Rising tides

Rising sea levels aren't a futuristic prospect – they're happening now right across the globe, with the potential to impact millions of lives. As sea walls and traditional infrastructure fracture under increasingly perilous circumstances, what other solutions are being considered to protect the most vulnerable?

by Lucy Kehoe

Harbour walls have long protected ports from rough seas, but however large, relying on man-made structures may no longer be enough to combat rising tides

How do you slow the melting of a glacier the size of Britain, that's shedding a dizzying 35 billion tonnes of ice into the ocean every year? According to Mike Wolovick, a postdoctoral research associate at Princeton's Atmospheric and Oceanic Sciences department, one solution is to geoengineer a vast wall across its base, blocking warm water flow. His 2018 study suggested that such a wall could 'buy time' at Antarctica's Thwaites Glacier – the engineering project would likely be the largest in human history.

Wolovick's glacier wall is just one of a handful of radical ideas for how to divert – or prevent – rising seas. With satellite observations by the NASA Goddard Space Flight Centre tracking an average rise of 95mm since 1993, and projections from the IPCC estimating that oceans will rise between 52cm and 98cm by 2100, outlandish projects are now springing from science fiction onto the main stage. It's perhaps not surprising when you consider that IPCC estimates are considered very conservative by some in the scientific community. A bleaker study last year suggested that the current trajectory of global emissions will see sea levels rise a staggering 238cm in the same timeframe.

A BATTLE ON ALL FRONTS

Rising seas are a multi-faceted problem, compounded by other issues. From Accra to Alexandria and Shanghai to London, at-risk communities face a combination of subsiding land, grumbling tectonic plates, sediment compaction and eroding natural barriers, alongside creeping tide marks.

Melting ice is a huge contributor. The Greenland and Antarctic ice sheets would, if melted, contribute up to 7 and 60 metres respectively to global sea levels. Furthermore, as temperatures rise, more than 90 per cent of atmospheric heat trapped by greenhouse gases is now being absorbed by oceans, causing them to expand. NASA estimates that between 2005 and 2010, there was a thermosteric increase of sea water levels of 0.5mm per year; and waves aren't just higher – they're also stronger, as abnormal weather patterns drive larger waves shorewards.

Even if we stay on track, 570 cities and some 800 million people will still be vulnerable

At a seaside resort in Dai, Hoi An, Vietnam, coastal erosion compounds problems

The consequences are already visible, be it coastal erosion in Bangladesh, where sea level rises of just one metre would leave 17.5 per cent of the country uninhabitable; unprecedented salinisation in the Mekong Delta; seawater seeping through permeable ground rock in Miami; or vanishing islands in the Pacific. According to The World Economic Forum's 2019 Global Risk Report, even if we stay on track for a two degree temperature rise, 570 cities and some 800 million people will still be vulnerable.

BLUE SEA THINKING

With more than 90 per cent of the world's coastal areas set to be affected by this rising tide, increasingly ambitious geoengineering projects are now emerging.

Bobbing in the waters of San Francisco's Bay Area, the Buoyant Ecologies Float Lab looks like an unpainted Tracey Island model, with a solar cell stuck atop its lumpy exterior. Made of fibre-reinforced polymer composite, and based on five years of applied research at California College of the Arts, it's a prototype for a floating breakwater which, if it works,

might also provide a blueprint for building human habitation over the waves. Under the waterline, the hull also aims to provide a habitat for fish, helping to aid biological growth. The team hopes that in large volumes this natural mass will diminish wave strength and reduce erosion.

The Float Lab team aren't alone in hoping that we might be able to protect our coastlines with tech. On Mexico's eastern coast, in Puerto Morelos, a UK-based start-up called CCell has just completed crowdfunding for their ambitious coral reef building pilot. The hotel-heavy coastal stretch of Quintana Roo has seen its beaches diminish thanks to rising waters and increases in wave strength of up to one per cent per year over the past 30 years.

'Globally, coral reefs protect over 200 million people from coastal erosion,' says CCells's Magda Nawrocka-Weekes. 'But we can't just rely on them. We've got to get smarter and combine nature with technology.'

