4 Improving coastal protection

> If the coast is to be conserved as habitat, it has to be protected. This not only entails prudent management of coastal areas, taking all stakeholder groups into consideration, but also maintaining a catalogue of effective coastal protection measures that can be adapted as sea level rises. Worldwide there are examples which give cause for hope. One challenge that remains is that of creating homelands in new places for the coastal dwellers that lose their homes because of climate change.

The art of coastal management

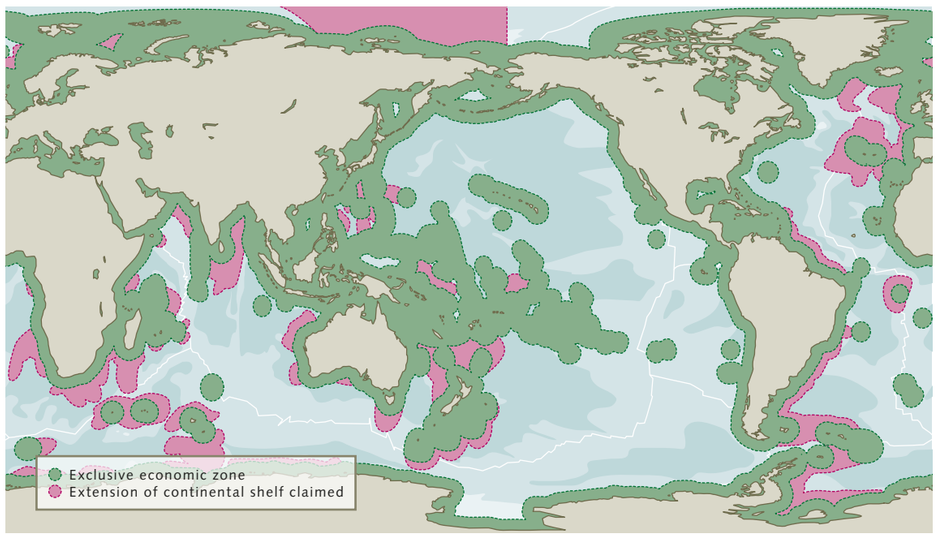
> Divergent interests give rise to conflicts time and time again in the course of comprehensive coastal protection. However, if all stakeholder groups can agree on a sustainable management plan, this often generates considerable benefits for all.

The significance of coasts – a question of perspective

The world's coasts are diverse. Some are popular as holiday destinations and have remained almost unspoilt. Others, located on important shipping routes, have been heavily developed industrially. Then there are coastal regions that are significant for small-scale fisheries. These supply large quantities of fish from which millions of people earn their living; on the other hand, they are often used as a natural water-purification plant for the effluents of a growing coastal population. The significance of the coasts in traditional or indeed religious respects varies greatly from culture to culture. And whether a region or a country considers the coasts as significant at all depends on all kinds of factors, but is most obviously reflected in active political measures for their protection.

International ground rules for the world's coastal areas

Anyone who is permitted to use a coastal area in any way today is subject to clear international regulations through the United Nations Convention on the Law of the Sea (UNCLOS) which was adopted at the UN Conference on the Law of the Sea of 1982 and entered force in 1994 after arduous negotiations. It sets out the ground rules for all uses of the ocean, such as shipping, fishing, natural gas and oil drilling and environmental protection. The provisions of UNCLOS apply to all states and as a general principle in all zones of the ocean. Nevertheless, it must be noted that different bodies are responsible for the implementation of the law in each of the various oceanic zones. Distinctions are made between the following coastal and marine zones:



4.1 > Coastal states have exclusive rights within their exclusive economic zones (EEZ) to exploit marine resources such as fish. If certain conditions are satisfied they can even extend their EEZ to include part of the continental shelf.

4.2 > The Banc d'Arguin National Park is an area of tidal mudflats and lagoons on the coast of the West African state of Mauritania. The national park is an important over-wintering site for migratory birds which feed there to build up their fat reserves for the long flight ahead.

TERRITORIAL SEA: The territorial sea is the 12-nautical-mile zone. It belongs to a state's sovereign territory. Activities in this zone are governed by the legislation of the individual states. However, legislation must conform to the internationally agreed rules if the state has ratified UNCLOS.

EXCLUSIVE ECONOMIC ZONE (EEZ): This extends from the outer edge of the territorial sea to 200 nautical miles (approximately 370 kilometres) offshore. Therefore the EEZ is also called the 200-nautical-mile zone. Included within the EEZ are the sea floor and the water column. Unlike the territorial sea, the EEZ is not part of a state's sovereign territory. Nevertheless, within its own EEZ the coastal state alone may extract resources such as petroleum and natural gas, mineral resources, and of course fish stocks. Other nations may only use the resources if the relevant coastal state consents. Resource extraction in the EEZ is subject to the coastal state's legislation, which in turn must be in line with the international rules laid out in UNCLOS. For other uses of the ocean, particularly shipping, the freedom of the high seas applies equally within the EEZ.

CONTINENTAL SHELF: The continental shelf is the gently or steeply sloping sea floor off the coast, which is a natural geological extension of the mainland. The term has both a legal and a geological definition. In the legal sense it denotes the area that extends to 200 nautical miles beyond the coastline, while in the geological sense, the term is synonymous with the shelf. The shelf referred to is the shallow, near-coastal section of the sea floor. The shelf slopes away gently to an average depth of 130 metres, and is adjoined by the continental slope which slopes more steeply up to 90 degrees. The continental shelf is of special economic interest because among other resources, large quantities of natural gas and oil can be found there. In many parts of the world there are regions where there is geological evidence of an outer continental shelf that begins within the exclusive economic zone and

continues beyond the 200-nautical-mile limit, thus enlarging the coastal state's sphere of influence. Such evidence must be submitted scientifically to the Commission on the Limits of the Continental Shelf (CLCS) in New York, and accepted by that body. This outer continental shelf which goes beyond the EEZ can then be extended up to a line at a maximum of 350 nautical miles off the coast. Alternatively a state can claim a marine area up to 100 nautical miles past the 2500-metre-depth line as an extension of the continental shelf past the limits of the EEZ, and in some cases even beyond that.

HIGH SEAS: Adjoining the EEZ are the high seas, which no national government may claim for itself alone; they are available to be used by all countries. Nevertheless, the use of resources in the high seas is regulated. Fisheries, for instance, are regulated by Regional Fisheries Management Organizations (RFMOs) which, among other issues, specify maximum catch sizes for fish species. In contrast, the International Seabed Authority (ISA) is the sole body that supervises the use and distribution of seabed resources. It is responsible for all mineral resources on the sea floor. These are defined in the Convention on the Law of the Sea as common heritage of mankind.

National-level regulations

Whereas UNCLOS sets out clear international regulations on the use of the various marine zones and thereby defines whom the ocean or the coastal waters belong to, the management of the 12-nautical-mile zone is the sole province of the coastal state concerned. Consequently the administrative details are regulated differently from one nation to another (and, in federal countries, sometimes even from one federal state to another). For the management of coastal waters this means a considerable need for coordination between different authorities.

How many different authorities can be involved in coastal administration can be exemplified by the administration of the German North Sea coast, which borders onto the German states of Lower Saxony, Schleswig-Holstein and Hamburg. In Lower Saxony alone the responsibility for the coastal sea is shared between the following authorities or bodies:

- Water and Shipping Authorities: These are subordinate to the Federal Ministry of Transport and Digital Infrastructure and are responsible for the safety of shipping in the coastal sea and on the federal waterways of the rivers Elbe, Weser and Ems, which are under the control of the German federal government. Among their tasks are the siting and servicing of navigational aids and the maintenance of bank reinforcements as well as locks and weirs along the federal waterways. Responsibility for nature conservation along the banks of the federal waterways rests with the subordinate nature conservation authorities of the district authorities, provided that these areas are not part of a national park or a biosphere reserve.
- Lower Saxony Ministry for the Environment, Energy and Climate Protection: The ministry is responsible for the natural areas along the coast that have biosphere reserve status. Biosphere reserves are model regions initiated by the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the aim of achieving sustainable development in environmental, economic and social respects.
- Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN): This agency is subordinate to the Lower Saxony Ministry for the Environment, Energy and Climate Protection and is responsible for coastal defences on the islands belonging to Lower Saxony; the authority cooperates closely with the dike associations. In addition, the NLWKN is responsible for nature conservation in part of the dike forelands – in the salt meadows for example.
- National Park Administration: It is subordinate to the Lower Saxony Ministry for the Environment, Energy and Climate Protection and is responsible for the Lower Saxony Wadden Sea National Park, and beyond this, for the dike forelands located within the bounds of the national park.
- Main Dike Associations: These are public-law bodies which are responsible for the safety of the dikes that defend the full length of the mainland coast. The dike associations have a long tradition, going back several hundred years in some cases. They were founded by the residents of the different coastal municipalities and to this day consist largely of a voluntary workforce. The president of a dike association bears the title of "dike reeve" (Deichgraf). In the 1960s several dike associations were merged, leaving a total of 22 Main Dike Associations controlling and improving the dikes along the Lower Saxony coastline.
- Lower nature conservation authorities: These are subordinate to the respective districts and are responsible for natural areas along the coastline that are not part of the national parks.

Even just the example of Lower Saxony shows what a proliferation of responsibilities there can be in one German federal state. In Hamburg and Schleswig-Holstein, by comparison, there are differences of detail in the regulations and the official structures. This diversity is explained in large part by Germany's federalist system, but is also an example of how the management of an entire coastal area can only function when there is clear coordination and division of work between the different authorities. For example, over the years it can be deemed a success that the German Wadden Sea as a whole has been designated as a protected national park in spite of the disparate responsibilities across federal state boundaries. Beyond this, the responsibility for infrastructures of supraregional importance such as the federal waterways rests with a single body – the Federal Ministry of Transport and Digital Infrastructure. However, experts also emphasise that the division into different authorities can have advantages. They point out that within the different authorities there are large numbers of experts who possess important detailed and specialist knowledge, be it on coastal defences or nature conservation or regarding waterway safety.

Many demands – many conflicts

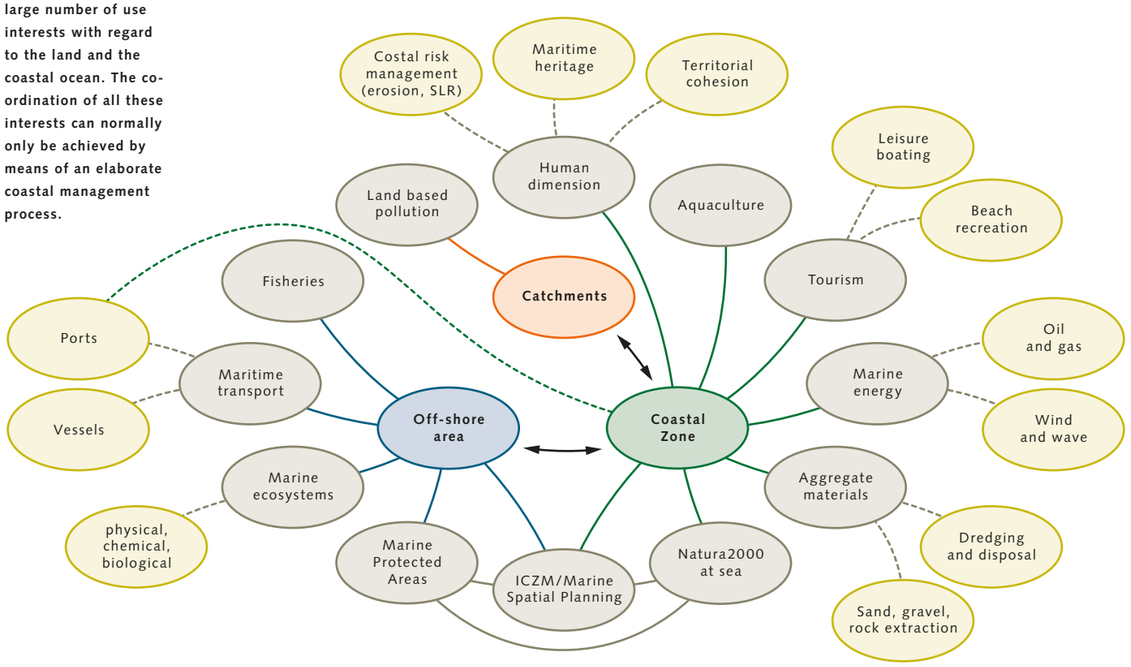
Coasts have many functions and provide many ecosystem services – such as fish, navigable waterways, tourism and

4.3 > Responsibility for the maintenance and safety of federal waterways like the river Elbe, pictured here, rests with the Federal Ministry of Transport and Digital Infrastructure, whereas the dikes protecting the hinterland are cared for by dike associations.

recreation, or space for agriculture and construction projects. That is to say, countless activities are concentrated on the relatively slender strip between land and sea in densely settled or heavily used coastal regions – which automatically results in a plethora of responsible authorities.

