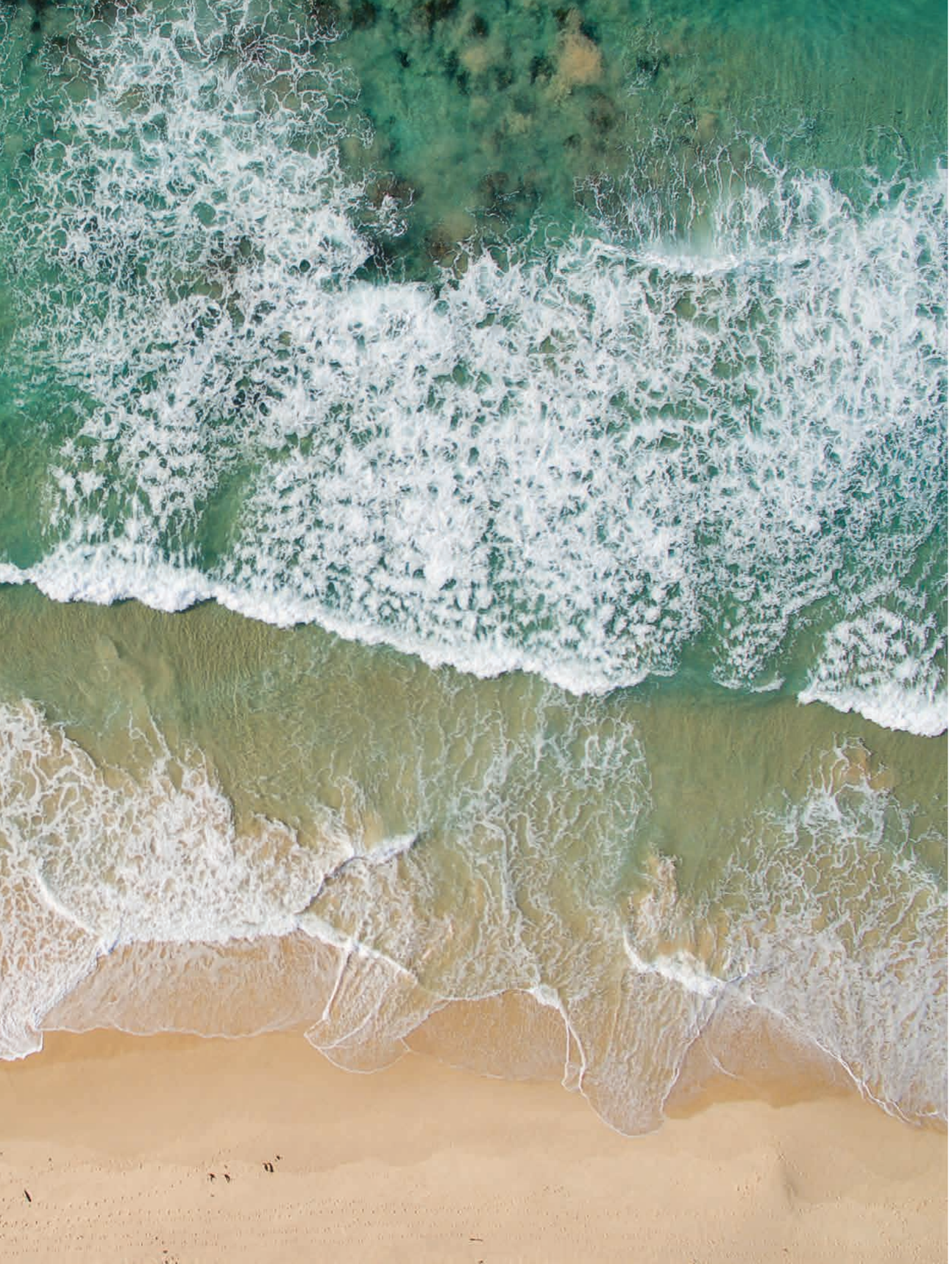

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Coasts – A Vital Habitat Under Pressure

Coasts are a special habitat. They are the transitional zone between land and sea, are influenced by both spheres, and are extraordinarily polymorphous. Whereas Brittany's northern French coastline is rocky and gouged by innumerable inlets, the high dunes of the Namib Desert on the coast of Namibia extend panoramically to meet the Atlantic, while differently again, the low-lying coast of Siberia consists of permafrost, i.e. ground frozen to a depth of several metres.

