand mining as a calamity for the nation's much-needed tourism industry. Yet mining continues.

SAND MINING IN OTHER COASTAL AFRICAN COUNTRIES

NORTH AFRICA

Egypt, Libya, Tunisia, Algeria, Morocco, and Western Sahara make up what is considered to be North Africa. Relatively small amounts of beach mining have been going on in Egypt and Tunisia, although Nile Delta beach sands have a potential trove of valuable minerals, in-

FIG 9.3 The remnants of the town of Grand-Lahou near the Lakka Beach Resort in Sierra Leone. The erosion here has been caused almost entirely by nearby mining activities, which started in 2013. The destroyed buildings act as a seawall, slowing down erosion. Grand-Lahou was moved 10 miles (16 km) inland—an example of managed retreat. Photo © Tommy Trenchard.

cluding ilmenite, magnetite, zircon, rutile, garnet, and monazite. Algeria has large beach-sand operations under the control of a strong sand mafia. The mining is primarily in the eastern coastal region of El Taref, around Skikda, near the Tunisian border, and in the northeastern coastal region of Jijel. In 2019, the Algerian National Gendarmerie carried out thirty-four operations against illegal sand miners, compared to eighteen cases in 2018. In the 2019 raids, a lot of equipment was seized, including thirty-four trucks, three vehicles, one tractor, one back-loader, two donkeys, and twelve motorcycles. Twelve sand miners were arrested, seven of whom were imprisoned. In Western Sahara, the politics of sand mining remain uncertain. A Spanish mining company is accused of illegally mining beach sand in Laâyoune. The mining situation in Morocco has been described earlier in this chapter.

WEST AFRICA

West Africa starts with Mauritania to the north and ends with South Africa at the southern end. Between these geographic extremes are eighteen countries with shoreline lengths ranging from 49 miles (79 km) in Gambia and 35 miles (56 km) in Togo to 975 miles (1,569 km) in Namibia to 1,770 miles (2,849 km) in South Africa. As in virtually all African countries with a shoreline, illegal mining is widespread.

In Senegal, the government plans to build a 2.2-mile-long (3.5 km) concrete wall to prevent access to the beach by sand trucks. North of Dakar, a combined French and Australian company had a contract in 2020 to begin mining dune sands for heavy minerals (ilmenite, rutile, and zircon). This operation will need to be done responsibly, if at all, and the remaining sand will need to be placed back on the dune. The government in tiny Gambia has outlawed mining, but operations continue with foreign companies in an atmosphere of corruption. The illegal mining, mostly for minerals, endangers the villages of Kartung, Batukunku, and Sanyang. As in Mozambique, the companies have failed to restore or repair mining sites. On Santiago Island in the Cape Verde Islands, the locals have found a way to prevent sand stealing. The military stands guard over the mineral-rich black sand near the city of Pedra Badejo.

Shoreline erosion in Liberia is rampant, mostly because of mining activities that are largely illegal, including some by a Chinese company. The highly damaging civil war in Liberia, just as in Sierra Leone, has created a great need for aggregate sand for the repair of war-damaged buildings and new construction. In Ghana, the pattern is to mine sand for use in construction at the expense of coastal dunes and beaches and then to build seawalls, even though such structures are known to cause additional beach losses. The end point is complete loss of beaches, and tourists will go elsewhere. The Ghanaian government is planning to build a 19-mile-long (over 30 km) seawall in the vicinity of Ada Foahto to protect the buildings. A 2011 Togo law prohibited all sand mining—but to no avail. Severe erosion, often related to beach mining, has damaged or destroyed several villages. Some families place magic talismans outside their homes facing the sea to ward off erosion.

Widespread mining, accompanied by natural erosion, caused the 2002 collapse of the Palm Hotel in the city of Cotonou, Benin's largest city. A BBC report claimed that taking sand from the beaches is, in effect, digging the city's (Cotonou) grave (Okanla 2015). Probably in spite of all factors involved, illegal sand mining is the most damaging cause of the degradation of Benin's beaches. Hundreds of small boats ply the waters of Lagos Lagoon in Nigeria, next door to Benin each of these boats is filled up with buckets of sand supplied by divers (figure 9.4). Some concrete blocks are made on the beach, using fresh (and salty) sand. Lekki, a town east of Lagos, once a popular tourist destina-

FIG 9.4
A sand miner in Nigeria carrying sand ashore from a boat filled with sand brought up by divers. Diving to mine sand from river bottoms is a dangerous mining technique that has resulted in a number of drownings. Photo © Robin Hammond—Panos Pictures.

tion, is close to abandonment because of erosion that is partly related to mining. Offshore sand is often contaminated by oil spills.

Most sand mining in Namibia is from rivers and is illegal. However, extensive legal diamond mining on beaches (where lions roam and feast on dead whales) is causing beach destruction without beach reconstruction in these very remote areas (figure 9.5). Diamonds here are said to be larger and of higher quality than most coming from South African diamond mines.

South Africa has the continent's most modern economy and development, and its coast transitions from the Atlantic Ocean in the west to the Indian Ocean in the east. The large coastal dunes along the South African east coast, not unlike the huge dunes of Morocco, are prime mining targets in a number of locations, both for mineral sand and construction (concrete) sand (figure 9.6). River-sand mining near Durban on South Africa's east coast is clearly responsible for a decrease in sand reaching the shore, resulting in more than three feet per year (just under one meter) of erosional beach retreat and the expected eventual loss of the city's tourist beach. In South Africa's Wild Coast Region of the KwaZulu-Natal and Eastern Cape, extensive beach-sand mining (more than two hundred illegal mining operations) is taking place in the vicinity of Coffee Bay and Port St. Johns. Two Australian mining com-

FIG 9.5 This satellite image shows coastal diamond mining operations located in southwest Namibia near Oranjemund and the mouth of the Orange River. The dark patches are water-filled holes excavated to obtain the diamond-bearing sand. Clearly, the sand is not being replaced in the beach and dunes after removal of the diamonds. No tourist industry is present on this very remote and heavily guarded beach. Photo courtesy of NOAA.

panies have been accused of doing serious damage with their beach-mining operations.

EAST AFRICA

East Africa begins with the east-facing portion of South Africa and ends with the east-facing shoreline of Egypt, between which are eight countries ranging from tiny Djibouti to Mozambique which has the largest ocean-facing shoreline of 1,616 miles (2,600 km). Mozambique beach- and dune-sand mining, which is at a relatively small scale, is discussed earlier in the chapter.

FIG 9.6 A large, mechanized dune-sand mining operation at Strand, near Cape Town, on the west coast of South Africa. The white sand dunes shown here were once the size of the large dunes on the Atlantic coast of Morocco. Much of South Africa's mining of beaches is illegal, just like in so much of Africa (and a lot of other places). Photo © Denis Delestrac.

Three million tons of beach sand (120,000 full truckloads) were mined between 2005 and 2015 on Zanzibar Island, a possession of Tanzania. But according to a government source, possibly twice that amount was mined "off the books" in small-scale operations (Fröhlich 2017). Kenya has beautiful beaches with potential for great tourism. South Coast residents successfully halted a proposed beach-mining project by a Chinese company to continue mining where they already had destroyed reefs; but elsewhere, 1.5 million cubic yards (800,000 m^3) of sand are mined annually near tourist beaches. Kenya's impoverished youth often mine beaches in a dangerous way, and according to a study in *Journal of Education and Practice*, employment of children as miners, a quick way for poor kids to earn money, has a strong negative effect on the quality of education at all levels (Taylor 2017). Ethiopia is a landlocked country, but sand mining in Lake Tana (the source of the Blue Nile) has major negative impacts on biodiversity and the local fisheries. Ethiopia's neighbors, Somalia, Djibouti, and Eritrea, make up the Horn of Africa coast, from the Indian Ocean to the Gulf of Aden and the Red Sea, with some significant stretches of beaches. However, given the long history of political unrest, limited tourism development, and lack of coastal access, little information regarding coastal sand mining is available for these countries.

AFRICAN SANDS' FUTURE

Africa is booming on many fronts. On the basis of current projections, the continent's current population is expected to grow from 1.2 billion to 2.5 billion by the middle of the twenty-first century. There are many ramifications, both global and local, for such population growth, but one outcome will be a massive construction effort. And a massive construction effort will lead to a greatly increased need for sand for concrete. Very likely the current trend of mining coastal sands and feeder rivers will continue with potentially extreme negative impacts in terms of the damage caused to beaches, dunes, and nearshore ecosystems, including increased rates of shoreline erosion, degradation of beach quality, and destruction of the currently expanding tourist industry. In addition, the role of beaches and dunes in protecting coastal infrastructure and development will be diminished at a time of sea level rise and intensified storms. There could not be a worse time to mine beaches and dunes.

It seems that every African country bordering the coast has at one time or another outlawed or restricted beach- or dune-sand mining. It also seems that prohibition of mining has never worked and that much of African beach mining is and will continue to be illegal.

Time is of the essence for African countries to take control of their shorelines. But the way forward is a difficult one because beach and coastal dune sand is cheap, many poor people depend on mining it for a living, poor countries need revenue, and political corruption isn't likely to fade away.

Ironically, Africa has a superabundance of sand in its deserts, although most of these sand resources aren't close to the coasts. In part, the problem that desert sand is assumed to be too spherical, and therefore unsuited for concrete aggregate, adds to desert sand being underutilized.

For the sake of Africa and the rest of the world, an economically feasible aggregate substitute for natural sand is desperately needed.

Finally, it seems that young activists of Africa are beginning to be heard, finding both regional and international audiences receptive to their concerns about environmental damage by mining of all kinds as well as about health care and government corruption. In 2019, the Swedish Environmental Protection Agency, the United Nations, and the Kenyan Environment Management Authority participated in training activities related to sustainable natural resources. The African Youth Initiative on Climate Change is also raising awareness of various environmental issues, some related to mining; and the Young Environmental Journalists organization is publicizing their youth activities.

Perhaps there is a light at the end of the tunnel.

BEACH MINING

CH.10

Truths and Solutions

"Don't turn your back on the beach" is a warning to tourists arriving in Hawaii, a simple phrase that summarizes the danger from rogue waves, known to the locals, which catch the unknowing or the careless. We've known some of the victims who were lucky enough to wind up with only mouths, ears, and eyes full of sand, and the loss of an expensive camera or two. A lot of life's lessons are summarized by simple folk expressions, and one can create one's own list of *Truths of the Shoreline* with respect to beach processes and human interactions with the beach (Pilkey et al. 1980).

We did just that some years ago when we developed a set of truths with respect to coastal engineering (e.g., emplacement of seawalls, groins, beach nourishment, and other means of holding a shoreline still). These truths are worth repeating here because they also relate to impacts from mining sand dunes and beaches, as well as mining to replenish beaches:

- There is no erosion problem until there is something there to be affected by erosion (i.e., buildings, infrastructure).
- Beachfront construction often is a cause of shoreline erosion.
- Shoreline engineering protects the interests of a very few, often at a very high cost in federal and state dollars.
- Shoreline engineering at times destroys the beach it was intended to save.
- The long-term cost of saving beach property through shoreline engineering is usually greater than the value of the property to be saved.

- Once you begin shoreline engineering, you can't stop it! (This last is what is commonly known as "Throwing good money after bad.")

TRUTHS OF MINING BEACHES AND DUNES

The foregoing chapters can be summarized in terms of a similar set of truths, each related to mining beaches and dunes as well as to mining riverbeds, inlets, tidal deltas, river deltas, estuaries, lagoons, tidal flats, and the continental shelf. These truths include the following:

- The global shortage of sand for use in construction (concrete) and other purposes is real and growing.
- Mining beach and dune sands adds to natural shoreline erosion and is in itself a form of erosion.
- Beach and dune sand grains are usually the correct shape, size, and sorting to make good concrete aggregate.
- Globally, widespread desert sand is assumed to be too spherical for use in concrete aggregate—an assumption in need of verification.
- Beach and dune sand can usually be mined at low cost and is typically located a short transport distance from the construction site of development attracted by the beach.
- Destroying beaches and dunes for coastal construction removes the very protection the development will need from intensifying storms and sea level rise.
- Beach and dune mining is a disaster for the tourist industry as well as for the ecosystem.
- Globally, most beach and dune mining is done in opposition to local opinion and laws.
- Illegal beach and dune mining creates an atmosphere of corruption in many coastal societies.
- Beach and dune mining has been the basis for the formation of violence-prone sand mafias, who defend illegal sand mining.
- The river sand feeds the beach. Downstream sand flow is as important as water flow and should be protected (see appendix B).
- A great need exists both for an artificial substitute for sand and for methods of construction that use less concrete.

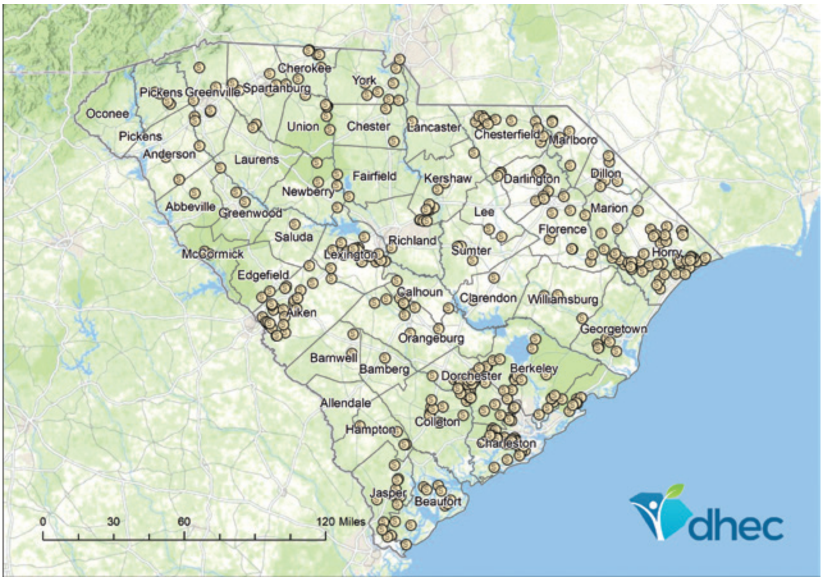

FIG 10.1 A map showing the distribution of registered sand mines in inland South Carolina. The point is that there are many possible sources of sand, but beach sand is preferred because it is easy to mine and often free. Map courtesy of the South Carolina Department of Health and Environmental Control.

ARE WE THERE YET?

Not in the United States or anywhere else. Recognizing the truths is only a very small, initial step toward solutions to maintaining the natural state of our shorelines. The United States is making progress but has not reached the goal line yet.

In many countries, there are large numbers of sand mines in the interior, even on coastal plains and rivers. Figure 10.1 is a map of South Carolina, showing the location of hundreds of licensed sand mines throughout the state. Much of this sand is found in old shoreline deposits (former barrier islands) formed at a time of higher sea levels during the Ice Ages. Presumably, coastal plains in other states have a similar distribution of local sand mines. So, why aren't these mines the sole sources of sand for construction in the state? The problem probably lies in variable sand quality, cost of extraction, and royalties to property owners. Beach mining, especially if it is illegal, provides high-quality sand in abundance and can be mined relatively cheaply.

Besides the large amounts of sand mined for beach nourishment, beach-sand mining in the United States is typified by local exceptions,

FIGS 10.2A & B Examples of illegal extraction of beach and dune sand in the United States.

FIG 10.2A After everybody was ordered to evacuate Surfside Beach, South Carolina, a barrier island, as Hurricane Matthew was approaching in 2016, the shady characters under the Surfside Pier began to mine sand. Photo © Kerry Pilkey.

FIG 10.2B The surreptitious miners managed to get a pickup truck full of illegal sand in white bags before leaving the scene and perhaps leaving the pier a little less stable. This is one version of a common form of small-scale illegal beach mining in the United States. Small scales become large scales over time. Photo © Kerry Pilkey.

such as stealing sand from under a pier in South Carolina when nobody is around; cutting a large notch in a gravel beach bar in Maine; mining Puerto Rico's dunes, where all such mining is illegal; and leaving holes in the sand the size of dump truck–loads, visible at the high-tide line on some beaches in Hawaii (figures 10.2A and 10.2B).

The United States doesn't have any beach mining sites like those in Morocco, where two hundred dump truck–loads of sand per day are mined. We aren't stealing sand from the beaches of other countries like Singapore has done, but we are contemplating getting sand (legally) from the Bahamas to bolster Florida's eroding beaches. However, undocumented mining at a bucket, wheelbarrow, or pickup-load scale is probably more widespread in the United States than is realized.

Globally, a high proportion of beach sand mines are illegal. Either people are mining where it is forbidden to mine, or they are mining larger volumes of sand than they were permitted. The illegality of beach mining is a major cause of governmental corruption. This widespread criminal activity has given rise to what are known as sand mafias that defend, sometimes with violence, their sand mines. As we described in chapter 4, sand mafias in India are particularly violent and are responsible for killing many, including policemen, environmental activists, and property owners (see appendix A).

Early warnings about the global crisis facing beaches have been sounded by the Santa Aguila Foundation in its support of the widely circulated *Sand Wars* (2013) documentary and the website CoastalCare.org, which hosts a treasure trove of beach-mining research and global media reports. Vince Beiser's book, *The World in a Grain* (2018), plus several United Nations reports have clearly documented the shoreline crisis created by sand mining (e.g., UNEP 2019; UNEP 2022).

