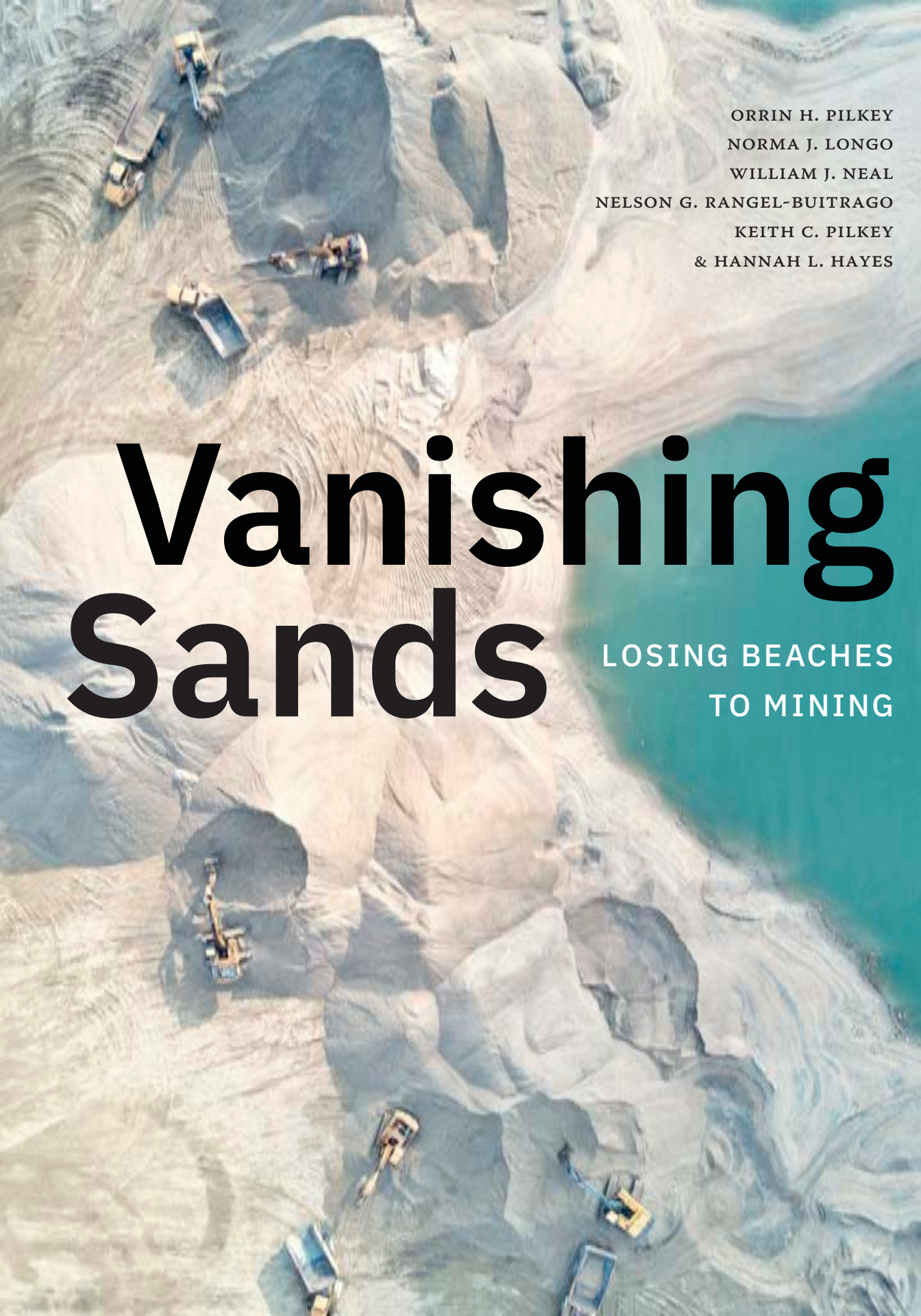


An aerial photograph showing a massive sand mining operation. Several yellow excavators and large blue trucks are visible, working on a vast, light-colored sand dune. The machinery is creating deep tracks and large pits in the sand. To the right, a body of turquoise water meets the shore.

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# Vanishing Sands

LOSING BEACHES  
TO MINING

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BUY

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DUKE

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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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## 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<sub>2</sub> 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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PREFACE

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## ACKNOWLEDGMENTS

Significant recognition of the coastal sand-mining problem has already been publicized by Coastal Care ([coastalcare.org](http://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 not 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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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 irreg-

ular 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](http://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.

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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 downdrift 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 truck-load. 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 Thiel.

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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, non-industrial 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

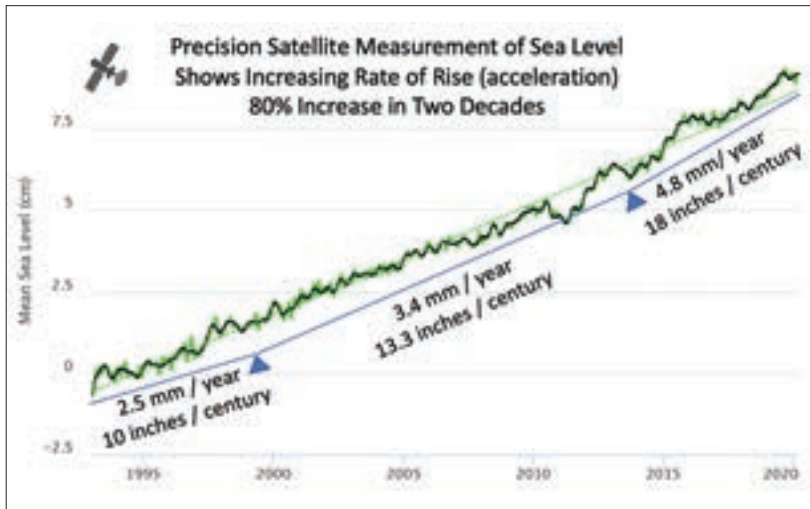
The fourth major type of coastal mining is taking sand to rebuild beaches, to provide a recreational beach, and to protect shorefront development and infrastructure. Commonly, sand is dredged from the adjacent continental shelf and pumped up onto the beach, essentially creating an artificial beach. Sometimes 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](http://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 trifolius*), 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.

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## 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 antimin- ing 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.

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