



Artificial islands were constructed inside the lagoon of Addu Atoll in the Maldives to create space for new resorts.

BUILDING ISLANDS IN THE OCEAN

The Maldives is expanding its territory by dredging up sediment from the ocean floor. But scientists say such reclamation can harm marine ecosystems and make the country more vulnerable to rising seas.

By Jesse Chase-Lubitz



80% of its land less than one metre above sea level, some scientists predict that the islands could be completely submerged by 2100.

In an effort to keep the country above water and thriving, the government is adopting a strategy used by many nations around the globe: land reclamation. The sandy stretch in front of Shaiz's hotel is some of the newest land on the planet, dug up from the bottom of the ocean, sucked through pipes and piled along the coast to make more space.

Maldivian government officials say that the land is necessary to make room for economic development, especially as sea levels rise.

"This will be a doorstep, a job destination and an income-generating destination," said President Mohamed Muizzu at the inauguration of a new land-reclamation project last December.

Critics are unconvinced, and say that the country has enough space to thrive. One swathe of land on a neighbouring island near Shaiz's hotel was reclaimed in 2016. It remains undeveloped today. "Call me in five years," Shaiz says, gesturing to the newly created desert in front of his hotel. "This land will be the same."

In addition to the disputed economics, there is serious concern about the environmental damage that land reclamation can cause. Studies in the Maldives and at other sites around the world have shown that it can harm corals and seagrass, damage natural barriers, such as sand bars, mangroves and estuaries, and destroy marine habitats. "Atolls are extremely vulnerable ecosystems," says Bregje van Wesenbeeck, the scientific director of Deltares, a Dutch research institute for water management in Delft. "Once you start to interfere with them, you're sort of failing them."

Expanding territories

Dutch planners are often considered the founders of land reclamation, with a history of water engineering going back some 800 years. Over the centuries, land-forming projects have shaped some of the world's major cities, including Singapore, London, New York and Miami. In recent decades, most of the reclaimed land has been in East Asia. In China, Shanghai has reclaimed 350 square kilometres – more than three times the size of Paris – over the past few decades. Colombo has added 100 km² in just 4 years, and 65 km² of Mumbai is reclaimed. A study on twenty-first-century coastal-land reclamation found that of 135 large coastal cities with populations of more than one million people, 75% had reclaimed land¹.

With projects stretching back to 1997, the Maldives is a veteran of large-scale land reclamation. Then-minister of state for environment Abdulla Naseer said in 2018 that there are an estimated 50 islands with reclaimed land in the country, although many specialists say that's a conservative estimate.

Land scarcity is a key factor driving reclamation projects. Although the nation's territory

covers 90,000 km², more than 99% of it is ocean (see 'Islands at risk'). Around half a million people live on a total land area of just 300 km², and the country welcomes around 1.3 million tourists each year, who contribute 80% of its gross domestic product. The capital, Malé, is one of the most densely populated parts of the planet. It's possible to walk across the entire island in 20 minutes.



**ATOLLS ARE
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The Maldives' 1,200 islands are all atolls – rings of coral reef that surround lagoons. When the government decides to reclaim land, it takes sand from the lagoons using boats outfitted with suction pipes, which collect sand and coral debris from the ocean floor like giant vacuum cleaners. The boat then deposits the material in a different spot, either inside or outside the atoll, to form new land. Sometimes reclamation projects fill in the entire lagoon.

Environmental damage

Addu Atoll, the site of Shaiz's hotel, is about two hours south of Malé by aeroplane. Its rich coral reefs support more than 1,200 species of fish – one of the factors that led the United Nations cultural organization UNESCO to include the atoll in its World Network of Biosphere Reserves in 2020.

Some of the islands are so narrow that you can almost always see water on both sides while standing in the centre. It's a largely quiet and rural place that feels forgotten. Yet construction marches on.

The Ministry of National Planning, Housing and Infrastructure announced the Addu Development Project in 2021, aiming to reclaim parts of the atoll and develop a road connection between existing islands. One of the ministry's justifications is that it will provide extra housing. In the Maldives, land for houses is given away to eligible individuals and families. Addu City's mayor, Ali Nizar, says that there have been more than 5,000 requests for housing since he entered office in 2021. "We need land," he says. "There's no other way."

Because Addu has one of the few international airports in the country, the hope is also that the extra land will attract international investment. "With this huge expansion project, the transformational development of Addu City has commenced," said former

"Sun, sand and sea." Those are the three ingredients for tourism in the Maldives, Mohamed Shaiz's father told him. For more than a decade, Shaiz's family owned a successful local hotel in Addu, the Maldives' southernmost atoll. But nearly 9 months ago, the government took away the sea.

