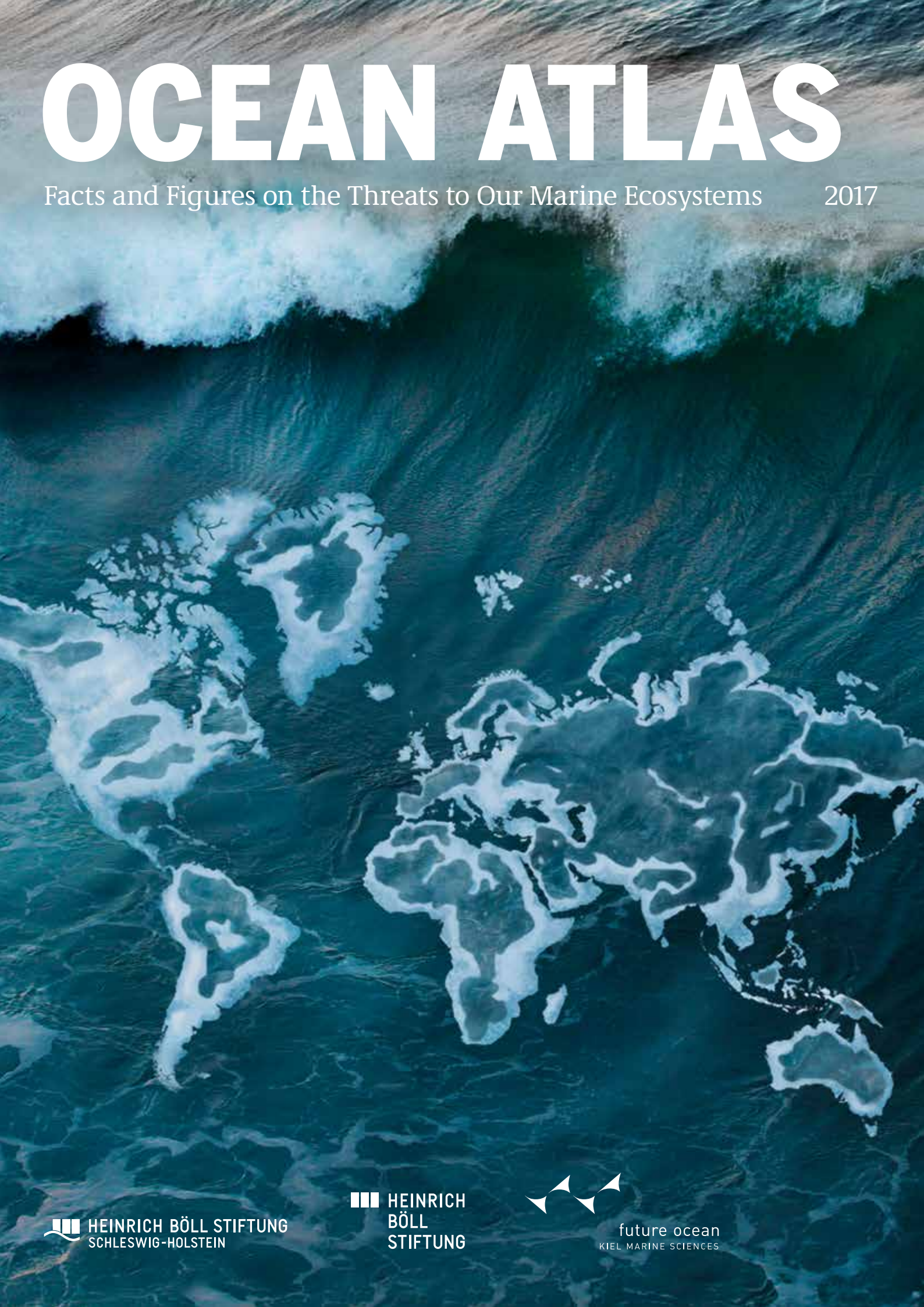
OCEAN ATLAS

Facts and Figures on the Threats to Our Marine Ecosystems 2017



HEINRICH BÖLL STIFTUNG
SCHLESWIG-HOLSTEIN

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future ocean
KIEL MARINE SCIENCES

IMPRINT

The **OCEAN ATLAS 2017** is jointly published by the
Heinrich Böll Foundation Schleswig-Holstein,
the Heinrich Böll Foundation (national foundation),
and the University of Kiel's Future Ocean Cluster of Excellence.

Chief executive editor:
Ulrich Bähr, Heinrich Böll Foundation Schleswig-Holstein

Scientific advisors:
Dr. Ulrike Kronfeld-Goharani, University of Kiel, Future Ocean Cluster of Excellence
Peter Wiebe, Heinrich Böll Foundation Schleswig-Holstein

Design coordinator: Natascha Pösel

Project management:
Ulrich Bähr, Heinrich Böll Foundation Schleswig-Holstein
Annette Maennel, Heinrich Böll Foundation (national foundation)

Text: Natascha Pösel, Ulrich Bähr, and Dr. Ulrike Kronfeld-Goharani
Translation: Kevin Brochet-Nguyen
Proofreader: Rachel Sampson
Art direction, illustration and production: Petra Böckmann
Documentation: Alina Dallmann and Lara Behling
The opinions expressed in this volume do not necessarily reflect the views of all the partner organizations.

Editorial responsibility: Heino Schomaker, Heinrich Böll Foundation Schleswig-Holstein

1st edition, May 2017

Production manager: Elke Paul, Heinrich Böll Foundation (national foundation)

Printed by Bonifatius GmbH Druck – Buch – Verlag, Paderborn
Climate-neutral printing on 100 percent recycled paper.

ClimatePartner°
klimaneutral

Druck | ID 53323-1705-1006

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Heinrich Böll Foundation Schleswig-Holstein, Heiligendammer Str. 15, 24106 Kiel, Germany, www.meeresatlas.org
Heinrich Böll Foundation (national foundation), Schumannstraße 8, 10117 Berlin, Germany, www.boell.de/meeresatlas
University of Kiel Future Ocean Cluster of Excellence, Olshausenstr. 40, 24098 Kiel, Germany, www.futureocean.org

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Facts and Figures on the Threats to Our Marine Ecosystems

1ST EDITION
2017

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12 ARE FISH FARMS THE FUTURE?
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Bits of plastic floating in the ocean are only the visible sign of a much larger problem. That's because only 0.5% of plastic waste actually winds up in the garbage patches. The lion's share of the plastic that ends up in the ocean lies hidden on the seafloor.

20 THE DANGER OF DECLINING DIVERSITY
Invasive species, typically introduced to foreign ecosystems by international shipping, drive out native species. Other negative factors, such as rising water tempartures, weaken many species' resistance to environmental changes. Even more troubling, the resulting loss of genetic diversity cannot be reset.

22 HOW THE OCEAN SLOWS CLIMATE CHANGE
Without the climate-regulating effect of the ocean, our world would be very different. Above all it would be much warmer. The ocean stores heat and CO_2 in large quantities, slowing climate change and ameliorating its effects – which is good for us. But the ocean and its ecosystem are suffering significant damage.

24 WARMING WATERS AND RISING RISKS
The oceans are warming and the sea level is rising – but not in the same degree overall. Islands and coastal areas in the southern hemisphere are especially affected, and many have already been abandoned. But that is just the beginning, and even more people may be forced to flee in the future.

26 LIFE IN THE DANGER ZONE
Most of the world's large metropolises lie on the coasts, many of them on river deltas. Though the risk of being struck by a natural disaster is especially high there, the growth of coastal megacities continues unabated. But only rich countries can afford the necessary coastal protection measures.

28 A CORROSIVE FUTURE
The oceans are acidifying faster than ever in Earth's history – too quickly for many organisms to adapt. Calcifying species like mussels, snails, and corals have been especially hard hit. It is difficult for them to form their protective shells in acidic water. The offspring of fish are also threatened.

30 EXPLOITATION AND PROTECTED AREAS

The idea that the ocean must be protected is a recent one. Our ancestors thoughtlessly overexploited natural resources, including the sea. A treasure trove of sea life has been lost in the past, a loss we can hardly imagine today. Only in the last 30 years has the size of the protected areas grown significantly – but it is still just a fraction of the total area.

32 WHO OWNS THE OCEAN?

Tiny, uninhabited islands that lie thousands of kilometers from the mainland have become geostrategically valuable. They enable countries to expand their spheres of influence. The only requirement is a location on a continental shelf.

34 GLOBAL HUNGER FOR RESOURCES

Large mining companies, in conjunction with industrialized nations, are grasping for the treasures of the deep sea. Global market prices and declining acceptance for mining on dry land have made the intensive business lucrative. The exploitation of the nearly untouched depths is about to begin, even though the ecological and social effects have not been adequately studied.

36 WHERE DOES THE FUTURE LIE?

Renewable energy from the ocean offers hope to many. The sea may be the future of energy. Untapped reserves of fossil fuels beckon, but getting them brings risks – known ones from extracting oil from the deep sea and unknown ones from mining methane hydrate.

38 DESTINATION: OCEAN

Holidays on and near the sea are a booming business. Cruise ships are growing larger and larger, and more and more coasts are being converted into vacation destinations. But what are the consequences for nature and for the people who keep the vacation industry running at these tourism hotspots?

40 WORLD TRADE AND PRICE WARS

International shipping is the engine of the global economy, but it has been in a deep crisis since 2008; freight prices have fallen drastically, and shipping multinationals are caught in price wars that only a few will survive. And what happens to the now unnecessary giant freighters?

42 LIVING WITH THE OCEAN

The ocean gives us so much, and our lives and livelihoods often depend on it. If we want to benefit from its gifts in the future, we must change our behavior toward this vast aquatic continent. However, that's not the only reason to act.

44 THE WORLD MUST ACT TOGETHER: TOWARDS A NEW GOVERNANCE OF THE OCEAN

There are no comprehensive global strategies that address the complexity of the marine ecosystem. The oceans today are among the least protected and responsibly administered areas of the world. Due to the importance of the ocean, inaction is irresponsible and change must come quickly.

46 SOURCES OF TEXTS, MAPS, AND DATA

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FOREWORD

The ocean covers more than two-thirds of our planet's surface and occupies a vast three-dimensional volume, much of which is still unexplored. It is rich in resources and provides us with food, energy, and minerals. We use the ocean to transport goods between continents. The ocean is also crucial for the stability of our climate and the weather.

Without the ocean and its resources, the wealth and well-being enjoyed by some of the world's population would not exist. The future of this unique ecosystem faces a grave threat today. The principle of the freedom of the seas, which has held for hundreds of years and grants everyone unlimited access to the ocean and its resources, has led to overfishing, the loss of biodiversity, and ocean pollution.

Our oceans and coasts are important parts of our environment – and they urgently need our protection. At the international level, the first steps in the right direction are clear. The concept of sustainability is increasingly anchored in international protective agreements and treaties, which share the goal of enabling current and future generations to live in balance with nature, to ensure the health and integrity of the global ecosystem, and to partially restore it.

In the final document of the 2012 Rio+20 Conference, the member states of the United Nations demanded comprehensive and integrated approaches to sustainable development and a sustainable approach to the ocean. Research has improved over the years, enabling us to better understand the system of the oceans and to develop solutions for dealing with the ocean sustainably. Agenda 2030, ratified by the UN in 2015, also considers the importance of the ocean for sustainable development. Of the 17 Sustainable Development Goals (SDGs), SDG 14 is devoted to the ocean. Reaching this goal will require significant efforts toward institutional cooperation in order to implement the necessary national, regional, and global action plans.

These measures will only achieve long-term success if they receive broad support from society. Scientific experts and political and economic decision makers are just as necessary as actors from civil society, and every individual citizen counts.

This is where the atlas you're holding comes into play. It is intended to illustrate the important role played by the ocean and its ecosystems – not only for people living on the coasts but for all of us. What wealth and wellbeing does the ocean provide to us? How should we manage its resources? What is the state of the marine ecosystem's health, and what are the significant threats facing it? How does the climate change caused by humans affect the ocean and coasts? What is the connection between a more sustainable use of marine resources and changes in our production and consumption patterns?

We hope to stimulate a broader social and political discussion about the importance of the ocean as a system and the possibilities for protecting it.

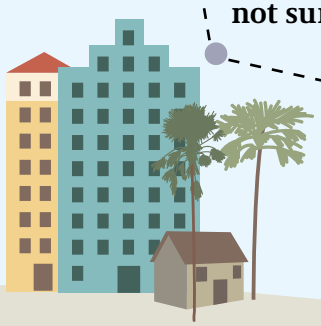
Dirk Scheelje
Board of Directors of the Heinrich Böll Foundation Schleswig-Holstein

Barbara Unmüßig
President, Heinrich Böll Foundation

Martin Visbeck
Spokesperson for the University of Kiel's Future Ocean Cluster of Excellence

12 BRIEF LESSONS

ABOUT THE OCEAN AND THE WORLD

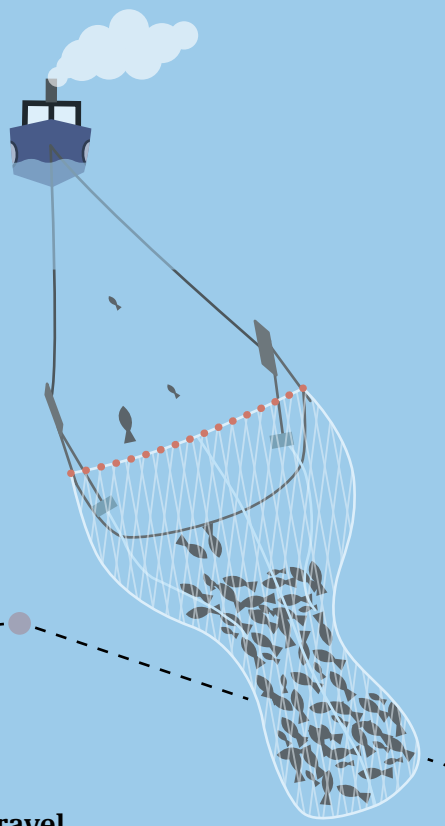


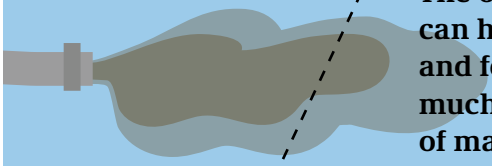
1 The ocean is the **SOURCE OF LIFE AND LIVELIHOOD FOR A GROWING GLOBAL POPULATION.** 2.9 billion people around the world obtain 20 percent of their protein needs from fish. The Earth's climate is strongly influenced by the interaction between the atmosphere and ocean. Without the ocean we would not survive.

2 The ocean is under great stress due to a number of factors. The situation results not from any single problem but rather from a whole confluence of troubling issues. **WE HAVE AN OCEAN CRISIS!**

3 The ocean covers 71 percent of the globe. **THE SEAS SUFFER BECAUSE OF CLIMATE CHANGE.** Acidification, warming, and rising sea levels are already altering habitats. The global sea level has risen 20 centimeters in the last hundred years. That figure could reach one meter by the end of the century.

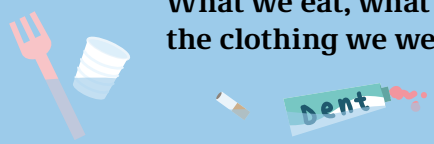
4 **WE TAKE MORE THAN THE OCEAN CAN GIVE.** Simply put, we are overexploiting the ocean. One example: overfishing. 90 percent of the global fish population is maximally exploited or has already been overfished. The resulting decline in biodiversity is particularly troubling.





5 **WE USE THE OCEAN AS A GARBAGE DUMP.** The ocean accepts a lot—more than it can handle: greenhouse gases, manure and fertilizer, plastic, oil pollution, and much more. The result: the destruction of marine ecosystems.

6 **OUR CONNECTION TO THE OCEAN IS OFTEN INVISIBLE.** What we eat, what we use to brush our teeth, where we travel, the clothing we wear—it all has an effect on the ocean.



12 Yet there is still movement in the right direction. The ocean crisis is coming into the spotlight. People around the world are starting to change their behavior and their consumption. With the 2017 United Nations Ocean Conference in New York City, the global community is **BEGINNING TO WORK TOGETHER TO PROTECT THE OCEAN**.

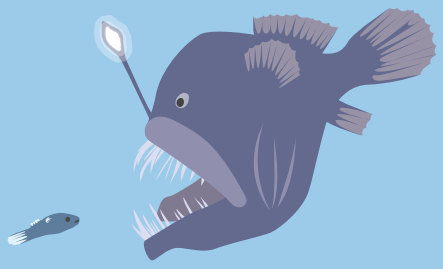
11 The ocean surrounds the world. But **THERE IS NO SUPREME INTERNATIONAL AUTHORITY THAT IS TRULY RESPONSIBLE** for the protection of the entire ocean. The result is fragmented jurisdictions, inadequate laws, and loopholes.

10 If we continue doing what we're doing now, many people will lose their livelihoods. **THE POOREST ARE THE MOST STRONGLY AFFECTED.** Migration will become the last resort.

9 **THERE COULD BE ENOUGH FOR ALL.** A sustainable and just approach to dealing with the ocean's natural resources is possible. The necessary preconditions are conscientious consumption, fair distribution, and intelligent fisheries management.

8 Many of **THE SECRETS OF THE DEEP SEA** have yet to be discovered or explored. Deep-sea mining may destroy whole ecosystems before we even realize they exist.

7 Yet the **INDUSTRIALIZATION OF THE OCEAN** is just beginning! The most significant changes are still ahead of us. The demand for natural resources and energy from the deep sea is large and will only grow in the future.



FISHERIES MANAGEMENT

FISH—ALMOST OUT OF STOCK?

Fish is a cornerstone of global food security. It is the world's most traded natural product. But global dependence on fish is actually the greatest threat to our fish populations. Many are overfished, and the number is rising.

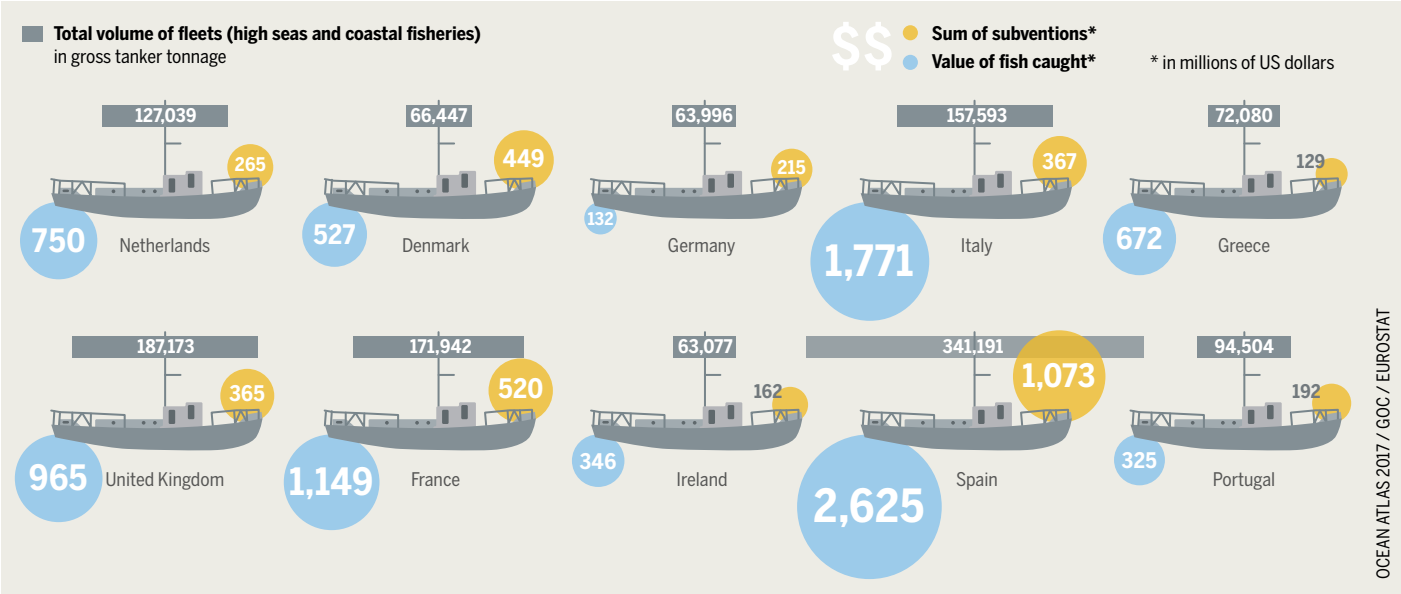
Thousands of years ago our ancestors already relied on fishing to feed themselves. On land, hunting and gathering was eventually replaced by a sedentary yet sustainable agricultural way of life. For those at sea, fishing was and is oriented towards one thing – the hunt. Those who fish do not sow. They take.

This hunting behavior, together with increasing demand for fish driven by a growing global population, has caused global fish populations to shrink. According to the Food and Agriculture Organization of the United Nations, about 30 percent of fish are overfished or even exhausted because they are not sustainability harvested. Another 58 percent have been pushed to the very edge of sustainability. That means approximately 90 percent of the world's commercially exploited fish populations are exhausted. It is not possible to exploit them any further. All hope is not lost. With smart fishery management, most populations could recover in anywhere from a few years to a few decades. There are successful examples of such concepts in the USA, New Zealand, Australia, Norway, and the EU. Many populations have recovered there. In 2009 Europe's seas were 90 percent overfished – today, that number has sunk to just 50 percent, in part because of stronger restrictions and limits on catches.

But not all populations are in a position to recover quickly, even if they are sustainably exploited. Some populations of large food fish like marlin, swordfish, shark, and cod have already shrunk by up to 90 percent. Dolphins and sea turtles, victims of bycatch, are partly threatened by extinction. They do not recover quickly. And many types of tuna belong to the species whose populations will not recover as long as they are still actively fished to any extent. Their market value is so high that hunting them is still profitable, even though few of them remain to be caught. Red tuna is so highly valued that it regularly fetches dizzying prices on the Japanese market. In 2013 a Japanese sushi chain bought a particularly impressive specimen for 1.3 million euros. In total, 85 percent of red tuna caught from in Mediterranean, and two-thirds of the entire global catch, goes to Japan.

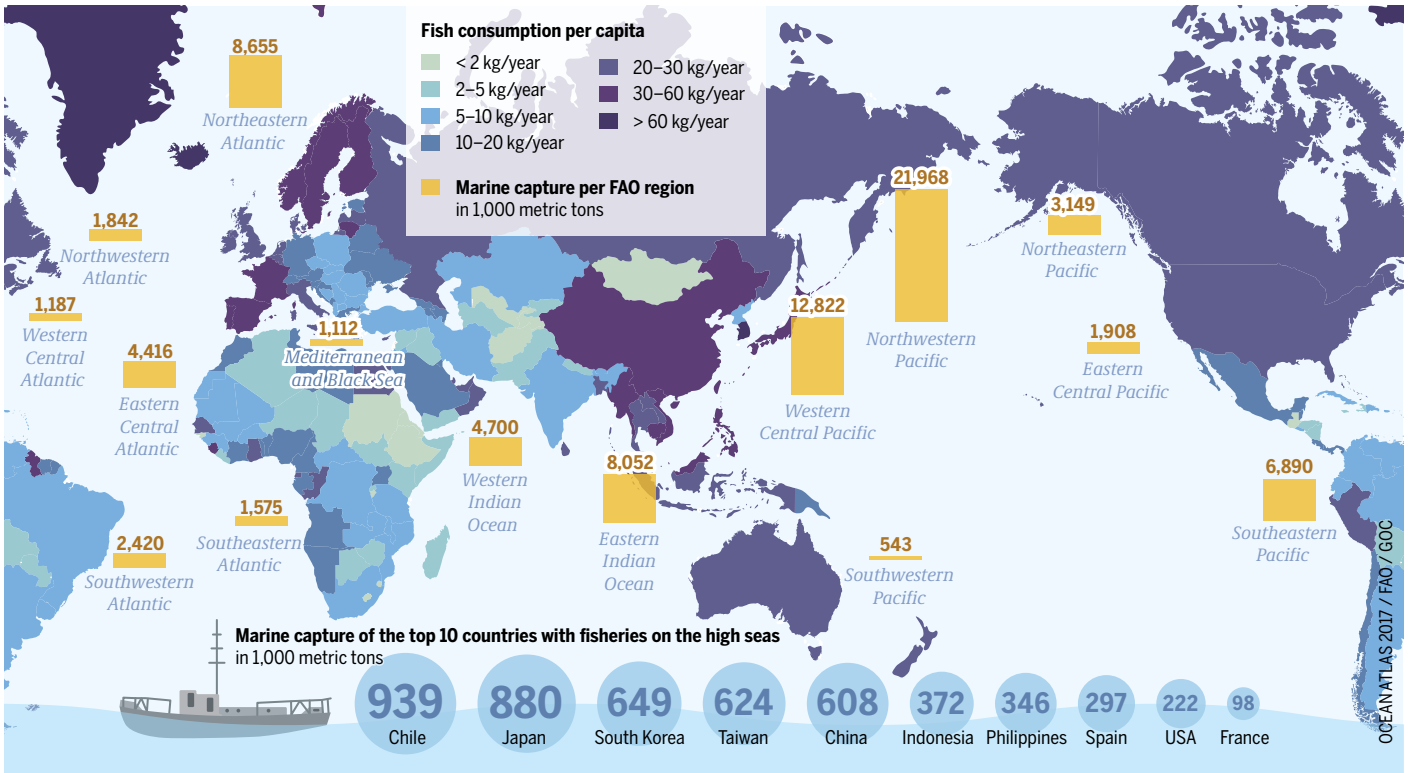
Many developing countries are especially dependent on fishing, particularly when it is the primary economic activity. It is estimated that there are approximately 12 million small-scale fishermen globally. On the other hand, industrial fisheries only employ 500,000 people. Per person, though, these industrialized operations catch many times what small artisanal fishers pull from the sea with

Subventions and Catches—What's Left Over



Fisheries are heavily subsidized in all European countries. The relationship between the subsidies and the results is unequal. While Italy and Spain still turn profits, Germany actually takes a loss.