This plurality can easily lead to conflicts if there is not sufficient coordination between the respective authorities or among the different stakeholder groups generally. For example, human use often comes into conflict with nature conservation aspects. In China the desire for economic development led to substantial pollution of coastal areas. In order to catch up with the high economic standards of the West as fast as possible, often very little attention was paid to environmental aspects. Today there is growing resistance to such a one-sided focus among the Chinese population, and it is being realized that goal conflicts have surfaced which can only be resolved by rising above the mere satisfaction of particular interests. Not just in China but in many other regions worldwide, such stringently sectoral approaches are preventing efficient protection of coastal habitats or sustainable use. The situation is even more difficult if coastal habitats extend beyond national borders, as the Wadden Sea does, for example, in Germany, the Netherlands and Denmark. Here an effective coastal management scheme is only possible in international cooperation.

4.4 > Many coastal areas are subject to a large number of use interests with regard to the land and the coastal ocean. The coordination of all these interests can normally only be achieved by means of an elaborate coastal management process.



All parties around the table

An appropriate concept for the sustainable and comprehensive management of coasts was presented for the first time in 1992 during the United Nations Conference on Environment and Development in Rio de Janeiro: Integrated Coastal Zone Management (ICZM), the aim of which is sustainable development of coastal zones and which seeks to reconcile all aspects of coastal development. To this day many countries and international communities – for example, the European Union – have made ICZM the guideline for planning future coastal development, defined as follows: "Integrated Coastal Zone Management seeks, over the long term, to balance the benefits from economic development and human uses of the Coastal Zone, the benefits from protecting, preserving and restoring Coastal Zones, the benefits from minimizing loss of human life and property, and the benefits from public access to and enjoyment of the Coastal Zone, all within the limits set by natural dynamics and carrying capacity." Although ICZM is acknowledged today as a tool for future coastal zone management, coordination of the particular interests of the different stakeholder groups remains the greatest challenge.

According to the Food and Agriculture Organization of the United Nations (FAO), nowadays there are a series of causal factors that result in the exploitation or degradation of coastal habitats rather than their sustainable use. These include:

- large business enterprises geared towards quick profits, which exploit or destroy resources and which conflict with the interests of the coastal population;
- a shortage of serious governmental follow-up measures for the support and implementation of nature conservation programmes;
- low awareness among local people and policy-makers about a form of management that relies on sustainable resource use;
- poverty which is exacerbated by the increasing scarcity of resources, damage to habitats and fish breeding grounds and a lack of alternative livelihoods;
- strong population growth.

Good management delivers benefits

This conflict potential can be defused, the FAO notes, if all these aspects are taken into consideration as part of an integrated coastal zone management scheme, and ICZM programmes, once drafted, are actually implemented in full. According to the FAO approach, ICZM programmes can benefit countries or individual coastal regions in the following ways:

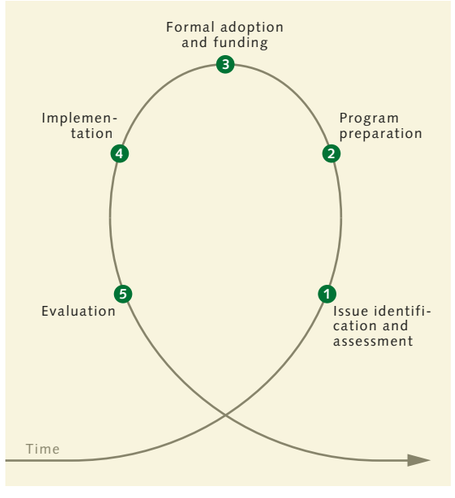
- Facilitating sustainable economic growth based on natural resources;
- Conserving natural habitats and species;
- Controlling pollution and the alteration of shorelands and beach fronts;
- Controlling possible pollution in watersheds that drain into the coastal region;
- Controlling excavation, mining and other construction impacts on coral reefs and on the near-coastal sea floor generally;
- Sustainable use of overused resources so that these can recover, such as fish stocks and other marine organisms;
- Providing mechanisms and tools for equitable and sustainable resource allocation among the various stakeholder groups;
- Quicker and more focused implementation of projects by involving all stakeholder groups, because this averts later disputes that might delay a project;
- Avoiding damage to the marine environment or marine resources.

Furthermore, a comprehensive ICZM programme today must address more than just the immediate shorelands and coastal waters but also the multifarious relationships between the coast and the hinterland – be it for the creation of sales markets for new, sustainably harvested products, or with regard to preventing land-based pollution of coastal waters. The FAO emphasises that this list represents the ideal form of ICZM and that in today's world not all the goals of ICZM projects will be achieved in every case. Nevertheless, the ICZM idea has gained traction in many places.

Depending on the number of use interests, an Integrated Coastal Zone Management process can vary in its complexity. If only individual or a handful of user groups are involved, the overall process is generally more streamlined. This may be the case in coastal regions of developing countries, for instance, where artisanal fishery is the main feature and few other types of use exist. In the meantime, successful examples exist from which much can be learned.

Optimization through quality control

Regular monitoring of whether certain measures have resulted in a set objective is of crucial importance for a successful ICZM process. This also means that ICZM is not a one-off project but a cyclical process in which results are continually reviewed and assessed. Thus it is also possible to adapt the ICZM process little by little to new conditions and optimize it. An ICZM cycle begins with an analysis of the situation and assessment of the problems. This is followed by the drafting of an action plan that takes account of all the issues. Next, the action plan is formally approved by all parties involved. A prerequisite for this, however, is that financing is pledged for the complete set of measures from the action plan. This is followed by the implementation phase. Once the measures defined in the action plan have been implemented, an evaluation takes place which assesses the measures to determine their impact. If further problems or new difficulties arise, the action plan must be refined. This completes the cycle.



4.5 > Ideally an ICZM process takes place in cycles, during which measures are planned, implemented and then evaluated. If optimization is found to be needed, the next cycle begins with the planning of new measures.

Depending on the scale of an ICZM process, the duration of a cycle may vary. Best-practice examples show that one cycle of an ICZM project on a national scale, from situation analysis to evaluation, takes around eight to twelve years. If the process only encompasses a certain coastal region or a single coastal town, one cycle lasts around three to four years on average.

Bringing local people on board

Depending on the situation in the given location, various stakeholder groups must be involved in the ICZM process. The following successful examples will make this clear.

In the year 2000 the Locally-Managed Marine Area Network (LMMA) was founded in the Indo-Pacific region, the marine region that encompasses the Indian Ocean and the Western Pacific. This network was first instigated by the work of non-governmental organizations and individual, well-networked scientists, and could ultimately be established in the region. Its objective is to protect coastal waters by making use of them sustainably and prudently – for example, if fishers switch from destructive dynamite fishery to gentler methods of catching fish. The LMMA idea was born from the insight that marine protected areas (MPAs) that are defined at high political level are often not accepted by the population because they can massively curtail their rights. In concrete cases the population was completely prohibited from fishing in MPAs, which could not be reconciled with the local people's traditional customs. The local people resisted the prohibition on use, which undermined marine protection in the areas concerned from the very start. In the meantime many village communities in different countries now belong to the LMMA network, and have regular opportunities to engage with each other at regional, national and international workshops. The supreme objective of the LMMA is marine protection.

It differs from the idea of MPAs in that grassroots groups are given a voice during the planning phase and take charge of sustainable management in their locality themselves. Thus, all stakeholder groups are involved in the planning: village communities, associations of land-

4.6 > A self-painted sign for a self-administered protected area. The ocean around the island of Vanua Levu, which belongs to Fiji, was declared a locally managed marine area (LMMA) in a comprehensive management process. Here the local fishers themselves ensure sustainable use of the fish and seafood.

owners, nature conservationists, representatives of regional or national authorities who live locally, with scientists on hand to provide advice and backup.

The problems are similar in many coastal areas of the Indo-Pacific region. In many places the marine biotic communities and natural resources are being harmed by overfishing, by destructive fisheries such as dynamite and cyanide fishery, by pollution or by industrial activities on land. The coral reefs in the region suffer additional degradation from being trampled by tourists and damaged by anchors or by the removal of corals for sale as souvenirs. It is important that the local population can retain its sovereignty through the LMMA process by participating in deciding, in consultation with other stakeholder groups, which fishery methods they should use in future. Also as part of the planning process, alternative activities need to be developed whereby local people can secure their incomes in future. Compliance with the agreed rules is overseen either by local chiefs, traditionally organized village communities or else the local coastal fishery authorities. As a rule, some territory is also defined during the LMMA planning process where a complete prohibition on use applies, which guarantees that stocks of the marine organisms subject to use can recover. In this respect the LMMA idea certainly comes close to the principle of the MPAs. In summary, the LMMA approach pursues the following objectives:

- Improved quality of the marine habitat (coral cover, sea grass, mangroves);
- Increased fish population, and hence improved reproduction of fishes and higher fish biomass;
- Increased incomes resulting from the use of marine resources;
- Enhanced capacity of the local population to manage their resources;
- Stronger sense of environmental stewardship and community cohesion.

The long road to the Wadden Sea World Natural Heritage site

How complex and laborious it can be to reconcile opposing positions and achieve sustainable use of a coastal area is exemplified by the North West European Wadden Sea, which was granted World Natural Heritage status by UNESCO (United Nations Educational, Scientific and Cultural Organization) in 2009. This area of tidal mudflats, the world's largest, is around 500 kilometres long and extends across large parts of the Dutch, German and Danish North Sea coasts. Today, with its World Natural Heritage status, it is recognized internationally as an ecological region of special aesthetic quality and of particular significance as a breeding ground for the fish of the North Sea and millions of breeding and resting birds. Several million holidaymakers currently visit this region every year.

It took almost 50 years for protected status to be achieved. Interestingly, this was accomplished despite the fact that each of the coastal states pursued the protection of this transboundary ecological region through their own national legislation rather than through trilateral treaties. Moreover, this example shows that initial resistance can be overcome, in this case thanks mainly to the enduring commitment of individual protagonists and nature conservation organizations over many years.

A severe storm surge affected the Netherlands in 1953 and Germany in 1962. In both cases, the dikes along the North Sea coast were breached in many places. Some 1800 people died in the Netherlands in 1953 and more than 300 in Germany in 1962. In the following years, dikes were reinforced in many places and the shorelines straightened by damming bays. In the Netherlands and Germany there was also discussion of large-scale solutions – constructing dikes around major areas of the Wadden Sea. The intention behind this was not merely to protect the land from further floods; additional plans were made to put the newly reclaimed land areas to industrial and agricultural uses. In the 1960s the Wadden Sea was considered by all three countries as a backward region that required economic development. To this end, initially a series of nuclear power stations was to be constructed in the enclosed areas, which would then be likely to attract other industrial enterprises. The construction of an airport was also proposed.

4.7 > In 1972 fishers in the Netherlands protested against the damming of the Eastern Scheldt estuary.

The first critiques of these plans were voiced in 1965 in the Netherlands where activists published letters of protest in the daily press. Out of this solitary act of resistance, the first nature conservation organization came into being that was dedicated wholly to the protection of the Wadden Sea, the Landelijke Vereniging tot Behoud van de Waddenzee (Association for protection of the Wadden Sea). At about the same time, the Royal Dutch Academy of Sciences had commissioned a group of younger scientists with a first systematic survey of data on the Wadden Sea's ecology. Although the significance of the habitat for fish breeding and bird life was known, very little else about the ecosystem was understood. Strong advocates from the scientific world thus stood shoulder to shoulder with nature conservationists. Even then, the scientists were emphasising the significance of the Wadden Sea as a transboundary habitat which needed to be protected by means of international agreements. In Germany, too, the first groups emerged in the 1960s, cooperated with their Dutch partners and were very early in calling for the establishment of a Wadden Sea National Park. But little notice was taken of them at the time. In Denmark, on the other hand, there was no lobby worth mentioning at first, which was partly due to the fact that the Wadden Sea only accounted for a relatively small proportion of the total coastline of around 7000 kilometres and its importance was barely perceived.

The fact that in the following years the Wadden Sea still came to be perceived as an ecological region of transnational importance was due to the adoption of the international Ramsar Convention for the protection of wetlands such as peatlands, marshes, salt meadows, swamps and tidal mudflats. It had been drafted at the instigation of UNESCO and the non-governmental IUCN (International Union for Conservation of Nature and Natural Resources) and was adopted on 2 February 1971 in the Iranian city of Ramsar. Although the Convention was not binding in international law, it did engender a signal effect. Most wetlands until then had been treated as a land reserved for future economic use. The Convention for the first time officially underscored on the policy level the international importance of wetlands, especially for waterfowl and migratory birds.

In 1974, the new left-wing liberal government of the Netherlands abandoned most of the construction and economic projects planned for the Wadden Sea in the previous years, and the nature conservation organizations never tired of proclaiming the Wadden Sea's importance as an ecological region, particularly for the population at large. In Germany, meanwhile, nature conservation associations set up information centres along the North Sea coast in which tourists were informed about the ecology of the Wadden Sea by means of talks and guided tours of the tidal mudflats. But politically there was no letting go of the idea of making industrial and agricultural use of the Wadden Sea and strengthening coastal protection by means of dike construction.

