



Residents of Kiribati make their way home through floodwaters. Rain and severe weather can exacerbate the high tides that often rush into villages.

Before we drown we may die of thirst

The island nation of Kiribati is one of the world's most vulnerable to rising sea levels. But residents may have to leave well before the ocean claims their homes.

BY KENNETH R. WEISS

High tide left its mark on the houses like a dirty ring in a bathtub. The flood crept into the village of Teaoraereke under the cover of darkness, sending filthy seawater sloshing through pigsties and shallow graves, and into people's homes.

CIRIL JAZBEC

Teaoraereke residents scrambled to retreat, hoisting sleeping children, sodden bedding and other belongings to higher ground. But some stayed put, including Rerema Kauria, a 63-year-old grandmother who was marooned just inches above the floodwaters on a raised platform bed. She was still there by mid-morning as the water receded, her possessions tucked into the rafters of her traditional house of wooden poles and thatch. She knew that when high tide returned that afternoon it would bring more flooding, but she gave a roaring laugh when asked if she had considered leaving. "Where would I go?"

The uncertain future of people such as Kauria has drawn attention to a collection of atolls in the central Pacific Ocean that make up the Republic of Kiribati (pronounced Keer-re-bahs). The average height of the country's 33 islands is little more than 2 metres above the ocean,

which makes Kiribati acutely vulnerable to climate change. By the end of the century, melting polar ice and the thermal expansion of warmer seawater is expected to raise global ocean levels by perhaps 1 metre. That upsurge would, according to some predictions, displace many from Kiribati and millions of others around the world — and the water will keep going up.

For years, Kiribati President Anote Tong has sounded the alarm over his nation's plight, warning that residents would soon have to abandon their homeland. The flooding that hit Teoraereke last year reinforces those dire predictions. Although it is impossible to know how much, if at all, climate change contributed to the flooding, village residents say that they have never before seen such inundation. To some of them, it seemed as if the swelling seas were starting to consume Kiribati and the end of the atoll might come sooner than they had thought.

But researchers who study Kiribati say that the situation is not a simple story of rising seas swallowing low-lying islands. In fact, some coastal experts dispute the idea that Kiribati will soon sink beneath the waves like a modern Atlantis. They have gathered evidence that many of these islands have been gaining ground in recent decades by capturing sediments from surrounding coral reefs. "It's just plain wrong to assume that all atolls are washing away," says Arthur Webb, a coastal geomorphologist affiliated with the University of Wollongong in Australia who has spent two decades living and working in the Pacific Islands. "It's also wrong to sugar-coat the sobering facts that rising sea levels will ultimately seal the fate of low-lying islands and their limited soils and groundwater. The confusion isn't surprising. It's just more complicated than many expect."

Even if Kiribati does not drown in the near future, its residents may soon need an exit strategy. Poverty, overcrowding and poor sanitation are galloping ahead of rising seas to deplete the islands' resources, especially their supply of clean fresh water. And residents' habits of altering the shoreline and removing coastal protections can magnify the impacts of the swelling oceans, leaving villages more exposed to flooding.

The story playing out on these tiny islands shows how difficult it is to tease out the impact of climate change from other human and environmental pressures. And what happens to the Kiribati people has implications for the hundreds of millions in low-lying coastal areas across the globe who will be threatened with flooding and displacement in coming decades. But unlike the residents of Miami, Guangzhou or Mumbai, the Kiribati people have no option of retreating inland or up-slope as their vulnerable flyspecks of land become uninhabitable. As Kauria says: where would they go?

AT THE MERCY OF THE TIDES

From the air, Kiribati's Tarawa atoll emerges from the Pacific as narrow strands of land that join to form a wispy V shape. On the outside of the V is the deep blue of the ocean; inside are the aquamarine and turquoise waters of the shallow lagoon.

Tarawa is the capital of Kiribati, which is one of the most remote countries on Earth, located on the equator about halfway between Australia and Hawaii. Its atolls are scattered across a patch of the Pacific the size of India, and yet they have a total of just 811 square kilometres of land, about half the size of Greater London.

When a plane lands on Tarawa, a crowd gathers at the airport, drawn by the excitement of the jet making the three-hour flight from Fiji. Aside from occasional freighters bringing canned food, this twice-weekly Fiji Airways flight provides the primary connection to the outside world.