That's the plan behind the company's programme, which will see electrified modular steel structures placed on the seabed alongside existing coral reefs off the coastline. The low current will force seawater minerals to grow around the structures, forming calcium carbonate rocks – the same material reefs are made from. Once formed, coral grown in Mexican hatcheries will be seeded into the structures, creating, in time, new reefs which CCell claim will be up to 20 times more erosion-resilient. After five years, the currents will be switched off, but the electronics kept in place. If the reefs are damaged, they can be 'healed' by switching the flow back on and, as sea levels rise, the structure allows for additional growth. The idea is that coastal hotels will pay for the installation of sections of reef to protect their properties, as the biological growth should weaken waves before they reach the shoreline.

The pilot will see a 200 metre reef constructed but, to succeed, CCell will need to build up to three kilometres of reef, costing £1,500 per metre. The electrification process is nothing new – it's been used for over 25 years in Indonesia – but this is the first time the reefs have been used as an erosion barrier.

PROTECTION FOR ALL

As highlighted by CCell's funding structure, a question mark hangs over who pays for such defences. Should governments cough up? Or, is it the responsibility of asset owners? Too often, funding arrives only after significant incidents of flooding. Seven years after Hurricane Sandy submerged parts of New York City, causing $19 billion of damage and taking 44 lives, mayor Bill DeBlasio announced a $10 billion project to build moveable flood barriers around lower Manhattan. Venice, which now sees up to 60 floods annually, has spent an estimated $6.5 million installing the MOSE barrier across its lagoon, set to launch in 2021. But for Venetian residents and business owners, who faced floods of up to 1.87 metres this winter, this may seem too late.

Large-scale infrastructure also requires co-operation from those living in impacted areas. In developing countries, cost-benefit analyses often erase the voices of vulnerable communities. Indonesia's controversial $40 billion, 24-metre-high seawall project in Jakarta, due for completion in 2025, aims to prevent a third of the city sinking beneath the waves by 2050. The project will redevelop 30 kilometres of coastal dams and build artificial islands and sea walls around Jakarta Bay. However, this means evicting around 200,000 people from at-risk, low-value housing. The seawall will also dam the city's shoreline, which could catastrophically impact fishing communities. And, it won't address the main cause of the city's sinking up to 20cm a year – aggressive groundwater pumping by residents who lack access to a comprehensive water network.

Lizzie Yarina, a researcher at MIT's Department of Urban Studies and Planning, has been exploring relocation programmes in Pacific Nations and further afield. 'If the aim of climate adaption is to reduce vulnerability and make the most vulnerable less exposed to climate risk, then you have to understand the underlying issues of what makes those people vulnerable,' she says. 'There's physical and environmental factors, but also there's going to be structural socio-economic factors – you can't disentangle them.'

That's something that Dutch architectural firm Kuiper Compagnon, which consulted on the original Jakarta plans, recognises. 'We were very critical of some aspects,' says Wouter Vos, director of the company's Liveable Cities project. 'When we began to work with NGOs, we started to understand that the biggest problem was actually the city subtracting groundwater.

Kuiper Compagnon

(And above) Dutch company Kuiper Compagnon has created plans for the development of Shantou, proposing a 'delta city' with infrastructure that collects excess rainfall

People wade through water following a flood in Jakarta on 8 February 2020

There needs to be a consensus by governments on what real problems need to be solved.'

The company's solution is to incorporate preservation into urban development. In the Chinese city of Shantou, rising water levels in an estuary have been complicated by polluted water and over-urbanised shorelines. 'The city had a great oyster culture,' says Vos, 'but it had been lost because of urbanisation and the lack of accessibility to oyster nurturing grounds. We realised that the oysters help filter the river water. So why not reintroduce the oyster grounds? We tested whether they would be resilient against the type of pollution in the river. It's a nature-based solution, combined with cultural heritage, to bring back local economies.'

ROOM FOR THE WATER

It's not uncommon to hear Dutch voices in international water management proposals. Since 1953's catastrophic flooding in the Netherlands, which killed 1,835 people, the country has spent billions building the Delta Works system, comprising sluices, storm barriers, dams and dykes. In Rotterdam, where 90 per cent of land lies beneath sea level, a recent initiative has encouraged city planners to build flood resistance into urban infrastructure, adding water reserves under parks and plazas to store excess water for the city's utilities. The 'Room for the river' project redevelops the country's relationship with water,

A low current will force seawater minerals to grow around metal structures, forming calcium carbonate rocks

viewing it as a resource, not a nuisance. During the announcement of the city's Climate Change Adaptation Strategy, Mayor Ahmed Aboutaleb asked that Rotterdam residents see climate change as 'an opportunity to make the city more resilient, more attractive and economically stronger'.

