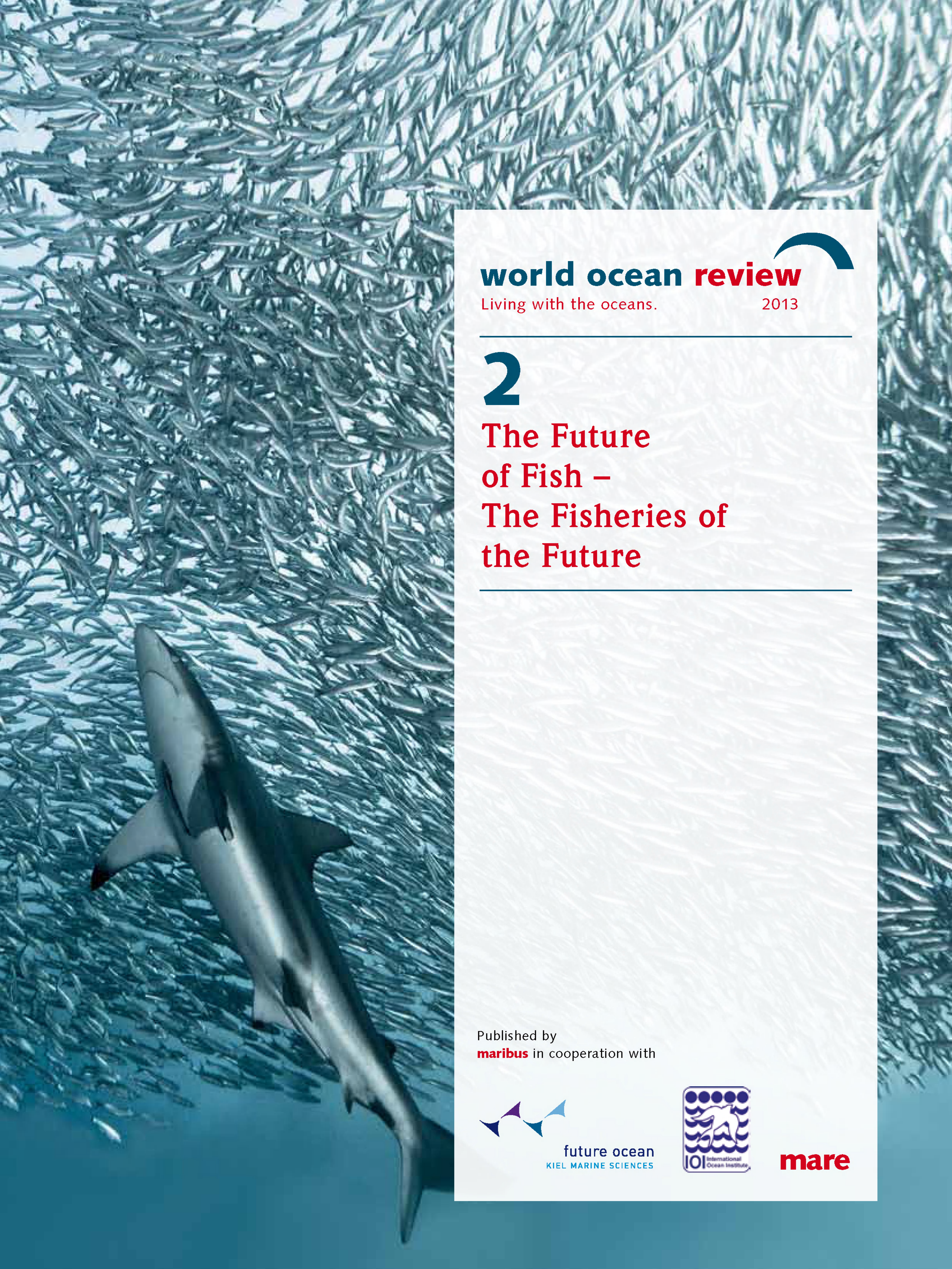


world ocean review

Living with the oceans. 2013

2

The Future of Fish – The Fisheries of the Future

Published by
maribus in cooperation with

future ocean
KIEL MARINE SCIENCES

IOI International Ocean Institute

mare

world ocean review

Living with the oceans. 2013

2
The Future of Fish – The Fisheries of the Future

Preface

Our first World Ocean Review (WOR) was published more than a year ago. This status report took a comprehensive look at the seas and encapsulated the current state of ocean science. It was read by almost 70,000 people, who either obtained a hard copy in German or English from non-profit organization *maribus,* or downloaded it as a PDF file from our homepage at www.worldoceanreview.com. Its readers included teachers, students, scientists and interested laypeople. Moreover, the WOR received intense media attention, with TV (e.g. *"Tagesschau",* the German evening news), online (e.g. *"Spiegel Online"*), radio and print coverage. It was also presented personally to members of parliament in Brussels, and to Federal Chancellor Merkel in Berlin.

The feedback we received was all positive, with many people commending its mix of scientific excellence and readability. The original WOR was a world first in that it was comprehensible to all, but also provided a sound basis for media debate, policy developments and lectures.

It is *maribus'* aim to publish a World Ocean Review each year. The first edition focused on the broad picture, while subsequent WORs will take a more in-depth look at individual aspects of the oceans. Interrelationships which are frequently presented in an abbreviated and simplified form will be thoroughly investigated and presented in all their complexity. Nonetheless the close cooperation between world-leading research scientists and "mare" magazine journalists guarantees that the articles will be straightforward and easily understood by all. They will provide a knowledge base for policy-makers and journalists wishing to hone their awareness of the problems involved.

This new report (WOR 2) focuses on fish and their exploitation. Fish have always been a vital source of life for mankind – not only as a food. Fish are still an essential element of the daily diet in most regions of the world. At the same time fisheries provide a livelihood to entire coastal regions and still have great economic clout. All this, however, is in jeopardy and is coming under close scrutiny. Fish stocks are declining worldwide, entire marine regions are considered overfished, and some species are on the Red List of Threatened Species.

It is not our intention with this World Ocean Review 2 to press the panic button. But by pointing out the true facts surrounding fish stocks and fisheries we seek to come to grips with an extremely complex situation. Only sound knowledge – not alarmism, nor appeasement – will save these vitally important inhabitants of the world's oceans.

Nikolaus Gelpke
Managing Director of *maribus gGmbH* and publisher of *mareverlag*

This publication is a wakeup call for managing humanity's relations with the ocean.

Mankind's *living with the ocean and from the ocean* has been anything but sustainable. The impact through use and exploitation has been destructive and unconscionable because humans have taken for granted the bounty of the oceans and its living resources. In so doing and despite decades of efforts since UNCLOS to evolve a global comprehensive governance regime, the ocean's fragile ecosystems are being systematically destroyed and species after species depleted or brought to extinction by irresponsible fishery practices and policies. This situation is further exacerbated by the impact of climate change.

The "management" of fisheries could be easily ranked amongst the most outrageous examples of human mismanagement. In spite of a plethora of ocean governance tools, the exploitation of this sector is driven by avarice and greed with little respect for the conservation of common goods and the right of future generations to enjoy and profit sustainably from these resources. Driven by illegal, unreported and unregulated (IUU) fishing piracy and combined with destructive fishing technology and practices, intensive bottom trawling, wasteful bycatch practices – the fisheries sector and the biodiversity of oceans and coasts are under unprecedented threat.

Today we face a governance deficit that allows vessels flying under flags of convenience to operate with impunity and with disregard for laws, common ethics or morals of decent and sustainable behaviour. It is time for noncompliant flag states vessels to be stopped and to eliminate the subsidies that increase capacity leading to overfishing.

The time has also come to revise outdated concepts such as that of the maximum sustainable yield in fish harvesting and for the industry to work hand in hand with the scientific community where conservation is assimilated with ethics of use.

This publication, while promoting greater enforcement and compliance with international and regional agreements, is about future commitment to conservation, the creation of sustainable fisheries, the protection of high sea areas and sea mount biodiversity and the contribution to global food security that is underpinned by adherence to the principles of common heritage and the peaceful use of the ocean: principles very dear to the IOI and its founder, Professor Elisabeth Mann Borgese.

IOI will continue its advocacy, capacity building, outreach and education efforts in favour of a new paradigm in the sustainable exploitation and management of the living and non-living resources of our oceans and the protection of its biodiversity by promoting a culture of collective and individual responsibility in managing humanity's relations with the ocean.

Dr. Awni Behnam
President of International Ocean Institute

Since time began we humans have been living with the oceans and exploiting them in many ways – but at the same time we fear them. We fear the mighty forces at sea and along the coasts. We are interested in new resources, including those on the seabed. Who spares a thought for the future of the oceans? Who is concerned about their health? For many of us the sea is not a daily fact of life. We only react with alarm when exceptional events such as oil tanker accidents occur. However, the most damage to the oceans is done on a normal day-to-day basis.

Any discussion on fish and fisheries makes this fact abundantly clear. That fish have been taken from the sea – sometimes at great risk – has been a fact of life for thousands of years. Fish is still the main source of animal protein in many regions. For generations this occurred in balance with the marine environment. But the increasing use of technology has thrown the interrelationship between human societies and fish populations off balance. Intensive fishing practices worldwide are leading to the overexploitation of many fish stocks. Fish can be easily traced using cutting-edge echo sounding equipment, while the supersized nets and capacity of trawlers, working day and night, are slowly but surely emptying out the oceans. What kind of a future do the fisheries and the oceans have? What kind of a future do we want?

The second volume of the World Ocean Review is dedicated to fishery and throws light on the many different aspects of the topic. It provides facts about the development of fish stocks and fisheries. It shows that fishing is deeply rooted in the fabric of many cultures. It documents the ecological and economic value of fish and points out ways of making fisheries sustainable. This is a global concern. It is not limited to those few areas of the world where rapid changes to fishing practices enjoy wide acceptance in society. It also aims to preserve the livelihoods of fishermen in the newly-industrializing and developing nations.

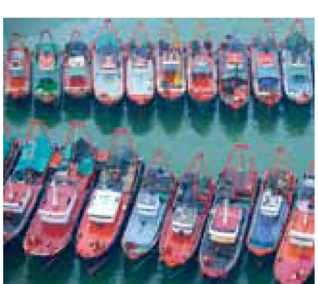
If we want to leave healthy, productive oceans for our grandchildren, we must take the long view and rethink fishery. The review gives good reasons – both ecological and economic – for modernizing today's fisheries! Any collapse of the stocks would put an end to the traditional trade of the fisherman. The prospect is real. Is that really what we want? What can we do to make sure this does not happen? What can be done at a regional level, and what must be negotiated in the national and international policy arenas?

We give our best possible answers to all these questions, sharing our knowledge and assessing the situation, while at the same time identifying options for change.

The future of the oceans is closely linked to the future of the fisheries and thus to the future of many – if not all – the world's peoples. With this in mind, I hope you find this gripping and enlightening reading.

Prof. Dr. Martin Visbeck
Spokesman for the Cluster of Excellence "The Future Ocean"



1 The importance of marine fish

> Fish are a vital component of marine habitats. They are complexly related to other organisms – through the food web and through other mechanisms. Intensive fishing therefore results not only in the decimation of fish species but also affects entire biological communities. The results are often unpredictable. Although industrial fisheries rarely cause the complete eradication of individual species, they may already be having an evolutionary impact on heavily fished species.

The role of fish in the ecosystem

> Economically important fish species have long been regarded in isolation from each other and their habitat. In order to comprehensively assess the impacts of fisheries the entire habitat must be considered. Only then will a sustainable and economic fishery system be possible. Methods now exist for these kinds of comprehensive analyses. Moreover, it is now known that not only the fisheries, but also changing environmental conditions can affect the size of fish populations.

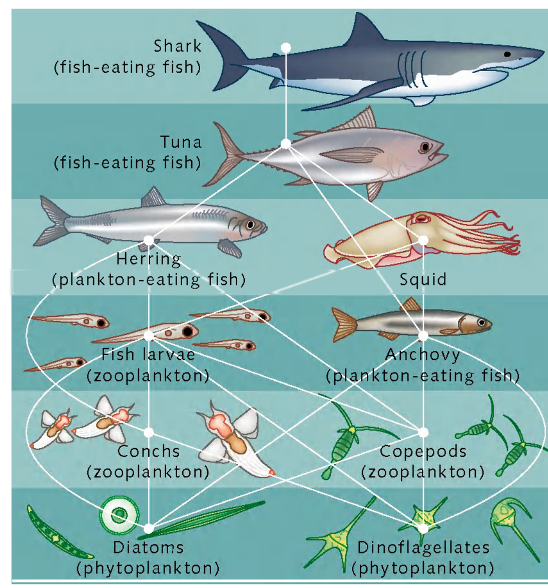
Fish and life in the sea

The ocean is tremendously diverse and species-rich. It is the home of countless organisms living in very different ecosystems. Mussels and worms thriving in the Wadden Sea are a food source for millions of migratory birds. Communities of tube worms, crustaceans and bacteria have developed at volcanic hydrothermal seeps in the deep sea. Elsewhere kelp forests sway with the currents while sea otters on the hunt swim through. Sea birds nest on rugged and rocky coasts while thousands of iridescent fish species frolic in reefs.

Fish are a key component of marine biotic communities. For millennia mankind has had an especially close bond with them because they provide people with food. Around 43 million people worldwide make their living directly from fishing or fish breeding. But people are careless with this natural resource. Over thousands of years too many fish have been taken. Many fishing grounds have been overfished. Furthermore, the ocean is being polluted by effluents from industry, settlements and agriculture. Some habitats such as mangrove forests are destroyed directly by construction. Considering the serious situation, it is important to investigate the present status of marine fish.

Fascinating diversity

The diversity is amazing: there are over 30,000 fish species in the world. Some are only a few centimetres long and live hidden among corals. Others, like the blue marlin in the Atlantic, are up to 3 metres long and roam the open sea. Herring glide through the North Sea in large schools, while anglerfish do their hunting in the darkness of the deep sea with a bioluminescent lure extending from their foreheads. Each of these fish types is part of a habitat, an ecosystem, and exists in complex interdependence with many other species in a food web.



1.1 > Interrelationships between organisms can be illustrated as a food web with various trophic levels.

Specialists arrange the organisms within the food web into different nutritional positions called trophic levels. At the bottom there is a myriad of microorganisms. These include microscopic single-celled algae such as diatoms, dinoflagellates and cyanobacteria, collectively known as phytoplankton, which drifts freely in the water. It carries out photosynthesis, which means that it uses sunlight and nutrients to synthesize sugar, and from this builds other energy-rich substances. Scientists refer to this biochemical development of biomass as primary production. Phytoplankton is the food source for small, free-swimming

1.2 > Sardines are also threatened by predators from the air. Cape gannets off South Africa can plunge up to 8 metres below the surface to grab their prey.

crustaceans or fish larvae, referred to as zooplankton. Zooplankton, in turn, is food for small fish and other organisms. The amount of fish that can exist in a given region is primarily determined by the activity and amount of primary producers; greater primary production can support larger fish stocks. The simple model of a food web in which smaller organisms are eaten by larger ones, however, is not sufficient for explaining the relationships in the ocean. What the larger animals do has an impact on the entire habitat. Many other interactions are also taking place.

Network thinking

The knowledge that the web of relationships among marine organisms is complex is not new. Similar connections are also known for many habitats on land. But for a long time in the fisheries there was a tendency to focus on individual commercially important species such as cod, herring or sardines. Only in the past ten years has the importance of looking at entire ecosystems become accepted for the long-term preservation of fish stocks and effective management of fisheries. The reason: numerous stocks have been overfished in many ocean regions in the past. In some cases this has resulted in serious changes to the habitats. It is gradually being recognized that the complexity of the marine system has to be considered in fishery management. Marine habitats are by no means influenced only by primary production at the base, but also by factors at the higher trophic levels, from the top down.

An example can be seen in the eastern Atlantic waters of the Benguela Current off Angola, Namibia and South Africa. Persistent winds in this region push the surface waters out to sea. This is replaced by nutrient-rich water

1.3 > Specimens of the jellyfish *Nemopilema nomurai* can reach a size of 2 metres and weigh up to 200 kilograms. A few years ago hundreds of these animals drifted into Japanese waters, seriously interfering with fisheries.

rising from below near the coast. These upwelling regions are enormously productive and rich in fish. Over many years mostly foreign fleets have fished intensively for sardines here. At the beginning of this century the stock collapsed. Since then the jellyfish population in this region has greatly increased. Experts believe that the decline of sardines represented the loss of an important food competitor because both sardines and jellyfish feed primarily on zooplankton. In addition, young jellyfish are eaten primarily by fish. The jellyfish scourge was unexpected. It was assumed that with the decline of the sardines the abundance of anchovies, another small fish species native to this region, would increase. The anchovy has a diet similar to that of the sardine and should have kept the jellyfish in check. But the anchovy does not appear to be a true competitor of the jellyfish, because so far the anchovy population has remained smaller than that of the sardines. Perhaps the very dynamic upwelling area is a less suitable habitat for anchovies.

There is a similar situation off the coast of Japan. The population of the jellyfish *Nemopilema nomurai* greatly increased there after the intensive fishing of sardines. Individuals of *Nemopilema* can reach a size of up to two metres. The fishery is now seriously impaired by the jellyfish because they clog up or even tear the nets. But jellyfish do not always proliferate to create this kind of disaster. In the 1970s, off Peru, the large stocks of South American anchovies collapsed. As a result, sardines flourished and a jellyfish plague was avoided. In other words, it is almost impossible to predict today what effects the overfishing of a population will have.

When the big ones land in the net, the small ones benefit

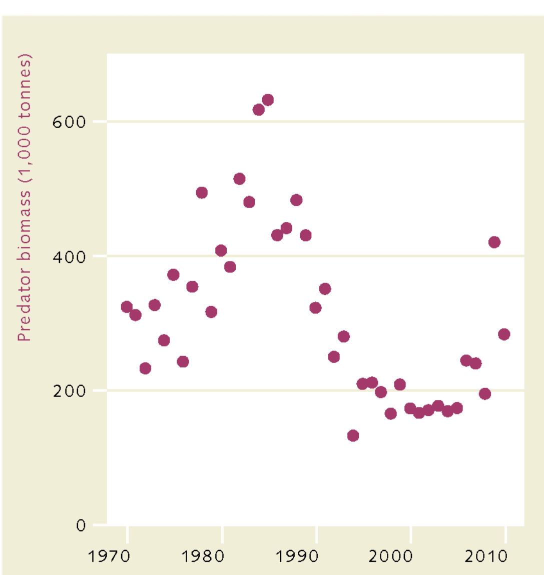
Overfishing has also altered the habitat in the waters off Nova Scotia on the east coast of Canada. For years cod and other bottom-living (demersal) predators such as coalfish have been heavily fished here. The stocks collapsed in the early 1990s. More than 40,000 fishermen lost their jobs. Although a ban on fishing was imposed relatively quickly, the stocks did not rebound even after many years. There is much concern that the habitat has been irreversibly altered.

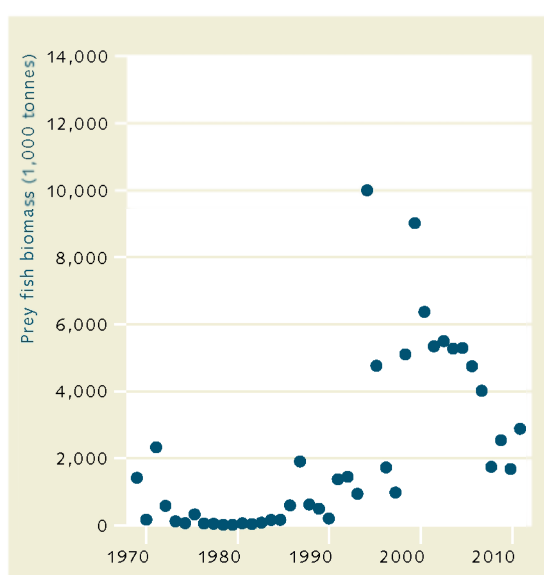
The cod is a predatory fish at a high trophic level that hunts small **planktivorous** species, plankton eaters such as the capelin and herring. As the cod disappeared the small planktivorous species became more abundant. Unfortunately, both the planktivorous fish and the larvae of the larger predators feed on zooplankton, which makes them competitors. In addition, the planktivores eat cod roe and larvae, which further increases pressure on the predators. The number of planktivores increased by a factor of nine, while predator stocks remained small.

The food fish therefore have a strong influence on their predators. Specialists use the term "predator-prey feedback". Because of this feedback, the stocks of cod, coalfish and other large predators off Nova Scotia have been slow to rebound. The planktivorous fish were thus able to predominate over the predators for a period of 20 years. But now the stocks of planktivores are declining. This is attributed to the fact that the capacity of this region is exhausted: there are so many planktivores that their food supply has become scarce. But a poorly nourished population produces fewer offspring, so the total biomass of the planktivorous fish stocks decreases. The predation pressure on the early life stages of the large predator fish off Nova Scotia has thus declined. As a result the stocks of some predators, for example the coalfish, have recovered. The warning status for cod stocks, however, cannot yet be lifted.

Similar interdependencies between predator and planktivorous fish are also known from other marine regions. In the Baltic Sea researchers refer to the "cod-sprat swing". After the general conditions for cod roe and larvae had deteriorated due to low salinity and oxygen deficiency, the cod stocks declined drastically. Because the cod fishery did not adjust to the situation and decrease the catch amounts rapidly enough, the stocks decreased even more. Thus the stocks of their prey, the planktivorous sprat, increased. Because the sprat diet also includes cod roe, pressure on the cod population was further increased. But in this case, temperature also had a crucial impact on the success of the population: slightly increased water temperatures enhanced development of the eggs and larvae of the sprat.

Now the "cod-sprat swing" is sweeping back because the fishery was adjusted: a reduction in cod fishing and





1.4 > "Predator-prey feedback": In the mid-1980s the stocks of the northwest Atlantic cod off Canada drastically declined (left figure). As a result the biomass of the smaller food fish increased (right). In recent years this trend seems to be turning around again.

interim increase in sprat fishing led to a moderate recovery of the cod stocks.

There is evidence that not only the planktivorous fish, but also algae benefit from the disappearance of large fish. Planktivorous fish feed on zooplankton, which, in turn, feed on the small free-floating algae, the phytoplankton. Increased numbers of planktivorous fish produce a drop in the amount of zooplankton, and phytoplankton can flourish. This can cause a problem, especially in the nutrient-rich coastal waters where phytoplankton can grow practically unchecked. The result is known as an algal bloom. When the algae die they sink to the bottom. There they are broken down by bacteria, which consume oxygen.

The formation of algal blooms is complex. It seems that a number of favourable conditions must be present at once. In addition to a sufficient supply of nutrients, moderate water temperatures are necessary. By adding the factor of overfishing of large predators, the problem is apparently exacerbated.

Greater amounts of algae sinking to greater depths results in increased bacterial activity there, and ultimately leads to a shortage of oxygen. Thus, oxygen-deficient dead zones develop in the ocean where neither fish, crustaceans, nor mussels can survive. Many scientists are therefore now urging fishery management to expand their focus from only the species being fished to consideration of the entire habitat. By recognizing the interdependencies among different species and the trophic levels, this ecosystem-based management should prevent the continued damage or drastic alteration of entire ocean regions caused by intensive fishing and consideration or monitoring of single species.

1.5 > Copepods are usually only a few hundred micrometres to a few millimetres in size. They are an important food staple for fish and for other crustaceans, and make up the largest share of the marine zooplankton.

The environment also influences stocks

Fluctuations in the size of fish stocks are not only caused by fisheries. Changes in environmental conditions also affect the stocks. For example, in cold, salty water the Baltic Sea cod produce more offspring than in warmer water with a lower salinity. On the other hand, the animals reach sexual maturity later in colder water. But water temperatures and other environmental parameters fluctuate over time in many marine regions. These are often triggered by natural climate cycles that produce regular changes in winds or ocean currents.

One example is the **North Atlantic Oscillation** (NAO), which influences the climate over parts of Europe and North America. The NAO is a fluctuation of the atmospheric pressure difference over the North Atlantic between the Azores high and the Icelandic low. Among its influences, the NAO affects the winter weather in Europe, and fluctuates with a 10-year rhythm. The wind and near-surface ocean currents in the North Atlantic also fluctuate with the atmospheric pressure.

In contrast, the **El Niño** climate phenomenon operates in the Pacific. It alters the current direction in upwelling regions, in this case between the west coast of South America and Indonesia. The large upwelling region off the coast of Chile and Peru is part of a powerful ocean current called the Humboldt Current. This brings cold water from the Antarctic northward along the west coast of South America. Here, like off southwest Africa, nutrient-rich, cold water rises to the surface. The engine for this upwelling is provided by the prevailing **trade winds** that push the warm surface water from South America westward towards Australia and Indonesia.

South American waters are among the world's richest in fish. Around 15 to 19 per cent of the world's catch comes from here, especially small species like sardines and anchovies. The larger horse mackerel, as well as wide-ranging species such as sharks and tuna, are also found here.

But in the years of the El Niño, the westward-blowing **trade winds** decline and may even reverse direction. This also changes the current direction of the water. Warm, nutrient-poor surface water now flows from the western Pacific towards Peru. These conditions inhibit the production of plankton off the coast of Peru. Food for the planktivorous fish thus becomes scarce, and the stocks collapse. The larger predatory fish and birds, including penguins, are affected, but also mammals such as seals, which rely on the fish as their main food source. In El Niño years they often produce fewer offspring.

Vital conditions for fish thus change more or less regularly. This can affect both the size of the stocks as well as their geographic extent. The cod population in the eastern Baltic Sea is highly dependent on incursions of salt water from the North Sea. These massive inflows of water occur only every few years under certain weather conditions. They have to be strong enough to override the Darss Sill, a kind of shallows off the coast of Mecklenburg-Western Pomerania. Under normal conditions the heavy salty North Sea water cannot pass over this sill. But during the massive salt-water incursions, enormous amounts of North Sea water flow over the sill and along the bottom of the Baltic Sea as far as Gdansk Bay, and even farther into the Gotland Basin between Latvia and Sweden. This salt-water influx is important because along with the cold saline water it also brings oxygen into the depths where

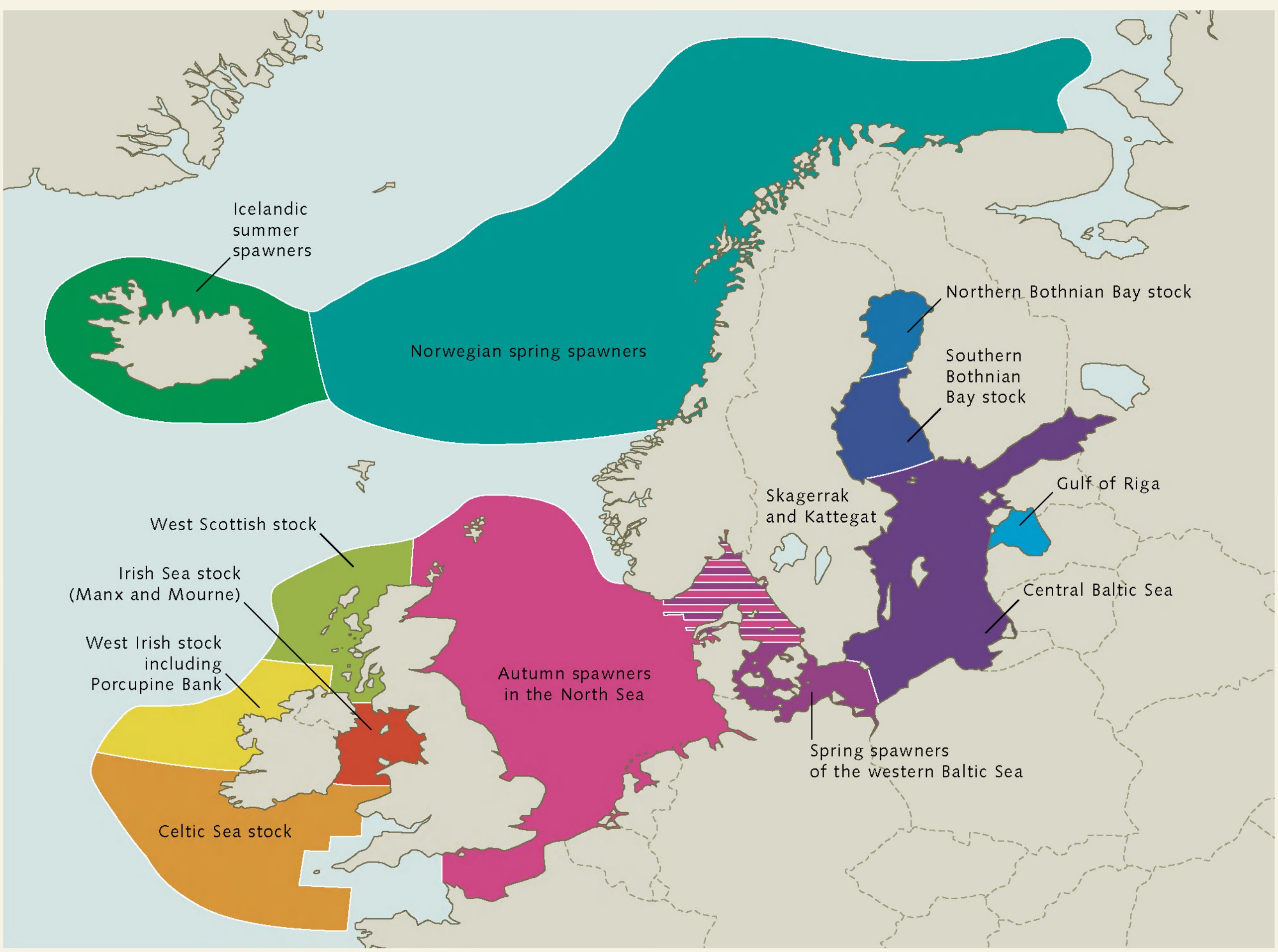
North Sea water for cod offspring

The Atlantic cod lays its eggs in the open water. The eggs do not sink, but float within the water column. They lie suspended at the "halocline". This is an abrupt boundary between a layer of light, lower-density fresh water floating above, and denser, more saline water below. The density of cod eggs is such that they sink in the fresh water but do not fall below into the denser salt water. For their optimal development the roe require salty and oxygen-rich water. In the Baltic Sea these parameters depend greatly on the influx of cool, saline and oxygen-rich North Sea water. If there is no inflow of North Sea water for an extended time, the Baltic Sea salinity decreases due to the input of river water, which also thickens the fresh-water layer above the halocline. The halocline thus deepens. But at greater depth the oxygen content decreases. In some cases the oxygen content is so low that the eggs develop poorly or not at all, especially in the deeper Baltic Basin. The conditions for development are improved again only with the next influx of fresh North Sea water.

One species – multiple stocks

A stock is a self-sustaining population of a species that occurs within a defined region of the ocean. As a rule, the different stocks of a fish species are spatially separated to such an extent that the individuals from one stock cannot breed with those of another, even though they belong to the same species. The herring provides an example.

The individuals in Norwegian waters spawn in the spring. Herring in the North Sea, however, spawn in autumn. Thus there is a very clear separation between the two stocks, which even has a biological manifestation. For fishery management and discussions of overexploitation of fish species, it is crucial to consider the stocks individually. Rarely is a species completely overfished, rather it is usually only a particular stock of the species. The herring stock of autumn spawners in the North Sea recovered after just five years, while the stock of spring spawners off Norway took almost 20 years to recover.



1.6 > Herring live in the transitional area between the northern temperate and polar zones. They occur not only in the North and Baltic Seas, but also throughout the North Atlantic, living at water depths up to 360 metres. Herring undertake extensive migrations between their feeding and spawning grounds and their winter stop-over areas. Different stocks spawn in different seasons.

cod spawn. If the salt-water influx does not occur for a long time the spawning conditions deteriorate. Furthermore, it is now known that long-term climate fluctuations impact cod stocks in the eastern Atlantic, the North Sea, and the Baltic Sea. In the 1980s the stocks of gadoids, the cod-like fish, increased greatly in these regions.

The environmental conditions that led to this "gadoid outburst" are still not known. There are a number of hypotheses. It may be that the cold winters of the 1960s and 1970s afforded ideal spawning conditions. In subsequent years the stocks decreased again, presumably not only due to fishing. It is generally true that when a population collapses it is usually associated with a combination of high fishery pressure and changes in environmental conditions.

More data for stock assessment

In order to determine the impact that fisheries have on different ocean regions or to assess the status of a fish species – for example, whether it is overfished or not – many more details are necessary beyond the usual information about the annual catch statistics for a species.

One factor of interest is how the stocks of other fish species in the same region develop, rather than focusing only on the species being fished. Special consideration should be given to the bycatch. This refers to the fish and other marine animals that are unintentionally caught along with the species of commercial interest such as cod or coalfish that are being fished for. As a rule, the bycatch is thrown back.

Because bycatch amounts have not been systematically recorded in the past, an important parameter is missing that would help to assess the population development of several species, as well as the status of the marine region. Fortunately, there are a number of regions today where discarding the bycatch is not allowed. The European Union also wants to make throwback illegal. This would make it possible in the future for fisheries to provide valuable data to scientists that would otherwise only be obtainable through expensive research cruises. There is continuing controversy among various specialists, not only about the status of individual species, but also about how the stocks of certain fish species can be best estimated. In any case, obtaining additional data would help a great deal.

In this regard, it would also be important to gather data on the primary producers, the algae and other single-celled organisms, whose quantities and composition substantially contribute to the biomass in the marine region. Such a multiple indicator approach, which considers all of these parameters, could be very important in establishing future catch limits. This kind of comprehensive data set is presently only available for a few fish species, because obtaining the data for all of these parameters is extremely expensive. Furthermore, it requires an intensive exchange of information among scientists of various disciplines, including fishery biologists, oceanographers, and plankton specialists, which has so far only been accomplished for a few stocks such as the Baltic Sea cod and the West Atlantic cod.

1.7 > Clupeids frequently form dense shoals, such as here off the Moluccas. They are an important food source for many marine organisms and very important for the ecosystem.

What does overfishing mean?

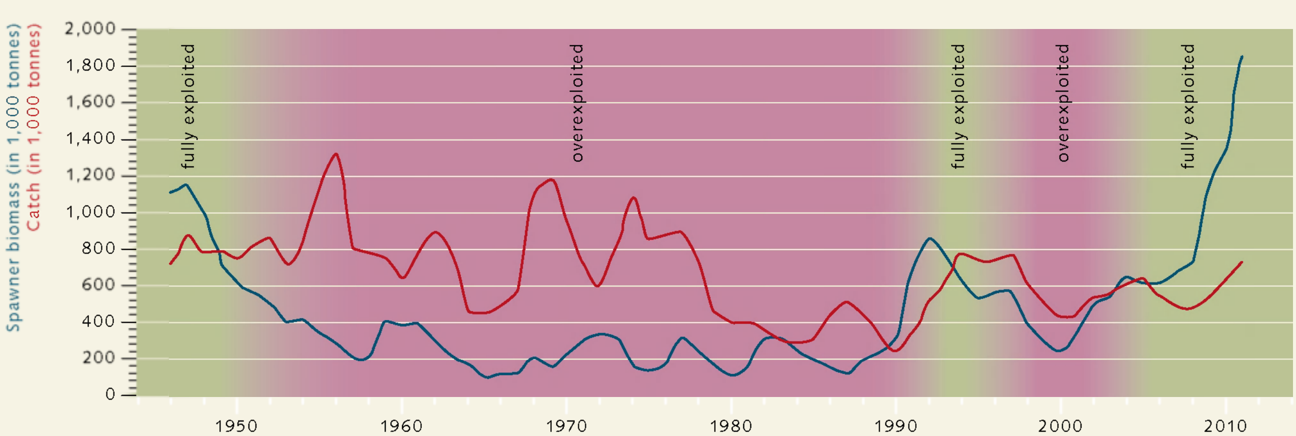
Fish cannot be counted like elephants in a national park. Fishery biologists therefore have to calculate the size of a stock based on specific parameters. The size of the annual catch is important. If this declines it could be a sign that the stock size is shrinking. The quantity of sexually mature adult fish, the spawners, is also important because they determine how many offspring are produced. After all, a stock can only sustain itself if the new offspring can compensate for the number of fish that are caught or die of natural causes. Fishery biologists commonly assign stocks to one of several categories: moderately exploited, fully exploited, overexploited, depleted, or recovering.

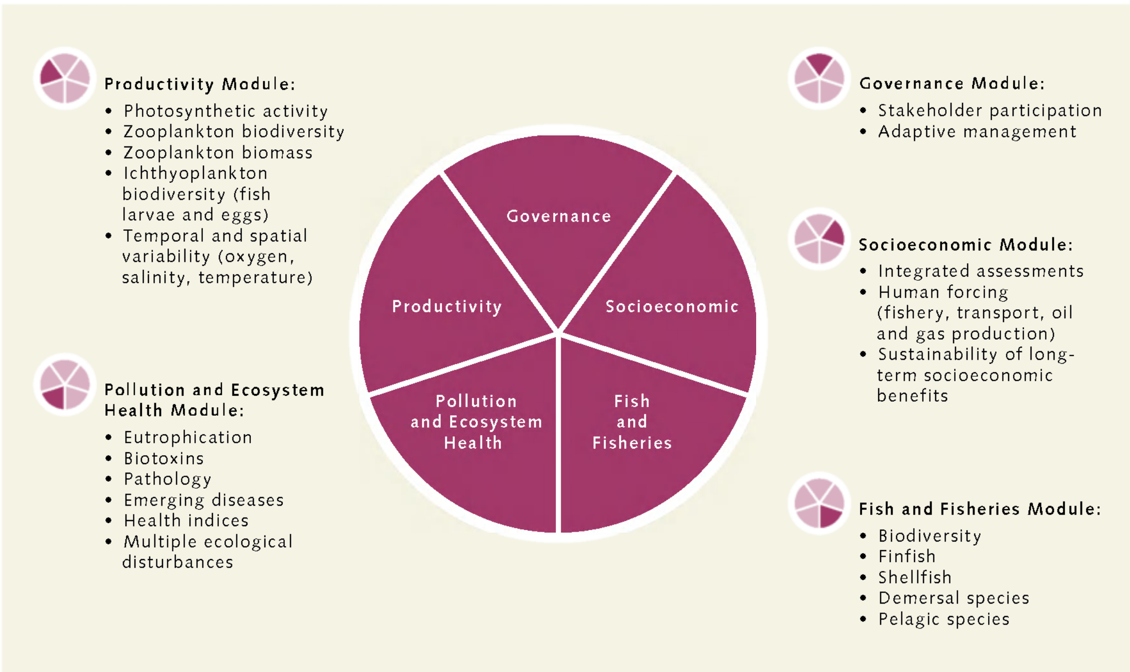
The transitions between these status classes, however, are not sharp, for example, the boundary between a fully exploited and overexploited stock. One reason for this is that different fish species react very differently to fishing pressure. Species that multiply in large numbers and reach sexual maturity early can react better to high catch volumes than species that produce fewer offspring and require several years before they can spawn.

But basically a stock is considered to be fully exploited when it is fished to the maximum and an increase in the catch is not possible. If the fishing is intensified at this point, the stock is then pushed into the overexploited status. This stock then continues to decline because there are not enough offspring being produced. The stock is considered to be depleted when the catch is significantly below the historically expected amounts. Many researchers define this situation as the point when only 10 per cent of the highest historical catch is achieved. When a stock is depleted the catch cannot be increased even with intensified fishing, which is referred to as an increase in fishing effort.

A stock is considered to be recovering when the catch begins to rise again after depletion. An example of this is the North Atlantic cod, whose stocks collapsed in the 1960s and recovered again after a fishing ban. The Food and Agriculture Organization of the United Nations (FAO) presently uses three categories to describe the status of the stocks: non-fully exploited, fully exploited, and overexploited.

1.8 > The example of the North Atlantic cod shows that a fish stock collapses when not enough mature fish (spawners) are present to produce offspring.





1.9 > The objective of the Large Marine Ecosystem concept is sustainable management of the oceans. Under this approach the status of marine regions is characterized in five different modules.

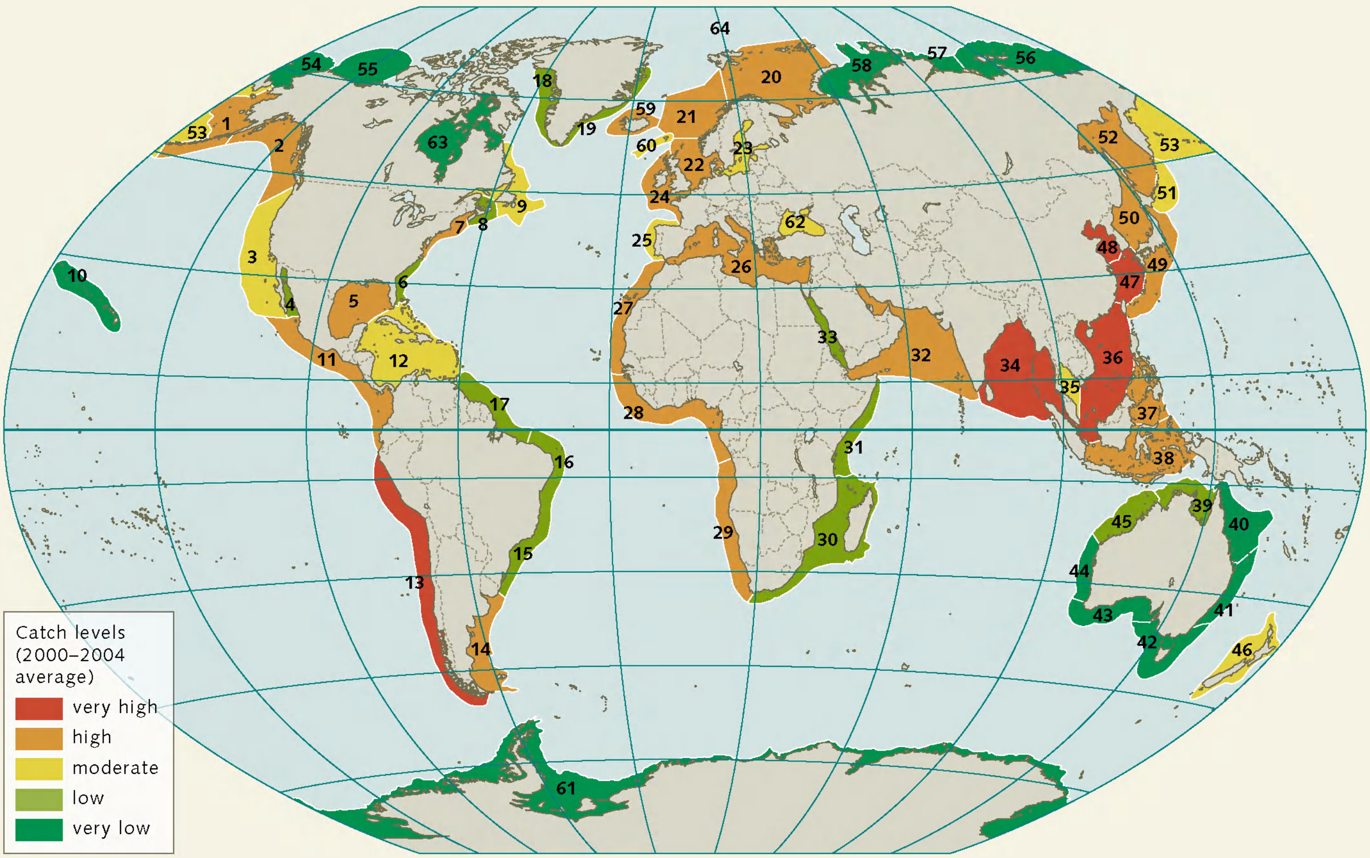
Large Marine Ecosystems

Most marine regions and habitats are so large that they extend across the coastal waters of multiple countries. Comprehensive conservation in these areas is only possible if the countries cooperate, for example, with regard to pollution of the ocean. Even larger fish stocks can only be sustained when the countries agree to joint policies of protective fishery management. For a long time, these kinds of international agreements regarding coastal regions had been lacking. For this reason the National Oceanic and Atmospheric Administration of the USA (NOAA) developed the concept of Large Marine Ecosystems (LMEs) in the 1990s. This divided the coastal marine regions of the Earth into 64 LMEs. Each LME is characterized by a typical flora and fauna. The LMEs extend along the coasts out to the continental slope, where the continental shelf ends and starts its downward incline towards the deep sea. The characterization of certain marine regions by large currents is also considered. For example, the upwelling regions off South America and Southwest Africa are each defined as an LME.

The LMEs comprise all of the coastal regions of the Earth. They are especially productive because they are well provided with nutrients from rivers or upwelling currents. The LMEs produce 95 per cent of the global fish biomass. These areas are also immensely important for humans. Hundreds of millions of people worldwide live near the coasts. Their existence depends more or less directly on fishing. Thus, in addition to the biological factors, the Large Marine Ecosystem concept also deals with socioeconomic aspects.

With the support of the World Bank and the United Nations Environment Programme (UNEP), an effort is being made to improve international cooperation towards protecting the joint ocean regions, particularly in the developing and newly industrialized countries. Researchers and politicians of the neighbouring countries meet at workshops and conferences. The major challenge is to achieve better protection of the marine environment in spite of differences in interests.

Economic aspects such as offshore oil production often have priority over protection of the environment. The concept of the LMEs should provide a counterbalance



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

1.10 > Near-coastal ocean regions have been divided into 64 Large Marine Ecosystems that cross geopolitical borders. This concept is expected to improve cooperation of countries with regard to international marine conservation. The individual LMEs are coloured to indicate the intensity of fishing from 2000 to 2004. In many marine regions the fishing pressure has not dropped since then.

and create an awareness of the importance of the marine habitat. Political crises and civil wars, however, like that in the Ivory Coast have continued to undermine cooperation in recent years.

One focus of the work is to educate qualified people locally. Together with international experts, native scientists are trained to record and competently analyse the stocks of fish, primary producers, and other marine organisms according to current standards. However, in the past many countries have lacked both the funds and sufficient specialists to carry out sustainable fishery management within their territorial waters. Technical knowledge is thus a critical prerequisite for future fishery conservation efforts.

Promising examples are illustrated by the two West African LMEs, the Benguela Current LME and the Guinea Current LME. Numerous courses, workshops and conferences have been held in the countries concerned.

One of the present goals is to find indicators for the various LMEs whereby the status of the marine regions can be assessed and described. A sustainable management of the seas should ultimately be achieved. Five working areas, referred to as modules, have been established for this purpose.

PRODUCTIVITY OF THE HABITAT: Record biodiversity of the phytoplankton and zooplankton and their biomasses, measure the photosynthetic activity, etc.

POLLUTION AND ECOSYSTEM HEALTH: Investigate the influences of biotoxins, eutrophication of the water, and the development of pathological changes in the marine organisms, etc.

FISH AND FISHERIES: Investigate the biodiversity and biology of finfish and shellfish, identify fish stocks and changes in their composition.

SOCIOECONOMY: Investigate the practical application of scientific findings for management of the ecosystems, assess diverse management methods based on economic and other criteria regarding the principle of sustainability.

GOVERNANCE: Consider ways in which various interest groups in the areas of fisheries, tourism, energy and environment can participate in the development of interregional management planning, etc.

The Large Marine Ecosystems programme has produced a series of studies in which scientists have investigated the development of the LMEs over recent decades. These have clearly illustrated the severe impact that fisheries can have on habitats, but in many cases it is still not clear to what extent natural processes have influenced the development of fish stocks.

In some years, large oxygen-deficient zones form in the Benguela Current. In these years the stocks of **pelagic** fish collapse, causing a shortage of food for many species of seabirds and seals. This results in a decline in the survival rates of their young.

Of course the upwelling areas generally exhibit low concentrations of oxygen at greater depths. But it is not yet known why the oxygen-poor areas sometimes extend nearly up to the surface.

There is some evidence that the oxygen deficiency occurs after periods of especially intense upwelling currents. This suggests an initial development of large amounts of phytoplankton that later die in large volumes and are subsequently broken down by bacteria. In some cases it appears that a change in current conditions causes expansion of the oxygen-poor areas.

This example illustrates again the importance of understanding the entire ecosystem in assessing the development of populations of marine organisms and ultimately also the fish stocks.

The concept of the Large Marine Ecosystems is important and necessary. But so far there is little indication that information gained from the international LME projects and activities have led to concrete political directives or national laws. Experts stress the need for action in the future. They agree, however, that LME activities are likely to lead to a greater awareness of marine protection and conservation of fish stocks for the future than has been the case up to now, even in developing and newly industrialized countries.

Diversity at risk

> Many stocks have been so strongly decimated by fisheries that it is no longer commercially profitable to fish for some species. Still, most species will survive thanks to their enormous reproductive capacity. But there are exceptions. Some species could actually be wiped out by humans. It is also alarming that the fisheries appear to influence evolution. Smaller fish often prevail while the larger ones become scarcer.

Are fish species facing extinction?