In Denmark at this time, Danish researchers also started to advocate protection of the habitat in their country.

Finally, in the early 1980s, the overall environmental policy situation in Europe began to undergo a distinct change. In view of pollution due to the discharge of industrial wastes and the high effluent loads in the rivers Rhine, Elbe, Humber and Thames, there was a growing perception of the North Sea, and the Wadden Sea along with it, as threatened habitat. This was also reflected in the intensive media reporting on the theme.

In Germany the issue of North Sea pollution definitively reached the top of the political agenda in 1980 after the German Advisory Council on the Environment had published an alarming report about the worrying condition of the North Sea and marine pollution generally. In the Netherlands, the conservation of the Wadden Sea ecological region was now integrated into an overall regional-planning concept as a government policy objective. The Dutch government took this step to try and strengthen trilateral cooperation, stressing the significance of the "indivisibility of the international tidal mudflats region". It sought to codify a statute for the Wadden Sea region which should transcend national borders and regulate common administrative objectives and cooperation with Denmark and Germany.

Closer cooperation with the neighbouring countries Germany and Denmark did not initially come about, however, because these countries wanted to continue managing the Wadden Sea according to their own rules. Furthermore, the idea of the Wadden Sea as a unified ecological region collided with the prevailing attitude in Denmark and Germany of unrestrained national sovereignty in their own territorial waters. In 1982 the three countries signed the Joint Declaration, a trilateral declaration of intent, but it was not binding: for example, Denmark retained the right to continue hunting seals in the Danish Wadden Sea while the Netherlands resolved to protect them.

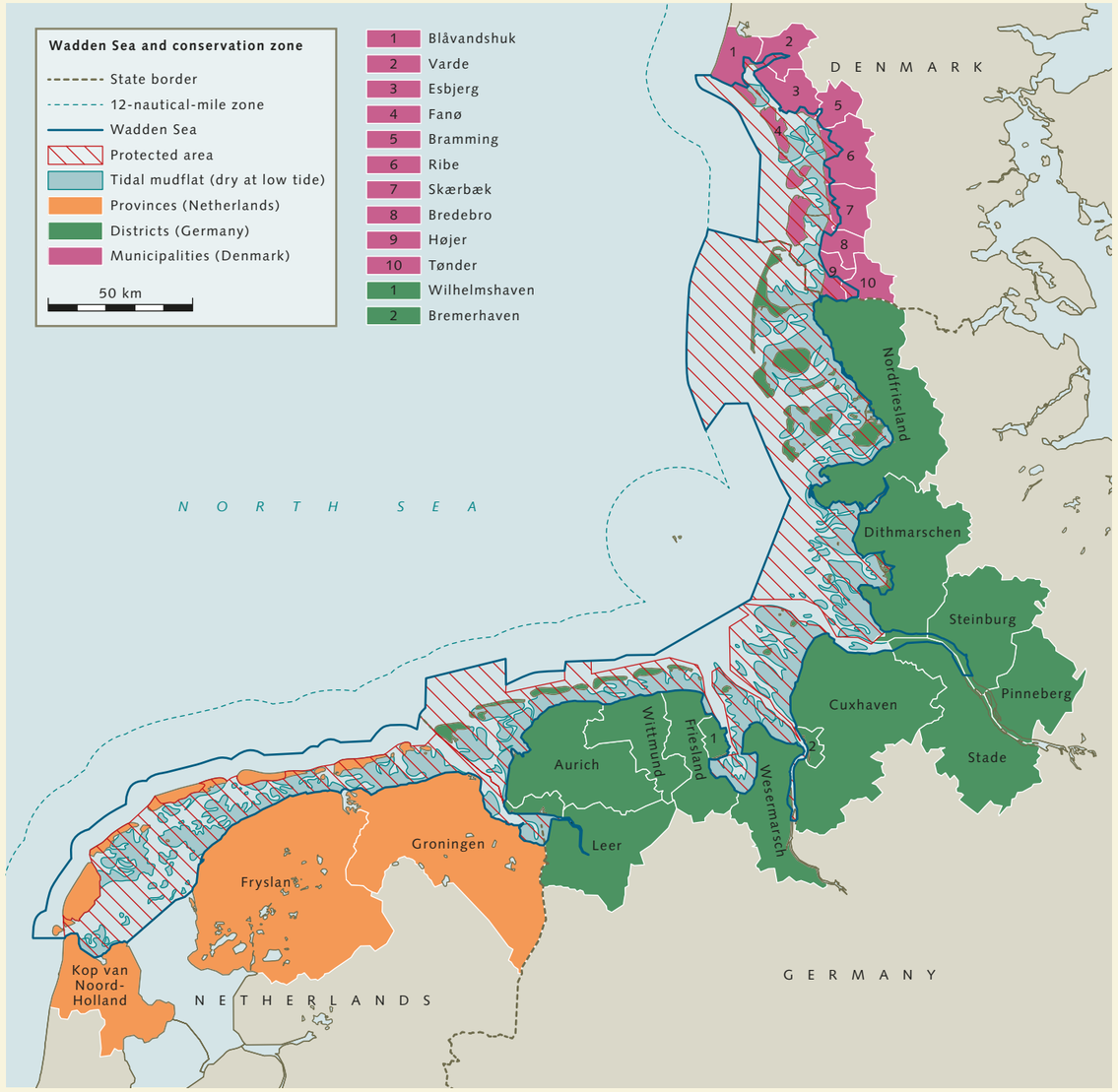
Nevertheless, progress began to be made from the mid-1980s. The Netherlands decided to protect areas of its Wadden Sea by barring them from agricultural, industrial or tourist uses or designating them as protected natural areas. Germany, on the other hand, embraced the idea of national parks, which had been discussed repeatedly since the 1970s and which have the highest protection status that can be conferred on an ecological region in Germany. Since the decision to establish a national park is a regional government matter, three German federal states designated three different national parks in succession – in the state of Schleswig-Holstein in 1985, in Lower Saxony in 1986, and a small section belonging to the city of Hamburg and located in the Elbe estuary in 1990. That did not amount to a solution to all problems, however.

Schleswig-Holstein was the main focus of criticism. The nature conservation organizations complained that oil drilling had been approved in the direct vicinity of the national park boundary. Furthermore, bird hunting as well as mussel fishery continued to be allowed on a limited scale. Denmark, for its part, did not initially consider it necessary to protect the Wadden Sea in its entirety. The establishment of a large-scale protected area would have entailed a prohibition on hunting for waterfowl or seals, for example.

A strengthening and internationalization of cooperation was only achieved at the renewed initiative of nature conservation associations from the three coastal countries. At their urging, the trilateral Wadden Sea Secretariat in Wilhelmshaven was finally founded in 1987. Over the years it has succeeded in establishing itself as a coordinating body that acts in a policy advisory capacity. Today it is financed jointly by all three countries. It coordinates research, public relations work and environmental monitoring programmes – for example, the control of invasive species – and organizes Trilateral Wadden Sea Conferences which take place every three to five years.

In the view of experts, it would be wrong to talk about an ideal integrated coastal zone management programme in relation to the Wadden Sea because of the divergent national regulations that apply. So far that has remained a goal for the future. While the existence of the Wadden Sea Secretariat means that a state-supported organization exists and the recognition as a World Natural Heritage site by UNESCO has further advanced the perception of the Wadden Sea as a transnational entity, there are no legally binding standards of any kind attached to this status. However, World Natural Heritage status has international charisma and finally induced Denmark, whose tidal mudflats were not initially included in the World Natural Heritage listing, to designate them as a national park. Having been brought up to the same protection status as had been achieved in Germany, in 2014 the Danish section of the Wadden Sea was then accordingly recognized as World Natural Heritage.

4.8 > In 1985 the Wadden Sea in Schleswig-Holstein was declared a national park. Despite this there was strong criticism to begin with because controversial coastal protection measures were still being carried out, such as the locking of the Nordstrand Bight with a dike formed from sand using hydraulic filling.



4.9 > Although the Wadden Sea in its entirety is a World Natural Heritage site, the responsibilities for this habitat are distributed among several countries. The area extends across three nations and is administered by a variety of regional authorities within these states.

Since the various village communities in coastal regions are now connected with each other via the network, best-practice solutions can easily be passed on. Since the year 2000 a series of LMMA projects have been carried out successfully – including in Indonesia, Papua New Guinea, and the Philippines, on the Solomon Islands archipelago and on the islands of Fiji, Pohnpei and Palau. Since the individual regions are often small, however, some national governments are not highly motivated to allocate ministry or civil service resources to support this type of engagement. Since coastal areas are significant for the local people's food supply, in certain cases in-situ projects are most likely to be initiated by non-governmental organizations.

Sustainable management in China: combining conservation and use

A range of comparable projects are taking place around the world which, while they do not designate themselves LMMAs or conform to that specification in every detail, nevertheless all have the same objectives, namely that local people are granted a kind of ownership over the marine resources and that these resources are managed by the community. China, for instance, has been trying for some years to reconcile the conservation and use of marine areas. Here as elsewhere, experience has shown that rigidly defined marine protected areas (MPAs) are not accepted and hence tend to be ignored. For that reason, since 2005 China has been designating what are known as special marine protected areas (SMPAs), in which zones are opened up seasonally for different uses such as fishery or tourism. Other zones in turn are barred from any kind of use.

A study has recently been undertaken to assess how effective this system is. To that end, interviews were carried out with advocates and critics of the SMPAs policy. The findings show that SMPAs can be considered as a complement to standard MPAs but are no substitute for them. Depending on the situation, either complete protection of a marine area or an SMPA solution might be appropriate. What clearly emerges is that consultation of the different interests during planning distinctly reduces conflict and boosts acceptance of the conservation zones within the SMPAs. Critical remarks have been voiced that so far there has been no scientific backup research to analyse whether the protection objectives are being achieved. One reason for this is the failure to fund such scientific work. An evidence-based evaluation as specified for ICZM processes, for example, first needs to be firmly anchored in the Chinese SMPAs concept. Overall, the current study finds that the SMPAs concept is assessed as a worthwhile tool for marine conservation in China, and one that is likely to continue to gain in significance in future.

Nature conservation and tourism – (not) in conflict

For the protection of coastal habitats it is indispensable to restrict certain forms of use. For example, the problem with tourism is that often precisely the most valuable and near-natural habitats exert a special attraction for holidaymakers because of their original character: there may be extensive dunes and beaches, or wetlands that are inviting to bathers or of special interest to birdwatchers because of their species diversity. Drawing the boundaries between zones used for tourism and the protected areas is difficult in this situation. This explains why in many European coastal regions, two environmental directives have led to an especially large number of conflicts between authorities, conservation organizations and other stakeholder groups: the Birds Directive of 1979, the purpose of which is to conserve wild species of birds, and the Habitats Directive of 1992, aimed at the conservation of various natural habitats together with the wild animals and plants living in them. When these directives were adopted, every EU member state was obliged to transpose these provisions into national law and to designate corresponding protected areas in its own country.

Findings of a study on conflicts between tourism and nature conservation in coastal areas of Germany that are especially popular among tourists suggest the following conclusions: conflicts arise mainly when the parties to the conflict were not in dialogue prior to the designation of protected areas. Where protected areas were simply imposed by the responsible authorities and the population was faced with a fait accompli, this led to great resistance not only among tourists but also among tradespeople, retailers and farmers.

One of the criticisms from tradespeople and from tourism associations was that the designation of conservation areas creates the necessity to steer tourist flows, which requires a major effort, particularly in large-scale protected areas. Paths through the protected areas must be fenced on either side and car parks set up at the margins.