Who Catches the Fish—and Who Eats Them?



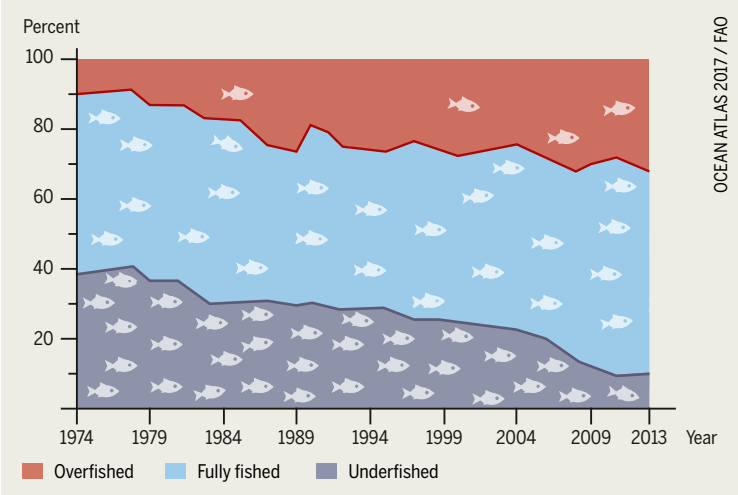
their nets. With industrial ships equipped with modern technologies like echolocation, reconnaissance planes, and gigantic nets, they fundamentally exhaust the traditional fishing grounds. These big ships operate around the world and search for the most profitable fishing grounds, like the area off the coast of West Africa, where there is little state regulation and they can easily outcompete the locals.

Another large problem for maintaining fish populations is illegal, unregulated, and undocumented (IUU) fishing. This refers to fish caught with unauthorized fishing devices, at unauthorized times, or in protected areas, as well as to catching species of fish that are prohibited or to catching more than is permitted. Illegal catches comprise up to 31 percent of the global fish catch. Some ship owners avoid state control by sailing under flags of convenience. Others exploit the fact that it is very difficult to track IUU ships in places like the islands and archipelagos of Indonesia. A similar phenomenon occurs in the Bering Sea, where IUU fishing is mainly driven by Russian and Chinese firms. The rate of IUU fishing there is 33 percent. An estimated 500,000 tons of illegally caught fish circulate each year. The EU has introduced stricter harbor controls, but illegally caught fish still end up on European plates.

Political expediencies are also responsible for putting pressure on fish populations. For example, for years Spain and Portugal, fearing unemployment, subsidized drastically oversized fishing fleets and thus accelerated the exhaustion of their fisheries.

If ministries of fishing would systematically follow scientific recommendations and only fish populations so that over the long term they take only the maximum sustainable yield (MSY), the world's fisheries really would be the constantly growing resources that we mistakenly assume they are. Ending subventions, like fuel subsidies, would be a good start.

Fewer Fish Than Ever Before



58% of global marine fish stocks are fully fished and 31% are overfished; only 10% are not at or over their limits.

AQUACULTURE

ARE FISH FARMS THE FUTURE?

Aquaculture is booming – in 2014 nearly every second fish consumed by people came from a fish farm. The ecological and social problems caused by this aquatic stockbreeding are immense.

Per-capita fish consumption has doubled over the last 50 years. Demand has risen especially sharply in industrialized and developing countries. Aquaculture has been promoted as a solution since the 1970s and supported by massive state and development fund subsidies. In 1950 aquaculture produced approximately 500,000 metric tons of live weight; in 2014 that figure rose to 73.8 million metric tons, 88 percent of it in Asia. China alone produces 62 percent of the global production and is thus the most important aquaculture country.

Aquaculture takes place in ponds, irrigation ditch systems, integrated recycling systems, and large cage systems in the sea. Fish, shrimp, crabs, and mussels are the primary stock. Fish farming on the high seas and on the coasts accounts for 36 percent of total production. The hope is that it will satisfy the continually increasing global demand for fish and seafood as well as provide a solution to overfishing. However, the current industrialized aquaculture is hardly an answer to overfishing and food security needs, as it is often highly questionable – ethically, ecologically, and socially.

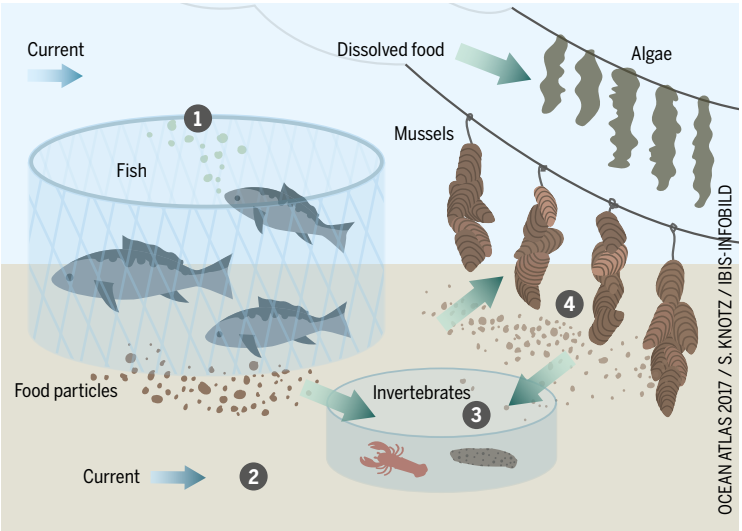
That's because fish and other animals require large quantities of food themselves: producing just one kilogram of shrimp, salmon, or other farmed fish requires 2.5 to 5 kilograms of wild-caught fish. The figure for tuna is closer to 20 kilograms. Raising red tuna in net-cages in Malta endangers the local mackerel and sardine populations used to feed large predatory fish. Therefore, aquaculture does not necessarily help halt overfishing in the world's oceans.

Aquaculture as industrialized underwater factory farming is an ecological disaster. The fish injure themselves, get sick, and fall victim to parasites more quickly. To counter those ill effects, fish farmers rely on antibiotics and chemicals, including pesticides, which pollute the water. The more animals are held in a breeding pool, the more excrement, uneaten food, and cadavers sink into the water below, overfertilizing the water. The nutrient-rich wastewater, replete with traces of chemicals and pharmaceuticals, then flows into rivers, lakes, and seas, and also soaks into the surrounding soil.

Additionally, mangrove forests must often give way to aquaculture. This is especially absurd, given that they serve as nurseries for many species of fish. 20 percent of the world's mangrove forests were destroyed between 1980 and 2005 by human actions, more than half of them (52 percent) due to the introduction of aquaculture. In the Philippines alone, two-thirds of the mangrove forests have been cut down because of shrimp farms.

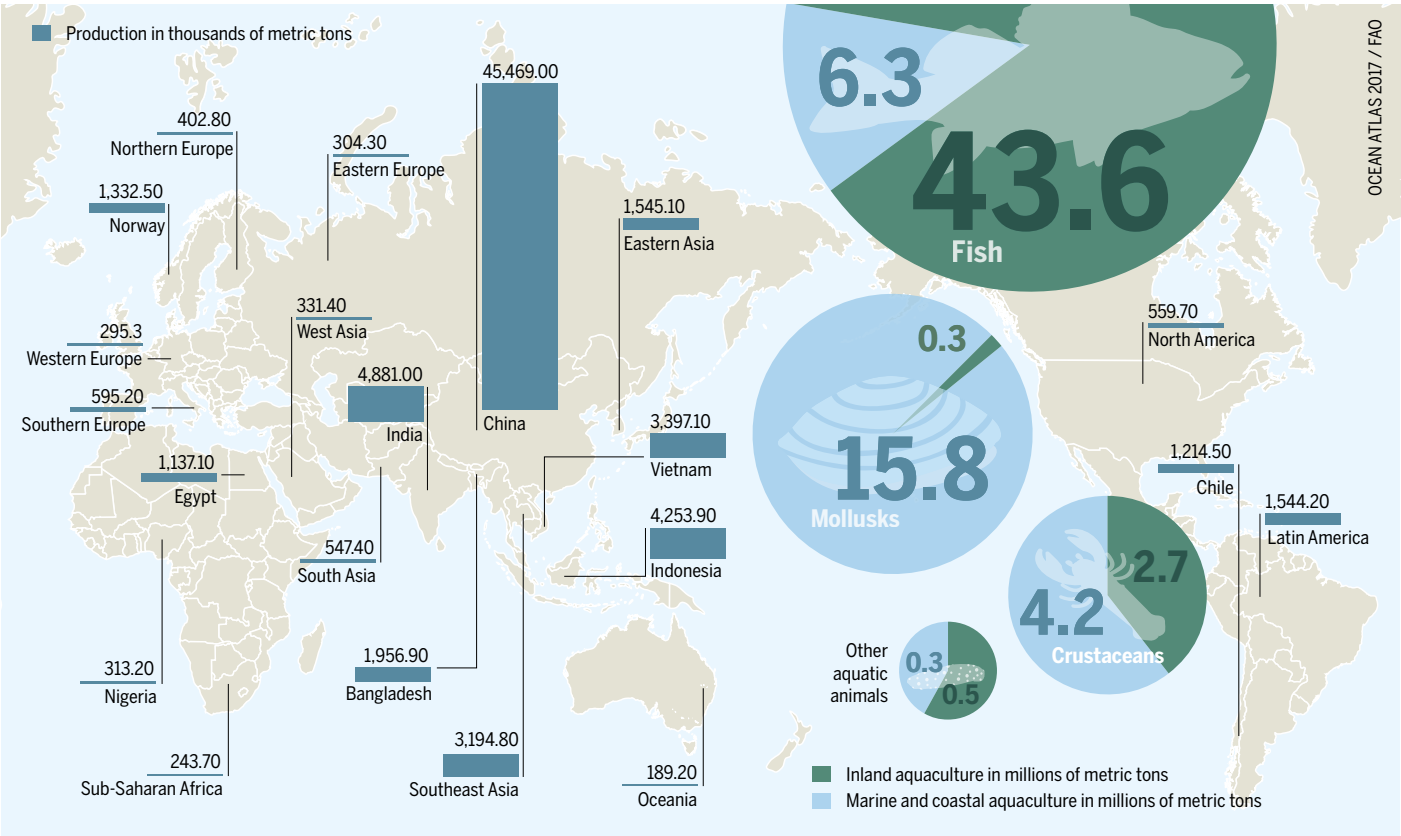
Aquaculture destroys the livelihoods of local populations and leads to local conflicts because it massively reduces the catches of the traditional coastal fisheries. People are driven away or forced into new employment

Another Way—Aquaculture as a Closed Nutrition Cycle



If farmed fish are kept in nets or cages and actively fed ❶, their excretions normally cause the environment to become overfertilized (eutrophication). The exception: when other organisms on lower levels of the food chain are kept downstream ❷. Shrimp, crabs, or sea cucumbers kept in cages ❸ eat particles that sink to the bottom. Mussels ❹ filter smaller particles out. Their excretions are metabolized by the algae and invertebrates.
Unlike conventional fish farming, so-called integrated multitrophic aquaculture is an environmentally friendly approach that actually takes the surrounding ecosystem into account.
However, it represents only a marginal share of global aquaculture, and the use of fish oil and fishmeal remains problematic.

Global View of the Largest Aquaculture Producers (2014)—Fish and Seafood



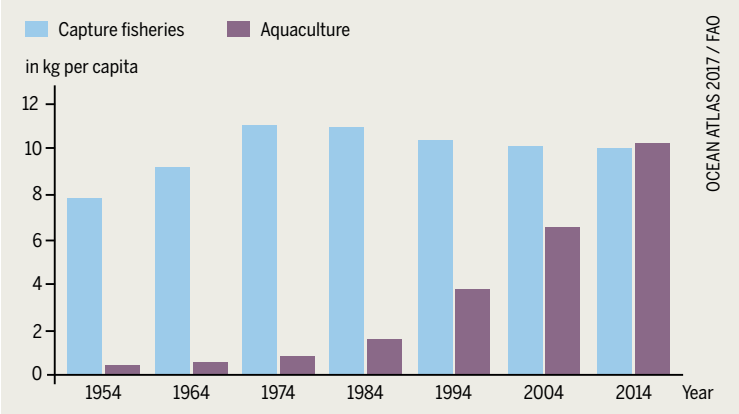
models. Today around 19 million people work in this sector. The working conditions are nevertheless extremely precarious. Contracts are often only verbally agreed upon, worker protection regulations are rare and their enforcement is even rarer. The result: exploitation and forced labor. The International Labour Organization (ILO) estimates that 70–80 percent of aquaculture sites and coastal fisheries are small businesses that rely on the labor of family members. That means that children are subjected to the often physically demanding and dangerous labor conditions of the fisheries.

Yet ecologically sound aquaculture is indeed possible, as carp and trout farming show. For many centuries ecological, locally run aquaculture has been a source of livelihood and protein for millions of people, especially in Asia. The example of pangasius farming in Vietnam shows that change is possible. Following the exposure of scandalous farming conditions, the industry is reforming step by step according to new environmental standards, including the ASC Seal (Aquaculture Stewardship Council). That means that no fishmeal from overfished populations is used, and good water quality and low mortality rates must be maintained. Technical solutions to environmentally friendly aquaculture are also being intensively researched. For example, closed recirculation systems significantly reduce the environmental strain, but are expensive and demanding to operate, as well as energy-intensive.

The grave social and ecological consequences of current industrial aquaculture approaches cannot be halted by technical and ecological changes alone.

The demand for fish and other sea creatures is the main driver for further developing industrial aquaculture. It serves a profit-driven global market with a great hunger for cheap fish, primarily in the form of mass underwater factory farming. The consumption of fish and sea creatures by the global middle class must be reduced. ●

Increasing Quantity of Farmed Fish



The quantity of fish farmed for human consumption rose steadily from 1954 to 2014. Today it actually slightly exceeds the quantity of wild-caught fish.

EUTROPHICATION

FERTILIZER FOR THE DEAD ZONES

Each summer, a 20,000-square-kilometer dead zone forms in the Gulf of Mexico near the Mississippi Delta. Hardly anything lives there now. The cause of the lifeless water lies not in the gulf itself but on dry land, 2,000 kilometers upriver.

Southwest of the Great Lakes lies the Corn Belt, where most of the USA's soy and corn are grown. Incredible amounts of artificial fertilizer and pig manure are used to fertilize these commercial crops. The region is also the heart of US pork production, with vast industrialized pig farms. All this industrialized agriculture produces massive amounts of waste products, including nitrates and phosphates. These chemicals contaminate the groundwater and then flow into the world's fourth-longest river system, the Mississippi-Missouri, which ends in the Gulf of Mexico south of New Orleans. There, the nitrates and phosphates overfertilize the sea, causing the formation of huge oxygen-starved areas devoid of life.

There are several such oxygen-deprived zones in the world's oceans. Some of the largest occur naturally. These lie in tropical regions, like those off the coasts of Peru, Namibia, and the Arabian Peninsula. Only a few specially adapted organisms like bacteria live there. The dead zones near river deltas, however, are usually manmade – and they are growing. These areas should be home to fish, mussels, and shellfish, as well as meadows of sea grass and forests of seaweed. But those organisms need oxygen to live – oxygen that is in critically short supply there now. Long before it was possible to identify the cause, fishermen had begun to call areas dead zones. It was readily apparent that something was amiss when they pulled in empty nets in waters that should have teemed with life. The animals that could flee the dead zones, like fish and shellfish, had done so. And those that couldn't, like mussels and oysters, had died – 150 years ago.

One cause was the growth of cities. As they grew, more wastewater flowed into the rivers and bays. Today there are filtration plants deal with wastewater, but since the middle of the last century, an even larger factor has emerged: we use so much artificial fertilizer in commercial agriculture that crops cannot absorb it all and it winds up in the ocean. Once there, it does its job all too well, stimulating the growth of plankton and algae. When these plants die, they sink to the seafloor where bacteria consume them – and in the process, use up the last bit of oxygen. For many species there is no escape.

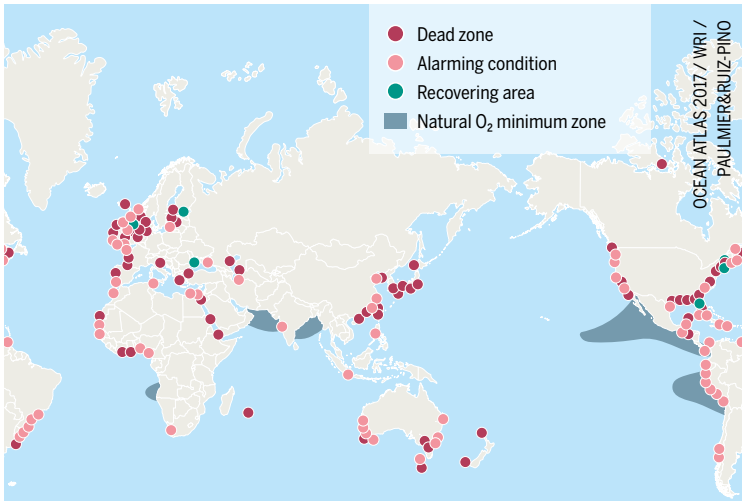
The effects of the overfertilization of seawater – called eutrophication – can be observed in many places around the world, like the Pearl River Delta in the South China Sea or in India, where the Ganges flows into the Bay of Bengal. One of the largest dead zones is located in the Baltic Sea. It has experienced a striking reduction in oxygen concentration since the 1950s and 1960s. As in deltas, the change is a consequence of industrialized agriculture. The effect is exacerbated by the fact that the Baltic Sea is a flat inland sea with little water exchange.

From 1900 to the 1980s nitrate levels increased four times while phosphate levels increased eight times. The increase in fertilizers detected in the Baltic Sea was particularly large in the 1960s and 1980s. Values have steadfastly remained at this high level in the years since. In 2009 the Helsinki Commission (HELCOM) conducted the first comprehensive study of the Baltic Sea, examining 189 areas. The shocking result only 11 were in good ecological condition.

All the same something is being done. The Baltic Sea Action Plan, which has been ratified by all the countries bordering the sea, sets concrete goals for further reducing the flow of fertilizer. Phosphorus emissions are to be reduced by 15,250 tons per year while nitrogen emissions are to be reduced by 135,000 tons per year. The goal is a Baltic Sea free of eutrophication.

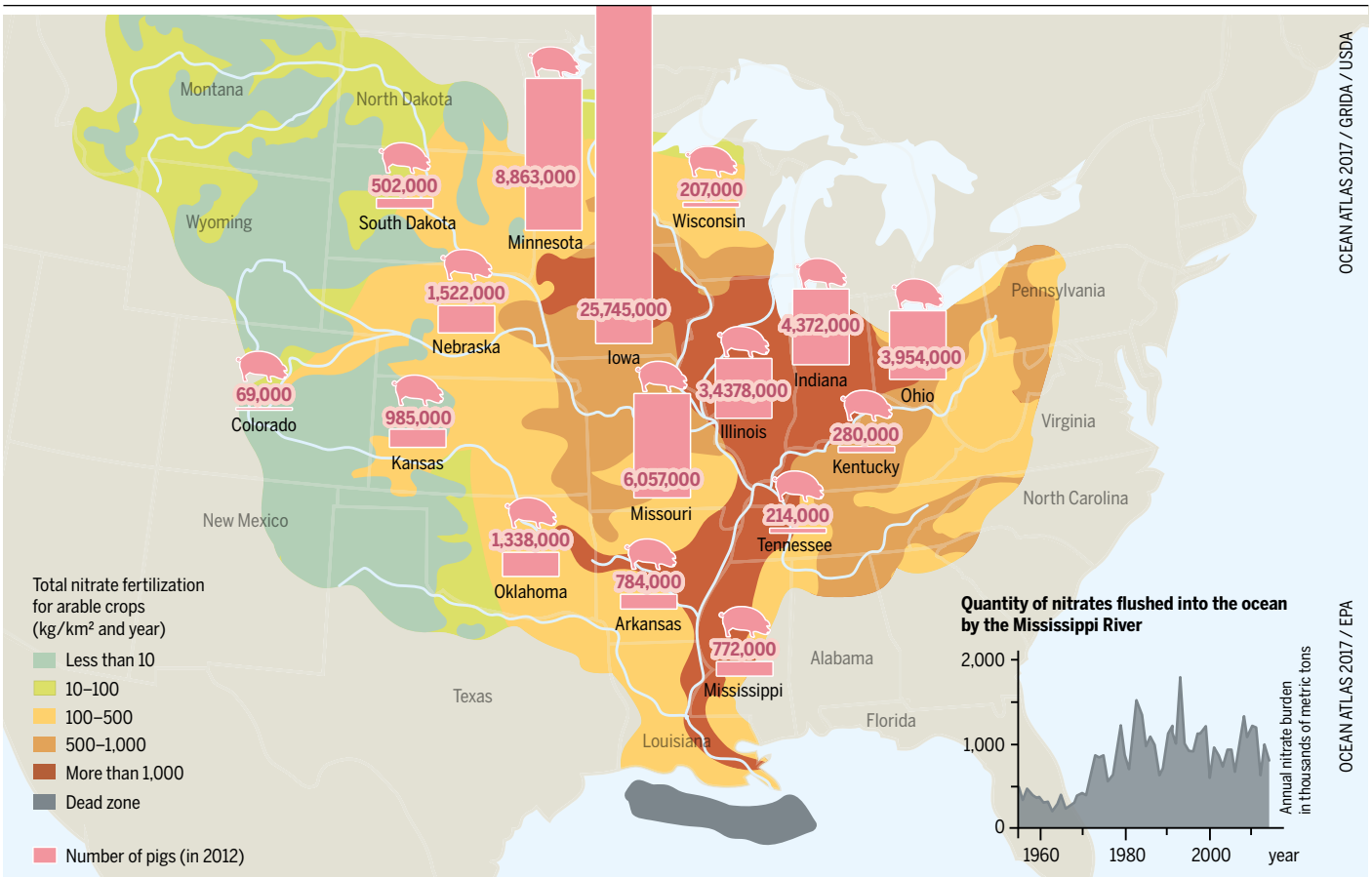
The plan is more than a non-binding statement of intent. For example, Germany had to appear before the European Court in September 2016 for violating the agreement. The country exceeded the limit for nitrates in

Running Out of Oxygen



Natural oxygen minimum zones can be found in the tropics. However, the numerous dead zones located near estuaries are manmade.

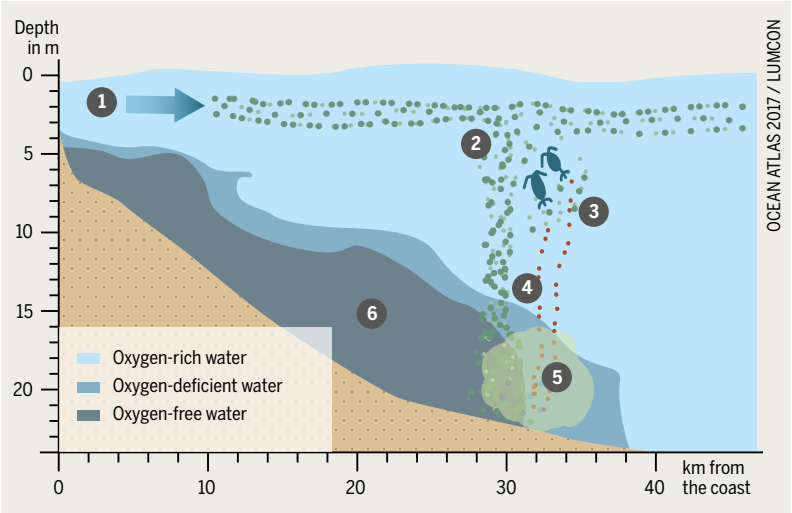
Causes of the Dead Zone in the Gulf of Mexico—Pig Farming and Intensive Agriculture



groundwater by about one third, the result of too much pig manure in the groundwater. The German government faces a six-figure fine – per day – as long as emissions continue to exceed the limit.

Eutrophication is a problem that cannot be solved without such agreements at the international level – national regulations are only effective if neighboring countries abide by the same rules. Coastal waters are part of the shared responsibility of neighboring states. Teeming with fish, mussels, and shrimp, the seas are at their most productive there. At the same time, that is also where they face the greatest stress. The bitter irony is that the agricultural production of food is itself endangering a resource that we urgently need for the world's food supply.

How Oxygen mininum Zones Form in the Ocean

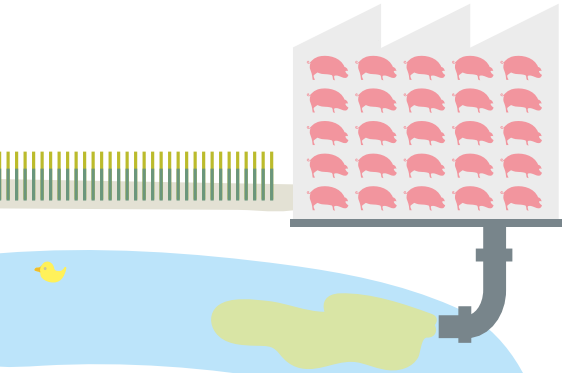


1. *Nutrient-rich water pours in.*
2. *Algae blooms unnaturally and then dies.*
3. *Zooplankton feed on the algae.*
4. *Bacteria feed on the waste of the zooplankton and the dead algae.*
5. *Bacteria use the oxygen in the water to break down the waste and dead algae.*
6. *If the oxygen level of the water drops below a certain level, marine organisms must flee or die.*

POLLUTION

TRASH IN THE SURF, POISON IN THE SEA

The mounds of garbage on some coasts pose clearly visible problems. Other types of pollution are less visible – but every bit as serious.



NITRATES AND PHOSPHATES

CAUSES: Industrial agriculture like intensive animal husbandry and intensive crop cultivation.

EFFECTS AND TRENDS: Since the 1950s and 1960s agriculture around the world has developed into a massive industry. Discharge of animal manure and artificial fertilizer reach rivers via groundwater and end up in the ocean, resulting in dead zones off the coasts. International agreements attempt to combat these effects by reducing discharges.