The global rush to the coast for large quantities of sand has been evident for roughly two or three decades, and the pressure to mine coastal sand is bound to increase if for no other reason than the growth of the world's population. But there are many other reasons why more sand for concrete will be needed. The expected increase in storm intensity, which is clearly underway now, will devastate many communities that will require major rebuilding efforts. The destruction resulting from the combined effects of storms and sea level rise will be even greater, and perhaps millions of climate refugees will be moving to new and higher ground by mid-century. In response to the sea level rise alone, more than four million people are expected to flee Miami and South Florida in this century.

The United States can expect a flood of refugees from Central America, and Europe can expect the same from Africa. Where will many of the 35 million people in Bangladesh's coastal zone relocate to when the area is inundated by the sea? Countless numbers of refugees will flee Sub-Saharan Africa because the region will be too hot for them to survive. All over the world, climate-change refugees will need lots of concrete and lots of sand for their new homes.

There is a desperate, global need to find sand substitutes, to look for new sources of sand, and to research the grain-sphericity assumption for all desert sands. The immediate need is also to encourage building designs that require less concrete. At the same time, public awareness of the sand-mining problems needs to be significantly increased, and stiff enforcement of beach-mining regulations needs to be encouraged (figures 10.3A and 10.3B).

Examples of sand substitutes are crushed rock and crushed concrete (recycling), obvious possibilities which now are being done on a small scale in many places. We remember well our surprise in coming

FIGS 10.3A & B Anti-sand-mining support can be shown at in-person gatherings or by spreading the word on wearing apparel—as with this protester's T-shirt.

FIG 10.3A About twelve thousand people gathered in France to participate in a Save the Beach demonstration on the beach of Kerhillio near Erdeven that was under threat from sea-sand miners. The sand extraction project was finally shut down after four years. Opposition to sand mining is international. Photo © Denis Delestrac.

FIG 10.3B In Ecuador, opposition to beach-sand mining may be expressed on clothing. This protester's T-shirt says, "Salvemos Playa Negra, Fuera Minería de Mompiche, Refugio de Vida Silvestre Manglares del Estuario Río Muisne" (Save Playa Negra, Out Mining Activities from Mompiche, The Muisne River Estuary Mangrove Wildlife Refuge). Stop the Mining Activities! Photo courtesy of La Casa Mompiche.

across a sand-producing, rock-crushing operation on a volcanic mountain top on the Caribbean Island of St. Lucia—an inspired way to fill a local need.

There are other available sources of sand besides beaches that could be utilized, most of which are far from construction sites (which is why they are available). One of these is Greenland, where melting ice leaves behind huge bodies of sand. The sand mined in remote places like Greenland might be competitive in cost with some government financial support, which could be justified as a way to relieve mining pressure on beaches, dunes, and rivers. But the certain detrimental impact on Greenland's environment should be considered (Bendixen et al. 2019).

Only 5 percent of the world's sand is currently suitable for use in concrete. The largest volumes of unconsolidated sand on the Earth's surface are found in deserts, sand which is not sought by miners because it is assumed to be too spherical to create strong concrete (see chapter 2). But the assumption that sand-grain shape in deserts is globally uniform seems to us to be geologically unlikely. A global investigation and inventory of variations in the character of desert sands is needed to test the assumption. Perhaps consider this: Can spherical desert sand be made more angular by crushing? Or can it be made useful for construction by a process of physical segregation of angular and spherical grains?

Unfortunately, we must edit the old saying of *Give a man a fish, he will eat today, but teach a man to fish, and he will eat forever* to *Teach a man to mine, and he'll dig until the river, dune, or beach is gone, but teach a man to conserve, and he will enjoy the beaches, dunes, and rivers for a lifetime.*

CAN WE SAVE OUR SAND?

When considering how to solve global beach problems associated with sand mining, retaining one's optimism is difficult. The best solution of all, of course, is to halt all large-scale mining of beaches and dunes, which is the present situation in the United States (see chapter 8). Elsewhere, legislative solutions to controlling sand-mining enterprises vary by country, but there is a widespread lack of will, often amplified by corruption, when it comes to enforcing regulations and good management practices.

The ultimate method may be for governments (national, state, local) to buy coastal and riparian lands to create management units or park lands. The United States has a start in its establishment of National Seashores and National Lakeshores. At the state level, several states have done well in establishing and expanding state parks (e.g., New Jersey's Island Beach State Park; Florida's state parks; and the Great Lakes' state parks in Indiana and Michigan; and Provincial Parks in Ontario, Canada). Similarly, there are efforts for counties or combined local government units to acquire properties along shorelines and rivers to provide greenbelts, thus reducing losses from flooding, and presumably keeping these areas in a natural state, that is, free from sand mining (figure 10.4)

Sand Rights should be recognized as a possible approach to reduce the damage resulting from beach and dune mining, a concept outlined in detail in appendix B. This idea holds that the sand of a beach is like the

FIG 10.4 Lighthouse on Long Island, New York, on top of a rapidly eroding bluff that supplies sediment to local beaches. Eventually, in order to save it, the lighthouse may have to be moved back like the Cape Hatteras lighthouse in North Carolina was. Photo © Miles Hayes.

air, water, and the beach itself. First put forward in 1988, "Sand Rights was designed to protect the shores of the Sea" (Stone and Kaufman 1988). The point is that the sand supply to the beach should be legally protected, just as the water in rivers or the air we breathe. We believe that fully implemented Sand Rights would largely solve the problem of illegal beach-sand mining wherever applied.

In Africa, where illegal beach-sand mining seems the rule rather than the exception, some countries like Ghana and Senegal (see chapter 9) are building seawalls, not to stop erosion but to stop the truck traffic needed for mining operations.

In Britain, the National Trust for Places of Historic Interest and Natural Beauty, an independent charity for environmental and heritage conservation, has acquired long stretches of coasts in England, Wales, and Northern Ireland. Private land conservancies can acquire lands and establish management units. The Nature Conservancy's Virginia Coastal Reserve, consisting of a chain of fourteen barrier islands, is an outstanding example from the United States. And there are many organizations, such as the Surfrider Foundation, taking on local communities or government agencies that seek to use hard engineering to hold shoreline reaches in place.

The Surfrider environmental organization is a large group concerned with preserving beaches and prohibiting mining. Surfrider has international clout, as was illustrated by its saving Imsouane surfing beach from sand miners in Morocco (see chapter 9).

One example that achieved much notice in Europe was a golf links owned by Trump International Golf Links (TIGL, a Donald Trump enterprise) in Ireland. The Trump Organization proposed building a long seawall to protect the eroding bluff at the edge of the course. The links were originally built in a dune field at the back of the beach — not the wisest spot in which to expect stability from wind, waves, and runoff. The long-wall proposal was defeated, although the local government did allow a much shorter structure. This example is just one of many where moneyed organizations overwhelm local governments that do not have the capital to prevail over expensive court challenges. In this case, it was the international surfers' organizations that tried to protect one of the best surfing areas and beaches in southwest Ireland through legal battle. How can the world's beaches, dunes, and rivers be protected from sand mining when leaders turn a blind eye to the law?

GLOBAL BEACHES: TO BE OR NOT TO BE?

Coastal sand exploitation is rapidly spreading in this time of sea level rise and intensifying storms. Such mining is slowly destroying the protective nature and touristic value of beaches on a global scale. Ultimately, the solutions must be the development and proliferation of an inexpensive substitute for sand to be used in concrete as discussed in chapter 2, an end to coastal sand mining, and a systematic move landward as the sea rises. Here's hoping that some wisdom will prevail.

SAND MINING VIOLENT EVENTS

APPENDIX A

CHINA

sand mining gang members	attacked each other with knives

INDIA

Subedar Singh Kushwaha	run over by a tractor trolley
R. Venkatesan	killed; run over by sand-laden lorry
B Mohan in Tamil Nadu	drowned and beaten with iron rods
an Administrative Service officer	hanged
journalist	burned alive
woman in Bengaluru	hand chopped off with swords
young farmer in Rajasthan	run over with an excavator
revenue officers	blatant murders; some by sand lorries
Paleram Chauhan	shot and killed in his bed
Sumaira Abdulali	beaten; hospitalized; survived; continues her activism
Sandeep Sharma	killed (run over by a truck)
Jagadeesan, police officer	killed (run over by a truck)
Navin Nischal and Vijay Singh	on motorbikes hit by SUVs; both killed
Sandeep Kumar & Neeraj Bali	beaten with sticks and gun butt (Punjab region)
Pratap Patra in Odisha	attacked with machete and/or other sharp object
an anti–sand mining activist	hacked to death in Ilayanur village
eighty-one-year-old teacher	hacked to death

AFRICA

XOLOBENI VILLAGE, PONDOLAND, EASTERN CAPE PROVINCE, SOUTH AFRICA

a Xolobeni family	attacked
Mandoda Ndovela	shot dead

Scorpion Dimane	died, probably of poisoning
sixty-one-year-old woman	stabbed
two journalists	attacked

MDATYA VILLAGE, PONDOLAND

anti-mining villagers	three injured: bones broken, one had head gashed open
Sikhosiphi Rhadebe	assassinated - shot dead

GAMBIA

two people	death due to sand-mining disputes
police officers and others	injuries, some severe

KENYA

two truck drivers	burned beyond recognition
one truck driver	shot with arrows
nine people	killed
dozens more	injured

INDONESIA

EAST JAVA

Salim Kancil	battered and stabbed to death
Tosan	attacked and run over with motorcycle

MEXICO

José Luis Álvarez Flores	murdered (shot)

SAND RIGHTS: BRINGING BACK REASON

APPENDIX B

Ultimately, legislation is the key to solving problems that arise with beach- and river-sand mining. But no accepted, unifying principle has been adopted with respect to looking at sand as a flowing resource. The use of water is tightly controlled but not so for sand. For many years, geologists viewed the beach as a river of sand, and in the 1980s this river principle was applied to the management of sand on beaches. This became the basis of a movement known as Sand Rights. The idea behind Sand Rights came from the late, great coastal engineer Orville T. Magoon, who championed the concept to the coastal engineering and science community.

Although the movement has fallen on hard times, the principles behind it remain widely understood. The time is right to once again bring that concept back to the attention of the stewards of our beaches and dunes—legislators, managers, responsible developers, property owners, and the taxpayers. It is a particularly useful concept when applied to sand mining.

As early as Justinian the Great (reign 527–565 AD), cultures have understood that certain natural resources are incapable of private ownership: "By the law of nature these things are common to mankind—the air, running water, the sea and consequently the shores of the sea" (*Encyclopedia of Coastal Science*, 820).

The need for a legal basis of Sand Rights originated in the 1980s with Katherine Stone, a California lawyer, who became involved with the proliferating lawsuits over issues such as accelerated beach loss, seawall problems, and coastal property loss, or the threat of such, that resulted from the cutoff of the beach sediment supply (Stone and Kaufman 1988). Cornelia Dean (1999) provided an excellent summary of Stone's activities, various related lawsuits, and the underlying legal basis for Sand Rights going back to the Roman emperor Justinian (quoted above), the Magna Carta, English law, and the principle of the Public Trust Doctrine from the US Constitution.

Dean quotes Stone's explanation that the principle of Sand Rights as applied to beach sand "encompasses the movement of sand throughout the greater littoral cell, which is basically the watershed that feeds all the beaches—combining physical laws and laws of society" (196).

Katherine Stone (2000) lays out a history of modern cases from the federal and state supreme courts down through lower courts. This document supports the Sand Rights concept, explains why it should be covered by the Public Trust Doctrine, and details how it could be integrated into the legal system.

Simply put, the sand of a beach is like air, water, and the beach itself (part of several environments that make up tidal lands under the Public Trust Doctrine). The sand supply to those environments should be protected, just as the waters in rivers or the air we breathe. A good analogy is from a city that was drawing on the stream waters that fed a lake where fishing rights were protected. When the lake level fell and the fishing resource was being destroyed, the city was forced in a legal case to lower its withdrawals from the stream and restore the lake to its former level. When a jetty, groin field, seawall, river dam, or sand-mining operation cuts off the sand supply to a beach, the resulting beach loss is also loss of protected public domain. The requirement should be for the miner, dam owner, or shore-hardening operator to replace the lost sand volume or provide financial compensation for resulting damage. Or as stated by Stone et al. (2005), "The basis doctrine is that human actions will not interfere, diminish, modify, or impede sand and other sediments from being transported to and along rivers, beaches, shores, or any flowing or windblown paths or bodies without proper restitution. Under this doctrine, projects should be designed or reevaluated to mitigate any interference that the project may have with sand transport" (1466).

Stone et al. (2005) laid out the Sand Rights principles to the legal and management communities as well as to the coastal science and engineering communities, but no movement on the legal front has occurred to include Sand Rights into the Public Trust Doctrine. The result is that there is continuing and increasing litigation with respect to beach loss and resulting hazards, most of it associated with the problems of beach sand supply being cut off.

Given the sand-mining crisis in terms of beach-sediment supply, especially in the face of rising sea levels, the time is ripe to bring back the fundamental guidelines that grew out of the Sand Rights movement. The Proclamation and recommendations of the 1999 conference "Sand Rights '99: Bringing Back the Beaches" are as follows (Ewing, Magoon, and Robertson 2000):

PROCLAIMED BY THE PARTICIPANTS

WHEREAS, beaches provide an enriched quality of life, worldwide recognition and unparalleled recreation and tourist opportunities;

WHEREAS, beaches are used regularly by coastal and inland residents and by numerous out-of-state and international visitors;

WHEREAS, beaches provide a natural habitat for many species, some that are protected species;

WHEREAS, the health of sand beaches depends on a steady supply of sand to the coast;

WHEREAS, many of America's beaches are in an advanced state of erosion because the natural supplies of sand, from inland watersheds, have been altered or interrupted by sand mining, harbors, flood control and water supply projects;

WHEREAS, carbonate beaches are being affected by natural and anthropomorphic alterations to reefs, and longshore transport has been altered or interrupted by sand mining, harbors, and coastal structures;

THEREFORE, we, the participants of Sand Rights '99, resolve and recommend as follows:

Local, regional, state, federal and international programs should recognize and value the importance of coastal beaches to the quality of the coastal environment. Sand is an integral element of these beach systems. All programs that result in a net decrease in available coastal sand supply shall be examined and steps should be implemented to re-establish stable, healthy beach systems in appropriate coastal locations. Toward this end, we recommend that the Corps of Engineers be funded to undertake both a National Coastal Inventory, and studies of regional sediment supplies for either all US coastal watersheds or littoral cells. Practices that are detrimental to the management of coastal sands shall be identified and, where possible, alternative practices recommended and implemented.

[committee of six signatories]

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Orville T. Magoon	Brian Brennan
Susan Brodeur	Melanie Coyne

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REFERENCES

PREFACE

Hardin, Garrett. 1968. "The Tragedy of the Commons." *Science* 162, no. 3859: 1243–48. https://science.sciencemag.org/content/sci/162/3859/1243.full.pdf.

CHAPTER ONE. WHO'S MINING THE SHORE?

Abdulali, Sumaira. 2021. "Why Beach Sand Mining Is So Dangerous." *Times of India*, November 11. www.timesofindia.indiatimes.com/blogs/voices/why-beach-sand-mining-is-so-dangerous/.

Anderson, Ryan, Kiki Patsch, Charles Lester, and Gary Griggs. 2020. "Adapting to Shoreline Retreat: Finding a Path Forward." *Shore and Beach* 88, no. 4: 1–21.

Awaaz Foundation and Bombay Natural History Society. 2013. "Application for Inclusion of Sand Mining in the Agenda of the Convention of Biodiversity, a New and Emerging Issue Relating to the Conservation and Sustainable Use of Biodiversity (Decision IX/29, paragraph 11)." India: Convention of Biodiversity. Accessed June 12, 2019. www.cbd.int/doc/emerging-issues/emergingissue-2013-10-Awaaz-Foundation-Bombay-NHS-en.docx.

BBC News. 2020. "Coronavirus: Outcry as Spanish Beach Sprayed with Bleach," April 29. www.bbc.com/news/world-europe-52471208.

BBC News. 2021. "Sardinian Sand Theft Leaves Dozens Facing Fines of up to €3,000," June 5. www.bbc.com\news\world-europe-57370740.

Beiser, Vince. 2018. *The World in a Grain: The Story of Sand and How It Transformed Civilization*. New York: Riverhead Books.

Berlinger, Joshua. 2020. "North Korea Might Be Making Millions—and Breaking Sanctions—Selling Sand. Yes, Sand." *CNN Business*, June 10. www.cnn.com/2020/06/09/business/north-korea-sand-intl-hnk/index.html.

Carter, R. W. G., David A. Eastwood, and Philip Bradshaw. 1992. "Small Scale Sediment Removal from Beaches in Northern Ireland: Environmental Impact, Community Perception and Conservation Management." *Aquatic Conservation Marine and Freshwater Systems* 2, no. 1: 95–113.

Chatham House. 2021. "Sand: Monitoring and Management for a Sustainable Future." Recording of research event, March 2, 2021. Accessed March 14, 2021. www.chathamhouse.org/events/all/research-event/sand-monitoring-and-management-sustainable-future.