Although many stocks have been overfished by industrial fisheries, as a rule this does not result in the extinction of fish species. The classical notion of a species being wiped out by human activity, like the case of the dodo, a flightless bird on the island of Mauritius, cannot be directly applied to fisheries. There is an economic reason for this: long before the last fish is caught it would become unprofitable to fish for it, so it would no longer be pursued by the fishery in the affected region. Specialists refer to this kind of situation as commercial depletion.

Some fish stocks have been reduced by 50 to 80 per cent in the past. This would spell extinction for many terrestrial animals, especially for species that produce small numbers of offspring. The death of even low numbers of young animals by disease or predation could then completely wipe out such a species. This is not the case with fish. As a rule, the stocks recover. One important reason for the resilience of fish stocks is their high reproductive capacity. Cod can produce up to 10 million eggs each year. An additional factor is that a fish species is usually represented by multiple stocks.

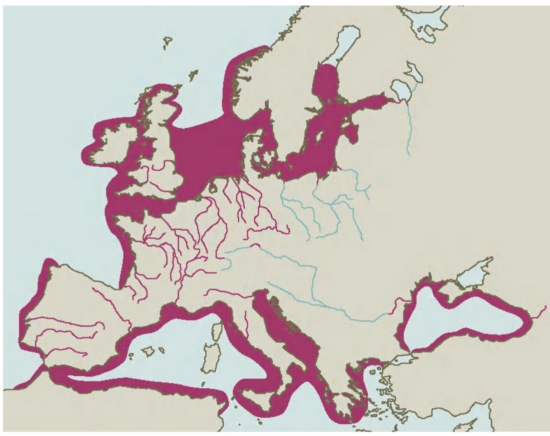
There is no question that intensive fishing has severely reduced the amount of fish, the fish biomass, in many marine regions. The higher trophic levels are especially affected. The large fish have been and still are the first to be depleted. But even these are usually not in danger of biological extinction. In order to draw conclusions about the status of a fish species, all of its stocks have to be assessed. For several years there has been some controversy about the best mathematical and statistical models to use for this.

The Food and Agriculture Organization of the United Nations (FAO) has established a general classification system. It classifies fish stocks as overexploited, fully exploited and non-fully exploited. According to the FAO, almost 30 per cent of all fish stocks are considered to be overexploited. As a rule, however, the species will be preserved.

1.11 > Animal conservationists have been trying for several years to reintroduce the sturgeon to German waters. A number of the animals released have yellow markers on their backs. Fishermen who catch one of these are requested to report the number on the marker to the conservation group and return the fish to the water.

Regrettable exceptions

There are, however, exceptions. Some species of tuna fish bring such high prices on the market that catching them is profitable even when their numbers are very limited. One fish can weigh up to 500 kilograms. Certain species, such as the bluefin tuna *(Thunnus thynnus)*, which lives in the Atlantic, can bring a price of 100 dollars per kilogram. In Japan, hundreds of thousands of Euros may be paid for the first or best tuna of the season. Expensive fish is a mark of prestige there. Furthermore, the first tuna of the season are considered to be bringers of good luck, for which some customers will pay a lot of money. For practical purposes, fishing for such valuable specimens can be compared with



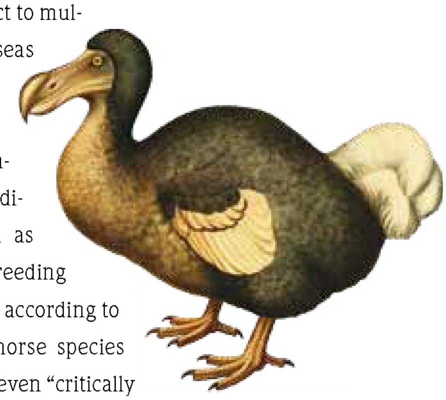
1.12 > Around the year 800 the European sturgeon was indigenous to many rivers and almost all of the coastal areas of Europe. Since then its marine distribution has shrunk significantly, and it is now limited to the region between Norway and France. The only remaining spawning area of the European sturgeon is the Gironde Estuary in France.

hunting rhinoceroses on land. As late as the 1920s bluefin tuna still appeared regularly in the nets of Norwegian mackerel fishers. Today this species has completely disappeared from the Kattegat and the North Sea. And in the Atlantic there are only very small numbers of bluefin tuna remaining.

Other species of fish are threatened with extinction because they are under multiple pressures at the same time, both from fisheries and destruction of their habitats. One example is the European sturgeon *(Acipenser sturio)*, whose distribution once extended from southern Spain to eastern Europe. The sturgeon spawns in rivers and grows to sexual maturity in the sea. Like salmon, the European sturgeon migrates back into the rivers to spawn. The species once inhabited the Eider, the Elbe, and small north German rivers like the Oste and the Stör. But over the past hundred years the stocks have greatly declined. Today there is only one remaining stock in Europe, in the Gironde Estuary in southwest France, but it has also been shrinking in recent years.

The decline of the sturgeon has multiple causes: river training, installation of weirs, pollution of the water, and fishing. Today, the remaining animals are threatened primarily with ending up in fishing nets as unintentional bycatch. The European sturgeon is classified as "Critically Endangered" on the **Red List** of the International Union for Conservation of Nature (IUCN). The release of juvenile individuals to rivers has therefore been ongoing for several years, in order to re-introduce the species into its various native regions of Europe, including Germany. In addition, attempts are being made to encourage the fish to spawn in their once-native waters by returning some stretches of river to their natural state or building fish steps around weirs. It is still uncertain whether these efforts can save the European sturgeon.

Some species of seahorse are also subject to multiple threats – including pollution of the seas and destruction of their habitats, the mangroves. There is also a large demand for them. They are fished on coral reefs, in mangroves or seagrass beds, and are sold as traditional medicine on Chinese markets and as ornamental fish for aquariums. There are breeding programs, in Vietnam for example. But still, according to the IUCN Red List, of 38 worldwide seahorse species seven are considered "endangered" and one even "critically endangered". The species primarily at risk are those that occur in a small, relatively limited geographic area. These are referred to as **endemic species**.



1.13 > The dodo died out at the end of the 17th century. Native exclusively to the islands of Mauritius and Réunion, the flightless bird had no natural predators before the arrival of humans. It was completely wiped out by imported rats, monkeys and pigs.

Examples such as these illustrate that humans need to be more responsible in using and protecting fish resources in the future. The fact remains, however, that for most fish species in the world there is no danger of extinction. The IUCN list was originally established for land organisms. These generally do not have the reproductive capacity of fish. Critics therefore say that the risk of extinction expressed in IUCN standards is exaggerated for many commercial fish species.

Other marine animals are also affected

Not only do fisheries alter the natural species structure of the fish that are being fished for; they also have an impact on the stocks of animals that are taken as bycatch. U. S. researchers have calculated that at least 200,000 loggerhead sea turtles and 50,000 leatherback turtles worldwide were caught incidentally in the year 2000 by tuna and swordfish fishers. The turtles are caught on the hooks of "longlines". These are usually several kilometres long and can be fitted with thousands of baited hooks. If the turtles snap at these they will be hooked. Some are able to free themselves and others are thrown live back into the ocean by the fishermen. But thousands die an agonizing death. Tests are now being carried out to shape the hooks so that the turtles will no longer be caught by them.

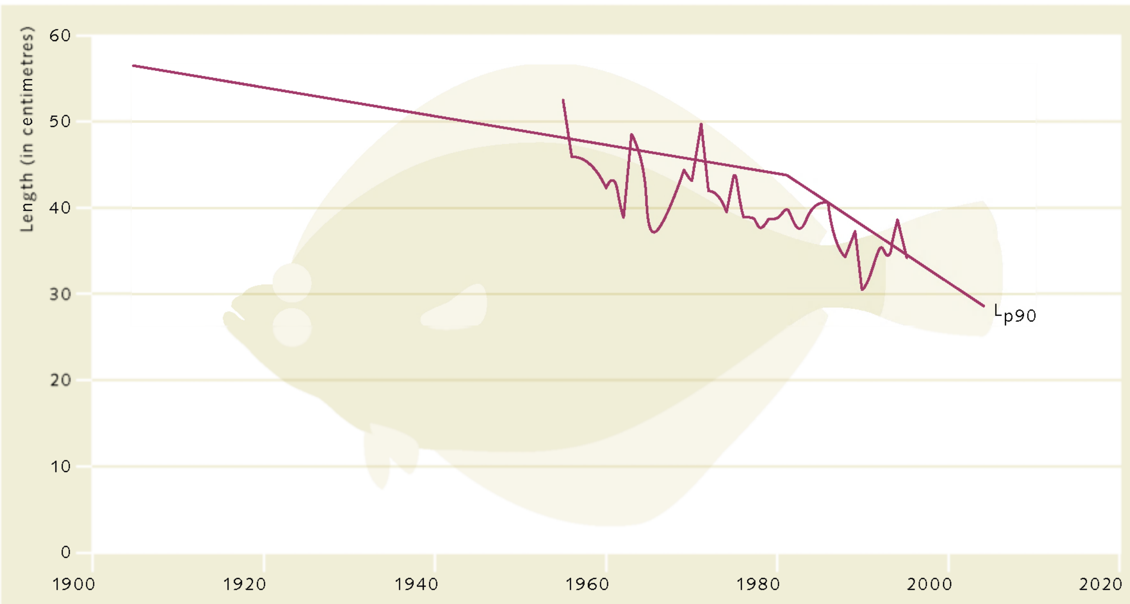
The longlines can also be fatal for albatrosses because they do not sink to the working depth immediately after being let out, rather they float for a while at the surface and attract the birds. Environmental organizations estimate that hundreds of thousands of sea birds are unintentionally killed annually worldwide by longline fishing. New methods are therefore also being tested by which longlines are deployed through tubes that extend up to 10 metres below the surface, so that albatrosses cannot see or reach the bait. In the Baltic Sea, the harbour porpoise is also endangered as bycatch. There are only an estimated 500 to 600 individuals remaining in the eastern Baltic Sea. The harbour porpoise was hunted here for decades. Severe icy winters are also a strain on them. Today, every unintentionally caught animal brings the stock closer to extermination. It is a near tragedy that the eastern Baltic Sea harbour seals very rarely mate with their relatives in the North Sea and western Baltic Sea. The North Sea stock is comparatively large. Researchers estimate it to be around 250,000 animals. Because the eastern animals do not mate with their western relatives, it is feared that the species could die out in the Baltic Sea. This would mean a loss of species diversity in the region.

1.14 > This bluefin tuna, weighing 268 kilograms, fetched a price of 566,000 Euros at a fish auction in Tokyo in January 2012. It was bought by Kiyoshi Kimura (left), president of a sushi gastronomy chain. In early 2013, Kimura even paid a full 1.3 million Euros for a tuna. That translates into a price per kilogram of more than 6000 Euros.

The fisheries influence evolution

Intensive fishing, however, also changes the biological diversity in another way. Scientists are now discussing the phenomenon of fisheries-induced evolution. When the fisheries primarily catch large and older individuals, then, over time, smaller fish that produce offspring at an earlier age become more successful. The fisheries thus critically upset the natural situation. In natural habitats that are not affected by fisheries, larger fish that reach sexual maturity at a greater age are more dominant. Their eggs have lower mortality rates. The eggs and larvae can better survive phases of hunger in the beginning because they possess more reserve substance, more yolk, than the eggs and larvae of parents that reproduce at a younger age. The entire stock benefits from this because many offspring are regularly produced, which preserves the stock.

Under heavy fishing pressure, on the other hand, the animals that primarily reproduce are those that are sexually mature at a smaller size. But they produce fewer eggs, and their eggs have higher mortality rates. Through computer models and analyses of real catch data, and using the example of the northeast Arctic cod, researchers have been able to show that this fish stock has actually undergone genetic alteration through time. Fish with the genotypic trait of becoming sexually mature at a young age and small body size have become more successful. This is true for both males and females. To illustrate this, the researchers have employed catch data in their model that extend



1.15 > Over decades of fishery, plaice in the North Sea that achieve sexual maturity with a smaller body size have gradually become predominant. This relationship can be clearly depicted by using different probabilities (p) in mathematical models. The body length (L) of 4-year-old plaice that will become sexually mature in the coming season with a 90 per cent probability (p90) is illustrated. As the graph shows, this body length (Lp90) has decreased significantly over recent years.

back to 1930 and document the gradual changes with respect to age, size, and reproductive capacity. The study was based on especially detailed data sets of the catches in Norwegian waters. Originally the northeast Arctic cod became sexually mature at an age of 9 to 10 years. In the northeast Atlantic today, the cod is sexually mature at 6 to 7 years old. It is notable that this fisheries-induced evolution has occurred over a period of just a few decades. Experts feel that one reason for this is that the fisheries exert a much greater pressure than natural selection factors such as predators or extreme environmental conditions, such as heat or cold. The computer models also indicate that it would take centuries for the effects of the fisheries-induced evolution to turn around – even if the fisheries were completely stopped. In actual practice, the effects may even be irreversible. Within the past 10 years fisheries-induced evolution has been verified for a number of species, including the North Sea plaice.

The effect of fisheries is thus exactly the opposite of what an animal breeder usually aims for. The animal breeder, as a rule, selects the largest and most productive animals in order to continue breeding with them. As a result of the fisheries, by contrast, precisely those older and larger animals with the highest reproductive capacity are killed.

Genetic impoverishment in fish?

In proportion to their body size, large and mature fish invest relatively more energy into the production of eggs than small, young animals that have considerably less body mass and volume. Older fish thus provide a kind of reproductive insurance. As long as enough older fish are present, sufficient offspring will be produced. But in stocks that consist of few age groups, and primarily of younger age groups, the danger of offspring deficiency increases when the reproductive conditions intermittently worsen, such as times of food scarcity. Stocks in which older fish predominate can more efficiently withstand these kinds of fluctuations, because the mature ones will reliably produce offspring in the following season. Stocks

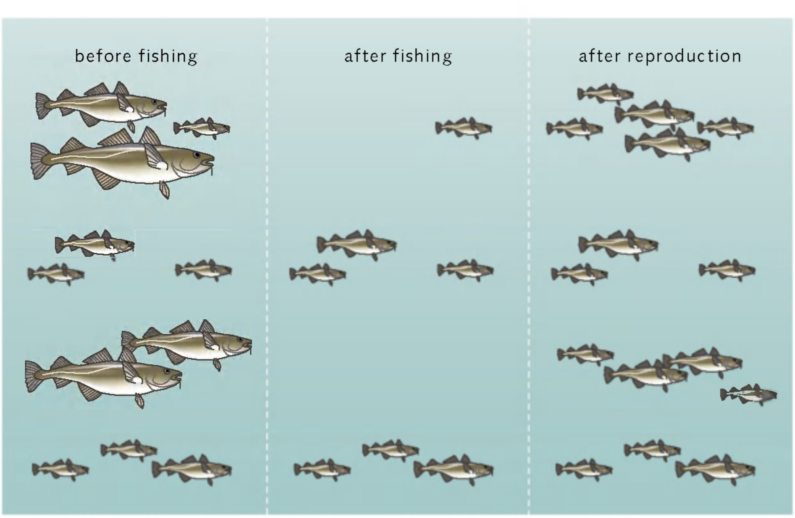
Genotype
Genotype refers to the total genetic information of an organism that is stored in the cell nucleus of each body cell. Among individuals of a species most of the genes are identical. But their combination is unique for every individual

Phenotype
The phenotype is expressed in the appearance of an individual: the observable characteristics of the individual genotype. Phenotypic attributes include eye colour, psychological traits, or genetically caused illnesses.

comprising different age groups also exhibit greater resilience because the spawning season of the fish varies with their age. There are thus a sufficient number of spawning animals at any given time in a mixed stock. Periods of unfavourable environmental conditions therefore have a less severe impact.

Warnings are now being raised that fisheries can also cause genetic impoverishment, or "genetic erosion" in the species being fished. This phenomenon is also recognized in land animals. With the destruction of habitats like rain forests, the distribution areas of species become critically limited. Many individuals die before they can mate. In addition to the species-specific genetic material, every organism possesses a small share of individual genetic attributes. If the animal dies without producing offspring, these individual attributes are lost and the population is genetically impoverished. Extreme genetic erosion is referred to as a genetic bottleneck. In this case, a species is reduced to a small number of individuals. This could occur as the result of a natural catastrophe such as a volcanic eruption or flooding. Intensive hunting of geographically restricted populations like the Siberian tiger can also lead to a genetic bottleneck. In extreme cases this leads to inbreeding. The animals produce offspring with genetic defects or that are susceptible to disease. Some scientists are concerned that genetic erosion leading to genetic bottlenecks occurs not only in land animals, but also in some fish species through overfishing. So far, however, this assumption is hypothetical and it is presumably not valid. For most of the commercially depleted fish stocks neither genetic erosion nor genetic bottlenecks can be statistically verified. Specialists believe that even fish stocks that have been commercially depleted still possess thousands of individuals capable of reproduction. The genetic variability thus probably remains great enough to preclude the erosion effects.

1.16 > A fish stock before fishing, after fishing, and after reproduction. The changes in body size are a result of fisheries-induced evolution.



Slowing down fisheries-induced evolution

Experts recommend giving more attention to the ecogenetic aspects of fishery management in the future. There is already a general consensus that fishery management should not consider a fish species independently of its habitat. Beyond this, however, ecogenetic models are necessary. These can be used to estimate which changes are caused by fisheries and to what degree genetic changes influence a stock, but also how these ultimately affect the future fishery harvests. Through responsible fishing, there is hope that fisheries-induced evolution can be reversed, or at least slowed down. It can probably not be completely stopped. Researchers also need to employ complex evolution models. Up to now, often only the age classes of a fish stock have been considered in detail for calculations of stock development. Fish sizes are entered into the calculation simply as the mean of an age class. This mean, in turn, has been calculated from long years of body-length measurements. An age class for a fish stock, therefore, always has a fixed, assigned average size. In fact, however, the mean size of an age class changes from year to year, depending mainly on the food supply. In years of scarce food supply immature animals grow more slowly. This variability has to be given greater consideration in the future. And, of course, there are always larger and smaller individuals within an age class. These fluctuations also have to be addressed. The mean value is not sufficient for an evolutionary model. Researchers therefore call for more intensive cooperation between fishery authorities, who have access to detailed data, and mathematicians and statisticians, who can develop powerful computer models.

Conclusion

The "big picture" in the ocean

Worldwide there are over 30,000 fish species. Several hundred of these are fished commercially. The species of commercial interest have long been regarded in isolation. The primary concerns for fisheries management have been merely the annual catch of a species and its presumed stock, from which the maximum catch for the next season is derived.

The web of relationships in the ocean, however, is complex. Catching huge volumes of fish changes the entire habitat. The idea that entire ecosystems have to be taken into account if fish stocks are to be preserved over the long term is gradually becoming accepted. An improved and more sustained management of fish stocks in the future will require much more extensive investigations than have been previously carried out.

One topic of interest is how phytoplankton, the basis of life in the ocean, proliferates in particular regions. The amount and composition of zooplankton, on which smaller fish species primarily feed, also play an important role. Although these kinds of complex ecosystem investigations have only been carried out for a few species so far, the gain in knowledge has been great.

Furthermore, scientists are calling for accurate data on bycatch to be recorded at last. "Bycatch" refers to those fish and marine animals that unintentionally end up in the nets while fishing for particular species, and are usually thrown overboard dead. The numbers and composition of the bycatch can provide further important information about the ecological status of a marine region.

The increase in joint international efforts to promote marine conservation in recent years is encouraging. The coastal regions of the world, for example, have been classified into Large Marine Ecosystems (LMEs), large-scale regions that span geopolitical borders. The LMEs produce 95 per cent of the global fish biomass. Hundreds of millions of people worldwide live near the coasts.

This initiative should be effective in bringing together international experts, especially from developing and newly industrialized countries. The first positive indications of international marine conservation projects between neighbouring countries have already been seen off south-west Africa and in the Gulf of Guinea.

Fortunately, people will not be able to completely eliminate most of the commercially fished species. Fishing will become unprofitable before the stock is reduced to the point at which a species disappears. There are, however, some possible exceptions such as the sturgeon and certain species of tuna. Although some protection measures have now been introduced, such species could be annihilated in the coming years. The stock of sturgeon, in particular, has already been so weakened by fishing and habitat degradation that the species probably cannot be saved.

It is also disturbing that industrial fishing probably alters the evolution of certain species. Large fish are fished out while small individuals become more predominant. Under intensive fishing, being small apparently gives the individual fish an evolutionary advantage. The consequences of this fisheries-induced evolution cannot be foreseen. There are strong indications that fish stocks of small, young-reproducing fish are less stable than stocks with large animals that reach sexual maturity later. Computer models indicate that these human-induced changes will take centuries to reverse, if at all. The precondition will be that humans catch fish with more foresight in the future, and reduce pressure on the species.

2 Of fish and folk

> Fish and human societies have had special connections for millennia. The fabric of this relationship has many strands. For one thing, fish is an important source of food for millions of people, supplying proteins and minerals in a combination offered by almost no other foodstuff. Although the industrialization of fishing has led to the loss of many jobs over the years, around 50 million people worldwide still earn their living by catching fish.

Fish – a prized commodity

> People have always relied upon fish as a basic resource to sustain life – as food and as a source of income. Many fishermen in industrialized countries have had to give up their work. In many developing and newly-industrializing countries, however, fishing is a major branch of employment, not least because fish has developed into an important export commodity. As the main importers, the western industrialized countries have a responsibility to push for a low-impact, socially equitable fishing industry in the exporting nations.

Fish – a foodstuff and the stuff of legends

For millennia fish have been a vital source of human nutrition. Archaeological finds suggest that people have been catching fish since the Stone Age at least. For example, artefacts found in northern German river valleys include fishhooks made from bones and teeth as well as early spears with barbed hooks.

But fish is more than just a food. In many cultures the fish is raised to near-mythical status. The Maori people call New Zealand's North Island Te-Ika-a-Maui – "the fish of Maui". According to legend the demigod Maui pulled a mighty fish out of the water, which then transformed into the island. In the days of Alexander the Great, inhabitants of the Mediterranean town of Ascalon were such devout worshippers of the goddess Derketo, a mermaid-like being, that eating fish was taboo. The Christians even elevated the fish to a symbol of their faith community. They used the Greek word for fish, *ichthȳs*, as an acronym. It stands for *Iēsous Christós Theoú Hyiós Sōtér* (Jesus Christ God's Son Saviour).

Today there is little remaining sign of mythical veneration. Fish is a foodstuff and a straightforward trade commodity. According to estimates by the Food and Agriculture Organization of the United Nations (FAO), today a total of 660 to 820 million people are directly or indirectly dependent on fishery. These include the families of fishermen and of their suppliers – the makers of fishing equipment, for instance. The FAO estimates the number of fishermen per se at around 54 million, of which 87 per cent live in Asia alone. Many of them work in small fisheries, and fish production per person is correspondingly low. On average it amounts to just about 1.5 tonnes. For comparison, the figure in Europe is around 25 tonnes per person.

2.1 > A traditional fishhook from New Zealand.

2.2 > The Maori demigod Maui catches a fish, which transforms into the North Island of New Zealand, Te-Ika-a-Maui.

Large-scale versus small-scale?

Experts differentiate roughly between industrial fishery, which operates with factory ships, and artisanal fishery. Beyond this, different countries break the industry down into various other categories.

In Germany and other European countries, for example, fisheries are subdivided into the following three fleet segments:

- Small-scale coastal fishery: carried on with small motorboats which usually put out to sea for a day at a time. The home and landing ports are generally found in smaller coastal locations.

- Small-scale offshore fishery: makes use of vessels between 18 and 40 metres in size. The boats stay at sea for several days and land mainly fresh fish in large ports.
- Large-scale offshore fishery: ships are usually more than 40 metres long and do not necessarily stay within EU territorial waters. Catches are frozen immediately on board and sold throughout the world.

To take another example: in Mauritania, West Africa, distinctions are made between the following types of fishery:

- Small-scale fishery: includes vessels under 14 metres in length without any superstructure (wheelhouse). In many cases these are wooden boats, which may be powered by sails or motors.
- Coastal fishery: covers unmotorized vessels between 14 and 26 metres in length as well as motorized vessels with a superstructure but under 26 metres long.
- Industrial fishery: includes all larger ships that do not fit into the first two categories. Mauritania has its own industrial fleet that exclusively catches octopus. It is mainly made up of trawlers of Chinese origin, which are old and in poor technical condition.

2.3 > Mass processing: Pangasius is filleted in Vietnam for export to Europe.

Fishery production per fisher or fish farmer by region in 2010 (Tonnes/year)

Region	Capture	Aquaculture	Capture and aquaculture
Africa	2.0	8.6	2.3
Asia	1.5	3.3	2.1
Europe	25.1	29.6	25.7
Latin America and the Caribbean	6.8	7.8	6.9
North America	16.3	69.0	18.0
Oceania	17.0	33.3	18.2
World	2.3	3.6	2.7

2.4 > The industrialization of fishery raises per-capita production. It is still low in Asia compared to Europe. Intensive feeding and feed optimization means that productivity in aquaculture is higher than in capture fisheries. The figures for North America are probably too high.

Like Mauritania, many developing or newly-industrializing countries have an old ocean-going fleet – if they have one at all. Offshore fisheries in the latter countries are mainly operated by factory ships based in other countries, which pay licence revenue to the State. This industrially operated fishery is often held up as exploitative in comparison to original artisanal-fishery practices. But it is important not to generalize. There is barely any market in Europe for small pelagic fish, which are mainly fished by Dutch operators in Mauritanian waters and deep-frozen on board. The small fish are only marketed in preserved form, packed in cans or jars. In contrast, the pelagic fish caught off West Africa are largely sold directly in African countries. In many places the deep-frozen fish are hacked out of their blocks of ice in the marketplace itself. In other countries like Senegal, on the other hand, governments issue too many catch-licences to foreign fleets. As a result the fish stocks are overfished. Local coastal fishers rightly fear for their income source.

During the apartheid era the Namibian waters were severely overfished by foreign fishing fleets. This exploitation led to the collapse of the sardine fishery in the 1970s and subsequent closure of the mostly South African owned canneries and reduction plants. After independence in 1990, the Namibian Government focused on developing what was hitherto a small local hake fishery into a fishing industry with state of the art processing plants serving global markets. This was quite an ambitious goal considering that Namibia was a country with only limited fishing tradition. Nowadays Namibia's innovative fisheries policy aims towards sustainable exploitation of the fishery and equitable distribution of the benefits among the Namibian population. Nonetheless, catch limits exceed scientific recommendations and foreign involvement in the fishery remains a concern as social, economic and ecological goals are in conflict on the political stage.

How "small fry" die out

The threat posed by industrial fishery to the livelihoods of artisanal fishermen is not just a developing-country phenomenon. In many industrialized countries, too, smaller family-run fishing businesses have had to give up. In many cases, no successors could be persuaded to take on this hard work. Small businesses were also squeezed by rising fuel costs, so that fishery was often taken over by larger and more efficient operations.

Off the east coast of Canada, the overfishing of cod was to blame for driving hundreds of small family businesses into closure in the early 1990s. Coastal fishermen had long warned that fish were becoming scarcer, in Canadian ocean bays for instance. Nevertheless, the large companies with their industrial trawlers continued to fish further out at sea. Their argument was that coastal fish and the offshore fish stocks had nothing to do with each other.

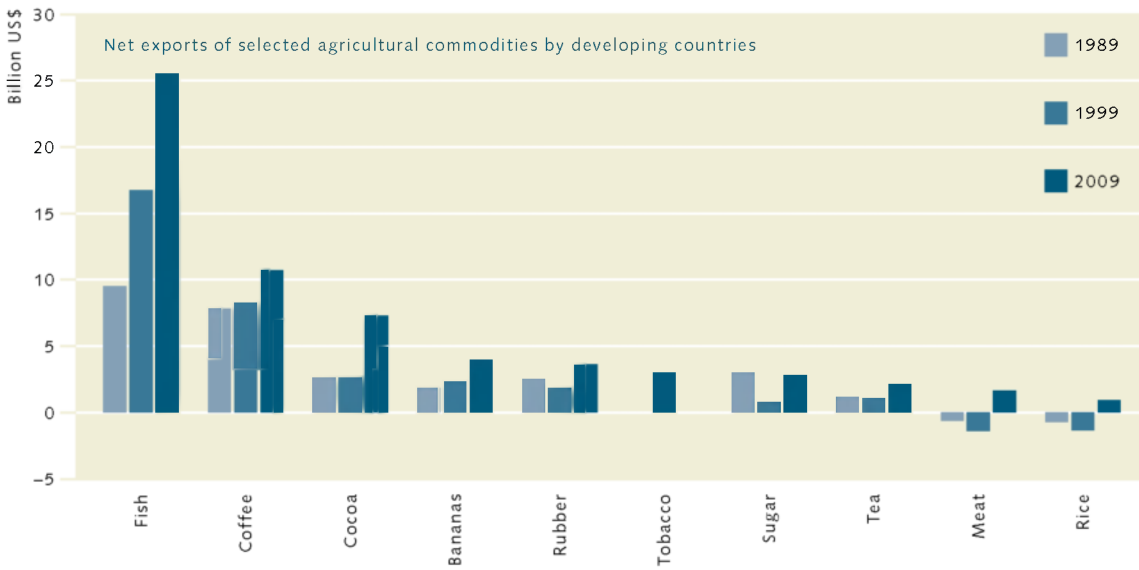
Today we know that this argument was based on false assumptions. In reality they all belonged to a single, large fish population, which was finally definitively overfished at the end of the 1980s. The coastal fishermen lost their livelihoods. Some switched to lobster fishing. Unknown numbers were uprooted and moved away. As a consequence of this rural exodus, the population slumped dramatically in many places along Canada's east coast.

The situation of herring fishers on the North Sea was similar. In the 1970s, officials reacted to the collapse of the stock with a fishing ban lasting several years. This enabled

2.5 > Europe, the USA and Japan are the most important importers of fish and fishery products worldwide. China is the main exporter. Norway's position as the second largest exporter is primarily because the country exports especially valuable fish such as salmon.

Top ten export countries	2000 (million US$)	2010 (million US$)
China	3,603	13,268
Norway	3,533	8,817
Thailand	4,367	7,128
Vietnam	1,481	5,109
United States of America	3,055	4,661
Denmark	2,756	4,147
Canada	2,818	3,843
Netherlands	1,344	3,558
Spain	1,597	3,396
Chile	1,794	3,394
Top Ten	26,349	57,321
World	55,750	108,562

Top ten import countries	2000 (million US$)	2010 (million US$)
United States of America	10,451	15,496
Japan	15,513	14,973
Spain	3,352	6,637
China	1,796	6,162
France	2,984	5,983
Italy	2,535	5,449
Germany	2,262	5,037
United Kingdom	2,184	3,702
Sweden	709	3,316
Republic of Korea	1,385	3,193
Top Ten	26,349	69,949
World	60,089	111,786



2.6 > For many developing countries, fish exports are more important than the coffee and cocoa trade.

herring stocks to recover, but many family businesses did not survive the enforced interruption. Today that fishery is dominated by a few large companies.

In order to avoid such drastic consequences for the people affected, social scientists are urging that more attention be given to sociological aspects in fishery management, rather than concentrating solely on the conservation of fish stocks and the marine environment. They criticize the way that so far, experts from the different disciplines – biology, economics and sociology – seem to collaborate far too seldom. Of course, the sociological approach is labour-intensive and costly, say researchers, because it requires field researchers to travel to coastal regions in order to interview the people affected, the fishermen, in situ and to analyse their situation. Yet this could avert future problems or help to solve them more quickly.

The responsibility of industrialized countries

In recent years, jobs in fisheries in the European countries have undergone varying degrees of decline. Particularly because there is a shortage of alternative jobs, nations like Portugal and Spain continue to maintain large fishing fleets, often kept alive by state subsidies. Denmark and Germany, on the other hand, have drastically reduced the size of their fleets. In these countries the demand for fish, which has risen in recent years, is increasingly met by means of imports.

Today Europe is the world's most important fish-importing region but the demand for fish varies enormously from one country to another. In 2010 Europe imported fish to the value of 44.6 billion US dollars, around 40 per cent of the worldwide trading volume. The second largest importer is the USA, with Japan in third place. Hence a special role falls to these three regions in the conservation of global fish stocks: consumers in these industrialized countries should make a stand and demand more produce from sustainable fisheries and environmentally sound aquaculture. For wholesale purchasers, in turn, labour conditions in the countries of production are beginning to matter more when they choose their suppliers. Workers in developing and newly-industrializing countries are still often underpaid and receive no social security benefits. Moreover, child labour is often used in these countries, according to FAO data. Children are put to work particularly in artisanal fishery and small family businesses, but it happens on board ships as well. They are also being used as cheap labour to repair nets, to sell fish or to feed and harvest farmed fish. All these problems have now been recognized. It is to be hoped that the first projects and initiatives currently being embarked upon as good examples will set a precedent for the future.

The goodness in fish

> A unique combination of high-quality protein and vital nutrients make fish an invaluable food. Fish is the most important protein source in many developing countries. Fish consumption is highest in China and in western industrialized countries. The fish sold in industrialized countries is mainly deep-frozen, whereas fish is bought and sold fresh in developing countries.

Taurine, selenium & other essentials

Compared with the world cereal harvest of around 2.2 billion tonnes per annum, the total global fish and seafood production of around 140 million tonnes seems very modest. Nevertheless fish is extremely important for human nutrition. It not only contains healthy protein but also many nutrients that do not occur in such quantity and diversity either in cereals or other crops or in meat. So fish makes an essential contribution to a healthy diet.

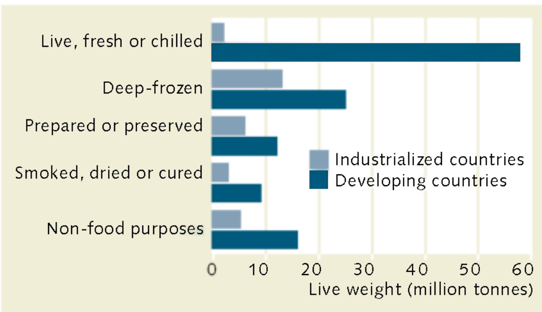
2.7 > Fish consumption in 2009, by region and development status. Viewed in terms of continents alone, Asia leads the world in total consumption

	Total food fish supply (million tonnes live weight equivalent)	Per-capita food fish supply (kilograms per year)
Africa	9.1	9.1
North America	8.2	24.1
Latin America and the Caribbean	5.7	9.9
Asia	85.4	20.7
Europe	16.2	22.0
Oceania	0.9	24.6
Industrialized countries	27.6	28.7
Other developed countries	5.5	13.5
Least-developed countries	9.0	11.1
Other developing countries	83.5	18.0
China	42.6	32.0
World excl. China	83.0	15.1
World	125.6	18.4

Its most important constituents include proteins, certain fatty acids, vitamins and minerals. The specific nutrients supplied by fish include:

- low-fat muscle meat containing 15 to 20 per cent protein, in the case of lean fish like pollock, cod or haddock;
- large quantities of unsaturated fatty acids, particularly omega-3 fatty acids, in the case of fatty fish like salmon and mackerel;
- iodine;
- selenium, a chemical element that is an important component of proteins. Proteins containing selenium can intercept free radicals and are thought to prevent cancer;
- taurine, a metabolite product of protein that is important for the development of the brain and retinal tissue. Moreover it plays a key role in the development of cell membranes and in the detoxification of the body.
- vitamin D, which very few foods contain in worthwhile amounts. Vitamin D mainly occurs in fatty fish;
- niacin, vitamin B_6 and vitamin B_{12};
- all the important amino acids for human nutrition, including those known as "essential amino acids" which the human metabolism cannot synthesize itself.

Whereas average fish consumption in the 1960s was 9.9 kilograms, by 2010 annual per-capita consumption had risen to 18.6 kilograms. But fish consumption varies massively from country to country depending on local traditions and supplies. Fish is especially important in many developing countries because it is often the only afford-



2.8 > In the industrialized nations fish is mainly bought and sold deep-frozen (2010). Sophisticated cooling chains make this possible. The fish often comes from offshore fisheries and is landed frozen prior to onward distribution. In developing countries fish is predominantly bought and sold alive or fresh. In some cases it is chilled during transportation.

able and relatively easily available source of animal protein. In Bangladesh, Cambodia and Ghana, for instance, around 50 per cent of animal protein is supplied by fish. Often it is the only source of numerous other important nutrients, too. In many African countries south of the Sahara, the people traditionally make little use of fish – in Congo, Gabon or Malawi, for example – although fish could actually make a substantial contribution to human nourishment. In the year 2009, fish supplied 16.6 per cent of the total worldwide consumption of animal protein and 6.5 per cent of total protein, i.e. animal and plant protein combined.

Smoked, fresh or frozen?

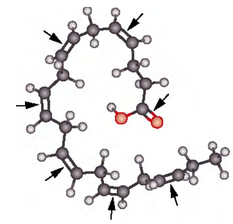
Fish and seafood are traded and transported in different forms around the world. For 2010 the proportions were as follows:

- live, fresh or chilled: 46.9 per cent;
- deep-frozen: 29.3 per cent;
- prepared and preserved: 14.0 per cent;
- smoked, dried, cured: 9.8 per cent.

Variations in these percentages depend on region and on consumer behaviour. Many developing countries lack the infrastructure to be able to transport chilled or deep-frozen fish to all customers. Fish is mainly offered on the coast or beside large lakes, directly where it has been caught. In other parts of the country the use of fish is far less widespread. In industrialized countries, on the other hand, the vast bulk of fish is sold as a deep-frozen product and is generally imported nowadays. To a lesser extent, fish is eaten smoked, salted or marinated in these countries. Some seafood like oysters are even eaten alive.

In the year 2010 around 20 million tonnes of fish and seafood were utilized in the non-food segment. The vast majority of this was processed into fishmeal and fish oil, predominantly for use in aquaculture.

Furthermore, fish and seafood or extracts derived from them are used in the manufacture of cosmetics and medicines. Over the past 20 years the cosmetics and pharmaceuticals industries have increasingly recognized fish wastes as a valuable resource. In the past these waste products were simply disposed of. Today they are quite matter-of-factly used in production.



2.9 > Long fatty acid molecules like DHA consist primarily of carbon (dark grey) and hydrogen (light grey). Fatty acids are unsaturated if carbon atoms are linked by double bonds because they are missing hydrogen atoms.

Famous fish oil

Fatty fishes like mackerel, salmon or herring contain large amounts of so-called omega-3 fatty acids. These are some of the healthy, unsaturated fatty acids that help to strengthen the immune system and prevent cardiovascular disease.

The labels "saturated" and "unsaturated" are the technical terms used in chemistry to denote how many hydrogen atoms occur in the long molecule chains of fatty acids. Unsaturated fatty acids contain little hydrogen. Docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) are especially beneficial.

DHA is important for the development of the brain and the eyes, while one of the uses of EPA is for the treatment of rheumatoid arthritis. These two long-chain highly unsaturated omega-3 fatty acids are found almost exclusively in marine fish and marine algae. Phytoplankton is able to generate these two omega-3 fatty acids on its own, whereas fish cannot synthesize the substances themselves. Instead, the fatty acids are taken in by plankton feeders as they feed, and passed up through the food chain to predator fish. The highest contents of DHA and EPA are found in mackerel. Land plants also contain omega-3 fatty acids – particularly alpha-linolenic acid, large amounts of which are found in rapeseed, soya and walnut oil. But this compound is far less effective in the human body than DHA and EPA.

2.10 > A Senegalese fish seller carries a large fish, a capitaine. In West Africa fish are usually sold fresh as there are often no means of refrigeration.

Cereal in place of fish fillet?

Critics emphasize that people should refrain from consuming fish so as to conserve fish stocks and the marine environment. Their opponents argue that there are hardly any alternatives; virtually no other food is a substitute for the unique combination of nutrients in fish. This applies particularly to the nourishment of people in developing countries, for whom alternative foods are unaffordable or quite simply unavailable.

It would also be difficult to replace the full amount of fish and seafood, some 140 million tonnes, entirely with plant-based foodstuffs. Ultimately wild fish and seafood are organically generated foods whose growth depends solely upon the photosynthesis carried out by phytoplankton. By contrast, most vegetable or cereal production requires the use of fertilizers and plant protection products. In addition, large areas of land are necessary for arable farming, some of which can only be obtained by destroying natural habitats. The amount of land area needed to replace the worldwide total marine catch of around 80 million tonnes of wild fish and seafood can only be roughly estimated, partly because protein content or nutritional value varies from one fish species to another and from one crop to another, and partly because the fertility of different soils varies enormously. Based on the assumption of cereal farming on averagely productive soils, worldwide it would take an area of land at least the size of France to match the nutritional value of the global wild fish catch. It is clear, however, that the worldwide fishing industry does need to be converted to the sustainable management of fish stocks.

Conclusion

Source of nutrition and income for millions

People have always relied upon fish as a basic livelihood resource. Estimates by the Food and Agriculture Organization of the United Nations (FAO) put the number of fishermen worldwide at 54 million. Counting their families and the suppliers of fishing equipment, 660 to 820 million people today are directly or indirectly economically dependent upon fisheries.

Around 140 million tonnes of fish and seafood per year are used for human consumption. Set against the global production of cereals of around 2.2 billion tonnes, that figure is comparatively low. Owing to its unique combination of nutrients, fish makes a major contribution to a healthy diet. It supplies proteins, healthy fatty acids, vitamins and other elements essential for health such as iodine and selenium. Furthermore, in developing countries fish is often the only affordable and relatively easily available source of animal protein. In some regions on Earth fish can provide up to 50 per cent of the total animal protein in people's diets. This is the case, for example, in Bangladesh, Cambodia and Ghana.

In the year 2009, fish supplied 16.6 per cent of the total worldwide consumption of animal protein.

Asia is home to the largest numbers of fishermen by far. Many work in small-scale operations, and fish production per person is correspondingly low at about 1.5 tonnes on average. For comparison: the figure in Europe is around 25 tonnes per person.

In many industrialized countries the number of artisanal fishers has declined. The lack of a successor to carry on the business or the poor economic outlook has led many of them to shut down their businesses. A contributory reason has been the overfishing of fish stocks in some regions. Social scientists recommend that in future, fisheries management should not consider the state of fish stocks in isolation but pay more attention to the possible social consequences of such management.

3 Plenty more fish in the sea?

> Ocean fish are not in particularly good shape. At least a quarter of the world's fish stocks are overexploited or depleted. In recent decades the search for new fishing grounds has taken fleets into ever-deeper waters. Stocks are further undermined by illegal fishing. It is now clear that overfishing is wreaking havoc on our marine environment and is economically unsustainable. For this reason many nations are adopting a more precautionary approach to fishing.

The global hunt for fish

> Within a few short decades, industrial fishing has expanded from the traditional fishing grounds of the Northern Hemisphere to include all the world's oceans and seas. Many stocks have been overexploited and are depleted. But the situation is not without hope. Some countries have shown that fish stocks can in fact recover when sustainable fisheries management systems are implemented.

The art of counting fish

No other group of animals is as difficult to monitor as fish. Spotting scopes and radar equipment are used to locate and count migratory birds along their flight paths. Bats can be monitored by placing ultrasound detectors and photoelectric sensors at the entrance of their caves. But what about fish?

Humans are not capable of looking into the ocean and counting the fish they see. Instead, they must try to estimate the size of fish stocks as accurately as possible. The Food and Agriculture Organization of the United Nations (FAO) uses various sources to estimate global fish stocks and trends as accurately as possible. The results are published every two years in the SOFIA Report (The State of World Fisheries and Aquaculture). The latest report was released in 2012 and reflects the developments to 2009/2010. Fish is the means of subsistence for billions of people around the world. Accordingly, the report is an important document on which UN decisions, international agreements and treaties are based. The data used for the SOFIA Report is taken from the following sources:

FISHERIES – Fishermen report their catches to their government authorities, such as the Ministries of Agriculture and Fisheries. The authorities are obliged to send this data to the FAO. The data is also forwarded to scientists in their own country.

THE SCIENTIFIC COMMUNITY – Fisheries' data is often incomplete or incorrect. For instance, fishermen only report the amounts of those fish which they are officially permitted to catch. They do not include any unwanted "bycatch" – all the fish and marine fauna which are caught inadvertently and until now have mostly been thrown back overboard. An quantitative assessment of bycatch levels would, however, be crucial as this could provide a more realistic estimate of the actual status of fish stocks. In order to improve the flawed basic data, fishery scientists therefore gather their own data.

1. Fishery-dependent data: Fishery scientists regularly accompany fishing vessels. They collect catch samples and detailed data including the age, size, length and number of adult fish. The volume and composition of the catch are of particular interest. They also record the effort expended, such as how long a net is dragged behind the vessel before it is full. This establishes the exact amount of effort involved in catching a certain amount of fish. Researchers call this the "catch per unit effort" (CPUE). It is the only way of ascertaining the stock density, or the number of fish found in a certain area.

2. Fishery-independent data: Scientists also conduct research projects using their own vessels. They take numerous sample catches – not only in the abundant areas highly sought after by the fishermen, but in many different parts of a maritime region. The sampling locations are either chosen randomly or according to a certain pattern. The objective is to obtain a comprehensive overview of the entire maritime region as well as the distribution of fish stocks. During these expeditions it is important that all the marine fauna caught are counted and measured, to enable a reliable assessment of the entire ecosystem to be made. The scientists are also interested in the age of the fish. Using close-meshed nets, therefore, they catch young fish (juveniles) which are not usually taken by the fishermen. The age distribution of the fish is an extremely important aspect of stock predictions. It shows how many of the fish will grow to sexual maturity and thus how populations are

3.1 > Venerable gentlemen of fisheries science: ICES researchers held their statutory meeting at the House of Lords in London in 1929. Upon its foundation in 1902, the ICES had 8 member nations: today it has 20.

likely to develop in future years. How many research expeditions are undertaken differs from country to country. Researchers sample individual fish stocks up to five times a year. Information on the eggs and larvae of some stocks is also recorded. These numbers indicate the parent stock and the numbers of young to be anticipated.

The researchers utilize both the fishery-dependent and the fishery-independent data to adjust and augment the fisheries' official catch numbers. For instance, from their own sample catches they can estimate the approximate volume of bycatch in the fishing grounds. In many cases catches from illegal fishing are also shown up. For instance, double logbooks are frequently used – one for the authorities showing the official figures, and another for the scientists showing the higher but genuine catch numbers. Comparing these two allows a more accurate estimation of how many fish were actually caught in a maritime region.

How does the data reach the FAO?

The catch data from both the fishermen and the scientists is initially forwarded to higher scientific institutions which utilize it to estimate the current stocks of the various fish species and maritime regions. One objective is to generate a supra-regional overview from the national data. For example, the International Council for the Exploration of the Sea (ICES) in Copenhagen is responsible for the Northeast Atlantic. Its working groups use both the fisheries' official catch data and the scientific results to calculate the current stocks of the different species of fish and fauna. The ICES then sends these stock estimates to the FAO.

Data about stocks in other maritime regions reaches the FAO in a similar way. For example, the Northwest Atlantic Fisheries Organization (NAFO) is responsible for the Northwest Atlantic. It collates data from Canada, the USA, France (for the Atlantic islands of St. Pierre and Miquelon) and the foreign fleets from Russia and the EU which operate in this region. The NAFO then forwards the data to the FAO. The Canadian and US national fisheries institutes also report directly to the FAO.

The FAO does not re-evaluate this information, but merely summarizes, edits and ultimately publishes the data for the various maritime regions of the world.