The country's crown jewel in flood resilience is Maeslantkering: two 6,800-tonne buoyant doors waiting to be pulled shut across the Nieuwe Waterweg if sea levels rise by three metres. When shut, the barrier will prevent the North Sea from surging into Rotterdam. It hasn't been used – yet. But its existence has bolstered the nation's reputation in worldwide protection solutions.

NATURAL PROTECTION

Appropriately enough, Wetlands International's headquarters sit in Rotterdam, but their teams are active worldwide. A key location for the organisation is Indonesia's Demak district which, unlike the eroding

shores of Mexico, features no glitzy hotels. Instead, the fast-eroding landscape is home to 22.6 per cent of the world's mangrove forests, of which 2.7 million hectares have been lost in 30 years.

Over the last decade in the Bogorame area, up to six kilometres of coastline has been permanently flooded, swamping two villages and threatening six others. A combination of land subsidence caused by groundwater extraction in nearby Semarang and loss of mangrove forests for aquaculture have seen the Java Sea encroach, salinising agricultural lands and destabilising communities.

But things are changing. Spearheaded by Wetlands International, the 'Building with Nature' programme has united local communities and the government. Permeable gridded barriers have been installed on shorelines, which attenuate waves but still allow sediment to reach shallow waters and settle, meaning mangrove forests can reseed, creating a natural barrier. 'There's momentum worldwide to do mangrove planting, but actually 80 per cent of that planting is failing because it's done in the wrong sites, using the wrong species,' says Wetlands International programme manager Femke Tonneijck. 'You need to understand the natural system and work with nature to recreate the habitats. In this case, there's no replanting. We're restoring the habitats, so the mangroves come back.'

By 2030, the Global Mangrove Alliance aims to expand mangrove coverage worldwide by up to 20 per cent. Since the project began, several kilometres of permeable barriers have been installed along a 20-kilometre stretch of the Java coast. It's an approach that relies on a long-term vision from multiple partners. Historically, much mangrove forest has been lost to aquaculture pond creation, the profits of which support local communities. Wetlands International works at village level, training communities to influence district policy. They also educate a network of local engineers and coastal managers.

'Building-with-nature solutions are a combination of technical and socio-economic solutions,' says Tonneijck. 'We've developed an extensive programme that boosts the aquaculture practices, raising productivity and increasing incomes so that fewer hectares produce the same profits. You need to ensure restoration is combined with a financial incentive.' Studies have shown that 400 hectares of ponds in which best practices have been implemented have seen tripled yields and incomes. Since the programme began, the use of permeable structures along Indonesia's coastline has been adopted by government partners in 15 districts, with an investment of nearly €2.5 million. Even where ground subsidence has been greater than expected and mangrove restoration has been limited, permeable structure building has still prevented large-scale erosion.

HOW TO SOLVE A PROBLEM LIKE MIAMI

Such solutions are not limited to the developing world, or to tropical regions. On a list of US urban areas most at risk from rising seas, the state of Florida features five times. Its capital, Miami, is one of the world's most vulnerable cities. 'To understand the impact of sea level rise in the state, a rule of thumb is that for every foot of sea level rise, storm surging will travel inland 100 feet,' says Laura Geselbracht, a senior marine scientist at The Nature Conservancy, a non-profit US organisation. A recent report from the National Oceanic and Atmospheric Administration in the country predicted that by 2070, Miami will flood every day. Estimates put future state costs on seawall construction at £74 billion by 2040. Thanks to the city's complex topography, even this is likely to be only partially successful. The city sits on porous limestone which allows seawater to seep under infrastructure on the seabed. During surges, this rises up into residential areas. When it floods in Miami, it arrives through shower drains and roadside grates. More than $4 billion has already been set aside by the state for redeveloping sewage systems, road raising and seawall improvements but with an approximate rise of one inch every three years, built infrastructure is a finite resource in the battle against the water.

Once again, mangrove planting could provide the answer. According to The Nature Conservancy, mangroves averted $1.5 billion in flood damages to Florida properties during the 2017 Hurricane Irma storm surges, which saw raised waters of between three to ten feet along the Florida coastline. The risk-reduction benefits of growing mangrove forests in front of properties equates to 25.5 per cent. 'As sea levels rise, Florida's remnant mangrove forests will be squeezed between rising seas and developed lands, with little room to migrate to higher elevations,' says Geselbracht. 'But mangroves are an effective natural defence against storm surge flooding.'