Coastal Care. 2020a. "Category: Sand Mining." Accessed January 23, 2021. https://coastalcare.org/sections/inform/sand-mining/.

Coastal Care. 2020b. "Sand Mining Database." https://coastalcare.org/sand-mining-database/.

Davis, Matt. 2019. "Illegal Sand Mining in India Is Fatefully Hurting Gharial Crocodiles, Ganges River Dolphins." *Big Think*, April 26. www.bigthink.com/politics-current-affairs/india-sand-mafia?rebelltitem=2#rebelltitem2.

Delestrac, Denis, dir. 2013. *Sand Wars: An Investigative Documentary*. Produced by Rappi Productions and La compagnie des Taxi-Brousse.

DiDonato, Valentina, and Lianne Kolirin. 2020. "A Tourist Who Took Sand from a Beach in Italy Has Been Fined More than $1000." *CNN Travel*, September 7. www.cnn.com/travel/article/sardinia-beach-sand-scli-intl/index.html.

Dinh, Cam. 2020. "Asia's Hunger for Sand Is Harmful to Farming and the Environment." *Economist*, January 18. www.economist.com/asia/2020/01/18/asias-hunger-for-sand-is-harmful-to-farming-and-the-environment.

Froetschel, Susan. 2017. "Sand Mining: Growing Pains of Cross-Border Trade." *Yale Global Online*, August 29. https://archive-yaleglobal.yale.edu/content/sand-mining-growing-pains-cross-border-trade.

Gayle, Barbara. 2011. "Dumped—Charges Dropped against Accused in Coral Springs Sand Theft." *Gleaner*, February 9. https://jamaica-gleaner.com/gleaner/20110209/lead/lead3.html.

Giuffrida, Angela. 2019. "French Tourists Face Six Years in Jail over Claims They Stole Sardinia Sand." *Guardian*, August 19. www.theguardian.com/world/2019/aug/19/french-tourists-in-hot-water-in-sardinia-over-sand-souvenir.

Goodell, Jeff. 2021. "Miami's Climate Dystopia Gets Real: South Florida's Real Estate Is Only Going to Get More Deadly if We Continue to Ignore All the Warning Signs of a Doomed Coastline." *Rolling Stone Magazine*, July 1. www.rollingstone.com/politics/politics-features/miami-beach-building-collapse-climate-change-1191989/.

Grant, Charles N., and Johann M. R. Antoine. 2018. "Instrumental Neutron Activation Analysis in Forensic Science in Jamaica: The Case of the Coral Springs Beach Theft." *Forensic Chemistry* 7 (March): 88–93. https://doi:10.1016/j.forc.2017.10.001.

GreenFacts Scientific Board. 2020. "The Mining of Sand, a Non-Renewable Resource." Accessed June 16, 2020. http://www.greenfacts.org/en/sand-extraction/l-2/index.htm. Source document: UNEP GEAS (2014). "Sand, Rarer Than One Thinks—Why Is This Issue Important?" http://www.wedocs.unep.org/bitstream/handle/20.500.11822/8665/GEAS_Mar2014_Sand_Mining.pdf?%20sequence=3.

Grossman, Daniel. 2016. "Why Our Intuition about Sea-Level Rise Is Wrong." *Nautilus: Science Connected*, February 9. https://nautil.us/why-our-intuition-about-sea_level-rise-is-wrong-4259/.

Hardin, Garrett. 1968. "The Tragedy of the Commons." *Science* 162, no. 3859 (December): 1243–48.

Horton, Benjamin P., Nicole S. Khan, Niamh Cahill, Janice S. H. Lee, Timothy A. Shaw, Andra J. Garner, Andrew C. Kemp, Simon E. Engelhart, and

Stefan Rahmstorf. 2020. "Estimating Global Mean Sea-Level Rise and Its Uncertainties by 2100 and 2300 from an Expert Survey." *Climate and Atmospheric Science* 3, article no. 18 (May). Author correction published on June 11, 2020. https://doi:10.1038/s41612-020-0121-5.

Huifeng, He. 2013. "Shenzhen Construction on Hold after Alert over Cheap Sand in Concrete." *South China Morning Post*, March 16. Accessed October 3, 2021. https://www.scmp.com/news/china/article/1191896/shenzhen-construction-hold-after-alert-over-cheap-sand-concrete?module=perpetual_scroll_0&pgtype=article&campaign=1191896.

Krulwich, Robert. 2012. "Which Is Greater, the Number of Sand Grains on Earth or Stars in the Sky?" Krulwich Wonders, NPR, September 17. https://www.npr.org/sections/krulwich/2012/09/17/161096233/which-is-greater-the-number-of-sand-grains-on-earth-or-stars-in-the-sky.

Kumar, Krishnachandran Sampath, Kandasamy Kathiresan, and Senniappan Arumugam. 2019. "*Vachellia bolei* (Leguminosae, Mimosaceae): A Possibly Extinct Coastal Stenoendemic Legume of Southern India." *Phytotaxa* 397, no. 1: 107–13.

Noor, Dharna. 2020. "Climate Threats Are Grounds for Seeking Asylum, UN Body Rules." *Gizmodo*, January 12. www.earther.gizmodo.com/climate-threats-are-grounds-for-seeking-asylum-un-body-1841132046.

Owen, David. 2017. "The World Is Running Out of Sand." *New Yorker*, May 22. Accessed June 15, 2019. www.newyorker.com/magazine/2017/05/29/the-world-is-running-out-of-sand.

Ripple, William J., Christopher Wolf, Thomas M. Newsome, Phoebe Barnard, and William R. Moomaw. 2021. "The Climate Emergency: 2020 in Review." Climate Change, Opinion, *Scientific American*, January 6. Accessed February 9, 2022. https://www.scientificamerican.com/article/the-climate-emergency-2020-in-review/.

Ryapolova, Irina. 2020. "India Worries China May Be Constructing South China Sea-Like Artificial Island in Maldives." *Sputnik International*, May 12. www.sputniknews.com/asia/202005121079271084-india-worries-china-may-be-constructing-south-china-sea-like-artificial-island-in-maldives/.

Science.gov. 2020. "Sample Records for Beach Sand Mining." Accessed July 27, 2020. https://www.science.gov/topicpages/b/beach+sand+mining.

Sherman, Douglas J. 2020. "Understanding Wind-Blown Sand: Six Vexations." *Geomorphology* 377. https://doi:10.1016/j.geomorph.2020.107193.

Sutton, H. I. 2020. "Satellites Show Scale of Suspected Illegal Dredging in South China Sea." *Forbes*, May 12. www.forbes.com/sites/hisutton/2020/05/12/satellites-show-scale-of-suspected-illegal-dredging-in-south-china-sea/#3b93b9bd4310.

UNEP (UN Environment Programme). 2019. "Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources." Geneva: grid-Geneva. Accessed December 3, 2019. https://unepgrid.ch/en/resource/2AD54533.

Welland, Michael. 2009. *Sand: The Never-Ending Story*. Oakland: University of California Press.

Wesley, David T. A., and Shelia M. Puffer. 2018. "The End of Sand: Confronting One of the Greatest Environmental Challenges of the New Millennium." In *Reusable and Sustainable Building Materials in Modern Architecture*, edited by Gülah Koç and Bryan Christiansen, 1–27. Hershey, PA: IGI Global.

Young, Robert, and Adam Griffith. 2009. "Documenting the Global Impacts of Beach Sand Mining." April. EGU General Assembly 2009: *Geophysical Research Abstracts*. Vol. 11, EGU2009-11593. Accessed January 23, 2021. https://coastalcare.org/2009/06/documenting-the-global-impacts-of-beach-sand-mining/.

CHAPTER TWO. SAND

Bailey, Mary Page. 2020. "Vale Opens Plant That Converts Mine Tailings into Construction Materials." *Chemical Engineering*, November 23. www.chemengonline.com/vale-opens-plant-that-converts-mine-tailings-into-construction-materials/.

Beiser, Vince. 2018. *The World in a Grain: The Story of Sand and How It Transformed Civilization*. New York: Riverhead Books.

Bendixen, Mette, Irina Overeem, Minik T. Rosing, Anders Anker Bjørk, Kurt H. Kjær, Aart Kroon, Gavin Zeitz, and Lars Lønsmann Iversen. 2019. "Promises and Perils of Sand Exploitation in Greenland." *Nature Sustainability* 2: 98–104. https://doi:10.1038/s41893-018-0218-6.

Block, India. 2018. "New Material Made from Desert Sand Could Offer Low-Carbon Alternative for Concrete." *De Zeen*, March 24. www.dezeen.com/2018/03/24/desert-sand-could-offer-low-carbon-concrete-alternative/.

Blum, Jordan. 2017. "Texas Frac Sand Mines Keep Opening, but Halliburton Says Usage Slows." *Houston Chronicle*, July 25. https://www.chron.com/business/energy/article/Texas-frac-sand-mines-keep-opening-but-11368797.php#photo-12701559.

Campos, Nicolás, Eduardo Engel, Ronald D. Fischer, and Alexander Galetovic. 2021. "The Ways of Corruption in Infrastructure: Lessons from the Odebrecht Case." *Journal of Economic Perspectives* 35, no. 2: 171–90.

Crelling, John. 2015. "Sand in Forensic Geology: Modified from a Powerpoint Presentation, Southern Illinois University." United States Documents. Accessed November 13, 2019. www.documents.pub/document/sand-in-forensic-geology-modified-from-a-powerpoint-presentation-by-j-crelling.html.

Delestrac, Denis, dir. 2013. *Sand Wars: An Investigative Documentary*. Produced by Rappi Productions and La compagnie des Taxi-Brousse.

Fritts, Rachel. 2019. "The World Needs to Get Serious about Managing Sand, UN Report Says." *Science*, May 10. https://doi:10.1126/science.aay0017.

Geological Society of America. 2020. "Tracing the Source of Illicit Sand—Can It Be Done?" *Science Daily*, October 28. http://www.sciencedaily.com/releases/2020/10/201028134032.htm.

Giles, Robert T., and Orrin H. Pilkey. 1965. "Atlantic Beach and Dune Sediments of the Southern United States." *Journal of Sedimentary Petrology* 35, no. 4: 900–910. https://doi:10.1306/74D7139D-2B21-11D7-8648000102C1865D.

Goodell, Jeff. 2017. *The Water Will Come: Rising Seas, Sinking Cities, and the Remaking of the Civilized World*. New York: Little, Brown.

Gornall, Jonathan. 2019. "Desert Sand May Hold Key to the Next Gulf Economic Miracle." *Arab News*, August 4. Accessed February 11, 2022. https://www.arabnews.com/node/1535191/middle-east.

Guthrie, Craig. 2020. "Vale Turns Upcycled Tailings into Construction Materials." *Mining Magazine*, November 24. www.miningmagazine.com/sustainability/news/1399917/vale-turns-upcycled-tailings-into-construction-materials.

Hawkins, Amy. 2019. "The Grey Wall of China: Inside the World's Concrete Superpower." *Guardian*, February 28. Accessed February 11, 2022. https://www.theguardian.com/cities/2019/feb/28/the-grey-wall-of-china-inside-the-worlds-concrete-superpower.

Klemetti, Erik. 2020. "Tracking the Source of Illegal Sand Mining." *Discover Magazine*, October 29. www.discovermagazine.com/planet-earth/tracking-the-source-of-illegal-sand-mining.

Love Big Island. 2021. "Green Sand Beach (Papakōlea)." Last updated November 24, 2021. Accessed March 10, 2022. https://www.lovebigisland.com/big-island-beaches/papakolea/.

Neal, William J., and Orrin H. Pilkey. 1991. "Beach Mining: Economic Development/Environmental Crisis." *Sea Wind* 5: 3–8.

Neumann, Frank, and Manfred Curbach. 2018. "Thermal Treatment of Desert Sand to Produce Construction Material." *MATEC Web of Conferences* 149, 01030 (January 2018). Accessed February 10, 2022. https://doi.org/10.1051/matecconf/201814901030.

Pettijohn, Francis J., Paul E. Potter, and Raymond Siever. 1972. *Sand and Sandstone*. New York: Springer-Verlag.

Pilkey, Orrin H. 1963. "Heavy Minerals of the U.S. South Atlantic Continental Shelf and Slope." *Geological Society of America Bulletin* 74: 641–48.

Powers, Maurice Cary. 1953. "A New Roundness Scale for Sedimentary Particles." *Journal of Sedimentary Research* 23, no. 2: 117–19. https://doi:10.1306/D4269567-2B26-11D7-8648000102C1865D.

Rocheleau, Jackie. 2020. "Using Dirt to Clean Up Construction." September 22. *Eos*, September 22. https://doi:10.1029/2020EO149480.

Rowell, Andy. 2014. "Public Backlash as Demand for Frac-Sand Soars." Oil Change International, August 6. https://priceofoil.org/2014/08/06/public-backlash-demand-frac-sand-soars/.

Siqi, Ji. 2021. "China Turns to Artificial Sand." Video. S*outh China Morning Post*, April 1. www.scmp.com/video/china/3127921/crushing-rocks-sand-rising-costs-push-china-manufacture-artificial-components.

Spencer, Ben. 2020. "Lafarge Canada to Produce Cement from Aluminium

Waste." Aggregates Business, October 23. Accessed February 11, 2022. https://www.aggbusiness.com/news/lafarge-canada-produce-cement-aluminium-waste.

Steffen, Sarah. 2020. "Philippines: Artificial White Sandy Beach Could Spell Eco Disaster." *Deutsche Welle*, October 26. www.dw.com/en/philippines-artificial-white-sandy-beach-could-spell-eco-disaster/a-55397340.

St. Lucia News Online. 2019a. "Dr. Kenny Anthony Calls on the Chastanet Government to Stop the Destructive Sand Mining in Vieux-Fort." *St. Lucia News Online*, December 11. www.stlucianewsonline.com/dr-kenny-d-anthony-calls-on-the-chastanet-government-to-stop-the-destructive-sand-mining-in-vieux-fort/.

St. Lucia News Online. 2019b. "Sand Mining Leaves Vieux Fort Residents Fearful for Their Homes," December 21. https://stluciatimes.com/sand-mining-leaves-vieux-fort-residents-fearful-for-their-homes/.

Tam, Carolyn, Hamza Oza, Matteo Maccario, and Saki Maruyama. 2020. "FINITE: A New Low-Carbon, Bio-Composite, Sustainable Replacement for Concrete." *UrbanNext*. Accessed January 2021. www.urbannext.net/finite-concrete-replacement/.

TBR Newsroom. 2017. "After 'Malufing' for Decades, Brazilian Rep. Paulo Maluf May Finally Do Time." *Brazilian Report*, December 20. Accessed February 14, 2022. https://brazilian.report/power/2017/12/20/brazil-paulo-maluf-corruption/.

Thorneycroft, J., J. Orr, P. Savoikar, and R. J. Ball. 2018. "Performance of Structural Concrete with Recycled Plastic Waste as a Partial Replacement for Sand." February 10. *Construction and Building Materials* 161: 63–69. Accessed February 11, 2022. https://doi.org/10.1016/j.conbuildmat.2017.11.127.

Torres, Aurora, Mark U. Simoni, Jakob K. Keiding, Daniel B. Möller, Sophus O. S. E. zu Ermgassen, Jianguo Liu, Jochen A. G. Jaeger, Marten Winter, and Eric F. Lambin. 2021. "Sustainability of the Global Sand System in the Anthropocene." *One Earth Perspective* 4, no. 5: 639–50. https://doi:10.1016/J.ONEEAR.2021.04.011.

Wade, Andrew. 2018. "UK Study Shows Waste Plastic Can Replace Sand in Concrete." *The Engineer*, September 14. Accessed February 11, 2022. https://www.theengineer.co.uk/uk-waste-plastic-sand-concrete/.

Watts, Jonathan. 2019. "Concrete: The Most Destructive Material on Earth." *Guardian*, February 25. www.theguardian.com/cities/2019/feb/25/concrete-the-most-destructive-material-on-earth.

Wentworth, Chester K. 1922. "A Scale of Grade and Class Terms for Clastic Sediments." *Journal of Geology* 30, no. 5: 377–92.

Whitaker, Samir, and Twyla Holland. 2019. "Time for a Radical Rethink About Sand?" Phys.org, September 10. https://phys.org/news/2019-09-radical-rethink-sand.html.

CHAPTER THREE. SINGAPORE SAND BANDITS

Abdullah, Ahmad Zhaki. 2021. "Reclamation Works for First Phase of Tuas Port Completed, Two Berths to Open by End-2021." Channel News Asia CNA/az(mi), November 30. Accessed February 10, 2022. https://www.channelnewsasia.com/singapore/tuas-port-reclamation-works-two-berths-open-end-2021-2347421.

Arsenault, Chris. 2016. "Cambodia Digs into Sand Mining Industry as Beaches and Crabs Vanish." *Reuters*, November 3. www.reuters.com/article/us-cambodia-landrights-environment-idUSKBN12Y224.

Asif, Furqan, and Jason Horlings. n.d. "Koh Sralao, Cambodia—Seas of Change: The Case of a Cambodian Coastal Fishing Community." Community Conservation Research Network. Accessed February 4, 2021. www.communityconservation.net/koh-sralao-cambodia/.