The variety of coastal landscapes is matched by the diversity of services they render to humankind. They provide important transport routes and industrial sites; they are favoured destinations for recreation and tourism, and they are sources of mineral and fossil resources. For that reason, coasts have always been especially popular sites for human settlement. The populations of many coastal areas have been growing for decades. According to United Nations estimates, around 2.8 billion people today live within 100 kilometres of the coast. Of the world's 20 megacities, i.e. cities with more than 10 million inhabitants, 13 are in near-coastal locations. It is widely expected that the urbanization of coastal areas will continue to advance in the next few years. It is estimated that in 2060 around 1.4 billion people will be living in low elevation coastal zones at elevations of no more than 10 metres above sea level.

In relation to terrestrial land mass as a whole, coasts are ultimately just a narrow strip where the land meets the sea. When people colonize this coastal strip, in many cases they give no thought to the fact that it is subject to constant natural change – and that over the course of time these changes can also destroy areas of human settlement. Changes of this kind happen on different time scales: those caused by plate tectonics occur over millions of years, permanently changing the form of the Earth's surface and the continents; temperatures swing between glacial and interglacial periods on a cycle lasting tens of thousands of years – while changes in recent centuries have largely come about due to the impacts of human settlement. Over relatively short periods of geological time, it is mainly fluctuations in sea level that dramatically affect the morphology of the coasts.

During glacial periods, large volumes of water are sequestered on land in the form of ice and snow. The sea level is lowered because very little water flows back from the land into the ocean. During the last glacial period around 20,000 years ago, it was around 120 metres lower than it is today. Many areas that are submerged today were dry land during that period, and the land mass protruding above the waterline was a total of 20 million square kilometres larger than it is today. For around 6000 years the sea level has barely changed. Due to human-induced global warming, however, for the last several decades it has begun to rise more markedly once again, by an average of 3 millimetres per year at the last count. There is an impending risk that entire island nations or low-lying coastal areas will be inundated in future – in Bangladesh, for example, which lies only slightly above the present-day sea level.

Depending on coastal morphology, widely diverse habitats have developed over time. Where rivers carry large quantities of nutrients and sediment into coastal waters, today – depending on climatic conditions and the prevailing currents – there are expansive river deltas with wide sand-

Overall conclusion

banks, tidal mudflats or salt marshes. Such coastal areas are often especially productive and abundant in fish, thanks to the heavy discharge of nutrients. One of the rivers that carry particularly high levels of sediment into the sea is the Mississippi, around the mouth of which a large delta has developed. The record-holder is the Ganges, though: every year it carries around 3.2 billion tonnes of material into the sea. In contrast, other shorelines are more barren and rocky, like the limestone coast of Croatia from which very few nutrients find their way into the sea. Likewise, tropical coral reefs are found mainly at sites where nutrients and sediment barely flow into the sea from the land.

Today the coastal areas of the world are intensively used. They supply the bulk of the world's wild-caught fish. In fact, 90 per cent of global fishery takes place in coastal waters. Another use of great economic significance is the drilling of natural gas and oil in coastal areas. Although the bulk of both resources is still extracted onshore, the proportion coming from the sea (offshore gas and oil) is substantial. Currently offshore oil accounts for about 40 per cent and offshore gas for about 30 per cent of total global extraction.

In the past few years, coastal waters have become increasingly attractive sites for the harnessing of wind energy to generate electricity. The number of offshore wind turbines has increased markedly, and by the end of 2015 the combined capacity of all the offshore wind turbines in operation worldwide was at least 12,000 megawatts, which roughly equates to the capacity of 24 nuclear reactors. Another resource supplied by coasts are mineral raw materials, particularly sand and gravel, which are used in concrete manufacturing, as filling sand on building sites, or for hydraulic filling to create new port or industrial sites on the coast. The largest sand-mining area is located on the coast of Morocco. Dunes are being excavated and removed on a massive scale with wheel loaders, so that the coast in some regions resembles a lunar landscape.