Disagreement on the condition of fish stocks

Around 1500 fish stocks around the world are commercially fished, with the various stocks being exploited to different extents. Comprehensive estimations of abundance currently exist for only around 500 of these stocks. In most cases these are the stocks which have been commercially fished for many decades. For many years, exact records have been kept of what and how much is caught:

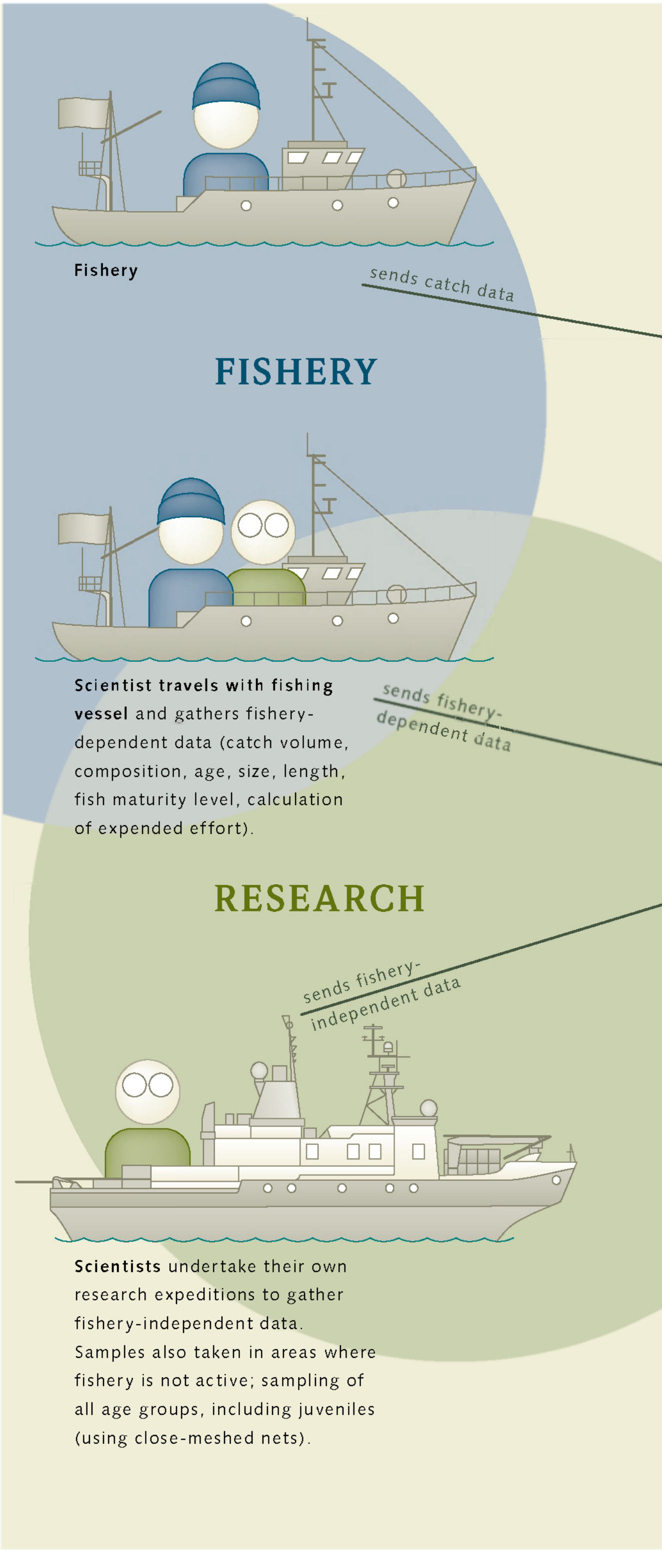
ICES
The International Council for the Exploration of the Sea (ICES) was founded in Copenhagen, Denmark, in 1902 and is the world's oldest intergovernmental organization. At that time there was a growing awareness in some European fishing nations that the long-term management of migratory fish stocks depended on a coordinated approach. Today the ICES acts on behalf of the EU and other fishing nations such as Canada, Iceland and Russia. It is responsible for all the living marine resources in the Northeast Atlantic, a total of 120 species. The ICES recommends the maximum fish catches within a specific maritime region.

the tonnages and also the age and size of the fish. Datasets for cod off the coast of Norway, for example, go back as far as the 1920s. Very little is known about other fish species and maritime regions – particularly the Exclusive Economic Zones of some developing countries. Many developing countries provide catch data alone, without any scientific assessment. The FAO makes limited use of such data. There are also some maritime regions for which not even simple catch data is available. The FAO believes that it is impossible to make any reliable estimation of such stocks.

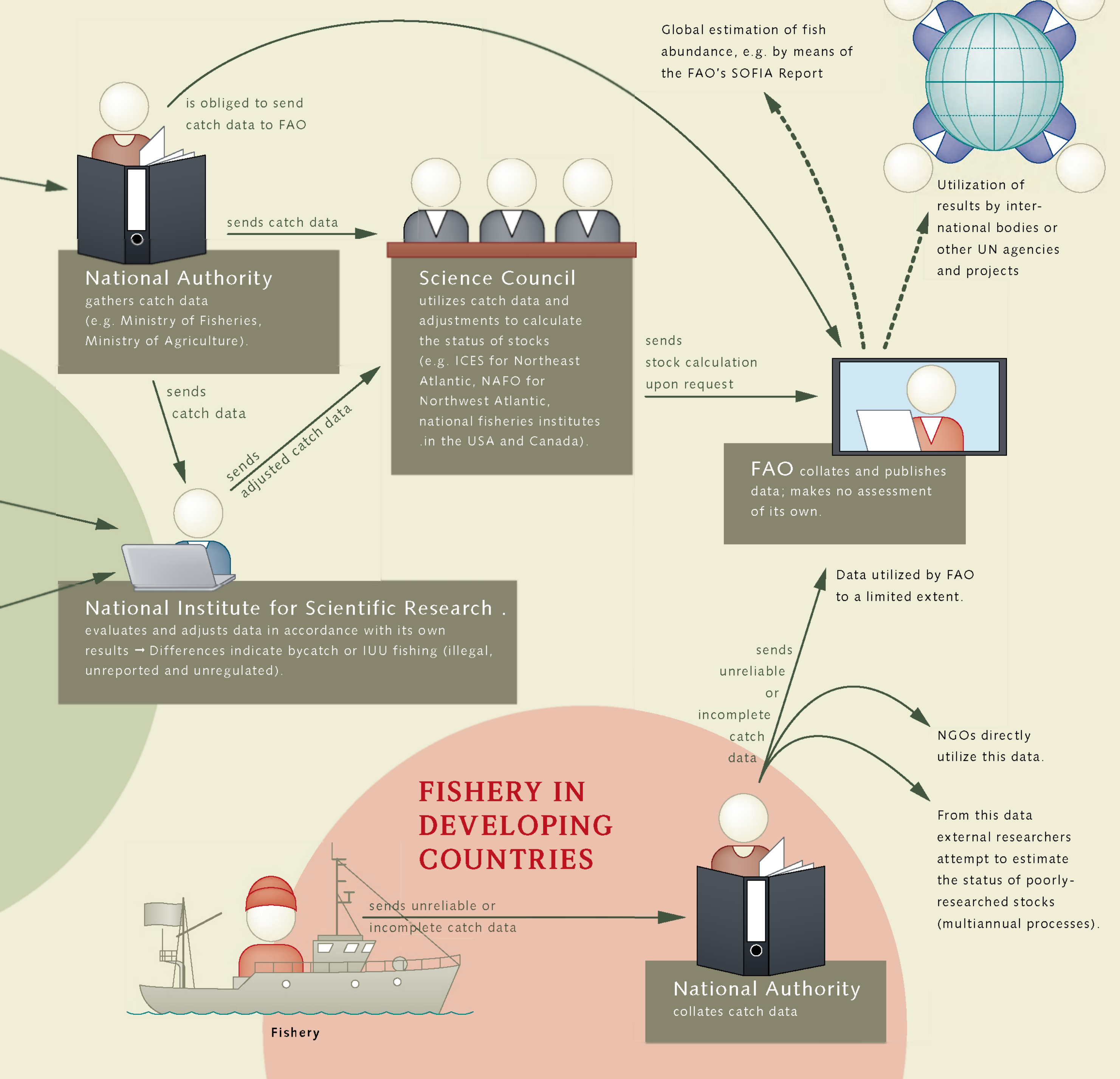
Therefore no reliable data exists for many of the world's fish stocks. Moreover, fisheries biologists are even unable to confirm how many fish stocks there actually are. If any data is available, it applies only to commercially exploited species. Naturally an overall survey of all the world's fish would be desirable – but the cost would be exorbitant. Hundreds of research expeditions would be required, making the exercise unaffordable.

Critics point out, therefore, that the FAO statistics do not take a large proportion of stocks into account. A joint American-German research group has therefore developed its own mathematical model to estimate the status of all populations from the catch amounts reported by the fisheries alone, without the fishery-independent data from the scientists. These researchers are also investigating how stock catches have developed over time. According to this model, a fish stock is depleted when the catch decreases conspicuously within a few years. Attempts are being made to circumvent the lack of stock calculations by simply interpreting catches over the course of time. The researchers have meticulously requested information from the authorities of the countries responsible for regions with no catch data at all. Based on the model, which takes 1500 commercially exploited stocks and around 500 other stocks into account, the fish are in even worse shape than assumed by the FAO: 56.4 per cent of the stocks are overexploited or depleted, not 29.9 per cent as claimed by the FAO. But the work of this American-German research group is itself under fire, with claims that its data is inconsistent and still unreliable. It presents a distorted picture of the reality, say other researchers. Which of the methods better illustrates the state of the

3.2 > Global estimation of fish abundance: Data on the status of fish stocks is provided by the fisheries and scientists. The FAO collates this information and then attempts to draw up a picture of the worldwide situation. The problem is that reliable data exists for only about 500 stocks. Experts do not agree on the status of other fish stocks.



How the data reaches the FAO



world's fisheries is currently a subject of heated debate. Despite the uncertainties, the researchers and the FAO agree on one thing: over the years the situation has deteriorated. Recovery will only be possible if the endangered stocks are fished less intensely for a number of years.

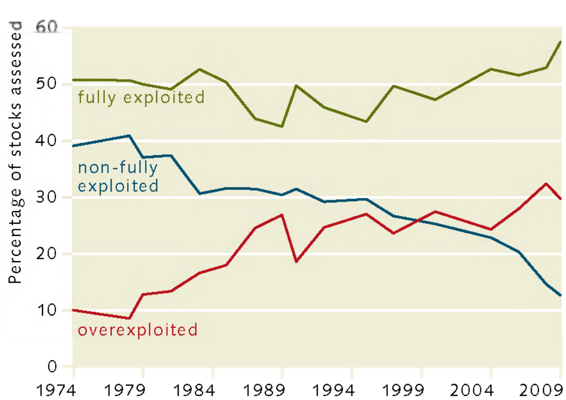
Things are gradually getting worse

The results are alarming, because the pressure on fish populations has been escalating for years. According to the current SOFIA Report, the proportion of overexploited or depleted stocks has increased from 10 per cent in 1974 to 29.9 per cent in 2009. After temporary fluctuations, the proportion of fully exploited stocks rose during the same period of time, from 51 per cent to 57 per cent. The proportion of non-fully exploited stocks, in contrast, has declined since 1974 from almost 40 per cent to only 12.7 per cent in 2009.

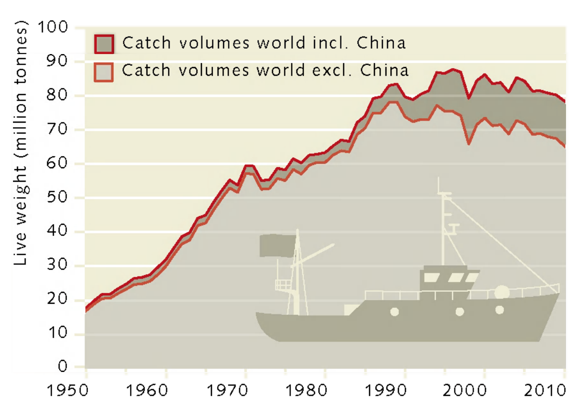
A clear trend is therefore emerging: as far as overfishing and the intensive exploitation of the oceans are concerned, the situation is not improving; it is slowly but steadily deteriorating. It is interesting that the total annual fish catch has been fluctuating for about 20 years between a good 50 and 60 million tonnes. It peaked in 1994 at 63.3 million tonnes. In 2011 a total of 53.1 million tonnes was landed – about four times more than in 1950 (12.8 million tonnes). The FAO, however, records the catches of not only fish but also other marine species such as prawns, mussels and squid. If these numbers are added to those for fish, total catches are much greater. Accordingly, for the past 20 years the total marine catch has been a steady 80 million tonnes annually. The peak was reached in 1996 with 86.4 million tonnes. In 2011 it was 78.9 million tonnes.

The reason why fish catches have remained fairly stable is because over time the coastal maritime regions were fished out, prompting the fisheries to spread out into new areas. They have expanded in geographical terms, from the traditional fishing grounds of the North Atlantic and North Pacific further and further south. They have also penetrated into ever-deeper waters. Only a few decades ago it was virtually impossible in technical terms to drop nets deeper than 500 metres. Today the fisheries are operating at depths of up to 2000 metres. Moreover, once the stocks of the traditional species had been exhausted, the fishing industry turned to other species. Some of these were given new names in an effort to promote sales and make them more attractive to consumers. For instance the "slimehead" went on sale as "orange roughy".

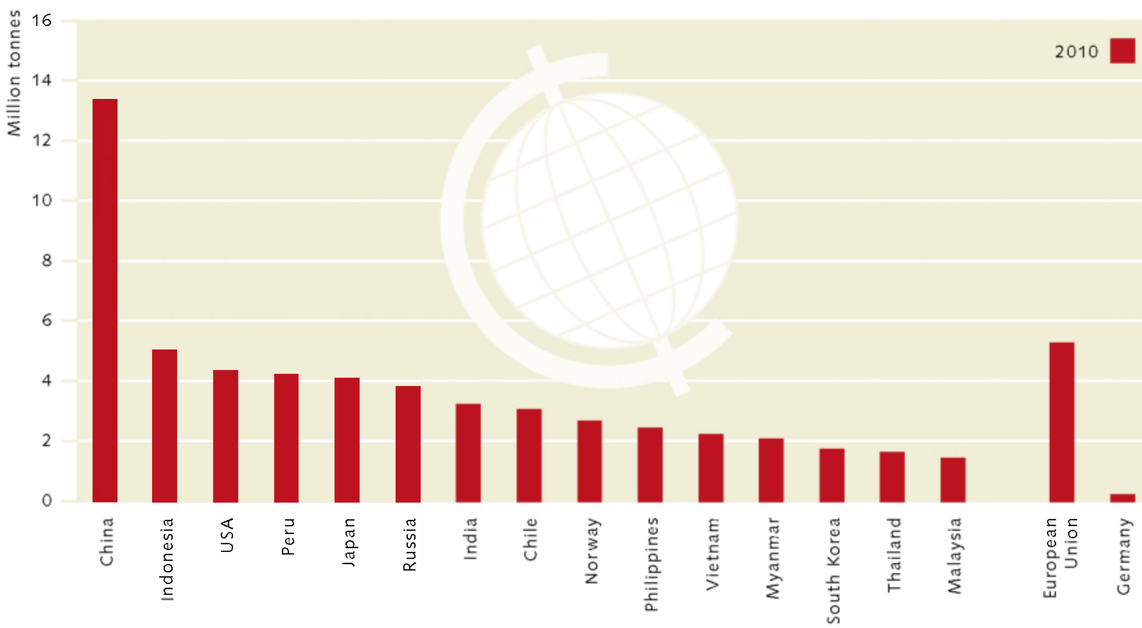
It is still possible to remove virtually the same amounts of fish from the oceans, therefore, but the composition of the global catch and the stocks themselves have changed. Consistent catches are no indication that fish stocks have remained stable.



3.3 > The number of overexploited stocks has soared since the 1970s, while the number of non-fully exploited stocks has decreased. Fully-exploited stocks are not, in principle, problematic. It is important to manage them sustainably, however.



3.4 > The development of catch volumes of world marine capture fisheries since 1950. Catches in China might have been adjusted upwards for many years, in order to comply with the government's official output targets.



3.5 > Top producer countries based on catch

China catches the most fish

Taking catch volumes as the benchmark, China has been the most important fishing nation for years now. However, the data available is extremely unreliable. A large number of experts believe that catches have been adjusted upwards for many years, in order to comply with the government's official output targets. Therefore the figures have presumably been too high for some time. Only recently has this practice begun to change in China.

Peru, until 2009 the second most important fishing nation, has slipped to fourth place. This is due to the low catches of anchovies which can be ascribed to climate change in particular, but also to a complete closure of the fishery designed to protect future anchovy stocks. Indonesia is currently the second and the USA the third most important fishing nation.

Developments in Russia are interesting. Since 2004, its catches have increased by about 1 million tonnes. According to the Russian authorities, this growth is a result of changes to the comprehensive documentation of catches. Until now some local catches were registered in the home port as imports and not as domestic catches. Russia plans to further expand its fishing industry in the coming years, the goal being to land 6 million tonnes by the year 2020. This would amount to slightly more than the combined catches of all EU nations, which totalled 5.2 million tonnes in 2010.

A new way of thinking

The situation is grave, but not without hope. The days of rampant overfishing are over in many regions. After stocks began to collapse in the 1970s, 1980s and 1990s, leading to the loss of many jobs, it gradually became clear to the fishing industry and policy-makers in various countries that overfishing is not only an environmental but also an economic problem. Some nations took the necessary steps to avoid any repeat of the situation. Australia, Canada, New Zealand and the USA, for example, developed fisheries management plans which limit catches to the extent that overfishing will be largely avoided in future. Europe has also learned from some of its mistakes. After massive overexploitation of the North Sea herring in the 1970s the fishery was completely closed for several years. The stocks recovered. Here too a fisheries management regime was introduced to prevent any renewed collapse. Even today, however, many other maritime regions and stocks

3.6 > A net bulging with herring is pulled on board the Norwegian trawler "Svanug Elise". The last good herring year off the coast of Norway was 2004.

are still not fished sustainably. One such area is the Bay of Biscay where the European hake *(Merluccius merluccius)* remains under heavy fishing pressure. Many stocks in the Mediterranean are also overfished.

Currently, therefore, the overall picture is mixed. Attempts are being made to maintain stocks in some regions through good management and sustainable fishing practices. In others, short-term profits still take priority over the precautionary approach to ensure the long-term productivity of stocks. It is therefore likely that stocks will continue to collapse. It is true that depleted stocks can recover when fishing is closed or drastically limited, but this can sometimes take many years. The herring stocks off the coast of Norway took about 20 years to recover from overfishing. Luckily, however, stocks of North Sea herring increased after just a few years, so that the fishing ban could be revoked. Nonetheless the effect of overfishing on the fishing industry is the loss of previously productive stocks for an extended period of time.

Around the world – the FAO fishing areas

The FAO divides the oceans into 19 major fishing areas. This regional classification has evolved over time. It simplifies the collection of data on fish catches, because the regional authorities and fishery associations work closely together. Other divisions – based on large-scale marine ecosystems, for example – might appear to make more sense today. Nonetheless, the FAO's traditional division is still an effective way of making a global comparison. The 19 regions are in turn divided into three categories. The first comprises areas where the catches have been fluctuating since 1950. The second consists of areas where catches have fallen over the years, and the third category covers areas where catches have continuously increased. Here again the FAO bases its analysis on the roughly 500 fish stocks for which reliable stock calculations are available. However, four of the 19 areas – the Arctic and the three Antarctic areas – are not considered in more detail below, either because there is little fishing in these regions or because few of the stocks are exploited for commercial purposes.

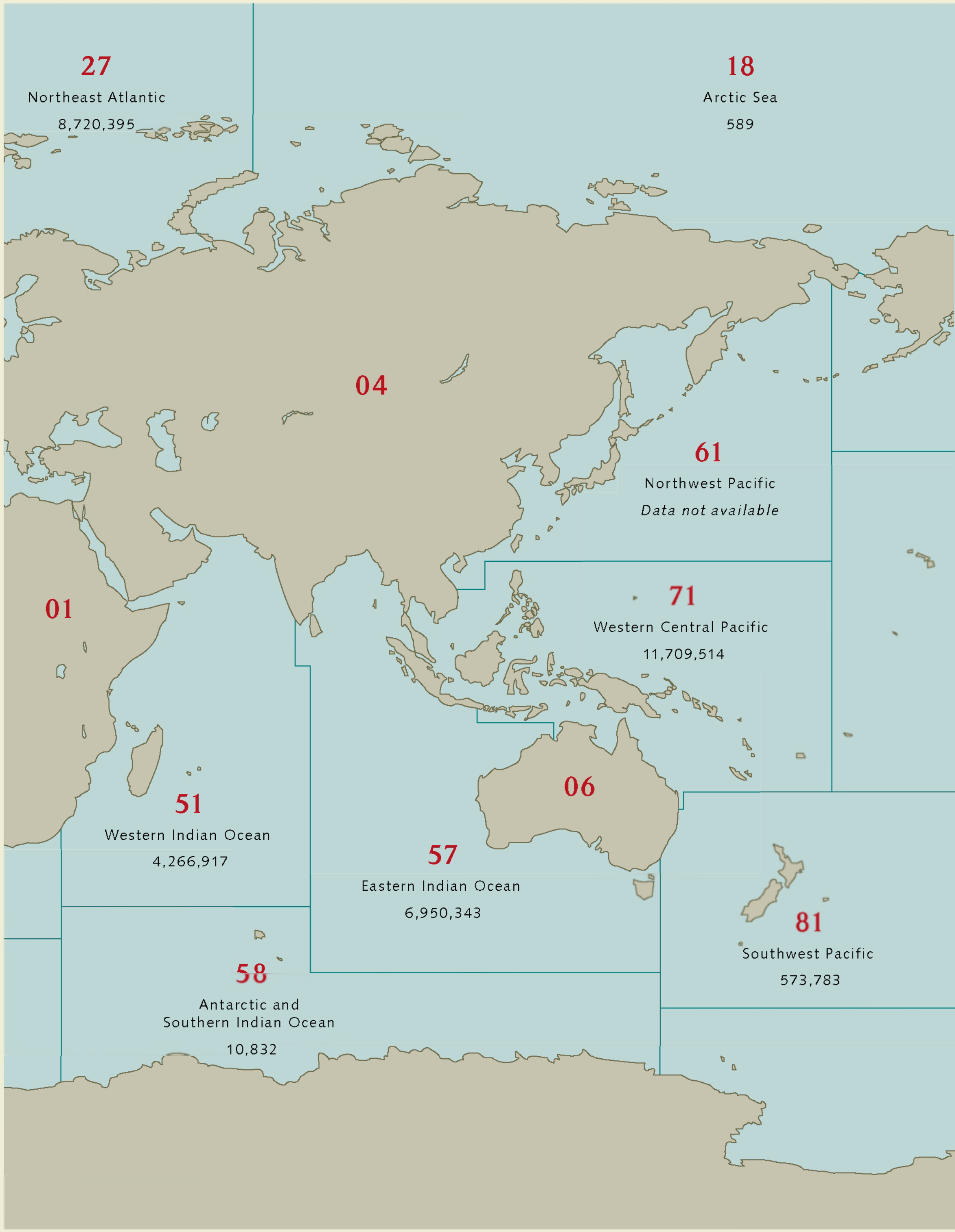
Areas with fluctuating catch volumes

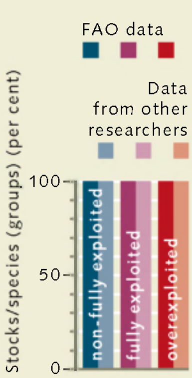
The first group includes the Eastern Central Atlantic (FAO fishing area 34), the Southwest Atlantic (41), the Northwest Pacific (61), the Northeast Pacific (67), the Eastern Central Pacific (77) and the Southeast Pacific (87). In the past five years these areas provided, on average, 52 per cent of the total global catch volume.

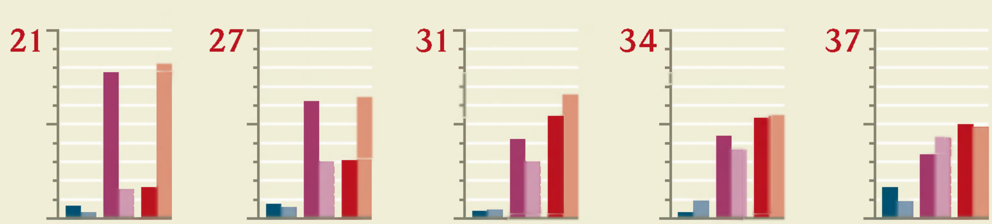
The most important area today is the Northwest Pacific. In 2010 a total of 21 million tonnes of fish were caught in this region – more than a quarter of the world's total marine catch. Small pelagic fish such as the Japanese anchovy make up the largest proportion of the total catch. The Eastern Central Pacific and the Southeast Pacific are also prolific due to the nutrient-rich upwelling areas off the coast of South America. Catches are prone to huge fluctuations, sometimes from one year to the next. One reason for this is the large numbers of small schooling fish (sardines and anchovies), stocks of which rely heavily on the current in the upwelling areas. Nutrient-rich water rises to the surface from the depths, stimulating the growth and reproduction of the plankton on which fish feed. When the current weakens due to climatic fluctuations, there is less plankton and thus less food for the fish.

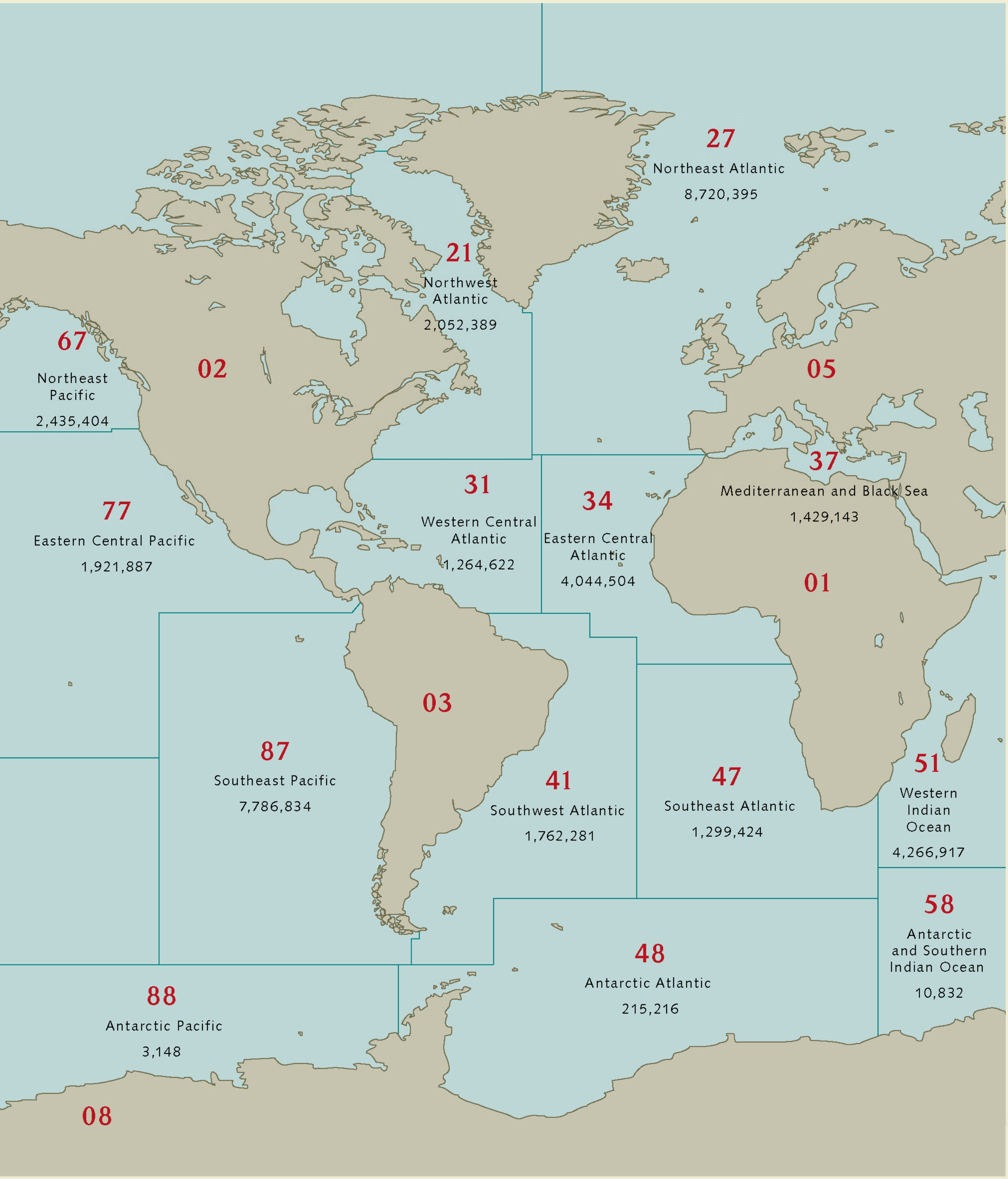
Compared with the general situation of world fish stocks, things are looking particularly grim in the Eastern Central Atlantic: 53 per cent of stocks in this area are considered overexploited, 43 per cent fully exploited and only 4 per cent non-fully exploited – off the coast of Senegal for example. The sardine *(Sardina pilchardus)* is the dominant species here. The Southwest Atlantic is also under heavy pressure. Important fish species are the Argentine hake and the anchovy off Brazil. Both are thought to be overfished. However, according to experts, the latter appears to be recovering. In this area, 50 per cent of stocks are considered overexploited, 41 per cent fully exploited and 9 per cent non-fully exploited. In contrast, the FAO data for the Northeast Pacific is comparatively positive. The annual catch peaked here in the 1980s. The largest proportion of the catch is made up of Alaska pollack, cod and hake. Today 80 per cent of the stocks in this region are considered fully exploited and 10 per cent each are overexploited and non-fully exploited.

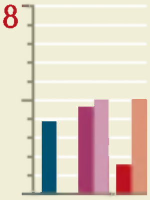
3.7 > The FAO divides the oceans into 19 major fishing areas which differ markedly in their annual catches (in tonnes living weight). The bar charts show the conditions in the corresponding maritime regions. The FAO figures (based on about 500 stocks) are compared with those of an American-German research group (based on about 2000 stocks). Despite the fact that the stock conditions were ascertained using different methods, it is still possible to compare the datasets. The Arctic is not shown in detail due to its limited catches. The red figures show the FAO number of the corresponding area. These areas differ considerably in their level of productivity. The coastal areas, or more accurately the continental shelves, are usually much more productive than the open seas. In FAO area 81, for example, there are few shelf areas, and the catch is correspondingly low, but the fish stocks are in a good condition (according to FAO data). Therefore, a low catch is not necessarily indicative of poor stock condition.

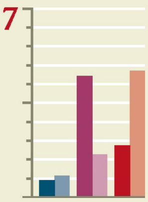


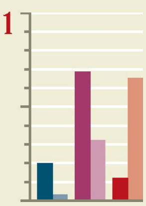


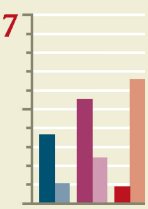


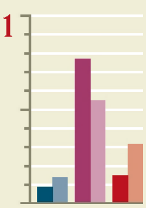


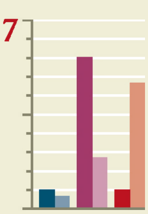
88


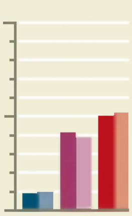
87


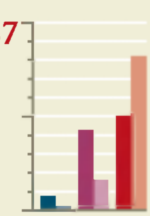
81


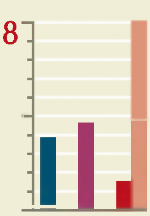
77


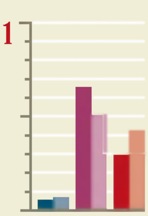
71


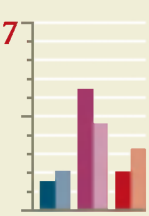
67


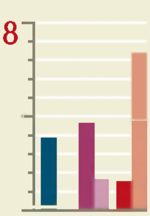
41


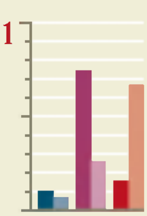
47


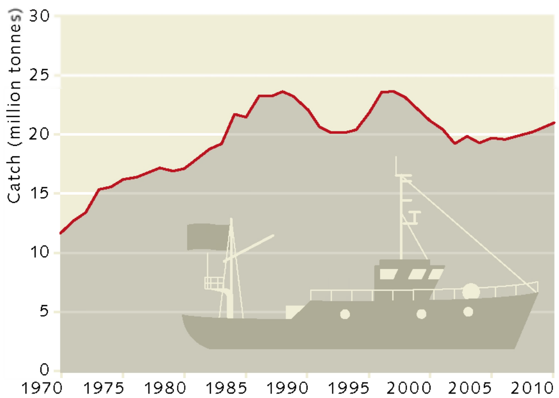
48


51


57


58


61




3.8 > The FAO includes the Northwest Pacific among the areas with fluctuating catch volumes.

Areas with falling catches

The areas in which catches have decreased over the years include the Northwest Atlantic (FAO fishing area 21), the Northeast Atlantic (27), the Western Central Atlantic (31), the Mediterranean and the Black Sea (both 37), the Southeast Atlantic (47) and the Southwest Pacific (81). In the past 5 years these areas provided an average 20 per cent of the world's total catch. In some areas reduced catches were a result of fisheries management regulations, and stocks are expected to recover here. If the annual statistics indicate diminished catch volumes, this does not always mean that a stock is being depleted or has been overfished.

In the Northeast Atlantic, for instance, the pressure on cod, plaice and sole has been reduced. Management plans are in place for the most important stocks of these species. Fortunately the spawning stocks of the Northeast Arctic cod have increased again here – particularly in 2008. Apparently the stocks have recovered following the low levels of the 1960s to 1980s.

The future is looking a little brighter for the Northeast Arctic pollack and the Northeast Arctic haddock, but other stocks of these species continue to be overexploited in some regions of the Northeast Atlantic.

Catches of blue whiting have decreased dramatically – from 2.4 million tonnes in 2004 to 540,000 tonnes in 2010 and 100,000 tonnes in 2011. This decline can be ascribed to the fisheries reacting too slowly to a sudden change in reproduction. Between the years of 1997 and 2004 the blue whiting for unknown reasons produced masses of young. During this period the species was fished intensively. But following a sudden drop in reproduction rates after 2004, the fishing industry continued to exploit the species at the same rate as before. The marked reduction of catch volumes in recent years, however, has helped the stocks to regenerate. In 2012 a harvest of almost 400,000 tonnes is expected.

The situation of some deep-sea fish species is critical. All in all, 62 per cent of the stocks assessed in the Northeast Atlantic are fully exploited, 31 per cent overexploited and 7 per cent non-fully exploited.

Fish stocks also remain in a poor condition in the Northwest Atlantic. Cod and ocean perch, for example, have not yet recovered from the intensive fishing of the 1980s, despite the Canadian authorities having completely banned the commercial fishing of these species. Experts ascribe the situation to adverse environmental conditions and competition for food (Chapter 1). Other stocks which are protected by fisheries management regimes appear to be regenerating. These include the spiny dogfish, the yellowtail flounder, the Atlantic halibut, the Greenland halibut and the haddock. Stocks in the Northwest Atlantic are considered 77 per cent fully exploited, 17 per cent overexploited and 6 per cent non-fully exploited.

Catch volumes in the Southeast Atlantic have declined considerably since the 1970s, from a previous 3.3 million tonnes to only 1.2 million tonnes in 2009. This can be ascribed partially to overfishing, and partially to catch reductions as a result of sustainable fisheries management. This applies in particular to the hake which is particularly important in this area. Thanks to the fishery measures introduced in 2006, some stocks of hake such as the deep sea *Merluccius paradoxus* off South Africa and the shallow water *Merluccius capensis* off Namibia appear to be recovering. In contrast, stocks of the formerly prolific South African sardine appear to be overexploited following a phase of intensive fishing. In 2004 the stock was classified as fully exploited. In the years since then, however, it has declined again as a result of adverse environmental conditions. This example highlights the speed at which a fully exploited stock can become overexploited, and the importance of forward-looking and sustainable

Spawners
"Spawners" is the term used for sexually mature male and female fish which help to maintain stocks by producing young. If spawner numbers decrease as a result of intensive fishing or adverse environmental conditions, insufficient young are produced and stocks can collapse.

fisheries management plans. The condition of the mackerel off the coast of Angola and Namibia has also deteriorated, since 2009 being considered overexploited.

The Mediterranean and the Black Sea are combined into a single FAO fishing area. Similarly, its situation is not particularly good. Of the stocks analyzed by the FAO, 50 per cent are overexploited, 33 per cent fully exploited and 17 per cent non-fully exploited. All stocks of the European hake *(Merluccius merluccius)* and the red mullet *(Mullus barbatus)* are classified as overexploited. Too little information is available about the condition of the sea breams and sole to categorize, but these are also suspected to be overexploited. The most significant stocks of small pelagic fish (sardines and anchovies) are considered fully exploited or overexploited.

Areas with increasing catches

In only three of the FAO major fishing areas have catches been continuously increasing since the 1950s. These are the Western Central Pacific (FAO fishing area 71), the Eastern Indian Ocean (57) and the Western Indian Ocean (51).

Catch volumes in the Western Central Pacific have constantly increased since 1970 to a peak of 11.7 million tonnes in 2010 – about 14 per cent of the total global catch. The situation has changed in the meantime, however, and stocks are now in a critical condition. Most are assessed as fully exploited and overexploited – particularly in the western regions of the South China Sea. It is thought that the high annual catches are due to China's intensive fishing industry expanding into this area where there was little commercial fishing in the past. But the FAO points out that the high catch numbers could be misleading. For many years China's catch statistics were adjusted upwards to comply with official output targets. It is assumed that fish were counted twice during transportation. For this reason it is conceivable that flawed data is masking an actual trend reversal – i.e. a reduction of fish stocks in the Western Central Pacific region.

The annual catch in the Eastern Indian Ocean has also escalated over the years, and this trend is continuing. Between 2007 and 2010 alone, the catch volume increased by 17 per cent. In the Bay of Bengal and the Andaman Sea catch volumes are steadily increasing. About 42 per cent, however, is not ascribed to any specific species and simply registered as "marine fishes not identified". This practice gives cause for concern because it is then impossible to assess the stocks of the different fish species in this heavily exploited region.

Each of the FAO's 19 major fishing areas comprises numerous sub-areas which are developing in different ways. Even when the total catch is increasing in one particular area, the trend for stocks of individual sub-areas can be the exact opposite. For instance, the catch volume in the Eastern Indian Ocean is increasing overall, but that

The end of the line?

At times over recent years researchers and the media have issued dire warnings about the state of ocean fish. According to some 2006 announcements, the oceans will be completely empty by 2048. This statement was strongly criticized at the time. Firstly the researchers had assumed that collapsed stocks would not recover in future decades. They failed to take into account the successful fisheries management measures aimed at stock recovery in the USA, New Zealand, Australia and other countries. Secondly, data from the past was projected 30 years into the future. Claims covering such a long time-frame are, however, riddled with uncertainty. Today the scientific community is agreed that the status of worldwide fish stocks calls for a differentiated approach.

The European Commission provided more bad news: 88 per cent of EU fish stocks are overfished, it declared in 2009. This number has now reduced to about 50 per cent, partly as a result of stricter catch limits. However, these figures are incomplete because the European Commission based its calculations on only about one fifth of the European fish stocks for which extremely good scientific data and reliable reference values were available. Overall, about 200 different stocks are exploited in the EU. But even bad news contains an element of good. In this case it has significantly helped to publicize the problem of global overfishing. Leading fisheries scientists for a long time took the view that they knew too little to assess the actual status of fish populations, and the fishing industry generally reacted by continuing to fish at the same rate of intensity. Despite a lack of knowledge, the scientists are now more prepared to make recommendations on the sustainable management of individual stocks. Furthermore, in many places the opinion is gaining ground that we must exercise more caution in our fishing practices. Sustainable, precautionary fishing is the aim. Some nations have already enshrined this objective in law, but many others still need to do so.

What shape are tuna stocks in?

Tuna is popular both in Western Europe and Japan where it is often prepared as sushi. At Japanese fish auctions in particular, prices in excess of 1000 euros per kilogram are paid for certain species of tuna. Visitors to high-class restaurants are quite prepared to pay top prices for the right product. The trade in tuna is therefore extremely lucrative.

As a result of strong demand, in 2009 stocks of seven important species of tuna were overexploited by a third, 37.5 per cent were fully exploited and 29 per cent were non-fully exploited. In the case of tuna the status of the species is often defined but not the populations, because it is difficult to define individual regional stocks of these fast-moving, highly migratory species. The most important species (as a proportion of total 2010 catch) are:

- Skipjack tuna: 58 per cent
- Yellowfin tuna: 26 per cent
- Bigeye tuna: 8 per cent
- Albacore tuna: 5 per cent
- Southern bluefin tuna *(Thunnus maccoyii):* 1 per cent
- Pacific bluefin tuna *(Thunnus orientalis):* 1 per cent
- Atlantic bluefin tuna *(Thunnus thynnus):* 1 per cent

Skipjack stocks are slightly increasing, meaning that in principle it should be possible to catch more of them. The problem with skipjack fishery, however, is that young bigeye and yellowfin tuna become caught in the net as bycatch. As several species often occur together it is difficult to catch only one species at a time. Accordingly, experts advise that any expansion of the skipjack fishery should be very closely monitored. There are also fears that all tuna stocks will further decline in the medium term if commercial fishing continues at the intensive rate of today. The bluefin tuna in particular is under threat. For this reason, in 2010 attempts were made to protect this species in accordance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This convention governs the import and export of endangered plants and animals. More than 170 nations have joined the convention since it came into effect in 1974.

Non-governmental organizations in particular have called for CITES to protect the bluefin tuna. The species is so popular, they claim, that commercial fishing is still economically viable even if only a few of them are caught in the net each time. The bluefin could become completely extinct. Opponents counter that overexploitation cannot be compared with extinction, that fishermen would stop fishing if it were no longer in their economic interests to continue. Even then, sufficient fish would remain to ensure the survival of the species. Whether CITES requirements can be used at all for ocean fish is doubtful, they say. So far, no international agreement has been reached on strict protection based on CITES criteria. It currently appears that the future protection of the bluefin tuna will be governed by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Whether this will work remains to be seen.

3.9 > Catching yellowfin tuna used to involve backbreaking manual labour, as seen here off the Galápagos Islands in the 1930s.

of one sub-area, Australia's Exclusive Economic Zone (EEZ), is decreasing in response to management plans. As far as the protection of fish stocks goes, Australia and New Zealand are now regarded as models of best practice. The trigger was a 2005 ministerial decision which ended overfishing in the EEZ and made it possible for stocks to recover.

The Western Indian Ocean has long been considered an area in which the catches have increased appreciably. A temporary peak was reached in 2006. Since then, catch volumes have slightly decreased. The volume for 2010 was 4.3 million tonnes. Current investigations show that the widespread Narrow-barred Spanish mackerel *(Scomberomorus commerson)* found in the Red Sea, the Persian Gulf, the Gulf of Oman and off India and Pakistan, is overfished. Catch figures from these areas are incomplete, making it difficult to estimate the population. Attempts are being made to gather valid data in other regions. The Southwest Indian Ocean Fisheries Commission responsible for the southwestern sub-area of the Western Indian Ocean carried out a systematic estimate of 140 species in 2010. Although there are some gaps in the data, the attempt to assess the region's stocks deserves recognition. Overall, 65 per cent of the stocks in the Western Indian Ocean are fully exploited, 29 per cent overexploited and 6 per cent non-fully exploited.

Alien species add to the pressure

Already weakened fish stocks in some maritime regions are faced with the additional threat of alien species. Predators which feed on the fish, eggs and larvae of weakened stocks are particularly problematic, and competitors for food can play further havoc with depleted stocks. The situation becomes critical when the alien species thrives under its new living conditions and begins to reproduce vigorously. For example, alien species migrate from the Red Sea and through the Suez Canal into the Mediterranean. Some of them are apparently supplanting the native species of the eastern Mediterranean. The anchovy and sprat stocks of the Black Sea collapsed in the 1990s. This was due partly to overexploitation and partly to a type of fist-sized comb jellyfish introduced in the **ballast water** from ship tanks further undermining the already low fish stocks. The swarms of jellyfish ate the fish eggs and larvae en masse, biologists believe. Stocks have still not fully recovered. They are considered either fully exploited or still overexploited.

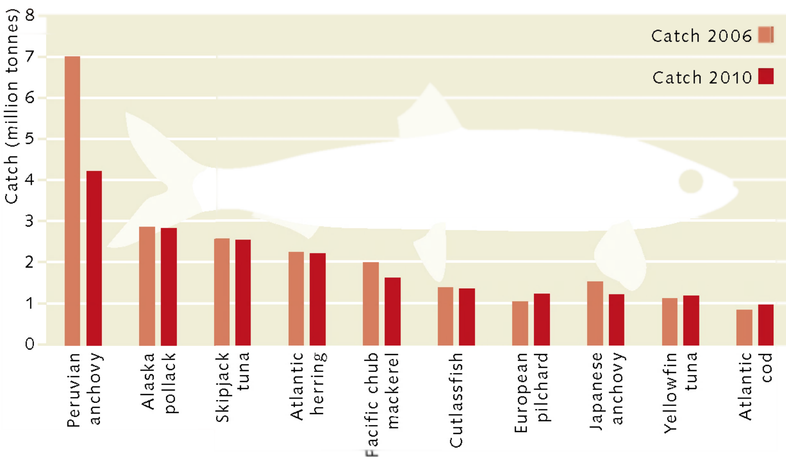
A closer look at the different species

Taking a closer look at the individual fishing areas of the world, it becomes clear that there is no simple response to the question of how the fish are faring. It's a complex situation. Without doubt many stocks are overexploited or have collapsed. But others are recovering thanks to sustainable fisheries management regimes. By way of illustration, the following section describes some individual fish species and their status – including the most important species with the highest total catch volumes. These fish species make up about 25 per cent of the world's total fish catch. Most of their stocks are considered fully exploited or overexploited.

3.10 > Tins of tuna generally contain the flesh of widespread species such as the skipjack tuna. Nonetheless, consumers should ensure that the products they buy are from sustainable fisheries.

The Peruvian anchovy – sometimes more, sometimes less

The development of the Peruvian anchovy *(Engraulis ringens)* is interesting. In terms of catch, it is the most important fish in the world. Large amounts are processed into fishmeal and fish oil to be fed to larger farmed fish in aquaculture operations. The largest volume ever caught, around 13 million tonnes, was landed in 1971. Today this would equate to a quarter of the global fish catch – excluding catches of other marine fauna such as mussels and squid. In the 1980s, the stocks crashed to about a tenth of this record level, not only as a result of intensive fishing but probably also because of a lack of food caused by the El Niño climatic phenomenon. The stocks later recovered. A new annual record of 12.5 million tonnes was reached in 1994. Since 2004, catch volumes have been dropping again, once more mainly due to El Niño. This anchovy example clearly shows the extent to which stocks can fluctuate. It also illustrates the vast amounts of fish which humans are removing from the seas; when adverse environmental conditions are added to the equation even vast



3.11 > The ten most important ocean fish species and their worldwide catch totals. As a result of the El Niño climatic phenomenon, catches of the Peruvian anchovy in particular fluctuate from year to year.

stocks can be decimated. This example also teaches us that a stock can regenerate rapidly due to the ability of the fish to reproduce profusely.

Other species of fish and stocks, however, are not capable of recovering so quickly from overfishing. One example of this is the Northeast Atlantic mackerel.

The Northeast Atlantic mackerel – departure from the North Sea

The Northeast Atlantic mackerel *(Scomber scombrus)* fishery comprises three components: the western, the southern and the North Sea stock. Each has its own spawning grounds. The North Sea mackerel spawn along the east coast of Britain, the southern component in the Bay of Biscay and off the Iberian Peninsula and the western component to the west of the British Isles and Ireland.

In spring, when the plankton proliferates in response to rising temperatures, the mackerel of all three stocks gather in large hunting schools and migrate to the region between the Shetland Islands and Norway. They later gradually leave this nutrient-rich summer feeding area to spawn in the three regions mentioned above. They display an amazing swarming instinct: by no means all the first-time spawners return to their traditional spawning grounds, but often follow the majority of the mackerel. The North Sea mackerel used to be the largest component, so many first-time spawners were attracted to the North Sea. However, stocks of this component collapsed in the 1970s due to overfishing.

Although the fishery was completely closed, the component has still not recovered. The western stock component then became the most prominent. The repercussions are clear: many mackerel which today begin their lives in the North Sea follow the main flow of fish towards the west when they first spawn. This occurs even in good years. Even when there are plenty of young fish in the North Sea most of them migrate westwards to spawn. The fact that there are still mackerel in the North Sea presumably means that a certain proportion of them continue to frequent the spawning grounds on England’s east coast. The question is whether a major mackerel stock will ever again be able to establish itself in the North Sea.

It is interesting that the Northeast Atlantic mackerel has apparently been increasingly orienting itself towards the west in recent years. The early-summer migration has been taking them more regularly into Icelandic waters. As a result, Iceland’s mackerel catches have soared from 4000 to 200,000 tonnes in only three years. Scientists are worried about the development because for years now too many mackerel have been caught. The reason is that the littoral states – the Faroes, Iceland, Norway, Russia and the European Union – cannot agree on lower catches. Each nation sets its own limits. When added together the total catch far exceeds the annual tonnage recommended by scientists. Fears that Northeast Atlantic mackerel stocks will be completely overexploited in the coming years are therefore justified.