Associated Press. 2010. "Malaysian Sand Smuggling Swoop Nets 34 for Bribery." *Taiwan News*, January 22. Accessed February 15, 2022. https://www.taiwannews.com.tw/en/news/1161614.

Banergee, Piyall. 2018. "Southeast Asia's Vanishing Sand Bans Are Destroying the Region." *Resilience*, June 21. Originally published by Asian Correspondent. https://www.resilience.org/stories/2018-06-21/southeast-asias-vanishing-sand-bans-are-destroying-the-region/.

Boh, Samantha. 2016. "Construction of Tuas Terminal Enters Phase I of Development." *Straits Times*, April 29. https://www.straitstimes.com/singapore/construction-of-tuas-terminal-enters-phase-1-of-development.

Clarke, Peter (host). 2020. "The Demand for Sand, and Its Impact in Asia." Vanessa Lamb (guest), and Melissa Marschke (guest). March 30. *Ear to Asia*, Episode 65, March 30. Produced by Asia Institute, The University of Melbourne. Audio Podcast. Accessed January 31, 2021. www.arts.unimelb.edu.au/news/past-news/episode-65.

Comaroff, Joshua. 2014. "Built on Sand: Singapore and the New State of Risk." In Essay No. 39, "Wet Matter," *Harvard Design Magazine: Architecture, Landscape Architecture, Urban Design and Planning* 39. Accessed January 15, 2021. www.harvarddesignmagazine.org/issues/39/built-on-sand-singapore-and-the-new-state-of-risk.

Daud, Sulaiman. 2019. "Development of Tuas Mega Port Proceeds Despite Sand Ban." Mothership, July 5. www.mothership.sg/2019/07/tuas-mega-port-sand-ban-reclamation/.

Down To Earth. 2001. "Sand Mining Destroys Community Resources," no. 51. Accessed January 19, 2021. www.downtoearth-indonesia.org/story/sand-mining-destroys-community-resources.

Down To Earth. 2016. "Illegal Sand Mining around the World: Islands Disappear; Livelihoods at Stake," June 27. www.downtoearth.org.in/news/mining/illegal-sand-mining-around-the-world-islands-disappear-livelihoods-threatened-54580.

Eco-Business. 2012. "Singapore Remains Well Prepared against Coastal

Erosion: Experts," July 14. www.eco-business.com/news/singapore-remains-well-prepared-against-coastal-erosion-experts/.

Economist Intelligence Unit (EIU). 2011. *Asian Green City Index*. Sponsored by Siemens AG, Munich. Accessed January 31, 2021. https://w1.siemens.com.cn/userfiles/AGCI%20Report_EN.pdf.

Global Witness. 2010. "Shifting Sand: How Singapore's Demand for Cambodian Sand Threatens Ecosystems and Undermines Good Governance." Accessed February 4, 2021. www.globalwitness.org/en/archive/shifting-sand-how-singapores-demand-cambodian-sand-threatens-ecosystems-and-undermines-good/.

Grist. 2010. "Indonesia's Islands Are Buried Treasure for Gravel Pirates." *New York Times*, March 27. www.nytimes.com/2010/03/28/weekinreview/28grist.html.

Henderson, Barney. 2010. "Singapore Accused of Launching 'Sand Wars.'" *Telegraph*, February 12. www.telegraph.co.uk/news/worldnews/asia/singapore/7221987/Singapore-accused-of-launching-Sand-Wars.html.

John, Robert, and William Jamieson. 2020. "Singapore's Scentless Growth Is Built on the Brutal Extraction of Cambodian Sand and Imported Labour." *Failed Architecture* (blog), March 3. www.failedarchitecture.com/singapores-scentless-growth-is-built-on-the-brutal-extraction-of-cambodian-sand-and-imported-labour/.

Kog, Yue-Choong. 2006. "Environmental Management and Conflict in Southeast Asia—Land Reclamation and Its Political Impact." (RSIS Working Paper No. 101). January. Accessed February 15, 2022. Singapore: Nanyang Technological University. https://dr.ntu.edu.sg/bitstream/10220/39959/1/WP101.pdf.

Lin, Derong. 2017. "Materialising Sand: Matters of New Terrain." Master's thesis, National University of Singapore. www.issuu.com/linderong/docs/a_-_copy.

Lin, Ted. 2011. "The Mountainous and Surreal Sand Reserves of Singapore." *Untapped New York*, December 15. www.untappedcities.com/2011/12/15/the-mountainous-and-surreal-sand-reserves-of-singapore/.

Mam, Kalyanee. 2019. "When Your Land Is Stolen from Beneath Your Feet." *Atlantic*, March 11. www.theatlantic.com/video/index/584563/singapore-cambodia/.

Maritime Singapore Connect. 2021. "5 Things You Should Know about the New Tuas Megaport." Accessed January 23, 2021. www.maritimesgconnect.com/features/spotlight/5-things-you-should-know-about-new-tuas-mega-port.

Milton, Chris. 2010. "The Sand Smugglers." *Foreign Policy*, August 4. www.foreignpolicy.com/2010/08/04/the-sand-smugglers/.

Moss, Daniel. 2020. "What Happens When Singapore Runs Out of Sand?" *Bloomberg Opinion*, November 15. www.bloombergquint.com/business/what-happens-when-singapore-runs-out-of-sand.

Rahil, Siti. 2007. "Indonesia Sand Ban Slows Builders in Singapore." *Japan Times*, May 12. www.japantimes.co

.jp/news/2007/05/12/business/indonesia-sand-ban-slows-builders-in-singapore/.

Sousa, Gregory. 2017. "Top 20 Sand Exporting Countries." *World Atlas*, April 25. www.worldatlas.com/articles/top-20-sand-exporting-countries.html.

Toh, Ting Wei. 2019. "Jewel Changi Airport Sees 50m Visitors since Opening Six Months Ago." *Straits Times*, October 18. www.straitstimes.com/singapore/transport/jewel-changi-airport-sees-50m-visitors-since-opening-six-months-ago.

Tuổi Trẻ News. 2017a. "Tracing Vietnamese 'Sand Drain' to Singapore—P1: Where Do the Ships Go?," March 2. https://wildsingaporenews.blogspot.com/2017/03/54acing-vietnamese-sand-drain-to.html.

Tuổi Trẻ News. 2017b. "Tracing Vietnamese 'Sand Drain' to Singapore—P2: How Much Does the Resource Cost?," March 3. https://tuoitrenews.vn/news/features/20170303/tracing-vietnamese-%E2%80%98sand-drain%E2%80%99-to-singapore-%E2%80%93-p2-how-much-does-the-resource-cost/17800.html.

Tuổi Trẻ News. 2017c. "Tracing Vietnamese 'Sand Drain' to Singapore—P3: National Resource Overexploited," March 4. https://tuoitrenews.vn/news/features/20170303/tracing-vietnamese-%E2%80%98sand-drain%E2%80%99-to-singapore-%E2%80%93-p3-national-resource-overexploited/17800.html.

Turtle Island Resoration Network. 2021. "Company Abandons Controversial Sand Mining Venture on Leatherback Nesting Beach Following Public Backlash." Press Release, March 1. https://seaturtles.org/company-abandons-controversial-sand-mining-venture-on-leatherback-nesting-beach-following-public-backlash/.

Ungku, Fathin, and Rozanna Latiff. 2019. "Exclusive: In Blow to Singapore's Expansion, Malaysia Bans Sea Sand Exports." *Reuters*, July 2. www.reuters.com/article/us-malaysia-singapore-sand-exclusive/exclusive-in-blow-to-singapores-expansion-malaysia-bans-sea-sand-exports-idUSKCN1TY0C4.

Waide, Scott. 2020. "Understanding the Madang Sand Mining Proposal in the Global Context." *EMTV*, October 13. www.emtv.com.pg/understanding-the-madang-sand-mining-proposal-in-the-global-context/.

CHAPTER FOUR. THE SANDS OF CRIME

Abdulali, Sumaira. 2020. "The Environmental and Social Impact of Sand Mining." TEDxSIUNashik, February. www.ted.com/talks/sumaira_abdulali_the_environmental_social_impact_of_sand_mining.

African Defenders: Pan-African Human Rights Defenders Network. 2020. "The Southern Africa Human Rights Defenders Stands in Solidarity with Activists against SLAPP Suit Litigation," June 16. www.africandefenders.org/the-southern-africa-human-rights-defenders-stands-in-solidarity-with-activists-against-slapp-suit-litigation/.

Aghor, Ashwin, M. Suchitra, Anupam Chakravartty, and Kumar Sambhav Shrivastava. 2012. "Sand Slips." *Down*

To Earth, April 30. www.downtoearth.org.in/coverage/sand-slips-37957.

Ananth, M. K. 2018. "Constable Gathering Info on Illegal Sand Mining Murdered in TN." *Times of India*, May 7. https://timesofindia.indiatimes.com/city/chennai/constable-gathering-info-on-illegal-sand-mining-murdered-in-tn/articleshow/64059155.cms.

Anitha, S. 2013. "One Woman's Fight to Protect a River." *Countercurrents.org*, August 12. www.countercurrents.org/anitha120813.htm.

Asia One. 2017. "Illegal Sand Mining in Vietnam Reaches 'Epidemic' Proportions," July 7. www.asiaone.com/asia/illegal-sand-mining-vietnam-reaches-epidemic-proportions.

Awaaz Foundation and Bombay Natural History Society. 2013. "Application for Inclusion of Sand Mining in the Agenda of the Convention of Biodiversity, a New and Emerging Issue Relating to the Conservation and Sustainable Use of Biodiversity (Decision IX/29, paragraph 11)." October. India: Convention of Biodiversity. Accessed June 12, 2019. www.cbd.int/doc/emerging-issues/emergingissue-2013-10-Awaaz-Foundation-Bombay-NHS-en.docx.

Beiser, Vince. 2015. "The Deadly Global War for Sand." *Wired*, March 26. www.wired.com/2015/03/illegal-sand-mining/.

Beiser, Vince. 2017. "He Who Controls the Sand: The Mining 'Mafias' Killing Each Other to Build Cities." *Guardian*, February 28. Last modified on May 11, 2018. www.theguardian.com/cities/2017/feb/28/sand-mafias-killing-each-other-build-cities.

Boediwardhana, Wahyoe. 2015. "Antimining Activist Beaten to Death in East Java." *Jakarta Post*, September 28. Accessed February 19, 2022. https://www.thejakartapost.com/news/2015/09/28/antimining-activist-beaten-.death-east-java.html.

Bosotti, Aurora. 2018. "World Is Running Out of Sand and It's Creating Deadly Sand Mafia: 'Completely Depleted!'" *Express*, May 6. www.express.co.uk/news/world/1123136/sand-shortages-sand-mafia-india-news-Vietnam-sand-Mafia-crime-illegal-construction.

Brilliant Earth. 2019. "Violence." Accessed November 3, 2019. https://www.brilliantearth.com/conflict-diamond trade/.

Brown, Erik. 2018. "Murdered for Sand." *Medium—Environment*, September 30. www.medium.com/s/story/murdered-for-sand-the-birth-of-the-sand-mafia-5fd5d16c9dcb.

Centre for Science and Environment. 2020. "Grains of Despair: Sand Mining in India." Green Rural Development Story. New Delhi: Centre for Science and Environment. Accessed May 16, 2020. https://www.cseindia.org/grains-of-despair-sand-mining-in-india--3878.

Chandran, Rina. 2019. "Sand Mining 'Mafias' Destroying Environment, Livelihoods: U.N." *Reuters*, May 7. Accessed November 13, 2019. https://www.reuters.com/article/us-southeast-asia-mining-sand/sand-mining-mafias-destroying-environment-livelihoods-u-n-idUSKCN1SD0KG.

Clarke, John G. I. 2020. "Restoring and Renewing the Fourth Estate: Submission to SANEF Media Ethics and Credibility Inquiry on Measure to Support Journalists to Heal from and Transcend the Effects of State Capture." Medium.com, September 11. Accessed February 18, 2022. https://medium.com/@johngeeic/restoring-and-renewing-the-fourth-estate-fef908b2e171.

Committee to Protect Journalists. 2018. "Sandeep Sharma: News World | Killed in Ghazipur District, India | March 26, 2018," March 27. https://cpj.org/data/people/sandeep-sharma/.

Davis, Judi. 2016. "Xolobeni Family Attacked." *South Coast Herald*, March 7. www.southcoastherald.co.za/131027/xolobeni-family-attacked/.

Davis, Matt. 2019. "Illegal Sand Mining in India Is Fatefully Hurting Gharial Crocodiles, Ganges River Dolphins." *Big Think*, April 26. www.bigthink.com/politics-current-affairs/india-sand-mafia?rebelltitem=2#rebelltitem2.

Delestrac, Denis, dir. 2013. *Sand Wars: An Investigative Documentary*. Produced by Rappi Productions and La compagnie des Taxi-Brousse.

Devasia, T. K. 2014. "Kerala Woman Calls Off Her Lonely Protest against Mighty Sand Mafia." *Khaleej Times*, February 2. Last updated April 4, 2015. www.khaleejtimes.com/international/kerala-woman-calls-off-her-lonely-protest-against-mighty-sand-mafia.

Dlamini, Kwazi. 2019. "Corruption Impeding on Human Rights in South Africa's Mining Sector." International Anti-Corruption Conference, February 1. www.iaccseries.org/blog/corruption-impeding-on-human-rights-in-south-africas-mining-sector/.

Dludla, Siphelele. 2019. "South Africa Environmental Activists Prepare for Showdown with Aussie Mining Giant." *IOL*, *South Africa*, May 21. www.iol.co.za/news/south-africa/environmental-activists-prepare-for-showdown-with-aussie-mining-giant-23686441.

Dumas, Laurent Ribadeau. 2019. "Les Plages du Maroc Vont-Elles Survivre aux 'Mafias du Sable'?" [Will Morocco's Beaches Survive the "Sand Mafias"?]. *AfricaFrance Televisions*, May 20. https://www.francetvinfo.fr/monde/afrique/maroc/les-plages-du-maroc-vont-elles-survivre-aux-mafias-du-sable_3449149.html.

ET Bureau. 2018. "Do You Know the History behind the Infamous Word 'Mafia'?" *Economic Times*. Last updated April 17, 2018. Accessed August 23, 2019. https://www.economictimes.indiatimes.com/articleshow/63795610.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst.

Ghosh, Deepshikha, ed. 2018. "Journalist Sandeep Sharma Crushed by Truck." *NDTV*, March 27, 2018. www.ndtv.com/india-news/on-camera-the-chilling-moment-a-journalist-sandeep-sharma-was-crushed-by-truck-1828777.

Guégan, Marion, and Cécile Schilis-Gallego. 2019. "Forbidden Stories Part 3: Sand Mafias Silence Journalists in India." *News24*, June 21. Last updated June 25, 2019. www.news24.com/Green/News/amabhungane-sand-mafias-silence-journalists-in-india-20190621.

Hawley, Samantha. 2017a. *India's Sand Mafia: The Dark Secrets of India's Booming Construction Industry*. Journeyman Pictures (YouTube channel). http://www.youtube.com/watch?v=ugT-zyXGNIY.

Hawley, Samantha. 2017b. "The 'Sand Mafia' Fuelling India's $120 Billion Building Boom." *ABC News*, March 27. www.abc.net.au/news/2017-03-28/the-great-sand-heist-fuelling-india-120-billion-building/8390984.

Hellwig, Christian. 2015. "Illegal Sand Mining Is a Thing and It's a Problem." *International Policy Digest*, April 19. https://perma.cc/Z8ZP-RW3R.

History.com. 2009. "Origins of the Mafia." *History.com*, October 29. Updated May 28, 2019. www.history.com/topics/crime/origins-of-the-mafia.

HRD Memorial. 2022. "Salim Kancil." HRD Memorial: Celebrating Those Who Were Killed Defending Human Rights. Accessed February 19, 2022. https://hrdmemorial.org/hrdrecord/salim-kancil/.

Human Rights Watch. 2018. "Diamond Trade Still Fuels Human Suffering," May 10. www.hrw.org/news/2018/05/10/diamond-trade-still-fuels-human-suffering#.

Human Rights Watch. 2020. "World Report 2020: South Africa Events of 2019." Accessed July 7, 2020. https://www.hrw.org/world-report/2020/country-chapters/south-africa.

India Today Web Desk. 2018. "Madhya Pradesh Journalist Murder: Driver of the Truck Which Ran Over Sandeep Sharma Arrested." March 26. Updated March 27, 2018. www.indiatoday.in/india/story/madhya-pradesh-journalist-murder-driver-of-the-truck-which-ran-over-sandeep-sharma-arrested-1198527-2018-03-26.

Kelsey-Sugg, Anna, and Taryn Priadko. 2020. "The World Is 'Running Out of Sand,' and It's Fuelling Murders, Mafias and Ecological Devastation." *ABC Radio National*, January 10. www.abc.net.au/news/2020-01-11/illegal-sand-trade-india-mafia-murders-vince-beiser/11779570.

Lasseter, Tom, and Rakteem Katakey. 2014. "When India Lost Its Student Engineers on Sand Mafia Path to Beas River." *Livemint*, December 17. www\.livemint.com/Home-Page/X8NaZmnppusJGEr6CgNkoK/When-India-lost-its-student-engineers-on-sand-mafia-path-to.html.