A state-sponsored project had pulled up sediment from offshore areas and used it to extend the beach in front of the hotel by 130 metres – too far to walk for most tourists who want easy access to the ocean. Now all Shaiz sees from his hotel is a human-made desert and a slew of cancelled reservations.

The Maldives is an 820-kilometre-long chain of nearly 1,200 islands dotting the Indian Ocean. The nation has become one of the most popular luxury tourism destinations in the world because of its Instagrammable beaches and its advertising slogan: "the sunny side of life". But the Maldives is also one of the countries most vulnerable to sea-level rise. With

Feature

president Ibrahim Mohamed Solih after inaugurating the project in June 2023.

The project has been controversial from the start. When it was announced, Ibrahim Mohamed was sitting at his desk at the Maldives' Environmental Protection Agency (EPA) in Malé. He instantly had concerns about how the project would affect Addu. Mohamed grew up in Addu in the 1970s, taking walks through the massive seagrass beds near his home. He remembers watching stingrays surf the waves, and marvelling at fiddler crabs along the shore.

Mohamed led the environmental impact assessment (EIA) process for land-reclamation projects. When the Addu proposal landed on his desk, he contracted an environmental consulting group called Water Solutions, headquartered in Malé, to do the review.

The report, published in February 2022 (see go.nature.com/49zhjat), found that “the proposed reclamation is well received by the community” and that there was “high interest to implement the project based on the potential economic benefits”. But it also concluded that “long-term irreversible negative impacts will be generated from the project” for both the environment and the community, including by destroying coral reefs and seagrass meadows and harming the fishing and tourism industries.

“It was sufficient enough for the EPA to reject the project,” Mohamed says. “But they didn’t.” In May 2022, he quit his job after 10 years at the agency.

After the report came out, the EPA pushed for changes, such as a smaller area from which the project would source sand. “We tried to change the scope because we are here to protect the environment and at the same time, help development,” says the agency’s director-general, Ibrahim Naeem. “Development has to go hand in hand with environment. It should not destroy the environment,” he says.

Once the changes were made to the proposed project, Water Solutions produced a second report at the end of September 2022 (see go.nature.com/49zhjat). It found



Humay Abdulghafoor has sued the government over reclamation projects.

that the altered project, with increased mitigation and monitoring in place, would still have irreversible negative impacts – ranging from moderate to major – on marine plants and animals, protected and sensitive areas, tourism, fisheries and recreational activities.

The assessment calculated that the cost of the damage to coral reefs alone would be between US\$340 million and \$851 million.

The September 2022 report does not offer explicit recommendations. “Our role is to share the information. We just wanted to present the facts,” says Ahmed Jameel, managing director of Water Solutions and one of the authors of the report. However, he adds, the assessment was not vague in its conclusions. The findings showed clearly that the project “would have an overall negative impact”, he says.

When asked about the concerns raised in the second report, Naeem says that the findings,

combined with insights he received from EPA staff members who conducted anonymous reviews of the EIA, indicated that there was “enough justification in the report to approve it in terms of social benefit”.

“Any development projects in this type of environment, especially in the marine area, will have an impact,” he says, adding that “if you do reclamation properly, and if you do it wisely, I think impacts can be minimized”.

The Dutch company responsible for doing the construction on the project, Van Oord, told *Nature* that environmental management for the project is overseen by the EPA and that it is working with the agency and local specialists to minimize the environmental impacts. Van Oord said it prepared a comprehensive environmental management plan “based on the mitigation measures mandated in the EIA and in compliance with international guidelines”. As part of its efforts, the company relocated coral and seagrass, and added silt screens to limit how much sediment would flow beyond the reclamation zone and affect other areas.

Van Oord, which is based in Rotterdam, the Netherlands, told *Nature* that “all the predicted impacts have been effectively managed by implementing a series of mitigation measures”.

In October 2022, the EPA approved the project. But critics say the environmental costs of the reclamation are too high.

“I think their efforts are not worth the amount of destruction and the irreversible damage,” says Mohamed. “It can never be compensated properly.”

Today, the land in front of Shaiz’s hotel is the result of that decision. Yet if you speak to people on Addu, many say that land is not what they need right now; they need jobs. Much of Addu is filled with empty, unfinished homes because individuals don’t have the income or resources to build houses on their free land.

“Fifty per cent [of our land] is abandoned or empty,” says Addu’s former deputy mayor, Abdullah Thoyyib, who served the city before this reclamation project took place. “We need economic benefits and job opportunities, but that’s not happening.”