The European hake (southern stock) – haggling over catch numbers

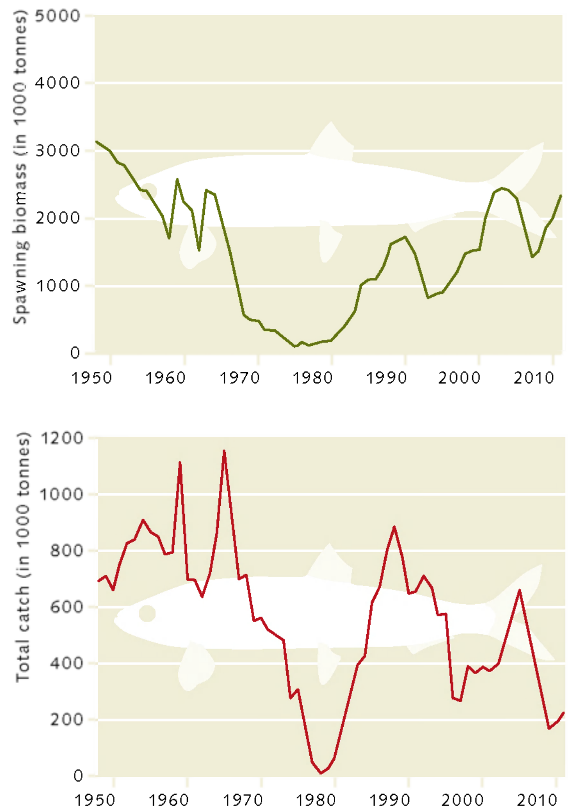
The future of the European hake (southern stock) in the Bay of Biscay and west of the Iberian Peninsula is also uncertain. This is a classic example of how difficult it is to accurately assess a stock. And it also shows that if in doubt, a fishing nation tends to continue fishing rather than protect a fish population.

The hake debate is difficult, mainly because the species seems to have been proliferating more rapidly over the past two years than had been observed previously. Its spawning biomass levels are increasing. ICES scientists, however, believe that for some time now, probably since the turn of the century, the stock has been overfished. The ICES fish abundance estimates have revealed that three times more hake has probably been caught than the stock can sustain over the long term. After tough and protracted negotiations with Spain, the European Commission in 2005 finally succeeded in establishing a management plan. But the ICES experts consider this inadequate, because it aims to reduce catches very slowly. In purely arithmetical terms, the stock could, at some stage, recover. However, the scientists claim that such an increase in the hake population would be so minimal as to be scarcely perceptible. Accordingly, it would be impossible to predict any stock recovery within the next ten years.

For this reason, many experts consider the management plan absurd, providing the hake with little protection. Nonetheless, Spain is persisting with it based on the evidence of the current increase in spawning biomass. The ICES believes that too many fish are still being caught, and it is simply a matter of luck that spawning stocks are expanding. They claim that hake numbers are growing in spite of and not because of the management plan. Spain is unlikely to back down. The data it has submitted to the ICES for 2012 is incomplete and is of little use in this form. This has led to the current heated debate taking place between the ICES and Spain.

The North Sea herring – recovery is possible

The example of the North Sea herring shows that a stock can recover if it is given a chance. Within a few years of the introduction of seine fishing in the 1960s, the stocks collapsed. The herring fishery was therefore completely closed between 1977 and 1981 – a measure which was both logical and correct. The stock recovered. In the early 1990s the spawning biomass level reached a new high. The next crisis followed not long after. This time many juvenile fish were captured in the nets as bycatch, leaving fewer fish to grow to maturity and rebuild depleted populations. As a result the spawning biomass dropped markedly once again, and stocks reached another low point in the mid-1990s. But this time reaction was swift. In mid-season 1997 catch amounts were again cut back drastically, and stocks recovered.



3.12 > Resolute fisheries management can ensure the recovery of a fish stock. After the North Sea herring was overfished in the 1960s (as revealed by the drop in spawning biomass), the fishery was completely closed. The stock, particularly the numbers of sexually mature fish (spawners), regenerated. After renewed over-fishing in the 1990s a management plan was agreed in 1997, which once again limited catches. The spawning stock was able to recover. The reduction of spawning biomass since 2002 can presumably be ascribed to climatic changes.

This example shows that the development of a stock can be very specifically controlled by restrictions and bans on fishing, resulting in positive change. Since 2002 the spawning biomass has again been dropping – most probably due to natural climatic fluctuations. Apparently the reproduction of the herring is partially connected to the North Atlantic Oscillation (NAO), a large-scale fluctuation in atmospheric pressure which occurs at regular intervals. This is leading to more differences of opinion between the ICES which makes the recommendations, and the EU Council of Ministers which is responsible for fisheries management in the North Sea. The positive stock development prompted the Council of Ministers in 2011 to set higher catches than envisaged in the management plan and recommended by ICES. The ICES is urging that catches should remain as they were, in spite of the good spawning stocks. Especially in good times a management plan should be complied with, it claims, so that stocks can further regenerate and cushion years with poor reproduction.

Purse seine
A purse seine is a net that is used to encircle a school of fish. The net is then drawn together to retain the fish by using a line at the bottom, allowing the net to be closed like a purse.

The deep sea – remote and endangered

> People have been fishing in the deep sea for over half a century. Over time, ever deeper ocean regions have become accessible to deep-sea fisheries. These hidden habitats are doubly endangered, because they are home to rare as well as sensitive organisms. Fortunately, the knowledge that these ecosystems require special protection is gradually becoming accepted.

Fishing in the dark

The assertion that the moon has been more thoroughly researched than the deep sea is still true. The deep sea refers to the totally dark layers of the ocean below around 800 metres.

Submersible robotic vehicles that can penetrate to the deepest parts of the ocean, the deep-sea trenches, have been in use for some time, but expeditions with these are expensive and complex. So our knowledge of life at great depths is still fragmentary. At best, submersible vehicles provide only highlights in the vast darkness, and sea-floor samples obtained with grab samplers or trawls deployed from research ships allow only isolated snapshots of the deep-sea ecosystems.

Although the impact of human encroachment on these systems is largely unknown, the deep ocean regions have been fished since the end of the Second World War. At first, fishing mostly targeted species of *Sebastes,* at depths of only a few hundred metres. Now fish are being caught from depths around 2000 metres, where the living conditions are fundamentally different from those in shallow regions. The Food and Agriculture Organization of the United Nations (FAO) defines deep-sea fisheries as those conducted between the depths of 200 and 2000 metres.

Flourishing life in the darkness

Off northwest Europe the transition from land to the sea bottom is a gradual slope. Off the coast lies a sprawling continental shelf. The North Sea is situated here as a shallow, offshore marginal sea. A similar situation is found off the coast of China with the South China Sea. The wide continental shelf ends at the break to the continental slope, which falls more steeply to greater depths. There are also coasts, however, where the transition from the land to deep sea is more abrupt. Here the wide continental shelves and marginal seas are absent. An example of this is the coast of Japan, where the sea floor descends abruptly and steeply into the depths.

Distinctive structures rise from the sea floor all around the world: submarine banks, ridges and seamounts. A bank is defined as a sea-floor elevation that can be several hundred kilometres long or wide. Banks are composed of sandy material or massive rock.

The kind of fish that predominate in an area depends in part on the bottom characteristics. Individual fish species have different modes of life. Some live close to the bottom. They are demersal. Other species swim in the open water column and are called pelagic. There are also species that live near the bottom, but rise into the water column to hunt for food. These are benthopelagic species.

It is amazing that special biological communities have developed in the deep sea in spite of the darkness. Most of them have only been superficially investigated and biologists are constantly discovering new species that have not yet been described. In recent years researchers have been focussing on cold-water corals in particular, as well as the ecosystems around seamounts and at deep-sea hydrothermal vents and cold seeps. The great biological diversity discovered here was completely unexpected because the deep sea had long been considered to be a dead and muddy desert. The species diversity in the deep sea was sensational for researchers.

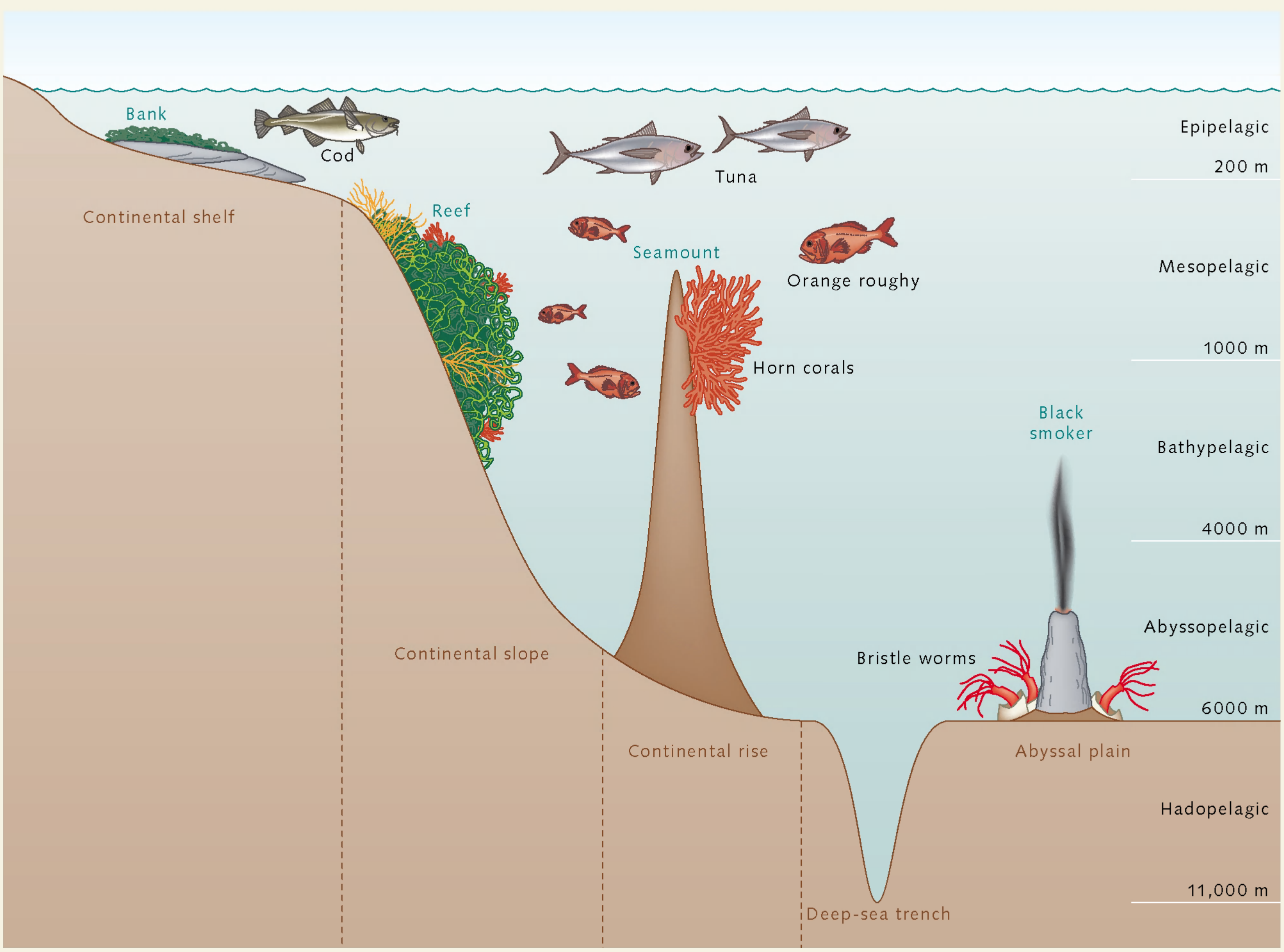
Seamounts

Seamounts are underwater mountains that are formed by volcanic activity and rise at least 1000 metres above the

Depth zones of the ocean

The ocean is divided into different depth zones. The epipelagic extends from the water surface down to a depth of 200 metres. The word comes from the Greek terms *pélagos* (open sea) and *epí* (upon). This upper layer, which is influenced by light, is especially productive because the primary producers (algae, cyanobacteria and seagrass) produce biomass here through photosynthesis. This primary production is the foundation of life in the sea.

Below the epipelagic zone lies the mesopelagic, extending down to around 1000 metres (Gr.: *mésos* = middle). Below this, the bathypelagic zone encompasses depths from 1000 to 4000 metres (Gr.: *bathýs* = deep). Many deep-sea species live within this zone, including fish, crustaceans and snails. And even deeper, between 4000 and 6000 metres, lies the abyssopelagic (Gr.: *ábyssos* = bottomless), where the prevailing temperatures are near the freezing point. Even here specialized animal species can be found, including crustaceans. The deepest regions of the sea are called hadopelagic (Gr.: *hades* = underworld). The hadopelagic extends into the deep-sea trenches, down to a depth of 11,000 metres. The inhabitants of this deepest marine region include bristle worms. The ambient pressure here is around 1000 times greater than at the water surface.



3.13 > The depth zones in the ocean. Diverse habitats such as black smokers or cold-water coral reefs have formed in these zones. Where different species settle depends on the depth and structure of the sea floor among other factors.

sea floor. Some are 3000 or even 4000 metres high. Their peaks often rise up into the upper layers of the mesopelagic zone. Seamounts can be regarded as islands or volcanoes that do not reach up to the sea surface. It was long believed that these were rare occurrences. Today it is known that seamounts are present in all oceans. The total number is estimated in the thousands.

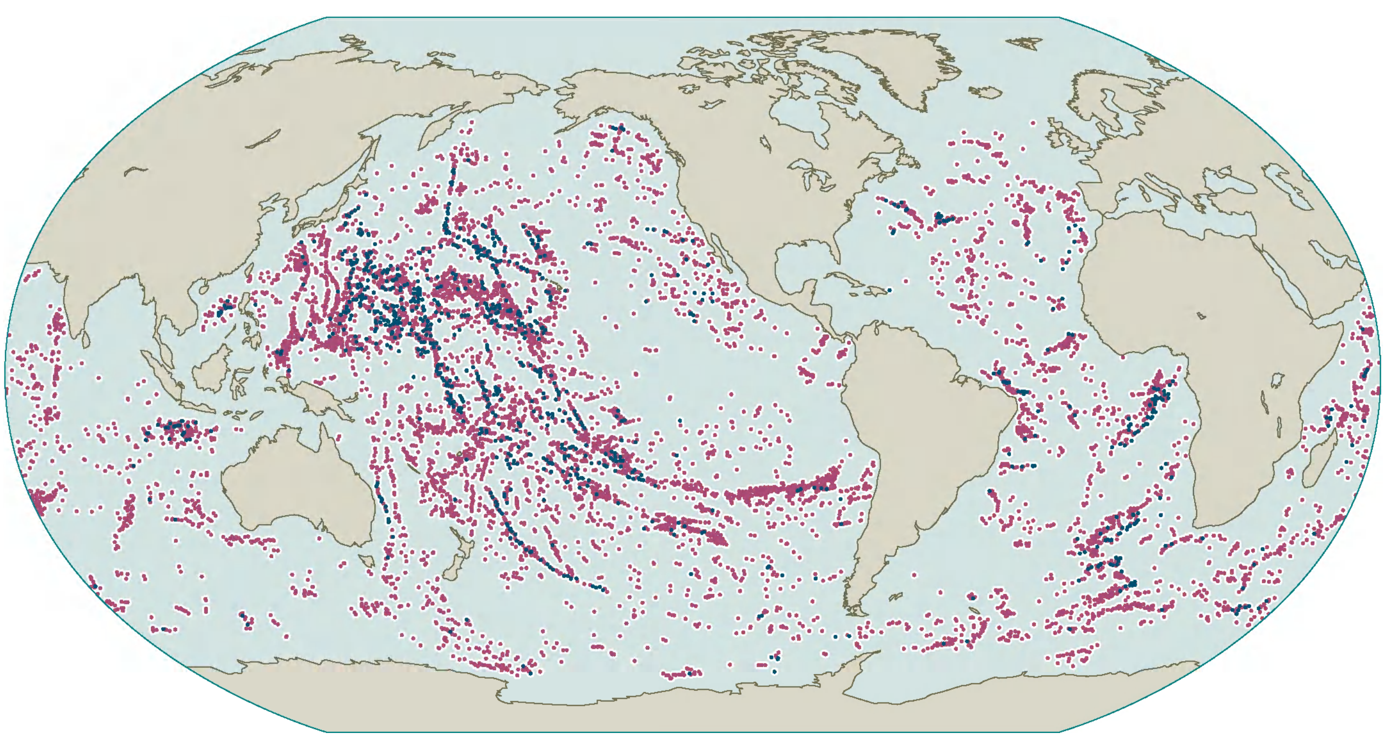
Research has shown that some seamounts are home to communities of unique, **endemic** species. These include lower animals like sponges and sea cucumbers, relatives of the starfish, but also vertebrates such as fish, which can occur in large schools around seamounts with high species diversity. This makes the seamounts especially interesting for fisheries.

There are still many unanswered questions regarding the significance of seamounts. Many scientists believe that seamounts act like gigantic stirring rods in the ocean, where small-scale eddies break off from the large ocean currents. It is presumed that nutrients and dead plant and animal remains from the epipelagic are trapped in these eddies and attract fish. That would be a logical explanation for the high diversity at seamounts and the sometimes very high fish densities. It is also known that migratory birds on their transoceanic flights and large predatory fish like sharks commonly hunt and feed in marine regions with seamounts.

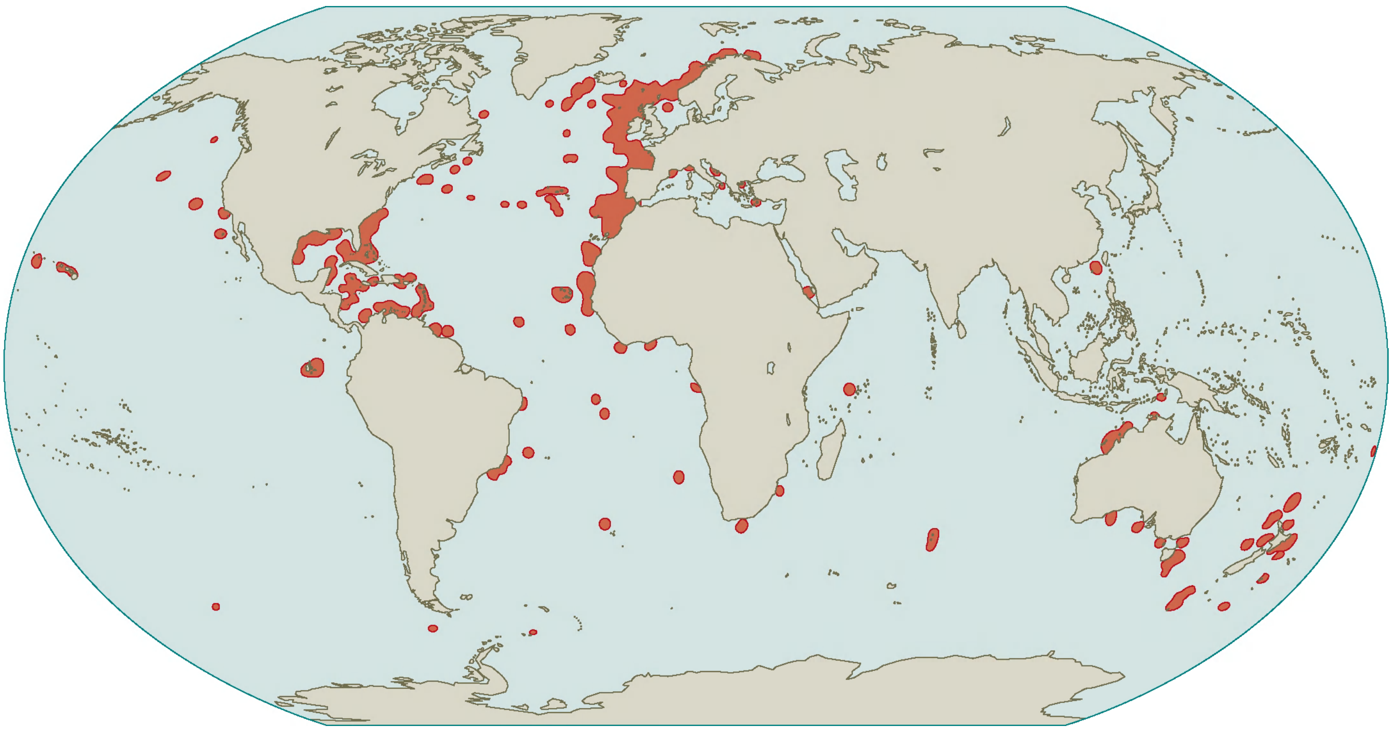
Furthermore, sharks apparently use seamounts as geomagnetic orientation points and sometimes mate there in large groups. Elsewhere, bigeye tuna may converge to hunt among the dense schools of prey fish. An example of this hunting is seen in eddies over the Hawaiian seamounts.

Cold-water corals

Corals usually evoke a mental picture of idyllic South Sea Islands, white palm beaches and swarms of colourful luminescent fish darting through clear waters suffused with light. Actually, however, some coral species also live in cold, deep water layers. They occur primarily in the Atlantic, off the coast of Norway or northwest of Ireland, but they are also found in the Pacific near Australia and New Zealand.



3.14 > Seamounts are commonly located at volcanic structures such as the ocean ridges, and sometimes form long chains along the sea floor. Seamounts with a height between 1000 and 3000 metres are marked in red, those higher than 3000 metres in blue.



3.15 > Cold-water corals occur worldwide. They can even flourish at depths of 2000 metres.

It has been known for centuries that there are corals living in deeper waters because fishermen have often found pieces of them in their nets. Until 20 years ago, however, no one had any idea of the areal extent of cold-water coral reefs. While searching for an ideal route for a pipeline in 1982, workers for the Norwegian energy company Statoil discovered large populations of the cold-water coral *Lophelia pertusa*. The underwater photographs caused a sensation at the time.

Today it is known that the Norwegian coral reef has an area of around 2000 square kilometres and, in terms of size, exceeds even the warm-water coral reefs in the diving grounds of the Seychelles. A great number of rare and even unique species live on the Norwegian coral reef. Furthermore, these reefs serve as a nursery ground for fish, providing an effective retreat and protection area for the offspring.

The term "cold-water coral" does not refer to a particular species. It includes around 1000 species that thrive in cold water at temperatures between 4 and 12 degrees Celsius. Many of them occur in the mesopelagic zone between 200 and 400 metres of water depth. Some species, such as the Antarctic deep-sea coral *Flabellum impensum*, can live at depths down to 2000 metres – at a water temperature of around 1 degree Celsius.

Hydrothermal vents and cold seeps on the sea floor

Hydrothermal vents on the sea floor are found primarily in regions of volcanic activity, most commonly in areas where continental plates drift apart. **Mid-ocean ridges** have formed at these plate boundaries over thousands of years as fresh magma continuously rises from the Earth's interior. They have built up over time to form high mountain chains thousands of kilometres long. Water seeps 2 to 3 kilometres down into the Earth's crust through fractures and cracks in the rocks and is heated by the magma chambers. Because the heated liquid has a lower density, it rises again. At some locations minerals stain the water black. For this reason the vents are also called black smokers. The minerals are an elixir for bacteria, primary producers that generate biomass. Experts refer to this process as chemosynthesis, an allusion to the photosynthesis carried

Reefs

Reefs are narrow, elongated elevations on the sea floor. Coral reefs are composed of the carbonate skeletons of corals, which have built up to form reefs several metres high over thousands of years. Mussels can also build reefs. In addition, there are reef-like sand banks and rocky reefs.

out in sunlight. The bacterial biomass provides the foundation for higher life forms. The black smoker sites are also populated by shrimp, fan-shaped gorgonian corals, or tube worms.

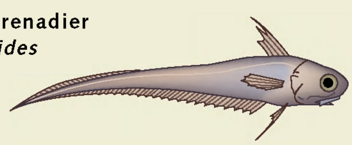
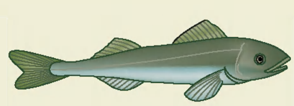
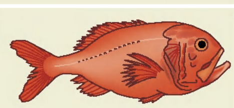
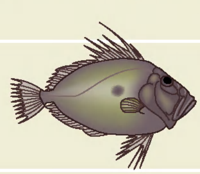
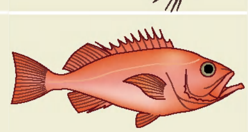
Today there are around 300 known black smoker sites worldwide. Most of them are in the Pacific. There are, however, almost no commercially important fish species living in these extreme habitats. It has only been known for a few years that cold seeps in the deep sea are special and important habitats. Cold nutrient-rich water flows out of the sea floor here.

During an expedition off the coast of Pakistan in 2007 scientists discovered densely populated cold seeps. There are mussel banks, crabs, snails and sea cucumbers. Although experts had long known about heavily populated cold seeps in the Gulf of Mexico, they were believed to be an exceptional case. Actually, however, cold seeps are found in numerous ocean regions. Off the coast of Pakistan, for example, the Arabian continental plate is being pushed beneath the Eurasian plate. In the process, water contained in the sediments is pressed out. It flows back into the ocean through fissures in the bottom. Substances contained in the water provide nutrition for bacteria and small animals, which in turn become food for higher organisms such as crustaceans.

Exclusive economic zone
The Exclusive Economic Zone (EEZ) is also referred to as the 200-nautical-mile zone. Here, coastal states have sovereign rights to the exploration and exploitation of living and non-living resources. This includes the exclusive use of fish stocks in one's own EEZ. Furthermore, within its own EEZ a state may erect offshore drilling rigs or wind farms.

The fish of the deep sea

In the nutrient-rich and highly productive coastal regions, massive reproduction is typical of many species, and this ensures their survival. Many deep-sea fish species, on the other hand, are characterized by slow growth, late sexual maturity, long life, and the production of fewer offspring. They are adapted to life at great depths, to a habitat in which unchanging environmental conditions prevail. The strong temperature fluctuations that can impact the repro-

Species	Habitat	Age at sexual maturity	Maximum age
Roundnose grenadier ***(Coryphaenoides rupestris)*** 	Continental slope and sea floor; Northern Atlantic; 600–800 m	10	54
Sablefish ***(Anoplopoma fimbria)*** 	Continental slope and sea floor; Northern Pacific; 300–2700 m	5	65
Orange roughy ***(Hoplostethus atlanticus)*** 	Seamounts and banks; Atlantic, parts of the Pacific; 180–1800 m	20–40	>100
Smooth oreo dory ***(Pseudocyttus maculatus)*** 	Seamounts and banks; Southern Atlantic and Pacific; 400–1500 m	20–30	100
Pacific ocean perch ***(Sebastes alutus)*** 	Seamounts and banks; Northern Pacific; 180–640 m	10	100

3.16 > Many fish species of interest to fisheries occur in the deep water layers. Some do not reach sexual maturity until a relatively late age.

duction of fish in shallow coastal regions are absent here. However, the deep sea is not as rich in nutrients as the coastal waters. The carrying capacity is almost exhausted and competition for food is great. Most species have therefore adapted by producing fewer, but highly competitive offspring. This reproduction strategy is called K-strategy (K refers to the carrying capacity of the environment). There is a high parental investment in the offspring. The eggs of many deep-sea fish are relatively large and rich in nutrients so that the larvae have a good chance of developing well.

One example of this is the deep-sea orange roughy *(Hoplostethus atlanticus),* which does not reach sexual maturity until the age of around 25 and can live to be 125 years old. The orange roughy lives at seamounts and builds up very large stocks over time. These fish grow slowly and can survive periods of scarce food supply. Furthermore, thanks to the long life expectancy of the individual fish, the stock can compensate for times of low offspring production. Fish species of the K-strategy type are especially threatened by deep-sea fisheries. When the older fish are continuously removed by fishing, at some point there will be too few sexually mature animals remaining to sustain the population.

However, not all fish living in the deep sea are K-strategists. The blue whiting *(Micromesistius poutassou),* for example, occurs on the continental slopes at depths from 100 to 1000 metres. It is, however, a species that produces great numbers of offspring. The reason for this is that the immature fish spend most of their time in the shallow shelf areas in water depths around 100 metres, where there are numerous predators and food competitors. Massive reproduction is therefore the ideal strategy for the blue whiting.

Fisheries in the deep sea

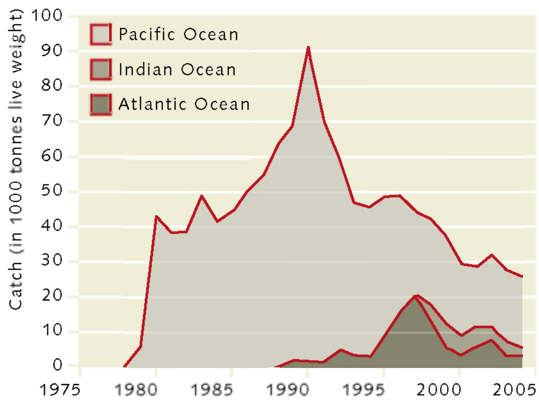
Commercial fishing has only been carried out in deep waters over the past few decades. Although longline fishing has been practised since the 18th century, industrial fishing far out in the ocean first became practicable in the 1950s with the availability of seaworthy refrigeration ships. Deep-sea fishing received a boost in the early 1970s with the introduction of the 200-nautical-mile zone, or Exclusive Economic Zone, which made it impossible for foreign ships to fish close to the coasts of another country. The high seas, including the deep sea, were an alternative fishing area. The Soviet Union and Japan in particular were soon specializing in the deep-sea regions. In the beginning the catch amounts were enormous – especially around structures such as seamounts and banks.

To the extent that fish stocks were gradually shrinking in the coastal areas, deep-sea fishing became increasingly interesting for other countries as well. According to a survey by the FAO, there were 27 countries conducting deep-sea fishing in the year 2008, with Spain, South Korea, New Zealand and Russia at the forefront. Around 70 per cent of the ships employ trawl nets, and these are often demersal-trawl nets. Today these can be deployed to a depth of 2000 metres.

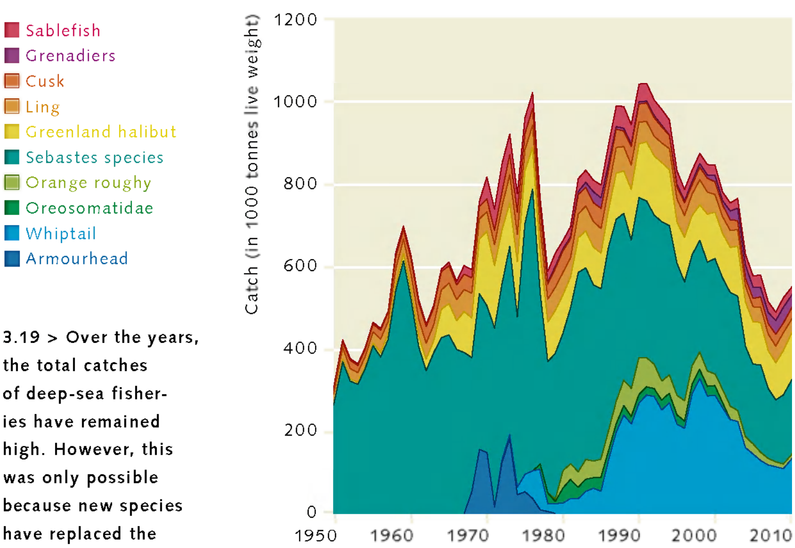
It soon became obvious that deep-sea fishing is problematic in two respects. For one, valuable habitats such as cold-water corals or the ecosystems at seamounts are destroyed when nets come in contact with the bottom. Secondly, fish species are quickly decimated, particularly

3.17 > The orange roughy lives at depths down to 1800 metres.

High seas
The "high seas" are the areas of the ocean to which all states have free access. No country may claim sovereignty over any part of the high seas. The high seas, where freedom of navigation, research and fishery are internationally recognized, begin at the boundary of the 200-nautical-mile zone. Much of the deep-sea region lies outside the EEZ, and is therefore part of the high seas. All nations have the right to exploit fish stocks there.



3.18 > The catches of many deep-sea fish, like the orange roughy shown here, declined rapidly within just a few years because of overfishing.



3.19 > Over the years, the total catches of deep-sea fisheries have remained high. However, this was only possible because new species have replaced the overfished stocks of other species. The figure shows the total amounts for different species in each year. An example of overfishing of a deep-sea species is provided by the armourhead, which had been fished by Japanese and Russian trawlers at Pacific seamounts since the 1960s. Within 10 years the stocks were so strongly reduced that the species was commercially depleted and abandoned by fisheries.

the K-strategists. For example, newly discovered stocks of orange roughy were reduced to 15 to 30 per cent of their original size within just 5 to 10 years. In many areas the species was commercially depleted. This "boom and bust" kind of fishery is typical in the pursuit of deep-sea fish species. The reason for this is that species like the orange roughy not only produce a small number of offspring, their reproductive performance is also very erratic and episodic. Several years can pass with low production of offspring before a strong season occurs again. It is still not known what controls or triggers these fluctuations. Investigations at the Great Meteor Seamount west of Madeira have indicated an influence of changes in the winds affecting eddy currents above the seamount.

It is a certainty that the deep-sea species cannot compensate for heavy fishing activity. Deep-sea fishing is also both ecologically and economically questionable. For one thing, it is very destructive, and for another the catch levels are relatively low because most deep-sea fish stocks are comparatively small due to their K-strategy. Thus, taken as a whole, the deep-sea fisheries represent only a small proportion of the worldwide catch amounts. Basically they can only be maintained because of the high subsidies, since the costs for fuel are high for the great distances ships often have to cruise out.

Again and again over the years, new species that previously were not considered by fisheries have become interesting, usually to replace species that were overfished. The pursuit of various species of *Sebastes* is a striking example of the substitution of an overfished species by a new one. The total catch has dropped since the 1970s, but it has still remained at a comparatively high level. This has been possible because new species have been targeted.

In the northeast Atlantic, starting in the 1950s, *Sebastes marinus* (golden redfish) was initially caught. In 1980 it still made up more than 40 per cent of the catch of *Sebastes* species. But then the stocks declined. In the 1990s *Sebastes marinus* made up less than 20 per cent of the total catch of *Sebastes* species in the northeast Atlantic. In lieu of *Sebastes marinus*, fishing of the Greenland stocks of *Sebastes mentella* (deepwater redfish) intensified. In this region the species is mainly demersal. As these Greenland stocks shrank, the focus shifted to the more pelagic-living *Sebastes mentella* stocks in the open Atlantic. Due to restraints on fishing, it has been possible for some time now for the *Sebastes mentella* stocks off Greenland to recover.

Destruction of unique habitats

Many species of deep-sea fish build up large stocks, especially at structures like seamounts, banks and cold-water coral reefs. Fishing for these species represents a potential threat to the environment, especially when demersal trawls are used that can destroy fragile corals. The prob-

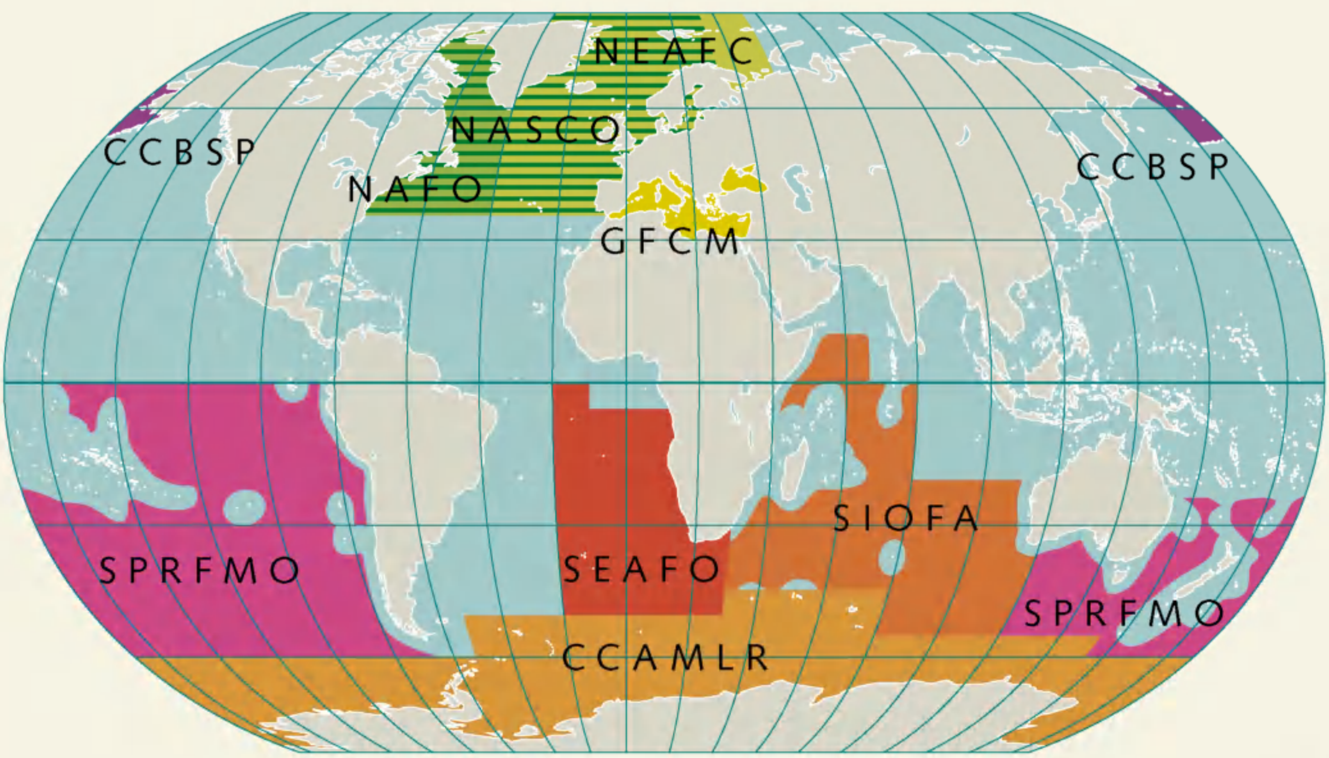
3.20 > In Norway's Trondheimsfjord the red bubble gum coral *(Paragorgia arborea)* occurs beside the white stony coral ***Lophelia pertusa.*** There are around 1000 cold-water coral species worldwide.

Catching fish in international waters

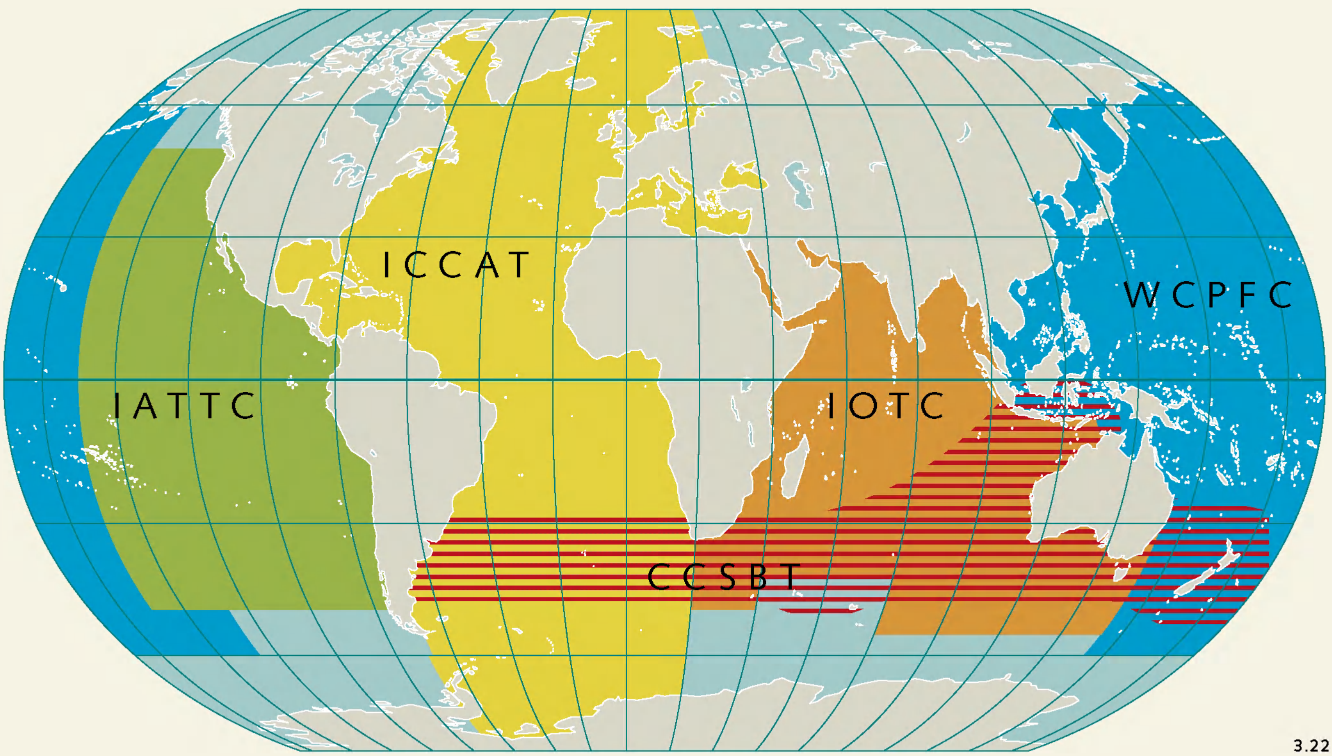
The fish catch in international waters outside the EEZ is regulated by the Regional Fisheries Management Organizations (RFMOs) and their member countries. These members include not only the bordering states, but also countries that are heavily involved in fishing in a given marine region. For example, China and Japan also fish in the northeast Atlantic. This is consistent with international maritime law and completely legitimate according to the principle of freedom of access to the high seas. The European countries, in turn, are represented in numerous RFMOs through the European Commission. Annual negotiations are held to determine which countries are allowed to catch how much of a species. Almost all commercially relevant fish species are covered by the RFMOs.

There are specific RFMOs for the management of certain fish species, for example, salmon and pollock. The catch of highly migratory species, above all tuna, is also regulated by special RFMOs. In these, the countries that carry out tuna fishing are represented as are the bordering and coastal states whose Exclusive Economic Zones are adjacent to the fishing ground. This also takes into consideration the fact that tuna, in contrast to most fish species, do not live in geographically defined stocks. Sharks are covered, in part, as a subgroup of the ICCAT.

There are only a few remaining marine regions today that are not supervised by RFMOs, or that are insufficiently supervised due to a political situation. These include the Indian Ocean around the Horn of Africa. Although the area is covered by the IOTC, fishing cannot be regulated due to piracy. Illegal, unreported and unregulated fishing (IUU fishing) is common there. The Arctic, on the other hand, is not yet managed by RFMOs because fishing there is rare. With the growing worldwide demand for fish, however, this region could become more interesting for fisheries in the future.



3.21



3.22

3.21 > RFMOs that manage fish stocks by region:

- North East Atlantic Fisheries Commission (NEAFC)
- Northwest Atlantic Fisheries Organization (NAFO)
- North Atlantic Salmon Conservation Organization (NASCO)
- South East Atlantic Fisheries Organisation (SEAFO)
- South Indian Ocean Fisheries Agreement (SIOFA)
- South Pacific Regional Fisheries Management Organisation (SPRFMO)
- Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)
- General Fisheries Commission for the Mediterranean (GFCM)
- Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea (CCBSP)

3.22 > RFMOs that manage highly migratory fish species, mainly tuna:

- International Commission for the Conservation of Atlantic Tunas (ICCAT)
- Indian Ocean Tuna Commission (IOTC)
- Western and Central Pacific Fisheries Commission (WCPFC)
- Inter-American Tropical Tuna Commission (IATTC)
- Agreement on the International Dolphin Conservation Program (AIDCP)
- Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

3.23 > Rockall, off Ireland. At its base is a marine area considered to be one of the most species-rich and deserving of protection in the northeast Atlantic.

lem is that corals grow very slowly, usually only a few millimetres each year. So it can take decades for the habitats to recover. Studies at several neighbouring seamounts off Tasmania have shown that 43 per cent of the species were previously unknown and thus could be unique. In areas where demersal trawls were used, the total number of species was diminished to 59 per cent of the original number. 95 per cent of the surface was reduced to bare, stony bedrock. It is thus highly conceivable that endemic species that only exist at a single seamount could be completely exterminated.

Is it possible to protect the deep sea?

In 2008, in response to the growing knowledge that deep-sea habitats are especially threatened by fisheries, the FAO established the International Guidelines for the Management of Deep-sea Fisheries in the High Seas. These guidelines are not legally binding. They do, however, contain clear recommendations for the protection of fish species that are vulnerable to overfishing. They relate to methods by which the fishing gear comes into contact with the sea floor. These guidelines, by definition, should regulate protection in international waters outside the Exclusive Economic Zone (EEZ), where freedom of the seas and fishing is recognized. The FAO refers to areas deserving protection as vulnerable marine ecosystems (VMEs). In addition to banks, seamounts and cold-water coral areas, these include large species-rich sponge communities as well as densely populated undersea hydrothermal vents and cold seeps. The following criteria are used to determine whether a marine area is given the status of a VME:

1. UNIQUENESS OR RARITY:
Ecosystems that are unique or contain rare species. The loss of the ecosystem cannot be compensated for by similar ecosystems. These include: habitats with endemic species, habitats with endangered species, breeding or spawning areas.

2. FUNCTIONAL SIGNIFICANCE:
Habitats that are important for the survival, reproduction or recovery of fish stocks, or are significant for rare or threatened species, or various development stages of these species.

3. FRAGILITY:
An ecosystem that is highly susceptible to destruction or weakening by anthropogenic activities.

4. SIGNIFICANCE FOR SPECIES WITH SPECIAL LIFE-HISTORY TRAITS:
Ecosystems that are characterized by species or assemblages with the following traits: slow growth rates, late sexual maturity, low or unpredictable reproduction, long-lived.

5. STRUCTURAL COMPLEXITY:
An ecosystem that is characterized by complex structures, for example, by corals or isolated rock outcrops. Many organisms are specially adapted to these structures. Such ecosystems often have high diversity.

The designation of an international marine area as a vulnerable marine ecosystem according to the FAO guidelines is decided, as a rule, by the Regional Fisheries Management Organizations (RFMOs). It is the task of the RFMOs to apportion the catch of fish stocks or individuals of migrating species such as tuna in their area among the member countries. In addition, they are responsible for ensuring that the protection measures and catch limits are complied with. RFMOs develop management plans and announce sanctions in cases of non-compliance. Critics claim that many fish stocks in areas managed by the RFMOs are still not fished with sufficient restraint, and that vulnerable areas are not adequately protected.

A number of regional fisheries management organizations have now placed certain VMEs within their areas under special protection, particularly those at several seamounts off southwest Africa. Fishing is either completely banned there or demersal trawl fishing is prohibited. Pelagic fish that swim in the upper water layers may still be fished. Fishing for demersal species, however, which live near the bottom, is halted. There are other protected areas with VMEs northwest of Ireland, including Hatton Bank and the Rockall Bank, which is several hundred kilometres long. Here the responsible RFMO has established Marine Protected Areas (MPAs), whose primary objective is to protect overfished stocks. The relatively small vulnerable marine ecosystems are located within these much larger MPAs. Demersal trawl fishing has been banned here to protect the cold-water corals.

Incidentally, one of the first protected areas in VME terms was established long before the FAO published its guidelines. In 1995, after the publication of studies on the devastating effects of demersal trawl fishing at seamounts, the Australian government established a deep-sea protected area of 370 square kilometres on the continental slope off Tasmania. There are 15 seamounts here and large stocks of orange roughy. The objective was to protect slow-reproducing fish species as well as their vulnerable habitats on the sea floor. The Australian officials only allow fishing down to a depth of 500 metres. This should prevent the overfishing of deep-sea fish and the fragile bottom from net contact. With this decision the Australian officials were more than 10 years ahead of their time and the FAO guidelines. On the other hand, in the region south of Tasmania there are a total of 70 seamounts and only 15 are protected. The question of whether the protected area is large and representative enough to preserve all of the species indigenous to the Tasmanian seamount region is still being discussed today.

The FAO guidelines for deep-sea fishing on the high seas were developed to protect vulnerable habitats in international waters. Of course, they also apply to equivalent deep-sea areas inside national waters that fulfil the criteria for a VME. In this respect, the guidelines are also an important orientation point for the countries themselves. Many nation-states have now designated valuable areas as VMEs and placed them under special protection. Norway, for example, protects parts of its cold-water coral regions in this way. Critics claim, however, that the extent of these areas is far from sufficient to preserve the full diversity of the cold-water coral systems.

Species and genus
A species is designated by a two-part name. The first part (for example, *Sebastes*) indicates the genus. Usually many closely related species belong to one genus. The second part indicates the species *(marinus)*. Although species can often be very similar to one another, such as, in birds, the blue tit and great tit, they still remain clearly separated, either by a large distance (continent) or because they no longer interbreed. Around 100 species belong to the genus *Sebastes*.

Illegal fishing

> In many maritime regions of the world, illegal fishing has massively contributed to the depletion of fish stocks, especially in developing countries' coastal waters. Better international cooperation to control fishing vessels is now being launched. The aim is to eliminate illegal fishing in future.

Unscrupulous fishing worsens the problems

Nowadays, the world's fish stocks are not only under threat from intensive legal fishing activities; they are also at risk from illegal, unreported and unregulated (IUU) fishing. It is difficult to estimate precisely the total catch from pirate fishing. Researchers are engaged in the painstaking process of collating data from various countries' fisheries control agencies, experts' estimates, trade figures and the findings of independent research expeditions in order to arrive at an approximate figure for the total IUU catch. As this is a black market, however, estimates are bound to be unreliable. Some experts put the annual figure at around 11 million tonnes; others suggest that it may be as high as 26 million tonnes – equal to 14 or 33 per cent respectively of the world's total legal catch (fish and other marine fauna) in 2011. These catches are additional to the world annual catch of fish and other marine fauna, currently 78.9 million tonnes.