Mahadevan, Prem. 2019. *Sand Mafias in India: Disorganized Crime in a Growing Economy*. July. Geneva: Global Initiative Against Transnational Organized Crime. www.globalinitiative.net/wp-content/uploads/2019/07/Sand-Mining-in-India-Report-17Jul1045-Web.pdf.

Mekouar, Hamza. 2019. "'Sand Mafias' Threaten Morocco's Coastline." Phys.org, June 17. https://phys.org/news/2019-06-sand-mafias-threaten-morocco-coastline.html.

Mexico News Daily. 2019. "Environmental Activist Who Fought Illegal Mining Murdered in Chiapas," June 11. www.mexiconewsdaily.com/news/activist-who-fought-illegal-mining-murdered/.

Morton, Oren F. [1920] 1973. *A History of Rockbridge County, Virginia*. Staunton, VA: McClure Company. Reprint, Baltimore, MD: Regional Publishing Company.

Muthomi, Simon, Pontian Okoth, Edmond Were, and Silvia Vundi. 2015. "An Assessment of the Contribution of Natural Resources Use Conflict to Poverty Alleviation with Special Reference to Sand Harvesting in Makueni County—Kenya." August. *International Journal of Education and Research* 3, no. 8: 133–50.

Nair, Sandhya. 2019. "Sand Mafia Try to Mow Down Cop during Night Raid in Virar." *Times of India*, November 20. www.timesofindia.indiatimes.com/city/mumbai/sand-mafia-try-to-mow-down-cop-during-night-raid-in-virar/articleshow/72134558.cms.

Neelanbaran, A. 2019. "Anti-Sand Mining Activist Murdered by Sand Mafia in Tamil Nadu's Ramanathapuram." *NewsClick*, June 21. www.newsclick.in/anti-sand-mining-activist-murdered-sand-mafia-tamil-nadu-ramanathapuram.

News Minute Staff. 2018. "TN Policeman Investigating Illegal Sand Mining Killed, Hand of Sand Mafia Suspected." *News Minute*, May 7. https://www.thenewsminute.com/article/tn-policeman-investigating-illegal-sand-mining-killed-hand-sand-mafia-suspected-80817.

Nithya, R. 2013. "My Sea, My Sand." *NewsClick*, November 27. https://www.newsclick.in/my-sea-my-sand.

Paul, Sonia. 2015. "How India's 'Sand Mafia' Pillages Land, Terrorizes People, and Gets Away with It." *VICE News*, October 7. www.vice.com/en_us/article/ney7z8/how-indias-sand-mafia-pillages-land-terrorizes-people-and-gets-away-with-it.

Pearce, Fred. 2017. "Murder in Pondoland: How a Proposed Strip Mine Brought Conflict to South Africa's Wild Coast." *Yale Environment 360*, March 13. www.e360.yale.edu/features/titanium-mine-conflict-south-africa-pondoland-rhadebe-caruso.

Peduzzi, Pascal. 2014. "Sand, Rarer Than One Thinks." UNEP Global Environmental Alert Service (GEAS), March. www.na.unep.net/geas/archive/pdfs/GEAS_Mar2014_Sand_Mining.pdf.

Pillay, Kamleshan. 2015. "The Xolobeni Heavy Minerals Sands Project on the Wild Coast, South Africa." Environmental Justice Organisations, Liabilities and Trade (EJOLT) Factsheet no. 27. Accessed April 4, 2020. www.ejolt.org/wordpress/wp-content/uploads/2015/07/FS-27.pdf.

Popescu, Alexandra. 2018. "Inside the Ecologically Damaging Practice of Illegal Sand Mining." *Pacific Standard*, February 16. www.psmag.com/environment/people-are-stealing-sand.

PTI. 2018. "Illegal Sand Mining: Tractor Driver Held for Killing Madhya Pradesh Forest Officer." Indian Express, September 8. www.indianexpress.com/article/india/illegal-sand-mining-tractor-driver-held-for-killing-madhya-pradesh-forest-officer-5346470/.

Raab, Selwyn. 2016. *Five Families: The Rise, Decline, and Resurgence of America's Most Powerful Mafia Empires*. New York: Thomas Dunn Books.

Rajasekaran, Ilangovan. 2015. "Sand Mafia: Murders Most Foul." *Frontline*, July 24. https://frontline.thehindu.com/cover-story/murders-most-foul/article7391526.ece.

Rege, Aunshul. 2015. “Not Biting the Dust: Using a Tri-Partite Model of Organized Crime to Examine India’s Sand Mafia.” *International Journal of Comparative and Applied Criminal Justice* 40, no. 2: 101–21.

Rege, Aunshul, and Anita Lavorgna. 2017. “Organization, Operations, and Success of Environmental Organized Crime in Italy and India: A Comparative Analysis.” *European Journal of Criminology* 14, no. 2: 160–82. https://doi:10.1177/1477370816649627.

Reporters without Borders. 2018. “Two Indian Journalists Rammed by SUV Killed Outright,” March 27. Last updated August 23, 2019. www.rsf.org/en/news/two-indian-journalists-rammed-suv-killed-outright.

Romig, Rollo. 2017. “How to Steal a River.” *New York Times Magazine*, March 5, 42–49, 59, 8. www.nytimes.com/2017/03/01/magazine/sand-mining-india-how-to-steal-a-river.html.

Roos, David. 2017. “Sand Is in Such High Demand People Are Stealing Tons of It.” *How Stuff Works*, March 6. www.science.howstuffworks.com/environmental/conservation/issues/sand-is-such-high-demand-people-are-stealing-tons-it.htm.

Roughneen, Simon. 2017. “Race to the Bottom for Region’s Sand Miners: Asia’s Beaches and Riverbeds Suffer as Sand Demand Piles Up.” *Nikkei Asia*, July 19. www.asia.nikkei.com/Economy/Race-to-the-bottom-for-region-s-sand-miners.

Salopek, Paul. 2019. “Inside the Deadly World of India’s Sand Mining Mafia.” *National Geographic*, June 26. www.nationalgeographic.com/environment/2019/06/inside-india-sand-mining-mafia/.

Seshu, Geeta, and Urvashi Sarkar. 2019. *Getting Away with Murder: A Study on the Killings of and Attacks on Journalists in India, 2014–2019, and Justice Delivery in These Cases*. Thakur Foundation. Accessed April 2, 2020. https://www.thakur-foundation.org/report-on-attacks-on-journalists-in-india-2014-2019.pdf.

Sickels-Taves, Lauren. 2016. “The Care and Preservation of Historic Tabby.” Benson Ford Research Center, The Henry Ford. Accessed July 21, 2021. www.thehenryford.org/docs/default-source/default-document-library/the-henry-ford-tabby-conservation.pdf? sfvrsn=2.

Singh, Akoijam Amitkumar, Mirinchonme Mahongnao, Federico Demaria, and Venni V. Krishna. 2015. “Illegal Sand Mining Conflicts in India.” Environmental Justice Organizations, Liabilities and Trade (EJOLT) Factsheet no. 10. Accessed August 12, 2019. www.ejolt.org/wordpress/wp-content/uploads/2015/02/FS_010_India-Sand-Mining.pdf.

Singh, Rajesh Kumar. 2015. “Inside the World of Sand Mafia: Terror Casts Gloom as Cops Bury Heads.” *Hindustan Times*. Last updated April 25, 2015. Accessed June 5, 2019. www.hindustantimes.com/india/inside-the-world-of-sand-mafia-terror-casts-gloom-as-cops-bury-heads/story-ioZ1p2jE3dt4uMfLWtUmKO.html.

Singh, Shri Majoj Kumar, U. Sridharan, R. B. Lal, and Sonu Singh. 2016. *Sustainable Sand Mining Management Guidelines 2016*. March 15. Accessed April 4, 2020. New Delhi, India: Ministry of Environment, Forest and Climate Change. http://environmentclearance.nic.in/writereaddata/SandMiningManagementGuidelines2016.pdf.

SANDRP. 2017. (South Asia Network on Dames, Rivers and People). "Illegal Sand Mining 2017: Rivers Continue to Lose Mindless Mining Battle," December 19. www.sandrp.in/2017/12/19/illegal-sand-mining-2017-rivers-continue-to-loose-mindless-mining-battle/.

SANDRP. 2019. (South Asia Network on Dams, Rivers and People). "Sand Mining Issues Proliferate Even in Monsoon." DRP *News Bulletin*, September 9. https://sandrp.in/2019/09/09/drp-nb-8-sept-2019-sand-mining-issues-proliferate-even-in-monsoon/.

Southern Africa Human Rights Defenders Network. 2020. "The Southern Africa Human Rights Defenders Stands in Solidarity with Activists against SLAPP Suit Litigation," June 16. www.africandefenders.org/the-southern-africa-human-rights-defenders-stands-in-solidarity-with-activists-against-slapp-suit-litigation/.

Srivastava, Roli. 2018. "Indian Miners Drowning for Sand Despite Government Crackdown." *Reuters*, August 12. www.reuters.com/article/us-india-slavery-sand-mining-insight/indian-miners-drowning-for-sand-despite-government-crackdown-idUSKBN1KY00G.

Srivastava, Roli, and Ed Upright. 2017. "Drowning for Sand: Miners Risk All for India's Building Boom." Thomas Reuters Foundation, July 18. www.news.trust.org/shorthand/drowning-for-sand/.

Suchitra, M. 2013. "Mother of Three Wages Lone Battle against Sand Mining Lobby." *Down To Earth*, August 17. www.downtoearth.org.in/news/mother-of-three-wages-lone-battle-against-sand-mining-lobby--41867.

Times of India. 2018. "Shocking but Gangs, Mining Mafia Train Guns on Cops." October 19. https:/timesofindia.indiatimes.com/city/jaipur/shocking-but-gangs-mining-mafia-train-guns-on-cops/articleshow/66283261.cms.

Times of India. 2019. "One Dead in Sand Mafia Gang War," December 15. www.timesofindia.indiatimes.com/city/bhopal/1-dead-in-sand-mafia-gang-war-in-umaria/articleshow/72626308.cms.

Times of India. 2020. "Pune: Crackdown on Sand Mafia: 23 Boats Set on Fire," January 5. www.timesofindia.indiatimes.com/city/pune/crackdown-on-sand-mafia-23-boats-set-on-fire/articleshow/73103587.cms.

Tomar, Shruti. 2018. "Forest Ranger Mowed Down in MP Mining Mafia's Latest Attack on Officials." *Hindustan Times*, September 7. www.hindustantimes.com/india-news/forest-officer-crushed-to-death-while-trying-to-stop-tractor-with-illegally-mined-sand-in-mp/story-TRtxbmX6HQtkCGjpoald8M.html.

Tweedie, Neil. 2018. "Is the World Running Out of Sand? The Truth Behind Stolen Beaches and Dredged Islands." *Guardian*, July 1. www.theguardian.com/global/2018/jul/01/riddle-of-the-sands-the-truth-behind-stolen-beaches-and-dredged-islands.

UNEP. 2019. (UN Environment Programme). "Sand and Sustainability:

Finding New Solutions for Environmental Governance of Global Sand Resources." Accessed December 3, 2019. Geneva: grid-Geneva, UNEP. http://www.unepgrid.ch/en/resource/2AD54533.

Venter, Zelda. 2018. "Xolobeni Community Scores Huge Victory against Mining." *Pretoria News*, November 22. www.iol.co.za/news/south-africa/gauteng/watch-xolobeni-community-scores-huge-victory-against-mining-18223575.

VICE *News*. 2021. *Illegal Sand Mining Is Ruining These Countries' Ecosystems*, September 11. Produced by Joe Casey. http://www.youtube.com/watch?v=H4d6LT87pMo.

Washinyira, Tariro. 2016a. "We Will Die for Our Land, Say Angry Xolobeni Villagers as Dune Mining Looms." *Mail and Guardian*, February 12. www.mg.co.za/article/2016-02-12-we-will-die-for-our-land-say-angry-xolobeni-villagers-as-dune-mining-looms-1/.

Washinyira, Tariro. 2016b. "Wild Coast Battle to Save Land from Mining." *Ground Up*, February 12. www.groundup.org.za/article/imbizo-xolobeni/.

Watts, Jonathan. 2019. "Jagendra Singh: The Indian Journalist Burned to Death." *Guardian*, June 17. www.theguardian.com/environment/2019/jun/17/writing-truth-weighing-heavily-on-my-life-murder-jagendra-singh.

Yeshwantrao, Nitin. 2010. "Sand Mafia Fill 600 Trucks a Day." *Times of India*, December 2. www.timesofindia.indiatimes.com/city/mumbai/Sand-mafia-fill-600-trucks-a-day/articleshow/7026398.cms.

Yogesh, S. 2018. "Sand Mafia: A Network of Politicians, Construction Companies and Criminals." *NewsClick*, June 27. www.newsclick.in/sand-mafia-network-politicians-construction-companies-and-criminals.

CHAPTER FIVE. SAND RIVERS TO THE BEACH

Abam, Tamunoene Kingdom Simeon, and Tamunotonye Oba. 2018. "Recent Case Studies of Sand Mining, Utilization and Environmental Impacts in the Niger Delta." *Journal of Environmental Geology* 2, no. 2: 64–67.

Australia Network News. 2013. "Philippines Detains Chinese for Illegal Mining." August 6. https://www.abc.net.au/news/2013-08-06/philippines-detained-18-chinese-for-illegal-black-sand-mining/4869348.

Beiser, Vince. 2017. "Sand Mining: The Global Environmental Crisis You've Probably Never Heard Of." *Guardian*, February 27. www.theguardian.com/cities/2017/feb/27/sand-mining-global-environmental-crisis-never-heard.

Bendixen, Mette, Jim Best, Chris Hackney, and L. L. Iversen. 2019. "Time Is Running Out for Sand." *Nature* 571 (July): 29–31. https://doi:10.1038/d41586-019-02042-4.

Binh, Doan Van, Sameh Kantoush, and Tetsuyi Sumi. 2020. "Changes to Long-Term Discharge and Sediment Loads in the Vietnamese Mekong Delta Caused by Upstream Dams." *Geomorphology* 353. https://doi:10.1016/j.geomorph.2019.107011.

Bravard, Jean-Paul. 2019. *Sedimentary Crisis at the Global Scale 2: Deltas, A*

Major Environmental Crisis. London: ISTE Ltd.

Centre for Science and Environment. 2022. *Sand Mining, India Environment Portal: Knowledge for Change*. http://www.indiaenvironmentportal.org.in/search/?q=sand+mining.

"Charon." 2021. https://en.wikipedia.org/wiki/Charon.

Coastal Care. 2021. "Sand Mining." https://coastalcare.org/tag/sand-mining/.

Datta, Damayanti. 2018. "Uncontrolled Sand Mining Led to Kerala Floods. This Is Only Waiting to Happen Again." *DailyO*, August 27. www.dailyo.in/variety/kerala-floods-sand-mining-sand-mafia-illegal-mining-soil-erosion-rivers/story/1/26297.html.

Gámez, Luna. 2020. "La Muerte de un Río Amazónico Asfixiado por las Hidroeléctricas y la Minería." *El Pais*, June 3. www.elpais.com/elpais/2020/05/12/planeta_futuro/1589279924_166617.html.

Gardner, John R., Xiao Yang, Simon N. Topp, Matthew R. V. Ross, Elizabeth H. Altenau, and Tamlin M. Pavelsky. 2021. "The Color of Rivers." *Geophysical Research Letter* 48, no. 1. https://doi:10.1029/2020GL088946.

Gray, Denis D. 2011. "Sand Mines Boom in Asia—at a Cost to Nature." *Associated Press*, August 22. https://www.nbcnews.com/id/wbna44230562.

Griggs, Gary. 2014. "Dams—Cutting off Our Beach Sand." *Our Ocean Backyard: Collected Essays*, 194–96. Self-published, CreateSpace Independent Publishing Platform.

Harder, Ben. 2001. "Flood Experiment Built Beaches." *Science*, July 17. www.sciencemag.org/news/2001/07/flood-experiment-built-beaches.

Hossain, Sulayman. 2021. "In Pictures: Illegal Sand Mining Threatens Bangladesh Farmland." *Al Jazeera*, January 11. www.aljazeera.com/gallery/2021/1/11/in-pictures-sand-extractions-puts-farmland-at-risk-in-bangladesh.

Kindu, Mizan, Esayas Aklilu, Meshesha Balkew, and Teshome Gebre-Michael. 2018. "Study on the Species Composition and Ecology of Anophelines in Addis Zemen, South Gondar, Ethiopia." *Parasites and Vectors* 11, no. 215. https://doi.org/10.1186/s13071018-2701-3.

Koehnken, Lois, and Max Rintoul. 2018. "Impacts of Sand Mining on Ecosystem Structure, Process and Biodiversity in Rivers." Washington, DC: World Wildlife. https://wwfint.awsassets.panda.org/downloads/sand_mining_impacts_on_world_rivers__final_.pdf.