There is also criticism that in many places, during the first phase of designation of the area, members of the public are not adequately notified, informed, and hence taken seriously. The approach taken by many administrations, merely to have focused on the EU directives without having communicated the advantages and opportunities, was seen as a particular mistake. Consequently there was a widespread public perception of being affected by measures imposed from the top-down without having any influence. For the future, the study therefore suggests the following measures:

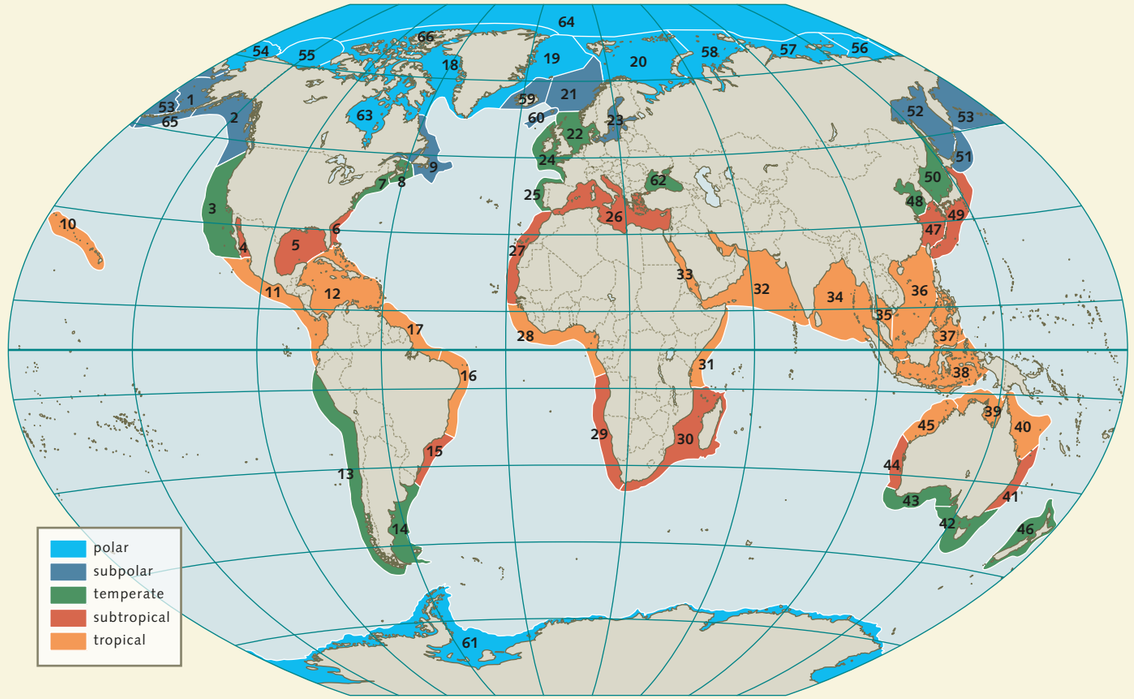
- Negotiations and consultations with the responsible organizations in each case (tour operators, municipalities, sporting associations) in order to develop common solutions, for example coordinating the scheduling of guided hikes, designating car parks or moorings for boats and canoes;
- Well thought-through action plans for visitor information and education, particularly by maintaining a comprehensive network of rangers and information centres and by means of information boards;
- Communication of the quality of an area on the basis of existing natural assets and the need for protection with the perspective of developing new business models, such as ecotourism.

The recipe for success: involving citizens from the outset

A successful example of an ICZM process in the tourism sector is presented by the coastal defence measures that were undertaken in the two German Baltic Sea municipalities of Scharbeutz and Timmendorfer Strand between 1999 and 2011, after a study had shown that these were severely threatened by flooding. Both municipalities are densely settled and intensively used for tourism as holiday destinations. A feature of these locations is a long shoreline promenade providing open access to the Baltic Sea and following a course between a parade of shops and small businesses on one side and the beach on the other. Both places are located in a bay in which the water level can rise significantly in the event of a strong easterly wind. An economic valuation analysis found that at water levels of more than 3 metres above mean sea level, severe flooding can occur. This would pose a threat to up to 6000 people and material assets of more than 3.4 billion euros. The municipalities therefore decided to construct a coastal defence dike with financial support from the district authority and the Federal State of Schleswig-Holstein. The local community put up resistance right from the start because it was feared that such an embankment would destroy the aesthetics of the promenade, which could ultimately damage the tourist trade. For this reason the population's involvement was sought in subsequent planning – firstly via information material which explained the issues at length, and secondly through participation in public meetings, where more than 50 people from the local population and the administration discussed various solutions which ranged from dispensing with coastal defences altogether to the maximum-intervention solution of constructing the dike.

A combined solution emerged from this participatory process: a flood abatement scheme that would be tastefully adapted to the local circumstances. By refraining from constructing the dike, it was possible to retain the character of the promenade completely. While the structural works were in progress, public tours of the construction site were held fortnightly on a Saturday in order to inform people about the current progress of the works and address unanswered questions.

A significant measure of success was that the scheme delivered altogether more aesthetic coastal defences. In one section, for example, it was decided not to fell trees



1. East Bering Sea
2. Gulf of Alaska
3. California Current
4. Gulf of California
5. Gulf of Mexico
6. Southeast U.S. Continental Shelf
7. Northeast U.S. Continental Shelf
8. Scotian Shelf
9. Newfoundland-Labrador Shelf
10. Insular Pacific-Hawaiian
11. Pacific Central-American Coastal
12. Caribbean Sea
13. Humboldt Current
14. Patagonian Shelf
15. South Brazil Shelf
16. East Brazil Shelf
17. North Brazil Shelf
18. West Greenland Shelf
19. East Greenland Shelf
20. Barents Sea
21. Norwegian Shelf
22. North Sea
23. Baltic Sea
24. Celtic-Biscay Shelf
25. Iberian Coastal
26. Mediterranean Sea
27. Canary Current
28. Guinea Current
29. Benguela Current
30. Agulhas Current
31. Somali Coastal Current
32. Arabian Sea
33. Red Sea
34. Bay of Bengal
35. Gulf of Thailand
36. South China Sea
37. Sulu-Celebes Sea
38. Indonesian Sea
39. North Australian Shelf
40. Northeast Australian Shelf/ Great Barrier Reef
41. East-Central Australian Shelf
42. Southeast Australian Shelf
43. Southwest Australian Shelf
44. West-Central Australian Shelf
45. Northwest Australian Shelf
46. New Zealand Shelf
47. East China Sea
48. Yellow Sea
49. Kuroshio Current
50. Sea of Japan
51. Oyashio Current
52. Okhotsk Sea
53. West Bering Sea
54. Chukchi Sea
55. Beaufort Sea
56. East Siberian Sea
57. Laptev Sea
58. Kara Sea
59. Iceland Shelf
60. Faroe Plateau
61. Antarctic
62. Black Sea
63. Hudson Bay
64. Arctic Ocean
65. Aleutian Islands
66. Canadian High Arctic and North Greenland

4.10 > The near-coastal areas of the world's oceans have been classed into 66 large, transnational marine ecosystems, known as the large marine ecosystems (LMEs). It is hoped that this approach will enable better cooperation among nations on international marine conservation.

and instead a steep storm-beach was installed, with additional breach protection in the form of an unobtrusive wall about half a metre high. A recreational footpath now runs between the low wall and the row of trees. Overall this approach succeeded in gaining a high level of acceptance of the coastal protection scheme, which now even enriches the visual appearance of the promenade thanks to the high quality of project execution.

The concept of large marine ecosystems

ICZM always becomes a particular challenge when coastal areas and habitats are so large that they extend to several countries. Comprehensive protection of these areas is only possible if the countries cooperate on such matters as marine pollution or the management of fish stocks. In the 1990s, researchers at the US National Oceanic and Atmospheric Administration (NOAA) therefore developed the concept of large marine ecosystems (LMEs). Under this system, today the Earth's near-coastal marine areas are classed into 66 LMEs, each of which is distinguished by a typical flora and fauna. LMEs are defined along coasts and extend to the continental slope, the part of the sea floor where the continental shelf drops steeply into the deep ocean. The main difficulty is that for successful coastal zone management it is necessary to realize transboundary cooperation on different levels. Firstly, the individual states must consent to high-level cooperation between national governments. Secondly, the responsible sectoral authorities and the local administration must be involved to ensure that the local coastal population can actually be included in the transboundary cooperation. The conservation of larger fish stocks, for example, is only feasible if the new rules for sustainable fishery are put into practice by all fishers and authorities throughout the LME.

With the support of the World Bank, the Global Environment Facility (GEF, an international institution for the financing of environmental protection projects) and the United Nations Environment Programme (UNEP), efforts are being made principally in developing and newly industrializing countries to improve international cooperation over the protection of the LMEs. Researchers and politicians as well as members of the general public from neighbouring nations meet up at workshops and conferences. Since economic aspects such as marine oil drilling often take priority over conservation of the environment, the concept of the LMEs is aimed at providing a counterbalance and creating awareness within the countries of the ocean as habitat.

A fledgling network for protection of the Bay of Bengal

One example of successful cooperation is the Bay of Bengal Large Marine Ecosystem (BOBLME), within which the coastal states of the Bay of Bengal to the east of India work together: Bangladesh, India, Indonesia, Malaysia, the Maldives, Myanmar, Sri Lanka and Thailand. Within this area, the BOBLME project was launched in 2010 for a planned five-year term. Its aim was to manage fish stocks more effectively in order to tackle overfishing, and additionally to combat marine pollution. A comprehensive analysis of the local situation was the first item on the agenda. The many different local, regional and national responsibilities had to be clarified and joint work priorities defined. These in turn depended on the hardships or needs reported by the people in the given localities. For example, fishery is administered by different authorities in every nation, sometimes by fishery offices and sometimes by economic authorities, so it was first necessary to locate the relevant contact partners, who were then put in touch with one another at international conferences and workshops. A further objective of the project was to survey the status of the various fish populations. In this respect there was a large gap in knowledge because in many countries it had been some long time since research ships had last undertaken regular estimates of fish populations. In Myanmar, for example, no such census had been carried out for the last 30 years. With support from a Norwegian research ship, population estimates were carried out for the entire bay. Thanks to these estimates, for the first time a management recommendation could be made for the region to ensure sustainable catches of the economically important Indian mackerel and Hilsa herring. In order to be able to

monitor fish populations and the state of the marine environment in future, scientific working groups were also formed with researchers from all coastal states so that they could cooperate in future on matters relating to fish population statistics, the monitoring of marine pollution and on ecological studies in the Bay of Bengal. In addition, the working groups compiled best-practice solutions for sustainable fishing in the region and will attend local workshops and present these methods to other fishers, who will adopt them. In 2015 the BOBLME project came to an end. Since then gradual introduction and implementation of the fishery practices and management recommendations developed during the project term have continued in every country.

Conservation through regional self-governance

For the sustainable use of coastal areas, it can be sufficient for a single affected group of users to change its behaviour. For instance, this is true of artisanal fishery in various coastal regions, which can be practised under new management methods in such a way as to make prudent use of fish stocks. One example is the Chilean loco fishery. Locos are sea snails of the species *Concholepas concholepas*, the very popular Chilean abalone, which are harvested from the sea floor along the coast by divers. Fishery biologists refer to fisheries like these as “S fisheries”, a term derived from the categories “small-scale fisheries”, “sedentary stock” and “spatially structured”. Spatially structured means that a number of geographically separated populations exist at various sites within one region. The danger with S fisheries is that these populations will be overfished locally.

4.11 > The mollusc *Concholepas concholepas* is a popular shellfish in Chile. To harvest them, geographically delimited fishery territories administered by individual local cooperatives were established along the Chilean coast.

In the past that is precisely what happened in Chile. Once one population had been harvested to exhaustion, the fisher-divers moved on to the next area. This led to conflicts with the resident fisher-divers in each new location, because it increased pressure on the population in their locality. At the end of the 1980s, loco stocks had shrunk to the extent that loco fishery was in crisis along the whole of the coast. Many fishers lost their livelihoods. The Chilean government therefore instituted a new management system in 1991, whereby spatially delimited fishery territories along the coast and corresponding locality-based cooperatives of fisher-divers were established. The cooperatives based in the area were thus granted exclusive rights of use as well as self-governance. These areas with territorial use rights are called Management and Exploitation Areas for Benthic Resources (MEABR), or in Spanish, Áreas de Manejo y Explotación de Recursos Bentónicos (AMERB). Another phrase in general use is MEABR management. Internationally this type of local management is referred to as territorial use rights in fisheries (TURFs).

This territorial fishery use right was only granted if the fisher-divers organized themselves into cooperatives and then, with support from experts, drew up a management plan for future prudent use of the loco population in a certain territory – for instance with regard to the maximum daily quotas for permitted extraction from the marine area. These quotas were then allocated among the individual members of the cooperative. Fisher-divers from other coastal areas and cooperatives were excluded from extraction in this area. As an additional benefit of organizing themselves into cooperatives, the fishers found themselves in a better negotiating position vis à vis middlemen. Most of the fisher-divers previously used to fish for locos and sell on their catch alone, whereas now they could collectively negotiate a price for the shellfish.

The loco stocks did indeed recover, which was a successful result for MEABR management. Subsequently the principle went on to be adopted for other fisheries in

4.12 > A fish market in Bangladesh. Hilsa herrings are the main product on sale, and are especially popular here in the Bay of Bengal region. After years of overfishing an international project has finally succeeded in developing a responsible fishery management regime for the entire Gulf.

4.13 > In future, the breeding of algae could become established in many parts of the Indian Ocean and in the Pacific as an alternative to fishing. Algae breeding has the advantage of low costs because very little is required in the way of equipment and materials.

Chile. Today around 45 benthic organisms, which include bivalves and molluscs but also algae, are fished according to MEABR management plans.

But not in every case was this kind of management successful. Sometimes populations have collapsed and the carefully designed MEABR strategy has become redundant. A notable reason for this has generally been that the population dynamics of certain organisms had not been sufficiently researched, and thus overfishing could still occur on the basis of mistaken estimates.