PLASTIC WASTE

CAUSES: Only 20 percent of the plastic waste that ends up in the ocean actually comes from the ocean. The other 80 percent comes from dry land, mainly from countries where there is no, or very poor, waste management.

EFFECTS AND TRENDS: Five large garbage patches are known. Most garbage, however, lands on coastlines around the world and is thus a global problem. In 2015, for example, 100 cubic meters of plastic waste collected on the coast of Spitsbergen, a remote island halfway between Norway and the North Pole. The mounds of trash grow larger each year.

CHEMICALS AND HEAVY METALS

CAUSES: Industrial wastewater and waste gas, mining, burning heating oil.

EFFECTS AND TRENDS: According to the OECD, there are around 100,000 different chemical substances in circulation around the world. They include heavy metals like lead and mercury but also persistent organic pollutants (POP). Many of these substances are highly problematic because they accumulate in the bodies of marine organisms, entering the food chain where they pose a risk to human health.

RADIOACTIVITY

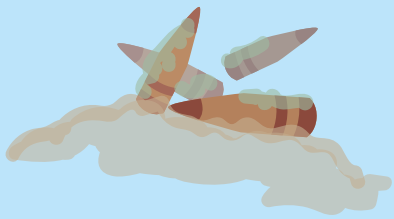
CAUSES: Atomic powers and countries that operate atomic power plants like the USA, Russia, Japan, and several European countries.

EFFECTS AND TRENDS: Starting in the 1950s, countries began legally dumping barrels of radioactive waste from nuclear power plants into the ocean. Barrels in the English Channel that should have remained sealed for hundreds of years have already begun leaking. The marine dumping of atomic waste was finally forbidden in 1993. However, the ban only applies to radioactive solids. Expelling radioactive wastewater into the ocean is still permitted and practiced. The Fukushima nuclear catastrophe as well as atomic weapons tests conducted by the great powers have had measurable effects.

MUNITIONS IN THE OCEAN

CAUSES: World wars and other conflicts. Many countries around the world have dumped chemical as well as conventional weapons in the ocean.

EFFECTS AND TRENDS: The experts agree that recovering the munitions would be too expensive and possibly too risky. However, leaving them is risky as well, though: for example, 70 years after the Second World War, clumps of white phosphorous from firebombs still wash up on beaches. They look like amber and children like to collect them. Phosphorous bursts into flames if it comes in contact with oxygen and warmth. At 1,300 degrees Celsius, it can burn all the way to the bone. This military waste will continue to pose a threat long into the future.



OIL POLLUTION

CAUSES: Wastewater, leaks during oil drilling, regular shipping, illegal tank cleaning, oil spills, and drilling accidents.

EFFECTS AND TRENDS: It takes exposed rocky and sandy coasts anywhere from a few months to five years to recover, while sheltered rocky coasts and coral reefs need from two to more than ten years.

Although the rate of extraction is higher than ever, pollution from oil spills has decreased due to stricter maritime transport regulations. On the other hand, the risk of drilling accidents increases the farther we penetrate into the depths.

NOISE

CAUSES: Shipping, deep-sea mining, military activities, driving sheet piling for harbors and offshore plants into the seabed, searching for oil and gas reserves with long-range acoustic devices (LRADs), and oil and natural gas extraction.

EFFECTS AND TRENDS: The amount of noise in the ocean is increasing due to the continually increasing usage of the ocean. Fish and especially marine mammals like whales and dolphins that communicate and navigate with sound are affected. The animals get confused, beach themselves, and perish in shallow water.

PLASTIC WASTE

THE MICROPLASTIC PROBLEM

Beaches littered with plastic garbage, seabirds strangled by bits of plastic – these images are ubiquitous today. Yet we also see photos of people cleaning beaches and hear about plans for purifying the ocean. Are things actually improving?

The world produces 300 million tons of plastic each year. About two percent of it – around eight million metric tons – ends up in the ocean. It's a staggering amount – yet only one percent of that plastic is actually found on the surface of the ocean. Half of that one percent winds up in trash vortices; the other half is more widely dispersed. That leaves 99 percent (7.92 million metric tons) unaccounted for each year. Where does it go? Science only began to unravel the riddle at the turn of the millennium when we uncovered a previously unknown phenomenon: microplastic.

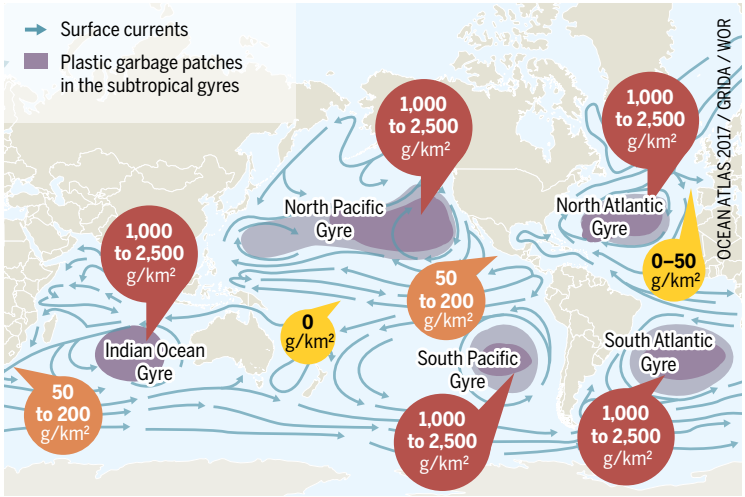
80 percent of plastic waste ends up in the ocean, often via rivers. 20 percent is tossed overboard from ships. A portion of the plastic waste is carried great distances by ocean currents and gathers in the large trash vortices like the Great Pacific Garbage Patch in the North Pacific Gyre. On this journey, which can take up to 10 years, large pieces of plastic are progressively eroded, broken down by sunlight and eaten by bacteria, fragmenting into many smaller pieces. The result is microplastic, meaning plastic particles that are smaller than 5 millimeters. The plastic gyres are thus not the massive islands of trash that one might first imagine. Large bits of plastic are relatively rare, and one could actually swim through a gyre without noticing the microplastic that composes it. The remaining 99 percent of the waste that begins its journey on the coasts never reaches garbage patches. It also breaks down into microplastic and disperses through the ocean before finally sinking into the depths. In fact, the plastic concentration on the ocean floor is 1,000 times greater than on the surface. The microplastic is trapped there, embedded in the sediment. It is gradually forming a new geological layer, the "plastic horizon," which researchers of the future will attribute to our era. The sad truth is that we use the deep sea as a gigantic trashcan and benefit from the fact that the majority of the waste seemingly disappears forever rather than washing up at our feet again.

The ocean floor is not the only "plastic sink," however. Microplastic is also found in very high concentrations in floating sea ice. The ice is not as reliable a warehouse as the ocean floor. The accelerated melting of sea ice as a consequence of climate change could release 1,000 billion plastic particles in the coming years. That's 200 times the amount of plastic currently found in the ocean.

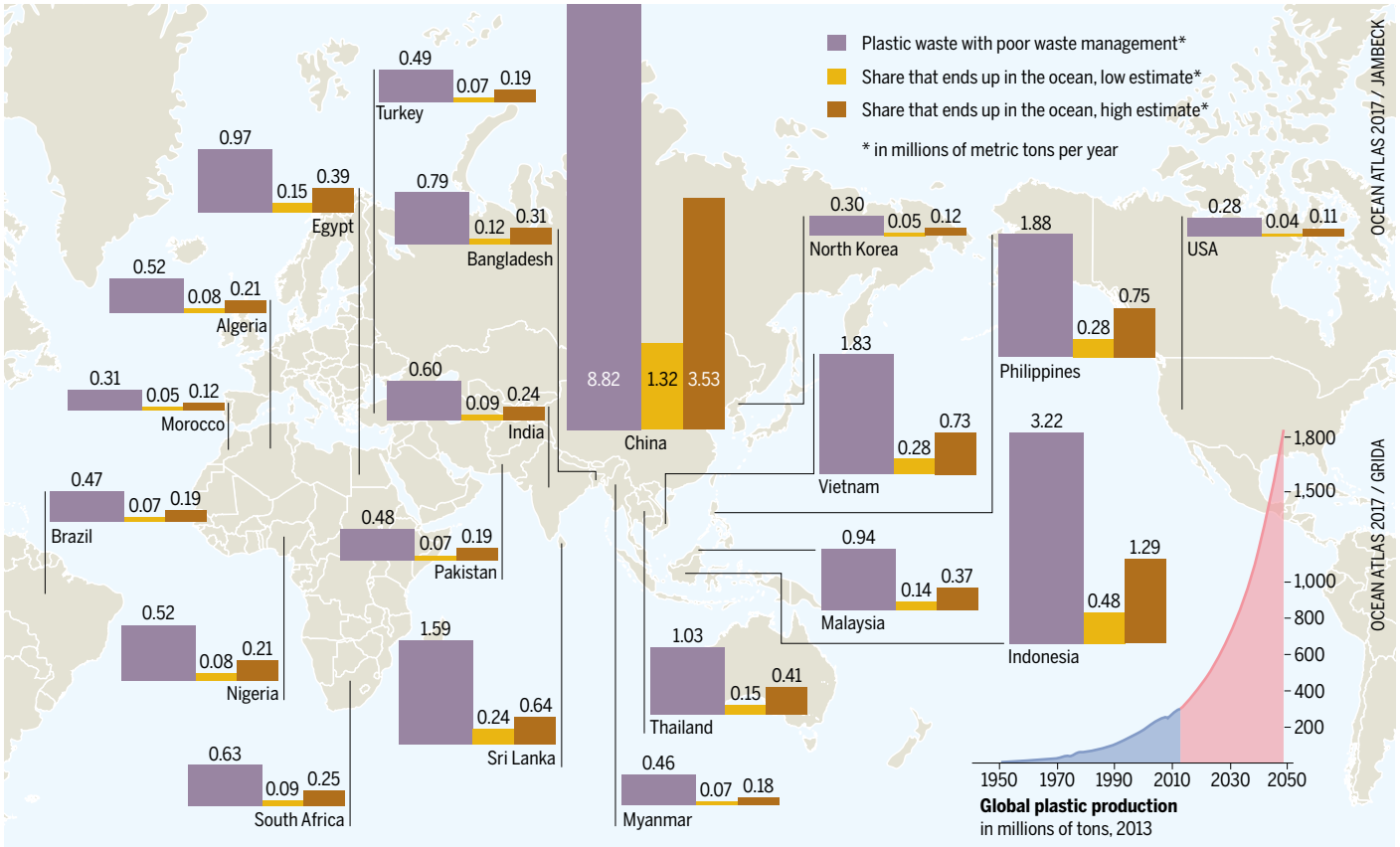
While the portion of microplastic that remains afloat may seem small, it is the cause of a large problem with far reaching effects. Fish mistake microplastic with plankton and eat it – and no wonder, since there is six times as much plastic as plankton in some parts of the ocean. Very small pieces of plastic can penetrate the fish's intestinal walls and become trapped in the surrounding tissue. The microplastic then enters the food chain and eventually winds up on our plates and in our own stomachs. The consequences of consuming microplastic have yet to be studied – after all, microplastic itself has only been a research topic since 2007. One finding is already cause for concern: the surface of microplastic acts like a sponge that soaks up toxins, including environmental poisons like PCB and disease-causing germs, helping them spread and threatening entire fish populations.

Once plastic gets into the ocean, there is no way to get it back out. Most becomes microplastic, which is so small that filtering it out of the water would filter out the aquatic life as well. That would still leave the larger pieces of plastic that are dangerous to larger animals. There are many technical solutions aimed at these aspects of ocean cleanup under development. Here we must consider the ecological consequences as well as the benefits. For instance, if one plans to scoop garbage out of large areas of the sea fish and other organisms will also be caught unintentionally, as happens in commercial fishing. We must ask how great is the benefit compared to the damage that will result?

Where Does All the Plastic Waste Wind Up?



Where Does the Plastic Waste Come from? The Top 20 Countries with the Worst Plastic Waste Management



31.9 million metric tons of plastic waste are improperly disposed of globally; 4.8 to 12.7 million metric tons of it ends up in the ocean. The top 20 countries shown above are responsible for 83 percent of global plastic waste mismanagement. Taken together, the 23 coastal EU countries would rank 18th on this list. North America, China, and Europe produce around two-thirds of the world's plastic.

The solution to the problem actually lies on dry land, on coasts and river deltas, at markets and in households. The good news is, it is within our grasp. A significant portion of the plastic waste in the ocean comes from the packaging and products we use – and we can have a direct influence by changing our consumption. We can also ban the use of microplastics in cosmetics. But the most effective step that we can take is to build up a globally functioning recycling economy so that fewer new plastics are created and less are disposed of in an uncontrolled manner. Political engagement is a powerful lever for setting the right incentives to change. Developing a circular economy is just a matter of political will.

How Does All That Plastic Get into the Ocean?

1. *A poor waste management/recycling system (or none at all) is the leading cause.*
2. *Plastic garbage from cities and industrial centers flows directly into rivers and seas with untreated wastewater.*
3. *Microplastic used as additives in cosmetic products is not filtered out by water treatment plants.*
4. *Fishing nets and lines lost or intentionally abandoned at sea.*
5. *Lost loads and ship materials.*
6. *Garbage illegally dumped at sea.*
7. *Catastrophic waste: wreckage and garbage swept out to sea by hurricanes, floods, and tsunamis.*

THE DANGER OF DECLINING DIVERSITY

Food connoisseur visiting Sylt, Germany's idyllic North Sea vacation destination, can choose between fresh Pacific oysters and native blue mussels. But what seems like fine dining is actually a cautionary tale; invasive oysters threaten to overrun the native mussels.

While the main threat to marine biodiversity is the exploitation and pollution of natural habitats, there is another: invasive species. The case of the Pacific oyster's colonization of the Wadden Sea, a UN World Heritage Site along the German and Danish North Sea coast, is a prime example. The oyster is more than just a delicacy there – it is also a plague. But how did it get there?

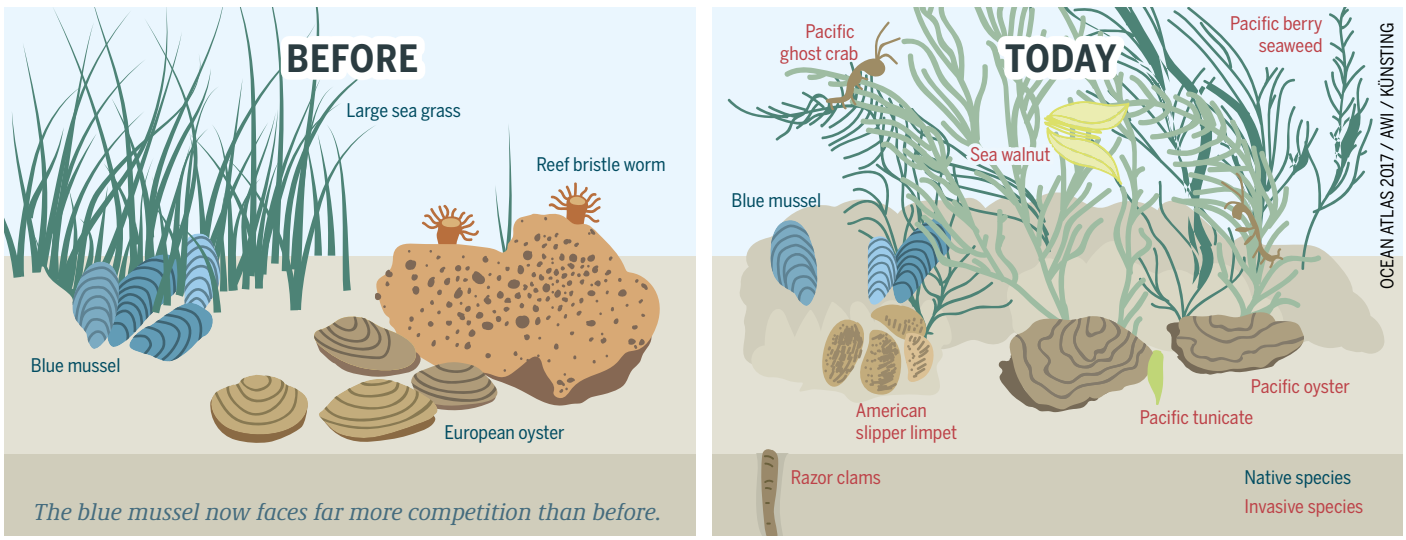
Drifting tectonic plates have separated continents and isolated islands for centuries, enabling millions of species to develop in diverse habitats. Now continents are coming together again in a very different way. Each day, thousands of species cross the oceans in the ballast tanks of ships or on bits of floating plastic waste, eventually disembarking from their long journeys in foreign ecosystems. For some the differences are too great and they perish. Others, though, are able to thrive in their new surroundings. The Pacific oyster is one such generalist.

What sets the conquest of the Wadden Sea apart from similar tales of invasive species is that we know how the Pacific oysters got there, and why. By the 1950s the native European oyster was nearly extinct due to disease and overfishing. At the end of the 1970s, a team from the German Federal Research Agency for Fisheries began investigating whether the hardier Pacific oyster could provide an alternative for local oyster farmers. The results were promising – the foreign oyster flourished in the North Sea. The Wadden Sea was rich in nutrients and the well-fed oysters thrived.

Until the mid 1990s there were fewer than 10 Pacific oysters per square meter off the coast of Sylt. By 2007 that number had increased to 1,800 per square meter. During the same period the blue mussel population declined drastically. They were not the only species affected. For instance, the oystercatcher, a species of bird, feeds primarily on mussels. The shell of the Pacific oyster is too thick and hard to serve as a replacement meal. Pressure to adapt is rising – and the lower an ecosystem's biodiversity, the more difficult it is for it to react to environmental changes.

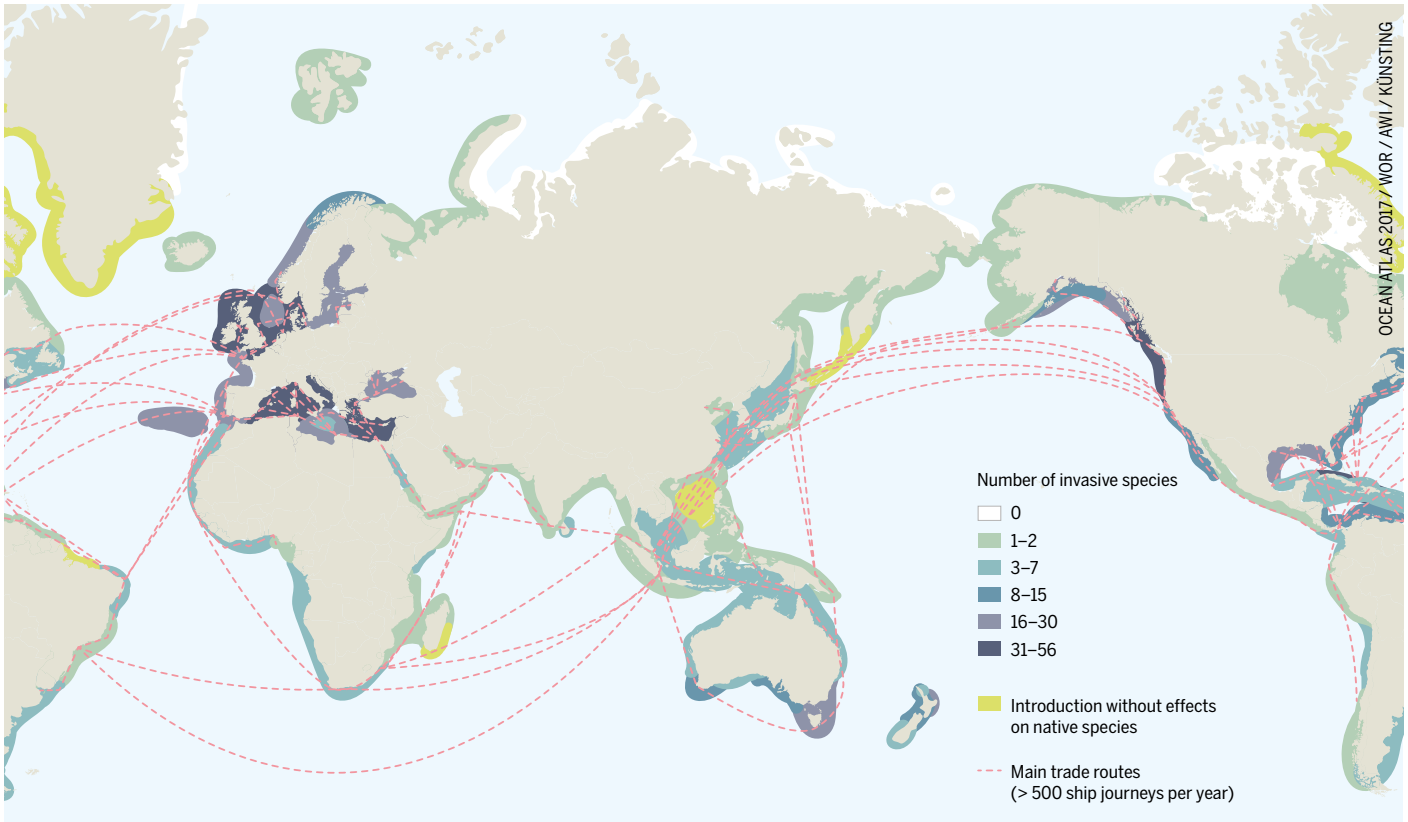
An even greater problem for the biodiversity of a habitat arises when a foundation species is threatened. Foundation species provide the basis of an ecosystem; other species rely on them. Think of the kelp growing in the seaweed forests on the North American Pacific coast, which resemble underwater primeval forests teeming with life. Or consider the coral of the Great Barrier Reef off the coast of northern Australia 360 hard coral and 80 soft coral species of the world's largest coral reef are home to more than 1,500 species of fish, 1,500 species of sponge, 5,000 species of mollusk, and 200 species of bird. Many of them are threatened with extinction, including aquatic mammals like the sea cow. If the coral die, the entire ecosystem will lose its foundation. Some of the more flexible species may adapt or move away, but others cannot. Like many other coral reefs, the Great Barrier Reef is currently in catastrophic condition. Consistently high temperatures, which can be traced back to the El Niño phenomenon, have caused 93 percent of the reef to bleach. It has already

The Blue Mussel and Its Neighbors in the Continually Submerged Area of the Wadden Sea



The blue mussel now faces far more competition than before.

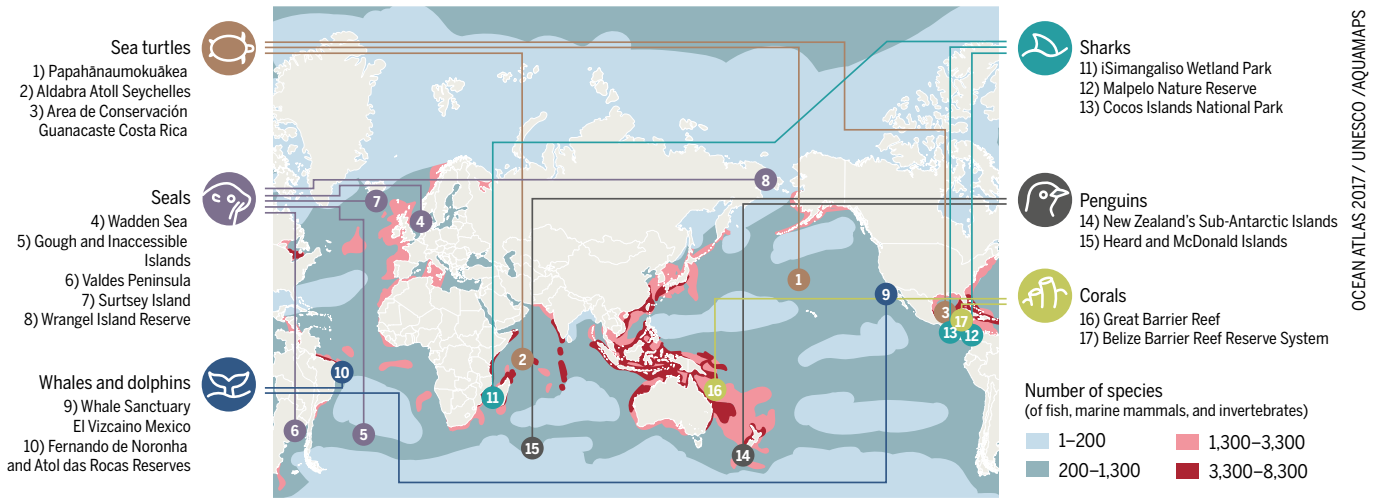
Primary Trade Routes: Shipping and Invasive Species



caused large parts of the northern section to die off dramatically. The Australian government, fearing the impact on tourism, insisted that all passages about the Great Barrier Reef be struck from the current UN report "World Heritage and Tourism in a Changing Climate."

How can we act sensibly in regional ways to protect the diversity of the ocean from global environmental changes? We cannot quickly halt the warming of the ocean, and it is impossible to reforest the coral reefs on a large scale. Saving the biodiversity of the Great Barrier Reef requires just one sensible act on our part: simply avoid adding additional stressors to the reef's ecosystem. Pollution must be prohibited. Other than preventing harm as much as possible, there is nothing that we can do besides rely on the self-healing power of nature. After all, parts of the southern reef are still alive. The flora and fauna there could eventually resettle the northern section. If the reef collapses completely, though, the original biodiversity would be irreparably lost. ●

Marine World Heritage Sites—Biodiversity Worth Preserving



Selected examples from the 49 marine UNESCO World Heritage Sites

CLIMATE CHANGE

HOW THE OCEAN SLOWS CLIMATE CHANGE

Without the ocean, climate change would proceed far more quickly. The massive volumes of water in the seas greatly influence the changes occurring in our atmosphere.