For many years, however, too little account was taken of IUU fishing in estimates of fish stocks. This is problematical, for unless the IUU share is factored into the calculations, the legal catch quotas for a given maritime region cannot be determined correctly. Based on the assumption that less fish is being caught than is in fact the case, experts overestimate the size of the stock and set the following year's catch quotas too high, potentially entrenching and accelerating the overexploitation of the stock.

IUU fishing also exacerbates the problem of overfishing because IUU vessels even operate in marine protected areas where a total fishing ban has been imposed. It also pays little or no heed to fisheries management plans which are intended to conserve overexploited or depleted stocks.

However, the main reason why IUU fishing is a particularly critical issue today is that many fish stocks have already been overexploited by legal fishing activities. IUU fishing therefore puts fish stocks under additional pressure. If stocks were being managed sustainably, on the other hand, IUU fishing would no longer exacerbate an already difficult situation to the extent that it does today.

The Food and Agriculture Organization of the United Nations (FAO) defines three categories of IUU fishing:

ILLEGAL FISHING refers to fishing activities conducted by foreign vessels without permission in waters under the jurisdiction of another state, or which contravene its fisheries law and regulations in some other manner – for example, by disregarding fishing times or the existence of the state's protected areas. For example, some IUU vessels operate in waters under the jurisdiction of West African states. As these countries generally cannot afford to establish effective fisheries control structures, the IUU vessels are able, in many cases, to operate with impunity.

UNREPORTED FISHING refers to fishing activities which have not been reported, or have been misreported, by the vessels to the relevant national authority. For example, some vessels harvest more tonnage than they are entitled to catch under official fishing quotas. In 2006, for example, several Spanish trawlers were inspected by the Norwegian Coast Guard near Svalbard (Spitsbergen). The trawlers were found to hold not only the reported catch of headed and gutted cod but also a total of 600 tonnes of cod fillets which had not been reported to the Norwegian authorities. The Norwegian authorities subsequently imposed fines on the Spanish trawler company equivalent to 2 million euros.

3.24 > A chase at sea near South Korea: an entire fleet of illegal Chinese fishing vessels attempts to evade the South Korean Coast Guard. The fishermen were arrested by armed units soon afterwards.

UNREGULATED FISHING refers to fishing activities in areas where there are no applicable management measures to regulate the catch; this is the case in the South Atlantic, for example. The term also applies to fishing for highly migratory species and certain species of shark, which is not regulated by a Regional Fisheries Management Organization (RFMO). And finally, the term applies to fishing activities in international waters in violation of regulations established by the relevant RFMO.

Although unregulated fishing is not in fact illegal under the law of nations applicable to the high seas, it is nonetheless problematical. It results in additional fish being caught over and above the maximum catches agreed by RFMO member states for their respective regions. As a result, fully exploited stocks can easily become overexploited. Furthermore, IUU fishermen often ignore the existence of marine protected areas established by the Regional Fisheries Management Organizations to support the recovery of overexploited stocks.

Why does IUU fishing exist?

From the fishermen's perspective, IUU fishing is highly attractive as they pay no taxes or duties on these catches. A further reason why IUU fishing takes place on such a large scale is that it can often be practised with impunity. This is mainly the case in the territorial waters or exclusive economic zones of countries which cannot afford to set up costly and complex fisheries control structures such as those existing in Europe.

The situation is especially difficult in the developing countries. In a comprehensive analysis of IUU fishing worldwide, researchers conclude that IUU fishing is mainly practised in countries which exhibit typical symptoms of weak governance: large-scale corruption, ambivalent legislation, and a lack of will or capacity to enforce existing national legislation.

The Sub-Regional Fisheries Commission (SRFC), comprising seven member states in West Africa (Cape Verde,

3.25 > Transshipment is typical of IUU fishing. As seen here off the coast of Indonesia, smaller fishing vessels transfer their illegally caught fish onto larger refrigerated transport ships (reefers). The fishing vessels are restocked with fuel and supplies at the same time, enabling them to remain at sea for many months.

Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone), has produced a detailed list of the various causes of IUU fishing:

- There are insufficient and inadequately trained personnel in the relevant authorities.
- The authorities' motivation to invest in relevant personnel is poor. Financially weak states set other priorities.
- Salaries are low, and vessel owners take advantage of this situation to make irregular payments to observers/ fisheries administrators to cover up their activities.
- The purchase, maintenance and operational costs of patrol boats and aircraft are very high. For effective control, there must be sufficient time spent out at sea or in the air. However, in some states, even though they are available, they are not operational due to logistical problems – lack of fuel, proper maintenance regime, etc.

Where does IUU fishing take place?

The situation off the coast of West Africa is particularly critical. Here, IUU fishing accounts for an estimated 40 per cent of fish caught – the highest level worldwide. This is a catastrophe for the region's already severely overexploited fish stocks. Confident that as a rule, they have no reason to fear any checks by fisheries control agencies or prosecution, some IUU vessels even fish directly off the coast – in some cases at a distance of just one kilometre from the shore. A similar situation exists in parts of the Pacific. Indonesian experts report that it is extremely difficult to track the whereabouts of IUU vessels around the country's islands and archipelagos. The volume of the illegal catch here is correspondingly high, amounting to 1.5 million tonnes annually. The Arafura Sea, which lies between Australia and Indonesia, is also very severely affected. After West Africa, the Western Central Pacific Ocean is the region with the highest rate of IUU fishing worldwide. In the Western Pacific, IUU fishing accounts for 34 per cent of the total catch.

A similar situation exists in the Northwest Pacific Ocean, especially in the West Bering Sea. Here, IUU fishing is mainly practised by China and Russia and amounts to 33 per cent of the catch.

Figures for the Southwest Atlantic are unreliable, but experts estimate that IUU fishing here amounts to 32 per cent.

What's the catch?

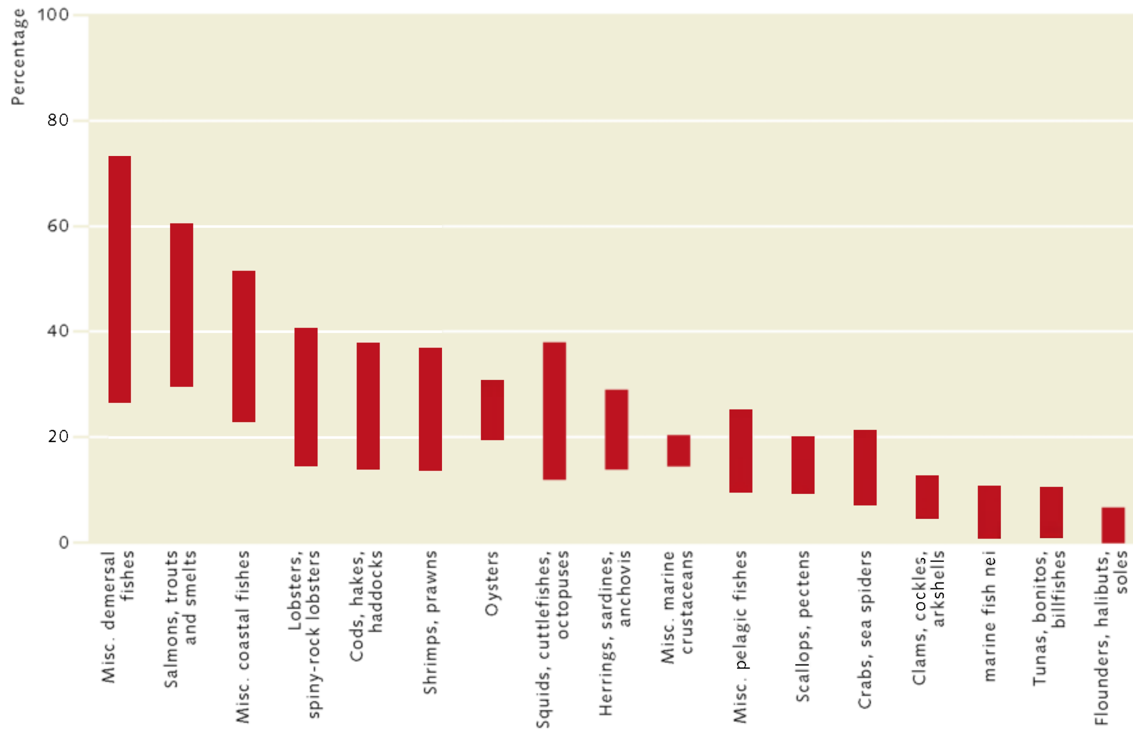
IUU fishing often targets high-value demersal species (i.e. those which live and feed on or near the bottom of the sea) such as cod, as well as salmon, trout, lobster and prawns. It is mainly interested in species which are already overexploited by legal fishing or which are subject to restrictions for fisheries management purposes. As these species can only be traded in small quantities, demand and prices are high – making this a lucrative business for IUU fishermen.

Too many loopholes

Combating illegal, unreported and unregulated fishing at sea is generally extremely expensive and very complex. Affluent countries such as Norway can afford to enforce stringent controls in the waters under their jurisdiction and deploy a large fleet of vessels and a great many personnel for this purpose. An effective and possibly less costly alternative is to carry out rigorous checks in port. However, this only helps to curb IUU fishing if all ports cooperate.

In the European Union (EU), regulations in force since 2008 and 2009 contain uniform provisions on the type of controls to be carried out in EU ports. Since then, it has become very difficult for IUU vessels to land their catches in EU ports.

Nonetheless, there are still ports in other regions where IUU fishermen can land their illegally caught fish with no repercussions. Here too, it is mainly the developing countries, with their absence of controls, which are particularly suitable for illegal transshipment. However, examples such as the Spanish trawlers near Svalbard



3.26 > Different species groups (fish and other marine fauna) are affected by IUU fishing to varying degrees. One particular study has shown that from 2000 to 2003, IUU fishing mainly targeted demersal species (i.e. those which live and feed on or near the bottom of the sea). The figure shows the illegal and unreported catch, as a percentage of reported catch, by species group.

show that even fishermen from EU countries are not immune to temptation and that the prospect of a healthy profit may persuade them to fish illegally.

The problem is exacerbated by the fact that not every IUU vessel needs to put into port in order to land its catch immediately. In many cases, especially off the coast of West Africa, the smaller fishing vessels load their catch onto larger refrigerated ships (known as reefers) while at sea. During this transshipment, fishermen on board are also resupplied with food and fuel, enabling them to remain at sea for many months.

The Sub-Regional Fisheries Commission (SRFC) concludes that some IUU vessels off West Africa are in operation 365 days of the year, putting massive pressure on fish stocks. The refrigerated ships then make for ports in countries with lax controls, enabling them to land their catches unhindered.

The practice of using a flag of convenience (FOC) also makes it easier to engage in IUU fishing activity. Instead of registering the ships in the shipping company's home state, IUU fishers operate their vessels under the flag of another state, such as Belize, Liberia or Panama, with less stringent regulations or ineffective control over the operations of its flagged vessels.

By switching to a foreign register of ships, restrictive employment legislation and minimum wage provisions in the home country can also be circumvented, allowing the shipping companies to pay lower wages and social insurance contributions for their crews than if the vessel were registered in Germany, for example. Furthermore, fisheries legislation in "flag-of-convenience" states is often extremely lax. These countries rarely, if ever, inspect their vessels for illegal catches.

Monitoring of onboard working conditions is also inadequate, and conditions are correspondingly poor. The fishermen work for low wages on vessels whose standards of accommodation are spartan in the extreme, and which rarely comply with the current safety standards applicable to merchant shipping under the International Convention for the Safety of Life at Sea (SOLAS regulations). The Convention contains exact details of equipment that must be available to ensure safety on board.

Combating IUU fishing

Today, IUU fishing is a global problem, with vast amounts of fish being caught illegally. Nonetheless, the worst seems to be over. IUU fishing was at its peak in the mid 1990s. Since then, according to the FAO, it has declined in various maritime regions, partly due to more stringent government controls. In Mauritania, for example, fisheries control structures have been established with support from German development assistance, with ships now being tracked by a satellite-based vessel monitoring system (VMS).

Other countries are now more inclined to comply with the relevant laws and agreements. Poland is a good example. For many years, Polish fishermen were constantly in breach of the EU's quotas for cod fisheries for the eastern Baltic, routinely catching far more fish than the total allowable catch. This was tolerated by the Polish government of the day. With the change of government in November 2007, however, the situation changed, and Poland is now complying with the quotas.

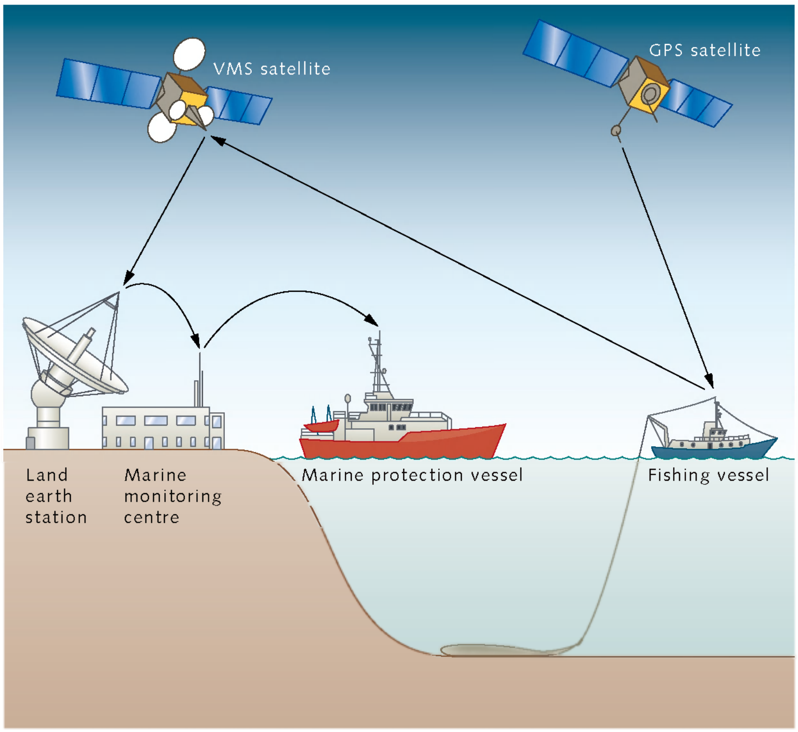
World population growth is likely to drive up the demand for fish even further. IUU fishing will therefore continue to be an attractive option, and can only be curbed with more stringent controls. To that end, controls and sanctions must be coordinated and consistently enforced at the international level. The FAO therefore adopted the Code of Conduct for Responsible Fisheries (CCRF) in 1995, which was endorsed by around 170 member states. Although the CCRF is voluntary and non-binding, a number of countries, including Australia, Malaysia, Namibia, Norway and South Africa, have incorporated some of its provisions into national law. Predictably, IUU fishing has decreased in these regions.

In order to prevent landings of illegally caught fish in the EU, Council Regulation (EC) No 1005 on IUU fishing was adopted in 2008; this was followed by Council Regulation (EC) No 1224 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy in 2009. These regulations describe in precise detail which vessels may land fish in the EU, which specific documents they must produce, and how the catch is to be controlled. The aim is to prevent IUU fishing EU-wide and close any loopholes. The current procedure for landing catches in an EU port is therefore as follows:

A Before the vessel lands its catch, it must provide reasonable advance notice.

B Once the vessel has docked,
- the fishing licence is checked. This includes the vessel's operating licence issued by the flag state and information showing who is authorized to operate the vessel.
- the fishing authorization is checked. This contains detailed information about the vessel's permitted fishing activity, including types of fish, times, locations and quantities.
- the catch certificate is checked. This contains information about the catch currently on board, including where and when it was caught.
- the logbook in electronic format is checked. The master of the vessel must record on a daily basis when and where the fish was caught, and in which quantities.

3.27 > An armed unit of the South Korean Coast Guard arrests Chinese fishermen who have been fishing illegally in South Korean waters. Very few countries can afford such effective fisheries control structures.



3.28 > Nowadays, fishing vessels must be equipped with electronic devices, or "blue boxes", which form part of the satellite-based vessel monitoring system (VMS). The blue box regularly sends data about the location of the vessel to the fisheries monitoring centre (FMC). Vessels are also equipped with GPS transmitters which track the ship's speed and position.

If a ship lacks any of the relevant documentation, it is not permitted to land its catch and must head instead for a port outside the EU. Permission to land the catch is also refused if there are any discrepancies between the figures given in the catch certificate and the daily entries in the electronic logbook. In this case, the fisheries control agency – in Germany, this is the Federal Office for Agriculture and Food – may require vessel monitoring data to be produced. Nowadays, electronic devices, or "blue boxes", are installed on board fishing vessels and form part of the satellite-based vessel monitoring system (VMS). The blue box regularly sends data about the location of the vessel to the fisheries monitoring centre (FMC) responsible for the area where the vessel is currently fishing. If the vessel enters territorial waters or fishing grounds where it is not permitted to fish, the master of the vessel can be prosecuted.

In suspicious cases, the state in which the fish is to be landed may request the VMS data from the state in whose waters the vessel has been fishing. Furthermore, the landing procedure is observed in each EU port. The fisheries control agency checks how much is being landed and which species comprise the catch. Random checks are also carried out periodically. Relevant measures have been agreed by the EU and the other countries belonging to the North East Atlantic Fisheries Commission (NEAFC), including Iceland and Norway, putting this region beyond the reach of IUU fishermen.

The same applies to the Northwest Atlantic, ports in the US, Canada and other member states of the Northwest Atlantic Fisheries Organization (NAFO), such as Denmark, Iceland and Norway.

The example of Mauritania shows that more stringent controls can be introduced to good effect in developing countries as well. VMS-based monitoring of vessels and controls of landings in port have largely eliminated IUU fishing here.

The FAO has been lobbying for many years for stringent and uniform controls worldwide and is a firm advocate of close cooperation among ports. It takes the view that a concerted approach by ports will make it more difficult for IUU fishing vessels to find a port where they can land their catches without fear of repercussions. However, ports derive an income stream from the charges they impose on vessels using their facilities. Ports which are used by a large number of vessels generate very large amounts of revenue, and for some ports, this takes precedence over the protection of fish stocks. Although a draft Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing has existed for a good three years, based on the FAO Code of Conduct, no specific measures to enforce global action have been adopted yet.

A further initiative to combat IUU fishing consists of the blacklists held by the RFMOs. These include details of vessels which have attempted at some point to land IUU fish at an RFMO port. Port and fisheries control authorities regularly refer to these blacklists. This "name and shame" policy is intended to make it even more difficult for IUU vessels to find ports where they can land their catches. However, here too, states must be willing to cooperate in order to combat IUU fishing effectively. As long as the lack of international coordination allows loopholes to exist, IUU fishing will continue.

Conclusion

Slow but steady improvement

More than a quarter of the world's fish stocks are now classed as overexploited or depleted. Since 1950, the world annual fish catch has increased five-fold. In light of these statistics, it has often been claimed in recent years that overfishing will soon empty our oceans. However, the situation is by no means the same in all maritime regions. Although it is often the short-term profits that count, some countries such as Australia, New Zealand and the U.S. are now structuring their fishing industries towards sustainability. Here, the aim is to establish a future-proof fishing industry which yields abundant harvests while maintaining fish stocks.

What is worrying is that much of the information provided by many countries about their fish stocks and catches is still very patchy or inaccurate. As a result, the status of stocks is almost impossible to verify in many cases. In the past, many fishing companies therefore simply continued to fish as before, resulting in overfishing. For the future, then, there is only one solution: where there is a question mark over the future of fish stocks, fishing companies must reduce their catch.

In the past, scientists' recommendations on the total allowable catch (TAC) were often ignored. This situation is now changing to some extent, notably in the USA, although not in the case of tuna: the International Commission for the Conservation of Atlantic Tunas (ICCAT) is still setting larger total allowable catches for high-value and overexploited species of tuna than scientists recommend.

A gradual improvement can be observed in deep-sea fishing. From the 1970s to the 1990s, it was above all the Japanese, Russian and Spanish fleets which penetrated into ever-deeper waters and extended their fishing operations to shoals of fish which inhabit cold-water corals or seamounts (undersea mountains). This was highly problematical for two reasons. Firstly, many species of deep-sea fish are very slow to reproduce, so stocks were overexploited within just a few years. Secondly, bottom trawling inflicted severe damage on sensitive deep-sea habitats. Many countries, including Australia and New Zealand, have learned from past mistakes and have now established protected areas where fishing has either stopped completely or bottom trawling, at least, is now banned. And although critics claim that the number of protected areas falls a long way short of what is needed, it is at least a start.

Experts are also concerned about illegal, unreported and unregulated (IUU) fishing, which is still widespread and puts extra pressure on already overexploited stocks. The volume of illegally caught fish is estimated to be equal to 14 to 33 per cent of the world's total legal catch. Combating IUU fishing is difficult as IUU vessels often operate in the territorial waters of developing countries which cannot afford to establish complex and expensive monitoring, control and surveillance systems. Some years ago, the FAO produced a catalogue of measures to prevent, deter and eliminate IUU fishing which envisages closer international cooperation between port States. The aim is to prohibit IUU vessels from landing the fish, thus preventing the illegally caught fish from reaching the markets. Implementation of these joint "port State measures" has only recently begun, however, and progress is slow. The introduction of blacklists of all IUU vessels already identified is a promising step and is intended to make it more difficult to land IUU catches. Furthermore, a number of international assistance projects have helped developing and newly industrialized countries such as Mauritania to establish radar-based vessel monitoring systems or effective fisheries control structures.

4 A bright future for fish farming

> It is highly unlikely that wild capture fisheries will be able to produce higher yields in future. For aquaculture the opposite is the case. No other food production sector has grown as fast over the past 20 years. Abuses such as antibiotics in fish feed and the over-fertilization of marine waters, however, have brought the industry into disrepute. It must now prove that large-scale fish farming is possible without placing unacceptable demands on the environment.

Aquaculture – protein provider for the world

> During the 1970s aquaculture was a relatively insignificant industry, but today it is almost as productive as the ocean fishing sector. About 600 aquatic species are now raised in captivity, with different species being preferred for different regions. Experts predict that the importance of fish farming will increase even more in the future, because it has clear advantages over beef and pork production.

Fish for 9 billion people

The global population is growing at a breathtaking pace. In 1950 the world had a total of 2.5 billion people, a figure that had burgeoned to 7 billion by 2012. According to United Nations estimates, this number could exceed the 9 billion mark by mid-century. As populations increase, so too does the need for food. Fish is a widespread, affordable and healthy source of valuable protein. There is no question, therefore, that the global demand for fish will intensify in future.

When we consider that the amount of wild-captured fish has not increased in recent years, only one alternative remains: fish farming, or aquaculture, must fill the gap. Is it capable of doing so? This is the question many scientists around the world are trying to answer.

4.1 > No other food production sector has achieved such high growth rates as aquaculture in the past 40 years.

Average annual production increase (1970 to 2008)	
Plant Food Commodities	
Cereals	2.1 %
Pulses	1.1 %
Roots and tubers	0.9 %
Vegetables and melons	3.4 %
Animal food commodities	
Beef and buffalo	1.3 %
Eggs	3.2 %
Milk	1.5 %
Poultry	5.0 %
Sheep and goats	1.8 %
Fish	8.4 %

For many years aquaculture played a relatively minor role in global fish production, but its significance has increased dramatically over the past 20 years, spurred by the demand from Asia's fast-growing populations. Today, aquaculture makes a major contribution to human nutrition. For example, it provides a large proportion of the animal protein consumed in China, Bangladesh and Indonesia. Global production of fish, mussels and crab in 2010 was almost 60 million tonnes, a figure which includes production in marine waters, brackish water and freshwater. Aquaculture production is now about three quarters of that from ocean fish and seafood caught in the wild. In 2011 this amounted to 78.9 million tonnes.

No other food industry has shown such growth as aquaculture in recent decades. Between 1970 and 2008 annual production worldwide increased by an average of 8.4 per cent; much more than poultry farming and egg production, which have the second highest growth rates after aquaculture.

Asia – the cradle of fish farming

Aquaculture is not equally important in all countries and all regions. For instance, central Europe in general prefers its fish to be caught in the wild. In China on the other hand, fish farming is widespread and has enjoyed a millennia long tradition, since carp were first domesticated. China is still the undisputed leader in aquaculture production. Since 1970 it has recorded annual growth rates in aquaculture production of an average 10 per cent, although recently these have slowed to about 6 per cent. Today 61 per cent of global production comes from China, with

Asia as a whole supplying a massive 89 per cent. This figure includes both fish farming inland (in freshwater) and in coastal areas.

The proportion generated in the other world regions is therefore small. Europe and America produced approximately 2.5 million tonnes each in 2010, Africa a little below 1.3 million tonnes and Oceania less than 200,000 tonnes.

For a long time aquaculture in many Asian countries has mainly provided food for local populations. Nations such as Thailand and Vietnam traditionally farm fish in the flooded rice fields; many people catch their lunch or evening meal from the neighbouring rice paddy. This widespread peasant practice, never captured in actual numbers, makes it difficult to estimate the actual extent of aquaculture production. For this reason experts assume that some Asian states produce totals even greater than those quoted in the statistics.

What is certain, however, is that aquaculture has not developed equally in all Asian states. The 10 largest producers alone generate 53 million tonnes, a massive 86 per cent of global aquaculture production, with the remaining Asian states producing only about 1.5 million tonnes. These countries still use only small amounts of farmed fish for their own consumption needs.

Modest growth in America and Europe

Between 1970 and 2000 aquaculture production in America and Europe grew by 4 to 5 per cent per annum. Since then it has increased by a moderate 1 to 2 per cent a year. Chile is the most important producer in America, since major salmon farms were established there over the last 20 years. In 2010 Chile supplied a good 700,000 tonnes of farmed fish, mainly salmon. The second largest producer on the American continent is the USA with slightly under 500,000 tonnes of fish.

Norway is the most important aquaculture nation in Europe, with about 1 million tonnes of farmed fish, followed by Spain with a good 250,000 tonnes; France takes third place with 220,000 tonnes. The main aquatic products farmed in Europe are salmon, rainbow trout, eel and carp.

World	Tonnes	Percentage
China	36,734,215	61.35
India	4,648,851	7.76
Vietnam	2,671,800	4.46
Indonesia	2,304,824	3.85
Bangladesh	1,308,515	2.19
Thailand	2,286,122	2.15
Norway	1,008,010	1.68
Egypt	919,585	1.54
Myanmar	850,697	1.42
Philippines	744,695	1.24
Others	7,395,281	12.35
Total	59,872,600	100.00

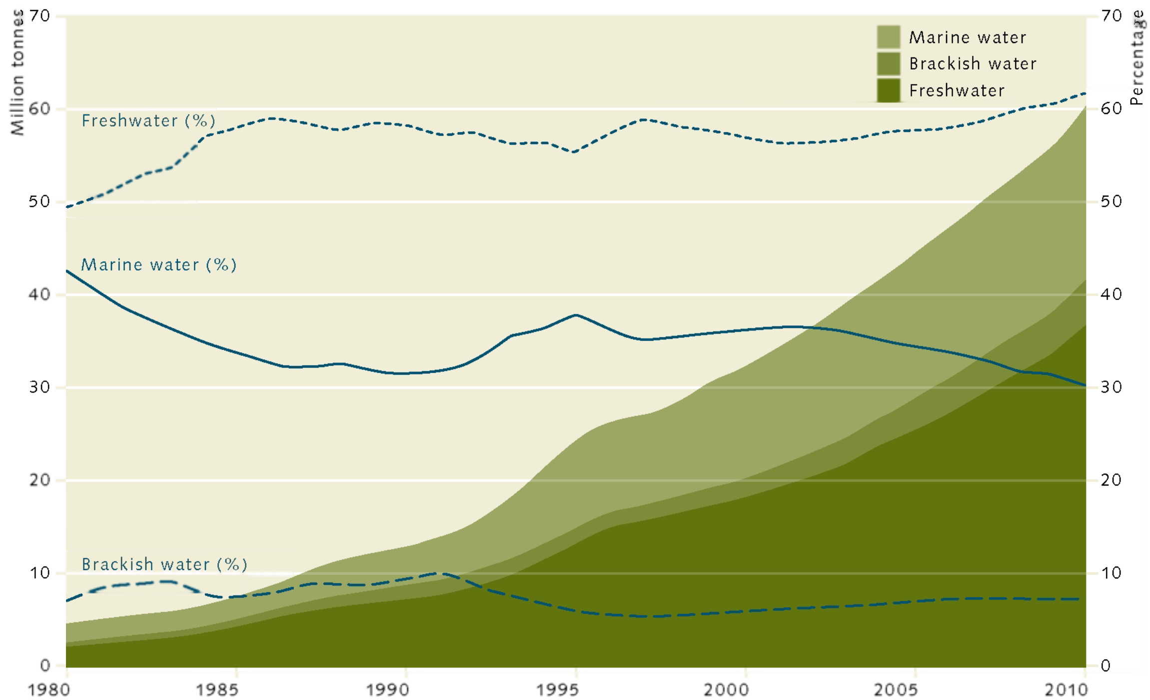
4.2 > Asia dominates world aquaculture. The total output of the top ten producer countries worldwide is shown. The amounts of farmed algae and aquaculture products not used as food are not included

Aquaculture – a prospect for Africa?

Developments in Africa are of paramount interest. Although aquaculture production was barely 1.3 million tonnes in 2010, experts nonetheless expect to see fish farming become further established in Africa. It would enable the – relatively easy – generation of large amounts of valuable protein for the growing population.

Egypt is the trailblazer here, with large numbers of finfish (tilapias, mullets and catfish) being farmed in the Nile Delta. Aquaculture is also expected to grow wherever fish is a traditional food, but where insufficient wild fish will be available to meet the growing demand.

The lack of wild fish, particularly in urban centres, is forcing a change in thinking. Take Lagos, the capital of Nigeria, on the Gulf of Guinea as an example. The people living around the Lagos Lagoon have always farmed catfish for their own use, but now the early stages of commercial aquaculture are becoming evident, and further expansion is expected. Similar developments are being



4.3 > Marine water, brackish water and freshwater – aquaculture production has shown strong growth in all areas over the past 30 years.

seen in Accra, the capital of Ghana, and Lusaka, the capital of Zambia. Small and medium-sized businesses are also becoming involved in Zambia and Uganda, with the aim of operating commercial aquaculture on a large scale. Experts are praising these approaches, because they believe this is the only way of making enough fish available to supply local markets.

Furthermore, there is great interest in the large-scale expansion of fish farming in countries such as South Africa. For about 5 years now a national aquaculture association has been involved in setting up aquaculture operations. Some of the technology applied will be exported to other African nations, although in some countries the importation of the facilities is still complicated by exorbitantly high duties.

In many other regions of Africa, however, an aquaculture industry is still a long way off. For this reason non-governmental organizations (**NGOs**) have been trying for some years to encourage aquaculture among individual communities.

With the exception of a few nations, aquaculture in Africa is still at an embryonic stage, and its potential is far from being exploited. It will take at least 10 years before any appreciable production increases are seen. Unfortunately, even if strong expansion should occur, aquaculture is unlikely to be able to keep pace with the needs of the fast-growing population.

From salmon to pangasius – aquaculture products

About 600 species are raised worldwide by aquaculture. Depending on local traditions and preferences, different species are in high demand in different regions of the world. The species raised include fish, crabs, mussels, amphibians (frogs), aquatic reptiles, sea cucumbers, jellyfish and sea squirts (fleshy organisms which live on the sea floor and filter the water). China farms mussels and carp in particular, and in terms of the latter, has done so for several thousand years. The carp is also a popular farmed fish throughout the rest of Asia. Finfish are found here, too, along with catfish and shrimps, and prawns which are exported all over the world. For some years now a popular Asian export fish has been the pangasius, of which there are several different species. These catfish are white-fleshed, neutral-tasting and almost bone-free. At first it was necessary to catch juvenile fish in the wild for breeding purposes, but in the early 1990s a French-Vietnamese project succeeded in breeding two types of pangasius in captivity. Only then was it possible to breed the fish in large numbers, allowing its export on a grand scale. Today the export of pangasius is a global winner.

In Europe, however, the farming of mainly salmonids is preferred, including salmon and trout along with turbot and mussels. Only small numbers of carp and other finfish are bred in captivity. In the past 10 years production of sea bass, common dentex and gilthead seabream has expanded, particularly in Greece, Italy and Turkey, mostly in net cages in coastal bays.

Salmonids are also the dominant group of farmed fish in South America, mainly in Chile, followed in equal parts by shrimps, prawns and mussels. Shrimps and prawns, catfish, mussels and salmonids are farmed in North America, mainly in Canada. Tilapia, catfish and other finfish are of particular interest in Africa, while shrimps and prawns predominate in Oceania.

Aquaculture production (Million tonnes)		
Species group	**2003**	**2008**
Carps	15.04	19.72
Catfish	1.03	2.78
Tilapias	1.59	2.80
Eels	0.32	0.48
Salmonids	1.85	2.26
Other finfish	4.40	5.79
Bivalves	11.06	12.65
Gastropods	0.21	0.37
Crabs and lobsters	0.49	0.76
Shrimps and prawns	2.59	4.35
Other invertebrates	0.12	0.31

4.4 > In terms of aquaculture production, carp is the most important fish worldwide.

Algae for Asia

The cultivation of algae is less widespread than that of aquatic animals. It is only practised in about 30 countries throughout the world, predominantly in Asia. In most cases cultivation is of large algae such as kombu *(Laminaria japonica)*, a Japanese seaweed which is several metres long. It is now farmed mainly in marine water and brackish water along the coast of China. Kombu is often used as a soup ingredient. Although the 19 million tonnes of algae produced in 2010 was much less than farmed aquatic animals, nonetheless its growth rate has been similarly strong in recent years – an average of 9.5 per cent per annum during the 1990s and 7.4 per cent in the past decade. In 1990 global algae production was 3.8 million tonnes. The most

	Milk	Carp	Eggs	Chicken	Pork	Beef
Feed conversion (kg of feed/kg live weight)	0.7	1.5	3.8	2.3	5.9	12.7
Feed conversion (kg of feed/kg edible weight)	0.7	2.3	4.2	4.2	10.7	31.7
Protein content (% of edible weight)	3.5	18	13	20	14	15
Protein conversion efficiency (%)	40	30	30	25	13	5

4.5 > Fish can convert feed into body mass much more efficiently than birds or mammals. They provide a great deal more mass per kilogram of feed.

important regions are China (58.4 per cent of global production), Indonesia (20.6 per cent) and the Philippines (9.5 per cent). Most of the algae produced worldwide is used in the cosmetics, chemical and food industries. Only a small proportion is used for human consumption, as a base for soups. The tropical algae *Eucheuma* and *Kappaphycus*, harvested throughout the Indo-Pacific region between the island of Zanzibar and the Philippines, are also of significance. They offer many fishermen an additional income and are utilized in the chemical, health and biological industries as a bacterial growth medium.

The strengths and weaknesses of aquaculture

Aquaculture has come in for some hefty criticism in recent years. For various reasons it still attracts controversy. Food, faecal and metabolic wastes from intensive fish farms can lead to the **eutrophication (over-fertilization)** of water in rivers and coastal bays. There have also been complaints that fish farmed under intensive conditions for maximum yields are more susceptible to disease than their relatives in the wild. Tremendous amounts of antibiotics and other medications are used to fight disease, particularly in relation to shrimp on farms in South East Asia – with unforeseeable consequences for surrounding ecosystems and consumer health. In some cases these points are valid, but they should not detract from the fact that aquaculture can be a very efficient and sustainable method of supplying humans with animal proteins – and counteracting over-fishing.

The farming of the classic common carp or mirror carp provides a positive example of environmentally-sound aquaculture. Carp are bottom feeders, generally eating small aquatic animals, plants, dead plant matter and waste

4.6 > In Belize, in Central America, the construction of huge aquaculture facilities has involved the destruction of large tracts of land and mangroves. The effluent is discharged to the sea without any prior treatment. Such operations have brought the sector into disrepute.

material which gather on the pond floor. They also sieve the water to extract suspended solids, thus helping to keep the water clean. Carp ponds often have very clear water. Intensive mussel farming also helps to keep the water clean. Mussels filter large amounts of water, sieving out tiny particles of food, thus counteracting the over-fertilization of water and **algal blooms.**

Although the nutrient-rich effluents from aquaculture facilities can lead to problems in rivers or coastal areas, nonetheless many fish farms are more environmentally-friendly than, for instance, the intensive farming of pigs or cattle. The latter emit large quantities of nitrogen and phosphorus from the slurry and manure used to fertilize the land. Aquaculture produces far lower emissions of nitrogen and phosphorus and can roughly be compared with those from the much less problematic farming of poultry. This is made abundantly clear by the example of the Mekong Delta. Only about 1 to 2 per cent of nutrient inflows into the delta come from pangasius aquaculture. The majority comes from agriculture, the production of vegetables and fruit as well as from untreated municipal sewage and industrial effluent. Aquaculture also scores well when compared to livestock breeding because fish and other aquatic organisms need less nourishment to build body mass than land animals. Therefore a lot less feed is required to produce 1 kilogram of carp than to produce 1 kilogram of chicken, beef or pork. One reason for this is that fish are cold-blooded creatures, meaning that their body temperature is approximately the same as that of their surroundings. They therefore need far less energy to produce heat than warm-blooded mammals or birds. Also, it takes greater expenditure of energy to move on land than in the water. As water is denser than air, it provides buoyant lift to the body, meaning that fish are supported without the development of heavy skeletal mass. Many marine animals such as mussels, snails and sea cucumbers also manage without an internal skeleton. This saves them the energy they would otherwise use to build bones. Fish have another energy advantage, too: they are capable of releasing into the water (as ammonium, a simple chemical compound) any surplus nitrogen they may have absorbed with their food. In contrast, land-based animals have to use energy to convert nitrogen into urea or uric acid. Only in this chemical form are they able to excrete the nitrogen with their faeces or urine.

Commodity	Nitrogen emissions (kg/tonne protein produced)	Phosphorus emissions (kg/tonne protein produced)
Beef	1200	180
Pork	800	120
Chicken	300	40
Fish (average)	360	102
Bivalves	–27	–29
Carps	471	148
Catfish	415	122
Other finfish	474	153
Salmonids	284	71
Shrimps and prawns	309	78
Tilapia	593	172

4.7 > Aquaculture emits much less nitrogen and phosphorus per tonne of produced protein than livestock farming. Farmed mussels even lower nitrogen and phosphorus levels as they filter the water. However, this also means that mussels from highly polluted waters can themselves contain high nitogen and phosphor levels.

Fish for all?

In an international collaboration scientists have investigated whether aquaculture and commercial fishing will be capable of meeting the global demand for fish in 2050. They are optimistic, believing that yes, they can. However, this would depend upon the world's fish stocks being managed sustainably in the long term. Also, the fish used as feed in aquaculture in the form of fishmeal and fish oil must be utilized more efficiently. Scientists have also queried the predicted direct impact of climate change and ocean warming on potential marine fisheries procduction. They have concluded that the amount of wild marine fish available for fisheries worldwide will probably be redistributed due to climate change and predict a slight 6 per cent overall increase on marine fisheries potential.

Towards more eco-friendly aquaculture

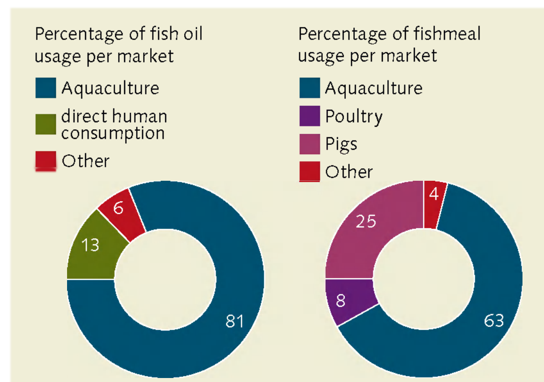
> Aquaculture is expected to satisfy the growing world population's demand for fish – and at the same time protect ocean fish stocks. Hopes are pinned on farming as an alternative to over-fishing. But the use of copious amounts of feed derived from wild fish, the destruction of mangrove forests and the use of antibiotics have given fish farming a bad name. Current research and development projects, however, show that environmentally-sound aquaculture systems are possible.

What do farmed fish eat?

The impact of aquaculture on the environment depends on several factors. It makes a difference whether the fish are farmed inland in freshwater, or along coastal areas. Intensive fish farms in coastal waters can pollute entire bays with uneaten food and fish faeces. Large areas of land are sacrificed to set up ponds, for example. An accumulation of effluent from aquaculture facilities can cause over-fertilization if it contains excess nutrients. Moreover it can contain residues of veterinary drugs. Feed is another important factor to consider when carrying out an environmental audit for an aquaculture operation. First of all, it is crucial to ascertain if any feeding at all is required, and if so, what kind of feed should be given to the aquatic animals. The aquaculture industry differentiates between natural feed and artificial feed.

- Natural feed includes the organisms that fish find and exploit in their surroundings. For example, mussels extract nutrients from the water without needing extra food. Carp feed on mosquito larvae, small mussels and zooplankton.

- Artificial feed (mostly in pelletized form) is processed in factories by feed manufacturers. The pellets are made of grain, fishmeal and fish oil. They contain all the nutrients which the species of farmed fish requires, and also a high proportion of protein and fat. Pellets are used for intensive fish farming – by companies which breed and sell fish on a grand scale. Salmon, tilapia, sea bass and some shrimps and lobster are fed with diets that contain fishmeal and fish oil from marine origin.

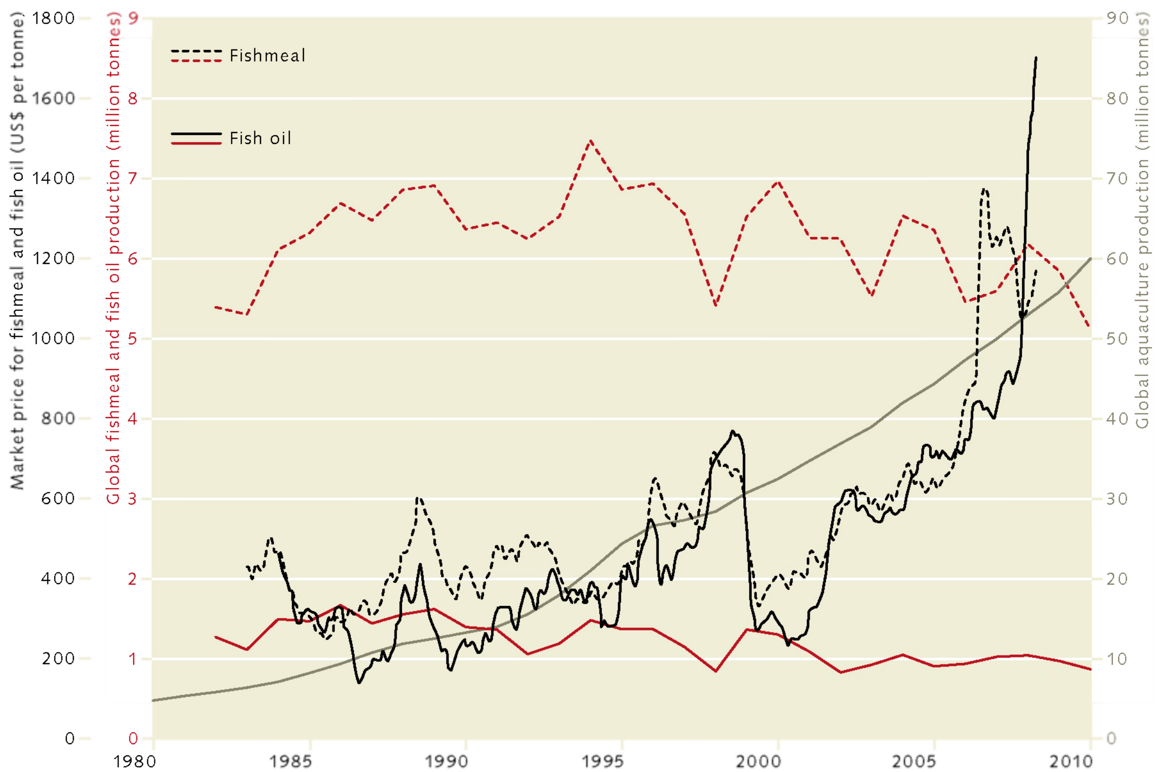


4.8 > Today fishmeal and fish oil are predominantly used in aquaculture. They are extracted mainly from anchovies and sardines.

Small aquaculture operators in particular tend to use feed which either grows or can be sourced locally at affordable prices. This includes plants, crop residues and fish waste.

The most controversial types of feed are those which contain a high proportion of fish. The problem is that the farming of some species requires the use of wild fish as feed – in most cases small pelagic fish, particularly anchovies, sardines and herring. Salmonid farming utilizes relatively large amounts of fish-based feed. Fishmeal and fish oil are produced in large industrial facilities, which involves grinding and boiling the whole fish. Centrifuges are then used to separate, dewater and dry the resultant mass.

In light of the fact that many wild fish stocks have been reduced to critical levels, it seems nonsensical to use them as fish feed, especially if the volume of wild fish produces a lower weight of farmed fish, as expressed by the "Fish In – Fish Out" (FIFO) ratio. For this reason critics are urging people to eat the wild fish directly, instead of using it as feed. However, so far there has been limited demand



4.9 > Although the output of aquaculture has increased greatly over the past 30 years, the sector's consumption of fishmeal and fish oil is at about the same level as in the 1980s. Greater use of plant-based nutrients is one reason; more efficient utilization of fishmeal and fish oils is another. The price of fishmeal and fish oils has multiplied, mainly due to rising demand in China.

around the world for small pelagic fish as food. Markets would first need to be developed. The fishmeal industry points out that the use of fishmeal and fish oil is justified because the fish utilized are from stocks that are in good state as a result of good fisheries management. But it is fair to say that not all these fish stocks are in fact managed sustainably.

Fishmeal and fish oil – expensive commodities

Not only salmon and eels, but many other farmed aquatic animals are currently being fed with fish caught in the wild – particularly with pellets processed from fishmeal and fish oil. Fishmeal and fish oil have been used in the farming of both poultry and pigs for decades. However, rising prices have reduced the proportion of these commodities in their feed. Aquaculture is by far the largest consumer, accounting for about 60 per cent of fishmeal and 81 per cent of fish oil. Fish oil is mainly used in the breeding of salmonids. Norway has greatly expanded its salmon farming facilities and is now the largest importer of fish oil. The amount consumed in food supplements and medicinal products for human use is 13 per cent.

Fishmeal and fish oil are extracted mainly from anchovies and sardines, which are found in large numbers off South America. China, Morocco, Norway, Japan and other nations also produce these commodities for their own consumption and for export. Among others, blue whiting, sand eels, capelin and sundry waste from fish processing are used in these countries. While Norway imports the most fish oil, China, Japan and Taiwan are the largest importers of fishmeal. Yet despite the strong growth in aquaculture of recent decades, the production of fishmeal and fish oil today is almost the same as it was in the early 1970s. There are several reasons for such growth combined with virtually constant inputs. First, the price for fishmeal has increased considerably in recent years as a result of strong demand in the importing countries, especially China. For this reason aquaculture producers are more interested in using feed substitutes – from crops for

How much fish does a fish need?

Aquaculture operators aim to raise as many fish as they can with as little feed as possible. Large predators such as salmon, however, require comparatively large amounts of feed to produce body mass. The FIFO ratio is the measurement of the amount they need. It indicates how much wild fish must be used as animal feed in order to produce an equivalent weight unit of farmed fish. If 1 kilogram of wild fish is used to produce the feeds of 1 kilogram of farmed fish, the FIFO ratio is 1 (1 kilogram/1 kilogram = 1). Any value more than 1 means that more than 1 kilogram of wild fish is required to produce 1 kilogram of farmed fish. In the mid-1990s the FIFO ratio for salmon was 7.5, while today the figure is between 3 and 0.5. Our increased knowledge of efficient feeding and improved feed formulations has contributed to this development.

Improved feeding efficiency as expressed by the FIFO ratio saves fishmeal and enables more farmed fish to be produced with less fish in feeds. Studies have shown that this technological adaptation from aquaculture industry is vital if we are to meet current and even larger per capita consumption rates. For example, if the current global consumption rate of fish of 17 kilogram per capita and year is to be maintained by 2050, aquaculture would have to reduce its FIFO ratio from approximately 0.6 in 2008 to 0.3 units of marine fish to produce a unit of farmed fish. The most recent assessments and projections indicate that this value is achievable if aquaculture continues to improve its efficiency at the current pace.

This seems to be possible – not only by optimizing feedstuffs, but also by breeding fish species which are less demanding. Catfish already achieve a ratio of 0.5, tilapia of 0.4 and milkfish, a popular fish group in Asia, a ratio of 0.2, which would mean that 5 units of cultivated milkfish are produced using one unit of marine fish.

instance. Second, the FIFO ratio of many fish species has been reduced by the use of improved feeds or improved feeding regimes.

Rapeseed in place of fishmeal?