Alternatives to fishery

One strategy of ICZM projects today in developing and newly industrializing countries consists of developing alternative income-earning opportunities locally with the coastal population. In regions dominated by fishery, this can help to take the pressure off overfished stocks or overused marine habitats. An example in the Philippines and in Indonesia are projects in which the breeding of marine algae (seaweed) on long ropes was established as an alternative to destructive fishing with dynamite and cyanide. Algae breeding has the advantage of low costs because very little is required in the way of equipment and materials. Moreover, there is a growing global demand for algae, the majority of which is used for the production of carrageenan, a substance extracted from algae that is used in the food industry as a setting and thickening agent. The projects show that while algae production cannot replace fishing, in some places it led to a reduction of the quantities caught so that pressure on the ecosystem did indeed diminish. In other places fishing continued at the same intensity despite algae breeding. Not in every case could the local population be sufficiently convinced of the significance of resource conservation. Experts therefore emphasise that one sole alternative source of income is not always enough. Ideally it should be possible to present a certain plurality of alternatives in ICZM projects of this kind.

Too many cooks impede development assistance

For successful integrated coastal zone management in developing and newly industrializing countries it is essential to integrate all national and local stakeholder groups into the management process, but that is not all: consultation is also necessary between the various international and regional organizations for development assistance. That is by no means always the case. There are regions in which different organizations are active in neighbouring localities, sometimes even with the same priorities, without conferring with or knowing about each other. This gives rise to several drawbacks: Firstly, it is not possible to share the use of resources such as infrastructure, offices or vehicles. Furthermore, when different development assistance organizations pursue their projects in isolation from one another or fail to coordinate with development priorities locally, it precludes the possibility of comprehensive integrated management whereby, for example, the drinking water supply, agriculture and coastal protection are monitored simultaneously. In unfavourable cases, results are achieved that are unsustainable or even counterproductive. To counteract these aspects and to increase the effectiveness of development assistance as a whole, in 2005 the OECD therefore adopted the Paris Declaration on Aid Effectiveness. This Paris Declaration pursues five essential objectives in total:

- Ownership: The partner countries, not the donor countries, exercise coordination and responsibility for every development process.
- Alignment: Donors adapt their strategies and processes to those of partner countries and use existing institutions of the cooperation countries or the partner organizations.
- Harmonization: Donors coordinate and harmonize their programmes and procedures among themselves.
- Managing for results: Donors have their results measured in terms of the effects of their development policy action, such as reducing the illiteracy rate, and not their financial input, such as 10 million euros for new schools.
- Mutual accountability: Donor and cooperation countries are jointly accountable to the public and their parliaments for their development policy actions and their progress.

Since 2012 these objectives, slightly modified in part, have been steered and further pursued via the Global Partnership for Effective Development Cooperation.

Kiribati leads by good example

Today the principles of the Paris Declaration are also being subsumed into integrated coastal zone management. An example is the Pacific island-state of Kiribati which comprises over 30 islands. The expanse of the island-state is vast. From west to east the nation extends over around 4500 kilometres, which is roughly equivalent to the distance from the west coast to the east coast of the USA. The people of Kiribati do not see themselves as inhabitants of a tiny island-state by any means, but as inhabitants of a large oceanic state boasting a tradition as seafarers in the Pacific going back thousands of years. Over the years many development assistance projects have been implemented but in many cases they did little to coordinate efforts with each other or to align their activities with national development objectives. In accordance with the Paris Declaration, the government therefore decided to require greater cooperation between the individual development projects and that these should also take their guidance from national and local priorities. To this end, a strategy called the “whole-of-island approach” was introduced on Kiribati a few years ago. In this way the state and several international development organizations have now agreed to implement projects jointly, paying attention not just to sub-aspects but always to a whole island in each case with all its problems and challenges. This means that individual aspects – such as coastal protection or agricul-

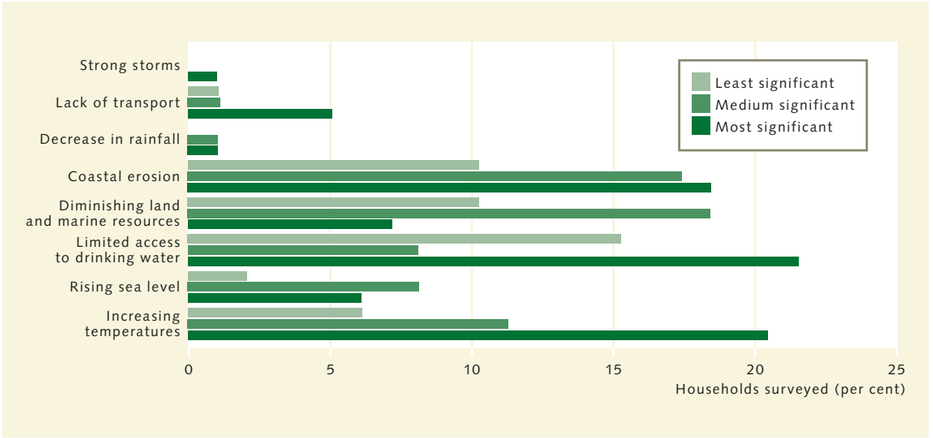
ture – are not considered in isolation from each other, but that solutions are developed for all domains of life at once and articulated in a development plan for the given island. What this contains in detail are measures promoting sustainable education, fishery, infrastructure, coastal protection, agriculture, energy, water supply and health. At the same time consideration is given to how the population can adapt to climate change.

Kiribati together with development assistance organizations wants to carry out analyses on all islands gradually in the next few years. Known as Integrated Vulnerability Assessments, these will be used to inquire into the population's needs and study the impacts of climate change. Under a whole-of-island approach as with any typical ICZM process, cooperation with local people plays a decisive role, since this is the only way of ensuring that measures are implemented which people actually need and accept.

Taking the initiative on the island of Abaiang

On each of Kiribati's islands there is a council of elders consisting of members delegated from every village. The council of elders is the first port of call for cooperation. As a first step the staff of the development assistance organizations accompanied by representatives of the various responsible ministries from the capital of Kiribati, South Tarawa, visit the islands in order to carry out interviews. In doing so they take pains to ensure that it is not just the all-male council of elders who have their say. Individual interviews are also held to survey the needs and opinions of all other groups within the population – and particularly of the women and young people. The results are aggregated into a representative profile of opinions on how the inhabitants imagine their future in ten or 20 years' time. Talks are also held with representatives of the different local institutions such as the church or the police. The first

4.14 > The island state of Kiribati is endeavouring to protect its low-lying atolls from the ocean, partly with solid sea walls. But in many cases storm surges destroy the structures, as seen here off the capital, South Tarawa.



4.15 > For the island of Abaiang climate change is already a reality. According to a survey, the most obvious signs noticed by the inhabitants are freshwater scarcity, higher temperatures and erosion of the shoreline.

island on which the whole-of-island approach is currently being put into practice is the island of Abaiang. With 5500 inhabitants it is relatively populous. A vulnerability analysis has recently been carried out. One urgent issue is the question of a reliable water supply because the islands of Kiribati possess very small water reserves in the form of freshwater lenses located in the subsurface and recharged solely by rainwater. If too much water is extracted or rainfalls fail to materialize, but also if the sea level rises, salt water seeps in from the ocean and the water lenses become oversalinated. The freshwater lenses are subject to additional pollution caused by livestock or by fertilizers and crop protection products from nearby arable farms. To address these problems, water management on Abaiang is currently being improved. Furthermore, arable farming is now practised at a sufficient distance from the freshwater lenses.

Another issue is the avoidance or disposal of waste. Traditionally the island's waste, which used to be entirely organic, was deposited into the sea and transported away by the tide. In view of growing fractions of inorganic and toxic waste, this practice leads to considerable pollution of the ocean and environment and can result in substantial contamination especially of the freshwater lenses. Since the inhabitants obtain their drinking water from wells, the majority of which are heavily contaminated with germs, there are frequent cases of diarrhoea infections which mainly put children at risk. It has therefore been decided in accordance with the wishes of Abaiang's inhabitants that a better sanitation infrastructure will now be built. Currently a similar analysis is being carried out for a second island.

Furthermore, certain challenges are the same for all the islands of Kiribati. Apart from water supply and sanitation, these consist primarily of coastal protection, overfishing and declining yields in agriculture. Added to that is climate change, which strongly influences and considerably amplifies all these aspects. Today cumulative droughts are occurring on some of Kiribati's islands, leading to water scarcity and creating difficulties for farmers. Since there is not a vast amount of agriculture on the islands in any case due to their relatively infertile soils, shortages in the food supply are likely to ensue. The plan is therefore to practice alternative farming methods on the islands in future and to pilot the production of different fruits. During the process, care will be taken from the outset to ensure that the local population sets itself realistic goals. In this way the ministry representatives clearly communicate that the management process cannot fulfil gratuitous demands to increase prosperity dramatically. It is hoped that this will prevent the arousal of unrealistically high expectations.

Coping with rising sea levels

> Dikes, walls and barriers protect coasts from flooding. Yet sea-level rise calls for novel solutions that take account of ongoing natural impacts and can gradually adjust to the rising water. Even with these, some coasts will become uninhabitable in the future. For those who are affected new homes need to be located now, for they will become climate refugees.

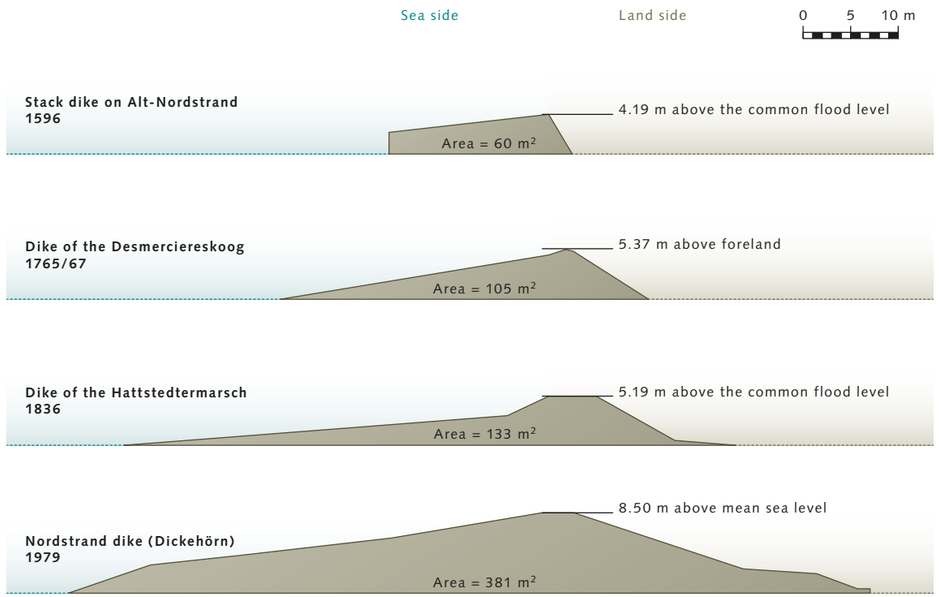
The development of modern sea dikes

Coastal populations have always been threatened by flooding. Although fairly helpless against such events at first, over time they learned to build protective structures against storm floods. In some countries buildings were built on stilts, so that water could flow freely underneath, while in other places houses were built on man-made earthen hills. As early as the twelveth century, ring dikes were already being built in northwest Europe for the protection of individual settlements. Through time, the design of dikes changed. In the early sixteenth century the dikes in many places consisted of two-metre-high walls of timbers, backed and stabilized by an earthen wall. But because these kinds of dikes were heavily battered by the surf, the vertical form was soon abandoned in favour of an elongated slope and flatter profile, where the wave energy of the storm floods could be absorbed more gradually. In the mid-eighteenth century, these dikes often had a height of around five metres. Although the gradually sloping profile proved to be effective, water would still spill over the top during high-surging floods. This would wash out material on the back side until the dam collapsed. The trend thus developed toward the construction of increasingly higher dikes with even flatter slopes. Today, the large sea dikes in northwest Europe have heights of around nine metres. They have low slope ratios of at most 1:6, and are around 100 metres wide at the base. These can withstand even high storm-flood surges. But with climate change and its accompanying rise of sea level, coastal inhabitants are facing new challenges.

4.16 > For several centuries the people in the Netherlands relied on "stack dikes" (Ger. – Stackdeiche) to protect the region around Amsterdam, as shown in this illustration of the Zuiderzee in 1702. These were repeatedly damaged during heavy storm surges.

Climate change as a new challenge to coastal protection

If sea level should rise by one metre by the end of the century, and even by several metres thereafter, today's tried and tested coastal protection systems will no longer be adequate. They will have to be upgraded in many places. No one knows, however, how strongly or rapidly climate change and sea-level rise will progress. In contrast to past centuries, when it was sufficient for engineers to design structures that were suitable for the existing conditions, precisely this question arises now in the face of climate change: What conditions will exist in the future? Coastal protection will have to account for diverse probabilities and consider the various scenarios of the IPCC (Intergovernmental Panel on Climate Change) in the planning and construction of protection systems.



4.17 > Through time, the profile of dikes on the North Sea coast of Schleswig-Holstein changed. There was a trend away from the steep structures to a long and much lower gradient, so that the storm-flood wave energy could gradually run out over a longer distance.