The airport was built on relatively high ground, an elevation of 3 metres, in one of the atoll's widest sections. It happens to sit above the main subsurface reservoir, a freshwater layer floating on top of the seawater that presses against the porous island from all sides.

Although the sea presents an existential threat, the more immediate problem is not too much water, but too little — of the fresh, clean kind. A dozen of Kiribati's islands are deserted, too arid to support human

habitation. Without enough replenishing rains, their thin lenses of groundwater turned brackish. On Tarawa, groundwater is heavily overdrawn and contaminated by the local practice of defecating on the beach or in the bushes. With little land, residents bury their relatives and raise pigs next to their homes, which also contributes to groundwater pollution.

Next to the road leading to the airport, a buried white plastic pipe that carries fresh water from the reservoir has been exposed in places, owing to erosion by waves and tides. Public workers have fought back by using old tyres filled with concrete to hold it in place. They have had less success keeping locals from tapping illegally into the waterline, directing the flow into hand-dug wells for their homes. Water supplies are so limited that authorities turn on the airport's groundwater pumps for only a couple of hours every other day.

The perils of water, both sweet and salty, are intertwined with Tarawa's history, says George Fraser, high commissioner to Kiribati from Australia, which is the biggest provider of international support to the developing nation. In one of the bloodier clashes in the Pacific during the Second World War, US commanders misjudged the tides and landing craft got stuck on the reef, forcing marines to wade through chest-deep water under heavy Japanese fire.

Fraser deconstructs that infamous battle as he takes a tour of the island the day before the king tide that flooded Teoraereke. A fast and confident driver, Fraser weaves his small sport utility vehicle around wobbly wheeled trucks, dodging potholes. In narrow spots, the atoll's main road is soaked with seawater and he swerves to avoid a wave splashing over a concrete berm. "Some people use calendars to get through the week," he says. "We use tide charts."

The road is the only paved one on the atoll. It crosses a series of causeways that have been battered by wheels and waves; road crews repair cavities, stuffing them with as much concrete and sand as possible to slow the decay. The Australian government has bankrolled much of a repaving project along the length of South Tarawa.

As Australia's top representative, Fraser has a keen sense of the various challenges that this poor country faces in coming decades, and how they stack up. "If you look at rising sea levels as the train coming down the track, it's a couple of kilometres away," he says. "If you look at what's 100 metres down the track, it's no water, and right behind it is no food."

More than half of Kiribati's 110,000 residents live on Tarawa, and their numbers are rapidly increasing as more arrive from outer islands seeking jobs, cash and better schools. Many were subsistence fishers and farmers on their home islands, struggling with depleted fisheries and poor soil damaged by periodic over-wash of salt water. When they get to Tarawa, they often end up

jobless or underemployed.

The Kiribati culture is communal, with families accustomed to bedding down together on woven mats on the floor. It is taboo to refuse the request of a relative, so households often pack dozens of extended family members from other islands under one roof. That has made South Tarawa one of the most densely packed places in the Pacific; its clusters of shanties resemble slums in the poorest capitals of Africa and Asia. Factoring in high birth rates and ongoing urbanization, the government projects that the population of the island will almost double in 15 years. The new Battle of Tarawa will be over where all these people will live.

THE INCREDIBLE SHRINKING ISLAND

Today's scientific debate about whether Kiribati is growing or shrinking can be traced to Charles Darwin — who first worked out how coral atolls form. While sailing the Pacific on the HMS *Beagle* in the 1830s, he theorized that these curiously shaped sand islands are produced by coral reefs that sprouted on the slopes of volcanic islands and have continued to grow as the volcanoes sink into the abyss. He was proved right a century later, when scientists drilled into an atoll and hit volcanic rock.

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Over the millennia, the exoskeletons of millions of tiny coral animals fuse with coralline algae and the shells of molluscs and other sea creatures to form limestone reefs, often arranged in a circle with a shallow lagoon in the middle. Living corals grow on the fringes of these limestone platforms. As the crest of the living reef reaches close to the ocean surface, waves break some of it into rubble and sand that gets deposited on the dead limestone platform to form land.