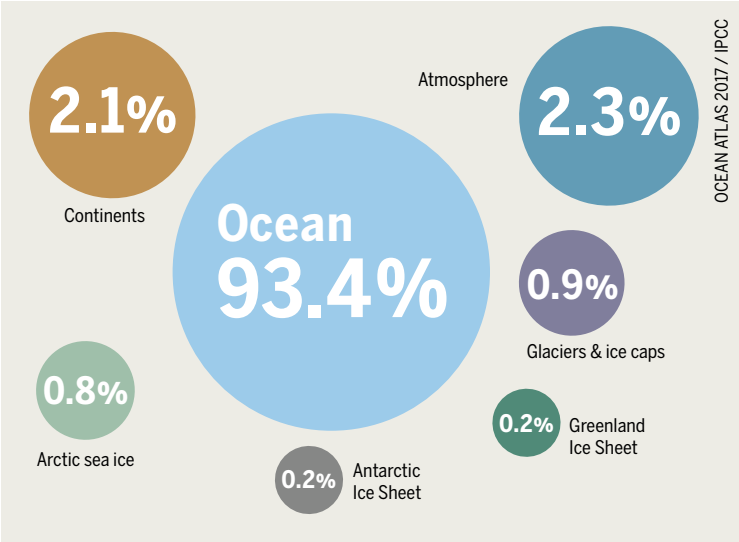
Climate change, particularly global warming, is mainly caused by the CO_2 we release into the atmosphere by burning fossil fuels like coal and oil. Since the beginning of industrialization in the 19th century the amount of CO_2 in the atmosphere has risen by 40 percent. CO_2 is a greenhouse gas. If not for the ocean, temperatures would be even higher than they are now because the ocean currently absorbs a quarter of the CO_2 released into the air. The atmosphere and the ocean are linked by a self-balancing concentration gradient. When the concentration of CO_2 in the atmosphere rises, the ocean absorbs more to restore the balance. The colder the seawater is, the more effectively the process works.

In the Labrador Sea and Greenland Sea as well as in regions near the Antarctic coast, large quantities of surface water sink into the deep sea where the CO_2 is stored for long periods of time. The largest amount of the CO_2 stored in this manner, from the start of the Industrial Revolution, will take centuries to return to the surface of the ocean. Part of it will remain fixed in the sediment of the sea floor. The ocean significantly slows climate change. The ability of the ocean to sequester CO_2 is not unlimited, though, and it varies. For example, while CO_2 absorption in the Southern Ocean declined between 1980 and 2000, it has increased in the years since. The ocean does more than absorb a considerable amount of our excess CO_2 it also soaks up nearly all of the additional warmth resulting from the man-made greenhouse effect. Over the last 40 years the Southern Ocean has absorbed an astounding 93 percent of the excess heat. Increased global atmospheric temperatures are attributable to just three percent of this additional thermal energy and would be much greater if not for the ocean. The extra warmth is essentially hidden in the ocean, where it slowly spreads through the depths. Because of this, the surface temperature only increases at a snail's pace.

This has a steep price. Absorbing excess CO_2 leads to the progressive acidification of the ocean, while absorbing excess heat contributes to rising sea level and troubling changes in marine ecosystems. The warming of the oceans contains another risk: positive feedback loops. For example, when the rate of evaporation on the ocean surface increases, it produces more water vapor, which causes temperatures to rise, which causes the rate of evaporation to increase. This positive feedback loop occurs because water vapor is a greenhouse gas that is even more effective than CO_2. It in itself is not a bad thing: around two-thirds of the natural greenhouse effect, which has made the Earth inhabitable for millions of years, is caused by water vapor; only a quarter of it is caused by CO_2. But if we release too much CO_2 into the atmosphere, the feedback loop described above greatly amplifies its effects.

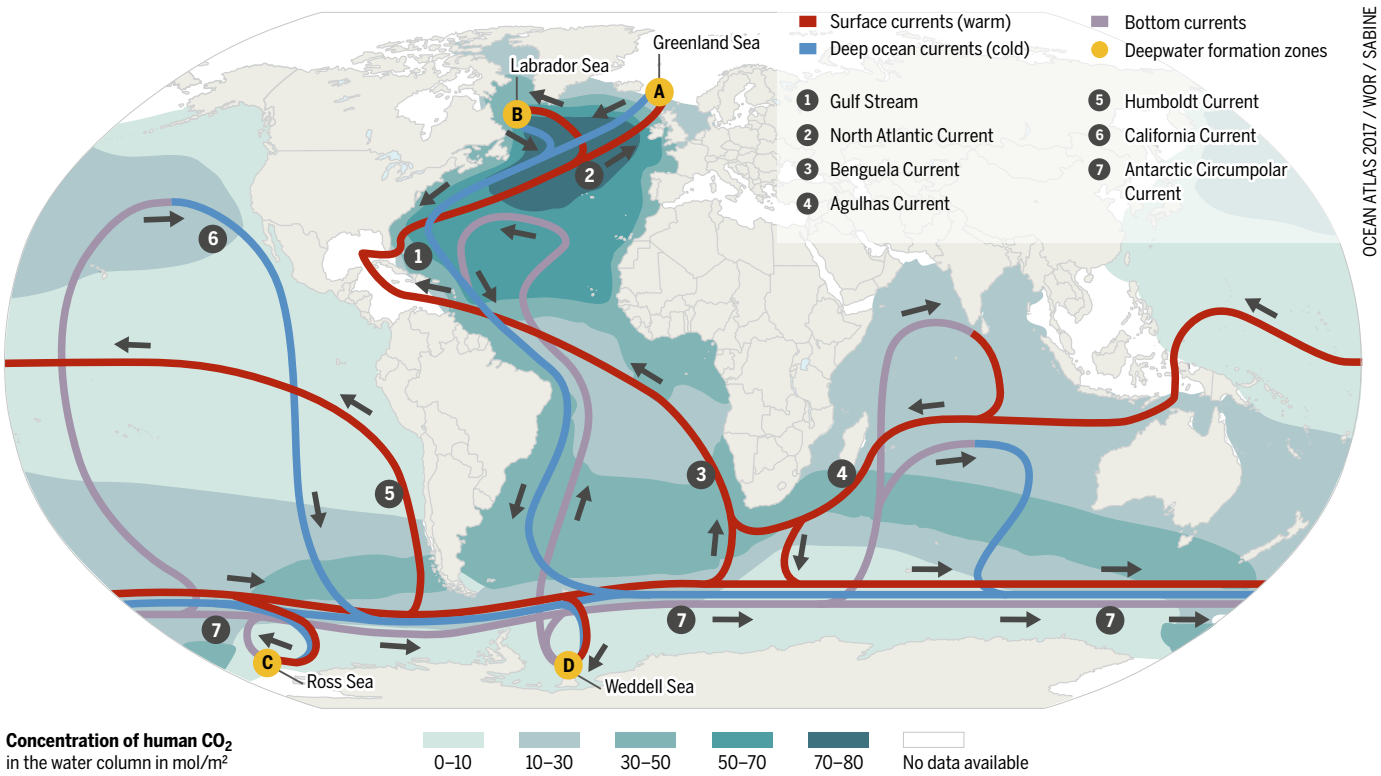
Another positive feedback loop is created by the melting of sea ice, which is also caused by rising temperatures. Arctic and Antarctic sea ice acts like a protective shield – it reflects up to 90 percent of the sun's rays. Due to rising temperatures, sea ice is continually shrinking. And where there's no ice in the ocean, there's water. Since water is dark it absorbs sunlight rather than reflecting it – up to 90 percent of it. As it does so, it warms up. The result: more ice melts. These positive feedback loops can accelerate global warming in ways that are difficult to predict – one more reason not to further burden the ocean system. For this reason, meeting the goal of limiting global warming to the two degrees Celsius agreed upon at the Paris Climate Conference is essential.

Where Does the Warmth Go?



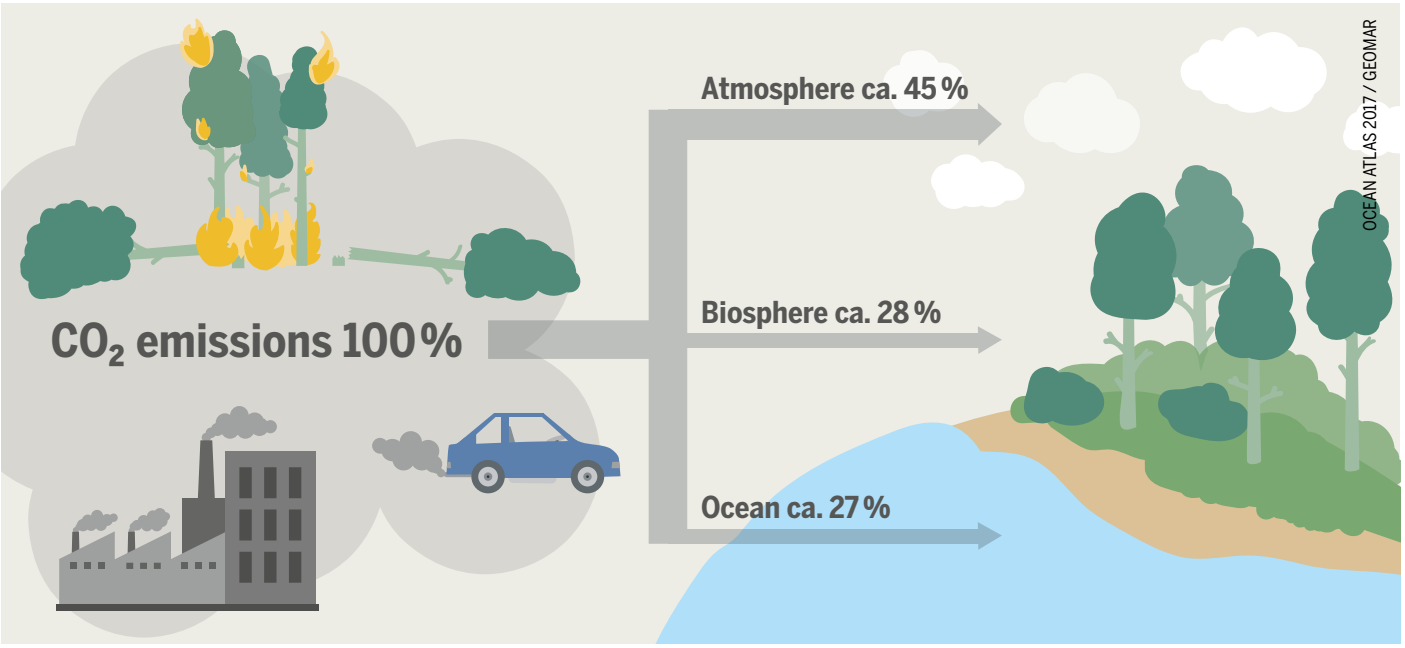
The ocean absorbs the lion's share of the additional warmth resulting from human CO_2 emissions, which supplements the natural greenhouse effect.

The Global Conveyor Belt—How the Ocean Stores CO_2



CO_2 entrapment is made possible by large oceanic currents. Working like conveyor belts, they carry warm surface water, which absorbs CO_2, from the tropics in the Atlantic towards the colder poles.
On the way, the water slowly cools and becomes saltier. When it arrives in the Greenland Sea (A), the Labrador Sea (B), and at the Antarctic coast in the Ross Sea (C) and the Weddell Sea (D), the heavy surface water sinks into the depths, taking the CO_2 with it. The CO_2-rich water then flows back towards the tropics. As it travels, the cold water slowly mixes with the warmer layers above and rises—very slowly—back to the surface.

Where Does the CO_2 Go?



The CO_2 produced by people (i.e., in addition to natural emissions) is distributed as shown.

WARMING WATERS AND RISING RISKS

The ocean is far, far away from Springdale, Arkansas, located at the foot of the dusty Ozark Mountains. Yet, the city feels the effects of rising sea level. Seeking safety, 10,000 of the 72,000 inhabitants of the Marshall Islands have made the city their new home.

The Marshall Islands lie in the Pacific between Hawaii and Australia. The island nation is one of the first countries whose existence has been threatened by climate change. It is only a matter of time before it is overwhelmed, and nearly a third of the population has already left for the safety of the USA.

The reason for their flight is the quickly rising sea level. One factor driving the rise is the melting of glaciers on the mainland. The other is the warming of the ocean: 93 percent of the additional heat that results from global warming is absorbed by the ocean. Since water expands when it gets warmer, the sea level rises. The melting and the warming now contribute in nearly equal measure to sea level rise. Since 1900 the sea level has risen 20 centimeters on average. It is expected to continue rising at a rate of 3 additional millimeters per year. That may not sound like much, but for a scattered, flat island country like the Marshall Islands it will be fatal. In the past the atolls, which often rise only a meter above the waves, were only flooded by the ocean every couple of decades. That trend has since changed; in 2014 alone, the islands were swamped 3 times. Too frequent flooding makes it difficult for the islands to recover. The land becomes too salty, the freshwater reserves in the lagoons become undrinkable, and the islands themselves can no longer support human habitation.

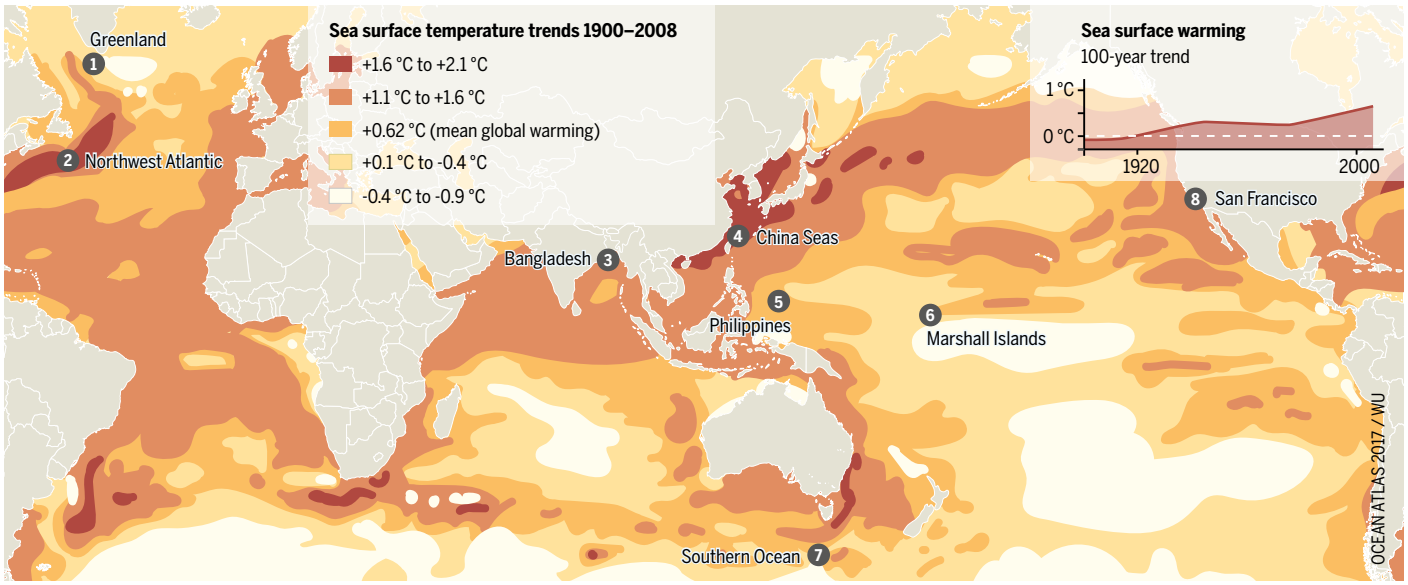
The sea level does not rise at the same rate everywhere, and long-term measurements show significant local variations in the ocean's surface temperature. Some regions in the area of the Gulf Stream have warmed four times more than the global average, while other areas in the South Pacific have cooled slightly. The Marshall Islands themselves lie in a region of weak warming. Sea level does not necessarily increase the most where the warming is strongest. Why? The prime cause of the regional variations in sea level is wind. For example, in the Pacific, strong trade winds press volumes of water from the east to the west, causing the sea level in the western Pacific to rise at an above-average rate while sea level at the west coast of the USA actually falls. This dependence on wind makes it difficult for scientists to provide answers. What will happen in the future to our region? What do we need to do to adapt? The problem is that reliable predictions about how regional sea levels will change do not exist yet, because the long-term behavior of the wind system is difficult to predict.

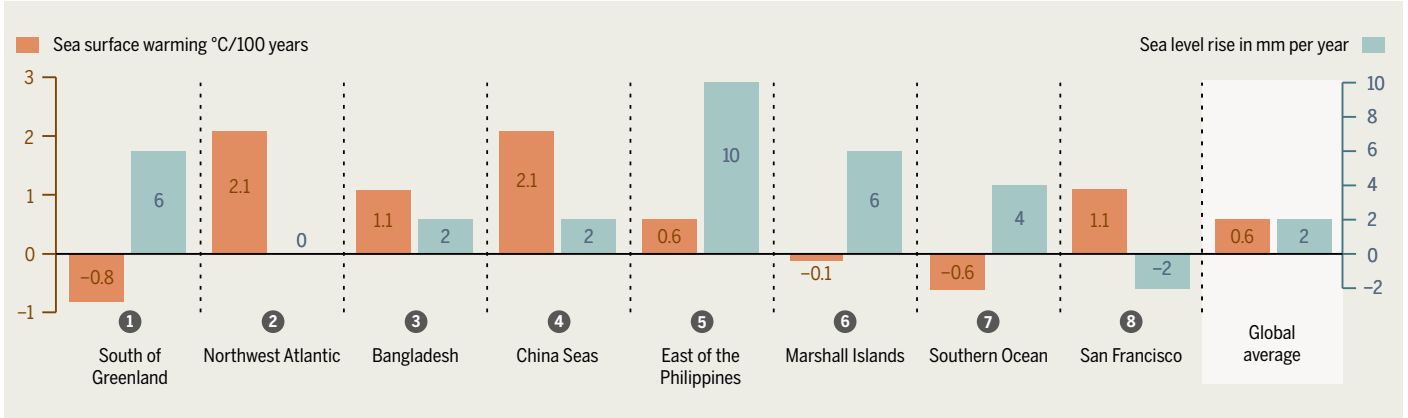
Rich states like the Netherlands are investing in research on new, sustainable forms of coastal protection. For example, instead of building dikes they now rely on a constant cycle of sand eplenishment. The intensity of the sand replenishment can change based on actual sea level increases in the future. Many poorer countries do not have such means of preparing for the consequences of a warmer ocean and of rising sea levels. Consider Bangladesh: it is one of the most densely populated countries in the world, with 160 million inhabitants. In order to make room for its growing population, Bangladesh's Sundarbans mangrove forests have been partially cut down to create living spaces, and dikes have been created to protect them from the surrounding sea.

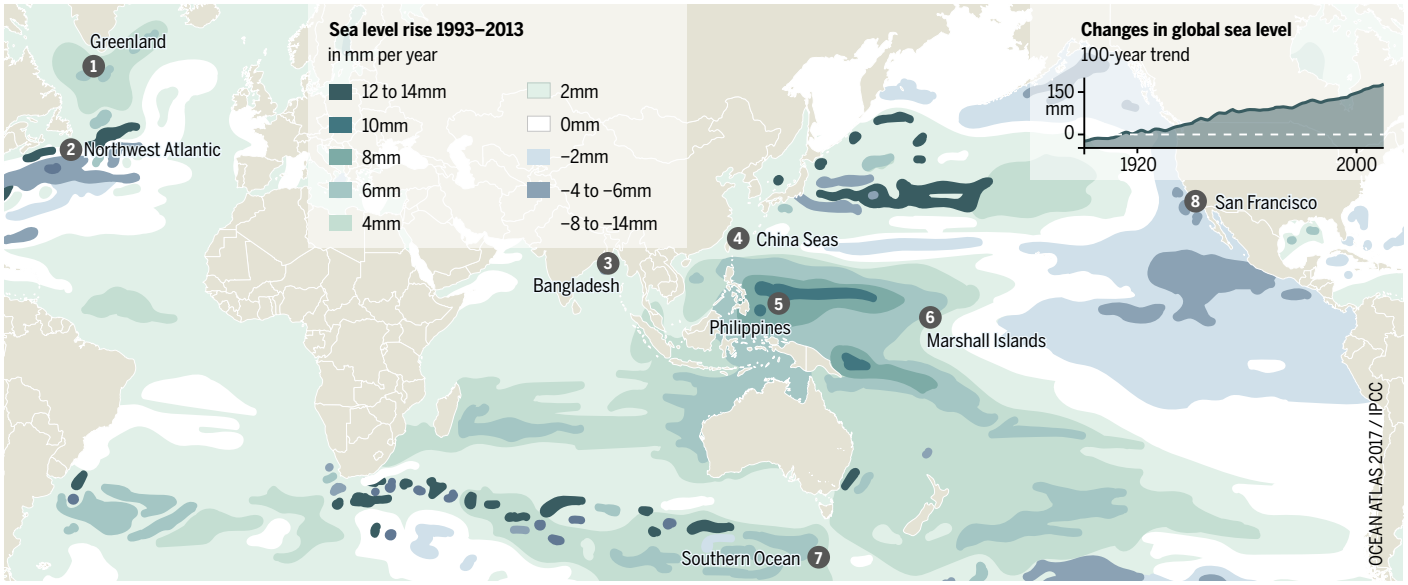
Bangladesh is at sea level, and the sea level has risen at twice the global average over the last two decades. The 13 million inhabitants of the Sundarbans are thus especially vulnerable. In 2009 this area was struck by Cyclone Aila. The dikes broke and large portions of the low-lying land flooded. What remained was a destroyed, salted landscape. Tens of thousands of refugees fled to cities in the interior. In the future, when the dams burst, millions of people may become climate refugees. The chances of that happening are increasing. Meteorologists in Bangladesh note that storms in the region are constantly growing stronger, probably as a direct consequence of the above-average warming of the Indian Ocean.

Rising sea levels, accompanied by more violent weather phenomena and the resulting stronger storm tides present coast and island dwellers with special challenges. Will it be possible to preserve all island and coastal cities? This question was strongly debated in the USA when New Orleans was flooded in 2005. While rich countries can protect themselves, poor countries remain especially sensitive. Yet if one considers the causes of these new and adverse climate conditions, it is the industrialized nations that bear a special responsibility for all the world's coastal inhabitants. One step towards shouldering that burden and protecting vulnerable regions is the creation of the UN's Green Climate Fund – it will enable affected countries to take adaptive measures like improving their coastal protection systems. For this to work, industrialized nations must be the ones to provide the necessary resources, and in turn they must be effectively utilized.

Global Variations—The Rising Sea Level and Surface Warming







Climate change has accelerated the warming of the ocean and caused a dramatic sea level rise since the beginning of the 20th century.
But the level does not rise at the same pace everywhere in the world; there are regional variations. The sea surface temperature has increased up to 2°C in some places, while the temperature has actually fallen in others. The global sea level rise was on average 20 cm over a period of 100 years.
Satellite measurements from the last 20 years, however, show strong regional variations in sea level increase.

LIFE IN THE DANGER ZONE

Flooding, erosion, sinking: our coasts are under ever-increasing pressure. People who live in coastal regions are especially endangered – and there are an ever-increasing number of them.

According to UN predictions, the population of the Earth will rise to nearly ten billion by 2050. When combined with the trend toward urbanization, megacities will experience accelerated growth around the world. By 2050, 22 percent of all people will live in a megacity, and these people will be especially vulnerable there. Currently, 62 percent of cities with populations of eight million or more lie on the coast.

Consider Bangkok. The population of Thailand's capital city has rapidly grown to around 10 million. Called the Venice of the East, most residence live in poverty in Bangkok, a city containing a canal network along the Chao Phraya Delta. Residents live in constant fear of the Three Sisters, the trinity of high river floodwaters. That's what they call the trinity of high river floodwaters, strong rains, and storm floods that are growing increasingly dangerous due to climate change. They have good reason to fear them. In 2011 the Three Sisters paid a shared visit to the city. Due to an unusually long and strong monsoon, the river breached its banks while at the same time a spring tide prevented the floodwaters from draining off into the sea. 657 people lost their lives, and the damages were enormous. The effects were even felt hundreds of miles away in Western offices: the price of computer hard drives doubled in the aftermath because nearly 50 percent of all hard drives are produced in the Bangkok region.

The megacities located on river deltas, like Bangkok, New York, Shanghai, Tokyo, and Jakarta, are considered hotspots of vulnerability. They are the high-risk zones of the ocean crisis. Megacities are especially threatened by "100 year" events meaning exceptionally severe flooding.. In river deltas, the largest threats to cities come together in a fatal way. In addition to the Three Sisters, the biggest threat is accelerating subsidence, meaning that the land on which the cities stand is actually sinking. Bangkok, Shanghai, and New Orleans have each sunk up to three meters in the 20th century. Tokyo and Jakarta have sunk four. Parts of these cities already lie well below sea level. Subsidence is a natural process in delta regions, but the extreme acceleration becomes a self-inflicting wound. Groundwater extraction and the compaction of the soil by the weight of unrestrained construction booms have taken their toll. Megacities are sinking – in some cases, twenty times faster than the sea level is rising. In the 20th century, the global average increase in sea level was approximately 20 centimeters.