Staying a step ahead of sea-level rise

A fundamental question for coastal engineers is how high or strong coastal defence structures should be designed today. Because the future global progression of sea-level rise is uncertain, and a more rapid advance than the global average is expected in some regions, it would be prudent to incorporate flexibility into coastal protection designs for the future. An adaptive pathways approach is now being promoted. This involves the planning of coastal protection measures adapted to the short-term consequences of change, and not rigidly committed to an uncertain assessment scenario to the end of the century. In this way it may be possible to keep pace with the rising water. A large barrier that closes off a river mouth during storm floods has to be completely rebuilt when it no longer provides sufficient protection as a result of rising sea level. The initial investment would thus be completely lost. It is more sensible to plan for smaller measures that build upon one another. Coastal protection is therefore now facing a paradigm shift. While the axiom of preserving a coastline through the use of large immobile structures was considered valid in the past, the adaptive pathways design approach introduces an array of different concepts and measures, including the selective opening of dikes and the creation of emergency flood plains, or "polders". Specialists today distinguish the following conventional and adaptive protection principles:

Conventional coastal protection

- Resistance: Planning and construction of coastal protection measures at a large economic cost, which are designed for today's extreme events such as 100-year floods. This approach represents the classical method for designing coastal protection systems. The disadvantage is that extensive damage can result if these systems do fail, as in the breaking of a dike.
- Static robustness: Planning and carrying out coastal defence measures that are already designed for the worst-case climate scenario for today. This principle has clear disadvantages. For one, enormous invest-

4.18 > Preparations are ongoing in the Netherlands for future flooding: Engineers have designed floating residences like these in Maasbommel. The amphibious houses are anchored to posts and can respond flexibly to high water.

ments would have to be made today. For another, the construction would be planned according to the present-day knowledge of climate change. This entails the danger that the protection measures will not be adequate if climate change becomes more intense than expected.

Adaptive coastal protection

- Resilience: Planning and construction of coastal protection structures that are designed so that their failure does not result in losses and severe damage to infrastructures, buildings or ecosystems, and allows rapid recovery or restoration. This could be achieved, for example, by building floating houses. Another possibility would be to build elevated streets and railways on the tops of dams. This would limit the extent of damage. Ideally, damage would be completely avoided.
- Dynamic robustness: Coastal protection structures are implemented in succession, to a degree that is based on the latest available knowledge about the development of climate change. This principle is based on a "no-regret" strategy. This refers to measures that would have societal benefits even when the extent of climate change turns out to be greater or less than what was expected, and that do not entail irreparable damage if false assumptions were made in the scenarios. One example of a "no-regret" measure is the creation of a "polder" that serves not only for coastal protection, but at the same time can function as a local recreation area or nature conservation area – and thus has an additional societal or ecological value. The disadvantage of this approach is that, in contrast to the concept of static robustness, the coastal protection is not fabricated in a short time by a single measure, but has to be repeatedly evaluated and expanded over a long time period by supplemental and complementary measures. It thus requires long-term and constantly adaptive planning, as well as a management system that can function over time periods of many decades and even has a planning horizon of a full century.

London leads by example

The larger bulk of coastal protection measures worldwide today are carried out according to the conventional resistance principle, but in a number of countries initial concepts are being developed that follow the adaptive pathways approach. An ongoing example is the protection of the Thames estuary in England. To protect London from flooding during storm surges, a large flood barrier, the Thames Barrier, was put into operation in 1984. It consists of large movable flood gates that are closed during storm tides and prevent the surge of high water from the sea from reaching the city. At the beginning of this century, because of concerns that the existing barrier will not be able to resist the higher storm tides expected in the future, debate began about whether it should be replaced by a new and even larger barrier further downstream within the estuary of the Thames. The ramifications for the population of London and the expected extent of damage if the barrier were to fail would be immense. The storm floods as a consequence of climate change and sea-level rise could indeed exceed the capacity of the existing Thames Barrier. They would acutely threaten 1.25 million people who live and work in the high-risk flood areas, as well as 500,000 dwellings, 40,000 commercial and industrial properties, important government buildings, 400 schools and 16 hospitals.

Coastal protection road map for the future

The construction of the new barrier in the Thames, which would cost up to five billion pounds, was rejected as an exclusive solution. Instead, in cooperation with scientists, the authorities created a kind of road map for future coastal protection that provides for various measures to be realized with continuing and accelerated sea-level rise, which is commensurate with the adaptive pathways approach. The Thames Estuary 2100 Plan presents a catalogue of measures, and provides clear options in dealing adequately with the risk situation at any given time, in spite of great uncertainties about the progression of climate change. Additionally, the financial burden that would result from

construction of a new barrier will be avoided for as long as possible. In this developmental plan, detailed critical points in time by which decisions must be made regarding planned future measures were identified, and by which times the measures must be carried out. Furthermore, and in agreement with the surrounding counties, it was decided which measures should be carried out on various segments of the river between London and the North Sea. In chronological order, the measures include:

Option 1: Classical defence systems
- Increase height of existing systems (sea walls, dikes, etc.);
- For old systems that need to be replaced, build the new structures higher;
- Design new defence systems so that they are more easily repaired, replaced, or raised.

Option 2: Create floodplain areas
- Create target areas for flooding – for this purpose four large areas have already been identified in the estuarine area of the Thames.

Option 3: New barrier
- Construction of a new barrier, for which possible sites have already been identified and the legal framework already established, so that if it becomes necessary construction can be started quickly without the need for elaborate negotiations.

Option 4: Massive barrier
- Construction of a barrier that, in contrast to the existing one, is always closed, in order to permanently hold back the water under higher sea level conditions. This barrier will include locks for ship traffic.

The Netherlands under pressure

Because large portions of the country lie below sea level, the Netherlands and the Dutch-Belgian border region, which lies in the shallow estuarine area of the Scheldt River, are at risk in the future. Sea-level rise and the processes it triggers present a dual threat for this region. For one, it is feared that the higher storm floods associated with rising sea level will damage or spill over the dikes and protective structures. For another, with climate change, an increase in precipitation is expected for Western Europe, so inland rivers could overflow their banks more frequently. When both processes occur together – higher water levels at the coast and strong rainfall inland – the river water is no longer able to flow into the sea, so it swells and backs up in the inland regions.

Around nine million people live in the low-lying areas of the Netherlands. In addition, there is a high concentration of economic assets, comprising infrastructure as well as business and industry. The city of Rotterdam, for example, incorporating Europe's largest harbour, presently lies an average of two metres below **mean sea level**. For many years now, these low-lying areas have been protected by massive structures such as dikes, dams or flood walls. Additionally, since the 1950s flood-defence systems comprising large barriers have been installed that seal off many former bays and rivers from the North Sea, either permanently or during storm surges. In order to upgrade this system to adapt to sea-level rise, expenditures have been calculated for the Netherlands of up to 1.6 billion euros annually to 2050. According to present estimates, if the massive coastal defence installations should fail in spite of these investments, and the region be flooded, the resulting losses could be as high as 3700 billion euros.

Making room for water

In view of the enormous costs for maintenance of coastal defence structures and the enormous risk that a failure of coastal protection installations entails, an additional strategy has been followed in the Netherlands since 2012 with the "Ruimte voor de Rivier" project (room for the river). While many river channels have already been highly altered by dikes and barriers, more than 30 separate measures will be carried out on the Maas (Meuse), Rhine and Waal Rivers in the Netherlands by the end of the project in 2019.

Polder
The term "polder" originally comes from the Dutch, signifying a piece of land that is protected from high water by dikes. In the context of coastal protection, "polder" designates areas that are purposely allowed to flood in order to diminish the crest of a flood wave.

4.19 > Steel colossus against storm floods: after a devastating flood, often referred to as the Dutch flood disaster of 1953, dikes and barriers began to be built to defend most of the river mouths in the Netherlands. This is an image of the Maeslant Storm Barrier, which protects a part of the Rhine estuary and the harbour of Rotterdam.

These include:

- Widening river beds so they can hold more water;
- Deepening of rivers;
- New construction of separate canals that will relieve the main river and provide a substantial creative landscape element for new residential areas, which would be built at the same time;
- Relocation of dikes and creation of wide polders, in order to give the high water more room.

With these measures, the "Ruimte voor de Rivier" project also fits rather well with the concepts of the "Building with Nature" initiative, which was jointly initiated in recent years by Dutch coastal protection experts, engineering agencies, government offices, and researchers, and has already been implemented through a number of pilot projects. "Building with Nature" means that coastal and high-water protection measures are designed to conform to the natural conditions, while at the same time offering new locations for the development of natural areas. An example is the relocation of dikes for the creation of flood polders where species-rich wetlands can develop. The "Building with Nature" concept expands on conventional coastal defence systems, which could more appropriately be described as "building IN nature". With the conventional measures, rigid artificial structures are imposed on the landscape, looking like foreign objects and often tending to slice through natural spaces.

Major project on the Scheldt estuary

One of the first major projects to adopt the "Building with Nature" concept is the creation of a number of polders along both the Belgian and Dutch sides of the Scheldt estuary. This involves flattening all of the old dike lines to make lower overflow dikes, and moving the position of the new dike back to form a polder. The polder is bounded on the river side by the overflow dike, which only allows water to spill over at times of high water. In addition, the water level in the polder is regulated by a sluice built into the overflow dike. The purpose of the low overflow dike is to keep water in the polder to sustain wetland habitats. The polders will have a total area of 40 square kilometres. In case of high water they can take on large volumes of additional water and protect against flooding in the hinterland in the future.

On around 60 per cent of the polder area wetland areas should develop naturally and will serve, among other things, as breeding grounds for birds. The first polder was created in 2006. The project is to be completed by 2030. The total costs will be around 600 million euros. Compared to this, the high-water damages that would result if the polders were not built would be significantly higher. These could be as much as one billion euros annually throughout the period to 2100.

4.20 > New polders are being built on the Scheldt estuary. The existing levee (A) is lowered to function as an overflow dike. The water level within the polder is regulated through a sluice (B) in order to form a wetland area (C). A new ring dike (D), located behind the original location, protects against high water surge.

Different coasts, different measures

As Belgian and Dutch experts point out, "Building with Nature" is possible in river estuaries and deltas as well as on sandy coasts. The latter are primarily impacted by erosion, which during the course of climate change could intensify through more frequent or higher storm floods. If buildings are present, they could be damaged or even destroyed over time. Many sandy coasts are therefore protected by massive structures. These include stone groynes in particular, which stretch from the shore out into the sea like long fingers, and considerably reduce current strength on the shore. These groynes prevent the erosion of material from the coasts during periods of strong wave activity. But this creates another problem when the primary current direction is parallel to the coast. Normally in this situation, sediment removed from one site is subsequently deposited at another location farther along the shore. It is then available to protect the sandy coast at another site. If this natural sediment transport is inhibited by groynes, other segments of the coast can be strongly eroded because the normal replenishment process is interrupted. The construction of groynes can thus lead to a deficiency of sediment somewhere else and to a gradual loss of beaches and protective dunes.

Artificial island as sediment contributor

On many coasts worldwide, beaches need to be restored by artificial filling after the storm season. This usually involves pumping sand from deeper sea-bottom areas through a pipeline onto the land, or transporting sand in with ships. This periodic filling with sand is an accepted, but laborious and expensive coastal protection measure. In the areas of sand removal and sand fill, biological communities can also be disturbed. Within the framework of the "Building with Nature" initiative, therefore, a pilot project was begun to find a different way to solve the erosion problem on a 17-kilometre-long strip of coastline in the Netherlands. To this end, a hook-shaped peninsula was filled in with a volume of 21 million cubic metres of material. This is enough sand to cover 60 football fields to a height of 50 metres. The artificial island functions as a natural sand repository that will be gradually worn away over several decades by waves, tidal currents and wind, thus providing long-term delivery of fresh sediment to the beaches on the 17-kilometre segment of coast to compensate for erosion there. This measure not only saves the construction of new massive groynes, but also the annual hydraulic filling at many sites along the coast. Thanks to this one-time filling action, it is possible to avoid repeated long-term disturbances of the ecosystem by annual sand removal.

In the Mississippi Delta, off the coast of the US state of Louisiana, natural coastal protection measures of even larger dimensions are planned. The delta is heavily impacted by flooding and erosion because the amount of sediments

4.21 > Since 2013, sand from the Mississippi River at New Orleans has been pumped through a pipe for a distance of over 20 kilometres into the delta. Sand banks are created on which many square kilometres of salt marsh can develop. These, in turn, act as natural coastal protection.

being supplied to the delta has been severely curtailed by reservoir dams along the river. In a major project that includes more than 100 separate measures, the delta should begin to grow again and the danger of flooding be reduced.

Since 2013, for example, sand has been transported out to the delta through a pipeline more than 20 kilometres long. This sand is retrieved from the bed of the Mississippi by dredgers and pumped directly from the ships into the pipeline. Ecologically important sandbanks are created where salt marshes many square kilometres in size will develop in the coming decades and act as a natural protection for the coast. In practical terms, this should protect towns south of New Orleans from flooding. At other sites along the Louisiana coastline dunes are presently being replenished and beaches broadened by dredging.