MOVING OUT

There is another solution to rising seas – do nothing. Or rather, allow the sea to rise but relocate at-risk communities. But uprooting residents has, in recent history, proved just as difficult as navigating complex urban planning.

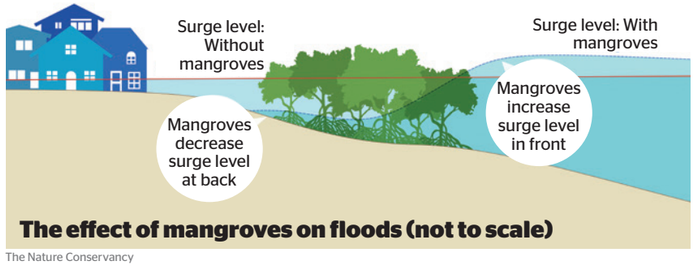
Take Alexandria, Egypt's second city, surrounded on three sides by the Mediterranean Sea, which has risen 3.2mm every year since 2012. The city is sinking, a result of natural gas extraction and subsidence caused by upstream dams reducing silt replenishment. A rise of just 0.5 metres will swallow up the famous Gleam and El Chatby beaches, while ferocious storms have already caused extreme flooding. Most at risk are the El Max canal fishing community, who were forced temporarily to abandon their homes during the 2015 floods. Since March 2019, however, the community has faced a separate expulsion, forced out by local authorities widening canals in an attempt to reduce flooding. Rehoused in tower blocks overlooking the canal, the community has lost its core source of income – fishing.

More relocations are inevitable. The village of Vunidogoloa in Fiji was the first of four communities already relocated inland under a Fijian climate change programme which has earmarked 80 communities across the nation of islands for potential relocation. And, at the start of 2016 the US government awarded Louisiana $48 million to relocate the people of Isle de Jean Charles to higher ground, a narrow ridge sinking into the Gulf of Mexico.

A 2020 study by researchers at the Georgia Institute of Technology estimates that in the United States alone, 13 million people could be pushed to relocate by the end of the century, while another study by research organisation Climate Central predicts that land currently home to 300 million people will flood at least once a year by 2050 unless carbon emissions are cut significantly and coastal defences strengthened.

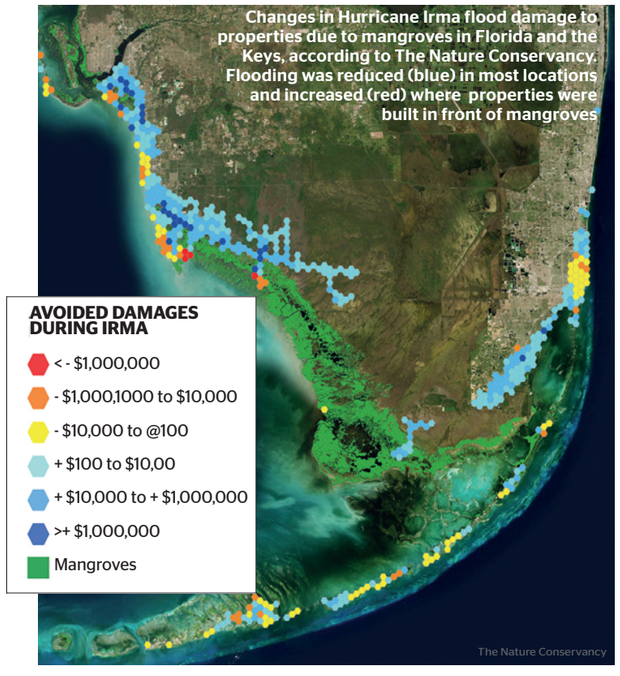
How these relocations are carried out will prove vital when it comes to people's well-being and livelihoods. When authorities attempt to mitigate the impact of rising sea level without providing a voice to those most affected, they forget that climate resilience is not only a technical challenge – it has social and political aspects too. 'People should be able to determine their own futures,' says MIT's Yarina. The question is, how late do we leave it to determine what we want the future of our coastlines to be? ●

Indonesia's Demak district is home to 22.6 per cent of the world's mangrove forests



The effect of mangroves on floods (not to scale)

The Nature Conservancy



Changes in Hurricane Irma flood damage to properties due to mangroves in Florida and the Keys, according to The Nature Conservancy. Flooding was reduced (blue) in most locations and increased (red) where properties were built in front of mangroves

The Nature Conservancy