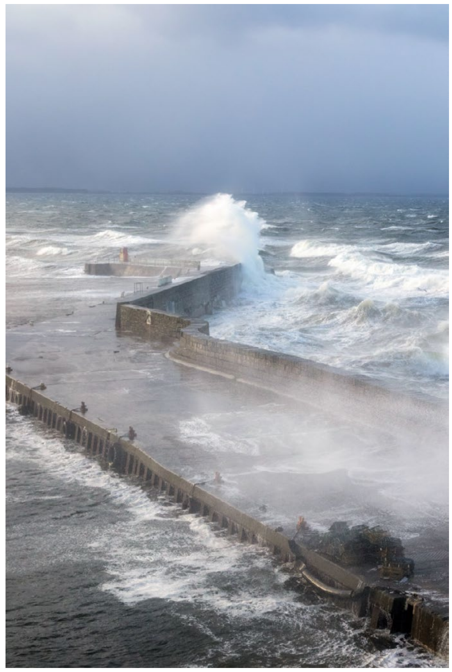
Complexities of coastal resilience

Mitigating the risks of coastal flooding as sea levels rise requires management of sediment as well as water.

By 2050, it's estimated that more than one billion people will live in the world's low-lying coastal zones[1]. Rich in resources and opportunities for trade and recreation, these regions are also susceptible to inundation and erosion, especially during extreme storm events. As the risk of coastal flooding increases due to changes in population, sea-level rise, and shifts in the location and severity of large storms, we need to recognize sediment as an important component of coastal resilience if we are to minimize the harm done by rising seas.

Storms, in particular tropical cyclones, are some of the most iconic threats faced by the world's shorelines. When compared with the exposure risk for extratropical cyclones alone, accounting for tropical cyclones produces a two-fold increase in the number of people exposed to low-probability coastal flooding[2]. The winds in these storms combine with other factors, such as topography and waves, to drive extreme, short-term increases in sea level that can reach many metres in height. In a warming climate, the conditions favourable to the formation and growth of tropical cyclones are expanding poleward, as discussed in an Article by Green et al. and a Review by Studholme et al. in this issue. These dynamic, and often catastrophic, storm events are punctuating a picture of already rising seas to put even more people at risk.

Sea-level rise is a global phenomenon with regional trends that lead to large variations in local exposure and risk. Accounting for the combined effects of sea-level rise, storminess, subsidence, population growth and urbanization, it has been suggested[3] that the total population of port cities exposed to coastal flooding could grow three-fold to 150 million people by 2070, with populations in Asia remaining the most exposed and those in Africa overtaking both North America and Europe. Sadly, for many, the risks of sea-level rise aren't a future projection but a current reality. In a speech made remotely to COP26, the Foreign Minister of Tuvalu — an island nation with a peak elevation just 4.5 m above sea level — demonstrated the reality of the risks faced by low-lying atolls as he stood knee-deep in water where once dry land had been.



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The rate of mean global sea-level rise has been quantified at approximately 0.3 cm per year over the past twenty years[4] and is accelerating[1]. However, when combined with the subsidence experienced by many coastal cities, especially those built on deltas, relative sea-level rise increases three times, to nearly 1 cm per year[4]. With mounting evidence that the dominant cause of global mean sea-level rise is anthropogenic[1], policies that address climate change (and therefore mean sea-level rise and storminess) must be combined with local action on subsidence in order to limit flood exposure for coastal inhabitants.

Coastal subsidence can be due to natural changes in tectonics, isostasy, and sediment compaction, over which we have little control. However, extraction of aquifer fluids such as groundwater or hydrocarbons can exacerbate and accelerate natural subsidence[5]. The balance of coastal systems is further disrupted by reduced sediment supply due to sand extraction and upstream dams. The world's dams impound at least one-sixth of the annual river flow into the oceans and act to severely reduce sediment delivery to deltaic regions[6]. Without sediment supply, deltas cannot rebuild and expand.

Similarly, the very storm-surge barriers, levees, and defences put in place to protect a shoreline from flooding can disrupt sediment flow and the long term resilience of the coast. In an Article in last month's issue, Tognin and colleagues showed that flood barriers designed to be deployed during storm surges in the Venice Lagoon led to a severe reduction in the influx of storm-reworked sediments. While the barriers were effective at reducing the direct impacts of flooding, the unintended consequence was starving the lagoon's salt marshes of sediment — marshes that are a key natural defence for future flooding in an area experiencing subsidence.

There are difficult trade-offs between preserving the natural balance of coastal systems and the resource provision and protection of populations. Effective mitigation must consider how complex coastal processes interact and the impact of disturbing any single component. By design, engineered defences against inundation aim to reduce water levels but, in doing so, they also inhibit sedimentation. With disrupted sediment supply, the natural buffering interfaces between land and sea — the tidal flats, salt marshes, and deltas — are unsustainable. Given the disproportionate impact of subsidence on the relative sea-level rise experienced, it is imperative that management of coastal flooding considers changes in sediment as well as changes in water levels. ❐

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