Shellfish protect coasts

Another ecosystem-based coastal protection measure that is being employed in Louisiana, in the Netherlands, and in other coastal areas is the creation of oyster beds off the coast. These act as natural breakwaters that absorb a large portion of the energy from storm-flood waves before they reach the shore. The advantage of oyster beds is that they sustain themselves because young shellfish larvae colonize every year. Artificial breakwaters, by contrast, have to be periodically maintained and improved. In many cases, for the colonization of oyster beds wire baskets with empty shells are placed on the sea floor. These shells provide the free-swimming larvae with a firm substrate on which they can colonize and grow to mature animals. Because new larvae settle year after year, a reef is created over time.

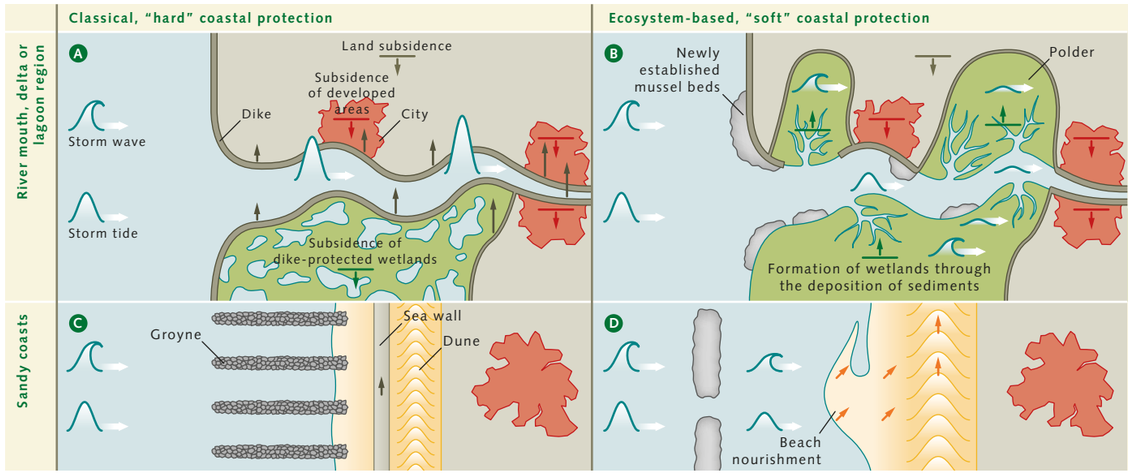
The ecosystem-based approach – a trend with a future

The Dutch “Building with Nature” concept is now being adopted by many countries as a model for semi-natural protection from storm floods on the coasts and high waters inland. A common phrase heard in international discourse today is ecosystem-based coastal defence. In Germany, for example, as a major pilot project, a dike has been relocated on the Elbe River in south Hamburg to create the Kreetsand polder. This polder will protect the surrounding area from flooding by high inland waters that occur as a result of sustained rainfall. This project is notable because in Germany, as well as many other countries, there are still strong reservations toward ecosystem-based coastal protection, in spite of the large projects in the Netherlands. This is mainly because specialists still have relatively limited experience with these alternative measures. There is also still too little knowledge about the effectiveness of the protection and its performance over time. In addition, there are no established standards for the construction and maintenance of ecosystem-based alternatives. Thus, more trust is still placed in the classical coastal defence approach with its rigid protective structures. Moreover, our knowledge about the design and construction of classical coastal defence systems such as dikes and barriers has grown significantly over many decades. We have learned from flood catastrophes how these structures have to be designed in order to provide adequate protection even during heavy storm surges.

Practical test of alternative coastal protection

In order to better assess the efficacy of ecosystem-based solutions in practice, a number of test projects are currently underway. On the Indonesian island of Bali, for example, an ecosystem-based structure is being directly compared to a conventional rigid coastal defence structure. Bali is a popular vacation spot for tourists around the world largely because of its wide beaches and clear water. Preservation of the beauty and unspoiled nature of the coasts is thus very important both economically and socially.

The purpose of the project is to protect a stretch of coastline on the south side of Bali that is being affected by erosion. Strong wave action here carries large amounts of sediment away, and there is a lack of fresh sediment because the region is surrounded by rocky peninsulas that



4.22 > While dikes or other man-made structures based on classical coastal defence concepts have to be raised to keep pace with climate change, ecosystem-based coastal protection utilizes the full natural potential of the coastal environment. Instead of setting forced limits on the water with increasingly higher dikes (A), polders can be built in estuarine areas to make more room for the sea (B). Instead of defence by groynes and sea walls (C), sandy coasts can be protected in the future through the creation of depots by artificial filling (D), which can provide the coastal areas with sand over several decades.

prevent the transport of sediment. In cooperation with coastal engineers from Europe, local agencies and the local population will compare the performance of a new protective structure made of bamboo poles and coconut-fibre mats with that of a recently built protective wall almost two metres high. Because it is known from other segments of Bali’s coast that rigid walls can actually increase erosion by altering the surf and wave activity, it is desirable to find out whether construction using natural materials is more suitable for protecting the beach from further breakdown by heavy surf. The structure consists of a series of bamboo poles, behind which the coconut-fibre mats are rolled out on the beach. To prevent them from washing away, the mats behind the poles are buried and then planted with small seedlings of a native dune grass, which form a dense network of roots over time and stabilize the structure.

This kind of direct comparison between a classical and an ecosystem-based construction with regard to their performance and effectiveness is new for the island of Bali. Because the bamboo and coconut-fibre construction has only recently been completed no information has yet been gathered regarding its effectiveness. Should the protection by bamboo and coconut-fibre mats prove to be effective, however, it would have the following advantages:

- Cost saving: In the past, specialists and labourers had to be flown to Bali for the construction of conventional coastal defence structures made of concrete. This resulted in high costs. Construction using bamboo and coconut fibres is less expensive than a concrete structure.
- Local expertise: In the past there has been a lack of local specialists to periodically test and maintain the concrete structures, which is why they are defective in many places. Local people help, however, in constructing the systems of bamboo poles and coconut-fibre mats. They then have the knowledge and ability to provide upkeep and maintenance on the systems.
- Use of native and renewable resources: Bamboo and coconut fibres are traditional, renewable materials that can be obtained locally. Long-distance transport is avoided.
- Creation of employment: Local employment is expanded through the construction and maintenance of the natural coastal protection systems.
- Identification with coastal protection: Because the local people themselves construct the protective structures, they have a more direct relationship to the structure and a feeling of responsibility for its preservation. When the construction is carried out by foreign companies, subsequent maintenance of the structures is often neglected.

Now a significant number of other projects worldwide representing “soft” ecosystem-based coastal protection have been carried out or are at the planning stage. Ecosystem-based coastal protection specialists recommend that new projects first be tested within smaller pilot projects and that their suitability and impacts be assessed by interdisciplinary teams comprising engineers, landscape planners and social scientists. It is particularly important to assess in advance the extent to which the local inhabitants accept the coastal protection. In the creation of polders, for example, the owners and occupants of the areas need to be involved. If the pilot projects are successful, then the new ideas can be scaled up gradually into larger projects.

Eelgrass – a plant with potential

One new idea for coastal protection that is to be realized as pilot projects in the coming years is the establishment of eelgrass beds. Eelgrass grows tall and prolifically, and in this respect is similar to grasses growing on land. Furthermore – in contrast to seaweed, which usually attaches to firm substrates – it produces roots that help it to withstand strong wave activity and to protect the sediments from damage and gradual erosion. While coral reefs and mangroves have long been recognized as natural breakwaters, the importance of eelgrass beds for coastal protection has only been recognized in recent years, primarily as a result of their disappearance from many coastal regions. The causes for this include water pollution and, in areas of heavy fertilizer use, high rates of algal growth, which leads to a cloudiness of the water. In areas where eelgrass has been lost, increased erosion of the sediments is often observed today. New colonization by eelgrass then becomes improbable. Seedlings can no longer get a foothold because the currents are too strong in the barren areas.

An international research team of coastal engineers, geoecologists and material scientists is therefore working on methods to facilitate the settlement of eelgrass. They are developing synthetic mats of artificial seagrass that they plan to lay out on the sea floor in the future. The artificial seagrass should reduce water currents sufficiently to allow the eelgrass seedlings to take root again. In addition, these mats are so loosely woven that the sea floor beneath them is not hermetically sealed off, so no other native organisms are harmed. While material scientists are developing a suitable synthetic composition for application in seawater, the engineers carry out experiments in a water channel at a college lab. These experiments will make it possible for the first time to quantify how efficient the damping effect of eelgrass beds can be with regard to coastal protection. A further aim is to determine how fast eelgrass seedlings can colonize.

Salt marsh and dike in a wave flume

As with the eelgrass concept, there are several other ecosystem-based coastal protection approaches being considered today whose levels of effectiveness have not yet been accurately determined. This quantification is important in order to be able to assess the extent to which they will be able to supplement or even replace classical coastal defence methods in the future. Salt marshes, for example, which are located in front of the dikes at many locations along the North Sea coast, are known to slow down approaching waves during storm floods. To what extent this occurs, however, is not precisely known. So far it has not been possible to measure how effective the protective properties of heavily vegetated salt marshes are when the blades of grass are broken by the force of the waves. To make the necessary measurements, an actual patch of salt marsh from the Wadden Sea was recently removed and exposed to a strong surf in a 300-metre-long wave flume. The experiment revealed that the baffling effect was only negligibly reduced when the blades broke.

4.23 > Accurate measurements to determine how well a salt marsh with high-growth vegetation could reduce wave energy were made for the first time in a wave flume.

There is a general rule in coastal protection, even today, that the turf on dikes should be kept short as possible through sheep grazing. For one reason, the ground is compacted by the treading hooves, so that the dikes do not weaken during flooding. For another, the grazing inhibits the tall growth of herbaceous plants. Strong waves could otherwise more easily rip out clusters of plants, creating holes in the dike that would then be enlarged by the wave action. In extreme cases this could lead to a breach in the dike.

For the first time coastal engineers are investigating the extent to which dikes can be seeded with various flowering plants in order to create diverse grassland biotopes. For this purpose, a dike replica of actual size is now being built in a wave tank and will be planted with various combinations of wild flowers. Storm floods will then be simulated to find out which combination forms a dense network of roots that stabilizes the turf, and which wild flowers can tolerate constant flooding by salt water.

A synthesis of old and new

More of these kinds of investigations will be necessary before ecosystem-based measures can receive wide acceptance as alternatives in coastal protection. Irrespective of this, the challenges that confront us with rising sea level in the future will have to be met with a combination of ecosystem-based and classical coastal protection methods. In the Netherlands and Germany, for example, it will not be possible to completely dispense with the use of dikes.

However, it is also evident that channelized estuaries cannot be sufficiently protected in the future by dikes alone. This has been shown through mathematical models produced by a team of Australian, German and US American researchers, which computed how wave dynamics

4.24 > Breakwaters known as reef balls. The spheres distributed by a US American non-governmental organization are deployed for coastal protection. At the same time they help to form productive submarine habitats.

change when the water surges higher due to sea-level rise. Under the assumption that the tidal flats will not grow proportionately to keep up with the rise of sea level, they found that the waves become higher not only by a measure equal to the amount of sea-level rise, rather their height will increase disproportionately. This is because friction with the bottom is reduced when the water level is higher. The baffling effect of the bottom is thus likewise reduced.

It is unsettling that this phenomenon already begins to become apparent when sea level is only a few centimetres higher. Because of this effect, waves could surge up to 56 per cent higher. This effect has so far not been taken into account in calculating the height of coastal protection structures. Presently only the amount by which sea level is predicted to rise in the future has been factored into the construction planning as a margin of safety.

Spheres that slow the wave surge

In contrast to groynes, which are built outward from the shore into the sea, breakwaters are elongate submerged structures that run parallel to the coast. They prevent the breakers from hitting the coast with unchecked strength, thus protecting beaches and promenades, for example. Today, they are typically made of massive concrete blocks or large stones in the water that otherwise have no further function. However, modules called reef balls have been in

use for quite a long time and provide an ecosystem-based alternative. Hollow concrete spheres about one metre wide, made by a US American non-governmental organization, have numerous openings and not only reduce the wave energy, but at the same time provide shelter for fish and many other marine organisms. They are submerged beneath several metres of water and are ideal for organisms that colonize on firm substrates, such as mussels, sea anemones or sponges. Over time a densely settled underwater habitat is formed. Reef balls have also been set out in Germany, for example in the Bay of Kiel.

Is ecosystem-based coastal protection worth it?

Intact coral reefs and mangrove forests provide coastal protection at no cost, but other ecosystem-based measures can incur quite high expenditures, as demonstrated by the polder project in the Scheldt estuary. This then brings up the question of not only how reliable and effective ecosystem-based solutions are, but also how expensive they are and how high the costs are compared to classical coastal defence measures.