Kondolf, G. M., Y. Gao, G. W. Annandale, G. L. Morris, E. Jiang, J. Zhang, Y. Cao, P. Carling, K. Fu, Q. Guo, R. Hotchkiss, C. Peteuil, T. Sumi, H.-W. Wang, Z. Wang, Z. Wei, B. Wu, C. Wu, and C. T. Yang. 2014. "Sustainable Sediment Management in Reservoirs and Regulated Rivers: Experiences from Five Continents." *Earth's Future* 2, no. 5: 256–80. https://doi:10.1002/2013EF000184.

Lasseter, Tom, and Rakteem Katakey. 2014. "When India Lost Its Student Engineers on Sand Mafia Path to Beas River." *Livemint*, December 17. www.livemint.com/Home-Page/X8NaZmnppusJGEr6CgNkoK/When

-India-lost-its-student-engineers-on-sand-mafia-path-to.html.

McCully, Patrick. 2001. "Dams and Geology: Morphological Effects." In *Silenced Rivers: The Ecology and Politics of Large Dams*, 33–35. New York: Blackwell. https://archive.internationalrivers.org/dams-and-geology.

Menon, Nikhil. 2018. "Illegal Sand Mining: India's Biggest Environmental Challenge?" *Weather Channel*, October 26. www.weather.com/en-IN/india/news/news/2018-10-26-illegal-sand-mining-indias-biggest-environmental-challenge.

Milliman, John D., and James P. M. Syvitski. 1992. "Geomorphic/Tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers." *Journal of Geology* 100, no. 5: 525–44. https://doi:10.1086/629606.

Niranjan, Ajit. 2021. "Sand Crisis: Mafias Thrive as Shortages Loom." *Deutsche Welle*, March 15. www.dw.com/en/sand-crisis-shortage-supply-mafia/a-56714226.

Padmalal, D., and K. Maya. 2014. *Sand Mining: Environmental Impacts and Selected Case Studies*. Dordrecht: Springer.

Rozsa, Matthew. 2021. "One in Three US Rivers Have Changed Color since 1984. Here's What This Means." *Salon*, January 3. www.salon.com/2021/01/03/one-in-three-us-rivers-have-changed-color-since-1984-heres-what-this-means/.

Sherman, Douglas, Kamron M. Barron, and Jean T. Ellis. 2002. "Retention of Beach Sands by Dams and Debris Basins in Southern California." *Journal of Coastal Research* 36, no. 1: 662–74. https://doi:10.2112/1551-5036-36. sp1.662.

Soleimani-Ahmadi, Moussa, Hassan Vatandoost, Ahmad-Ali Hanafi-Bojd, Mehdi Zare, Reza Safari, Abdolrasul Mojahedi, and Fatemeh Poorahmad-Garbandi. 2013. "Environmental Characteristics of Anopheline Mosquito Larval Habitats in a Malaria Endemic Area in Iran." *Asian Pacific Journal of Tropical Medicine* 6, no. 7: 510–15.

TeamLease RegTech Legal Research Team. 2020. "Enforcement and Monitoring Guidelines for Sand Mining." Supplement to *Sustainable Sand Mining Management Guideline-2016* (ssmg-2016). Ministry of Environment, Forest and Climate Change. Government of India, January 30. Accessed March 11, 2022. https://www.teamleaseregtech.com/legalupdates/article/7959/the-enforcement-and-monitoring-guidelines-for-sand-mining-2020/.

Torres, Aurora, Jodi Brandt, Kristen Lear, and Jianguo Liu. 2017. "A Looming Tragedy of the Sand Commons." *Science* 357, no. 6355: 970–71. https://doi:10.1126/science.aao0503.

Trout Unlimited. 2020. "Dam Removal." Accessed January 18, 2021. https://www.tu.org/blog/category/conservation/barriers/dam-removal/.

Vergil (Maro, Publius Vergilius). *The Aeneid*. Edited and translated by John Dryden. Book 6, 295. New York: P. F. Collier, 1697. http://data.perseus.org/citations/urn:cts:latinLit:phi0690.phi003.perseus-eng1:6.295-6.336.

VICE News. 2021. "Illegal Sand Mining Is Ruining These Countries' Ecosystems," September 11. https://www

.youtube.com/watch?v=H4d6LT87pMo.

Williams, Garnett P., and Harold P. Guy. 1973. "Erosional and Depositional Aspects of Hurricane Camille in Virginia, 1969." Professional Paper 805. Washington, DC: US Geological Survey.

World Wildlife Fund. 2018. "Uncovering Sand Mining's Impacts on the World's Rivers," August 24. www.wwf.panda.org/our_work/water/freshwater_news/?333451/Uncovering-sand-minings-impacts-on-the-worlds-rivers.

Zielinski, Sarah. 2013. "World's Rivers and Streams Leak a Lot of Carbon Dioxide." *Smithsonian Magazine*, November 20. www.smithsonianmag.com/science-nature/worlds-rivers-and-streams-leak-a-lot-of-carbon-dioxide-180947791/.

CHAPTER SIX. BARBUDA AND OTHER ISLANDS

Adams, Berta McKelly. 2017. "Removal of Sand from the Beaches Is Illegal." Government of the Virgin Islands, Press Release, November 8. www.bvi.gov.vg/media-centre/removal-sand-beaches-illegal.

Antigua Observer. 2017a. "Illegal Sand Mining on the Increase in Antigua," June 13. Accessed May 2, 2020. https://antiguaobserver.com/press-releaseillegal-sand-mining-on-the-increase-in-antigua.

Antigua Observer. 2017b. "Sand Mining Continues in Barbuda's National Park," April 21. www.antiguaobserver.com/sand-mining-continues-in-barbudas-national-park/.

Barbudaful. 2020. "The Barbuda Council." Accessed April 2, 2020. www.barbudaful.net/the-barbudaful-community/barbudaful-politics/local-government/.

Barbudaful. 2020. "Sand Mining." Accessed March 3, 2020. www.barbudaful.net/barbudaful-history/the-land-issue/sand-mining/.

Beiser, Vince. 2018. "How Sand Mining Helped Flood Houston." Pulitzer Center, February 12. www.pulitzercenter.org/stories/how-sand-mining-helped-flood-houston.

Bessell-Browne, Pia, Andrew P. Negri, Rebecca Fisher, Peta L. Code, Alan Duckworth, and Ross Jones. 2017. "Impacts of Turbidity on Corals: The Relative Importance of Light Limitation and Suspended Sediments." *Marine Pollution Bulletin* 117, nos. 1–2: 161–70. https://doi:10.1016/j.marpolbul.2017.01.050.

Boger, Rebecca, and Sophia Perdikaris. 2019. "After Irma, Disaster Capitalism Threatens Cultural Heritage in Barbuda." *NACLA*, February 11. Accessed June 25, 2020. https://nacla.org/news/2019/02/12/after-irma-disaster-capitalism-threatens-cultural-heritage-barbuda.

Brown, Desmond. 2013. "Facing Tough Times, Barbuda Continues Sand Mining Despite Warnings." *Inter Press Service*, June 22. www.ipsnews.net/2013/06/facing-tough-times-barbuda-continues-sand-mining-despite-warnings/.

Browne, Theodore. 2017. "Sand Mining in Brighton: A Blot on Government's Record." *Vincentian*, May 5. Accessed June 25, 2020. www.thevincentian.com/sand-mining-in

-brighton-a-blot-on-governments-record-p13174-133.htm.

Bush, David, William J. Neal, and Chester Jackson. 2009. "Summary of Puerto Rico's Vulnerability to Coastal Hazards: Risk, Mitigation and Management with Examples." *Special Paper of the American Geological Society* 460: 149–65.

Cambers, Gillian. 1997. "Beach Changes in the Eastern Caribbean Islands: Hurricane Impacts and Implications for Climate Change." In "Island States at Risk: Global Climate Change, Development and Population," edited by Stephen P. Leatherman. Special Issue, *Journal of Coastal Research*, no. 24: 29–47.

CIA. 2020. "Field Listing—Coastline." *World Factbook*. Accessed June 9, 2020. http://www.cia.gov/the-world-factbook/field/coastline/.

Coastal Care. 2013. "Pushing Grenada Backwards with Beach Sand Mining," June 21. Accessed May 2, 2020. https://coastalcare.org/2013/06/pushing-grenada-backwards-with-beach-sand-mining/.

Coastal Care. 2018. "Beach Sand Mining in Grenada Triggers Loss of Trees and Beach Erosion," November 20. https://coastalcare.org/2018/11/beach-sand-mining-in-grenada-triggers-loss-of-trees-and-beach-erosion/.

Conservation and Fisheries Department. n.d. *Legal Enforcement for the Environment of the British Virgin Islands*. Accessed June 15, 2020. Conservation and Fisheries Department. Government of the British Virgin Islands. www.bvi.gov.vg/sites/default/files/resources/surveillance_and_enforcement.pdf.

Convention on Biological Diversity. 2020. "Matrix for the Review of Implementation for the Programme of Work on Island Biodiversity." Accessed June 15, 2020. www.cbd.int/islands/doc/idr/voluntary-reports/RSPB-UK%20Overseas%20Territories-idr-en.pdf.

Eckert, Karen L., Julie A. Overing, and Bertrand B. Lettsome. 1992. "WIDECAST Sea Turtle Recovery Action Plan for the British Virgin Islands," ed. Karen L. Eckert. CEP Technical Report No. 15. Kingston, Jamaica: UNEP Caribbean Environment Programme. Accessed June 12, 2020. www.iwlearn.net/resolveuid/fbcd09f50d9a254070477c8a657a07b.

Elliott, Suzanne. 2019. "WVU Prof. Wants to Help People of Barbuda." Dominion Post, December 16. https://www.dominionpost.com/2019/12/16/wvu-prof-wants-to-help-people-of-arbuda/.

Erftemeijer, Paul L. A., Bernhard Reigl, Bert W. Hoeksema, and Peter A. Todd. 2012. "Environmental Impacts of Dredging and Other Sediment Disturbances on Corals: A Review." *Marine Pollution Bulletin* 64, no. 9: 1737–65. https://doi:10.1016/j.marpolbul.2012.05.008.

Fitzpatrick, Scott M. 2012. "On the Shoals of Giants: Natural Catastrophes and the Overall Destruction of the Caribbean's Archaeological Record." *Journal of Coastal Conservation* 15, no. 2: 173–86. https://doi:10.1007/s11852-010-0109-0.

Foundation for Puerto Rico. 2019. "Puerto Rico's Visitor Economy: Highlights," April 15. https://foundationforpuertorico.org/en

/foundation-for-puerto-ricos-visitor-economy-data-portal/.

Gelabert, Pedro A. n.d. "Environmental Effects of Sand Extraction Practices in Puerto Rico." Section B, in *Managing Beach Resources in the Smaller Caribbean Islands* (63–69). UNESCO/University of Puerto Rico Workshop. Accessed April 4, 2020. www.nsgl.gso.uri.edu/pru/pruw96001/pruw96001_pt-b1.pdf.

Global Facility for Disaster Reduction and Recovery. 2017. "Antigua and Barbuda: Hurricane Irma Post-Disaster Needs Assessment and Recovery Framework." ACP-EU Natural Disaster Risk Reduction Program. Accessed May 2, 2020. www.gfdrr.org/en/antigua-and-barbuda-hurricane-irma-post-disaster-needs-assessment-and-recovery-framework.

Global Legal Action Network (GLAN). 2020. "Land Grab and Wetland Destruction in Barbuda." Accessed July 15, 2021. www.glanlaw.org/barbudalandgrab. Gore, Shannon. 2011. "Beach Geomorphology and Management in the British Virgin Islands." PhD diss., University of Ulster.

Gould, Kenneth A., and Tammy L. Lewis. 2018. "Green Gentrification and Disaster Capitalism in Barbuda." *NACLA Report on the Americas* 50, no. 2: 148–53. https://doi:10.1080/10714839.2018.1479466.

Government of Grenada. 2010. The Workings of the Ministry of Carriacou and Petite Martinique Affairs: Newsletter, 1, no. 5. Accessed May 6, 2020. www.issuu.com/grenada/docs/carriacou_pm-vol_1_issue_5_oct-dec_2009/22.

Grenada Informer. 2016. "Sand Mining Dispute Resolved," May 18. www.thegrenadainformer.com/news/item/3199-sand-mining-dispute-resolved.

ILO (International Labor Organization). 2015. "Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies for All." Geneva. Accessed February 9, 2021. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf.

IPCC (Intergovernmental Panel on Climate Change). n.d. "How Is Life in the Sea Affected by Climate Change?" Frequently Asked Questions. Accessed January 2, 2021. www.ipcc.ch/srocc/about/faq/faq-chapter-5/.

Jamaica Observer. 2012. "Newspaper Editor Charged for Sand Mining," April 18. http://www.jamaicaobserver.com/news/Newspaper-editor-charged-for-sand-mining.

Joint Nature Conservation Committee. 2017. "Scope of a Natural Capital Assessment in the BVI." Accessed June 13, 2020. http://www.data.jncc.gov.uk/data/edca5b41-ef1c-48f4-a8f0-6c0fd1184340/OT-6-NCA-BVI-Scope-of-a-NCA-in-the-BVI.pdf.

Kanyuck-Abel, Chrystall. 2020. "Youngsters Join Effort to Restore BVI Mangroves." Government of the Virgin Islands. Department of Disaster Management, February 7. www.bvi.gov.vg/media-centre/youngsters-join-effort-restore-bvi-mangroves.

Knowlton, Nancy, and Ocean Portal Team. 2018. "Coral Reefs and Corals." *Smithsonian*. Accessed January 2, 2021. www.ocean.si.edu/ocean-life/invertebrates/corals-and-coral-reefs.

Lekomo, Ypolit Kemgang, Clautaire Mwebi Ekengoue, Aurel Douola, Rodrigue Fotie Lele, Guedjeo Christian Suh, Samuel Obiri, and Armand Kagou Dongmo. 2021. "Assessing Impacts of Sand Mining on Water Quality in Toutsang Locality and Design of Waste Water Purification System." *Cleaner Engineering and Technology* 2. https://doi:10.1016/j.clet.2021.100045.

Loerzel, Jarrod L., Theresa L. Goedeke, Maria K. Dillard, and Greg Brown. 2017. "SCUBA Divers above the Waterline: Using Participatory Mapping of Coral Reef Conditions to Inform Reef Management." *Marine Policy* 76 (February): 79–89. https://doi:10.1016/j.marpol.2016.11.003.

National Ocean Service. n.d. "Zooxanthellae: Corals Tutorial." National Oceanic and Atmospheric Administration. Accessed January 2, 2021. https://oceanservice.noaa.gov/education/tutorial_corals/coral02_zooxanthellae.html.

NBC News. 2008. "Sand Stolen across Caribbean for Construction," October 27. www.nbcnews.com/id/wbna27400598#. XuyfgJ5KhQI.

Now Grenada. 2013. "Sand Mining Areas Identified," July 12. http://www.nowgrenada.com/2013/07/sand-mining-areas-identified/07/sand-mining-areas-identified/.

Now Grenada. 2015. "Police Crack Down on Illegal Sand Mining," March 10. http://www.nowgrenada.com/2015/03/police-crack-illegal-sand-mining/.

Now Grenada. 2016. "Sand Mining Is Illegal," February 4. www.nowgrenada.com/2016/02/sand-mining-is-illegal/.

Office of the Prime Minister. 2001. "Antigua and Barbuda's First National Report to the Convention on Biological Diversity." Accessed February 5, 2020. www.cbd.int/doc/world/ag/ag-nr-01-en.pdf.

O'Marde, Dorbrene. 2016. "Country Document for Disaster Risk Reduction: Antigua and Barbuda, 2016." UN Office for Disaster Risk Reduction. Accessed July 17, 2020. www.preventionweb.net/files/54920_annex04drrcdantiguaandbarbuda.pdf.

Oxford Policy Management. 2011. "Montserrat Mining and Quarrying Industry, Final Report." Accessed February 8, 2021. https://silo.tips/download/montserrat-mining-and-quarrying-industry-study-final-report.

Parker, Hendren. 2002. "Caribbean Planning for Adaptation to Climate Change: Component 8: Formulation of Economic and Regulatory Mechanisms; Country Report: Antigua and Barbuda." Accessed June 24, 2020. www.oas.org/macc/Docs/CPACC_C8_ABReport.doc.

Parliament of Antigua and Barbuda. 1993. *Beach Protection (Amendment) Act (No. 6 of 1993)*. Accessed May 2, 2020. www.fao.org/faolex/results/details/en/c/LEX-FAOC018145.

Parliament of Antigua and Barbuda. 2007. *Barbuda Land Act, 2007 (No. 23 of 2007)*. Accessed May 2, 2020. http://www.ecolex.org/details/legislation/barbuda-land-act-2007-.

Peek, Katie, and Robert Young. 2012. "Isles Bay Beach, Montserrat." Coastal Care, Beach of the Month, March. https://coastalcare.org/2012/03/isles-bay-beach-montserrat/.

Pilkey, Orrin H., and J. Andrew G. Cooper. 2014. *The Last Beach*. Durham, NC: Duke University Press.

Pilkey, Orrin H., and Keith C. Pilkey. 2019. *Sea Level Rise: A Slow Tsunami on America's Shores*. Durham, NC: Duke University Press.