The atolls that exist today are the survivors, ones in which coral reefs kept pace with rising seas and the subsidence of the undersea volcano. The pressing issue is, what will become of those atolls as sea levels start rising faster? Researchers wonder whether corals can keep up, given the host of environmental problems they face. In many places, overfishing and nutrient pollution have triggered the growth of coral-killing bacteria and algae. Abnormally warm seawater is causing 'bleaching' die-offs throughout the tropics, and as ocean water takes up more carbon dioxide and acidifies, it will be harder for coral polyps to build rugged exoskeletons.

Around Tarawa, the coral reefs are in particularly poor shape, says Simon Donner, a climatologist at the University of British Columbia in Vancouver, Canada, who has done diving surveys. "Coral cover is lower than you'd expect around the island," he says. "That's the legacy of pollution, sewage mostly, and frequent bleaching events in the past 20 years."

To help predict how corals may fare in the future, Dennis Hubbard, a geologist at Oberlin college in Ohio, and his colleagues have been peering into the past, amassing a database of sediment core samples obtained by drilling into limestone beneath coral reefs. With carbon dating, they can determine how quickly these reefs have grown: in yet-to-be-published work, they have found that more than half of the world's coral reefs grew more slowly over the past 10,000 years than sea levels are rising today. Extrapolating forward, those results suggest that only half of all atolls in existence today have a chance of keeping pace with rising seas under the best of conditions, he says. "Given that this was in a time with no human impact, we feel this is the most optimistic scenario possible."

NOT SO FAST

Kiribati and other low-lying island nations have long been held up as the countries most susceptible to the ravages of rising seas. In 2001, the Intergovernmental Panel on Climate Change (IPCC) highlighted¹ predictions that two-thirds of Kiribati and the nearby Marshall Islands would be inundated by a sea rise of 80 centimetres.

But the idea that these atolls will disappear any time soon has been challenged by Paul Kench, a coastal geomorphologist at the University of Auckland. He and his colleagues have pored over satellite images, comparing new and old aerial photographs to see how such islands have changed.

In a 2010 study, he and Webb determined² that 23 out of 27 atoll islands scattered across Kiribati, Tuvalu and the Federated States of Micronesia had either increased in area or remained stable in recent decades. The results, they reported, "contradict widespread perceptions that all reef islands are eroding in response to recent sea level rise". The researchers concluded that these islands are more "resilient landforms" than previously thought. The study created a media stir in the region and beyond. It has been widely cited by climate-change sceptics seeking to punch holes in research on global warming and its impacts.

Kench recognizes the powerful forces of climate change but complains that too many scientists and activists focus solely on rising sea levels while ignoring the other part of the equation: how the land responds. "There are a lot of claims that islands are passive geological entities that will sit there and drown," he says. "Our work shows that they are anything but static. They are dynamic. They move around and they can grow. So just because sea level is rising, it doesn't mean doom and gloom for all atolls."

He also believes that most scientists make a mistake by tethering the fate of atoll islands to the health of surrounding coral reefs. Even if reefs



A man rebuilds the sea wall that protects his home on South Tarawa.

die, he says, they can provide sufficient sediment to maintain islands for a century or more.

But Hubbard considers Kench's views shortsighted. "If you run out of reefs, you run out of sediment, and once you run out of sediment, you run out of islands," he says. "A lot of this is a semantics issue, challenging when the reef island is going to be physically underwater. Those reef islands are going to be abandoned long before that because they are uninhabitable."

On Tarawa and other Kiribati islands (see 'Isolated islands'), most people do not dwell on such matters, going about their daily lives just like residents of other countries. But their president has earned international recognition for speaking out on the threats of climate change.

In an interview, Tong dismisses those who suggest that atolls are resilient to rising seas, saying that they have the luxury of "talking from the top of a mountain" and not putting their lives on the line. "These people are not living here. Their grandchildren will not be living here. If they believe that, let them come here," he says, pounding his fist on a chair armrest for emphasis. "I'd rather plan for the worst and hope for the best."