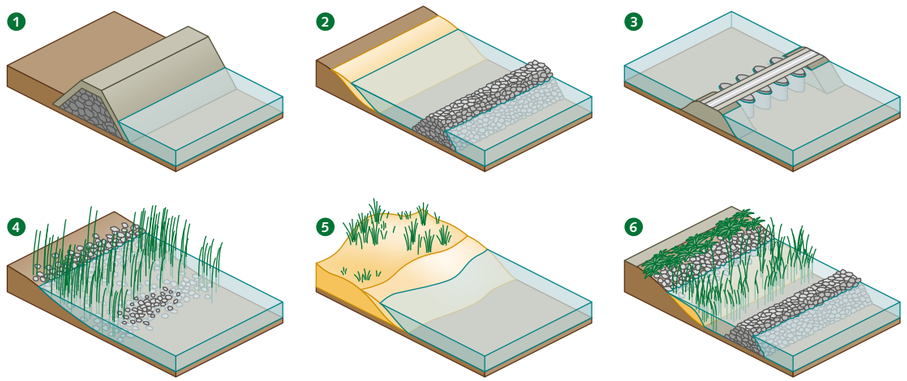
In a complex study, a team of international researchers analysed for the first time 52 coastal protection projects in which mangroves and salt marshes were planted or coral reefs were restored by introducing young corals. Eelgrass beds were also considered in the study. For one, they investigated how great the potential in the areas was for absorbing wave energy, and, for another, how high the project costs were compared to rigid defence measures. In a comparison of all projects, depending on the local situation, the various habitats decreased wave height as follows:

- Coral reefs by 54 to 81 per cent,
- Salt marshes by 62 to 79 per cent,
- Eelgrass beds by 25 to 45 per cent,
- Mangroves by 25 to 37 per cent.

It should be noted that the mangrove areas of the projects studied were only between 800 and 1500 metres wide. Mangrove forests that are many kilometres wide, however, can actually suppress waves at storm tide by 100 per cent before they reach the shore.

The salt marshes that were analysed, on the other hand, had widths from 100 to 2800 metres. The scientists point out, however, that in the creation of salt marshes one must take into account not only the width of the field but also the height of the vegetation. According to this study the cushioning effect in salt marshes is greatest when the vegetation height reaches up to just below the water surface.

For coral reefs, it was revealed that these have the greatest damping effect when they are at least twice as long



4.25 > Besides the classical coastal defence methods such as dikes (1), breakwaters (2), and barriers in river estuaries (3), ecosystem-based measures are being increasingly implemented today. These include the creation of man-made marshes (4) that collect fresh sediment, sand-fill areas (5) that promote the formation of sands and dunes along the coasts, and the installation of coastlines in harmony with nature (6) where species-rich green belts can develop behind structures that serve as breakwaters.

4.26 > The harbour of the British town of Cowes on the Isle of Wight is protected by massive breakwaters. Their construction is significantly more expensive than the creation of natural protection in the form of a salt marsh or eelgrass beds would be. Whether ecosystem-based coastal protection measures can actually be realized, however, largely depends on the form and use of a coastal area.

4.27 > In the Dutch resort town of Katwijk aan Zee, a parking garage was built parallel to the shore road and then covered with sand to create a high artificial dune.

as the incoming wave, and their tops lie at a depth of not greater than half the height of the wave.

Because there were no numbers for comparison for coral reefs and eelgrass beds, the cost analysis of the projects was limited to mangroves and salt marshes. For the latter, the study showed a clear cost advantage compared to conventional coastal defence in the form of breakwaters, and with the same damping effect. For the mangrove project, the study indicated that these can be three to five times cheaper than the construction of breakwaters. The salt marsh projects, which were primarily carried out in Europe and the USA, are either equal in cost or as much as three times cheaper than classical breakwaters, depending on the location. The differences are primarily due to the fact that the costs for breakwater construction increase disproportionately with water depth.

In addition to the cost factor, the creation of mangroves and salt marshes also has the advantage that both of these habitats can grow naturally with rising sea level. Frequent flooding transports more sediment into the areas, so the bottom surface is elevated and coastal protection remains in place. Breakwaters, by contrast, lose their protective effectiveness as sea level rises.

Limitations of the ecosystem-based approach

Ecosystem-based coastal protection solutions are not suitable for all kinds of coasts. A critical exclusion criterion is the large area required for many of the solutions. The installation of polders or mangrove areas of sufficient size is impossible in the vicinity of heavily developed coastal areas or harbours. In these cases the shore could be protected by installing artificial reefs or eelgrass beds in front of the dikes. In deeper waters, however, these measures are also ineffective and the only remaining option is the rigid classical coastal defence that simply offers resistance. With rising sea level these kinds of structures have to be designed with sufficient height.

In the Netherlands, for aesthetic purposes, dikes and flood walls are planned in combination with other functions to make them, to some extent, multi-purpose structures that are integrated into the townscape but retain an aspect of coastal defence. An example is the construction of parking decks within segments of dikes or dunes, whereby the massive wall is on the sea side and serves as coastal defence, and is additionally protected by a dike or dune in front. Streets or promenades could then be built along the top of the dike. A project of this kind has been realized in the Dutch resort of Katwijk aan Zee, where a parking deck built parallel to the coast was then covered with sand and planted with typical dune vegetation. Thus, a high artificial dune was created that protects the town and is integrated harmoniously with the natural landscape.

Confronting the inevitable

Even if conventional and ecosystem-based measures are combined for effective coastal protection in the future, not all of the coasts in the world can be protected if sea level rises by several metres in the coming centuries. There is no question that people will be forced to abandon certain areas because they will be permanently flooded or uninhabitable due to frequent flooding. To begin with, this fate will befall some island nations in the South Pacific, because some of these already lie less than one metre above sea level. The governments of these island nations are now already facing the question of how the withdrawal of citizens can be organized so that the island populations can gain a foothold in a new country and achieve the same standard of living that they had in their lost homeland.

In this regard, the efforts of the government of the West Pacific island nation of Kiribati are noteworthy. On the one hand, they are continuing to promote coastal protection measures for as long as possible, especially to protect economically important facilities like the airport. But in view of the early indications of sea-level rise, such as more frequent storm floods, increasing coastal erosion and saltwater intrusion into the freshwater lenses, preparations are already being made for a future emigration.

The government of Kiribati constantly points out, on an international level, that they do not want their citizens to be considered as helpless climate refugees, rather that they are a nation combatting the results of climate change, which they are not responsible for and to which their contributions have been negligible.

Orderly retreat instead of hopeless flight

Under the motto of “migration with dignity” the former president of Kiribati, Anote Tong, initiated an emigration strategy that should enable the population to gradually build a new life in another country before the islands become uninhabitable and the approximately 100,000 inhabitants of Kiribati become homeless refugees. Together with other Pacific island nations, a strong call has been made for climate justice and support from the industrial countries – in particular, the plea to those countries is that they should offer employment perspectives to citizens of the island nations as well as permanent resident status. This outspoken pressure has led to an increase in public awareness in recent years of the hazards faced by the Pacific island nations. Nevertheless, support by the industrial countries leaves much to be desired, including by the closely neighbouring countries Australia and New Zealand. New Zealand, for example, has launched a job programme that would accommodate workers from the Pacific island nations. But New Zealand officials do not want this to be perceived as a climate relief programme. Furthermore, the number of immigrants accepted is very low. From Kiribati, based on a lottery procedure, only 75 families are allowed to immigrate each year. If the immigrants make an effort to find employment they are given permanent resident status. Beyond this, New Zealand has been offering the inhabitants of Kiribati seasonal employment in agricultural jobs since 2007. Although permanent residency permits have resulted from these measures in some cases, it certainly cannot be viewed as a broad-based climate relief programme so far. Kiribati and other island nations are calling for unambiguous assurances from the industrial nations.

While other industrial nations have so far shown even less willingness to assure rights of residency to the inhabitants of island nations threatened by sea-level rise, there is a remarkable degree of solidarity among the Pacific island nations themselves. The island nation of Fiji, for

4.28 > The inhabitants of Nukunonu island in the South Pacific do not want to be seen as climate victims, but as warriors struggling against a rising sea level. According to a UN report, the atoll, which belongs to the island group of Tokelau, could be submerged in the twenty-first century.

instance, has sold Kiribati around 24 hectares of land. Many of Fiji's islands are higher in elevation than those of Kiribati, so they will be less impacted in the future by sea-level rise. Initially this area, which is located on Fiji's second-largest island, Vanua Levu, will be used for agricultural purposes. Kiribati wants to plant food here when their own agricultural areas are lost to flooding. If parts of the Kiribati Islands become completely uninhabitable in the future, the affected Kiribati natives will be able to settle on this land. The president of Fiji has given a public verbal promise of this.

One advantage of this settlement policy is that the emigrants from Kiribati will find living conditions on Vanua Levu similar to those in their homeland. The willingness of the Fiji government to accept refugees is even more remarkable considering that some of the Fiji islands themselves will be affected by flooding like Kiribati. Fiji will therefore also have to cope with the resettlement of internally displaced persons. According to present plans, these people will also settle for the most part on Vanua Levu.

New homeland for millions of people?

The example of Kiribati illustrates that it is possible for people, with advance planning, to leave threatened coastal areas in time to be able to build a new livelihood with dignity in another location. Critics, however, raise the concern that there must be assurances that not only a well-educated minority, but the entire population will have the opportunity to emigrate. It is also uncertain to what extent the example of Kiribati can be applied to other countries. The approximately 100,000 inhabitants of Kiribati may be completely taken in by other countries. By contrast, many millions of other people living in areas threatened by flooding, in Bangladesh for example, cannot readily be absorbed by the densely populated neighbouring countries. Many experts are therefore calling for higher levels of international solidarity with respect to the impacts of sea-level rise, particularly on the part of industrial nations.

An initial positive step in this direction is the Nansen Initiative, launched jointly by Norway and Switzerland in 2011 and named after the first High Commissioner for Refugees of the former League of Nations, Fridtjof Nansen. The work of the Initiative consists of advising various nations regarding the problems of climate refugees and involving political representatives of the industrial nations as well as those of the developing and emerging countries, which are usually the ones most affected, in the consultation process. Above all, the aim is to mediate among the countries – those from which the people are fleeing and those that are potential destinations for the refugees. The Initiative is active worldwide, both in inland areas where, for example, people are escaping from drought, as well as on the coasts. In the past it has initiated large consultation meetings in various regions, where the public authorities and affected people sat together at one table. The Nansen Initiative has now been renamed as the Platform on Disaster Displacement. This body continues the work of the Initiative, and is supported by governmental institutions such as the Swiss Confederation and the Department of Foreign Affairs of the Federal Republic of Germany, among others.

Conclusion

Together for conscientious use and better protection

Sustainable use of the coasts can only be achieved if the various interests of diverse users are brought into accord. To begin with, internationally, responsibility is explicitly regulated through the United Nations Convention on the Law of the Sea (UNCLOS). This establishes the concept of territorial waters, which are considered the sovereign territory of a country. Extending beyond this is the Exclusive Economic Zone (EEZ), within which the state has the exclusive right to exploit natural resources such as oil and fish, although it is not part of the sovereign territory of the state. How a nation uses its coastal areas, however, is its own decision.

In order to avoid conflicts of interest, Integrated Coastal Zone Management (ICZM) aims to achieve sustainable development of coastal zones. ICZM has succeeded in some cases in preventing conflict between nature conservation and tourism, and in realizing sustainable coastal fisheries.

Where important coastal areas extend across national boundaries, additional international coordination is necessary. For this purpose the concept of Large Marine Ecosystems (LMEs) was developed, which has already led to a number of positive achievements. For example, states bordering on the LME in the Bay of Bengal were able to agree measures to control overfishing and pollution of the sea.

Successful coastal zone management in the future will have to include effective protection from rising sea level. While the previous strategy was to protect the coasts in part with strong and rigid structures like dikes or barriers, there is now a move away from this paradigm. This is especially because the consequences of future climate change cannot be predicted accurately. Coastal protection measures must therefore be planned more flexibly. Adaptive coastal protection is a promising alternative that provides for a number of different measures that build upon one another, and that are adapted to the advance of sea level in planning and design. These can include raising the elevation of dikes with the help of protective walls or creating new flood-plain areas called polders, into which flood waters can be diverted. One of the first large adaptive projects to be initiated is for the protection of the Thames estuary near London. Adaptive coastal protection also entails building settlements in such a way that they are not susceptible to damage by high waters – perhaps by the construction of floating houses.

While coastal protection in the past has often meant creating large structures cutting across coastal areas, coastal engineers are now calling increasingly for a philosophy of "Building with Nature". This involves using the natural potential of the coasts, for example by promoting the colonization of oyster reefs or eelgrass beds, or by constructing polders where high-diversity salt marshes can develop. Despite the many encouraging examples of alternatives, however, coastal protection programmes around the world remain quite conservative because generally accepted standards or regulations for ecosystem-based measures are still absent and their effectiveness in many cases has yet to be demonstrated. This lack of knowledge needs to be remedied quickly.

In spite of all measures, it will not be possible to preserve all of the world's coasts in the face of rising sea level. The governments of island nations are thus already preparing for an orderly retreat, for instance through education programmes that make their populations attractive for employment abroad. It is hoped that this may put the people who could soon be climate refugees in a position to build new livelihoods in other countries.