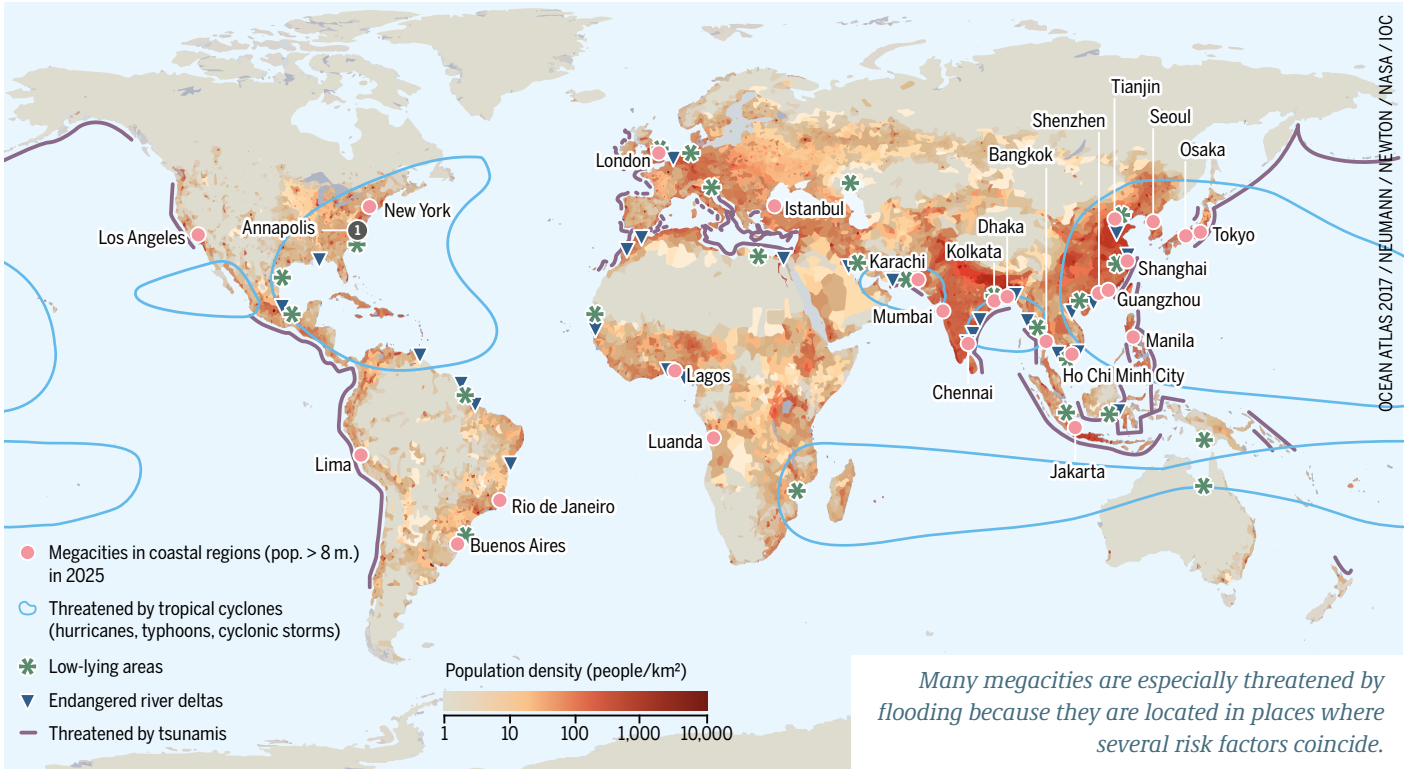
Dams erected on large rivers feeding into deltas are an additional driver of accelerated susidence. These dams hold back sand and sediment that would normally be washed out to sea. The flow of silt originally created deltas over several millennium ago. Now, in many cases only 50 percent of the typical quantity of silt actually makes it to the delta. Because of dams and additional river regulation measures, the deltas have no way of replenishing themselves. They are slowly disappearing as the tides constantly pull sand into the sea.

Scientists and urban planners are already asking if these cities can be maintained over the long term or if they will eventually have to be given up – even though they are growing rapidly. It is an enormous challenge for high-risk

Endangered River Deltas

1. *Megacities grow larger and larger.*
2. *Megacities sink because of soil compaction and the extraction of groundwater, oil, and natural gas.*
3. *Destruction of natural coastal protections like mangroves.*
4. *Rising sea levels.*
5. *Soil salinization caused by seawater.*
6. *Reduced sediment deposits in deltas due to construction of dams, etc.*
7. *Less sediment leads to stronger erosion.*
8. *Storms from the sea magnify incidents of flooding.*
9. *Strong precipitation (monsoons) leads to river flooding and to rising water levels in the deltas.*

Megacities: Dangerous Developments



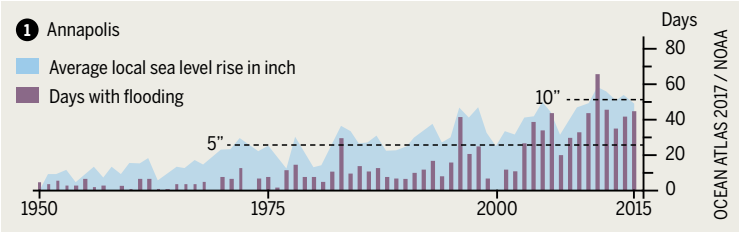
Many megacities are especially threatened by flooding because they are located in places where several risk factors coincide.

cities like Tokyo, New Orleans, and New York, which was hit by Hurricane Sandy in 2012. These wealthy cities invest billions in high-tech protective systems and building fortifications against the threat from the sea. But many developing and emerging countries lack the financial resources or awareness necessary to take timely action against these massive threats.

Determining whether only the wealthy can afford protective systems to survive is a pressing global matter. When Bangkok was threatened by flooding, the government created a 77-kilometer-long protective wall of sandbags. This wall divided the metropolitan region into areas in front of and behind the dike, setting apart the protected and the defenseless. When the flood hit, the people outside the dike tried to pierce through to allow the water to dissipate. The violent confrontations that ensued illustrate the potential for future conflicts, because the walls, pumps, and dikes typically protect the more affluent areas. For these social reasons alone, building floodwalls that divide cities and regions cannot be the only solution.

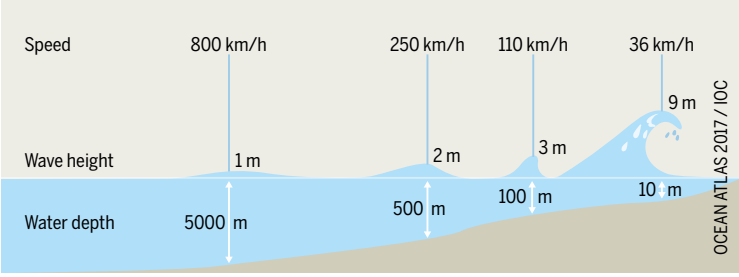
Tsunamis also pose a large threat, not only to the megacities but also to all people and settlements in the endangered coastal regions, is tsunamis. The probability of a tsunami is low but the effects are overwhelming. Consider, for example, the catastrophic results along the coasts of the Indian Ocean in 2004 and the east coast of Japan in 2011. Every endangered metropolis, every city, and the global community as a whole must engage in an open dialogue. What should we protect? What can we protect? What is sustainable? What is just? The situation on the coasts changes constantly and plans must be continually revised and adjusted. The needs and experiences of the population must be surveyed and considered, and new protective measures that are in harmony with nature must be devised. In some cases, that may mean that land must be relinquished to the sea in order to protect it elsewhere.

Increased Flooding on the East Coast of the US



Local flooding has greatly increased along the entire east coast of the United States. The water does not rise very high and quickly recedes—but it also gradually destroys neighborhoods and infrastructure, causing residents to move away and property prices to fall.

Emerging Giant—A Tsunami Races across the Ocean



Tsunamis are also a threat to the growing coastal populations.

ACIDIFICATION

A CORROSIVE FUTURE

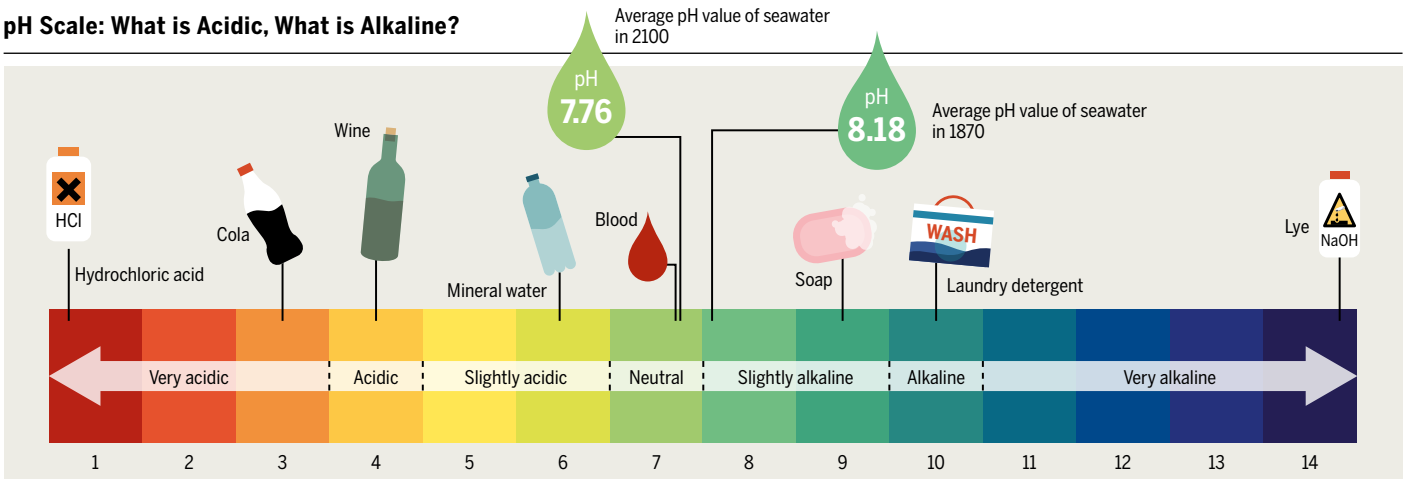
Our oceans are becoming more and more acidic. Though barely detectable to humans, for many of the animals that live there, the change is already proving fatal.

The four large upwelling zones near the west coasts of Africa and the Americas have been especially affected. In those areas, nutrient-rich water rises from deeper, darker layers up to the light-flooded areas near the surface. The nutrients they contain, like nitrates and phosphates, form the foundation of the food chain. They nourish phytoplankton (single-celled algae), which are eaten by zooplankton (tiny sea creatures). The zooplankton are in turn consumed by fish, which is why the upwelling zones are home to particularly rich fishing grounds. The diversity of species and the shear number of organisms is especially great there: seven percent of biomass is produced there, and they are home to 25 percent of the fish catch. They are places full of biotic abundance and an important source of livelihood for millions of people. But this source of life and livelihood is threatened by acidification. Consider the upwelling zone off the coast of California. Since the Gold Rush in the 19th century, it had been home to a flourishing oyster industry that supplied the delicacy to the entire country. But in 2005 the oyster farmers received an unexpected shock: the next generation did not appear. The oyster larvae had perished. The population did not recover in the years that followed, and the West Coast oyster industry collapsed. Thousands lost their jobs.

What happened? The upwelling of deeper water in coastal regions changed. Researchers determined that the pH value of the water near the coast had declined starkly. The deep-sea water had thus transformed from a source of nourishment into a life-threatening environment. When the acid concentration became too great, the oyster larvae died. Researchers discovered that a portion of this increased acidification could be traced back to the CO_2 that we have released into the air. The Earth has always experienced periods of greater and lesser CO_2 concentration, but today our oceans are acidifying at an unprecedented pace, faster than at any point in history. The oceans have already absorbed an estimated third of the CO_2 that we have emitted into the atmosphere since the Industrial Revolution. The result is a 26 percent increase in the acid content of the ocean.

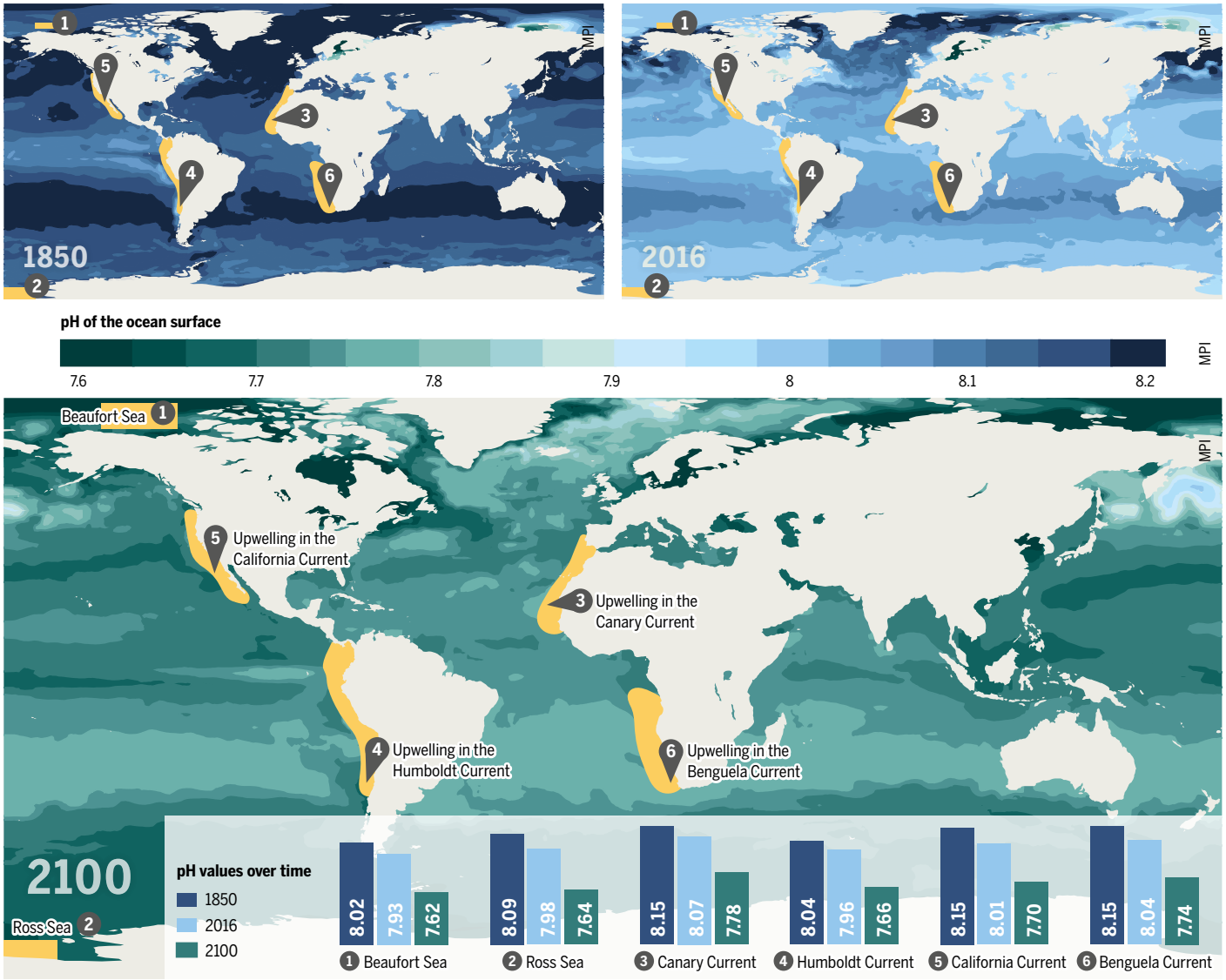
What are the concrete effects of acidification? First, CO_2 in the water transforms into carbonic acid and the carbonate saturation decreases. That is a problem for all animals that use marine carbonate to make their shells, like mussels, snails, corals, sea urchins, and many others. The less carbonate there is in the water, the more difficult it is for them to make suitable shells. The effects can already be seen among foraminifera, tiny calcifying creatures that make up an important part of plankton: the shell-thickness of animals from the southern ocean has noticeably decreased compared to specimens from the pre-industrial period. The effect on oysters is slightly different: it has been observed that the thickness of their shells does not decrease, but only because they invest so much energy in shell production that it stunts their overall growth. As a result, they are easier prey for predators, such as murex snails. The situation is particularly critical for calcifying species in zones in which the carbonate saturation drops too far. In that case, the water actually begins to draw carbonate out of their shells and corroding them. This is already happening in some regions in Antarctica and in the North Atlantic. The cold-water corals that live there cannot maintain their chalk skeletons and will eventually

pH Scale: What is Acidic, What is Alkaline?



The difference may seem small, but the decline in the pH value from 1870 to 2100 would mean a 170 percent increase in acidity. Much smaller changes already pose problems for many sea creatures.

The Manmade Ocean Crisis—Modeling Predictions

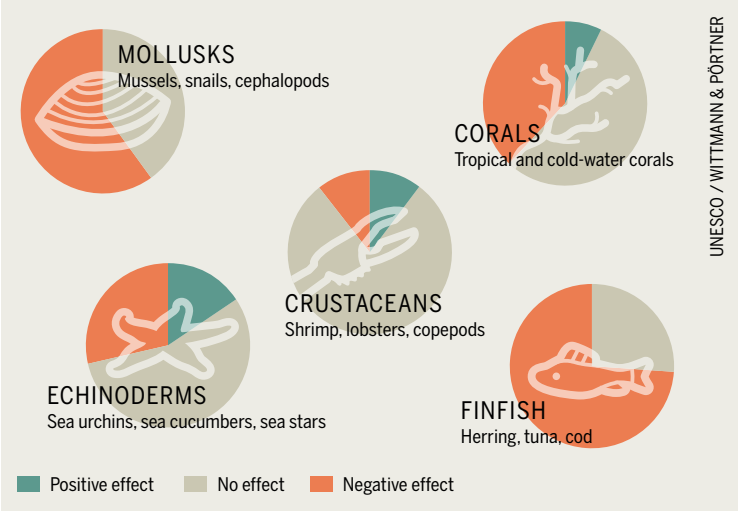


Reality is exceeding predictions. For example, in March 2017 a pH value of 7.6 was measured in the Humboldt Current—83 years sooner than predicted.

collapse. But other non-chalk-producing species, like fish, are also threatened. For instance, cod eggs have a very small chance of survival in general – 95 percent of the eggs die. If the water becomes more acidic, 97 percent will die – and that two percent decrease of already low odds is enough to endanger the future of the population.

What's worse, the areas of the ocean with corrosive, calcium carbonate-dissolving water are spreading. In addition to the polar seas, upwelling zones are under threat. The area off the coast of California will become fatally acidic in as little as 30 years. The ecosystems of the upwelling zones are especially endangered, because they are under pressure from the triple threat of acidification, warming, and oxygen-loss. This trend may be fatal, because they are so crucial for the global food chain. The shocking failure of oyster farming in California shows that we can hardly predict the effects these stresses will have. For that reason we should not exacerbate them, whether through pollution, tourism, or overfishing. ●

Acidification: Some Species Adapt—Others Don't



Many animals, like fish and snails, are negatively affected by acidification. Only a few actually benefit from it.

A LOOK INTO THE PAST

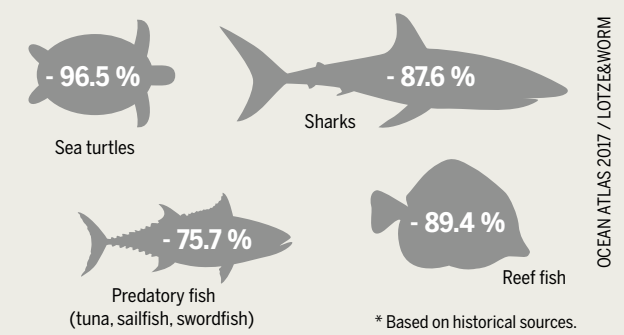
EXPLOITATION AND PROTECTED AREAS

The plants and animals that currently live in the "wilderness" of the ocean, and those we want to preserve in marine protected areas, are just a fraction of what once thrived in the seas. To understand what we've lost, and what we might be able to recover, we need to know what used to be.

Even if we sum up every type and category of protected area, only 3.5 percent of the ocean is currently protected. And only 1.6 percent is strictly or fully protected, like the Ross Sea. Designated as a no-take zone in 2017, the sea is now the largest marine protected area in the world. For the next 35 years, all types of exploitation are prohibited in more than 70 percent of the area, while the rest may only be used for limited research purposes. Environmental organizations and scientists demand that between 20 and 50 percent of the ocean be designated as protected areas. The goal is not to preserve things as they are – even in protected areas we see only a tiny fraction of the biodiversity that once existed – but to allow life to recover.

A thousand years ago, you could catch fish in many regions with nothing more than your bare hands and a net. Just 500 years ago, gray whales and right whales, whose meat was prized on the market, were a common sight in the North Sea. A few hundred years ago, there were still millions of sea turtles in the Caribbean – it is said that Columbus' men complained that they couldn't sleep because of the racket made by the gigantic animals constantly colliding with the ships' hulls. In the 17th century, there were still 90 million green sea turtles. Some dubbed them soup turtles because they served as ample fresh-meat for seafarers, and later as delicacies for the wealthy back home. Today there are only 300,000 of them left in the Caribbean.

Declining Populations* (Percentage Change)



Not just the populations were huge; the creatures themselves were also larger. At the start of the 20th century, fishermen pulled sturgeons more than three meters long from the Elbe River in Germany. In the same period, a manta ray weighing 2,200 kilograms was caught off the east coast of the USA. Today, though, there are hardly any big fish left. The reason is the fishing industry, because fish are caught before they have a chance to grow.

It is an old lesson that we are slow to learn. 2,000 years ago, the Romans commercially fished 150 different species. And the colonization of the new world in the 16th century had fatal consequences for more than just the green sea turtle. The history of whaling provides an excellent example. Whalers said the right whale got its name because it

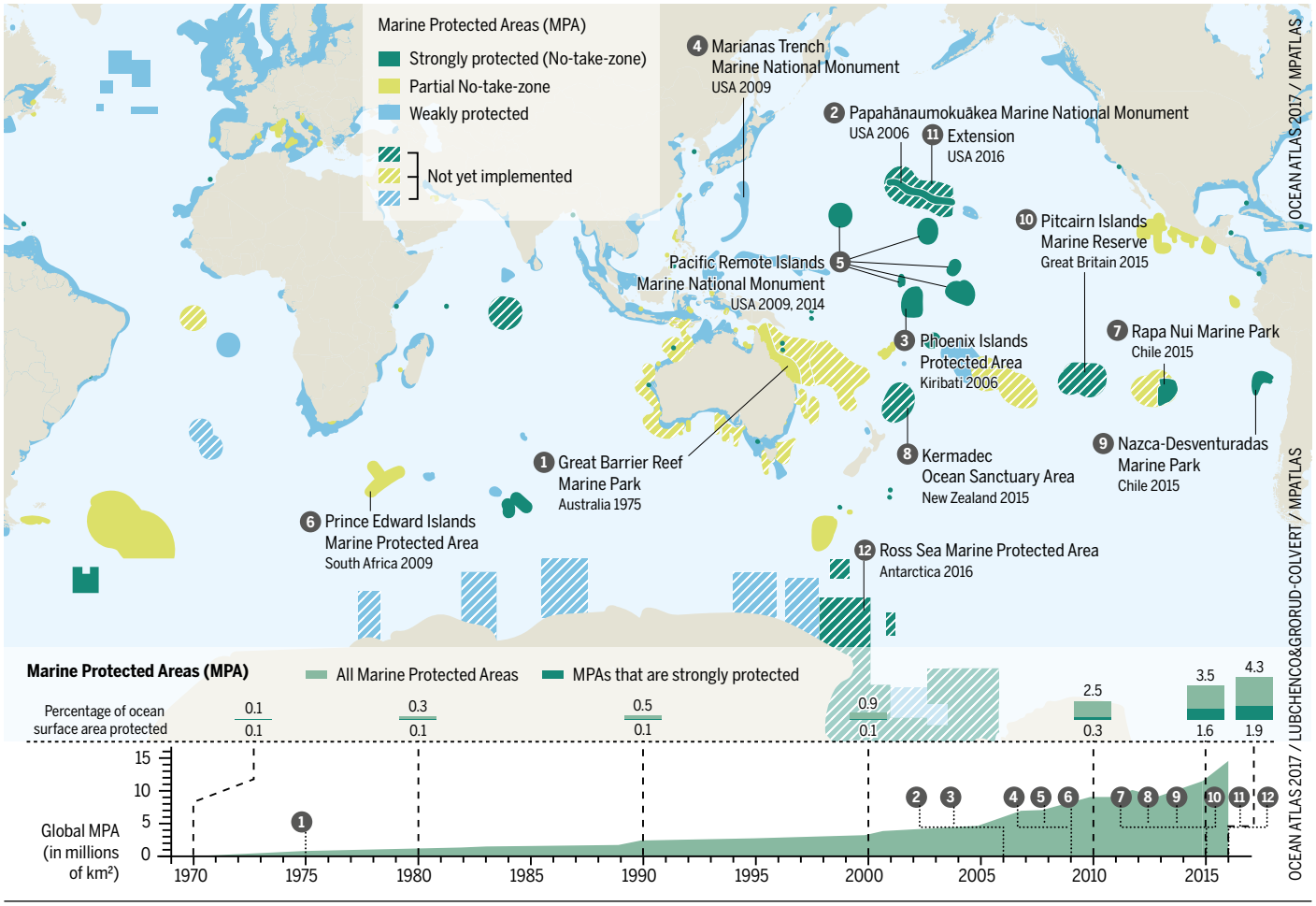
Living Memory—Old Fishermen Tell Their Tales

The Gulf of California for an old fisherman (1940s)

The Gulf of California for a middle-aged fisherman (1970s)

The Gulf of California for a young fisherman (1990s)

Marine Protected Areas—Space to Recover

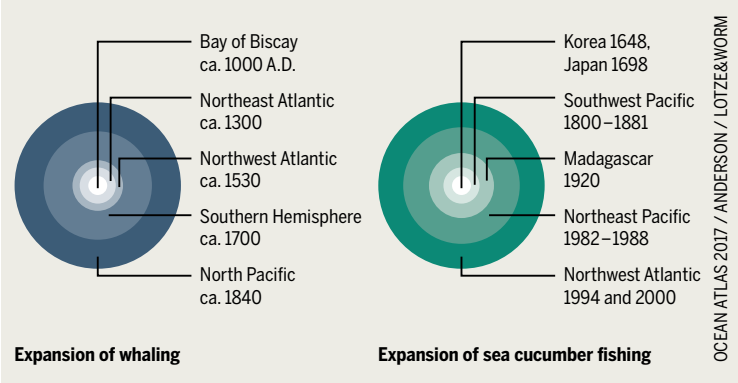


was the right one for whaling: as a coastal, slow-moving whale, they were easy to catch. They floated at the surface when killed and yielded a lot of valuable blubber that was then boiled into oil. People first began hunting them around 1000 A.D. As their ships grew more seaworthy, people pursued the whales further into the ocean. In the 18th and 19th centuries, the height of whaling, the right whale was hunted from the southern Atlantic to the northern Pacific. As a consequence, the right whale was nearly extinct by the start of the 20th century.