Scientists are working hard to reduce both the amount of additional feed used in aquaculture and in particular the FIFO ratio. One approach is to develop crop-based feedstuffs which are rich in protein. The problem is that fishmeal contains a high percentage of protein, about 60 per cent, which is essential to build muscle mass. Rapeseed *(canola)*, however, contains only 20 to 25 per cent. For this reason the researchers are trying to produce protein extracts, varying the amount of different proteins to ensure the feed is very easily digested and converted to body mass. Rapeseed is showing particular promise. This crop is utilized extensively for bioethanol (biodiesel) production: the large amounts of plant waste which accumulate would be suitable feedstock for aquaculture.

Protein can also be extracted from potatoes. Trials have been carried out using various different combinations of potato protein. Up to 50 per cent of fishmeal could be saved without any negative impact on the growth of the farmed fish. Alternative feedstuffs can also achieve the opposite result, however. So-called anti-nutrients can have a disastrous effect. These are substances which are poorly utilized by the fish and can induce metabolic disorders.

Scientists are convinced that feeding farmed fish with a combination of different ingredients is the most efficient approach. This would further reduce the use of expensive fishmeal and lower the FIFO ratio. It would make little sense to dispense with fishmeal and fish oil completely, however. Both provide essential omega-3 fatty acids which come from plankton. Fish cannot produce these themselves but ingest them with their food. If they are fed only plant-based feedstuffs, the farmed fish will lack these essential fatty acids, thus defeating the object. Such omega-3 fatty acids are one of the main reasons that consumers choose to eat fish.

More economical and environmentally-responsible feeding regimes require the following measures:

- the use of nutrients from local regions, to avoid long transportation routes;
- the improvement of processing and manufacturing methods to make the feed more nourishing and digestible, and reduce the content of anti-nutrients;
- the targeted and sparing use of fishmeal in combination with other alternative inputs;
- the increased farming of undemanding fish species which need fewer proteins and fats;
- the increased farming of fish species which are bred without fishmeal;
- the further development of high quality proteins and fats from plants and microorganisms.

The impact of aquaculture on marine habitats

If aquaculture is operated indiscriminately, environmental damage is often the consequence, especially in coastal areas. This can occur with mussel farming or fish farming in cages, where there is direct contact between the aquatic animals and the surrounding waters. In the past, farmed fish such as European Atlantic salmon in North America often escaped from their cages. In time they transferred diseases to the wild populations on the US coast. If the alien species feel at home in their new environment they can breed prolifically and in some cases completely crowd out indigenous species. Cultivation of the Pacific oyster was abandoned some decades ago by mussel farmers in Holland and off the North Sea island of Sylt. The species has become a problem, spreading over the entire mudflat area of the Wadden Sea – a shallow coastal sea bordering the North Sea – and overrunning the blue mussel, the staple food of the eider duck and the oystercatcher. The banks of mussels have now become inaccessible to the birds. “Invasive alien species” is the term given by experts to these non-native species. Regulations in Europe now govern the introduction of new species, prescribing a long period of quarantine. Many areas of Asia, however, do not take the problem of invasive alien species nearly so seriously. For this reason experts are calling for in-depth case-by-case assessments of the potential of species becoming prevalent in a new habitat and changing the ecosystem. Another problem can be the removal of juvenile fish or fish larvae from their natural habitat. The European eel, for example, migrates from the rivers of Europe to spawn in the Sargasso Sea in the western Atlantic. As this species cannot be bred in captivity, juvenile eels must be caught in the wild for breeding purposes. The practice places extra pressure on wild eel stocks. Happily, however, increased public pressure has virtually put a stop to mangrove clearances for new fish farms in the major river estuaries of South East Asia. The mangroves also proved to be unsuitable for the industry. Like the Wadden Sea mudflats, the sediment in mangrove forests contains nitrogen compounds, in particular toxic hydrogen sulphide. For several reasons this environment proved to be inappropriate for farming. According to development aid agencies, aquaculture facilities based on brackish water are no longer being established in the mangroves in Thailand, but in areas further inland.

4.10 > The Pacific oyster has colonized the entire Wadden Sea. It overruns the banks of blue mussels that are a vital source of food for seabirds such as eider ducks. It was originally introduced by mussel farmers in Holland and on the North Sea island of Sylt.

Effluent to feed plants

The excrement from fish farms can be used to sustain other organisms. For instance, the excretions from shrimps serve as food for large marine algae. Haddock feed on faeces particles and shrimp shells. This integrated multi-trophic aquaculture (IMTA) is now found in many different countries. It is operated mainly in breeding facilities along coastal areas.

Another type of integrated feeding used in inland breeding facilities is the aquaponic process. Effluent is used to fertilize crop plants; uneaten food, faeces and fish excreta provide the plants with nutrients. The plants in turn clean the water, thus closing the loop. Bacteria are often a part of the system which converts the food, faeces and excreta into chemical compounds that the plants can utilize. When animals and plants are combined with skill, such aquaponic facilities can be quite self-sufficient: operators neither have to feed the fish nor process the water. Tilapia, flowers and vegetables, among others, are farmed in aquaponic facilities. To date such facilities have seldom been operated on an industrial scale. The technology still needs optimization.

4.11 > Impressive aquaculture: fish and vegetables are produced together in this facility in the USA. Fish excrements provide nutrients for the plants. The plants purify the water. Such a closed-loop system is called "aquaponic".

The life cycle assessment

Aquaculture has drawn huge criticism in recent decades, not only for its feeding of fishmeal and fish oil. The use of antibiotics in breeding has also been condemned. Fish farmed in intensive systems to provide maximum yields are more susceptible to disease than their relatives in the wild. For this reason antibiotics and other drugs are widely used, especially in South East Asia. Already there are signs that these are no longer effective. In 2011 almost the entire shrimp production in Mozambique was destroyed by a viral disease. In 2012 the infection broke out on breeding farms along the coast of Madagascar. Experts blame the mass production of shrimps on factory farms. The antibiotics can in turn find their way through the food chain into the human body, potentially impacting on consumer health.

The antibiotics used in aquaculture and on other fattening farms – and also from hospital effluent – have in recent years led to the spread of multi-resistant pathogens, against which most established antibiotics are ineffective. Only special or newly-developed agents can help against multidrug-resistant infections. It is imperative therefore that the use of antibiotics in food production is strictly monitored and restricted.

The effluent from aquaculture operations is polluting rivers and coastal waters in other areas. However, the situation varies from region to region. In Norway, for example, production methods have improved as salmon farming has intensified and professionalized. Pollution with organic wastes (excreta) has reduced as a result of improved feeding techniques. And thanks to modern vaccines the use of antibiotics has almost completely been abandoned.

In order to better assess the adverse effects of aquaculture, experts now call for a comprehensive life cycle assessment (LCA). This is a methodology for evaluating the environmental performance of a product over its full life cycle – LCAs have in the meantime become established in industry in general. They analyse all the environmental effects of a product – from raw material extraction, to production, transportation, utilization and, finally, recycling.

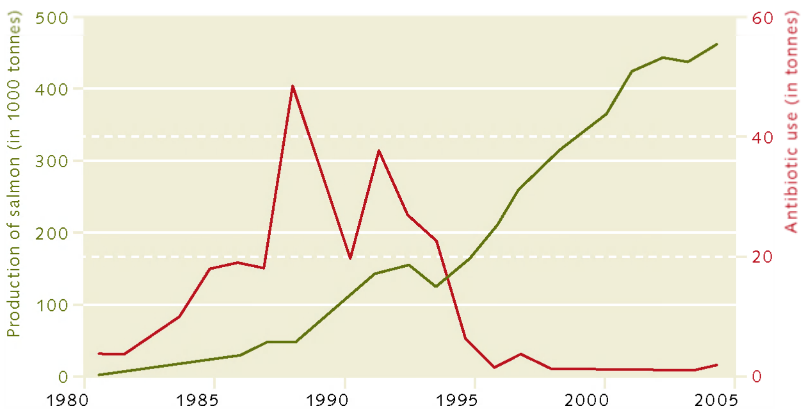
Among other aspects of aquaculture operation, eutrophication (over-fertilization) needs to be taken into account, along with nutrient inputs, such as faeces-enriched effluent discharged untreated into the water from the breeding ponds. The LCA also reflects the environmental pollution created by energy generation for an aquaculture operation: the cleaner the energy production, the better the result. The amount of wild fish used for feeding is also recorded, while land consumption is another important aspect. This includes the amount of land for the facility itself, and the amount used to grow the feedstuffs to meet operation needs. Critics of such life cycle assessments for aquaculture point out that it is difficult to compare the methods of production – carp pond and high-tech plant are two very different types of settings. Initial studies show, however, that such LCAs do indeed make sense for individual production methods.

A comprehensive analysis must also take into account the intensity of farm operations. Production can be broadly divided into three types:

- Extensive: natural bodies of water, such as ponds, are used for breeding, with little or no additional feedstuffs. Finfish, mussels, algae and some types of shrimps and prawns are produced by this method.
- Semi-intensive: natural bodies of water are used. Locally-sourced feedstuffs are fed to the fish. Typical species are finfish in Asia.
- Intensive: mainly operated in efficient, artificial pond systems or cages. The fish – e.g. eels from China – are fed with pellets.

According to a recent life cycle assessment of the different aquaculture systems (pond, breeding cages in coastal areas, mussels on the sea floor or suspended on a frame) and aquatic animal species throughout the world, intensive carp breeding in China is the most unsustainable. The ponds are heavily fertilized to speed up growth of the aquatic plants eaten by the carp. The effluent is often discharged without treatment, leading to eutrophication of

Sustainability certificates
Sustainability certificates are usually agreed between dealers, suppliers and producers. Environmental foundations are often involved. Such seals of approval verify that all parties concerned undertake to uphold binding social, environmental or sustainability standards. How far the specifications go depends on individual agreements. The aims are, among other things, to protect species, the environment and the water in the cultivated areas, as well as to improve social security for the employees. This includes a ban on child labour, the right to freedom of assembly as well as the right to health insurance and social insurance.



4.12 > The example of Norway shows that the intensification and professionalization of production can lead to improvements. Despite increasing numbers of salmon, the use of antibiotics in the Norwegian salmon farming industry has declined.

the rivers in many places. Conversely, in Europe carp farming is considered very environmentally-friendly, as the aquatic animals are bred under extensive production methods. This is mainly due to the fact that, unlike in China, the demand for carp is comparatively low.

The results for eel and shrimp farming in ponds are poor. As far as cage production along coastal areas is concerned, finfish are problematic. They involve a very high level of energy use, partially because of the frequent supply trips in boats. They also perform badly in terms of carbon dioxide emissions and acidification of the seas.

Improvement in sight

Europe imports large numbers of shrimp and fish from Asia in response to customer demand in countries such as Germany and France for affordable products. Cheap, however, can be synonymous with intensive, industrial, and often environmentally-damaging factory farms, which European consumers would prefer to be situated in someone else's back yard. Scientists claim that this is just outsourcing the problems from Europe to Asia, and the situation will not improve until attitudes change. The signs are promising, with many consumers now mindful of food safety and sustainability certificates. The certification of wild capture fisheries is already well established. Aware that such eco-labelling on product packaging can impact on purchasing decisions, the trade is now putting pressure on suppliers in the aquaculture industry, demanding fish from sustainable production. In the coming months farmed fish will appear on European shelves bearing the new "Aquaculture Stewardship Council" (ASC) label co-founded by the World Wide Fund For Nature (WWF), various food trading initiatives and fisheries. The "Marine Stewardship Council" (MSC) standard, the equivalent for ocean fish, has been around for many years.

There is no question that fish farming sustainability is gaining momentum or that the topic is being debated at the highest levels. Two years ago the Food and Agriculture Organization of the United Nations (FAO) published guidelines setting out clear standards for the certification of aquaculture operations. It is expected that traders will in future measure their producers against these guidelines. Certificates and voluntary commitments by the trade are already in existence, but consumers are unaware of them as they are only relevant for direct contacts between traders and suppliers. The same objectives, however, apply. For instance, trade cooperation agreements have been adopted for the distribution of pangasius from certified aquaculture operations along the Mekong Delta. Some major and international supermarket chains have also concluded individual agreements with producers.

For about 10 years now development aid agencies and non-governmental organizations in Asia have been trying to set up sustainable aquaculture operations. Converting a vast number of small operations is proving a challenge. For this reason efforts are being made to include as many farmers as possible in cooperation projects with the aim of improving production within an entire region. In some cases the solutions are extremely pragmatic. For example, extra ponds act as a buffer to protect rivers from the inflow of nutrients from farming ponds. The nutrients and suspended matter then settle as sludge for later use as fertilizer. In some regions of Vietnam there is now a brisk trade in sludge.

Experts also see a growing awareness in China for products from sustainable aquaculture, especially among the burgeoning middle class. National seals of sustainability are thus being promoted aggressively. Although this trend is promising, it will nonetheless take years for environmentally-sound aquaculture to finally become established.

Conclusion

The future of farmed fish

Driven mainly by massive population growth, urbanization and increasing wealth in Asia, aquaculture has grown by a good 8 per cent per annum over the past 20 years – faster than any other food sector. Today about 60 million tonnes of fish, mussels, crab and other aquatic organisms are farmed around the world each year. This is almost equal to the amount of ocean fish and seafood captured in the wild, which totalled 78.9 million tonnes in 2011. Asia, particularly China, is the most important aquaculture region, currently supplying 89 per cent of global production. Aquaculture will continue to grow strongly and thus make a significant contribution to providing the global population with valuable protein.

An advantage of aquaculture is that much fewer feedstuffs are needed to farm fish and seafood than beef and pigs. It takes 15 times as much feed to produce 1 kilogram of beef as to produce 1 kilogram of carp. Aquaculture is thus a resource-efficient method per se of producing protein-rich food from animals. Current studies investigating likely developments to 2050 indicate that aquaculture is capable of satisfying the world population's growing need for fish.

This ongoing growth, however, must not come at the cost of the environment or the climate. It is problematic that aquaculture still requires large amounts of wild fish, which is processed into fishmeal and fish oil and used as feed. Although the volumes of these commodities have been stagnating for years, in some cases they still make use of fish stocks which are not managed in a sustainable manner. Aquaculture can thus still be a contributor to the problem of over-fishing. Efforts are now being made to reduce the amount of fishmeal and fish oil used in fish farming, not least because prices have soared as a result of high demand in China. Many research groups are developing alternative types of fatty, protein-rich feed from potatoes and rapeseed. In many cases aquaculture production is still not sustainable. Facilities require too much energy and generate nutrient-rich effluent which is often channelled into rivers and coastal waters in an untreated state. The waters then become over-fertilized, causing algal bloom and oxygen-deprived dead zones.

Scientists are now developing methods to analyse the full life cycle of aquaculture facilities – life cycle assessments. For some time now the industry has been testing products for their environmental compatibility, embracing all aspects from the extraction of the raw materials through to recycling. The intensive rearing of carp and shrimps in ponds is considered very harmful. It scores extremely poorly in the life cycle assessment because it uses too much feed, produces nutrient-rich effluent, and consumes large amounts of energy. Yet in recent years environmental awareness has also become more widespread in the aquaculture sector. A change of thinking is evident, particularly in the industrialized nations which import large volumes of fish from Asia. Increasingly traders and customers are demanding goods which comply with environmental standards. For some years there have been sustainability certificates for marine capture fisheries, and products bearing this label are very much in demand. Soon the "Aquaculture Stewardship Council" certificate, a seal of approval for aquaculture operations, will be appearing on European markets. Traders and producers wishing to have this certificate must undertake to protect species, the environment and the water in farmed areas, and comply with a high level of social standards. We have an opportunity to gear the further expansion of aquaculture towards sustainability. Current environmental problems, over-fishing and climate change make this a matter of urgency.

5 Getting stock management right

> Overexploited stocks, unemployed fishermen, short-sighted structural policy – it is impossible to ignore that fisheries management has failed in many respects. Nonetheless, we can all learn from the positive approaches being taken in some regions. These aim to conserve fish species and ecosystems and take account of the social dimension – objectives which the European Union has yet to achieve with its current reform of fisheries policy.

Fishing at its limit

> The size of fish stocks can fluctuate considerably from one year to the next. Setting catch limits at sustainable levels is therefore a challenging task. Although there have already been some good scientific approaches to the problem, these have not translated into fisheries policy. Now, at last, a new fisheries management regime should safeguard the long-term sustainability of global fisheries.

The coming and going of fish

Fish stocks increase and decrease, with or without fishing activity. We have been aware of this natural phenomenon for hundreds of years. In the past it has spelled disaster for many people when fish stocks have suddenly declined. For instance, in 1714 and 1715 the cod inexplicably failed to appear along the barren west coast of Norway. In the poor region of Søndmør the fishermen, to avoid starvation, were forced to sell their most important possession – their boats.

For a long time it was unclear what triggered such fluctuations in fish stocks. Many fishermen and scientists believed that in some years the fish simply migrated to other maritime regions. Finally in 1914 the Norwegian fisheries biologist, Johan Hjort, produced a comprehensive statistical analysis of data he had gathered over numerous research expeditions. One of his most important findings was that variability in the number of fish and offspring is largely dependent on environmental factors – including the salinity and the temperature of the water.

Hjort's work dates back almost 100 years. Since then, our knowledge about the growth and decline of many fish stocks has increased tremendously. Today we know that many factors impact on the natural development of stocks. We still do not fully understand how everything interacts, however.

The natural factors with the greatest impact include the biotic environment with its species interactions, and also the abiotic environment, particularly the salt and oxygen content, temperature and quality of the water. The latter are also changed by long-term climate fluctuations – a further complicating factor in reaching an understanding of stock development. Of course, the size of fish stocks is not affected only by nature but also by human fishing activity. The condition of an exploited stock can be described by the following three factors:

STOCK BIOMASS (B) is the total weight of all large and small, juvenile and adult fish in a stock. This figure is estimated with the aid of mathematical models using fisheries' catch data and scientific samples and is quoted in tonnes. But even these mathematical estimates are riddled with uncertainty. Biomass can also fluctuate greatly from year to year. Of particular significance is the number of adult, sexually mature fish – the spawners – because they are responsible for producing offspring. This section of the stock is known as the "spawning biomass" which is also stated in tonnes. The spawning biomass level is crucial for fisheries scientists because they use it to derive vital benchmarks, known as reference points, used in fishery management. The total biomass of a stock is made up of the spawning biomass and the biomass of the juveniles, which have not yet reached sexual maturity.

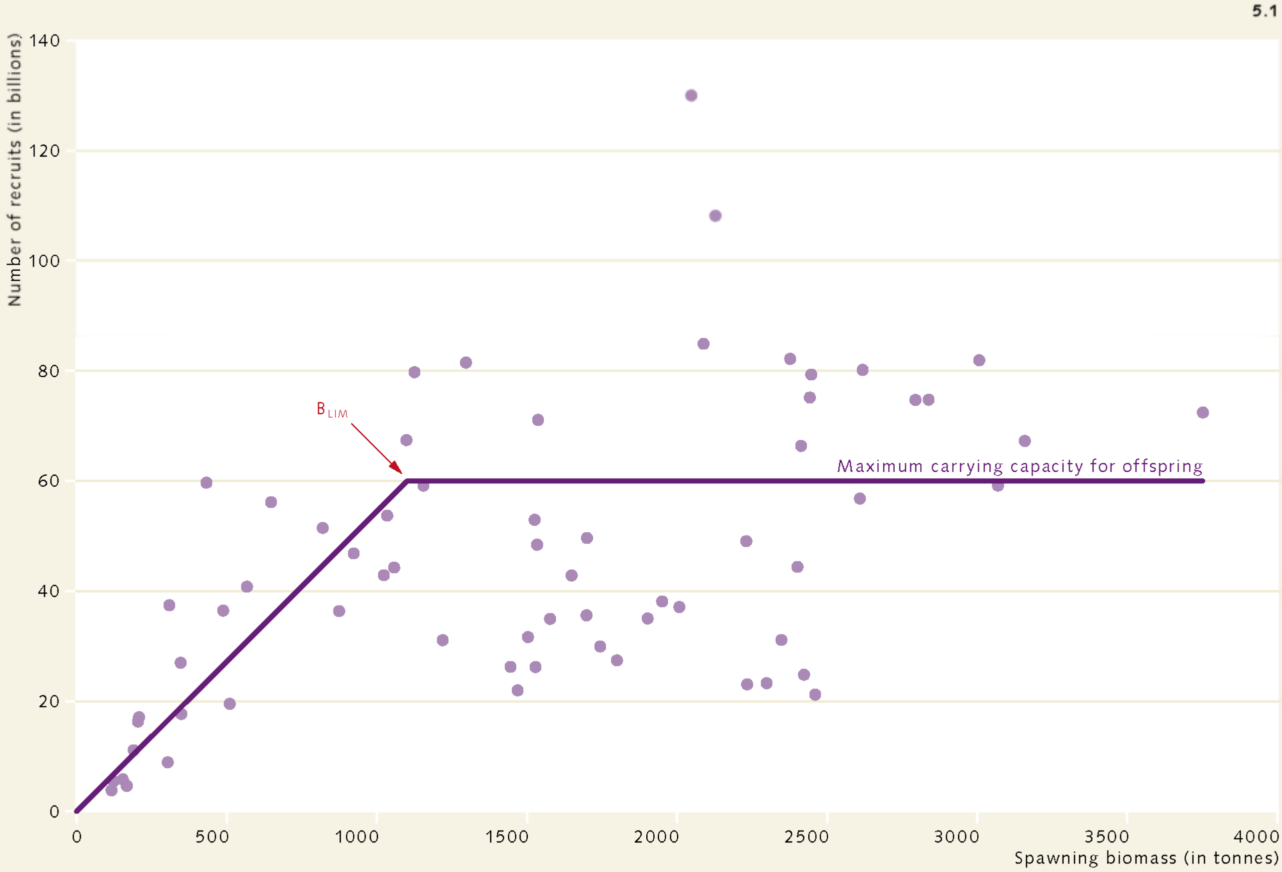
THE FISHING MORTALITY RATE (F) is a somewhat abstract measure of fishery pressure. It can be converted to a relative value which indicates the proportion of the stock biomass which is removed by the fisheries.

THE PRODUCTIVITY of a stock is calculated by subtracting the number of fish which have died of natural causes from the increase in mass resulting from offspring and natural growth of the fish. This correlation makes it clear that the productivity of a stock is highly dependent on the spawning biomass. It follows that the stock declines when the natural mortality rate and the fishing mortality rate together are greater than the productivity.

When things get too tight for the offspring

When the spawning biomass – the number of sexually mature parent fish – of a stock increases, then the number of juveniles or so-called recruits swells accordingly, but only up to a certain limit. Even if the spawning biomass continues to increase, the number of recruits remains at a certain level. The habitat has reached its maximum carrying capacity for offspring. The reason for this is that the more juveniles there are, the greater the competition for food. Many die. The habitat can therefore only support a certain number of offspring. In theory, this maximum carrying capacity stays the same for a long period of time. In reality, however, it fluctuates from year to year, mainly depending on how many predators are in the area and how much food is available. The amount of food, on the other hand, depends on the environmental conditions. The findings of scientific fish counts show that recruit numbers fluctuate accordingly. The figure below shows measurements taken over several years, which indicate that certain spawning masses are quite capable of producing different numbers of recruits (blue dots). In this respect, the maximum carrying capacity for offspring can be considered a type of median value. On the other hand, the point at which the spawning biomass is so reduced by fishing activity that the number of recruits falls below this maximum carrying capacity is known as the limit biomass (B_{LIM}).

5.1



5.2 > > Barren land, poor fishermen: In the Søndmør region of western Norway people's livelihoods used to depend almost exclusively on fishing, and particularly on the development of fish stocks.

The offspring production of a fish stock is limited. If the spawning biomass is large, the habitat at some stage reaches its maximum **carrying capacity**. Even if the spawning biomass then continues to grow, the number of juvenile fish remains at a certain level. At this stage the amount of offspring depends entirely on the environmental conditions. Various factors come into play here: eggs and larvae may be eaten by predators, for example, or starve because insufficient food is available. In addition there can be competition for suitable spawning sites to deposit eggs. The Baltic Sea herring, for example, deposits its adhesive eggs on aquatic plants. When there are too many spawners, they deposit the eggs on top of each other, and those underneath die from a lack of oxygen. As these conditions can fluctuate from year to year, so too does the number of offspring when spawning stocks are high. There can be strong but also very weak years for offspring.

If a stock is exploited too intensively the following can occur. The spawning mass is at some stage so small that few offspring can be produced. In such a case the number of offspring depends directly on the number of spawners. It is no longer capable of reaching its carrying capacity, even when good environmental conditions prevail. The value at which the spawning biomass is so small is called limit biomass (B_{LIM}). The corresponding fishing mortality rate is described as F_{LIM}.

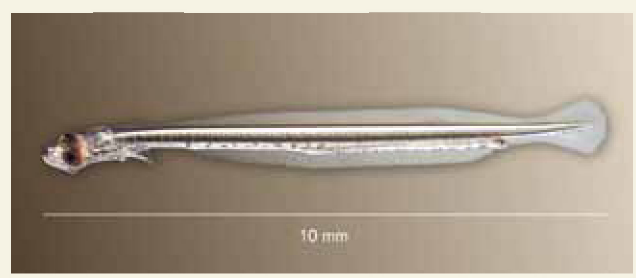
The failure of the precautionary approach

The massive overfishing of many stocks by the industrial fishing industry in the 1970s, 1980s and 1990s made the importance of limiting catch volumes abundantly clear. In 1995, the international community adopted a more cautious approach to fishing with the United Nations Straddling Fish Stocks Agreement (UNFSA). In the same year

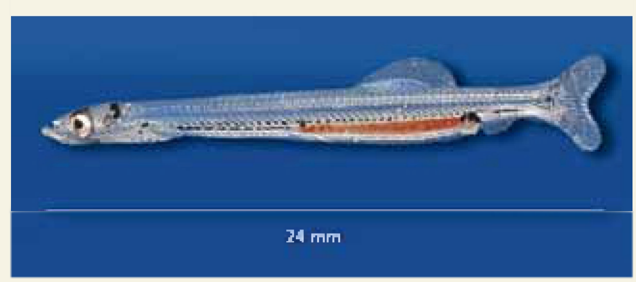
When does a fish become a fish?

The annual reproduction of fish is quite different from that of mammals. After they have hatched from the egg, fish pass through a larval stage. The larvae of many fish species spend this time in shallow waters away from the parent stock. In a manner of speaking, they live in a different world. At this stage, their numbers can reduce significantly because they are a food source for many other marine fauna. Many can die due to poor environmental conditions. Most fish larvae become juvenile fish in the first year. In fishery biological terms, however, they are only considered offspring or included in stock numbers when they join the parent stock and are large enough to land in fishermen's nets: in other words when they can be counted. These juvenile fish are known as recruits.

5.3a > Twelve hours before hatching: the large, well-pigmented eyes of the transparent herring larvae are particularly striking.



5.3b > Eat or be eaten: at eight days old, herring larvae feed mainly on the larvae of smaller crustaceans. They are themselves the prey of larger fish. Only about 1 per cent of herring larvae survive this stage.



5.3c > After 30 days the larvae have all the fins of adult fishes. The gills and scales are formed at this stage. The swim bladder is partially formed, so that the larvae can move up and down the water column following the food.

5.3d > Still almost scale-free. At 60 days the larvae look like fully-grown herring, but the stomach is not yet fully developed and they have few scales. However, the swim bladder is now fully functional. The larvae can swim strongly and flee from predators.

the Food and Agriculture Organization of the United Nations (FAO) published its Code of Conduct for Responsible Fisheries. The overriding aim of this precautionary approach (PA) is to prevent a stock from being reduced to such an extent that it can no longer produce sufficient offspring and becomes overexploited. It also stipulates that fisheries should err on the side of caution: the less that is known about a stock and its development the more carefully that stock should be managed, and the less it should be exploited. In principle, therefore, the precautionary approach aims to avert the risk of harm to fish resources. Limits were accordingly set for many commercially exploited fish species, in order to minimize fishing mortality and prevent severe depletion of stock biomass. For example, each year the EU Council of Ministers sets the total allowable catch (TAC) for stocks in the waters of the European Union, thus stipulating how many tonnes of a fish species may be caught in a specific area.

The precautionary approach also takes the dynamics of the stocks into account, because environmental conditions can change the size of a stock. If there is little food available, for instance, the productivity of the stock declines accordingly. The biomass shrinks. If there is plenty of food, the productivity rises and the stock grows. The fishing industry must take these stock fluctuations into account and adjust catch volumes accordingly, not continue to catch the same amount of fish. Such adjustment should be achieved using several benchmarks and limit reference points, terms which are still used for fishing according to the precautionary approach:

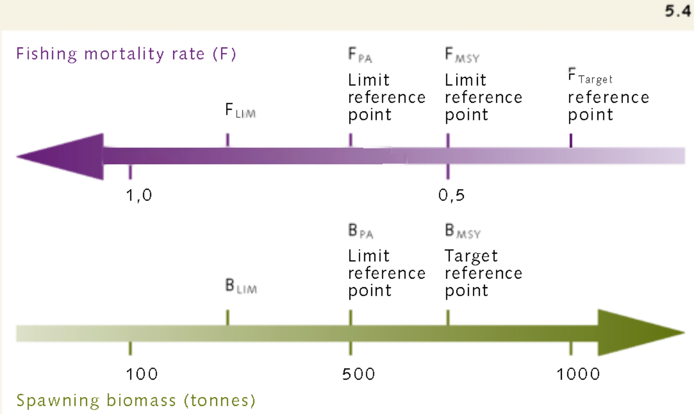
BIOMASS PRECAUTIONARY APPROACH (B_{PA}): It is difficult to predict the status of a fish stock, for several reasons. One is that the current fishery and research data used to calculate fish abundance is unreliable. Another is that all mathematical analysis programs are to a certain extent inexact. There is no 100 per cent certainty. The Limit Biomass (B_{LIM}) is therefore too risky as a reference point. The probability is too great that the biomass does actually fall below this limit in any given year, threatening population growth. In line with the precautionary approach, therefore, it was decided to stipulate a limit reference point which takes such uncertainties into account. This limit is known as the Biomass Precautionary Approach (B_{PA}). It is designed to guarantee that the biomass does not inadvertently fall below the B_{LIM}-threshold. The area between B_{LIM} and B_{PA} is therefore a buffer zone, as it were. Today it is still the most important benchmark used to ascertain the health of many stocks.

PRECAUTIONARY FISHING MORTALITY RATE (F_{PA}): As the biomass is a fundamentally unreliable and changeable variable which cannot be directly influenced by human activity, it is not practical to stipulate a limit reference point for the fisheries which takes only the biomass as its parameter. Therefore there is an additional limit reference

Guidelines against overexploitation

Fisheries science is geared to two parameters: the fishing mortality rate (F) and spawning biomass. If fishery is to be sustainable, F should be sufficiently low, and the spawning mass sufficiently large. Experience has shown that functioning fisheries management systems need limit reference points and target reference points. An adequately low F_{Target} should achieve a low mortality rate. An additional limit reference point (F_{MSY}) should prevent the fishing mortality rate from ever rising to critical levels, indicating that catches are too high. In future the F_{MSY} should replace the conventional F_{PA}-value. In practice these F-values are extremely important points of reference for the fisheries. In terms of total biomass, however, only a target reference point, the B_{MSY}, is specified. B_{LIM} is the crucial lower threshold for spawning stock which should never be reached. In this event the stock would be overfished.

5.4



point which is derived from the B_{PA}. This is known as the F_{PA}. This point specifies the maximum fishing mortality rate permissible to stay below the B_{PA}. Scientists use the F_{PA} to calculate the maximum annual catch tonnages for the next season. However, this is only possible when the current status of the stock is known. For this purpose the researchers use the catch data of past years, which provides information on the long-term development of the stock. They then add the catch data from the current season along with the data gathered by research vessels. Finally, they must make assumptions for the current year for which no fisheries data is yet available. From these figures they use mathematical models to estimate the status of a stock for the next season, which forms the basis of their catch recommendations for the fisheries. Adhering to these maximum catch tonnages ensures that fishing remains within the F_{PA}.

Fishing to the limits

In principle the precautionary approach was a good idea. In practice, however, it failed because Fisheries Ministers consistently took the limit reference points to mean the target reference points. Instead of ensuring that limits were not exceeded, they all too often set catch volumes as close as possible to the limit. In hindsight we know that the limits – because of the uncertainties already mentioned – were often violated, meaning that in certain years more fish was caught than the stock could cope with. Moreover, authorities, mainly for political reasons, are even today allowing fishermen to catch more than researchers recommend. The B_{PA} and the F_{PA} were therefore entirely misconstrued by both the fishing industry and the political establishment. The result is common knowledge. In too many cases too many fish were removed, resulting in weakened stocks, particularly in poor years with low numbers of offspring.

MSY – the new route to responsible fishing?

After only a few years, it became clear that the precautionary approach did not work. For this reason, shortly after

The MSY – harshly criticized and yet established

The term maximum sustainable yield (MSY) was developed in the 1930s. It is based on two findings. Firstly, there is a maximum size which the stock of an animal group can achieve within an ecosystem. Secondly, the net growth of the stock, resulting from reproduction and increased size and weight of individuals, is highest at 30 to 50 per cent of the maximum stock size. This stock size therefore allows the maximum long-term yield. However, such a maximum withdrawal is only achievable when the maximum stock size and the growth rate have been accurately determined. The current stock size must also be known. If the stock was already smaller than 30 to 50 per cent of the maximum size, the stock would be overfished. For this reason there has been much criticism of this concept, and there were recommendations that it should be abandoned. Nonetheless the term was taken up by the United Nations Convention on the Law of the Sea in 1982. With one important condition, however – that ecological and economic factors as well as the special needs of developing countries should be taken into account. For this reason the MSY concept is no longer applied in the theoretical, mathematical terms in which it was originally defined. It now also takes particular account of the above-mentioned uncertainties, species interactions and economic aspects.

the turn of the millennium, a different concept was developed which aimed to improve the regulation of fisheries. This traces back to the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002. The summit declared its intention that global fish stocks should be fished to sustainable and responsible limits, the objective being the maximum sustainable yield (MSY). This concept goes further than the precautionary approach which was only designed to protect stocks from overfishing. MSY is designed to manage fisheries efficiently with the aim of preserving stocks and ensuring the highest long-term yields. In other words, the MSY is the largest possible catch volume which can be removed from the sea on a long-term basis without reducing the productivity of the stock. The crucial reference point is the B_{MSY}, or $Biomass_{MSY}$. This is the total biomass which allows long-term fish yields in accordance with the MSY concept. It is large enough that neither strong fluctuations in offspring production and individual fish growth, nor years of very weak recruitment will threaten the stock. There are already some fisheries around the world which are guided by the

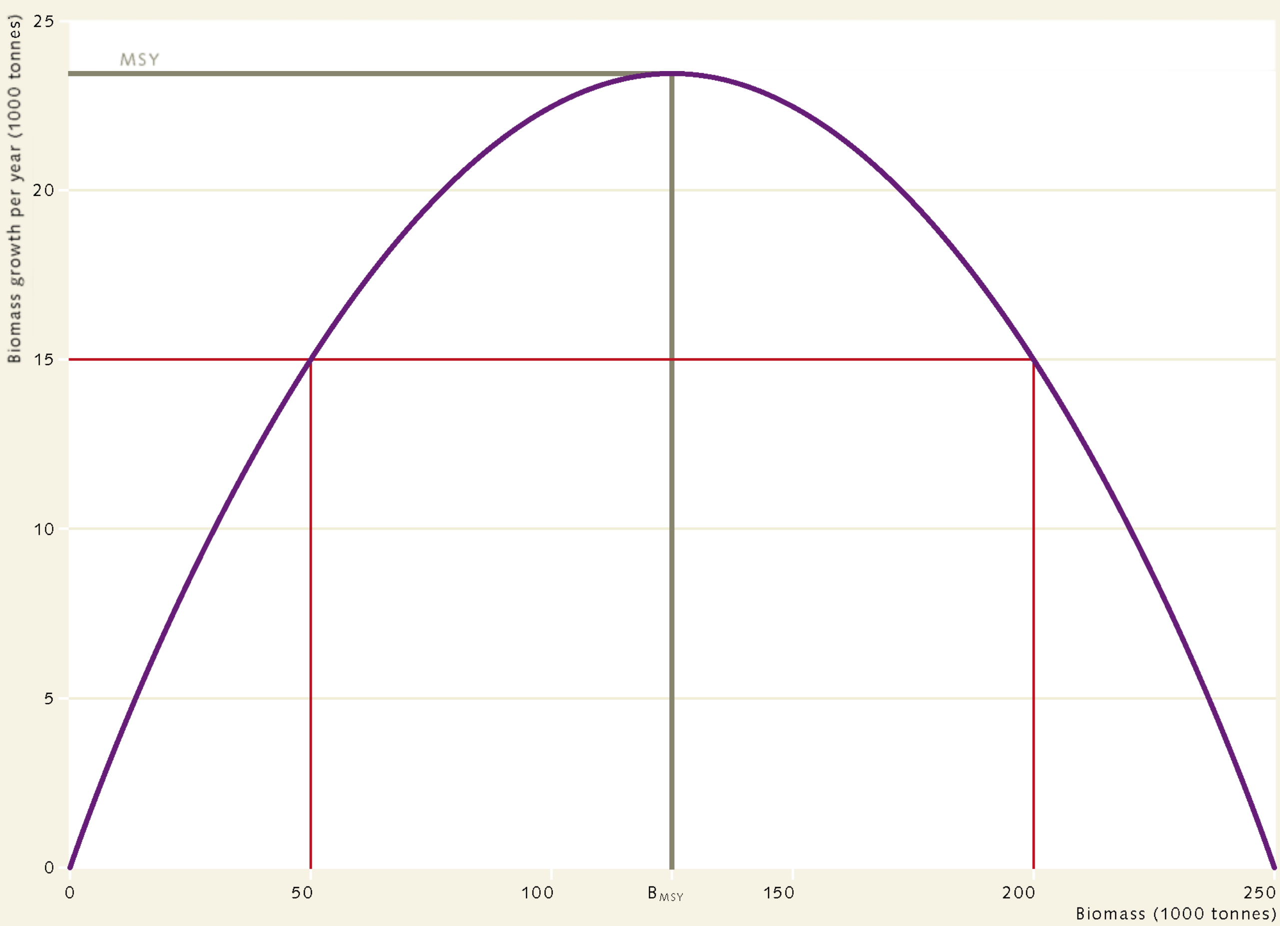
Why fishing at MSY levels delivers more

The maximum sustainable yield (MSY) is achieved at a certain level of biomass (B_{MSY}). This differs in size from fish stock to fish stock. At B_{MSY} the annual production of new biomass is at its maximum – firstly because the fish grow particularly well and increase their weight, and secondly because more eggs and larvae survive to develop into fish.

Above or below B_{MSY}, the stock is less productive. At about 200,000 tonnes biomass, for example, the stock provides only 15,000 tonnes of new biomass per year. This is because there are more fish in the stock to compete for food, and they each put on less weight. Also, more eggs and juvenile fish are cannibalized. A stock of only 50,000 tonnes biomass experiences a similar level of biomass growth. Although this smaller stock contains fewer spawners, the total achieved from the increase in weight of the individual fish (as a result of reduced competition for food) and the biomass of the offspring (which have a greater chance of survival within a smaller stock) is the same as for a large stock.

It is interesting that sustainable fishing is also possible with larger or smaller sized stocks than the B_{MSY}, but the annual fish yield is lower.

5.5



MSY concept – off Australia and New Zealand, for example. In most cases the B_{MSY} value is higher than the B_{PA} value used previously, simply because the MSY concept is geared towards the optimal use of a usually larger stock. The B_{PA}, in contrast, was a minimum level. For this reason, the biomass which can deliver the MSY is often larger than the biomass according to the precautionary approach (B_{PA}). Similarly, F_{MSY} is smaller than F_{PA}. Here too, however, there are differences from fish stock to fish stock. The reason why a fishery produces the highest yield with MSY is that there is neither too much nor too little fishing activity. An MSY catch is the happy medium, as it were. If the stock is too small, however, the stock growth is also poor because few offspring can be produced. If the stock is too large it will at some stage reach the carrying capacity of the ecosystem. This happy medium means that the right amount of biomass is produced to replace the amount that dies. With the medium-sized stock aimed for under the MSY concept, there is much less competition for food than in larger stocks with more individuals. The fish find more food, must expend less energy to find it and increase their body weight vigorously. The losses from fishing are offset by the faster growth of the animals. Fishing with MSY also means that more eggs survive and more fish can develop, due in part to the fact that there is cannibalism among predator fish such as the cod: the adult fish partially feed on eggs and larvae. Where there are large numbers of adults, the young are decimated to a much greater extent than occurs with fishing in accordance with MSY. All in all, this means that fishing to MSY levels results in more biomass being available. This is known as excess or surplus production. Surplus production is greatest with MSY.

Unbeatable team: limit and target reference points

The fishing industry and fishing ministries have abused limit and target reference points for far too long. If they had adhered strictly to the scientists' recommendations, one single point of reference would have been sufficient. A successful fisheries management system based on the MSY concept would consequently need only the B_{MSY} or the F_{MSY} as the limit reference point. But the precautionary approach has shown that this does not work: B_{PA} and F_{PA} were fixed limit reference points, but the fishing industry and policy-makers did not apply them properly – in other words, not in the sense of sustainable fisheries. For this reason the MSY concept today uses a target reference point which the industry can be guided by, and a limit reference point as a safeguard.

This type of approach has already been introduced in Australia and New Zealand. In these countries the F_{MSY} is the limit reference point. In addition, there is a lower target reference point, the F_{Target}. The fisheries are accordingly required to fish only until this target reference point is achieved as closely as possible. On the other hand, the F_{MSY} in this model, along the lines of the old B_{PA}, is the limit reference point, which should be avoided as far as possible. The essential difference between this and the conventional precautionary approach is that the fisheries no longer align themselves towards a limit reference point but to a lower target reference point (F_{Target}), which safeguards the F_{MSY}. These values are extremely important for the fisheries because it is from this that clear catch recommendations are derived.

In the greater context of the MSY concept, the stock biomass B_{MSY} is often the desired ideal, so to speak. But here too, because determination is uncertain, the B_{MSY} is in many cases taken as the limit, not the target. In Australia, for example, the biomass target is specified along with a correspondingly higher B_{Target}. The USA and New Zealand have developed similar models. Although the limit and target reference points in some cases have different names, all the current MSY approaches work with limits and targets and have thus abandoned the precautionary approach which used only the lower biomass limit.

The MSY concept in practice

The MSY concept is of course a theory, an ideal which still needs to be put into practice. For many fish stocks, the problem is that they have been so severely exploited that it is impossible to know the optimal values for biomass,

5.6 > Fishermen on the deck of the trawler "Messiah" sort cod that they have caught in the Pacific near the Aleutian Islands.

mortality and yield. We do not know the maximum spawning biomass of an unexploited stock, nor can we derive the B_{MSY} with any degree of certainty. For those stocks which were already depleted and recovered after catch limits were set, the best that can be hoped for is the B_{LIM}.

One example is the cod in the eastern Baltic Sea, which occurs mainly between Sweden and Poland. The stock was overfished for years, but in recent years it has been able to recover, particularly in Poland, as a result of improved environmental conditions and better controls of catch quotas. For the past two years, however, the stock has hardly grown at all. Apparently the carrying capacity of the habitat has been reached with its current 300,000 to 400,000 tonnes spawning biomass. Although the stock was much larger in the mid-1980s, current food shortages have apparently prevented further growth. This example shows that carrying capacities can change and do in fact fluctuate strongly over the years. For this reason the BMSY cannot be stipulated with any degree of certainty. Furthermore, this biomass analysis does not take into account the age structure of the fish stock. This information is crucial, however, for any assessment of offspring numbers and weight increases in individuals.

It is also impossible to stipulate B_{MSY} reference levels for many other intensively exploited fish stocks. For these cases we must continue to rely on the old PA values or determine a corresponding fisheries mortality rate F_{MSY} in the coming years. These values can be ascertained even if the B_{MSY} is unknown. The PA values would indeed be meaningful from a purely scientific point of view. They were set on the basis of many years' experience, catch and recruitment data, and scientific sampling. They have proved to be ineffectual for fisheries management, however.

The original aim of the PA concept was to allow fish stocks to slowly grow as a result of catch limits and then, as with the cod, to observe how a stock develops. To do this, however, policy-makers must set clear targets and limit catches accordingly. In a joint European research project involving more than 10 universities and institutes, researchers are now developing concepts to establish fishing on a sustainable footing in accordance with MSY while fishing continues. Fisheries off Alaska, Australia and New Zealand are already showing that fishing based on the MSY concept is possible. But the starting conditions there were better than in Europe. As industrial fishing only began about 20 years ago, the maximum stock size is known – and this could be used to reliably assess such levels as the B_{MSY}. It is also much easier to manage fisheries in nation states such as Australia and New Zealand than in a union of states such as the EU with its many conflicting opinions.

The aim of the World Summit on Sustainable Development in 2002 was to fish all worldwide fish stocks according to MSY guidelines by the year 2015. This target will not be achieved – mainly because many nations have been too hesitant and have not yet adequately limited fishing. It will therefore still take some years until all European stocks are fished in this way.

One fish species seldom comes alone

Until now fisheries management systems have in most cases examined each species separately. Catch volumes have been stipulated for individual species without considering that these are part of a food web in which the catch of one species also impacts on other species and their development. This applies in equal measure to the initial MSY management approaches. Fisheries should in future pay more attention to these interrelationships between the species. The following two interrelationships can be identified:

MULTI-SPECIES APPROACH: The multi-species approach takes account of the fact that removing one species by fishing also affects other interrelated species within the ecosystem – as predators and prey for example. The multi-species approach takes account of all these interrelationships when calculating catch volumes. For instance, a fish stock should only be exploited to the extent that sufficient food remains for its predators. Depending on how many species occur in a marine area, this multi-species approach can be implemented with different degrees of success. In the Baltic Sea, only 3 protagonists are interrelated as predator and prey – cod, herring and sprat. Scientists believe fisheries management according to the multi-species principle should be possible in the Baltic Sea within the next few years. By contrast, 17 species interact in one complex system in the North Sea. For this area, therefore, it is difficult to develop a multi-species concept. Although scientists have learned a lot in recent years about how species fundamentally interact and prey on each other, little is known about the volumes involved.

Analysing the stomach contents of fish or the faeces of sea birds and marine mammals is one way of determining how much of a given species is eaten. If these analyses are combined with data on speeds of digestion, a rough estimate can be made of how much fish is being consumed. But in most cases the required data is only available for certain years, as individual research projects tend to be time-limited. The data is, therefore, very unreliable. With the aid of mathematical models, however, efforts can be made to reduce these uncertainties and make a better assessment. Various projects are currently attempting to do this. The researchers hope to be capable of making a more reliable evaluation within the next 10 to 15 years.

CONCEPTS FOR MIXED FISHING: Fish of several different species are often caught in fishing nets at the same time – whether or not they are closely linked within the ecosystem. This is called mixed fishing.

One example is cod and haddock. Both cod and haddock are predators, but they do not prey on each other. Their similar size and habits mean that when one species is caught, the other inevitably ends up in the net too. This makes it difficult to optimize the catch volume for a single species. Cod is more valuable than haddock but occurs in smaller numbers and is classed as overexploited in the North Sea. If we concentrate on catching cod, we can catch very little without placing the stock under further pressure. But at the same time we forgo a large volume of haddock. If, alternatively, we rely on the cheaper, more

5.7 > Stomach content analysis shows what marine fauna feed on – in this case a crustacean, snails and a bullhead, a bony fish.

5.8 > Natural beauty against an urban backdrop: for the citizens of Seattle, orcas in the Puget Sound are a common sight.

freely available haddock, cod will also end up in the net as bycatch. Intensive haddock fishing will cause the cod stocks to dwindle. There are many such interdependencies which complicate mixed fishing, especially in the North Sea. Although not all the details are yet known, researchers are hoping to establish an initial pragmatic concept for the North Sea at last, within the next two to three years. This will take the problems of mixed fishing into account and simultaneously optimize the multi-species catch in terms of the MSY.

The ecosystem-based approach – the ultimate discipline

The situation becomes even more complicated if we look at the entire ecosystem – all the fish along with all the other marine dwellers. Currently there is controversy among the experts about whether it is better use of the expensive, time-consuming fishery research expeditions to find out more about the development of individual fish species – or whether all species in the ecosystem should be recorded as a whole in order to increase our understanding of the food web. Although our knowledge of these interrelationships has increased enormously, particularly over the past 20 years, we are still a long way from implementing an ecosystem-based fisheries management regime.

US researchers have developed a concept for ecosystem-based fisheries management in the Puget Sound off Seattle on the west coast of the USA, and are showing how this could perhaps function. Although not yet introduced by the US authorities, this concept is considered by other experts to be viable and could serve as a model for other parts of the world. The researchers analyse the extent to which a certain species may be exploited without causing any damage to the environment. They also take into account other human impacts on marine life such as construction work, shipping and tourism.