Dead corals

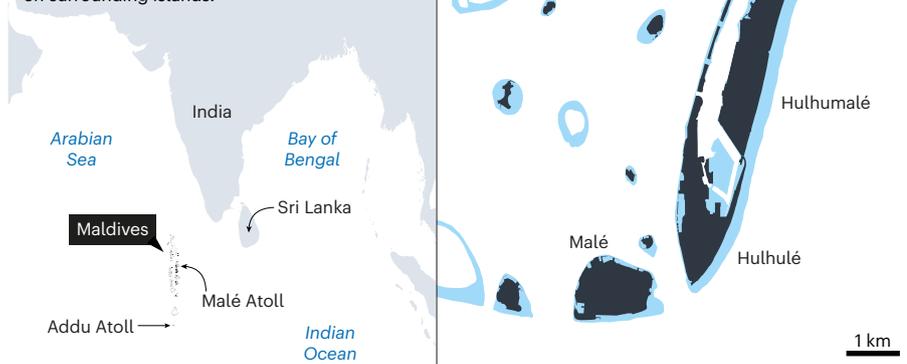
Sitting in a resort in Addu City, Nisal Musthag places a map of Addu’s main diving spots on the table. Musthag leads diving trips for one of the two active resorts in the atoll, and he has seen some of the damage that follows reclamation projects. He points at one of the four channels between the island’s lagoon and the ocean. “This is like a cemetery now,” he says.

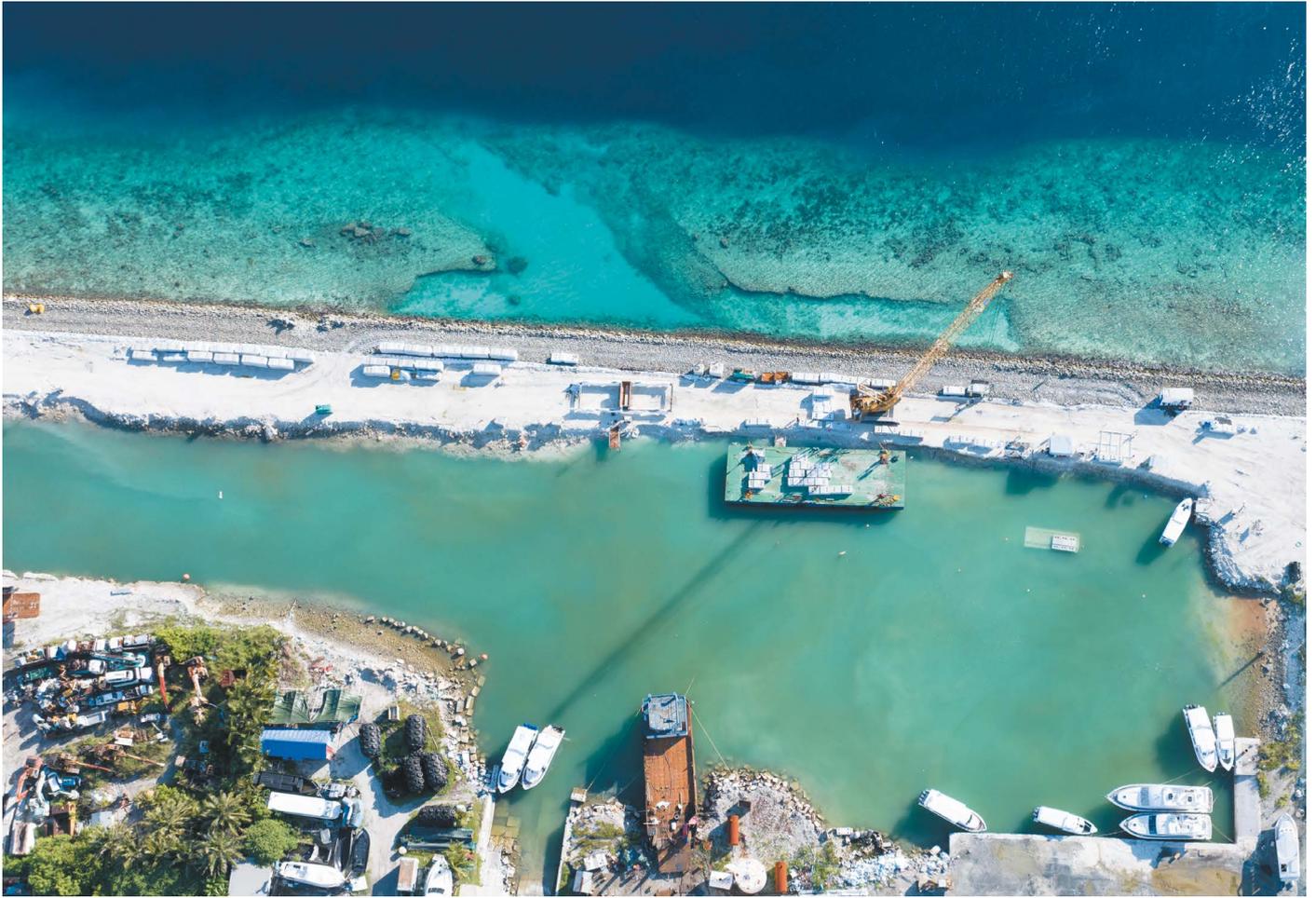
Musthag does three to four dives a day, six days a week. Since the most-recent reclamation, there are at least five sites he no longer takes guests to. “There are people who come back every year to dive, and this year they were like, hey, what’s happening?”