Potter, Amy E. 2011. "Transnational Spaces and Communal Land Tenure in a Caribbean Place: 'Barbuda Is for Barbudans.'" PhD diss., Louisiana State University.

Ramsar. 2014. "About the Convention on Wetlands." Accessed December 10, 2020. www.ramsar.org/about-the-convention-on-wetlands-0.

Ramsey, Vashti, J. Andrew G. Cooper, and Katherine L. Yates. 2015. "Integrated Coastal Zone Management and Its Potential Application to Antigua and Barbuda." *Ocean and Coastal Management*, part B: 259–74. https://doi:10.1016/j.ocecoaman.2015.04.017.

Rodriguez, Rafael. 2017. "Sand and Gravel Resources of Puerto Rico." US Geological Survey. Accessed June 18, 2020. www.pubs.usgs.gov/fs/sand-gravel/.

Ruiz, Andrea Handler, and Rojeanne Salles O'Farrill. 1988. *Wet-Pit Mining Impact Assessment: Coastal Zone of Puerto Rico*. San Juan, Puerto Rico: Department of Natural Resources. Accessed June 18, 2020. www.repository.library.noaa.gov/view/noaa/1769.

Schanche, Don A. 1989a. "Millionaire Sons Maneuver to Rule: Now Playing in Antigua; Real-Life Dynasty Drama." *Los Angeles Times*, April 19. www.latimes.com/archives/la-xpm-1989-04-19-mn-2059-story.html.

Schanche, Don A. 1989b. "Sands of Time Turn Unkind in Tiny Barbuda." *Los Angeles Times*, July 1. https://www.latimes.com/archives/la-xpm-1989-07-01-mn-2271-story.html.

Sluyter, Andrew, and Amy E. Potter. 2012. "Barbuda: A Caribbean Island in Transition." *Focus on Geography* 55, no. 4: 140–45.

Toro, Juan Ruiz. 2013. "Puerto Rico's Operation Bootstrap." Chapter 12, Essay #32, in *Modern Latin America*, edited by Thomas E. Skidmore, Peter H. Smith, and James N. Green, 8th ed. New York: Oxford University Press. Accessed June 18, 2020. https://library.brown.edu/create/modernlatinamerica/chapters/chapter-12-strategies-for-economic-developmen/puerto-ricos-operation-bootstrap/.

"Travel and Tourism: Economic Impact 2015; St. Vincent and the Grenadines." 2015. World Travel and Tourism Council. London. Accessed June 25, 2020. www.caribbeanhotelandtourism.com/wp-content/uploads/data_center/destinations/StVincentAndTheGrenadines-WTTC-EconomicImpact2015.pdf.

UNEP. 2008. (UN Environment Programme: Caribbean Environment Programme.) "Sedimentation and Erosion." Accessed May 4, 2020. www.unenvironment.org/cep/sedimentation-and-erosion.

UNEP. 2019. UN Environment Programme: GRID Geneva. "Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources." Accessed December 3, 2019. http://www.unepgrid.ch/en/resource/2AD54533.

US Agency for International Development. 2010. “Sand Mining in St. Vincent: Impacts and Options.” US Agency for International Development: Caribbean Open Trade Support.

US Environmental Protection Agency. n.d. “Threats to Coral Reefs.” Coral Reefs. Accessed January 2, 2021. www.epa.gov/coral-reefs/threats-coral-reefs#.

Water Science School. 2018. “Turbidity and Water.” US Geological Survey. June 6. Accessed January 2, 2021. www.usgs.gov/special-topic/water-science-school/science/turbidity-and-water?qt-science_center_objects=0#qt-science_center_objects.

World Bank. 2019. “St. Vincent and the Grenadines: First Fiscal Reform and Resilience Development Policy Credit.” Report No. 124773-vc. Accessed June 24, 2020. https://documents1.worldbank.org/curated/en/586591558118654567/pdf/St-Vincent-and-the-Grenadines-First-Fiscal-Reform-and-Resilience-Development-Policy-Credit-Project.pdf.

World Travel and Tourism Council. 2015. “Travel and Tourism: Economic Impact 2015; St. Vincent and the Grenadines.” London. Accessed June 25, 2020. www.caribbeanhotelandtourism.com/wp-content/uploads/data_center/destinations/StVincentAndTheGrenadines-WTTC-EconomicImpact2015.pdf.

Zhorov, Irina. 2018. “Puerto Rico’s Eroding Beaches Spell Trouble for Coastal Dwellers.” *The World*, September 19. www.pri.org/stories/2018-09-19/puerto-rico-s-eroding-beaches-spell-trouble-coastal-dwellers.

CHAPTER SEVEN. A SUMMONER’S THIRTEEN TALES

Aconcagua Resources. 2007. “Mineria de arena en Putú. Sand Summary profile.” Lima, Peru: Aconcagua Resources Publications.

Anthony, Edward. 2016. “Impacts of Sand Mining on Beaches in Suriname.” World Wildlife Fund report. Paramaribo: World Wildlife Fund.

“Beach Sand Mining, Chile; Video.” 2020. From: Noticias. “Se reanuda cuestionada extracción de arena en Boca Sur: municipio sampedrino evalúa nuevas medidas.” CoastalCare.org. www.canal9.cl/programas/noticias/2020/02/26/se-reanuda-cuestionada-extraccion-de-arena-en-boca-sur-municipio-sampedrino-evalua-nuevas-medidas.shtml. (Click on Activar Sonido.)

Clay, Rob. 2017. “Reserva de la Costa Atlántica de Tierra del Fuego Frente a la Extracción de Áridos.” Red Hemisférica de Reservas para Aves Playeras. September 27. www.whsrn.org/es/reserva-de-la-costa-atlantica-de-tierra-del-fuego-frente-a-la-extraccion-de-aridos/.

Darsan, Junior, Christopher Alexis, and Jason Barton. 2013. “Coastal Conservation Project: Status of Beaches and Bays in Tobago (2004–2008).” Port Spain: Institute of Marine Affairs.

Global Greengrants Fund. 2017. “Iron, Sand, and the Sweet Taste of Victory,” November 9. https://www.greengrants.org/2017/11/09/victory-in-chile/.

Gonçalves, Caroline C., and Paulo F. A. Braga. 2019. “Heavy Mineral Sands in Brazil: Deposits, Characteristics, and Extraction Potential of Selected Areas.” *Minerals* 9, no. 3:

176–81. https://doi:10.3390/min9030176.

Gracia, Adriana, Nelson Rangel-Buitrago, and Paola Florez. 2019. “Non-Native Plant Species in the Atlántico Department Coastal Dune Systems, Caribbean of Colombia: A New Management Challenge.” *Marine Pollution Bulletin* 141 (April): 603–10. https://doi:10.1016/j.marpolbul.2019.03.009.

INGEMMET. 2008. “Mineralizacion y Explotación Minera Artesanal en la Costa Sur Media del Perú.” Boletin 4, serie E. Lima: Instituto Geológico, Minero y Metalúrgico.

Isla, Federico. 2014. “Evaluación de áridos en el Litoral de Río Grande, Tierra del Fuego.” Informe Preliminar. Mar del Plata: Instituto de Geologia de Costas y del Cuaternario.

Marcomini, Silvia, and Rubén López. 1999. “Alteración de la Dinámica Costanera por Efecto de la Explotación de Arena de Playa, Partido de General Alvarado, Provincia de Buenos Aires.” *Revista de la Asociación Argentina de Sedimentología* 6, nos. 1–2: 1–18.

Marcomini, Silvia, and Rubén López. 2006. “Geomorfología Costera y Explotación de Arena de Playa en la Provincia de Buenos Aires y Sus Consecuencias Ambientales.” *Revista Brasileira de Geomorfologia* 7, no. 2: 61–71.

Muehe, Dieter, and Valentini Enise. 2003. “Danos Ambientais Provocados por Mineração Clandestina de Areia E Atividades Off-Road: Um Caso Extremo no Litoral do Rio De Janeiro.” *Planejamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa* 290, no. 1: 5–10.

Pool, Monique. n.d. “Environmental Organizations Oppose Beach Sand Mining at Braamspunt.” Green Heritage Fund. Accessed March 3, 2022. https://greenfundsuriname.org/environmental-organizations-oppose-beach-sand-mining-at-braamspunt/.

Rangel-Buitrago, Nelson, Giorgio Anfuso, and Allan Williams. 2015. “Coastal Erosion Along the Caribbean Coast of Colombia: Magnitudes, Causes and Management.” *Ocean and Coastal Management* 114: 129–44. https://doi:10.1016/j.ocecoaman.2015.06.024.

Rangel-Buitrago, Nelson, Manuel Contreras-López, Carolina Martínez, and Allan Williams. 2018a. “Can Coastal Scenery Be Managed? The Valparaíso Region, Chile as a Case Study.” *Ocean and Coastal Management* 163: 383–400. https://doi:10.1016/j.ocecoaman.2018.07.016.

Rangel-Buitrago, Nelson, Allan Williams, and Giorgio Anfuso. 2018b. “Hard Protection Structures as a Principal Coastal Erosion Management Strategy along the Caribbean Coast of Colombia: A Chronicle of Pitfalls.” *Ocean and Coastal Management* 156: 58–75. https://doi:10.1016/j.ocecoaman.2017.04.006.

Salazar, Diego, Victoria Castro, Jaie Michelow, Hernan Salinas, Valentina Figueroa, and Benoit Mille. 2010. “Minería y Metalurgia en la Costa Arreica de la Region de Antofagasta, Norte de Chile.” *Boletin del Museo Chileno de Arte Precolombino* 15, no. 1: 9–23.

UNEP 2019. (UN Environment Programme). 2019. “Sand and Sustainability: Finding New Solutions for Environmental Governance of Global

Sand Resources." Geneva: grid-Geneva. Accessed December 3, 2019. http://www.unepgrid.ch/en/resource/2AD54533.

CHAPTER EIGHT. A DIFFERENT KIND OF SAND MINING

Ammon, Francesca Russello. 2016. *Bulldozer: Demolition and Clearance of the Postwar Landscape*. New Haven, CT: Yale University Press.

Associated Press. 2008. "Caribbean Beaches Exposed to Tidal Surges Due to Sand Theft." *Fox News Network*, October 21. https://www.foxnews.com/story/caribbean-beaches-exposed-to-tidal-surges-due-to-sand-theft.

Beiser, Vince. 2018. *The World in a Grain: The Story of Sand and How It Transformed Civilization*. New York: Riverhead Books.

Black, Annetta. 2020. "Red Sands of Prince Edward Island." Atlas Obscura, edited by Rachel Allison. www.atlasobscura.com/places/red-sands-prince-edward-islands.

CBC News. 2008. "P.E.I. to Review Mining Sand from Beaches." June 12. http://www.cbc.ca/news/canada/prince-edward-island/p-e-i-to-review-mining-sand-from-beaches-1.743557.

CBC News. 2009. "Sand Mining Stopped on P.E.I. Beaches," May 1. https://www.cbc.ca/news/canada/prince-edward-island/sand-mining-stopped-on-p-e-i-beaches-1.805957.

Chrobak, Ula. 2019. "Your Favorite Pristine Beach Is Founded on Mass Invertebrate Death." *Popular Science*, August 6. www.popsci.com/beach-biodiversity-california-grooming/.

Coaldrake, J. E. 1979. "Coastal Sandmining and Landscape Rehabilitation in Eastern Australia." *Landscape Planning* 6: 359–74.

Coastal Care. 2020. "Sand Mining Database." https://coastalcare.org/sand-mining-database/.

Delestrac, Denis, dir. 2013. *Sand Wars: An Investigative Documentary*. Produced by Rappi Productions and La compagnie des Taxi-Brousse.

Fischler, Marcelle S. 2008. "Creating a Tribute to Men and a Mine." *New York Times*, August 22. www.nytimes.com/2008/08/24/nyregion/nyregionspecial2/24peopleli.html.

The Flood Hub. n.d. "Lincolnshire Beach Nourishment." n.d. Coastal NFM: Beach Nourishment. Accessed November 6, 2019. www.thefloodhub.co.uk/wp-content/uploads/2018/10/Coastal-NFM-Beach-Nourishment.pdf.

Fox, Alex. 2021. "Seafloor Trawl Fishing May Release as Much Carbon as Air Travel." *Smithsonian Magazine*, March 22. www.smithsonianmag.com/smart-news/bottom-trawl-fishing-releases-huge-amounts-carbon-180977288/.

Gayes, Paul T. 1991. "Post-Hurricane Hugo Nearshore Side Scan Sonar Survey: Myrtle Beach to Folly Beach, South Carolina." In "Impacts of Hurricaine Hugo: September 1–22, 1989." Special issue, no. 8, *Journal of Coastal Research* (Spring): 95–111.

Grabar, Henry. 2017. "South Florida, Out of Beach, Wants to Buy Sand from the Bahamas." *Slate*, November 2. www.slate.com/business/2017/11/south-floridas-beaches-are

-disappearing-and-the-state-wants-to-import-sand-from-the-bahamas.html.

Hayes, Miles O. [1967] 1974. "Hurricanes as Geological Agents: Case Studies of Hurricanes Carla, 1961, and Cindy, 1963." Bureau of Economic Geology, Report of Investigations No. 61. Accessed May 23, 2019. www.repositories.lib.utexas.edu/handle/2152/77760.

Hodge, Joshua Brian, Faisal Anzah, and Richard W. Dixon. 2018. "Miles O. Hayes, Hurricanes as Geological Agents: Case Studies of Hurricanes Carla, 1961, and Cindy, 1963, 1967." *Progress in Physical Geography: Earth and Environment* 42, no. 2: 257–64.

Kelley, Joseph T. 2013. "Popham Beach, Maine: An Example of Engineering Activity that Saved Beach Property without Harming the Beach." *Geomorphology* 199 (May): 171–78.

Kularatne, Ranil K. A. 2014. "Suitability of the Coastal Waters of Sri Lanka for Offshore Sand Mining: A Case Study on Environmental Considerations." *Journal of Coastal Conservation* 18: 227–47.

McCarthy, Eric. 2019. "Sand Mining Still Not Allowed on P.E.I." *Saltwire*, August 12. https://www.saltwire.com/prince-edward-island/news/sand-mining-still-not-allowed-on-pei-340653/.

Melius, Molly. 2017. "Impacts in the Southern Monterey Bay." Stanford Law School, Environmental Law Clinic, June 12. https://law.stanford.edu/2017/06/12/elc-weighs-in-on-sand-mining-impacts-in-the-southern-monterey-bay/.

Murphy, Bill, Jr. 2018. "United Airlines CEO Is Accused of Taking This Bizarre Thing from a Beach." *Inc.*, March 31. www.inc.com/bill-murphy-jr/united-airlines-ceo-is-accused-of-literally-stealing-sand-from-beach-yes-literally.html.

National Park Service. 2019. "Beach Scraping." US Department of the Interior. Last updated April 8, 2019. Accessed October 13, 2019. http://www.nps.gov/articles/beach-scraping.htm.

Neves, Luciana das. 2020. "Experiences with Beach Nourishments in Portugal." Coastal Wiki, Flanders Marine Institute. Accessed July 20, 2020. www.coastalwiki.org/wiki/Experiences_with_beach_nourishments_in_Portugal.

Nordstrom, Karl F., Nancy L. Jackson, Alana M. Rader, and Emir S. Garilao. 2018. "Protecting Natural Landforms and Habitats by Nourishing an Eroding Estuarine Beach." *Environmental Earth Sciences* 77, no. 680. https://doi:10.1007/s12665-018-7826-3.

Ogasa, Nikk. 2020. "Closing the CEMEX Plant: The Sands Will Be Shifting." *Monterey Herald*, November 14. Last updated November 16. www.montereyherald.com/2020/11/14/closing-the-cemex-plant-the-sands-will-be-shifting/.

Parry, Wayne. 2018. "Jersey Shore Beaches Get Explosive Surprise—Old War Munitions." *App.*, March 31. www.app.com/story/news/local/ocean-county/2018/03/31/beach-replenishment-munitions/33427167/.

Penketh, Anne. 2014. "Nice Beach Erosion Leads to Complaints from Swimmers." *Guardian*, August 3. www.theguardian.com/world/2014/aug/03

/nice-beach-erosion-complaints-swimmers-pebbles-slip.

Peterson, Charles H., and Melanie J. Bishop. 2005. “Assessing the Environmental Impacts of Beach Nourishment.” *BioScience* 55: 887–96. https://doi.org/10.1641/0006-3568(2005)055[0887:ATEIOB]2.0.CO;2.

Peterson, Charles H., Melanie J. Bishop, Galen A. Johnson, Linda M. D’Anna, and Lisa M. Manning. 2006. “Exploiting Beach Filling as an Unaffordable Experiment: Benthic Intertidal Impacts Propagating Upwards to Shorebirds.” *Journal of Experimental Marine Biology and Ecology* 338: 205–21. https://doi:10.1016/j.jembe.2006.06.021

Peterson, Charles H., Darren H. M. Hickerson, and Gina Grissom Johnson. 2000. “Short-Term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of a Sandy Beach.” *Journal of Coastal Research* 16, no. 2: 368–78.

Program for the Study of Developed Shorelines. 2020. “Beach Nourishment Database.” Western Carolina University. Accessed October 6, 2020. http://beachnourishment.wcu.edu/.