Tong has told his people that they must prepare to leave, seeding the idea of an early "migration with dignity", rather than fleeing as refugees when storm-generated waves wash

over the islands. Last year, his government completed an US\$8-million purchase of 22 square kilometres of hilly land in Fiji, to grow food and provide possible refuge for some of his people — although it will not accommodate all of them. He does not know when people will need to migrate, but he wants to purchase more land in Australia and New Zealand, saying that it is much cheaper than trying to build sea walls and other defences. "If we build up these lands, it's going to cost billions of dollars," he says. "We might as well be buying land for millions of dollars elsewhere."

DEVELOPING CHALLENGES

For nearly a week after Teoraereke flooded, resident Matua Kamori worked alongside his neighbours to build a makeshift sea wall where the high tide had breached a sand berm on the beach. Villagers piled up chunks of coral scavenged from the shore and grouted them together

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Children play in a king tide that flooded their family's land on Tarawa.



J. SUTTON-HIBBERTY/GREENPEACE, MAP: GOOGLE EARTH/DIGITALGLOBE/CNESA/ASTRUM

with cement donated by a local church.

Kamori, 33, lives in the village with his wife and 4 kids on a small parcel of land given to him by his wife's uncle in exchange for looking after one of his sons. To prepare the land, Kamori spent months scouring sand and coral gravel off the beach and hauling it to the site with nothing more than a rice sack. Over time, he fashioned a building pad half a metre high and constructed a hand-hewn traditional house of wood and thatch on it. Such beach mining is rampant on Tarawa, according to household surveys. Government studies³ show that it increases the likelihood of flooding by lowering the protective sand berm that keeps the highest tides at bay.

In the case of the recent inundation, Kamori says that he fared better than most: the water reached calf-deep in his house, rather than thigh-high. But nothing could be done to stop the briny stew of salt water, mixed with human and animal waste, from polluting his well or killing his garden of vegetables and banana and papaya trees.

Kamori says that he settled on the land because he had nowhere else to go. As crowding increases, new settlements are pushing into vulnerable lowlands, places they historically would have avoided.

The individual actions of settlers such as Kamori are only part of the problem on Tarawa. Large-scale construction projects over the years have also exacerbated flooding and erosion, says Naomi Biribo, Kiribati's secretary of fisheries and marine resources development. Biribo earned a PhD in Australia by examining the impact of the sea walls and other human structures on Tarawa. The construction of causeways, rather than bridges, to connect the islets had the effect of closing channels and disrupting the flow of sediment that normally resupply some eroding coastlines, she found⁴. Reclamation projects that create new land are another problem: although such efforts have added hundreds of hectares to Tarawa, they accelerate erosion elsewhere, says Biribo.

For Tarawa residents, she says, the thin ribbons of land leave little room to move. "In many places on Tarawa, you can stand in the middle and you can see the ocean on one side and still see lagoon on the other side," she says. "If we retreat from the ocean side, and institute a setback, we will fall into the lagoon."

Biribo's work suggests that sea-level rise may be having a small influence on the shoreline changes happening today, but nothing compared to human activities and the seasonal variations in erosive tides and waves in the Pacific that come with the El Niño periods of warming and La Niña cooling.

Donner agrees that climate change has been dwarfed by other factors so far. "You cannot blame the flooding on sea-level rise," he says. "At least not yet."

Where does this leave residents of Kiribati? Webb has long wrestled with that question. He is married to a woman from Tarawa, and they own a house there, where they live with their children for part of the year.

Webb was also a lead author of the small-islands chapter⁵ of the IPCC's fifth assessment report in 2014, which found that rising seas present "severe sea flood and erosion risks for low-lying coastal areas and atoll islands". It highlighted one projection⁶ that a 50-centimetre rise in sea level could displace 1.2 million people from low-lying islands in the Caribbean Sea and the Indian and Pacific oceans; that number almost doubles if the sea level rises by 2 metres. And yet, the latest assessment steered clear of the IPCC's previous assertion that an 80-centimetre rise would inundate two-thirds of Kiribati.

Scientific understanding of atoll geology has sharpened since that earlier projection. Webb expects some remnants of Tarawa to remain a century or two from now, but probably no more than some wave-washed gravel banks — and by that point, everyone will have long gone.

The geological evidence does not get to the key human question about the destiny of these Pacific islanders. That leaves Webb facing a difficult question — one he hears from his own Kiribati-born teenagers. "How long do we have?" they ask. To that, he replies: "Your children will not grow old in the atolls." ■

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