Humanity has grown rapidly, especially in recent history. Our respect for nature has not kept pace. Whole species have been sacrificed for new fashions and trends. People wiped out entire colonies of sea birds just to pluck their feathers for fashionable ladies' hats. Some old culinary stories sound dubious today. Can you imagine that lobster was so cheap in Boston in the 1890s that it was served for lunch in prisons? Then as now, we often view the ocean as an unlimited supermarket.

Humans would be foolish to believe that the ocean is still full of life. What we try to preserve and restore in the protected areas are just the remnants of the much greater richness and diversity that once existed. In one way, at least, we have become more clever. We hardly hunt large marine mammals anymore. That's great, but it's not enough. The sea cucumber is prized as a delicacy in Asia. Up until 50 years ago, it was only fished regionally. In the intervening years, though, the sea cucumber industry has spread across the whole ocean. They aren't as cute as baby seals, so they also aren't as well protected. So history threatens to repeat itself. Perhaps one day our grandchildren will look back on the vanished sea cucumber with the same sadness that we now feel for the loss of the whales. ●

Expansion of the Hunt



Southern right whales were hunted in the southern hemisphere for around 200 years. The historical peak population was approx. 80,000 whales. Today, only 7,500 remain. The global sea cucumber catch has risen from 2,300 to 30,500 metric tons in just 60 years (1950–2006).

OCEAN GOVERNANCE

WHO OWNS THE OCEAN?

For thousands of years, people have taken to the sea to fish and trade. For centuries wars have been fought as rival rulers claimed the rights to the sea and its exploitation. Those conflicts have continued to this day.

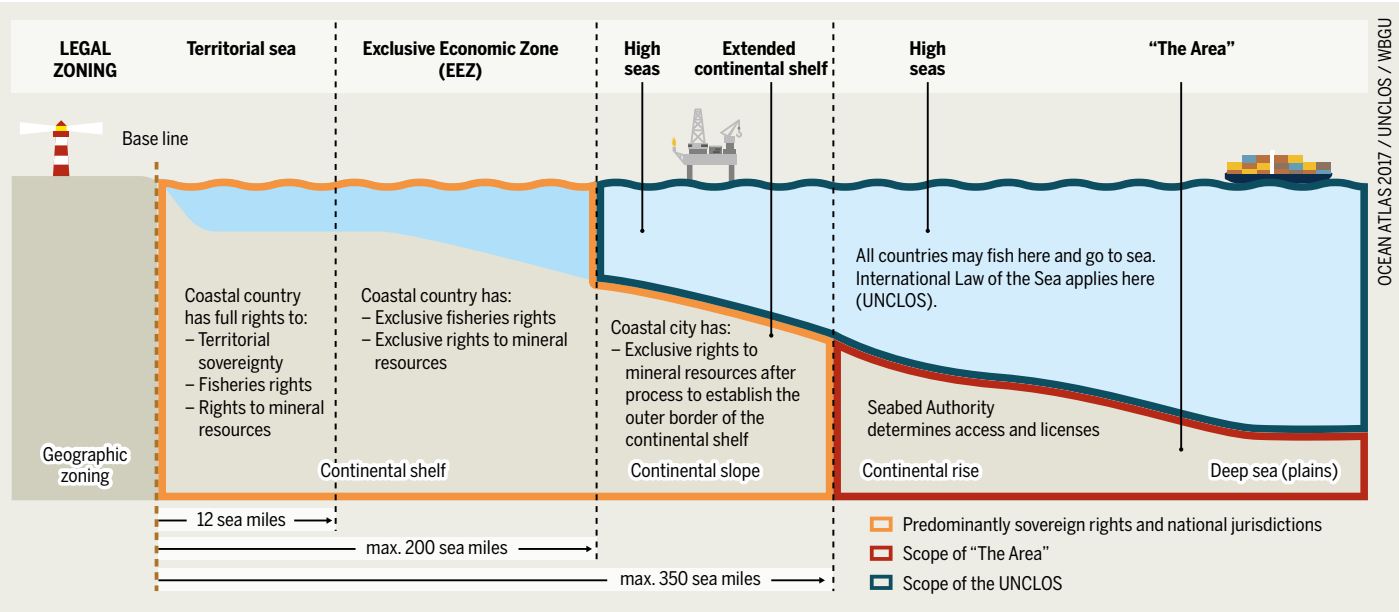
But it is no longer merely a matter of access to shipping lanes. The reason for the current international conflicts actually lies beneath the surface. Disputes revolve around the expansion of territorial seas and economic zones in order to secure exclusive rights to so-called non-living marine resources, like the valuable minerals and fossil fuels buried beneath the sea floor. They are about "territory" in the sea. Absurd? Not if you look at where land begins. And where it allegedly ends.

The foundation is the United Nations Convention on the Law of the Sea (UNCLOS 1982). It says that a country may claim an area extending 12 nautical miles from its coast as its own territorial sea. Additionally, it can exploit 200 nautical miles of the water column beyond its coast as its exclusive economic zone. The same applies to the first 200 nautical miles of the sea floor, the continental shelf. The resources found there can be exploited by that country alone. Furthermore, if the country can scientifically prove that its continental shelf extends even further – that it is continuously geologically connected to the mainland – it also has the sole rights to the resources there as well. This territorial claim includes islands but not rocks or other outcroppings.

This is particularly interesting for some uninhabited islands like Heard Island and the McDonald Islands. They are tiny islands located 1,000 kilometers north of eastern Antarctica. Thanks to them, Australia has secured a geological exploitation area of more than 2.5 million square meters, because these islands stand on the undersea Kerguelen Plateau, a gigantic mountain range that stretches more than 2,000 kilometers. Australia can now claim exclusive exploitation rights to it. The convention does place some limits on this, but the rights may still extend up to 350 nautical miles from the island.

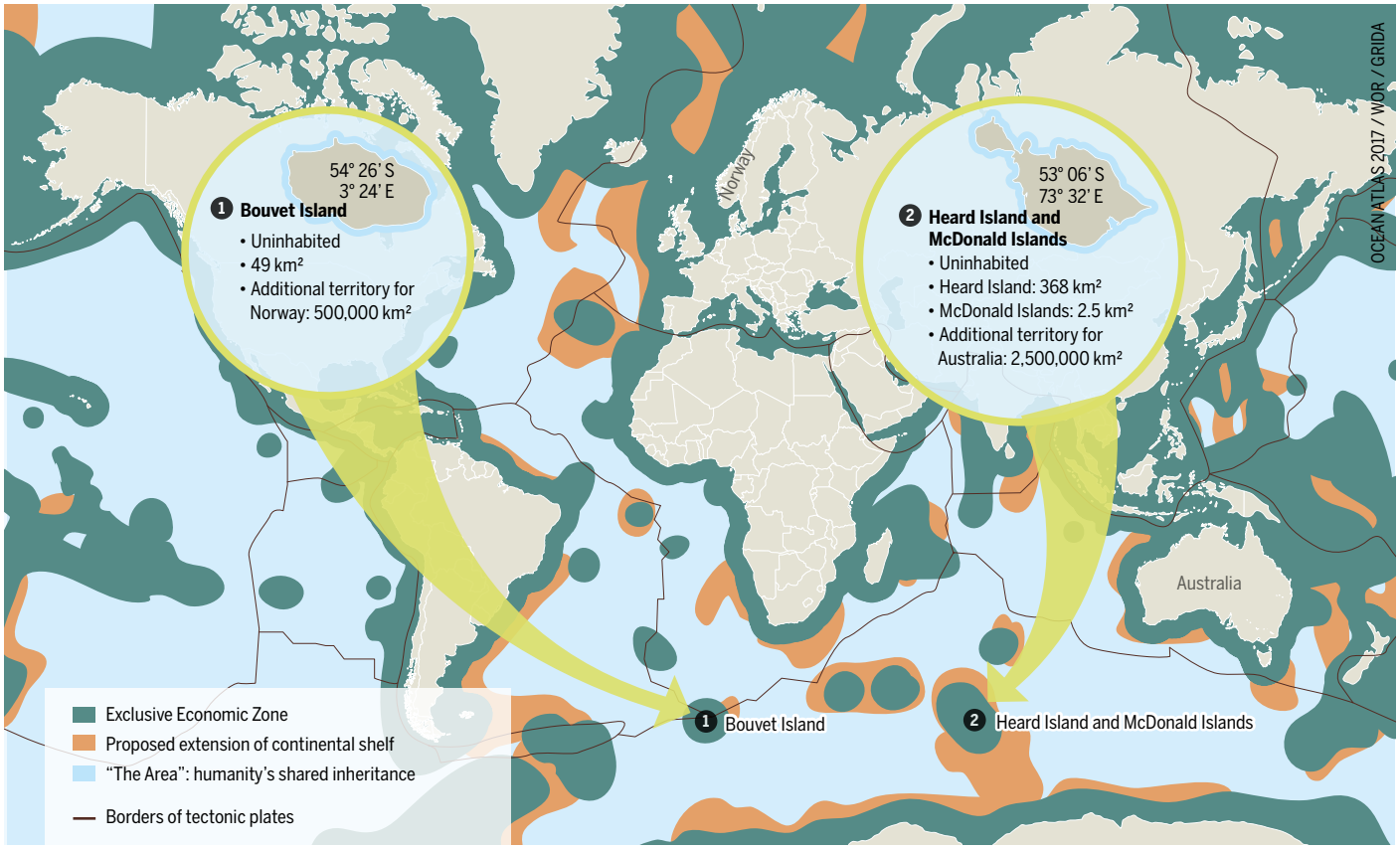
The Convention on the Law of the Sea (UNCLOS 1982), which is considered to be the constitution of the ocean and is intended to peacefully adjudicate the interests of all states, is still relatively young. Its approach to the areas of the ocean floor that lie totally outside national sovereign-

How the Lawyers Think—Maritime Zones and the International Law of the Sea



Today, humanity's inheritance is solely limited to the mineral resources of the parts of the seafloor that lie beyond national jurisdictions ("the Area"), which is administered by the Seabed Authority.
The UN Convention on the Law of the Sea (UNCLOS), together with its existing implementing conventions, defines the framework for ocean governance. The regional fisheries management organizations (RFMO) organize the cultivation of the fish stocks in the high seas as well as the trans-territorial and far-ranging fish stocks in the Exclusive Economic Zones (EEZ).

The International Community Is Losing Ground—As Individual Countries Gain It



The expansion of coastal countries' exclusive economic zones (dark green) into the area of the outer continental shelf (orange) reduces the international area. Any gain for an individual country is a loss for the community of nations. 57 percent of the sea floor is already partitioned. Only 43 percent of humanity's shared inheritance remains.

ty and national exploitation rights – referred to simply as "the area" in the language of the UN – is actually based on the concept of "the shared heritage of humanity." It is intended to guarantee that the environment is protected and that developing nations also have their share of the riches.

These strong words sometimes achieve only weak results. When a country can legally expand its exclusive economic zone, it reduces the shared inheritance. Consider the case of Norway, which has reserved an exclusive economic zone of 500,000 square kilometers thanks to its ownership of Bouvet Island, a small "island" completely covered in ice and lacking fresh water located in the South Atlantic, 2,600 kilometers from the Cape of Good Hope. France has also swelled in size thanks to many far-flung island dependencies – it is still "la grande nation" when it comes to stockpiling the treasures of the ocean floor.

In establishing these claims, the UN Commission on the Limits of the Continental Shelf plays an important role. There, states secure rights to raw material reserves that are sometimes only partly economically ascertainable or that are only suspected to exist – unknown chances of future riches, so to speak. It is not just a matter of fossil fuels, ores, metals, and the power that comes from their control. It is also about the global strategic interests of the states in legally expanding their spheres of influence. The remaining unclaimed "area" shrinks. It has already declined from more than 70 percent of the sea floor to just 43 percent. 57 percent of the ocean floor has already been parceled out. And as the international area shrinks, so does the ability of international influence to ensure that all nations have an opportunity to participate and that resources are fairly distributed.

These regulations are only related to the ocean floor. But the masses of water above, and everything that happens in and on them, are also subject to legal regulations. Within the economic zones, national laws apply to the exploitation of resources and environmental protection. Additionally, the law of the high seas applies – it is part of international law. But it also has loopholes: pirates can be detained by anyone who catches them, but not polluters, illegal fishing fleets, terrorists, weapons dealers, drug smugglers, or human traffickers. They can only be pursued by the countries from which they originate. It is often more than unclear who the responsible international organizations are. Territorially speaking, the high seas belong to no one – and so when it comes to exploitation, they belong to everyone. It is thus difficult to advance the protection of the ocean with reference to global problems. But it is not impossible, as current negotiations to create protected zones in the high seas at the EU level may prove.

DEEP-SEA MINING

GLOBAL HUNGER FOR NATURAL RESOURCES

Unseen treasures with mysterious names beckon from the depths of the ocean: manganese nodules, cobalt crusts, black smokers. Hidden within them are rich concentrations of valuable metals.

On average, each and every one of us consumers will use two metric tons of copper and 700 kilograms of zinc in our lifetimes. A single smartphone contains 30 different metals. Among them are cobalt and rare earth metals mined on land under questionable circumstances. And now talk has turned to the need for deep sea mining. Are the reserves on dry land already exhausted?

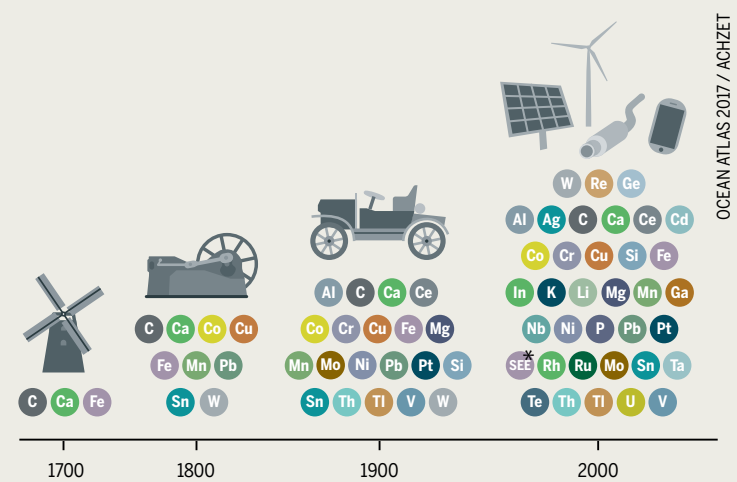
One might think so. After all, we've been mining for centuries, and the global demand for raw materials has risen rapidly in that time. Automobiles, IT, renewable energy – we need enormous quantities of metal for each. For example, a single wind power turbine contains 500 kilograms of nickel, 1,000 kilograms of copper, and 1,000 kilograms of rare earth metals.

But there is no geological shortage of metals – there are actually more than enough in the ground. So why is the interest in deep-sea mining so great? Because it is becoming more expensive and more difficult to meet our needs using the means available on land. Mining yields resources at the cost of substantial environmental damage – and fewer and fewer societies are prepared to pay the price. For instance, rare earth metals are not rare at all, all things considered. They are only "rare" because mining them is too expensive due to high labor costs and environmental considerations. That is the only reason that 97 percent of the supply currently comes from China. It really is economic reasons above all that have sent the Western industrialized nations searching for new sources of these valuable metals. For example, 40 percent of global cobalt production comes from the Democratic Republic of Congo, a country once wracked by civil war. It is still suffering from widespread corruption, in which the struggle for raw materials is often a bloody one. The European Commission ranks cobalt as "critical" – not because it is concerned about human rights but because the regional concentration makes the supply for the European industry insecure.

What could be better than dipping into the treasure chest of the deep sea? It is one of the few parts of the globe that has not been parceled out and exploited. Only about 10 percent has been surveyed topographically and less than one percent has actually been researched and explored.

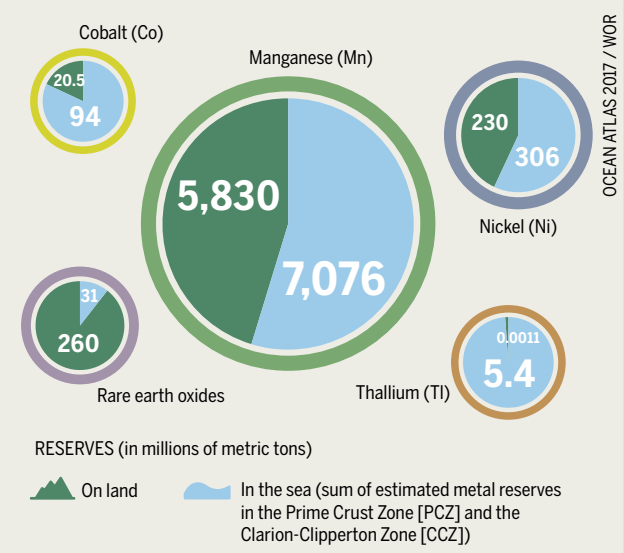
Here's what we do know: the deep sea is a habitat in which everything – everything – happens very, very slowly. The tracks made by equipment from the first expeditions to the sea floor in the 1980s are still visible even now, as though they were just made yesterday. It takes a million years for manganese nodules, the valuable metal nuggets on the ocean floor, to grow just 5–20 millimeters. Ecologists warn that anything that is destroyed there will

300 Years—Technological Development and Metal Consumption

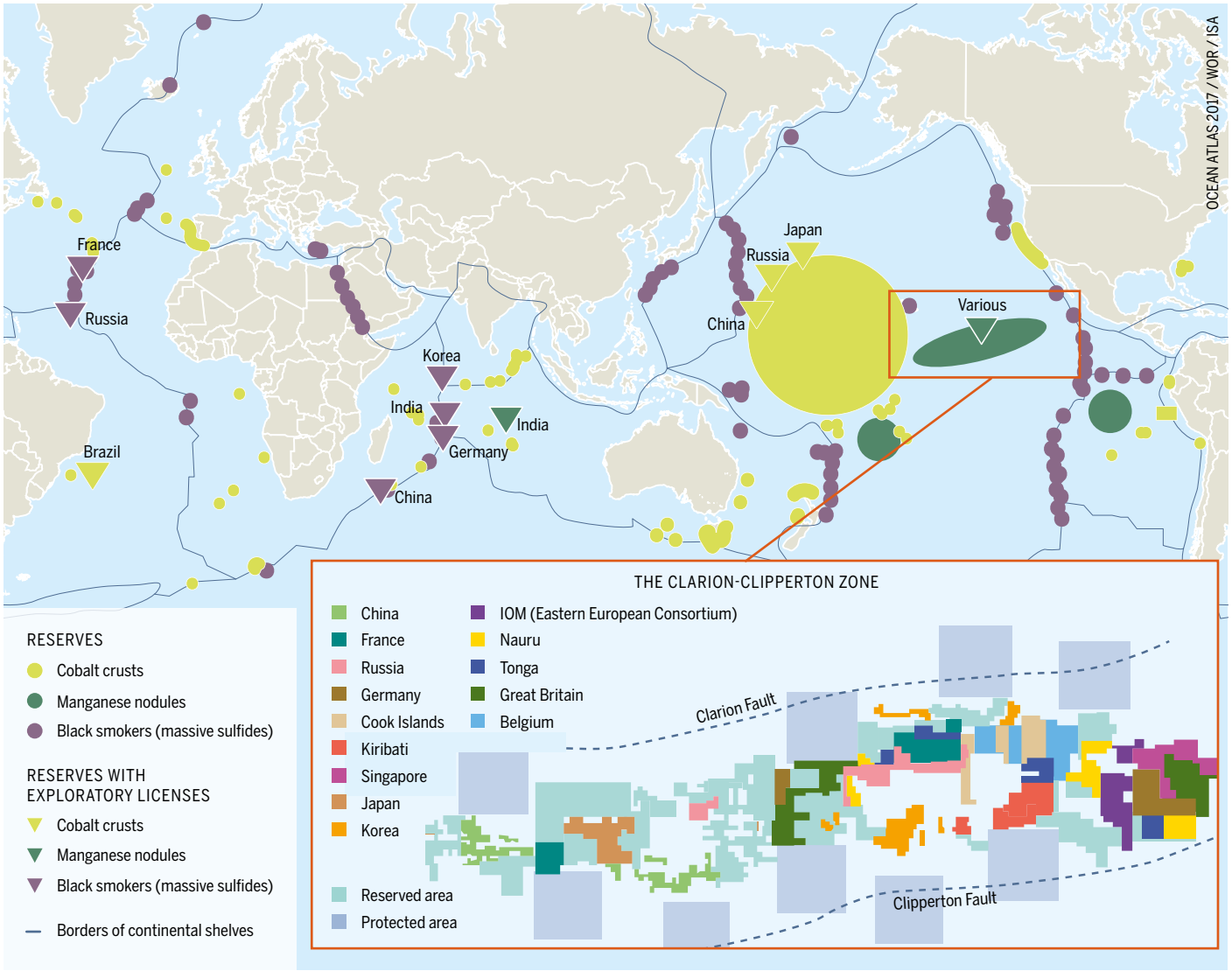


* The rare earth elements include the elements scandium, yttrium, lanthanum, and the 14 other lanthanides.

Metal Reserves Land/Sea in Millions of Metric Tons



Treasures Beneath the Waves—X Marks the Spot!



not regenerate for a long time, if at all. Before proceeding with extraction, we need to gather more knowledge about the effects it will have on the deep-sea ecosystem. But a number of countries and industrial companies are already chomping at the bit, eager to secure what they see as their piece of the cake. Germany is the proud owner of an ocean floor claim near Hawaii about the size of Ireland. A couple of nautical hours northwest is Belgian territory; a South Korean stake is right next door. French and Russian claims are not far away, and to the west one finds Chinese territory thousands of kilometers from the mainland.

According to the UN Convention on the Law of the Sea, activities on the high seas should serve all of humanity and not be possible only for industrialized nations. The International Seabed Authority, or ISA, has thus ruled that deposits of valuable raw materials must remain reserved for developing nations; it also acts on behalf of environmental protection in the ocean. Thus, large areas of the claims must be spared for protecting the ocean floor. The ISA is currently preparing regulations for the extraction of manganese nodules. It will be the first time in history that a clear division of raw materials was created before extraction began.

Despite all these concerns, commercial deep-sea mining is set to begin in the next few years. Not, however, in internationally regulated areas like the Clarion-Clipperton Zone, but rather in the exclusive economic zones of countries like Tonga and Papua New Guinea. International rules do not apply there and they alone decide on rules and environmental standards. The island nations are ready to take great risks in the hope of securing development opportunities and licensing profits. But like the ecological results, the sociological effects of massive disruptions of the fisheries, or tourism, or pollution of the ocean are difficult to predict. For this reason, thousands of inhabitants of Papua New Guinea and other South Sea islands have publicly protested against these plans since 2008. While these protests have hardly reached the global public, they have found solidarity with a whole range of international civil society organizations that demand a stop to all projects aimed at the extraction of mineral resources from the deep sea.

ENERGY FROM THE OCEAN

WHERE DOES THE FUTURE LIE?

Countries are turning their attention to the ocean in order to ensure that future demands for energy and raw materials can be met. Fossil fuels or renewable energy – which direction will they take? What are the opportunities and risks?

1. CLIMATE CHANGE

80 percent of global primary energy consumption is currently covered by fossil fuels. The largest portion is black and brown coal followed by oil and natural gas. In order to reach the two-degree climate goal, we can only burn 12 percent of the known coal reserves, two-thirds of the known oil reserves, and around 50 percent of the known natural gas reserves. Burning coal is far and away the most climate-damaging way of obtaining energy.

2. GEOSTRATEGIC INTERESTS

Arguments for energy independence lead countries to focus on oil and natural gas. They want to extract them from the depths of the ocean or the Arctic even though doing so is much more expensive than relying on conventional sources like the oil fields of the Middle East.

3. THE PRICE OF OIL

The price of oil is volatile. It is currently low, which reduces the incentive to search for unconventional sources in the ocean. In the years 2011 to 2013, the OPEC countries were still able to obtain prices in excess of 100 USD per barrel of crude oil. In 2016, though, the price sank to a historical low of 30 USD. The reasons were the fracking boom in the United States, the price war policy of the OPEC countries, the reemergence of Iran as an oil exporter, and the weak Chinese economy.

NATURAL GAS

Reserves: Offshore gas accounts for 28 percent of global natural gas production, and that figure is growing. The largest quantity of newly discovered fields is located at depths of more than 400 meters.

Natural gas is considered to be the most environmentally friendly of the fossil fuels. It thus is seen as an important supplemental energy source for the switch to renewable energy production. Doubts and criticism of its positive contribution to the climate are justified, though, as natural gas (methane) can leak into the atmosphere during extraction and transportation. There it acts as a greenhouse gas, contributing to global warming at a rate 35 times greater than the same amount of CO_2 over a span of 100 years. Over a timeframe of 20 years, natural gas is 84 times as damaging as CO_2. However, less methane escapes via offshore drilling than via drilling on land because most of the methane released on the ocean floor and into the ocean itself is consumed by bacteria.

DEEP-SEA OIL DRILLING

Reserves: Most oilfields are in deepwater areas at depths below 400 meters or even in ultra-deepwater areas below 1,500 meters. These extreme depths are currently not under consideration due to the low price of oil on the global market.