The impacts of reclamation on coral health

ISLANDS AT RISK

About 80% of the land area in the Maldives is less than one metre above sea level. Most of the population lives in the capital Malé and on surrounding islands.





Reclamation projects in the Maldives can fill the water with sediment, threatening coral reefs.

are one of researchers' main concerns. Some reefs die when sediment is dumped on them to create new land. But even corals that escape direct damage can be harmed because the construction work creates clouds of sediment that spread out and settle on more distant reefs. Robbed of light and nutrients, these corals can struggle to survive. The damage to reefs not only harms the ecosystem but can also leave the islands vulnerable to storms and sea-level rise, say scientists.

To reduce damage to corals during the work at Addu, the EIA required that at least 10% of existing corals be relocated outside the reclamation footprints. Van Oord says it has moved 73,000 corals to 9 recipient sites identified in conjunction with the EPA. The firm says that it "certainly surpassed the EIA requirement".

Saleem Rasheed is one of several local divers who helped to relocate the corals. He has been monitoring them for the past year. One species, blue coral (*Heliopora coerulea*), which was moved from the outside of the atoll to the inside, died completely. "We moved 80 colonies," says Rasheed. "They survived one week and died entirely after six months."

But the rest of the species have shown resilience. Three months after relocation, they were struggling, but now, Rasheed says, they

are alive and well.

Researchers have found that coral relocation can work if colonies are moved to areas with similar conditions that are protected from waves. A 2017 study in Hawaii, for example, showed that relocated corals were thriving a decade after they were moved². One study on coral restoration and relocation in the Maldives measured the survival rate of 242 coral fragments

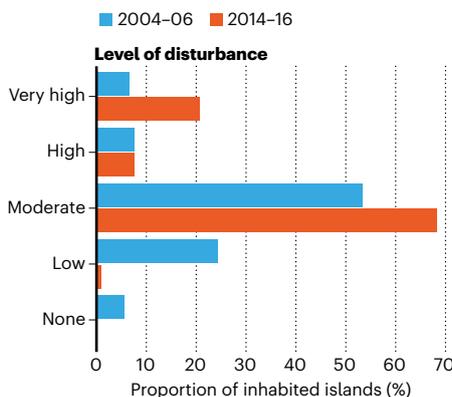
12 months after they had been moved³. The authors found a 70% survival rate, which they concluded was a promising result.

But coral health is only one concern for researchers studying the effects of reclamation. Mangroves, seagrass beds and coastal ecosystems can also be in harm's way, say scientists.

Water Solutions' second report about the Addu project, for example, projected that the reclamation process would bury about 98 hectares of seagrass meadow in the atoll's lagoon, at an estimated economic cost of more than \$3.7 million a year.

ALTERED ISLANDS

A study of 107 inhabited islands in the Maldives assessed the level of human disturbance to the shorelines and reefs. The number of islands showing moderate to very high levels of disturbance rose substantially over a decade.



Uncertain future

Not far from Shaiz's hotel, a sea wall stretches towards the horizon, protecting a new swathe of land made of sand and coral debris. Coastal protection efforts such as the sea wall – and the changes wrought by reclamation – could have long-lasting effects on the processes that keep the islands from eroding, say researchers.

Like other atolls, the Maldivian islands evolve with the seasons, with monsoons moving sand around them. Between December and February, the winds transport sand from the northeast to the southwest. Between June and August, the pattern reverses.

"In a natural island, you will see seasonally



The beach in front of Mohamed Shaiz's hotel on Addu Atoll was extended by 130 metres.

the sand shifting with the waves and the currents," says Mohamed. But reclamation can impede this process, he adds, by taking sand and coral debris from some locations through dredging – leaving a deficit in its wake – and depositing it where natural flows wouldn't. Some projects add another complication by building hard barriers, such as sea walls, to protect the land, because they can stop the natural flow of sediments.