In many places, human use of the coasts is exceeding their carrying capacity. The sources of pressure on these habitats are multifarious. High levels of nutrients are discharged into the sea from untreated effluents, from intensively fertilized agricultural lands or from aquaculture. This leads to eutrophication and to severe algal blooms. Pollutants from industrial processes that seep into coastal waters also pose a threat. These include heavy-metal compounds or persistent chemical substances that accumulate in the food chain and can give rise to illnesses like cancer. An example of these are polyfluorinated compounds, which have been in use for years now for everyday products like outdoor clothing or pan coatings. Likewise, the plastic waste that finds its way into the sea by many different routes raises a problem that is currently a matter of serious debate. Marine animals and seabirds swallow pieces of this plastic and die. Furthermore, the plastic decays into microscopically small fragments, microplastics, which are now in evidence in all the world's oceans. Scientific studies are currently investigating to what extent animals ingest them and how dangerous they are. Global plastics production has been increasing for years. Between 2005 and 2015 alone it rose by over 90 million tonnes, from 230 to more than 320 million tonnes.

Since coastal waters are especially productive, they are fished intensively, which has led to the overfishing of many stocks. Furthermore, seabed habitats – such as coral reefs – in many locations are being destroyed by fisheries. In some regions that are rich in corals, intensive fishing also means that other marine organisms are gradually overfished. If one species disappears, the next is hunted. Because of unsustainable fisheries, the coral reef habitats are becoming impoverished over time. This threatens the very foundation of many people's livelihoods.

Under particular pressure today are the coastal megacities with more than 10 million inhabitants. The distinctive feature of these regions is their high density of population and construction. There is a need to supply many people simultaneously with fresh water, food and electricity, which imposes major demands upon infrastructure, logistics and waste management. Because people from poorer rural regions inland are constantly moving to the coastal megacities in search of work or training, these metropolitan centres will continue to grow in future – above all in Africa, South America and Southeast Asia. Urban sprawl resulting from this growth blights the landscape. Natural areas such as floodplains, mangrove forests or salt meadows can very rapidly be lost. Regional species of fauna and flora are threatened with extinction. Added to this, the destruction of mangroves which normally act as natural wave-breakers means that many sections of coast are now particularly at risk of inundation. Flooding has been further exacerbated in some megacities by the fact that these densely built-up urban areas are slowly subsiding. This is largely caused by groundwater abstraction to obtain drinking water. Groundwater normally acts as a natural abutment that counterbalances the weight of built-up areas bearing down on the substrate. Compaction of the ground is another factor that contributes to subsidence. Currently the world's fastest subsiding city is the Indonesian capital, Jakarta, the centre of which is sinking by around 10 centimetres each year.

Added to these problems caused locally or regionally by human activities in coastal areas are those which are driven by the global phenomenon of climate change: ocean warming, ocean acidification and sea-level rise. How severely these consequences of climate change will affect coastal habitats depends to a great extent on how much carbon dioxide (CO_2) is released into the Earth's atmosphere in future. The direct consequence of high CO_2 emissions is gradual warming of the atmosphere and the ensuing warming of water, particularly at the ocean surface, which cannot then mix so easily with the cooler and heavier water layers beneath. As a result, the water that sinks to deeper levels is less oxygen-rich, which can lead to a shortage of oxygen in the deep ocean. In areas where this has occurred, it becomes virtually impossible for higher animals like crabs, bivalves or fish to survive. Warming also affects tropical coral species. At present it is assumed that around 20 per cent of tropical coral reefs face irreversible destruction and at least another 30 per cent severe degradation due to warming and other stress factors like marine pollution. In other marine organisms, it is primarily eggs and larvae that react sensitively to the warming of the water. In the Atlantic cod, for example, it leads to embryonic mortality. Model cal-

Overall conclusion

culations show that this could cause a drastic decline in catches for the cod fishery in the Barents Sea north of Norway.

Another consequence of climate change is acidification of the oceans. This occurs because of increasing atmospheric carbon dioxide dissolving into the seawater and forming acid, to express a complex process in simplified terms. The marine organisms principally affected are those that form calcareous shells or skeletons. In corals, bivalves and snails, in acidified water this calcification process declines by 22 to 39 per cent depending on the animal group being studied. On the other hand, studies have meanwhile been published which show that a few marine organisms are highly capable of adapting to acidification over the course of several generations. Today it is impossible to predict with accuracy how severe the future consequences of acidification will be.