Towards better fisheries management

> For many years, fishing around the world has been organized on the basis of management plans. And yet stocks have been overexploited and thousands of fishermen have lost their livelihoods. Future-proof fisheries management must master both these challenges: it must support sustainable fishing while achieving high long-term yields. The Alaskan fishing industry is one example of how this can work.

Conflict over a living resource

The importance of establishing clear regulatory arrangements for fishing activity was demonstrated with particularly dramatic effect by the Cod Wars in the Northeast Atlantic in the 1950s and 1970s. At the time, many foreign trawlers used to fish close to the Icelandic coast, for unlike today, there was no exclusive economic zone (EEZ) extending 200 nautical miles out from the coastal baseline. This led to a conflict over access to fish stocks, mainly between Iceland and Great Britain. At the peak of the conflict in 1975/1976, Britain even sent in warships. The situation was not defused until 1982, when the **United Nations Convention on the Law of the Sea** (UNCLOS) was adopted, establishing exclusive economic zones.

This example shows the high level of demand for fish, a lucrative and highly tradable commodity. It also shows how serious the consequences of a poorly regulated fishery can be. Even today, there are periodic conflicts between countries over fishing rights or the allocation of fishing quotas. A much greater challenge at present, however, is the overexploited status of many stocks. The primary task of modern fisheries management is therefore to limit catch volumes to a biologically and economically sustainable level and ensure equitable access to fish as a living resource.

5.9 > A scene from the Cod Wars: the Icelandic vessel "Ver" (left) attempts to cut the fishing lines of the British trawler "Northern Reward" (right). The British tugboat "Statesman" intervenes.

Fisheries policy or centralized fisheries management therefore focuses either on catch volumes (direct approach) or fishing effort (indirect approach):

- Fishing volume: To prevent too many fish being caught, the authorities can limit catch volumes (output). In most cases, this means setting a total allowable catch (TAC). This defines the maximum quantity of a given species that may be caught in a specific area, generally the EEZ, in any year.
- Fishing effort: To prevent too many fish being caught, the authorities can also limit fishing effort (input). For example, their effort-based management measures can include limiting the number of fishing days, fishing vessels' engine power, or the size of the fleet, or setting minimum mesh size for nets.

Fishing quotas – equal rights for all?

In fact, it is quite possible to regulate fishing effectively with the aid of fishing quotas. To that end, a total allowable catch (TAC) is set for a specific marine area. The TAC is then broken down into separate national fishing quotas for the various countries which border this maritime region. For example, each Baltic Sea state has a national fishing quota. Of course, for this system to function effectively, more is required than a single national quota:

5.10 > Classic approaches to fisheries management either focus on restricting catches or attempt to limit fishing effort. The term "fisheries management" encompasses a variety of methods which can be used to regulate the fishing industry. Their suitability in any given context depends on the fish stock and region.

otherwise, fishermen within a single country would find themselves in direct competition with each other and would attempt to catch as many fish as possible at the start of the season in order to fulfil a large share of the quota. This would lead to a glut of fish on the market for a short period, pushing down prices and ultimately harming the fishermen's livelihoods.

So in order to give fishermen a measure of security to plan their fishing activities for the entire season, the total allowable catch is generally allocated to individual fishing vessels, fishermen or cooperatives.

Fisheries policy strategies in which fishermen are allocated long-term fishing rights in some form are known as rights-based fisheries management. Individual transferable quotas (ITQs) are the prime example.

In an ITQ system, fishermen are allocated individual fishing quotas as a percentage share of the total allowable catch. As a rule, the ITQs are allocated for a period of several years, giving the fishermen the stability they need to plan ahead. The fishermen can trade their ITQs freely with other fishermen, which often results in relatively unprofitable enterprises selling their quotas to more efficient companies. Less economically efficient companies would be inclined to sell, and more profitable companies would be likely to buy the ITQs. The main goal of the ITQs is to achieve the greatest possible economic efficiency and sustainability. There is less focus on social objectives. In extreme cases, the quotas become concentrated in the hands of a small number of companies.

One example is the New Zealand hoki fishery, which is now dominated almost completely by a small number of large fishery enterprises.

Another example is the Icelandic fishery. The management of Iceland's cod stocks is considered to be fairly good nowadays as regards sustainability. Following the introduction of ITQs, however, many family-owned companies left the fishing industry and sold their quotas to other enterprises.

An end to discards?

Fishing quotas are generally allocated for individual fish stocks. In fisheries in which individual species can be caught on a targeted basis – in the main, these are schooling fish such as herring or mackerel – this works well. Often, however, various species of fish end up in the net. Fishery experts call this a **mixed fishery**. In the North Sea sole fishery, for example, large quantities of plaice, another flatfish species, are caught as bycatch. This causes problems because fishermen can only land the species for which they have been allocated a quota. All the other fish and marine fauna caught as bycatch are dumped overboard. Most of the discards are already dead when they go back into the water. This discarding of bycatch has been practised for decades. The European Union (EU) is keen to prohibit the practice of discarding under its new Common Fisheries Policy (CFP). A frequent criticism is that it is almost impossible to monitor compliance with a ban. For that reason, various measures and strategies are currently being discussed to reduce bycatch on a general basis in future and make monitoring more effective. They include:

- Use of sealed CCTV cameras to monitor activity on deck. This type of system is now being trialled on a number of fishing vessels in the North Sea and the Baltic Sea.
- More intensive onboard deployment of government observers.
- Counting of non-quota species against the quota. A shrimp fisherman, for example, who catches plaice as bycatch must then count this species against his shrimp (prawn) quota, based on a specific formula. This reduces the quantity of shrimp that may be caught under his remaining quota. The purpose of this measure is to exert gentle pressure on fishermen to switch to more sophisticated fishing gear that fishes more selectively and minimizes bycatch. For prawn fishing, for example, new nets are now being developed that use a mild electric pulse to disturb the prawns while the flatfish remain on the seabed.

The new Common Fisheries Policy (CFP) will probably allow a transitional period of several years for the introduction of the new technology. Based on the current stage of the discussions, it seems likely that the possibility of counting non-quota species against the quota will also be introduced on a progressive basis. The aim is to carry out fewer checks and compel fishermen to take more responsibility – in other words, to increase their ownership of the process. On the Faroe Islands in the North Atlantic, an attempt has been made to solve the problem of discards as follows. Instead of allocating fishing quotas, restrictions are imposed on fishing effort. The fishermen can only spend a limited number of days at sea. However, they can land their entire catch, so there is no need for them to discard any fish. This approach does not solve the problem of high-grading, however; this term describes fishermen's practice of sorting out the most valuable components of the catch, such as the largest and heaviest individuals from a given species, because large fish bring in more money per kg of body weight. Smaller or damaged fish are then dumped overboard. This is a waste of resources. High-grading is already banned in the EU, Iceland and Norway but is still practised despite the bans, so properly functioning controls are vital.

5.11 > In the North Sea, a typical bycatch is likely to include small flatfish and a great many crabs, such as shore crab *(Carcinus maenas).*

ITQs are traded like stocks and shares. High ITQ prices are therefore an indicator of good fisheries management: the higher the yield from the fish stock, the more valuable the fishing rights become. In Iceland, fishing rights were initially distributed free of charge to the fishermen based on their average catches at the time (grandfather rights). In other words, rights of access to this natural resource were allocated on the basis of historic fishing privileges, which in some cases go back many generations. As fisheries management has steadily improved, however, and fishing fleets became more efficient as a result of the rationalization measures described, the fishing rights – which are now very valuable – have become concentrated in the hands of a small number of enterprises.

In Iceland, this development is viewed very critically. The preferred situation is more equitable distribution of profits from fishing. Some experts are therefore proposing that rather than granting permanent fishing rights, annual quotas should be auctioned instead. The advantage of this system, it is argued, is that smaller or recently established fishing companies could enter the trading scheme and acquire quotas at any time, without having to hand over extremely large sums of money.

There are frequent demands at political level for small-scale coastal fishing to be protected, prompting calls for separate quotas to be allocated on the basis of fleet segment. This would mean that quotas allocated to small vessels could only be sold on to other small vessel owners and could not be used to increase a large vessel's fishing quota. The expert view is that the ITQs are an effective tool for the management of fisheries, but as soon as social goals come into play, it is essential to rethink the basic principles.

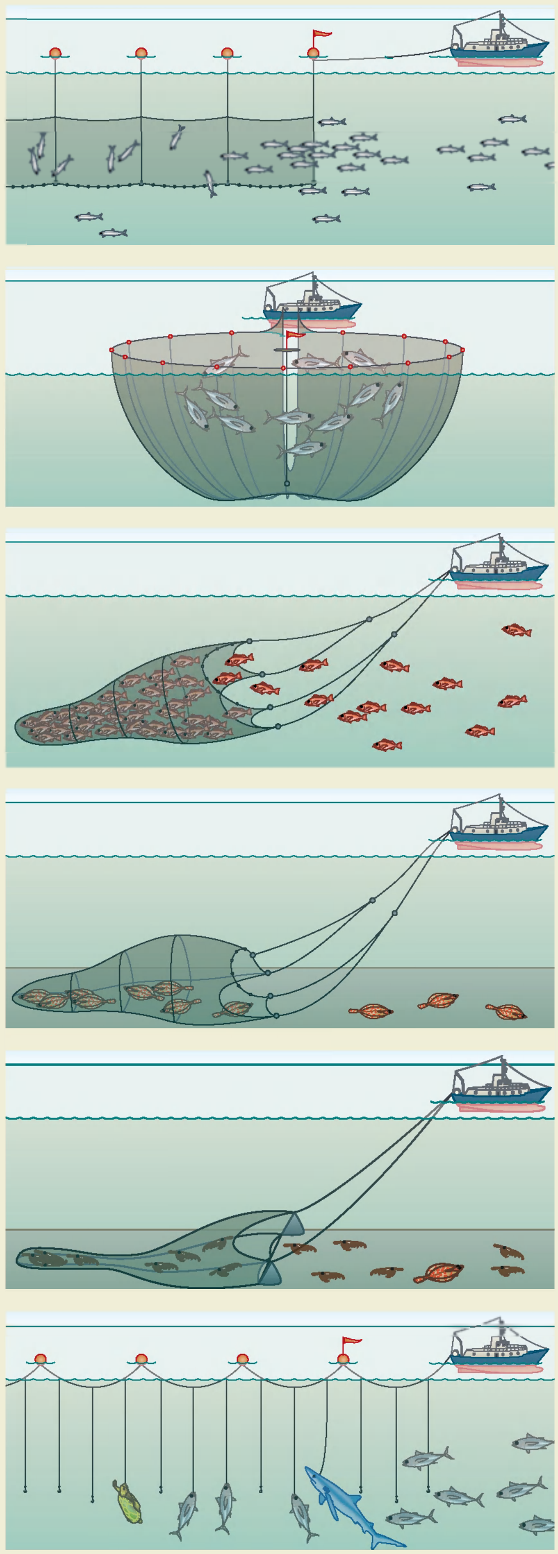
Effort-based management – fewer days, fewer ships

In addition to the use of quotas, fishing can also be regulated by restricting the fishing effort. For example, fishing capacity can be limited by capping the number of licences available for allocation to fishing vessels or by restricting the engine power or size of vessels. It is also possible to limit the duration of fishing, e.g. by capping the number of days that may be spent at sea. These restrictions on fishing effort are more common than ITQ schemes in some regions. However, effort-based management also has its shortcomings and is sometimes taken to absurd extremes by fishermen themselves. One example is the Pacific halibut fishery, where at the end of the 1980s, fishing was only permitted for three days a year in order to conserve stocks. In practice, during this very short fishing season, a vast fishing fleet was deployed and caught the same quantity of fish as had previously been harvested in an entire year. Another even more extreme example of a time limit is the fishing derby in Sitka Sound in the Gulf of Alaska. Here, the herring fishery is regulated by limiting fishing activity to a few hours a year. Rather like a horse race, all the fishing vessels line up and, as soon as they hear the signal, they set off at the same time. While fishing is monitored by an observer ship, the fishermen try to catch as much fish as possible in the very short time available. After a few hours, another signal tells the fishermen that it is time to stop fishing.

5.12 > Hot competition for limited resources: in Sitka Sound in Alaska, the herring fishery is only open for a few hours a year. Dozens of boats then compete for the catch.

Selective fishing with the aid of electric nets and LED lights

Various types of fishing gear are utilised, depending on the species or habitat. Bottom-living species are caught using



5.13 > Different fishing techniques and their impacts on the environment

> GILLNETS are anchored at a fixed position in the water. There is a low level of bycatch of other species because of the specific sites selected for the setting of gillnets. However, turtles, marine mammals and seabirds can become entangled in these nets.

> PURSE SEINE NETS are used to encircle a school of fish. The net is then drawn together to retain the fish by using a line at the bottom, allowing the net to be closed like a purse. There is a low level of bycatch of other species as purse seines target schools of one species. However, dolphins or turtles are often caught as bycatch. Modern purse seines therefore have escape mechanisms.

> PELAGIC TRAWLS are funnel-shaped nets that are towed by one or two vessels. The fish are scooped up and captured in the “cod end”, i.e. the trailing end of the net. Bycatch of other species can be a problem in some areas, depending which species is being targeted for trawling.

> BOTTOM TRAWLS work in a similar way to the pelagic trawl, but are dragged along the seabed. They are one of the most important techniques used in deep-sea fishing. The nets can damage underwater habitats such as cold-water coral reefs.

> BEAM TRAWLS are bag-shaped bottom trawls that are mounted on a heavy metal beam and towed along the seabed. This destroys many fauna living in and on the seabed

> LONG-LINES consist of a long main line, up to 100 km in length, with a large number of short lines (called snoods) carrying thousands of baited hooks. Bycatch is a problem. Dolphins, sharks, turtles and seabirds become trapped on the hooks

bottom trawls, whereas fish living in open waters are caught using pelagic nets. Steel long-lines – carrying hundreds of thin lines and baited hooks – are often used to catch tuna.

Some of these fishing techniques have considerable disadvantages. A prime example is the beam trawl, a type of net that is dragged across the seabed. Beam trawls are often equipped with iron chains that disturb the flatfish on the seabed and drive them into the net. The beam trawl is the subject of considerable controversy because it ploughs its way along the seabed and destroys numerous bottom-living creatures.

Long-lines, in turn, are notorious for their bycatch harvest of dolphins and turtles, which are attracted by the bait on the hooks. Seabirds such as albatross are also frequent casualties: they dive for the bait when the lines are thrown from the ship into the water and are briefly suspended near the surface. Over recent years, various alternative and gentler fishing techniques have therefore been developed:

- the Danish seine, a specific form of towed net. Conventional trawl nets are generally equipped with weights to help them sink. However, these weights can kill other marine fauna or damage sensitive seabed habitats. With a Danish seine, contact with the seabed is minimized due to its specific geometric structure, consisting of diamond knotted netting turned 90° from its usual orientation;
- pelagic trawl nets with escape hatches for turtles;
- long-lines with additional lead weights that cause the lines to sink rapidly, taking them out of seabirds' reach;
- unusually shaped hooks for long-lines that avoid turtle bycatch;
- electric fishing nets which produce a mild electric pulse to disturb the flatfish and drive them into the net, instead of using heavy chains (tickler chains) for this purpose;
- gillnets equipped with fishing lights (LED markers or lightsticks), which scare away turtles or alert them to the presence of the net.

For some years, the development of gentler (i.e. more selective) fishing technologies has been promoted by an international environmental organization through the Smart Gear initiative. It is noteworthy that it is not only researchers and engineers who are involved in the initiative; so too are professional fishermen. The many different solutions offer hope that gentler forms of fishing will come to the fore. Many fishermen, especially in Northern Europe, have already switched from beam trawling to alternative fishing techniques for pragmatic reasons. With rising oil prices, dragging a heavy beam trawl along the seabed is no longer economically viable. In many areas, lighter fishing gear such as Danish seines is being used instead.

Generally speaking, effort-based management must be constantly adapted to the latest technological advances. Increasingly efficient technology is available to locate fish, for example, making it possible to detect and catch a given amount of fish in ever shorter periods of time. Experts estimate that industrial fishing is achieving a 3 per cent increase in efficiency year on year, so fishing effort must be reduced.

Another way of protecting fish stocks is to establish designated marine protected areas, where fishing is restricted or subject to a total ban. In some areas, bottom trawling, for example, is prohibited altogether in order to protect seabed habitats. In other cases, specific areas are protected, notably those where fish come to spawn and juveniles grow to maturity. This approach can only be successful, however, if very accurate information is available about the whereabouts and reproduction habits of fish or marine fauna in relation to the protected areas. Furthermore, a protected area must be the right size. If it is too small, the stock will not be adequately protected. If it is too large, the fishermen will lose access to stocks that they could in fact catch without putting stocks at risk.

Sustainable, high-yield fishing is possible

Despite the numerous problems, well-organized fisheries management can work, as the examples of Alaska, Australia and New Zealand show. Most stocks in these regions are fished sustainably and are in a good state. In many cases, TACs and ITQs have been set in accordance with the maximum sustainable yield (MSY) principle, i.e. the maximum annual catch that can be taken from a species' stock over an indefinite period without jeopardizing that stock.

In some fisheries, the limit reference points and target reference points for the maximum annual catch are even more stringent than the MSY. The following factors contribute to successful fisheries management:

- The fishing industry and policy-makers comply with researchers' recommendations on catch volumes and with limit reference points and target reference points.
- Various interest groups are involved in the management process at an early stage. Researchers' expertise plays a key role in the setting of quotas. In addition to commercial fishing companies, recreational fishing associations and non-government organizations are involved in the allocation of fishing rights, in measures to avoid bycatch, and in other aspects of fisheries management.
- Responsibilities for the various aspects of fisheries management are clearly defined and hierarchically structured. Fishing in international waters is regulated by one of the Regional Fisheries Management Organizations (RFMOs). Fishing in the exclusive economic zone is managed by national authorities, while fishing in coastal waters falls within the jurisdiction of local authorities.
- Government observers are deployed and their operating costs are covered by the fishery enterprises, generating funds for the research community. The entire Alaska pollock *(Theragra chalcogramma)* fishery, for example, is monitored by onboard observers. Landings in port are also monitored by CCTV.
- The focus is not only on individual fish species: efforts are also made to manage fishing in a way which protects the ecosystem as a whole. Experts call this the ecosystem approach. Among other things, it means that no heavy fishing gear can be used that would potentially damage the seabed.
- The management authorities are willing to learn from others' mistakes and, from the outset, target their measures towards avoiding overfishing. This is the case in both Alaska and New Zealand, where industrial fishing began only around 20 years ago.

In the USA, the Magnuson-Stevens Fishery Conservation and Management Act adopted in 1976 contains the main legal provisions applicable to fishing. The Act has been revised several times over the years, most recently in 2007. The latest amendments introduce measures for the USA as a whole which are very much in line with some of those already in place in Alaska. For example, fishing should now take greater account of environmental conservation aspects and protect important fish habitats. The objectives defined in the Act are to be achieved with the aid of fishery management plans (FMPs) which incorporate the economic, ecological and social dimensions. Although there is some opposition to these stringent rules in the USA, they are now established in law and non-governmental organizations can bring legal actions in the event of violations.

The right management regime for each stock

So which management measures are most appropriate to generate a high but sustainable yield over the long term while protecting fish stocks and marine habitats? This will ultimately depend on the fish stock and the local situation. In industrial fishing, which is carried out using vast vessels and provides employment for around 500,000 fishermen worldwide, the fishing activity could, in theory, be monitored by onboard observers, although this is associated with high costs. However, in countries where artisanal fishing involving hundreds of small boats is the norm, as in West Africa, this type of surveillance measure cannot possibly work. With an estimated 12 million artisanal fishermen worldwide, it is quite impossible to monitor all of them at work. Nonetheless, there are some promising strategies for monitoring the catches of small and medium-sized coastal fisheries as well. In Morocco, for example, the authorities have introduced automated systems to

5.14 > Fishing without bycatch: stilt fishermen in Sri Lanka's coastal waters wait patiently for their prey, which they haul out of the water with rods and landing nets.

monitor coastal fishing. Machines are installed in port or in the coastal villages and fishermen are allocated a chip card which they insert into the machines to register their departure and arrival times. This gives the authorities an ongoing overview of which particular fishermen are at sea at any given time. If a ship does not return to port on time, the authorities can run preventive checks. This system also allows fishing effort to be estimated very accurately. The catches are recorded by the authorities on landing. At present, the system is used to record vessels of trawler size, but from next year, smaller motor boats will also be monitored using this system, with spot checks on these smaller vessels' catches also being carried out. Penalties are imposed on fishermen who provide false information about their catch. These penalties depend on the severity of the offence, but in some cases can include the confiscation and scrapping of the boat.

More regional responsibility

Territorial use rights in fisheries (TURFs) are an alternative to centralized approaches to fisheries management. Here, individual users or specific user groups, such as cooperatives, are allocated a long-term and exclusive right to fish a geographically limited area of the sea. Catches and fishing effort are decided upon by the individual fishermen or user groups.

This self-organization by the private sector can also help to achieve a substantial reduction in government expenditure on regulation and control. Users also have a vested interest in ensuring that they do not overexploit the stocks, as this is necessary to safeguard their own incomes in the long term. However, a use right for a stock of fish or other living resource in the ocean is exclusive only for non-migratory species such as crustaceans and molluscs.

One example of successful management by means of TURFs is the artisanal coastal fishery in Chile, which mainly harvests bottom-living species, particularly sea urchins and oysters. Fishermen here have shown that they have a vested interest in pursuing sustainable fishing once they have the prospect of obtaining secure revenues from these fishing practices over the long term. Similar approaches are being pursued in the lobster fishery

Mauritania, Senegal and the difficult path towards good fisheries management

The waters off West Africa are among the most heavily fished in the world and the irresponsible approach to fishing there is heavily criticized. Mauritania is a good example of how difficult it is to move towards sound and sustainable fisheries management. Mauritania is not a traditional fishing nation, so fish is not a staple food here. Instead of engaging in fishing activity itself, Mauritania has, for many years, granted licences to foreign fishing companies – an important source of income for this desert state. However, the licences have until now been granted solely on the basis of vessel size (tonnage) – a very imprecise measure for targeted management of fish stocks. Mauritania, with support from various other nations and development projects, therefore decided to establish a more effective fisheries management system. In 2006, it adopted its first management plan, which focused on octopus fisheries. Then on 1 August 2012, a comprehensive new fisheries protocol entered into force on a provisional basis with the aim of regulating many other fisheries as well. Among other things, the protocol sets precise quotas for each species and defines the number of ships and maximum catch per species. This type of arrangement makes it much easier to manage fishing activity. The licence fees were also increased. In order to monitor compliance with the various quotas, catches of demersal fish (bottom-living species including shrimp and deep-water crab) must be landed in Mauritania's only fishing port, namely Nouadhibou. Pelagic fish, of which up to 1 million tonnes are caught off Mauritania annually, cannot be landed here due to capacity limitations, however. The transshipment of the catches from the trawlers to the large refrigerated transport ships must therefore take place just outside the port of Nouadhibou so that random checks can be carried out at any time.

5.15 > Worried about their livelihoods, Senegalese fishermen held protests in March 2012. The President in office at the time intended to sell more fisheries licences to foreign fishing companies.

With the new fisheries protocol, an effective management regime is available – in theory. However, it is currently being boycotted by most owners of the foreign fishing fleets on the grounds that it is too stringent. These are just some of their complaints:

- Spanish octopus fishermen are no longer permitted to fish for octopus as the stocks are overexploited;
- the fishing ban area for pelagic fish has been extended from 12 to 20 nautical miles, thus reducing yields;
- 2 per cent of the catches of pelagic fish must be handed over to the Government, which intends to distribute these fish to the poor at low cost or free of charge;
- 60 per cent of crew members working on international vessels operating in the exclusive economic zone must come from Mauritania, even though an appropriately skilled workforce for the industry is virtually non-existent in that country;
- licence fees have increased sharply.

As a result of the boycott, virtually no new licences have been purchased and many international fishing companies have withdrawn their vessels from Mauritanian waters. As an expression of solidarity with the Spanish octopus fishermen, for example, the Spanish shrimp fishermen have also pulled out. Only the French tuna fishermen and the Spanish hake fishermen have acquired licences. This is resulting in a substantial loss in licence revenue for Mauritania. There is a strong possibility that Mauritania will bow to international pressure and amend the protocol in the near future. This highlights a wider problem in Mauritania, namely that sound rules and good management regimes are often implemented in a half-hearted manner by the Government, or are circumvented by means of exemptions. If in doubt, the Government invariably opts to make a quick profit instead of protecting fish stocks.

As well as the difficulties of establishing a sound management regime, a further sobering fact is that Mauritania is currently experiencing setbacks with regard to its fisheries control system. In order to curb illegal fishing far out in the EEZ, but also to monitor vessels operating legally, Mauritania has, over the past 10 years, established a fisheries inspectorate with international assistance. Monitoring vessels were deployed to patrol the 200 nautical mile zone and the country also has an aircraft for this purpose. Radar systems were installed to monitor the coastal areas. These measures have done much to curb

5.16 > Artisanal fishing is pursued very intensively in some areas, as is apparent from the large number of pirogues moored on this beach in Senegal.

illegal fishing. But now, aid organizations are lamenting the growing disinterest on the part of the Government. The surveillance aircraft has not been in operation for some time, and the fisheries inspectorate's vessels are generally in such a poor state that they cannot be operated safely. The only vessel which is still seaworthy is often seen in dock, tied up by the quay, due to a shortage of fuel. When it does take to the seas, its surveillance activities are generally confined to coastal waters. As a consequence of this situation, the fisheries inspectorate's deterrent effect has recently decreased.

Unlike its neighbour Mauritania, Senegal has a long tradition of fishing. The Senegalese have for generations relied on long narrow wooden boats, around 14 metres in length, known as pirogues, which can carry more than 10 tonnes of fish. As Senegal is a much more impoverished country than Mauritania, however, it cannot afford a fisheries inspectorate. Foreign fleets from China, Russia and even Spain, operating under flags of convenience, are therefore engaged in illegal fishing on a massive scale in Senegal's waters. What's more, as the Government under former President Abdoulaye Wade allocated a very large number of fishing licences to foreign companies, the Senegalese people have been complaining for years that their once abundant fishing grounds have been ravaged. When Wade was about to sell even more licences to Russian trawlers in spring 2012, the Senegalese people took to the streets in protest. Already heavily criticized for his political power games, Wade lost the presidential election. The new President, Macky Sall, has now cancelled 29 of the 44 fisheries licences allocated during Wade's presidency – thus honouring one of his key election pledges.

This example highlights the close bond felt by people in countries with a strong tradition of fishing towards this natural resource. It is also clear that it is essential to take their concerns and interests seriously and to involve them in fisheries management. It is hoped that the new Government of Senegal will take this to heart and continue with its vigorous measures to combat what has been, in effect, the sell-off of the country's fishing grounds.

5.17 > Generous subsidies, large fleets: the Spanish fishing fleet in particular – part of which is seen here in the port of Muros – was dependent on state subsidies for many years.

in Canada. Experts use the term "co-management" to describe this trend towards more individual responsibility for fishermen (ownership).

Economic benefits of sustainable fisheries management

Overfishing of stocks is not only an ecological problem. It is also uneconomic. As fish stocks decline, the effort required to catch a given quantity of fish increases. The fishermen spend more time at sea and use more fuel to catch a given quantity of fish. So it makes sense to manage stocks in accordance with the MSY principle. One problem is that even now, many countries are still heavily subsidizing their fishing industry. Government subsidies allow the fishery to be maintained even when the direct costs of the fishing effort, in the form of wages or fuel costs, have already exceeded the value of the fishing yield. Fishermen's individual operating costs are reduced in many cases by direct or indirect subsidies. Every year worldwide, around 13 billion US dollars is paid to fishermen in the form of fuel subsidies or through modernization programmes, with 80 per cent of this in the industrialized countries. A recent study concludes that restructuring of subsidized fisheries would pay off because it would put an end to overfishing. Stocks would recover, leading to higher yields in future. Restructuring would mean that fishing would have to be suspended for a time or substantially reduced in certain regions. Instead of subsidizing the fishing industry, the money would be used to support fishermen who were unemployed, even if only temporarily, as a result of these measures. The great importance of social protection schemes is shown by the closure of the herring fishery in the North Sea between 1977 and 1981. Although stocks were able to recover, small coastal fishing companies did not survive this enforced break, and today, the North Sea herring fishery is dominated by a small number of major companies. However, if periods when restrictions on fishing activity are in force can be managed in a socially equitable manner and stocks recover, fishing can then be resumed. Of course, the fishing industry loses revenue as a result of the closure of a fishery or a reduction in fishing activity. However, the study concludes that this type of restructuring measure would only take around 12 years to pay for itself and would generate as much as 53 billion US dollars in additional revenue for the fishing industry annually. These calculations are very much in line with older estimated figures produced by the World Bank. It estimates the loss of net benefits due to overfishing, inefficiency and poor management to be in the order of 50 billion US dollars annually worldwide – a substantial figure compared with the total annual landed value of fish globally, i.e. around 90 billion US dollars. Admittedly, this global analysis is based on generalizations to some extent, as there are strong variations between countries' fishing industries, but experts regard the estimated figures as sound.

Certificates increase the appeal of sustainable fishing

Overall, the status of fish stocks worldwide still gives cause for concern. On a positive note, however, sustainable fisheries management is becoming increasingly attractive to many fishing companies. The reason is that fishing companies that fish sustainably can now market their products under an ecolabel. For many food retailers in Europe and North America, the most important importing regions worldwide, these labels are now a key prerequisite for including a given fishery product in their ranges. Various certification schemes are now in operation. Two of the best-known schemes are run by the Marine Stewardship Council (MSC) and the Friend of the Sea initiative. The MSC was established by a well-known environmental organization and an international food corporation in 1997 and became fully independent in 1999. There are currently 133 MSC-certified wild capture fisheries worldwide, harvesting more than 5 million tonnes of MSC-certified fish and shellfish annually. This represents almost 6 per cent of the total global wild capture catch. The Friend of the Sea initiative was also established by an environmental organization. Both schemes aim, among other things, to support the sustainable management of fish stocks in accordance with the MSY principle.

As a rule, certificates are granted to individual fisheries, not to individual species, and certification is contingent on compliance with various criteria. The condition of the fish stock, the impacts of fishing activity on the marine ecosystem, and the management of the fishery are all factors that are considered in the assessment. Certification to MSC standard, for example, is based on 31 separate criteria, and fisheries are required to meet a specific number of them. They include the following:

- Fishermen should utilize modern and improved fishing gear that reduces bycatch to a minimum.
- The fishing operation should implement appropriate fishing methods designed to minimize adverse impacts on habitat. For example, instead of heavy bottom trawls which churn up the seabed and destroy bottom-living fauna, rockhopper trawls should be used. These are fitted with large rubber tyres or rollers that allow the net to pass fairly easily over the seabed.
- The fishing operation should minimize operational waste such as lost fishing gear, oil spills, etc.
- The fishing operation should be conducted in areas where fisheries management systems are in place and in compliance with these systems. Areas where industrial fishing would compete with traditional coastal fishing should be avoided.
- The fishing industry should engage in intensive dialogue with scientists. Comprehensive data relating to the current status of fish stocks should be collected for use in fisheries science.

The fishery should also prevent illegal, unreported and unregulated fishing. The certificates also state which ports are to be used. Landings are limited to a specific number of ports where there is proper monitoring of catch landings. A certificate is awarded for 5 years and can be renewed. Checks are carried out at intervals to ascertain whether the rules are being complied with. This takes the form of logbook checks and perusal of records, as well as onboard inspections. These audits may also be attended by observers from non-governmental organizations or environmental associations. Observers also travel out with the ships in order to carry out random checks to determine how much fish is being caught and from which species. In the case of the South African hake fishery, the South African Deep Sea Trawling Industry Association provides the funding for the deployment of observers. These are experts from various environmental organizations and South African ornithological associations with a particular interest in seabird bycatch. The catch is also subject to video camera surveillance. In the cod and pollock fisheries in the Barents Sea, observers commissioned by a government-funded Polar Research Institute of Marine Fisheries and Oceanography have an onboard presence on 5 per cent of all fishing expeditions. Critics argue that the certification procedures are not stringent enough as only a proportion of the criteria must be fulfilled. They claim that certificates are in some cases awarded to stocks that are in a less than optimum condition or that have not yet fully recovered. This applies to stocks with biomass growth lower than the level needed to supply a maximum sustainable yield. The critics are therefore calling for even more restrictive certification. From the certifiers' perspective, however, ecolabelling is entirely justified, as it imposes obligations on companies to fish in a manner that enables stocks to recover. The certificate establishes clear targets and objectives for the companies, which must be achieved within a specific timeframe.

Turning the tide in fisheries policy?

> In 2013, the European Union will agree a new Common Fisheries Policy (CFP), which will establish the regulatory framework for the management of fisheries in future. The European Commission has made numerous proposals for improving the disastrous fisheries policy pursued over recent decades. Discussions are still ongoing, but it is hoped that the ambitious goals can be translated into effective legislation.

High ambitions, clear goals

The EU's fisheries policy has failed. Many fish stocks are overexploited. The fishing fleet is too large: there are too many boats out fishing, and not enough fish. For decades, catches have regularly exceeded the levels recommended by scientists. But this situation is about to change. The European Commission has resolved to overhaul the EU's fisheries policy and management at long last. A reform of its Common Fisheries Policy (CFP) – the regulatory framework applicable to all the EU Member States – is scheduled for 2013 and aims to achieve the following goals:

- In future, fish stocks in the EU will no longer be fished in accordance with the precautionary approach; instead, stocks must be exploited at levels that produce the "maximum sustainable yield" (MSY) (i.e. the amount that can be harvested with a view to protecting stocks).
- Fleet overcapacity is to be reduced.
- The amount of unwanted bycatch is to be reduced and discards eliminated.
- Fishing should not only exploit fish stocks sustainably, but should also have minimum impact on marine habitats, the aim being to ensure that fisheries management follows the ecosystem approach.
- There should be a stronger focus on regionalization. Fishermen in the various countries and regions should be involved to a greater extent in fisheries management, with Brussels merely establishing the general policy framework.

Many of these goals have already been achieved in other countries. In Europe, however, a sustainable and economically efficient fishing industry is still far from being a reality. It has become apparent that in a union of states like the EU, reconciling highly diverse national interests is a difficult process. However, the mere fact that the European countries were able to agree on a Common Fisheries Policy in the first place should be viewed as a success in itself. The Treaty of Rome, which created the European Economic Community (EEC) – the precursor to the EU – in 1957, contained a commitment to the formulation of a common fisheries policy. In those days, however, the fisheries sector was still relatively small and industrial fishing fairly rare. Furthermore, the scope of European fisheries policy extended only to the 12 nautical mile zone then in force.

Much has changed since then. Firstly, as time went on, major fishing nations such as Denmark, the United Kingdom, Portugal and Spain joined the EEC. And secondly, the scope of application of European fisheries policy increased with the introduction of the exclusive economic zone (EEZ), which extends to a distance of 200 nautical miles out from the coastal baseline. As a result, individual Member States acquired exclusive rights to fish in much larger areas of the sea. A Common Fisheries Policy was first adopted in 1982, and was accompanied by the introduction of the quota system. Under this system, the EU sets a total allowable catch (TAC) for the various species of fish and then allocates a fishing quota (based on a percentage of the catch) to each fishing nation, calculated according to a specific formula.

Fewer vessels, more efficiency

Whereas Denmark and Germany have already substantially reduced their fishing fleets, the Dutch, Portuguese

5.18 > Brussels: animal rights activists protest about overfishing.

and Spanish fleets in particular are still too large. In regions such as Galicia, the fishing industry is still an important source of income, as very few jobs exist in other sectors. Politicians therefore shy away from any reduction in the fishing fleet, which is also heavily subsidized for structural policy reasons. In the structurally weak fishing regions, EU funding has been – and is still – accessed in order to put new fishing vessels into service or refurbish older ships. The welfare of the region as a whole thus takes precedence over the greater goal of sustainable fishing. But generous subsidies create a vicious circle for the fishing industry. Government loans for fleet development have to be repaid, which compels fishermen to fish intensively with no regard for the welfare of fish stocks. This is one of the reasons why the Fisheries Ministers, who form the Fisheries part of the EU's Agriculture and Fisheries Council and are responsible for setting the new Total Allowable Catch (TAC) every year (in tonnes), have regularly set TACs which are far higher than recommended by fishery scientists – in extreme cases, up to 48 per cent higher.

An oversized fishing fleet also makes fishing inefficient, as there are far too many vessels in pursuit of the available stocks. In order to achieve even approximate compliance with the fishing quotas, each individual vessel can only harvest a small percentage of the Total Allowable Catch. It would be more sensible to reduce the number of vessels in operation and utilize their capacity to the full. One possible solution for reducing overcapacity is to introduce tradable quotas – initially at country level and later EU-wide. Fishing companies could sell these individual transferable quotas (ITQs) to others at a profit. Less economically efficient companies would be inclined to sell, and more profitable companies would be likely to buy the ITQs. In this way, the industry gradually sheds the less profitable companies, and the number of fishing vessels is reduced.

A system of catch quotas has already been introduced in Denmark. Here, in order to prevent the formation of monopolies and the bulk purchasing of quotas by a handful of fishing companies, no more than four vessels may be operated by a fishing company. The European Commission

Tradable quotas
Tradable quotas are a fisheries management tool used by various countries around the world. In 1986, New Zealand became the first country to incorporate a tradable quota system into national legislation. These tradable quotas are often known as „individual transferable quotas (ITQs)". The term preferred by the EU is „transferable fishing concession" (TFC).

is proposing to subdivide ITQ trading according to vessel size (i.e. vessels longer than 12 metres, and vessels under 12 meters in length). Owners of smaller vessels would not be permitted to sell their quotas to owners of ships in the larger-vessel category. This measure is intended to protect artisanal coastal fishing using smaller boats.

Doing battle against discards

In its current draft of the new CFP, the European Commission also makes a number of proposals for dealing with the problem of discards. All over the world, millions of tonnes of freshly caught fish and marine fauna are dumped back in the sea every year. Most of the discards are already dead when they go back into the water. This practice is a massive waste of natural resources. What's more, the discards are not systematically recorded, creating a large gap in the data that fishery scientists need to estimate the size of fish stocks accurately. In North Sea sole fishery, for example, large quantities of plaice and other flatfish, such as dab, are caught as bycatch. In some cases, this unwanted bycatch amounts to 70 per cent of the catch. As many plaice are too small to be landed legally and other flatfish are unpopular as eating fish, the bulk of this bycatch – with the exception of a few high-grade individuals – is dumped overboard. As the discards are not recorded, researchers find it almost impossible to make an accurate assessment of the status of flatfish stocks other than sole and plaice.

There are various reasons why fish are discarded:

- For some species, such as crustaceans, starfish and smaller fish such as the European eelpout and the family of gobies, there is simply no market.
- The fishermen sort out the high-grade components of the catch, such as the largest and heaviest individuals from a given species. The rest is dumped overboard. This high-grading has been prohibited in the EU since 2010 but is still practised.
- The fish are too young or too small. The rules currently in force prohibit the landing of these undersized fish.
- Fishermen are not permitted to land species for which they have not been allocated a quota. Nor can they land species for which their quota is already fulfilled. This problem occurs in mixed fisheries, where several species of a similar size occurring in a single habitat are sometimes netted together. A haddock fisherman, for example, is not permitted to land any cod caught as bycatch. Under the current rules, the cod must be discarded.

Due to the rules currently in place under the existing CFP, this type of prohibition on landings means that discarding still takes place on a large scale within the EU. As one possible solution, the European Commission is proposing a reform of the old quota allocation system. At present, individual quotas are still allocated for many species, even though these species are only caught in mixed fisheries. In future, it would be possible or even obligatory to acquire additional bycatch quotas, for example for cod and haddock. These bycatch quotas would be allocated in a flexible and straightforward manner. For example, rather than automatically being allocated for an entire year, they could be assigned on an ongoing basis throughout the course of the fishing season, depending on the status and development of stocks. The aim is to encourage fishermen to avoid bycatch of unwanted species – for example, through the use of better and more selective fishing gear. If they failed to achieve an appropriate reduction in the amount of bycatch, they would be obliged to apply for a bycatch quota. A fisherman would then have to demonstrate that he had been allocated a separate quota for each species likely to occur in the fishing grounds. In a mixed fishery, his fishing activities would then be oriented towards the stock with the smallest population.

In the North Sea, for example, the haddock stock is in a good state but the status of cod is less favourable. At present, a fisherman can catch as much haddock as he needs to fulfil his quota. Inevitably, though, some cod are caught as bycatch in the net and must be discarded. If the fisherman had two quotas, he could land both haddock and cod. However, he would have to stop fishing – for both haddock and cod – as soon as he had met his cod quota. This

5.19 > Pot fishery: a form of artisanal fishing still practised in Denmark.

is intended to protect cod from overfishing and avoid discards. Furthermore, the European Commission is keen to encourage the use of more selective fishing gear in future, as more sophisticated fishing technology can also help to reduce the amount of bycatch. A further proposal aims to reduce bycatch by obliging fishermen to avoid certain areas of the sea with large stocks of bycatch species at certain times of the year. A further possibility being discussed with a view to reducing discards is to equip the EU's fishing vessels with electronic surveillance systems, including CCTV, in future. This would enable checks to be carried out to determine whether any fish had been discarded, and if so, of which species. More intensive deployment of observers is a further option. However, the advantage of CCTV, compared with observers, is that it is far less expensive.

5.20 > Discarding of bycatch is a problem worldwide, not just in the EU. This Mexican prawn fisherman is dumping fish with no market value overboard.

More power for fishermen

At present, the EU's fisheries policy is still largely a top-down policy. The rules are agreed in Brussels at the highest level and must be adhered to by every fisherman in the same way. National or, indeed, regional approaches to fisheries management are virtually non-existent at present. As a result, conflicts are inevitable. Many of the sometimes contradictory rules agreed in Brussels are viewed by fishermen themselves as excessive or impractical. Indeed, some are ignored altogether. The Commission is proposing to defuse the situation by involving fishermen in fisheries management and decision-making to a greater extent, in the hope that this will increase their acceptance of the rules.

There is to be stronger regionalization of fisheries policy, as the Agriculture and Fisheries Council explains in its proposal on CFP reform. The proposal envisages that Member States would be able to devolve decision-making to the regional level. In recent years, a number of Regional Advisory Councils (RACs) have been established by various EU Member States, e. g. for the Baltic Sea and for the waters in the Arctic and around Iceland. These RACs have produced a number of proposals for CFP reform. Up to two-thirds of the members of the RACs are experts from the fisheries sector, with experts from other interest groups, such as nature conservation organizations and trade unions, comprising the remaining one-third. In future, the RACs, in conjunction with the relevant national authorities, could potentially undertake the management of fisheries in their specific region and submit their proposals to Brussels. Provided that there were no objections from the European Parliament or individual countries, the proposed fisheries management strategy would then enter into force.

Open-ended

Only time will tell which of the European Commission's reform proposals will be implemented; that will become clear when the new CFP is adopted in 2013. Ultimately, it is up to the Council and the European Parliament to decide which of the Commission's proposals will be incorporated as rules and provisions in the new CFP. We can only hope that the two institutions manage to agree on a fisheries policy which is good for both the economy and the environment. In fact, there is cause to be reasonably optimistic here: with the Marine Strategy Framework Directive, the European Union, in 2002, imposed an obligation on all Member States to take the necessary measures to protect and conserve the marine environment and achieve or maintain its good environmental status by the year 2020 at the latest. The Council is therefore obliged not only to ensure, with the new CFP, that fisheries are exploited at levels which produce the maximum sustainable yield (MSY); it must also minimize the impact of fishing on the marine environment at the same time.

Conclusion

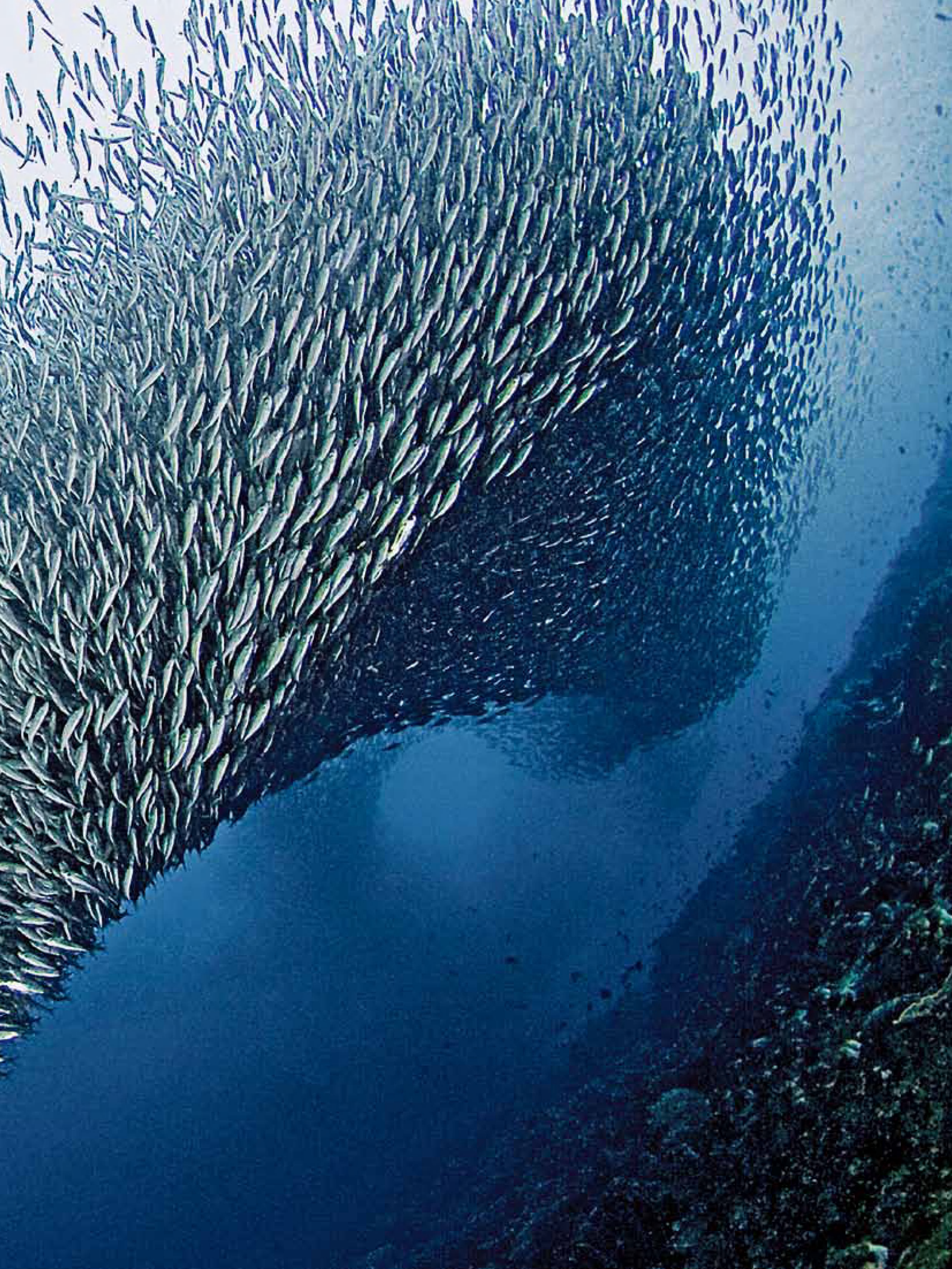
Learning from bitter experience?

Today, many fish stocks are in a poor state because they were badly managed, or not managed at all, for many years. One reason for their parlous condition is that policy-makers and fishing companies have often disregarded scientists' recommendations on Total Allowable Catch. From the scientists' perspective, the TACs were meant to be upper limits which should not be exceeded; their aim was to ensure that stocks were not put at risk. However, policy-makers and the fishing industry viewed these upper limits as recommendations on the maximum amount that could be caught. With disastrous results: in years when stocks were already in an unhealthy state due to poor environmental conditions, fishing activities often exceeded the level that stocks could reasonably sustain. Quick profits or short-term protection of jobs were often viewed as more important than the recovery of stocks and the creation of a sustainable, high-yielding fishing industry for the long term.

There now appears to be a willingness to learn from past mistakes, with alternative and more sustainable fisheries management strategies slowly coming to the fore all over the world. These strategies are based on the concept of maximum sustainable yield (MSY), i.e. the amount that can be harvested with a view to maintaining abundant stocks for the long term. This concept can be easily adapted to diverse local conditions and allows countries to tailor their approach, also taking account of the social dimension.

In future, fisheries management strategies based on the MSY principle should also consider the interaction between the various species and the impact of fishing on the ecosystem. These modern fisheries management strategies also aim to promote more stakeholder involvement in order to identify solutions which are acceptable to everyone. The stakeholders concerned are fishermen, relevant authorities, professional associations and environmental organizations at regional and local level. But how can all these various aspects be reconciled within the framework of the Common Fisheries Policy (CFP)? That is currently the subject of intense debate in Europe. The problem with the previous fisheries policy was that outdated provisions constantly had to be revised and improved upon. This led to a plethora of rules which were often ignored, and made compliance extremely difficult to monitor.