Rodriguez, Rafael W. 2017. “Sand and Gravel Resources of Puerto Rico.” Last modified, October 13, 2017. Fact Sheet, US Geological Survey, Guaynabo, Puerto Rico. Accessed June 9, 2019. www.pubs.usgs.gov/fs/sand-gravel/.

Rosov, Brad, Stephanie Bush, Tiffany Roberts Briggs, and Nicole Elko. 2016. “The State of Understanding the Impacts of Beach Nourishment Activities on Infaunal Communities.” ASBPA White Paper. *Shore and Beach* 84, no. 3: 51–55.

Rowling, Megan. 2021. “Carbon Emissions from Trawler Fishing on a Par with Aviation, Say Ocean Researchers.” *Devdiscourse*, March 17. www.devdiscourse.com/article/science-environment/1499181-carbon-emissions-from-trawler-fishing-on-a-par-with-aviation-say-ocean-researchers.

Sala, Enric, Juan Mayorga, Darcy Bradley, Reniel B. Cabral, Trisha B. Atwood, Arnaud Auber, William Cheung, Christopher Costello, Francesco Ferretti, Alan M. Friedlander, Steven D. Gaines, Cristina Garilao, Whitney Goodell, Benjamin S. Halpern, Audra Hinson, Kristin Kaschner, Kathleen Kesner-Reyes, Fabien Leprieur, Jennifer McGowan, Lance E. Morgan, David Mouillot, Juliano Palacios-Abrantes, Hugh P. Possingham, Kristin D. Rechberger, Boris Worm, and Jane Lubchenco. 2021. “Protecting the Global Ocean for Biodiversity, Food and Climate.” *Nature* 592 (March): 397–402. https://doi:10.1038/s41586-021-03371-z.

San Francisco Baykeeper. 2018. “Protecting Sand in the Bay Means More Sand for Ocean Beach,” April 10. www.baykeeper.org/blog/protecting-sand-bay-means-more-sand-ocean-beach.

Schmalz, David. 2016a. “Cemex Sand Mine Decision Anticipated before Year’s End.” *Monterey County Weekly*, August 18. https://www.montereycountyweekly.com/news/local_news/cemex-sand-mine-decision-anticipated-before-years-end/article_2aad918a-64bf-11e6-921a-1ff542066407.html.

Schmalz, David. 2016b. "County: Marina Sand Mine Operated Illegally Since 1965." *Monterey County Weekly*, May 27. www.montereycountyweekly.com/blogs/news_blog/county-marina-sand-mine-operated-illegally-since/article_12132318-2457-11e6-a840-8f249761655e.html.

Schooler, Nicholas K., Jenifer E. Dugan, and David M. Hubbard. 2019. "No Lines in the Sand: Impacts of Intense Mechanized Maintenance Regimens on Sandy Beach Ecosystems Span the Intertidal Zone on Urban Coasts." *Ecological Indicators* 106 (November): 105457. https://doi.org/10.1016/j.ecolind.2019105457.

Shodell, Elly, ed. 1985. *Particles of the Past: Sandmining on Long Island, 1870s–1980s*. Port Washington, NY: Port Washington Public Library.

Smith, Larry. 2017. "Tough Call: Why Bahamian Beaches Are Safe from the Excavators." *Tribune*, January 18. www.tribune242.com/news/2017/jan/18/tough-call-why-bahamian-beaches-are-safe-excavator/.

Smith, Stephen D. A., Matthew A. Harrison, and Jennifer Rowland. 2011. "The Effects of Beach Scraping on the Infauna of New Brighton Beach, Northern NSW." Report prepared for Byron Shire Council. Southern Cross University: National Marine Science Centre. Accessed March 9, 2019. www.yumpu.com/en/document/read/32935292/the-effects-of-beach-scraping-on-the-infauna-of-new-brighton-.

Smyth, Thomas A. G., and Patrick A. Hesp. 2015. "Aeolian Dynamics of Beach Scraped Ridge and Dyke Structures." *Coastal Engineering* 99 (May): 38–45.

Speybroeck, Jeroen, Dries Bonte, Wouter Courtens, Tom Gheskiere, Patrick Grootaert, Jean-Pierre Maelfait, Mieke Mathys, Sam Provoost, Koen Sabbe, Eric Stienen, Marc Van De Walle, Vera Van Lancker, Wouter Van Landuyt, Edward Vercruysse, Magda Vincx, and Steven Degraer. 2005. "How May Beach Nourishment Affect the Sandy Beach Ecosystem? The Case of Belgian Beaches." In *Proceedings "Dunes and Estuaries 2005"—International Conference on Nature Restoration Practices in European Coastal Habitats, Koksijde, Belgium, 19–23 September 2005*, edited by Jean-Louis Herrier, Jan Mees, Albert Salman, Jan Seys, Hannah Van Nieuwenhuyse, and Ingrid Dobbelaere, 557–68. VLIZ Special Publication 19. Ostend, Belgium: Vlaams Instituut voor de Zee (Flanders Marine Institute).

Steimle, Susie. 2018. "Corporate Sand Mining in SF Bay Sparks 'Sand Wars.'" *KPIX CBS SF BayArea*, December 3. https://sanfrancisco.cbslocal.com/2018/12/03/corporate-sand-mining-in-sf-bay-sparks-sand-wars/.

"Stop CEMEX Sand Mining." July 13. www.surfrider.org/campaigns/cemex-sand-mining.

Surfrider Foundation. 2017. Welland, Michael. 2009. "Building New York—the Long Island Sandminers." *Through the Sandglass* (blog), February 4. https://throughthesandglass.typepad.com/through_the_sandglass/2009/02/building-new-york-the-long-island-andminers.html.

Wells, John T., and Jesse McNinch. 1991. "Beach Scraping in North Carolina with Special Reference to Its Effectiveness during Hurricane Hugo." Special issue, *Journal of Coastal Research* 8: 249–61.

CHAPTER NINE. AFRICA SANDS

Abderrahmane, Abdelkader. 2021. "Organised Crime in Africa/Illegal Sand Extraction Threatens Morocco's Tourism Economy." *ENACT Observer*, April 27. https://enactafrica.org/enact-observer/illegal-sand-extraction-threatens-moroccos-tourism-economy.

Africa Times. 2018. "China Dismissed Amnesty Report on Mozambique Mining Damage," April 5. https://africatimes.com/2018/04/05/china-dismisses-amnesty-report-on-mozambique-mining-damage/.

Amnesty International. 2018. "'Our Lives Mean Nothing': The Human Cost of Chinese Mining in Nagonha, Mozambique." AFR 41/7851/2018. www.amnesty.org/download/Documents/AFR4178512018ENGLISH.PDF.

Amrouni, Oula, Abderraouf Hzami, and Essam Heggy. 2019. "Photogrammetric Assessment of Shoreline Retreat in North Africa: Anthropogenic and Natural Drivers." *ISPRS Journal of Photogrammetry and Remote Sensing, Science Direct* 157 (November): 73–92. https://doi:10.1016/j.isprsjprs.2019.09.001.

Anderson, Stacey Stanfield, Kiki Patsch, and Raquel Baker. 2020. "Eroding the Future: Telling the Story of Sand Mining, Climate Change, and Environmental Justice in Coastal South Africa." In "Rhetorics and Literacies of Climate Change." Special issue, *Enculturation: A Journal of Rhetoric, Writing, and Culture*, 32. www.enculturation.net/erodingthefuture.

Barwell, Laurie. 2016. "Coastal Mining and Its Influence on Coastline Stability." In *Regional State of the Coast Report: Western Indian Ocean*, edited by José Paula, 360–71. Nairobi, Kenya: UNEP/Nairobi Convention Secretariat. https://doi:10.18356/9ce803e8-en.

Beiser, Vince. 2018. *The World in a Grain: The Story of Sand and How It Transformed Civilization*. New York: Riverhead Books.

Bloom, Laura Begley. 2017. "The 27 Most Beautiful Beaches in the World." *Forbes*. https://www.forbes.com/sites/laurabegleybloom/2017/06/28/the-27-most-beautiful-beaches-in-the-world/?sh=57708cf16f4f.

Carvalho, Fernando P. 2017. "Mining Industry and Sustainable Development: Time for Change." *Food and Energy Security* 6, no. 2: 61–77. https://doi:10.1002/fes3.109.

Carvalho, Fernando P., Obete F. Matine, Suzete Taimo, João M. Oliveira, Lidia Silva, and Margarida Malta. 2014. "Radionuclides and Radiation Doses in Heavy Mineral Sands and Other Mining Operations in Mozambique." *Radiation Protection Dosimetry* 158, no. 2 (January): 181–86. https://doi:10.1093/rpd/nct202.

Coastal Care. 2020a. "470,000 U.S. Dollars Worth of Illegally Mined Sand Seized in 2019, Algeria," May 15. Accessed October 12, 2020. https://coastalcare.org/2020/05/470000-us-dollars-worth-of-illegally-mined-sand-seized-in-2019-algeria/.

Coastal Care. 2020b. Sand Mining Updates. Accessed 2018–2021. https://coastalcare.org/sections/inform/sand-mining/.

Delestrac, Denis, dir. 2013. *Sand Wars: An Investigative Documentary*. Produced by Rappi Productions and La compagnie des Taxi-Brousse.

Eliason, Margot. 2019. "UN Report: Sand Mafias Are Destroying Moroccan Beaches." *Morocco World News*, May 13. www.moroccoworldnews.com/2019/05/272951/un-sand-mafias-moroccan-beaches/.

Fröhlich, Silja. 2017. "Sand Mining Decimates African Beaches." *Deutsche Welle* (DW), February 15. https://www.dw.com/en/sand-mining-decimates-african-beaches/a-37546330.

Goswami, Subhojit. 2018. "This Coastal Village in Mozambique Now at the Mercy of Chinese Mining Company." *Down To Earth*, April 11. www.downtoearth.org.in/news/mining/mozambique-s-coastal-village-at-mercy-of-chinese-mining-company-60121.

Greene, Matthew. 2016. "Why Are Beaches Disappearing in Morocco?" *Middle East Eye*, September 1. www.middleeasteye.net/features/why-are-beaches-disappearing-morocco.

Jonah, F. E., N. W. Agbo, W. Agbeti, D. Adjei-Boateng, and M. J. Shimba. 2015. "The Ecological Effects of Beach Sand Mining in Ghana Using Ghost Crabs (*Ocypode Species*) as Biological Indicators." *Ocean and Coastal Management* 112 (August): 18–24. https://doi:10.1016/j.ocecoaman.2015.05.001.

Jonah, Fredrick E., O. Adams, D. W. Aheto, R. E. Jonah, and E. A. Mensah. 2017. "Coastal Zone Management Challenges in Ghana: Issues Associated with Coastal Sediment Mining." *Journal of Coastal Conservation* 21, no. 3: 343–53. https://doi:10.1007/s11852-017-0511-y.

Jonah, Fredrick Ekow, Daniel Adjei-Boateng, Nelson Winston Agbo, Emmanuel Abeashi Mensah, and Regina Esi Edziyie. 2015. "Assessment of Sand and Stone Mining Along the Coastline of Cape Coast, Ghana." *Annals of GIS* 21, no. 3: 223–31. https://doi:10.1080/19475683.2015.1007894.

Kanu, Ramatu. 2013. "How Illegal Sand Mining in Sierra Leone Is Destroying the Local Beaches." *Ecologist*, April 3. www.theecologist.org/2013/apr/03/how-illegal-sand-mining-sierra-leone-destroying-local-beaches.

Kenya Team of Young Environmental Journalists. 2020. "Growing Youth Activism for Environmental Protection in Africa." *Inter Press Service*, April 6. http://www.ipsnews.net/2020/04/growing-youth-activism-environmental-protection-africa/.

Liberte Algeria. 2020. "Jijel: Le pillage de sable menace le littoral," February 10. https://www.liberte-algerie.com/est/jijel-le-pillage-de-sable-menace-le-littoral-333622.

Lotayef, Dahlia. 2016. "West African Countries Commit to Common Vision for Coastal Resilience." *World Bank Blogs*, December 20. www.blogs.worldbank.org/africacan/west-african-countries-commit-to-common-vision-for-coastal-resilience.

Mafaranga, Hope. 2020. "Sea Level Rise May Erode Development in Africa." *Eos*, November 13. https://doi:10.1029/2020EO151568.

Masterson, Miles. 2021. "Miners Are Ripping Up the West Coast." *Daily Maverick*, January 9. www.dailymaverick.co.za/article/2021-01-09-miners-are-ripping-up-the-west-coast/.

Mensah, John Victor. 1997. "Causes and Effects of Coastal Sand Mining in Ghana." *Singapore Journal of Tropical*

Geography 18, no. 1: 69–88. https://doi:10.1111/1467-9493.00005.

New Humanitarian. 2013. "Sand-Mining Threatens Homes and Livelihoods in Sierra Leone," February 1. www.thenewhumanitarian.org/news/2013/02/01/sand-mining-threatens-homes-and-livelihoods-sierra-leone.

Okanla, Karim. 2015. "Benin Seeks to Avert Sea Disaster." *BBC News*, September 6. www.news.bbc.co.uk/2/hi/africa/4216902.stm.

Quérouil, Manon, and Véronique de Viguerie. 2015. "Trucks and Children Are Sucking the Beaches of Morocco Dry." *VICE News*, May 18. www.vice.com/en_us/article/exqxgw/the-sand-looters-0000647-v22n5.

Safaris Africana. 2020. "The Nine Deserts of Africa: Everything You Need to Know about African Deserts." Accessed February 16, 2021. www.safarisafricana.com/deserts-in-africa/.

Schüler, Doris, Matthias Buchert, Ran Liu, Stefanie Dittrich, and Cornelia Merz. 2011. "Study on Rare Earths and Their Recycling: Final Report for The Greens/EFA Group in the European Parliament." Freiburg: Öko-Institut. Accessed July 8, 2019. www.oeko.de/oekodoc/1112/2011-003-en.pdf.

Surfrider Foundation Maroc. 2019. "Prélèvement de sable sur la baie d'Imsouane!!!!" Video on Facebook., March 8. Accessed March 12, 2021. http://www.facebook.com/354713094650445/videos/642963776142106/?__so__=channel_tab&__rv__=all_videos_card.

Taylor, Mark. 2017. "Child Labor, Learning Problems, and Poverty." *Journal of Education and Practice* 6, no. 11 (May 1): 134–47. https://files.eric.ed.gov/fulltext/ED580822.pdf.

UNEP. 2019. (UN Environment Programme). "Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources." 2019. grid-Geneva. Accessed December 3, 2019. http://www.unepgrid.ch/en/resource/2AD54533.

CHAPTER TEN. BEACH MINING

Bendixen, Mette, Irina Overeem, Minik T. Rosing, Anders Anker Bjørk, Kurt H. Kjær, Aart Kroon, Gavin Zeitz, and Lars Lønsmann Iversen. 2019. "Promises and Perils of Sand Exploitation in Greenland." February 11. *Nature Sustainability* 2: 98–104.

Debusmann, Bernd, Jr. 2021. "Using Plastic Waste to Help Solve Sand Shortages." *BBC News*, July 18. www.bbc.com/news/business-57832425.

Pilkey, Orrin H., Jr, William J. Neal, Orrin H. Pilkey Sr., and Stanley R. Riggs. 1980. *From Currituck to Calabash: Living with North Carolina's Barrier Islands*, 2nd ed. Durham, NC: Duke University Press.

Rosenwald, Michael. 2011. "Building a Better World with Green Cement." *Smithsonian Magazine*, December. www.smithsonianmag.com/science-nature/building-a-better-world-with-green-cement-81138/.

Stone, Katherine E., and Benjamin S. Kaufman. 1988. "Sand Rights: A Legal System to Protect the Shores of the Sea." *Journal of the American Shore and Beach Preservation Association* 56: 8–14.

UNEP. 2020. (UN Environment Programme). "Mineral Resource Governance in the 21st Century: Gearing Extractive Industries Towards Sustainable Development." Report by the International Resource Panel. Nairobi, Kenya. http://www.resourcepanel.org/reports/mineral-resource-governance-21st-century.

APPENDIX B

Dean, Cornelia. 1999. *Against the Tide: The Battle for America's Beaches*. New York: Columbia University Press.

Ewing, Lesley, Orville T. Magoon, and Sheila Robertson, eds. 2000. *Sand Rights '99: Bringing Back the Beaches: Conference Proceedings: September 23–26, 1999, Holiday Inn Ventura Resort, Ventura, California*. Reston, VA: American Society of Civil Engineers.

Stone, Katherine E. 2000. "Sand Rights: A Legal System to Protect the Shores of the Sea." *Stetson Law Review* 29, no. 3: 709–32.

Stone, Katherine E., and Benjamin S. Kaufman. 1988. "Sand Rights: A Legal System to Protect the Shores of the Sea." *Journal of the American Shore and Beach Preservation Association* 56: 8–14.

Stone, Katherine E., Orville Magoon, Billy Edge, and Lesley Ewing. 2005. "Sand Rights." In *Encyclopedia of Coastal Science*, ed. Maurice L. Schwartz, 1466–68. Encyclopedia of Earth Science Series. Dordrecht: Springer. https://doi.org/10.1007/1-4020-3880-1_266.

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