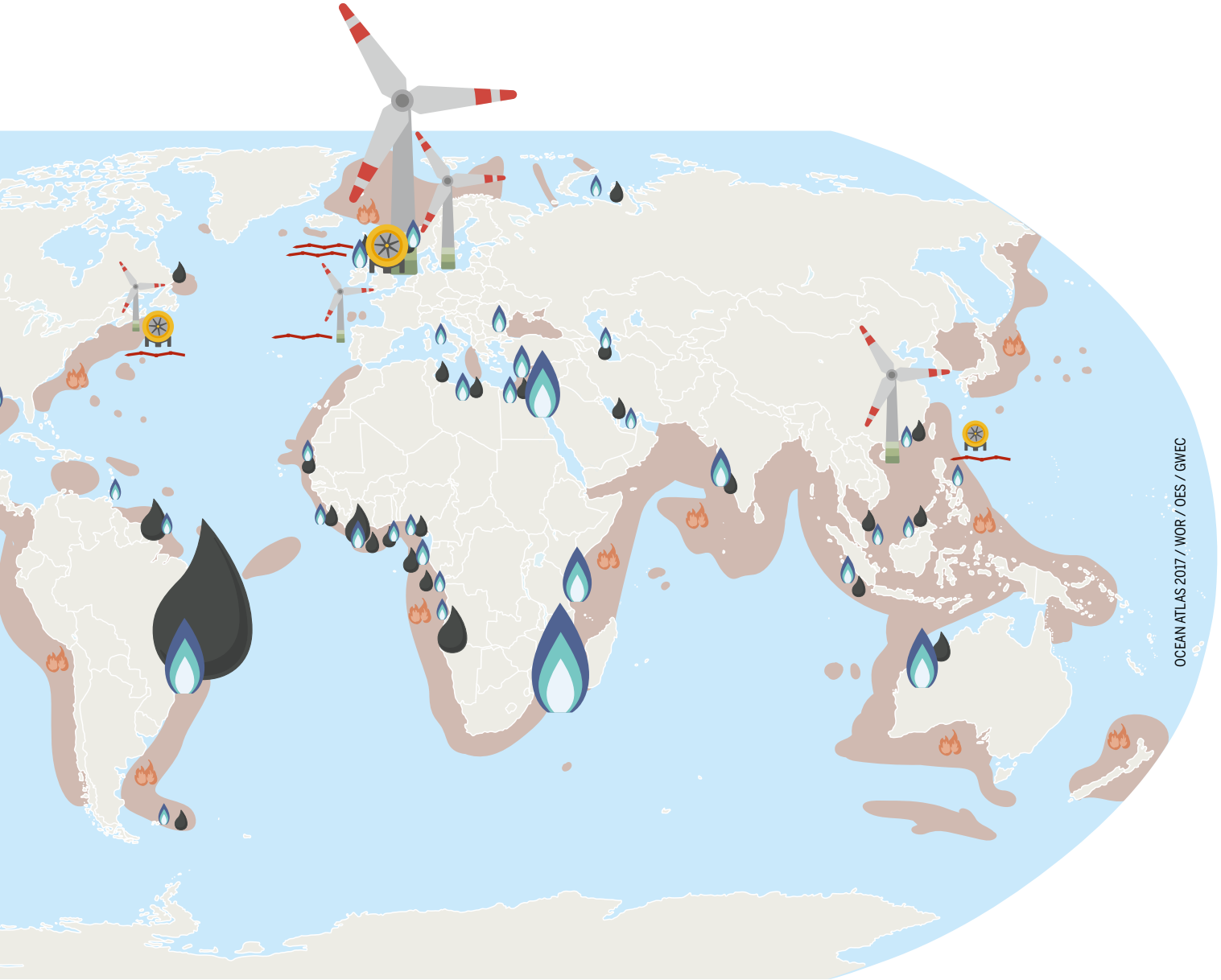
Large oil reserves capable of meeting the growing demand for energy are suspected to exist in the ocean. Offshore oil makes up 37 percent of global oil production. High pressure at such depths makes blowouts – uncontrolled releases of oil – impossible to control. It took engineers five months to seal the leak in the Macondo oil field after the explosion on the Deepwater Horizon drilling platform in 2010.

METHANE HYDRATE

Reserves: Methane hydrate is located on continental shelves around the world. Especially rich reserves are located near Japan and Alaska, along the Pacific coasts of North and South America, near India and West Africa, and in the Black Sea.

Methane hydrate is frozen natural gas locked in crystal structures of water similar to ice; methods for extracting it are currently being studied. It may be possible to fill the resulting cavities with CO_2 produced by power plants and industrial plants. However, the process also carries ecological risks, like landslides that would release large quantities of methane into the environment.

The advantages and disadvantages of this method of natural gas extraction must be more broadly debated. Technological approaches that seem to postpone an immediate transition away from fossil fuels must be critically evaluated.



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Disclaimer: The sizes of the renewable energies and fossil fuels do not represent the actual size of their reserves/potentials.

OFFSHORE WIND POWER PLANTS

Locations: In principle, wind power plants can be placed anywhere with strong, constant winds, like on the high seas. However, to be economically and technically feasible, the turbines must be securely anchored in depths of 40 meters or less. Numerous offshore plants are hooked up to the grid and profitable.

These plants compete with other industries and concerns like shipping, fishing, tourism, and nature preservation for the right to use the seas. There is also much debate (and little research) about how the plants affect sea birds, aquatic mammals, and other sea creatures.

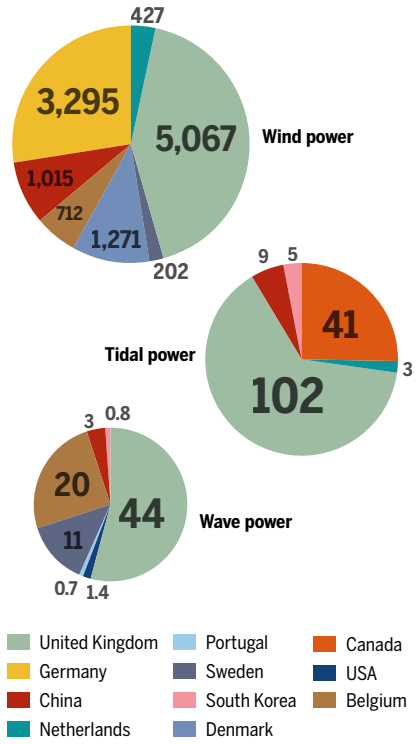
RENEWABLE ENERGY—INNOVATIVE TECHNOLOGIES

The climate-damaging usage of fossil fuels must be reduced to zero over the long term. Tidal, current, and wave-based power plants represent another way to generate renewable energy. Unlike wind power plants, they cannot be placed anywhere. Wave height, tidal amplitude, and strength of current must all be considered.

Some of these innovative technologies are still in their infancy. The problem is the economic viability of energy production. It is thus uncertain if these technologies will produce a solution.

Wind and solar technology already offers a way to address the energy transition in a decentralized way.

Oceans of Energy—Approved Projects and Installed Capacities
in 1,000 kW



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MARINE TOURISM

DESTINATION: OCEAN

Cruise ships carrying 4,000 travelers, all-inclusive beachfront resorts – increasing global tourism places an ever-greater strain on the ocean and coastal populations.

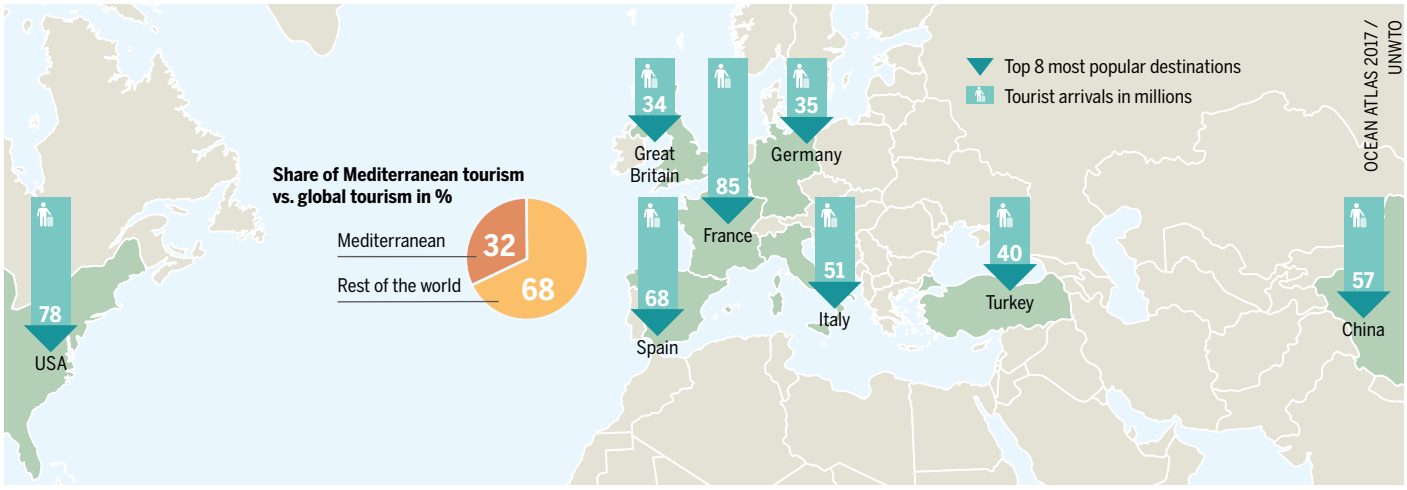
Tourism has become one of the most important economic factors in the world. For some islands and coastal regions, it is actually the number one economic driver. In 2015 nearly 1.2 billion people traveled abroad. And that number is no longer made up only of travelers from North America and Europe. More and more international guests come from Southeast Asia, China, Russia, India, and Brazil. The whole world is looking abroad, and those who can afford to do so take their vacations on foreign shores. The number of those who vacation in their own countries amounts to 5 to 6 billion.

As a result, the number of overseas travelers has risen forty-fold since 1950. According to estimates from the World Tourism Organization (UNWTO), the global total may rise to 1.8 billion by 2030. In 2015, 608 million people traveled to Europe alone and 343 million visited the Mediterranean in 2014. That amounts to a third of all international travelers.

A holiday by the sea – for many people, it is the ideal image of a relaxing vacation. But many tourist hotspots in and near the ocean increasingly suffer from the stress of large-scale tourism. Consider Venice: the city has been a magnet for tourism for 300 years, though for much of that time it only entertained a few well-off travelers at a time. But that changed after the Second Word War. At the time, the city had 200,000 inhabitants. Today, just 50,000 remain – and they play host to 30 million travelers each year. Ten cruise ships visit the city's lagoons each day, all of them traveling more or less directly past Piazza San Marco. Venice is a prime example of the problem of booming tourism: while the number of visitors increases rapidly, the number of desired destinations does not. In 1980, 1.4 million people went on cruises. Ten years later, that figure had risen to 15 million, and in 2016 CLIA (Cruise Lines International Association) announced 24 million passengers. Many of the world's coasts have long since reached their tourism capacities – increasing cruise tourism places them under even more pressure.

And the cruise ships themselves are growing too: ships with 3,000 to 5,000 passengers plus 2,000 crewmembers are no longer rarities. The pollution produced by these floating cities is just one of the significant problems that tourism destinations must cope with. Resource consumption is another. The many people who want to visit beautiful beaches, enchanting diving areas, spectacular natural

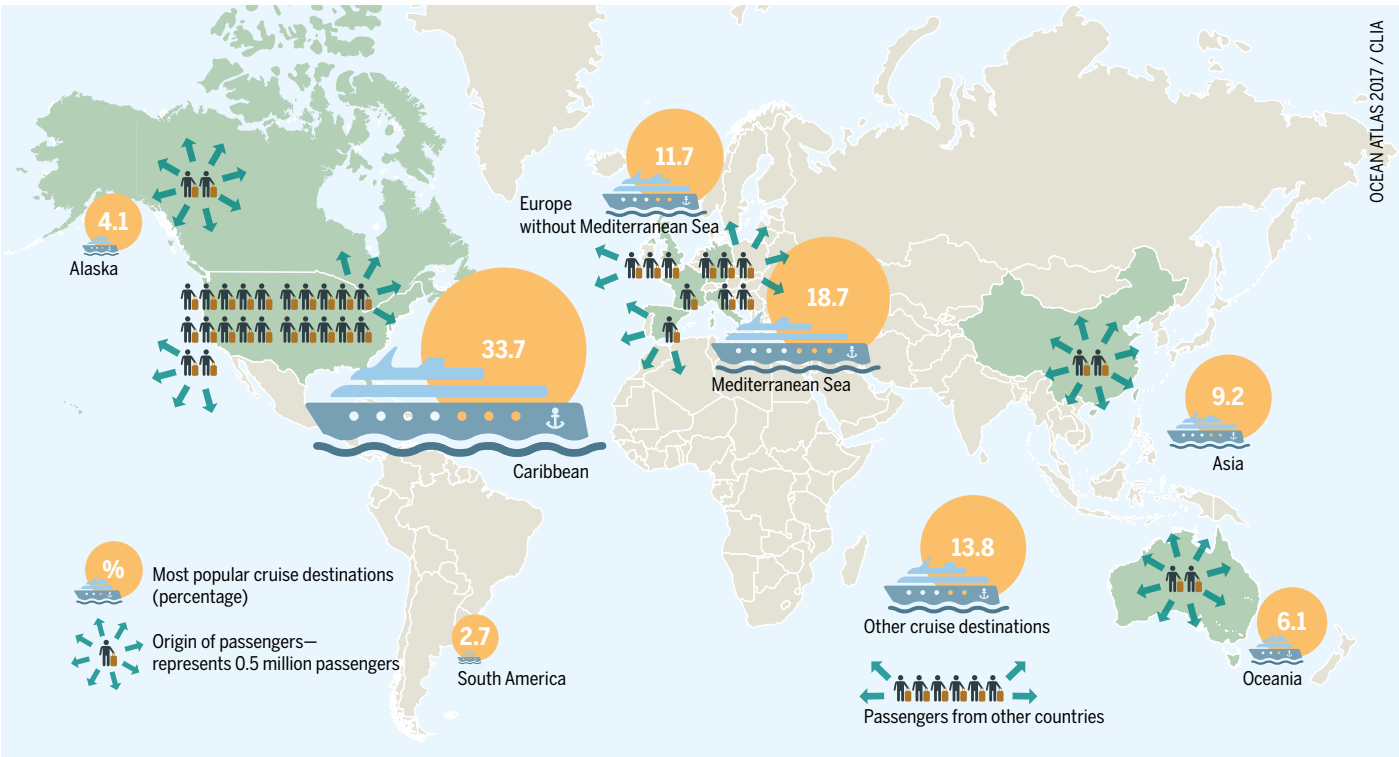
One-Third of the World's Tourists Travel to the Mediterranean



The Mediterranean is the most popular destination for tourists from around the world. This causes a number of problems for the region that individual tourists don't see. Air travel and increased traffic increase CO_2 emissions in the region. The expansion of infrastructure, like hotel complexes and marinas, reduces available open space and leads to the urbanization of the regions around the Mediterranean.

Since every tourist wants comfortable accommodation, pressure on natural resources like fresh water increases. At the same time huge quantities of wastewater and garbage result. The many tourists are also a strain on the beaches and dunes because the more people who gather there, the more the negative effects of the crowds of people on the ecosystems are amplified.

The Maritime Tourism Boom



wonders, and romantic cultural sites contribute to high water and energy consumption, increased wastewater production, garbage problems, and the dredging of channels for ever-larger luxury ships. In the long run, those factors will overwhelm many dream destinations. That is because every island and every national park has a natural limit to the number of people it can accept. If it is surpassed, the result is the destruction of the natural resource that attracted the tourists in the first place. And that loss will be followed by the loss of the livelihoods of current and future local populations as well. This risk exists for every type of tourism on the ocean, from exclusive resorts to big concrete hotel complexes to cruise destinations.

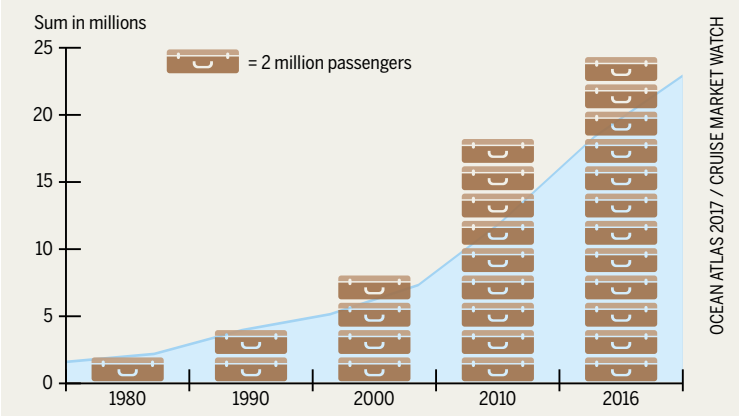
What has been lacking until now are sustainability-oriented controls of the streams of tourists at the global level. When such controls do exist locally, they are often exceptions to the rule, like on the Jardines de la Reina, a chain of islands belonging to Cuba, in whose waters a maximum of 500 divers are allowed each year. Authorities also reacted strongly in Thailand, closing the island of Koh Tachai, which was popular with vacationers. The reason: environmental damage caused by too many visitors. Such necessary actions lead in turn to the question of fairness in tourism: if the capacity of the destinations is limited, who is allowed to visit? Only those who can afford it?

A profound change in tourism demands new thinking on the part of politics as well as among companies and travelers: the strategy that is adopted should not be simply to support tourism but rather to support strategies that enable sustainable, future-proof tourism while also discouraging non-sustainable practices in the industry.

The United Nations named 2017 the International Year of Sustainable Tourism for Development. Time will tell how seriously the international community and cities take Agenda 2030 and if they can initiate measures that effectively stem the tide.

Controlling the flow of tourism with capacity limits is an effective instrument for ensuring that future generations will also be able to visit dream destinations. Imagining and communicating this reality is the responsibility of each individual government and of the tourism industry as a whole. And tourists themselves have the power to demand sustainable tourism. ●

More and More People Vacation on Ships



MARITIME TRANSPORT

WORLD TRADE AND PRICE WARS

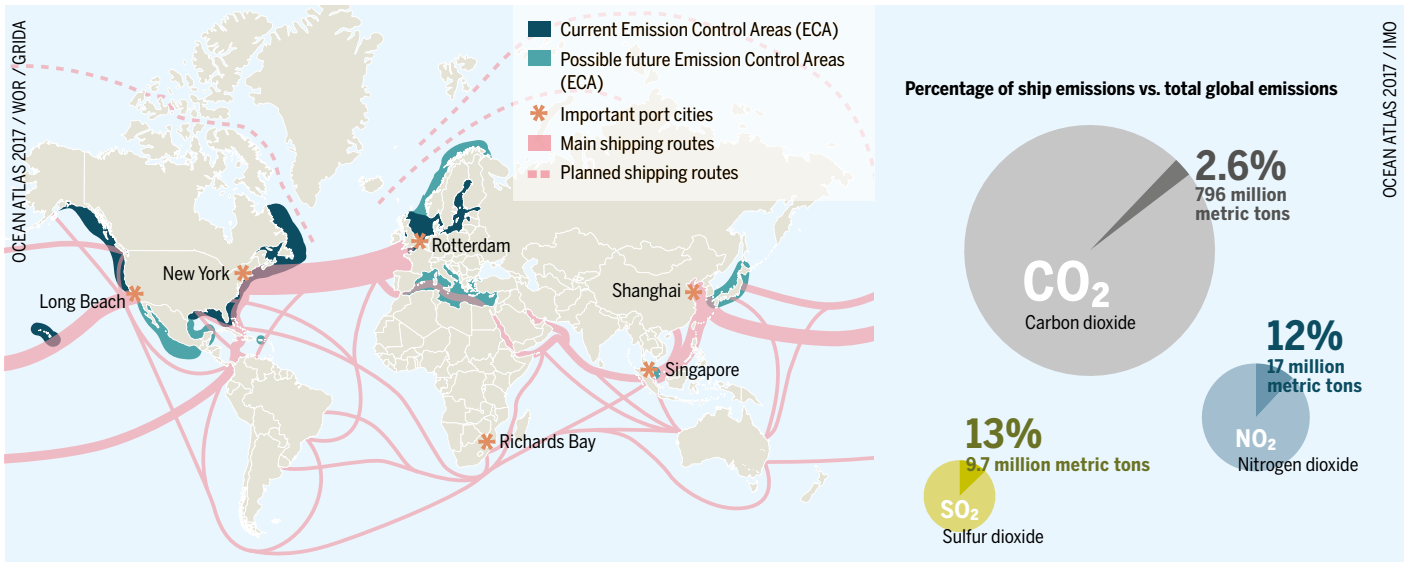
Coffee, bananas, smartphones, automobiles: cargo ships transport goods around the world. Shipping routes are the world's arteries and ships are its blood cells. 90 percent of global trade is seaborne. Who does what – and who pays for it all?

Nine billion tons of goods are transported on around 90,000 ships each year. The trend is toward ever-larger ships with gigantic cargo capacities. Shipping is an industry in 170 countries around the world and employs more than 1.65 million sailors and crewmembers. Shipping is thus the most international industry. That also means that the same conditions for safe and environmentally friendly transportation must apply to all ships. That is why the United Nations created the IMO, the International Maritime Organization, headquartered in London, where all shipping nations are represented. The rules and laws governing international shipping are created there. But despite encouraging successes in increasing safety and reducing pollution – the international regulation of maritime transport is seen as "the UN at its best" – there are still problems.

The effects of the global financial crisis in 2008 plunged the shipping industry into a deep crisis. During the boom years of globalization, building and financing ever-larger container ships seemed like a safe business – but the expected growth, including that of the Chinese market, proved to be little more than a speculative illusion. As a result, there are now too many ships for too few goods on the world market. This overcapacity, combined with sinking freight rates and pressure from competition, has led to fierce price wars: it is now possible to ship a metric ton of iron from Australia to Europe for about 12 USD. And the 10,000 sea miles that a container ship travels between Hong Kong and Hamburg make up just a fraction of the total freight cost. The lion's share, 80 percent of all freight costs, comes from overland transport. The final 800-kilometer stretch from Hamburg to Munich, for example, is far more expensive than the much longer sea journey. Under these conditions, many shipping companies do not earn enough to cover their operating costs or service their credit.

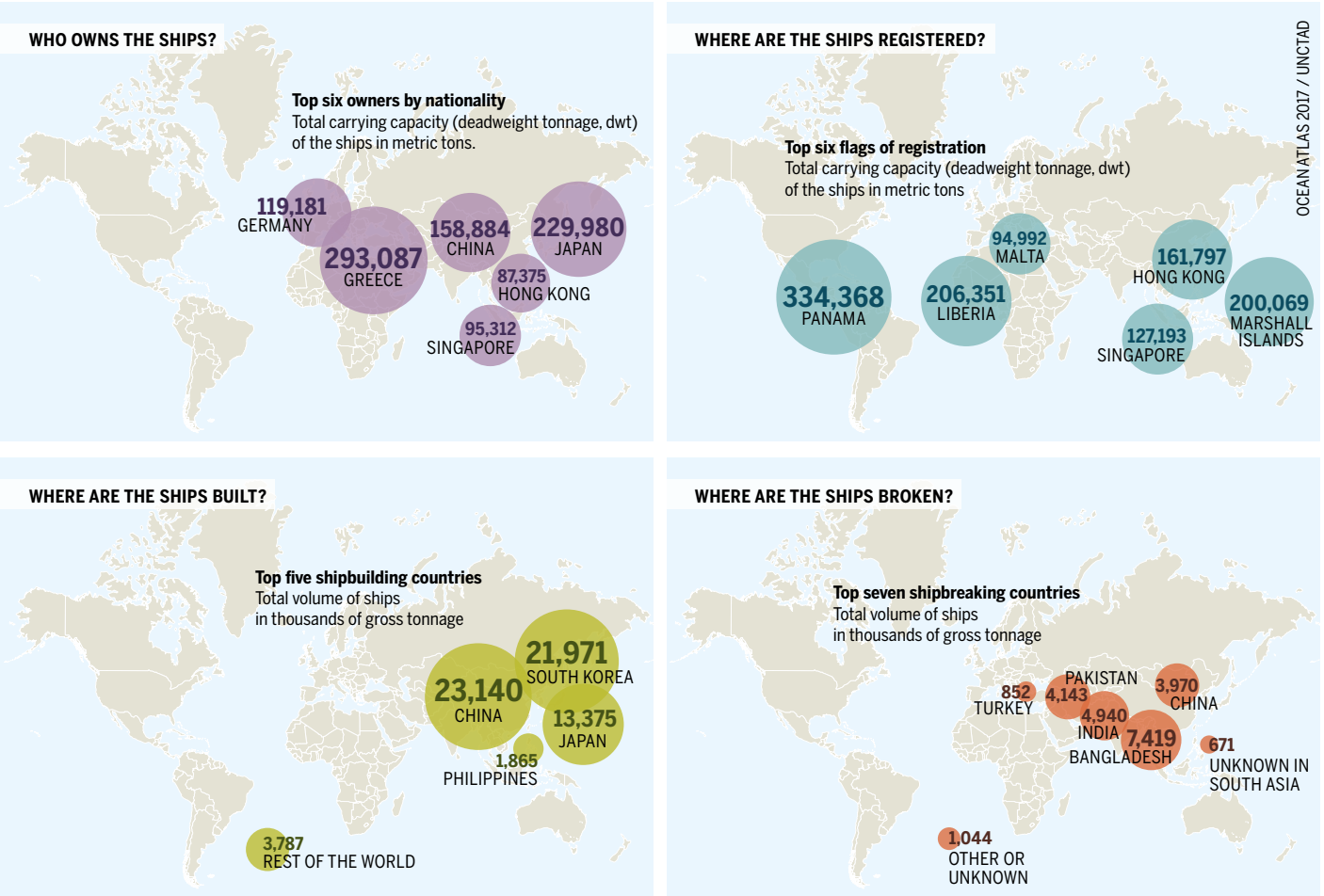
The shipping business was traditionally run by mid-sized family businesses, but that is changing now. As a result of the price war, more and more of them are being forced out of the market. Even larger shipping companies are facing difficulties, like South Korea's Hanjin, which declared bankruptcy in 2016. A further wave of rationalization will come as the result of increasing digitalization: innovations like self-driving ships and end-to-end real-time monitoring will come, but so too will increasing pressure on shipping lines to cover much larger parts of the transport chain by themselves, on sea and on land, than they do today. Even companies like Google and Amazon may

Heavy Fuel Oil—More Emission Control Areas Are Needed



Shipping has a better climate balance when considering CO_2 emissions. Per ton of load and kilometer traveled, ship emissions are around three to eight grams of CO_2, while road traffic emits around 80 grams and air travel emits around 435 grams. On the other hand, its sulfur and nitrogen emissions are significantly higher than other forms of transportation. These chemicals are very damaging to health.