One problem which is still largely unresolved is the issue of discards: unwanted bycatch is simply dumped overboard. This causes the wastage of millions of tonnes of fish and marine fauna all over the world every year. Fish which cannot be landed because they do not make the grade in terms of size, or because no quota is in place for the species, are very likely to be discarded. The practice of high-grading is also a problem: this means that fishermen pick out the most valuable parts of the catch and dump the rest overboard. Various methods are currently being discussed to reduce the quantity of discards, such as more intensive deployment of government observers or onboard surveillance using CCTV. This type of system is now being trialled on some fishing vessels in the North Sea and the Baltic Sea. The European Commission is also keen to use the CFP as an opportunity to demand more industry responsibility, which turns the spotlight on fishermen themselves. Anyone whose fishing practices result in several species being netted simultaneously will be required to obtain a licence for each of the relevant species. This is intended to encourage fishermen to set their nets in areas where only one species of fish is likely to be caught, or to use nets which are designed to catch one specific species.



world ocean review
Living with the oceans. 2013

2
The Future of Fish – The Fisheries of the Future

Overall conclusion

The first World Ocean Review aimed to provide a comprehensive overview of the state of our oceans. This second issue concentrates in greater detail on a single aspect – the future of fish and fisheries. Fish and people have been intimately linked with each other for thousands of years. Fish is an important food, it is the subject of myth, while in some cultures – and in Christianity – it is considered a divine symbol. However, we humans are not treating this precious ocean resource with the care it needs. Never before have we exploited the world's fish stocks as rapaciously as during the past 50 years – reason enough for us to devote this volume entirely to the issue.

Fish are a widely distributed resource. Around the world there is a total of about 30,000 different species, of which approximately 15,000 live in the sea. They are a crucial element of the various marine habitats. Fish and all other living organisms in the sea are linked through complex food webs. Humans, through their fishing practices, are tampering with this network of relationships. If large numbers of any one fish species are removed, there are also repercussions for the other organisms which depend on this species. Slowly we are beginning to understand how severely fisheries have impacted on the massive ocean system and what changes we have already inflicted on marine environments. Specialists already know that in future it will not be enough to consider commercially-interesting fish species in isolation. For this reason many experts are developing new fisheries management concepts based on the entire ecosystem, which will allow for the interactions between the different species. Fortunately many nations are now working together to protect jointly-exploited stocks or "Large Marine Ecosystems" – such as along the coast of southwest Africa. Sustainable fisheries which conserve stocks are of particular importance to the developing countries. Along coastal areas, fishing represents the main occupation and fish are the most important source of animal protein. In nations such as Bangladesh and Ghana fish accounts for more than 50 per cent of the animal protein in the population's diet.

Even today non-industrial fishing from small craft often predominates in the developing countries. The number of such artisanal fishermen worldwide is estimated at about 12 million. In contrast the industrialized nations now fish with modern vessels. The largest of these, known as factory ships, can take vast amounts of fish from the sea. The fish are immediately processed, packaged and deep-frozen on board. Only about 500,000 people worldwide work in the industrial fishing industry. The amount they catch per person is many times that caught in the nets of artisanal fishermen.

Factory ships with deep-freeze facilities on board make it possible to fish in any ocean, no matter how far from the coast. The fish no longer spoils as it used to do on long voyages. Since the 1960s, therefore, we humans have been able to exploit global fish stocks at will, far beyond their tipping points. The outcome is that today, according to Food and Agriculture Organization of the United Nations (FAO) data, more than a quarter of fish stocks are overfished. Since 1950 the amount of the annual fish catch worldwide has increased fivefold. In 2011 alone,

Overall conclusion

78.9 million tonnes of fish and seafood were harvested from the sea. In order to catch such large amounts over a period of many years, the fisheries have spread further and further south from the traditional grounds of the Northern Hemisphere to take in all maritime regions. Once the stocks had been exploited, the fleets moved on to new fishing grounds. Overfished species were replaced by other lesser-known and scarcely-exploited species. Fisheries have also penetrated into ever-deeper waters. Today the nets of some trawlers extend to depths of 2000 metres, partially or completely destroying important underwater regions such as cold-water coral reefs and habitats at seamounts.

Despite all the bad news, the situation is not entirely desperate. There are some examples of good fishery practices, mainly in regions or nations which entered the industrial fishing industry relatively late and were prepared to learn from the mistakes of others. These include Alaska, Australia and New Zealand. Most nations have for many years oriented their fish catch to individual limit reference points which are calculated by fisheries scientists. The researchers make recommendations of maximum annual tonnages of fish which should be caught within a certain region. Despite this, too many fish have been taken. One reason is that these reference points are beset by uncertainties, and another is that policy-makers and fisheries regularly exceeded the limit reference points. Alaska, Australia and New Zealand, by contrast, pursue the concept of a long-term sustainable yield which is guided by the current status of stocks. Their reasoning is that if the stocks are healthy, more fish can be caught in the long run, and greater revenues can be generated. This concept of "maximum sustainable yield" (MSY) was very controversial for a long time, because its original aim was solely to maximize yields – not to conserve the fish resource. The current examples clearly show, however, that the concept conforms to local conditions and can be expanded to take account of ecological and social aspects such as fishermen's interests. For this reason many experts consider it a positive development that the MSY idea is slowly gaining acceptance at an international level. It does seem to be capable of preventing overfishing.

A major problem today is illegal (IUU) fishing. Most illegal fishing is carried out in the territorial waters of developing countries, as these nations cannot afford to establish effective fisheries control structures. It is estimated that between 11 and 26 million tonnes of fish are caught illegally each year, further weakening already overfished stocks. But here too there are encouraging signs. International cooperation projects, for instance, have been involved in developing monitoring systems in West Africa which act as a deterrent and keep IUU fishermen away. On the other hand illegal fishing is likely to remain an attractive option for black market dealers because rapid population growth will continue to drive up the global demand for fish.

From a nutritional point of view is makes sense to eat fish regularly because fish caught in the wild is a natural, healthy food. It contains high-quality proteins, valuable fatty acids and many minerals. Consumption today is the highest in the industrialized nations, at 28.7 kilograms per head per annum. The lowest is in Africa, at 9.1 kilograms. Experts believe that more and more fish will be consumed worldwide in future. Therefore, if we do not want to plunder the ocean fish stocks any further, the only alternative is aquaculture, or fish farming. Large amounts of fish and seafood are already produced by this method. In 2010 a total of 60 million tonnes of fish, mussels and crustaceans came from aquaculture. Global production has increased by 8.4 per cent per annum in recent decades – more than any other food industry. Its growth is unabated, particularly in Asia which accounts for 89 per cent of global aquaculture production. However, it is vital for fish farming to become more environmentally sound. Various factors have given the sector a bad name, including antibiotics in the fish, overfertilized waters and the felling of mangrove forests to establish new facilities. Many international projects have now been successful in making production more sustainable, and the first products from ecologically managed operations are already on the market. Relevant eco-labels are currently becoming established. Consumers in the industrialized nations, particularly Europe and the USA – the world's largest importers of fish – are called on to assert their influence in this respect.

Aquaculture has also been under fire for processing ocean fish into the fishmeal and fish oil which is fed to the farmed fish. The problem is that considerably more than 1 kilogram of marine fish is required to produce 1 kilogram of farmed fish. Critics view this as a waste, claiming it would be better to eat the wild fish directly. The counterargument is that there is no demand anyway for the small fish species used in aquaculture facilities. As fishmeal and fish oil prices have soared in recent years in response to the high demand from China, researchers have been trying to reduce the proportion of fish in the feed – by replacing some of it with plant-based supplements and by using more digestible feed mixes.

Wild capture fishery or aquaculture: we already know how the fishing industry could be improved. Now it is time for us to set the course for a sustainable future. This applies in particular to Europe where solutions for its new Common Fisheries Policy are currently under discussion. It is important to reduce the oversized fishing fleets of Portugal and Spain. Fears of high unemployment have prompted policy-makers to subsidize and modernize the fisheries for years, thus speeding up the sell-out of the fish stocks. The problem of bycatch is also unresolved. Fishermen throw overboard any undersized fish and those for which they have no licence. Most of the creatures die. In some cases this discard amounts to 70 per cent of the catch – an enormous waste. In future improved licensing systems and monitoring by CCTV cameras or state observers on board should help to bring the problem under control. The next few months will show whether the policy-makers, particularly the EU Fisheries Ministers, manage to introduce a sustainable fisheries management system. It is to be hoped that this publication will help convince them of its importance.

Nikolaus Gelpke, Awni Behnam, Martin Visbeck

Glossary

The Glossary explains the meaning of specialist terms which are particularly important for an understanding of the text but which cannot be defined in the individual chapters due to space constraints. Glossary terms are printed in bold and are easy to identify.

Algal bloom: a massive reproduction event by algae and other single-celled organisms in rivers, lakes or the ocean triggered by an increased input of nutrients. Algal blooms are a natural phenomenon. As a result of →overfertilization, however, especially pronounced episodes occur today in many marine areas. When the algae die, they are broken down by bacteria, which consume oxygen. This produces "dead zones" in severely overfertilized waters.

Ballast water: water that is pumped into special ballast water tanks in ships' hulls for stabilization. Ballast water is transported over large distances, particularly by cargo vessels. Organisms in the water such as algae, larvae and bacteria can easily cross the oceans in this way. When they become established in a new habitat they can displace native species.

Carrying capacity: the maximum number of individuals or species that can exist in a habitat. It is determined in part by the amount of available food and, in the case of fish, by the available spawning sites.

El Niño: an irregular climate phenomenon occurring every 3 to 8 years in the Pacific Ocean between Indonesia and Peru. The direction of the →trade winds and ocean currents reverses due to atmospheric pressure changes. Off the coast of Peru this leads to a decline in the upwelling of cold, nutrient-rich water from the deeper layers to the surface. El Niño is Spanish for infant Jesus. The phenomenon was so named because it often occurs around Christmas time.

Endemic: plant and animal species that only occur in a particular and limited area of the world are called endemic. Endemic species are very susceptible to extinction due to degradation of their habitat.

Multispecies fishery: fishing for multiple species of fish at the same time. Whether a fisherman catches a number of different species in his net depends on several factors, including the behaviour of the fish, the marine area, and the time of year in the case of migrating fish. In multispecies fishing, species are often caught that are of no interest to the fisherman, or that he is not allowed to sell. These fish are usually thrown overboard dead.

Non-governmental organization (NGO): civil-society interest group that attempts to influence policies. NGOs counterbalance the representation of governmental interests. NGOs are especially active on issues relating to social equity and environmental quality.

North Atlantic Oscillation (NAO): fluctuations in the atmospheric pressure difference between the Azores high and Icelandic low. The NAO is especially influential in determining the winter climate in Europe, but also has an effect on North Africa, Greenland and the eastern USA. The aspects of its influence include water temperatures in the North Atlantic.

Oceanic ridge: ridges or mountain ranges on the sea floor that form where continental plates drift apart. At these plate boundaries, magma rises from the Earth's interior, is cooled by the water, and over time forms enormous mountains.

Overfertilization (eutrophication): the input of unnaturally large amounts of nutrients from agriculture or from industrial or municipal effluent into natural waters. Overfertilization leads to increased reproduction of algae, called →algal blooms. The problematic substances include nitrogen and phosphorus compounds from mineral fertilizers of from faeces and urine.

Pelagic: organisms that live and feed in open waters are called pelagic.

Planktivores: organisms that feed on plankton (microalgae, fish and mussel larvae or krill) are called planktivores.

Red List: Plant and animal species as well as habitat types are classified into several categories in red lists according to the degree of threat, for example, from "near threatened" to "extinct". The most important worldwide Red List is issued by the International Union for Conservation of Nature (IUCN). Individual countries or regions also have their own lists that are released by various public authorities. For the Baltic Sea, for example, there is the Helsinki Commission, HELCOM. The classifications can differ from list to list. On the IUCN List, for example, the small-spotted catshark is classified as "least concern", because it still has a wide distribution. In the Baltic Sea region, however, it is now very rare and is therefore classified as "endangered" in the HELCOM List.

Trade winds (trades): winds that blow consistently in the tropics and are thus a driving force for ocean currents. The trade winds are located between approximately 23 degrees north and south of the equator. The northeasterly trades in the Northern Hemisphere are distinguished from the southeasterly trades in the Southern Hemisphere.

United Nations Convention on the Law of the Sea (UNCLOS): UNCLOS has defined the rights of nations with respect to the sea since 1982. For this purpose it divides the seas into various zones. For example, under UNCLOS every nation-state has the right to manage the fish stocks in its Exclusive Economic Zone (EEZ), which extends to a distance of 200 sea miles from its coast. Beyond the EEZ, the high seas freedoms apply under UNCLOS. Fish may be caught here by any country. In addition, UNCLOS regulates shipping, marine environmental protection, and the production of oil, gas and other resources in the ocean. UNCLOS is the legal foundation for the International Tribunal for the Law of the Sea.

Abbreviations

AIDCP Agreement on the International Dolphin Conservation Programme

ASC Aquaculture Stewardship Council

B Biomass

B_{LIM} Limit biomass

B_{MSY} Biomass maximum sustainable yield

B_{PA} Biomass precautionary approach

CCAMLR Commission for the Conservation of Antarctic Marine Living Resources

CCBSP Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea

CCSBT Commission for the Conservation of Southern Bluefin Tuna

CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora

CPUE Catch per unit effort

DHA Docosahexaenoic acid

EEC European Economic Community

EEZ Exclusive Economic Zone

EPA Eicosapentaenoic acid

EU European Union

F Fishing mortality rate

F_{LIM} Fishing mortality rate limit biomass

F_{PA} Precautionary fishing mortality rate

FAO Food and Agriculture Organization of the United Nations

FMP Fishery management plan

GFCM General Fisheries Commission for the Mediterranean

GFP Common Fisheries Policy of the European Union

IATTC Inter-American Tropical Tuna Commission

ICCAT International Commission for the Conservation of Atlantic Tunas

ICES International Council for the Exploration of the Sea

IMTA Integrated multi-trophic aquaculture

IOTC Indian Ocean Tuna Commission

ITQs Individual transferable quotas

IUCN International Union for Conservation of Nature

IUU-fishing Illegal, unreported and unregulated fishing

LCA Life cycle assessment

LED Light emitting diode

LME Large marine ecosystem

MPA Marine protected area

MSC Marine Stewardship Council

MSFCM Magnuson-Stevens Fishery Conservation and Management Act

MSY Maximum sustainable yield

NAFO Northwest Atlantic Fisheries Organization

NAO North Atlantic oscillation

NASCO North Atlantic Salmon Conservation Organization

NEAFC North East Atlantic Fisheries Commission

NOAA National Oceanic and Atmospheric Administration

PA Precautionary approach

RAC Regional advisory council

RFMO Regional Fisheries Management Organisation

SEAFO South East Atlantic Fisheries Organisation

SIOFA South Indian Ocean Fisheries Agreement

SOFIA Report The state of world fisheries and aquaculture

SOLAS International Convention for the Safety of Life at Sea

SPRFMO South Pacific Regional Fisheries Management Organisation

SRFC Sub-Regional Fisheries Commission

TAC Total allowable catch

TURFs Territorial use right in fisheries

UNEP United Nations Environment Programme

UNFSA United Nations Straddling Fish Stocks Agreement

VME Vulnerable marine ecosystem

VMS Vessel Monitoring System

WCPFC Western and Central Pacific Fisheries Commission

WSSD World Summit on Sustainable Development

WWF World Wide Fund For Nature

Contributors

Many experts have contributed their specialized knowledge to the compilation of the World Ocean Review 2013. In particular, scientists working together on questions related to the development of our seas in the Cluster of Excellence "The Future Ocean" participated in the present work

Dr. Malcolm Beveridge, Director of Aquaculture and Genetics at WorldFish. His research interests include aquaculture and fisheries and their impacts on poverty and hunger and on the environment. Beveridge is currently engaged with colleagues and partners in developing pro-poor aquaculture value chains in Africa, Asia and the Pacific as part of the CGIAR Research Programs on Livestock and Fish and on Aquatic Agriculture Systems. He is also researching into how the rise of aquaculture is impacting on food and nutrition security.
www.worldfishcenter.org

Dr. Anthony Charles, interdisciplinary marine and coastal researcher at Saint Mary's University in Halifax, Canada, and Principal Investigator of the global Community Conservation Research Network. A. Charles engages in research that seeks broadly to improve the governance, management and economics of fisheries, coastal and marine social-ecological systems. His particular research interests include fishery sustainability and resilience, governance of small-scale fisheries, adaptation of coastal communities to uncertainty and climate change, human dimensions of ecosystem-based marine management, impacts of marine and coastal disasters, and the role of participatory and community-based ocean governance.
http://husky1.smu.ca/~charles/

PD Dr. Ulf Dieckmann, theoretical biologist and leader of the Evolution and Ecology Program at the International Institute for Applied Systems Analysis in Laxenburg, Austria. His research focuses on fisheries-induced evolution, sustainable use of natural resources, biodiversity and speciation, various model-based analyses in the field of spatial and evolutionary ecology, as well as investigations on the conditions of cooperative behaviour in human and animal populations.
www.iiasa.ac.at/web/home/research/researchPrograms/EvolutionandEcology/New-page.en.html

Dr. Heino O. Fock, marine ecologist at the Thünen Institute of Sea Fisheries in Hamburg. His specialties are the assessment of fish stocks, evaluation of environmental implications in fisheries, and deep-sea ecology. His interests in these areas include determination of the fundamental conditions for sustainable use of fisheries and ecosystem services.
www.ti.bund.de/de/startseite/institute/sf/personal/wissenschaftler/fock.html

Dr. Rainer Froese, fisheries biologist at the Helmholtz Centre for Ocean Research in Kiel. His specialties are fisheries biology, population dynamics, aquatic biodiversity, biogeography, and fishery management. Together, he and Daniel Pauly developed the FishBase database (www.fishbase.org). Since 1990 he has been its project leader and coordinator. R. Froese was also a founding member of "Species 2000" and of the Ocean Biogeographic Information System (OBIS), which was a part of the "Census of Marine Life" project. He is presently coordinating various projects with the goal of producing the first global atlas of life in the ocean (www.aquamaps.org).
www.fishbase.de/rfroese/

Dr. Matthias Keller, agrarian engineer in the Fisch-Informationszentrum e. V. (FIZ – Fish information centre registered association). M. Keller is also the director of two other fishery science institutions and is chairman of the working group "Markets and International Trade of the Advisory Committee on Fisheries and Aquaculture" in the European Commission. M. Keller is the author of the handbook "Fisch, Krebs- und Weichtiere" (Fish, crustaceans and molluscs) published by Behr's-Verlag.
www.fischinfo.de

Dr. Ulf Löwenberg, fisheries biologist; presently working as the leader of a project for sustainable management of fishery resources in Mauretania on assignment for the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ, the German federally-owned international development company). He has been active in the field of fisheries for 30 years and has conducted numerous assignments abroad on behalf of German and European development institutions. He has been involved in numerous studies as an independent expert for public and private contractors.
www.giz.de

Dr. Gorka Merino, specialist for bioeconomic modelling of fisheries at the Spanish research centre AZTI-Tecnalia. He is primarily involved with aspects relating to the maximum sustainable exploitation of fish stocks. His scientific research has also focused on the interaction of economic and environmental drivers and their impact on the sustainability of marine resources. G. Merino worked at the Plymouth Marine Laboratory (UK) until the end of 2012.
www.azti.es/

Prof. Dr. Christian Möllmann, fisheries biologist at the Institute for Hydrobiology and Fisheries Science at the University of Hamburg. He studies the influence of fisheries and climate on the structure and function of marine ecosystems, particularly marine food webs. His research provides a basis for the development of ecosystem-based approaches for the management of living resources. C. Möllmann is editor of the journal "Fisheries Oceanography".
www.uni-hamburg.de/ihf/christianmoe_e.html

Rosemary E. Ommer, Adjunct Professor at the University of Victoria, Canada. She has directed marine-related institutes at the Universities of Victoria, Calgary and Memorial University of Newfoundland. She has also been the principal investigator on several interdisciplinary research projects involving natural and social scientists, humanists, and education and health sciences. She has a PhD in economic historical geography from McGill University, an MA in historical geography from Memorial University of Newfoundland, and she researched and taught in Atlantic Canada from the early 1970s until 1997. She is the author and/or editor/co-editor of *Coasts Under Stress: restructuring and social-ecological health* (McGill-Queen's Press 2007) and many other books. From 2001 until 2009 she was a member of the international scientific steering committee (ISSC) of GLOBEC – the global oceans ecosystem dynamics science research group, and was co-chair of their Focus 4 research group, which looks at the human dimensions of global ocean ecosystems.

www.fisheries.ubc.ca/faculty-staff/rosemary-ommer

Prof. Dr. Daniel Pauly, fisheries biologist at the Fisheries Centre of the University of British Columbia in Vancouver, Canada. D. Pauly is the leader of the "Sea Around Us" project, a research group that aims to research and document the most important trends in ocean fisheries since 1950. After completing studies in oceanography and fisheries biology at the Christian-Albrechts-University of Kiel, he worked for many years at an international research centre in the Philippines where he initiated numerous cooperative projects that are now globally recognized, including FishBase and Ecopath. He has worked at the UBC Fisheries Centre since 1994, and was its director from 2003 to 2008.

www.fisheries.ubc.ca/faculty-staff/daniel-pauly

Dr. Mark Prein, fisheries biologist and presently leader of an international project within the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ, the German federally-owned international development company) to promote sustainable fishery and aquaculture. Before that, for 15 years, he was head of the department of freshwater fishing and aquaculture at the WorldFish Center/ICLARM and worked at the FAO. In addition to his involvement in Germany's government-sponsored development work with frequent assignments abroad, M. Prein holds a teaching position in the faculty of Agricultural Sciences at the University of Hohenheim.

www.giz.de

Prof. Dr. Martin Quaas, economist at the Christian-Albrechts-University of Kiel and leader of the research group "Fisheries and Overfishing/Living Resources" in the Cluster of Excellence "The Future Ocean". The specialty areas of M. Quaas are environmental, resource and ecological economics. One goal of his research is the development of new fisheries management approaches and new market-based instruments of fisheries policy that promote sustainability in the sector.

www.bwl.uni-kiel.de/eree/Quaas_de.html

Dr. Jörn O. Schmidt, fisheries biologist at the Christian-Albrechts-University of Kiel in the working group "Sustainable Fisheries" in the Cluster of Excellence "The Future Ocean". J. Schmidt is the German member on the Science Committee of the International Council for the Exploration of the Sea, where he represents the scientific interests of Germany with respect to fisheries research. Together with two colleagues, one Dane and one American, he also leads a working group that investigates fishery management using coupled ecological-economic models.

www.bwl.uni-kiel.de/eree/Schmidt_de.html

Prof. Dr. Carsten Schulz, agrarian engineer at the Christian-Albrechts-University of Kiel and at the Society for Marine Aquaculture in Büsum. C. Schulz investigates innovative technologies for the development of environmentally sound aquaculture, especially in marine systems. His other areas of interest are in the field of fish nutritional requirements, and providing these with appropriate new products. C. Schulz is also involved in studies of the complex interactions of fish breeding with physiological health and reproduction processes.

www.gma-buesum.de/index.php?contentID=162

Dr. Rüdiger Voss, fisheries biologist at the Christian-Albrechts-University of Kiel in the working group "Sustainable Fisheries" within the Cluster of Excellence "The Future Ocean". R. Voss investigates environmental factors that impact the early life stages of fish. He also studies species interactions, and from these derives multispecies system and ecosystem management strategies. His work integrates biological and economic factors of fisheries, and combines ecological expertise with economics in coupled models.

www.bwl.uni-kiel.de/eree/Voss_de.html

Dr. Christopher Zimmermann, fisheries biologist at the Thünen Institute of Baltic Sea Fisheries in Rostock. C. Zimmermann is the German member on the Advisory Committee of the International Council for the Exploration of the Sea, and is therefore responsible for scientific recommendations on the management of commercially exploited living resources in the northeast Atlantic. In recent years, C. Zimmermann has focused primarily on fishery management and alternative management approaches, and on survey strategies and marine data. In addition, he advises the German federal government, the European Commission and the European Parliament (particularly with regard to reforms of the Common Fisheries Policy), as well as the retail trade, the processing industry and environmental groups on various aspects of the sustainable use of marine fish.

www.ti.bund.de/de/startseite/institute/of/personal/leitung/zimmermann-christopher.html

Bibliography

Chapter 1 – The importance of marine fish

Baum, J. & B. Worm, 2009. Cascading top-down effects of changing oceanic predator abundances. Journal of Animal Ecology 78: 699–714.

Dieckmann, U., M. Heino & A.D. Rijnsdorp, 2009. The dawn of Darwinian fishery management. ICES Insight 46: 34–43.

Dunlop, E.S., M. Heino & U. Dieckmann, 2009. Eco-genetic modeling of contemporary life-history evolution. Ecological Applications 19: 1815–1834.

Enberg, K., E.S. Dunlop, C. Jørgensen, M. Heino & U. Dieckmann, 2009. Implications of fisheries-induced evolution for stock rebuilding and recovery. Evolutionary Applications 2: 394–414.

Fock, H.O., 2011: Natura 2000 and the European Common Fisheries Policy. Marine Policy 35: 181–188.

Frank, K.T., B. Petrie, J.A.D. Fisher & W.C. Leggett, 2011. Transient dynamics of an altered large marine ecosystem. Nature 477: 86–88.

Frank, K.T., B. Petrie & N.L. Shackell, 2007. The ups and downs of trophic control in continental shelf ecosystems. Trends in Ecology and Evolution 22, 5: 236–242.

Geßner, J., M. Tautenhahn, H. von Nordheim & T. Borchers, 2010. Nationaler Aktionsplan zum Schutz und zur Erhaltung des Europäischen Störs (Acipenser sturio). Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Bundesamt für Naturschutz (BfN).

Heino, M., U. Dieckmann & O.R. Godø, 2002. Reaction norm analysis of fisheries-induced adaptive change and the case of the Northeast Arctic cod. ICES CM 2002/Y: 14.

Jørgensen, C., K. Enberg, E.S. Dunlop, R. Arlinghaus, D.S. Boukal, K. Brander, B. Ernande, A. Gårdmark, F. Johnston, S. Matsumura, H. Pardoe, K. Raab, A. Silva, A. Vainikka, U. Dieckmann, M. Heino & A.D. Rijnsdorp, 2007. Managing evolving fish stocks. Science 318: 1247–1248.

Richardson, A.J., A. Bakun, G.C. Hays, M.J. Gibbons, 2009. The jellyfish joyride: causes, consequences and management actions. Trends in Ecology and Evolution 24: 312–222.

Sherman, K. & A.M. Duda, 1999. An ecosystem approach to global assessment and management of coastal waters. Marine Ecology Progress Series 190: 271–287.

www.lme.noaa.gov/

Chapter 2 – Of fish and folk

Charles, A., 2010. Good Practices in the Governance of Small-Scale Fisheries, with a Focus on Rights-Based Approaches. Prepared for the Food and Agriculture Organisation of the United Nations Regional Workshop on Small-Scale Fisheries.

Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department, 2012: The state of the world fisheries and aquaculture 2012.

Miller, K., A. Charles, M. Barange, K. Brander, V.F. Gallucci, M.A. Gasalla, A. Khan, G. Munro, R. Murtugudde, R.E. Ommer & R.I. Perry, 2010. Climate change, uncertainty, and resilient fisheries: Institutional responses through integrative science. Progress in Oceanography 87: 338–346.

Ommer, R.E., 2010: The Coasts Under Stress project: a Canadian case study of interdisciplinary methodology. Environmental Conservation 37, 4: 478–488.

Perry, R.I. & R.E. Ommer, 2003. Scale issues in marine ecosystems and human interactions. Fisheries Oceanography 12, 4: 1–10.

Perry, R.I. & R.E. Ommer, 2010. Introduction: Coping with global change in marine social-ecological systems. Marine Policy, 34, 4: 739–820.

Perry, R.I., R.E. Ommer, M. Barange, S. Jentoft, B. Neis & U.R. Sumaila, 2011. Marine social- ecological responses to environmental change and the impacts of globalization. Fish and Fisheries, 12: 427–450.

www.fischinfo.de/

www.mri.bund.de

Chapter 3 – Plenty more fish in the sea?

Agnew, D.J., J. Pearce, G. Pramod, T. Peatman, R. Watson, J.R. Beddington & T.J. Pitcher, 2009. Estimating the worldwide extent of illegal fishing. PLoS One 4, 2: e4570.

Agriculture and Rural Development Sustainable Development Network, Worldbank & Food and Agriculture Organization of the United Nations, 2008: The sunken billions – the economic justification for fisheries reform.

Berkes, F., T.P. Hughes, R.S. Steneck, J.A. Wilson, D.R. Bellwood, B. Crona, C. Folke, L.H. Gunderson, H.M. Leslie, J. Norberg, M. Nyström, P. Olsson, H. Österblom, M. Scheffer & B. Worm, 2006. Globalization, roving bandits, and marine resources. Science 311: 1557–1558.

Branch, T.A., R. Watson, E.A. Fulton, S. Jennings, C.R. McGilliard, G.T. Pablico, D. Ricard & S.R. Tracey, 2010. The trophic fingerprint of marine fisheries. Nature 468: 431–435.

Branch, T.A., O.P. Jensen, D. Ricard, Y. Ye & R. Hilborn, 2011. Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Biological Conservation 25: 777–786.

Burnett, M., N. Dronova, M. Esmark, S. Nelson, A. Rønning & V. Spiridonov, 2008. Illegal fishing in arctic waters – catch of today – gone tomorrow? WWF International Arctic Programme, Oslo.

Costello, C., D. Ovando, R. Hilborn, S.D. Gaines, O. Deschenes & S.E. Lester, 2012. Status and solutions for the world's unassessed fisheries. Science 338: 517–520.

Cullis-Suzuki, S. & D. Pauly, 2010. Failing the high seas: a global evaluation of regional fisheries management organizations. Marine Policy 34, 5: 1036–1042.

Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department, 2012. The state of the world fisheries and aquaculture 2012.

Froese, R., 2004: Keep it simple: three indicators to deal with overfishing. Fish and Fisheries, 5: 86–91.

Froese, R., A. Stern-Pirlot, H. Winker & D. Gascuel, 2008: Size Matters: How Single-Species Management Can Contribute To Ecosystem-based Fisheries Management. Fisheries Research, 92: 231–241.

Froese, R., T.A. Branch, A. Proelß, M. Quaas, K. Sainsbury & C. Zimmermann, 2011. Generic harvest control rules for European fisheries. Fish and Fisheries 12, 3: 340–351.

Froese, R., D. Zeller, K. Kleisner & D. Pauly, 2012. What catch data can tell us about the status of global fisheries. Marine Bio-logy, 159, 6: 1283–1292.

Hughes, T.P., F. Berkes, R.S. Steneck, J.A. Wilson, D.R. Bellwood, B. Crona, C. Folke, L.H. Gunderson, H.M. Leslie, J. Norberg, M. Nyström, P. Olsson, H. Österblom, M. Scheffer & B. Worm, 2006. Keeping bandits at bay. Reply. Science 313: 614.

Jones, A.J., 2007. Combatting IUU fishing in West Africa – a regional approach. European Parliament hearing on IUU fishing.

Kleisner, K., R. Froese, D. Zeller & D. Pauly, 2012. Using global catch data for inferences on the world's marine fisheries. Fish and Fisheries. doi:10.1111/j.1467–2979.2012.00469.x.

Martell, S. & R. Froese, 2012: A simple method for estimating MSY from catch and resilience. Fish and Fisheries. doi:10.1111/j.1467–2979.2012.00485.x.

Pauly, D. & R. Froese, 2012. Comments on FAO's State of Fisheries and Aquaculture, or 'SOFIA 2010'. Marine Policy 36: 746–752.

Rossing, P., C. Hammer, S. Bale, S. Harper, S. Booth & D. Zeller, 2010. Germany's marine fisheries catches in the Baltic Sea (1950–2007). 107–126. In: Rossing, P., S. Booth & D. Zeller (eds.). Total marine fisheries extractions by country in the Baltic Sea: 1950–present. Fisheries Centre Research Reports 18, 1. Fisheries Centre, University of British Columbia, Canada.

Sethi, S.A., T.A. Branch & R. Watson, 2010. Fishery development patterns are driven by profit but not trophic level. Proceedings of the National Academy of Sciences, U.S.A. 107: 12163–12167.

Srinivasan, U.T., R. Watson & U.R. Sumaila, 2012. Global fisheries losses at the exclusive economic zone level, 1950 to present. Marine Policy 36: 544–549.

Swartz, W., E. Sala, R. Watson & D. Pauly, 2010. The spatial expansion and ecological footprint of fisheries (1950 to present). PLoS One 5, 12: e15143.

Worm, B., E.B. Barbier, N. Beaumont, J.E. Duffy, C. Folke, B.S. Halpern, J.B.C. Jackson, H.K. Lotze, F. Micheli, S.R. Palumbi, E. Sala, K.A. Selkoe, J.J. Stachowicz & R. Watson, 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314: 787–790.

Worm, B., R. Hilborn, J.K. Baum, T.A. Branch, J.S. Collie, C. Costello, M.J. Fogarty, E.A. Fulton, J.A. Hutchings, S. Jennings, O.P. Jensen, H.K. Lotze, P.A. Mace, T.R. McClanahan, C. Minto, S.R. Palumbi, A.M. Parma, D. Ricard, A.A. Rosenberg, R. Watson & D. Zeller, 2009. Rebuilding global fisheries. Science 325: 578–585.

http://fischbestaende.portal-fischerei.de/

Chapter 4 – A bright future for fish farming

Deutsch, L., S. Gräslund, C. Folke, M. Troell, M. Huitric, N. Kautsky & L. Lebel, 2007. Feeding aquaculture growth through globalization: Exploitation of marine ecosystems for fishmeal. Global Environmental Change 17: 238–249.

Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department, 2012. The state of the world fisheries and aquaculture 2012.

Hall, S.J., A. Delaporte, M.J. Phillips, M.C.M. Beveridge & M. O'Keefe, 2011. Blue Frontiers: Managing the Environmental Costs of Aquaculture. The WorldFish Center, Penang, Malaysia.

Merino, G., M. Barange, C. Mullon & L. Rodwell, 2010. Impacts of global environmental change and aquaculture expansion on marine ecosystems. Global Environmental Change 20: 586–596.

Merino, G., M. Barange, J.L. Blanchard, J. Harle, R. Holmes, I. Allen, E.H. Allison, M.C. Badjeck, N.K. Dulvy, J. Holt, S. Jennings, C. Mullon & L.D. Rodwell, 2012. Can marine fisheries and aquaculture meet fish demand from a growing human population in a changing climate? Global Environmental Change 22, 4: 795–806.

Nagel, F., H. Slawski, H. Adem, R.-P. Tressel, K. Wysujack & C. Schulz, 2012. Albumin and globulin rapeseed protein fractions as fish meal alternative in diets fed to rainbow trout (Oncorhynchus mykiss W.). Aquaculture 354–355: 121–127.

Naylor, R.L., R.W. Hardy, D.P. Bureau, A. Chiu, M. Elliott, A.P. Farrell, I. Forster, D.M. Gatlin, R.J. Goldburg, K. Hua & P.D. Nichols, 2009. Feeding aquaculture in an era of finite resources. PNAS 106, 36: 15103–15110.

Naylor, R.L., R.J. Goldburg, J.H. Primavera, N. Kautsky, M.C.M. Beveridge, J. Clay, C. Folke, J. Lubchencos, H. Mooney & M. Troell, 2000. Effect of aquaculture on world fish supplies. Nature 405: 1017–1024

Samuel-Fitwi, B., S. Wuertz, J.P. Schroeder & C. Schulz, 2012. Sustainability assessment tools to support aquaculture development. Journal of Cleaner Production 32: 183–192.

Tacon, A.G.J. & M. Metian, 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285: 146–158.

Tacon, A.G.J. & M. Metian, 2009. Fishing for Feed or Fishing for Food: Increasing Global Competition for Small Pelagic Forage Fish. Ambio 38, 6: 294–302.

Tusche, K., S. Arning, S. Wuertz, A. Susenbeth & C. Schulz, 2012. Wheat gluten and potato protein concentrate – Promising protein sources for organic farming of rainbow trout (Oncorhynchus mykiss). Aquaculture 344–349: 120–125.

Chapter 5 – Getting stock management right

Costello, C., D. Ovando, R. Hilborn, S.D. Gaines, O. Deschenes & S.E. Lester, 2012. Status and Solutions for the World's Unassessed Fisheries. Science 338: 517–520.

Cullis-Suzuki, S. & D. Pauly, 2010. Failing the high seas: a global evaluation of regional fisheries management organizations. Marine Policy 34, 5: 1036–1042.

Froese, R. & A. Proelss, 2012. Evaluation and legal assessment of certified seafood. Marine Policy (2012).

Hilborn, R., 2006. Fisheries success and failure: The case of the Bristol Bay salmon fishery. Bulletin of Marine Science 78, 3: 487–498.

Hjort, J., 1914. Fluctuations in the great fisheries of northern Europe – viewed in the light of biological research. Rapports et Procès-Verbaux Des Réunions, Conseil International pour l'Exploration de la Mer 20: 1–228.

Kraus, G., R. Döring, 2013. Die Gemeinsame Fischereipolitik der EU: Nutzen, Probleme und Perspektiven eines pan-europäischen Ressourcenmanagements. ZUR 1/2013: 3–10.

Southall, T., P. Medley, G. Honneland, P. MacIntyre & M. Gill, 2010. MSC sustainable fisheries certification. The Barents Sea cod & haddock fisheries, Final Report. Food Certification International Ltd.: 1–188.

Sumaila, U.R., W. Cheung, A. Dyck, K. Gueye, L. Huang, L. Vicky, D. Pauly, T. Srinivasan, W. Swartz, R. Watson & D. Zeller, 2012. Benefits of rebuilding global marine fisheries outweigh costs. PLoS One 7, 7: e40542.

Worm, B., R. Hilborn, J.K. Baum, T.A. Branch, J.S. Collie, C. Costello, M.J. Fogarty, E.A. Fulton, J.A. Hutchings, S. Jennings, O.P. Jensen, H.K. Lotze, P.A. Mace, T.R. McClanahan, C. Minto, S.R. Palumbi, A.M. Parma, D. Ricard, A.A. Rosenberg, R. Watson & D. Zeller, 2009. Rebuilding global fisheries. Science 325: 578–585.

www.asc-aqua.org/

www.friendofthesea.org/

www.globalgap.org/uk_en/

www.msc.org/

Table of figures

Cover: Alexander Safonov, pats0n.livejournal.com; p. 2: Henry Jager, www.conartix-photo.ch; p. 9 from top: Reinhard Dirscherl, 2007 Hans-Guenter Mueller/Collection: Flickr/Getty Images, Arnulf Husmo/Getty Images, Franco Banfi/WaterFrame/Getty Images, Jason Hawkes/The Image Bank/Getty Images; pp. 10/11: Reinhard Dirscherl; fig. 1.1: maribus; fig. 1.2: Alexander Safonov, pats0n.livejournal.com; fig. 1.3: Lucia Terui/Collection: Flickr/Getty Images; fig. 1.4: after Frank et al. (2011), online: http://en.wikipedia.org/wiki/File:Atlantic_cod.jpg, Date: 13.11.2012; fig. 1.5: Sinclair Stammers/NPL/Arco Images GmbH; fig. 1.6: Christopher Zimmermann/Johann Heinrich von Thünen-Institut; fig. 1.7: Jason Isley – Scubazoo/Science Faction/Getty Images; fig. 1.8: http://fischbestaende.portal-fischerei.de/; fig. 1.9: www.lme.noaa.gov; fig. 1.10: www.lme.noaa.gov; fig. 1.11: Jens Koehler/Imago; fig. 1.12: after Holčik et al. (1989), Elie (1997) and Ludwig et al. (2002); fig. 1.13: Image courtesy of Biodiversity Heritage Library; fig. 1.14: Shizuo Kambayashi/AP Photo/ddp images; fig. 1.15: Dieckmann et al. (2009); fig. 1.16: after Dieckmann; pp. 30/31: 2007 Hans-Guenter Mueller/Flickr/Getty Images; fig. 2.1: online: http://en.wikipedia.org/wiki/File:MAP_Expo_Maori Hame%C3%A7on_13012012_4.jpg, Date: 28.12.2012/Vassil; fig. 2.2: Wilhelm Dittmer, 1866–1909, Te Tohunga. London, Routledge, 1907/National Library of New Zealand; fig. 2.3: LookatSciences/laif; fig. 2.4: after FAO (2012); fig. 2.5: after FAO (2012); fig. 2.6: after FAO (2012); fig. 2.7: after FAO (2012); fig. 2.8: after FAO (2012); fig. 2.9: maribus; fig. 2.10: Patrick De Wilde/laif; pp. 40/41: Philip Plisson; fig. 3.1: ICES 2012; fig. 3.2: maribus; fig. 3.3: after FAO (2012); fig. 3.4: after FAO (2012); fig. 3.5: after FAO (2012); fig. 3.6: Jean Gaumy/Magnum Photos/Agentur Focus; fig. 3.7: maribus, after FAO; fig. 3.8: after FAO (2012); fig. 3.9: Courtesy of Claire Alves, Portuguese Historical Center/San Diego History Center; fig. 3.10: Michal Saganowski/Getty Images; fig. 3.11: after FAO Fishstat (2012); fig. 3.12: http://fischbestaende.portal-fischerei.de; fig. 3.13: maribus; fig. 3.14: Seung-Sep Kim/Chungnam National University; fig. 3.15: Roberts et al. (2006); fig. 3.16: maribus; fig. 3.17: Courtesy of JNCC; fig. 3.18: www.fao.org/docrep/009/a0653e/a0653e07.htm; fig. 3.19: after FAO Fishstat; fig. 3.20: Birgitta Mueck; fig. 3.21: http://ec.europa.eu/fisheries/cfp/international/rfmo/index_en.htm; fig. 3.22: http://ec.europa.eu/fisheries/cfp/international/rfmo/index_en.htm; fig. 3.23: Chris Murray; fig. 3.24: Dong-A Ilbo/AFP ImageForum/Getty Images; fig. 3.25: Alex Hafford/AFP ImageForum/Getty Images; fig. 3.26: after Agnew et al. (2009); fig. 3.27: Dong-A Ilbo/AFP ImageForum/Getty Images; fig. 3.28: maribus; pp. 78/79: Franco Banfi/WaterFrame/Getty Images; fig. 4.1: after Hall et al. (2011); fig. 4.2: after FAO (2012); fig. 4.3: after FAO (2012); fig. 4.4: after Hall et al. (2011), FAO Fishstat; fig. 4.5: after Smil (2001) and Hall et al. (2011); fig. 4.6: Christian Ziegler/Minden Pictures; fig. 4.7: after Flachowsky (2002) and Hall et al. (2011); fig. 4.8: www.iffo.net; fig. 4.9: after FAO (2012), Tacon and Metian (2008); fig. 4.10: Achim Wehrmann/dapd/ddp images; fig. 4.11: Jon Lowenstein/Noor/laif; fig. 4.12: after Asche (2008) and Hall et al. (2011); pp. 94/95: Jason Hawkes/The Image Bank/Getty Images; fig. 5.1: maribus; fig. 5.2: National Library of Norway/Foter/CC BY; fig. 5.3a–5.3d: Dr. Bernd Ueberschär, Helmholtz-Zentrum für Ozeanforschung Kiel/GEOMAR; fig. 5.4: maribus; fig. 5.5: maribus; fig. 5.6: Steven J. Kazlowski/Alamy/Mauritius Images; fig. 5.7: FISHBIO; fig. 5.8: Mark Sears/thewhaletrail.org; fig. 5.9: National Museum of the Royal Navy; fig. 5.10: after Quaas; fig. 5.11: Martin Kirchner/laif; fig. 5.12: Klas Stolpe/AP Photos/ddp images; fig. 5.13: maribus; fig. 5.14: Lakruwan Wanniarachchi/AFP/Getty Images; fig. 5.15: Seyllou/AFP/Getty Images; fig. 5.16: Pierre Gleizes/Greenpeace; fig. 5.17: Xurxo Lobato/Getty Images; fig. 5.18: Yves Logghe/AP Photo/ddp images; fig. 5.19: R. Nagel/ WILDLIFE/picture alliance; fig. 5.20: Naomi Blinick/Marine Photobank

All the graphics in the World Ocean Review were produced exclusively by Walther-Maria Scheid, Berlin. The list of illustrations states the original sources which were used as a basis for the preparation of the illustrations in some cases.

Index

Page numbers printed in **bold** draw attention to passages within the text which are especially important for an understanding of the concept in question.

Partners

The Future Ocean: The Kiel-based Cluster of Excellence brings together marine scientists, earth scientists, economists, medical scientists, mathematicians, lawyers and social scientists to share their knowledge and engage in joint interdisciplinary research on climate and ocean change. The research group comprises more than 250 scientists from six faculties of the Christian-Albrechts-University of Kiel (CAU), the GEOMAR Helmholtz Centre for Ocean Research in Kiel, the Institute for World Economy (IfW) and the Muthesius University of Fine Arts

IOI: The International Ocean Institute is a non-profit organization founded by Professor Elisabeth Mann Borgese in 1972. It consists of a network of operational centres located all over the world. Its headquarters are in Malta. The IOI advocates the peaceful and sustainable use of the oceans..

mare: The bimonthly German-language magazine mare, which focuses on the topic of the sea, was founded by Nikolaus Gelpke in Hamburg in 1997. mare's mission is to raise the public's awareness of the importance of the sea as a living, economic and cultural space. Besides the magazine, which has received numerous awards for its high-quality reporting and photographs, its publisher mareverlag also produces a number of fiction and non-fiction titles twice a year.

Acknowledgements

Producing a publication like the World Ocean Review is a collective effort which relies on the dedication and commitment of a large number of people. I would therefore like to first express my thanks to all the participating scientists for their contributions to this review. I am also most grateful to the organizational team of the Cluster of Excellence "The Future Ocean" for ensuring a smooth and uninterrupted communication process and for working so hard behind the scenes.

I further wish to express my particular appreciation to the scientific journalist Tim Schröder, who gave structure to the individual texts and ensured that they could be read and enjoyed by scientists and the general public alike. My sincere thanks also go to designer Simone Hoschack, photo-editors Petra Kossmann and Peggy Wellerdt, text editor Dimitri Ladischensky, and last but not least Jan Lehmköster, the project manager at maribus, who nurtured the World Ocean Review from the beginning and whose leadership helped to shape it into the publication it is today.

Nikolaus Gelpke
Managing Director of *maribus gGmbH*

Publication details

Project manager: Jan Lehmköster
Editing and text: Tim Schröder
Copy editing: Dimitri Ladischensky
Coordinator at the Cluster of Excellence: Dr. Jörn Schmidt
Editorial team at the Cluster of Excellence: Dr. Jörn Schmidt, Dr. Rüdiger Voss, Dr. Kirsten Schäfer
Design and typesetting: Simone Hoschack
Photo-editing: Petra Kossmann, Peggy Wellerdt
Graphics: Walther-Maria Scheid
Printing: DBM Druckhaus Berlin-Mitte GmbH
Paper: Recysatin, FSC-certified

ISBN 978-3-86648-201-2

Published by: maribus gGmbH, Pickhuben 2, 20457 Hamburg

www.maribus.com

World Ocean Review is a unique publication about the state of the world's oceans, drawing together the various strands of current scientific knowledge. The following report, the second in the series, focuses on the future of fish and their exploitation. It is the result of collaboration between the following partners:

future ocean
KIEL MARINE SCIENCES

The Kiel-based Cluster of Excellence brings together marine scientists, earth scientists, economists, medical scientists, mathematicians, lawyers and social scientists to share their knowledge and engage in joint interdisciplinary research on climate and ocean change. The research group comprises more than 250 scientists from six faculties of the Christian-Albrechts-University of Kiel (CAU), the GEOMAR Helmholtz Centre for Ocean Research in Kiel, the Institute for World Economy (IfW) and the Muthesius University of Fine Arts.

IOI International Ocean Institute

The International Ocean Institute is a non-profit organization founded by Professor Elisabeth Mann Borgese in 1972. It consists of a network of operational centres located all over the world. Its headquarters are in Malta. The IOI advocates the peaceful and sustainable use of the oceans.

mare

The bimonthly German-language magazine *mare*, which focuses on the topic of the sea, was founded by Nikolaus Gelpke in Hamburg in 1997. *mare's* mission is to raise the public's awareness of the importance of the sea as a living, economic and cultural space. Besides the magazine, which has received numerous awards for its high-quality reporting and photographs, its publisher *mareverlag* also produces a number of fiction and non-fiction titles twice a year.