"Ecosystems can adapt if we allow them to," says van Wesenbeeck at Deltares. "By interfering, you will kill the whole system in the end."

Not only does this change how the island naturally maintains itself, but it can also draw development to places that are at a high risk of a storm surge or erosion, say some researchers.

"Islands can't occur anywhere," says Virginie Duvat, a coastal geographer at La Rochelle University in France, who has studied the effects of land reclamation in the Maldives. "If you put an island where there was naturally no island, you create vulnerable land and you will necessarily have to build strong engineered structures, breakwaters and sea walls," she says.

In a 2019 study⁴, Duvat and Alexandre Magnan, a geographer at the Institute for Sustainable Development and International Relations – Sciences Po in Paris, assessed the scale of coastal changes that humans had made to 107 inhabited islands in the Maldives between 2004–06 and 2014–16 (see 'Altered islands'). On almost half the islands, the researchers found significant degradation in the reefs' abilities to weaken waves and provide natural sources of sediments. One-fifth of the islands had almost entirely or entirely "lost their natural capacity to respond and adjust to ocean climate-related pressures", the researchers say.

"It means that a decision you have taken one day to rely on reclaimed land will necessarily

cause you to invest more money," says Duvat. "You are locked into the engineered path for decades and decades and potentially the rest of the century."

"If you build a levee, people will think they're safe," says van Wesenbeeck. "But is it wise to destroy environmental assets to create investment in an area that's one of the most vulnerable in the world for climate change?"

The city of hope

Some 550 km to the north of Addu, the capital, Malé, sits like an overpopulated postage stamp in the middle of the ocean.

Malé is tiny – less than 2 km across at its widest point – but more than 200,000 people live on the island. To relieve population pressures, the government decided in the late 1990s to start reclaiming a massive atoll next to Malé, called Hulhumalé.

Hulhumalé has become known as 'the city of hope' – a place that not only has room but is also protected from sea-level rise. Architects designed it with sea-level-rise scenarios until 2100 in mind. The outer edges are 2 metres above sea level, more than twice the height of Malé.

Hulhumalé is regarded by specialists mainly as a worthwhile success for land reclamation, but critics have raised many questions about three newer projects on the western side of Malé, all of which are being built using sand from the nearby lagoon.

In 2021, Humay Abdulghafoor, a Malé-based veteran fighter against land reclamation, sued three institutional bodies of the government on the grounds that they violated an environmental-protection law. She said that a new reclamation project risked causing serious environmental, economic and cultural damage to the local community by undermining "the

economic and social benefits flowing from the natural environment and biodiversity richness of the Maldives", according to her legal case.

"By destroying the Maldives, you cannot develop it," she says.

The case has been ongoing for years, but on 14 February, it had its first breakthrough. The country's High Court decided to pause a dredging project near Malé. However, the next day, the Supreme Court said that this pause would cause significant financial losses and overturned the decision.

Mauroof Jameel, one of five architects chosen to build Hulhumalé, also has concerns about the latest projects. Jameel, who is based in Malé, says that it made sense to reclaim land at Hulhumalé to address congestion and help to build up the economy, but he is hesitant about how fast reclamation projects are now taking place. No one knows what the long-term impacts will be, he says.

In many parts of the world, including the Maldives, land reclamation can be beneficial, say scientists. "In my opinion, it can be a positive thing around Malé," says Duvat, because of population pressures there. But she doesn't see as much justification in more rural, distant atolls. "In this case, I cannot see the benefits."

Officials with the Maldivian government acknowledge that land reclamation can cause harm. But there is no indication that the process is slowing down. Just 3 months after Muizzu was inaugurated as president last November, he announced the biggest reclamation project the nation has ever seen – another endeavour to reclaim land near Malé on top of those already in the works. "The brand-new model city will revolutionize the country's urban landscape, addressing housing challenges in the greater Malé region by providing 65,000 housing units," he said in February at the World Governments Summit in Dubai, United Arab Emirates.

But many former officials urge caution. "How we create land, and the extent to which we do it, is excessive," says Mohamed Aslam, the minister of planning, housing and infrastructure for the previous administration, the agency responsible for land-reclamation projects. He says that land is often reclaimed as an easy way to keep the public happy, to show them that the government is doing something.

"The easy part is building the land," he says. "Only after that does the hard part begin."

Jesse Chase-Lubitz is a freelance journalist in London. Logistical support in the Maldives was provided by Shah Ahmed Yusuf. This article was produced in partnership with the Pulitzer Center.

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