A direct danger for people is the rise in sea level caused by climate change. Currently the sea level is rising by around 3 millimetres per year, but this will accelerate if greenhouse gases continue to be emitted in large quantities by burning fossil fuels. Since the trend cannot be predicted with precision, the Intergovernmental Panel on Climate Change (IPCC) works on the basis of four scenarios, each of which makes different assumptions about how high the CO_2 concentration in the Earth's atmosphere might be in future. According to the extreme scenario, by the end of this century the sea level could rise globally by around 1 metre. By the year 2500 a rise by more than 6 metres is far from inconceivable. Under these conditions, coastal protection will increasingly become a task of vital importance for human survival.

Over the centuries, societies have managed to adapt to storm surges and flooding and to develop appropriate sea defence structures. However, the future trajectory of sea-level rise is impossible to predict exactly. Coastal protection must therefore become more flexible so that despite this uncertainty, people and material assets can be protected. Whereas in the past people relied on rigid coastal protection in the form of dikes and barriers, in future they might increasingly transition to an adaptive approach to coastal protection, which provides for a range of successive measures and is augmented as the sea level grows progressively higher. What is crucial is that the various interventions are planned well in advance and structured in the form of a roadmap so that it is possible to keep abreast of sea-level rise at all times. Large-scale projects of this kind already exist in the Netherlands, and a catalogue of measures for adaptive coastal protection has been developed to protect London and the Thames estuary. Beyond this, coastal engineers are increasingly urging a policy of "building with nature". This involves utilizing the potential of the coasts themselves – perhaps by establishing oyster reefs or eelgrass beds, or by constructing polders in which species-rich salt meadows can develop. It is now also acknowledged that people must learn to live with the rising water – perhaps by constructing floating houses. Furthermore, coastal protection can be combined with other functions and, at the same time, executed in a near-natural form. In the Netherlands, for example, multi-storey car parks have already been built along the coast, and subsequently covered with sand and overplanted to create artificial protective dunes. Nevertheless, despite all measures, it will be impossible to save all the world's coasts in future. The governments of island nations such as Kiribati are therefore already trying to make preparations for an orderly retreat – with efforts such as education programmes that put the population in a position to be attractive candidates for foreign labour markets. This would give people the option of building a new livelihood in other countries in preference to becoming destitute climate refugees.

Added to all the pressures caused by human overuse and warming of the climate, coasts are exposed to natural hazards such as earthquakes, landslides or tsunamis. Of course these threats have always existed, but because the coasts are more densely settled today than ever, the scale of any damage is significantly greater. Therefore efforts are now being made to protect people from these hazards of nature by means of sophisticated early warning systems. Particularly the USA and Japan have taken on a pioneering role in this respect since the middle of the last century. The severe tsunamis of 2004 in the Indian Ocean and 2011 in Japan brought about an even stronger emphasis on tsunami research and early warning, so that today effective warning systems are in place in all the most vulnerable marine regions. But there can never be 100 per cent protection.

The world's coasts are threatened from many directions – but the greatest threat today is posed by human overuse. This raises the question of how it may be possible in future to achieve prudent coastal management and to pre-emptively avoid conflicts over use arising from competing interests. An important approach for solving these problems is Integrated Coastal Zone Management (ICZM), of which there are already plenty of successful examples at regional level. For instance, there have been ICZM processes in which conflicts between nature conservation and tourism were successfully avoided or sustainable coastal fisheries established. There have been cases in which authorities placed marine areas under protection without involving the indigenous local fishers in the decision-making process. Many of the affected fishers, for their part, refused to accept the bans on fishing in their territories and continued to fish. In ICZM processes, in contrast, the fishers are given a voice and can also contribute their own proposals.

For example, in the Indo-Pacific region, protected areas were established in which fishing is only permitted in certain sectors or is organized sustainably by the local fishers themselves in what are known as locally managed marine areas. Where important coastal areas extend beyond national borders, international agreements also become necessary, like those covering the large marine ecosystems (LMEs), extensive near-coastal areas of the ocean, each of which is distinguished by its own typical flora and fauna. By way of an example, the coastal communities of the LME in the Bay of Bengal succeeded in adopting joint measures to combat overfishing and marine pollution.

Last but not least, the world's coasts also play a special role in cultural and aesthetic respects. They are places of recreation and important travel destinations. To this day, coasts not only have a direct use but also a spiritual value for many people and cultures. A purely economic view of coasts and the ecosystem services cannot therefore always do justice to the true significance of the coasts.