The International Shipping Fleet—The Price of Globalization



Shipping is one of the most international industries. The large shipyards where ships are built are concentrated in a few economically powerful countries. The ships are broken in developing countries with low wages and lax environmental protections.
The work is dangerous and damaging. Most ships are owned by entities in industrialized European and Asian countries—primarily Greece—yet registered in countries offering cheap flags of convenience. While the shipping companies benefit from tax advantages, the crewmembers suffer from poor wages and working conditions.

present competition to traditional shipping companies in the future.

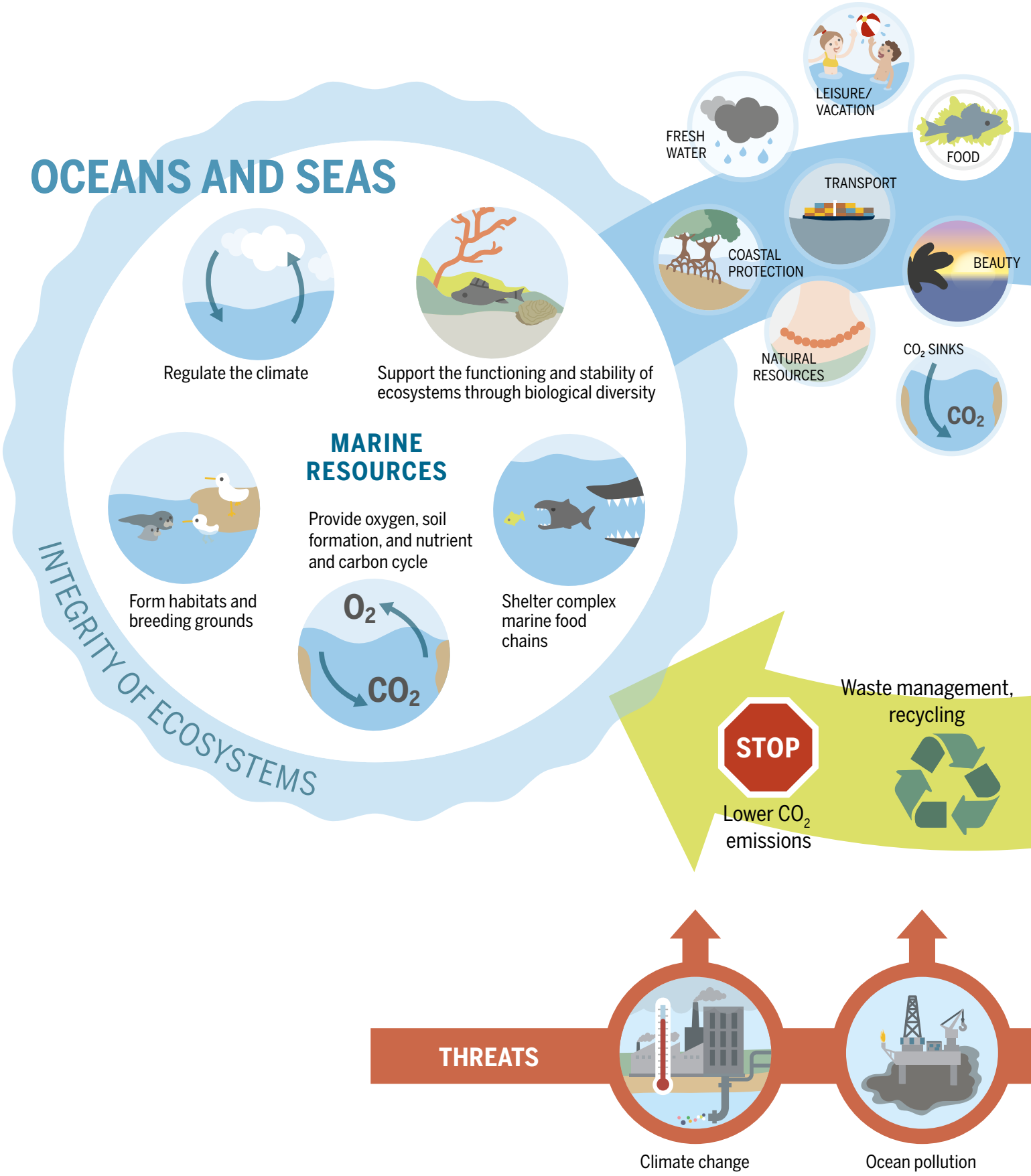
Shipping companies can only endure this price pressure today because they save in other areas, like wages. Open registries and flags of convenience allow ship owners to combine cheap money in industrialized nations with low wages in developing nations. An open registry means that the nationality of the owner and the flag of the ship do not need to be the same. Sailing under a flag of convenience allows companies to avoid expensive regulations imposed by industrialized nations, like labor laws. For that reason it is hardly surprising that, according to the United Nations Conference on Trade and Development, in 2016 more than 76 percent of the world's shipping fleet was registered in developing countries, including open registries. For comparison, it was just five percent in 1950.

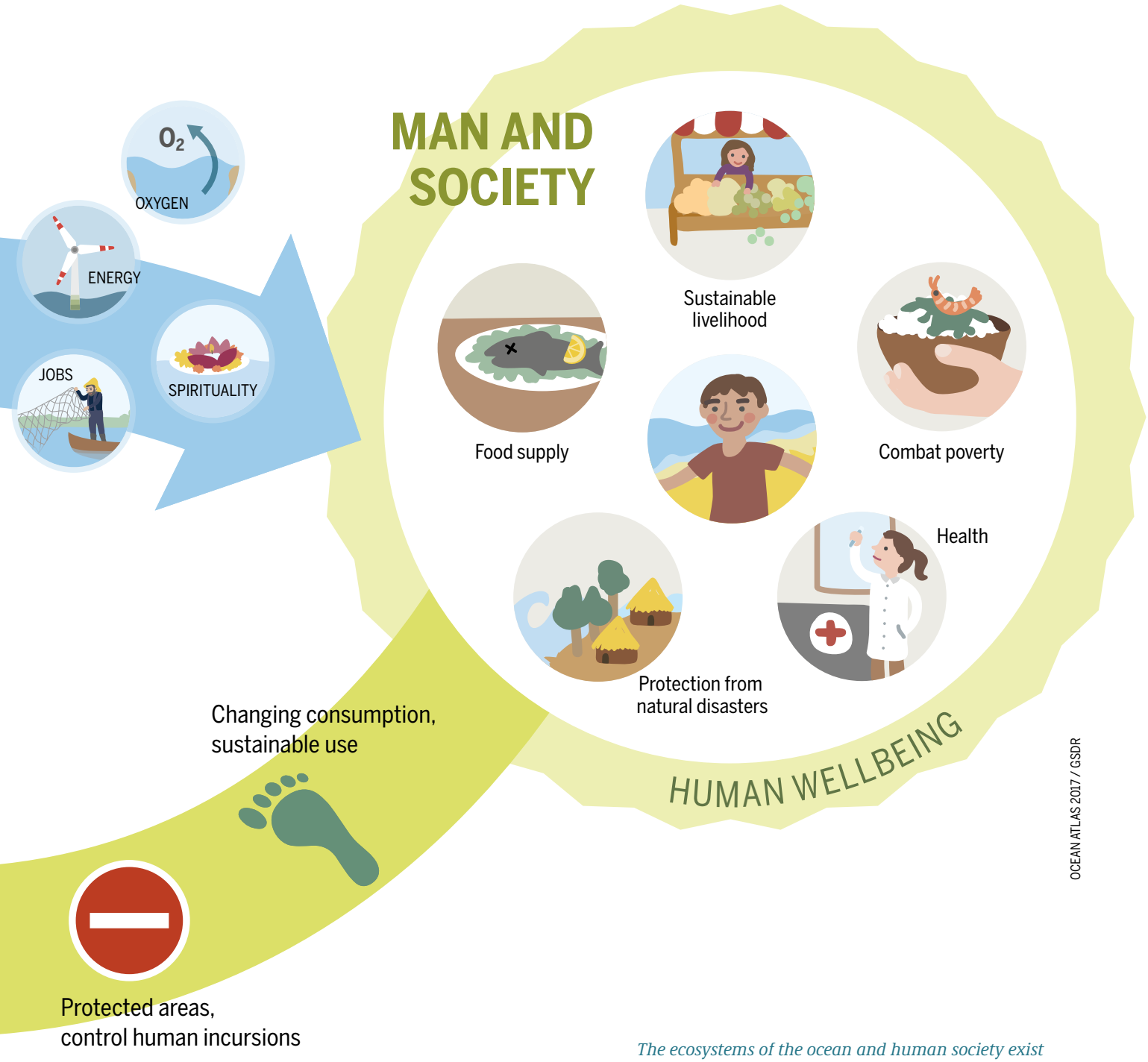
For lower ranking crew members – most sailors come from China, Indonesia, and the Philippines – this is an alarming development. Because of the large differences in wages and social security among international shipping personnel, a global maritime precariat – a class of people lacking socioeconomic security – has formed. The sailors are isolated by months-long absences and language barriers – only the higher ranks can afford expensive flights home. This creates strong dependencies that have led the International Labour Organization (ILO) to count many sailors among the 21 million potential victims of forced labor, which it considers to be a modern form of slavery.

At the end of the journey, it is also the weakest who suffer most from the effects of price pressure. After their service lives are over, the giant ships are sent to Alang in India and Chittagong in Bangladesh to be broken. The steel colossi are pulled directly onto the beach and disassembled there by hand, greatly endangering the lives and health of the people who live and work there. Whether the International Maritime Organization will act to ensure just working conditions on the ships is an open question – but it is surely a necessary step along the path to a sustainably organized shipping trade.

CIRCLE OF SUSTAINABILITY

LIVING WITH THE OCEAN





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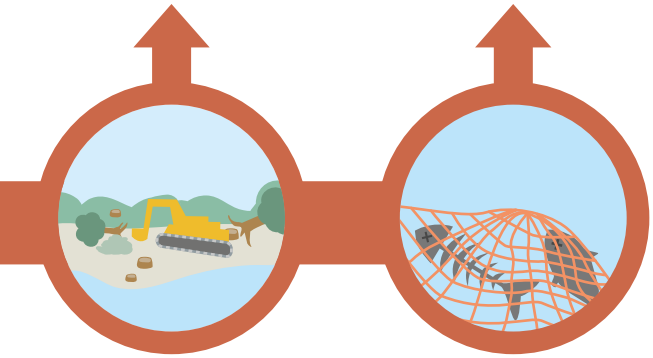


Destruction of coastal and marine habitats

Non-sustainable exploitation of marine resources

The ecosystems of the ocean and human society exist parallel to one another, and yet are also intimately connected. Humanity uses many gifts—material and immaterial—that the ocean generously provides. But what, if anything, do we give the ocean in return for this exploitation? The exchange is more than one-sided. And the ocean hardly expects compensation from humanity—it is a thing unto itself. And yet protecting and preserving the ocean is not an end in itself. The question remains: what can we do to ensure that the generations that follow us also enjoy some of the diverse gifts of the ocean? The answers: We should value nature and not take it for granted, and be responsible stewards, using the ocean's resources sustainably.

THE WORLD MUST ACT TOGETHER

TOWARDS A NEW GOVERNANCE OF THE OCEAN

Nearly half the Earth is covered by areas of the ocean that lie beyond national jurisdictions. They are among the least protected and least responsibly managed places in the world. In light of the importance of the oceans for our food supplies, for preventing climate change, and for preserving biodiversity, our actions are irresponsible. Change is needed – and urgently.

Recognizing the oceans and their resources as part of our common human heritage, as a shared global resource, is an old dream. In 1967 Malta's ambassador to the UN Arvid Pardo and Elisabeth Mann Borgese proposed administering the oceans for the good of all humanity in opposition to the so-called "freedom-of-the-seas doctrin."

The legal principle of the ocean as part of the "common heritage of mankind" is partially anchored in the 1982 United Nations Convention on the Law of the Sea (UNCLOS) as it applies to the seabed and ocean floor located beyond limits of national jurisdiction ("the area"). The Convention on the Law of the Sea is the constitution of the ocean. It establishes a system of different ocean zones along with rules governing usage rights and obligations to protect and preserve them, and provides an institutional framework.

In addition to international organizations responsible for individual industries, like the International Maritime Organization for shipping or the International Seabed Authority for deep-sea mining, there are many regional ocean protection agreements and action plans involving more than 140 countries. Regions work together to prevent ocean pollution or to promote the protection of biodiversity through ocean protection zones. Regional fishery organizations and agreements attempt to ensure the sustainable exploitation of fisheries. Under the umbrella of the Convention for Biological Diversity it was agreed that 10 percent of the ocean's surface area would become protected areas (science and environmental protection organizations recommend as much as 30 percent).

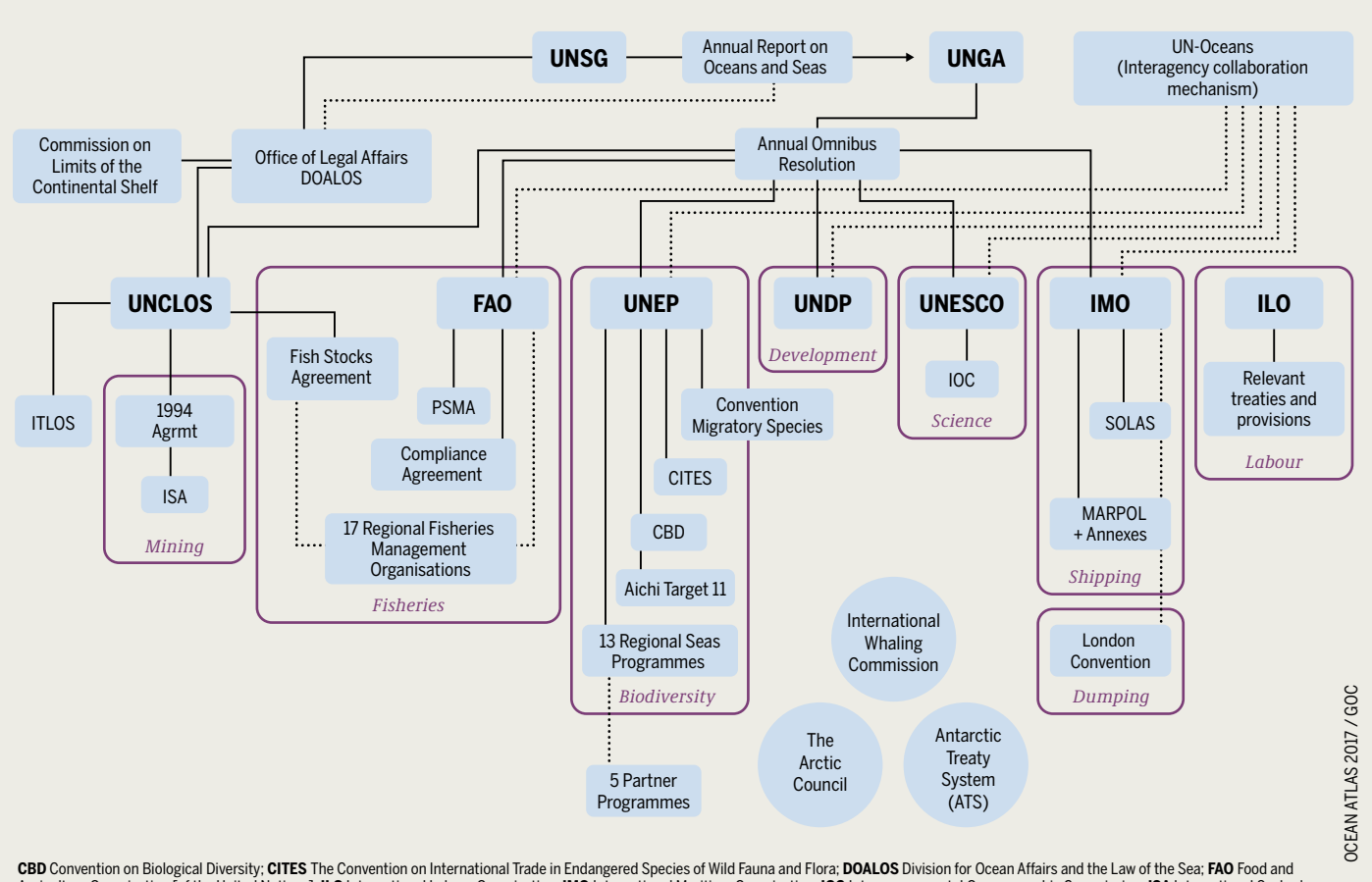
Nevertheless, ocean governance, the system for the management and sustainable use of the ocean, is insufficient. The institutional frameworks, including diverse agreements regarding shipping, fishing, whaling, mining, and ocean protection, are fragmentary. There is too little international agreement, consensus, and cooperation. Furthermore, agreed-upon rules and goals are often not implemented, or not implemented effectively. For example, we are far from achieving the goal of designating 10 percent of the ocean as natural protection areas by 2020. There are too few sanctioning mechanisms for addressing failure to comply with agreements. Comprehensive global strategies for integrated governance that measure up to the complexity of the oceanic ecosystem do not exist, even though the Convention on the Law of the Sea correctly emphasizes "the problems of ocean space are closely interrelated and need to be considered as a whole". Urgent change is needed if international governance of the ocean is to ensure that the world's oceans and their resources are managed in a way that keeps them rich, productive, and safe for us and for future generations.

NEW HOPE—SDG 14, A SUSTAINABILITY GOAL FOR THE OCEAN

A significant opportunity to adopt a more comprehensive approach to ocean protection is connected to the 2030 Agenda for Sustainable Development, which was ratified in 2015 by the United Nations. The protection and the sustainable development of the oceans, seas, and marine resources are addressed in their own goal, Sustainable Development Goal (SDG) 14. The seven sub-goals of SDG 14 are aimed at preventing ocean pollution, protecting the oceanic ecosystem, ending overfishing, and combating the effects of ocean acidification. Illegal, unreported, and unregulated (IUU) fishing should also be stopped. In addition to the subgoals of SDG 14, the cross-connections to other goals, like Dedcent Work and Economic Growth (SDG 8) or Responsible Consumption and Production (SDG 12) are important for protecting the ocean and ist resources.

Suggestions for and concrete steps toward achieving the goals of SDG 14 have not been enough so far. Analogous to the climate agreement, countries should report measures taken to reach SDG 14 to a centrally managed registry. This will produce transparency and long-term auditability. Additionally, inter-industry and regional cooperation on ocean and resource preservation issues must be strengthened. With all its subgoals and connections to the other SDGs, SDG 14 is an excellent point of departure for leaving the old "silos" and developing more coherent strategies for ocean protection. Regular reevaluations of the goals could strengthen this coherence and detect possible

International Governance Structures for the Ocean—Multi-sectoral Approach and a Plethora of Organizations



CBD Convention on Biological Diversity; **CITES** The Convention on International Trade in Endangered Species of Wild Fauna and Flora; **DOALOS** Division for Ocean Affairs and the Law of the Sea; **FAO** Food and Agriculture Organization [of the United Nations]; **ILO** International Labour Organization; **IMO** International Maritime Organization; **IOC** Intergovernmental Oceanographic Commission; **ISA** International Seabed Authority; **ITLOS** International Tribunal for the Law of the Sea; **MARPOL** International Convention for the Prevention of Pollution from Ships; **PSMA** Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing; **RFMOs** Regional Fisheries Management Organisations; **SOLAS** International Convention for the Safety of Life at Sea; **UNDP** United Nations Development Programme; **UNEP** United Nations Environment Programme; **UNESCO** United Nations Educational, Scientific and Cultural Organization; **UNGA** United Nations General Assembly; **UNSG** United Nations Secretary-General

conflicts with other SDGs in order to promote integrated implementation. But the sustainability goals for the ocean still lack bite. There will be a first chance in June 2017 at the UN Ocean Conference, where participants are expected to agree upon concrete steps for implementing SDG 14. Furthermore, in October 2017 the EU will hold the fourth "Our Ocean" conference in Malta, followed by Indonesia in 2018 and Norway in 2019.

PROTECTION AND SUSTAINABLE USE OF THE HIGH SEAS

There is a lack of comprehensive frameworks for the protection and sustainable exploitation of biodiversity in those areas of the ocean that lie beyond the national jurisdictions. A new agreement that will be concluded under the umbrella of the UNCLOS would close regulatory gaps. For example, for the protection and fair management of marine genetic resources, as well as for improving the area-based management of ocean protection zones. An international country-level conference will initiate the negotiation process in 2018.

DEEP-SEA MINING

Deep-sea mining presents an additional challenge for oceanic governance. Exploration is still ongoing and the deep-sea seabed and the deep sea itself have hardly been studied scientifically. The mining of resources in areas beyond national jurisdictions has not yet begun. The environmental risks posed by mining have been estimated to be very high. Global environmental regulations for deep-sea mining are currently being developed. This brings up a fundamental ethical question: should humanity begin risky deep-sea mining at all? There is no need for these resources at present. The deep sea should be protected, researched, and administered for the common good as part of the shared heritage of humanity. A no to deep-sea mining would be a signal that we are finally serious about protecting the ocean.

Our oceans must become the focus of effective, binding international agreements. The UN and EU are exploring new approaches. Implementing ambitious SDGs for the ocean can strengthen cooperation on ocean protection and support ideas for closing serious administrative gaps in ocean protection.

SOURCES OF TEXTS, MAPS, AND DATA

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EXPERTS

Many experts contributed their expertise to the Ocean Atlas, particularly scientists working together at the University of Kiel's Future Ocean Cluster of Excellence to research the development of our oceans.

Jens Ambsdorf
Lighthouse Foundation

Prof. Dr. Anja Engel
GEOMAR and University of Kiel (Future Ocean)

Jörg Grabo
Lighthouse Foundation

Dr. Ulrike Kronfeld-Goharani
Department of Social Sciences, University of Kiel (Future Ocean)

Prof. Dr. Mojib Latif
GEOMAR and University of Kiel (Future Ocean)

Dr. Mark Lenz
GEOMAR (Future Ocean)

Prof. Dr. Heike Lotze
Dalhousie University Halifax (Future Ocean)

Prof. Dr. Nele Matz-Lück
Walther Schücking Department of International Law, University of Kiel (Future Ocean)

Alexander Müller
TMG – Think Tank for Sustainabilty

Dr. Barbara Neumann
Department of Geography, University of Kiel (Future Ocean)

Prof. Dr. Konrad Ott
Department of Philosophy, University of Kiel (Future Ocean)

Dr. Sven Petersen
GEOMAR (Future Ocean)

Prof. Dr. Martin Quaas
Institute of Economics, University of Kiel (Future Ocean)

Prof. Dr. Thorsten B. Reusch
GEOMAR and University of Kiel (Future Ocean)

Prof. Dr. Ulf Riebesell
GEOMAR and University of Kiel (Future Ocean)

Prof. Dr. Carsten Schulz
Institute of Animal Breeding and Husbandry, University of Kiel (Future Ocean)

Barbara Unmüßig
President, Heinrich Böll Foundation

Sebastian Unger
Institute for Advanced Sustainability Studies (IASS)

Prof. Dr. Martin Visbeck
GEOMAR and University of Kiel (Future Ocean)

Prof. Dr. Martin Wahl
GEOMAR and University of Kiel (Future Ocean)

Prof. Dr. Klaus Wallmann
GEOMAR and University of Kiel (Future Ocean)

Lara Wodtke
Heinrich Böll Foundation

The texts in the atlas are based on interviews conducted with the experts listed above.
Interviewers: Natascha Pösel, Peter Wiebe, and Ulrich Bähr.

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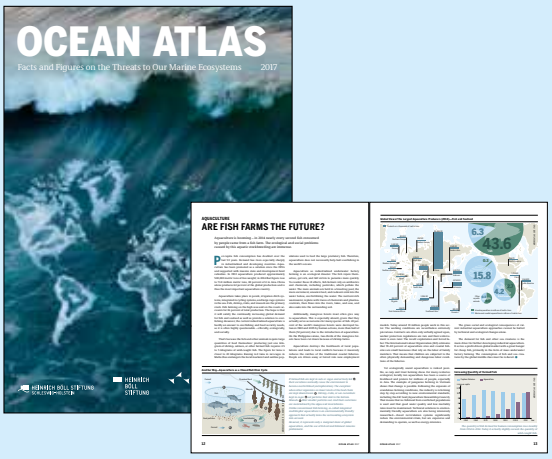
The Heinrich Böll Foundation Schleswig-Holstein conducts political education projects, primarily in northern Germany. As Schleswig-Holstein is located between the North Sea and the Baltic Sea, ocean politics is an important topic for us and is part of our focus on climate politics and sustainability. We see publishing the Ocean Atlas as a stimulus for cooperation with relevant actors like the University of Kiel's Future Ocean Cluster of Excellence in order to share Schleswig-Holstein's competence in matters relating to the sea and the ocean crisis beyond national borders. Following the motto "If not us, then who?", the goal is to lay the foundation for building a competence center for ocean politics in Schleswig-Holstein.



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CLUSTER OF EXCELLENCE "THE FUTURE OCEAN"

The future of humanity depends to a great extent on the development of the ocean and its coasts. In the Kiel Cluster of Excellence, "The Future Ocean", more than 200 scientists are exploring how protection and use can be reconciled and what concepts are in place to ensure the sustainable development of the ocean along with its coasts. Experts from the marine, geological, economic, social and legal sciences, medicine, computer science, mathematics and environmental science are working together on integrative and solution-oriented questions. The Cluster of Excellence is supported by Kiel University, the GEOMAR Helmholtz Centre for Ocean Research Kiel, the Institute for the World Economy and the Muthesius University of Fine Arts and Design.

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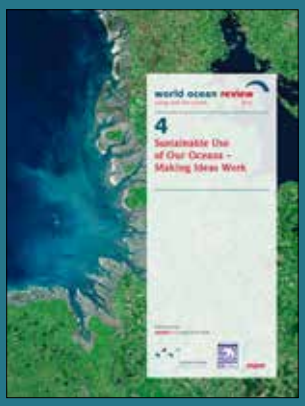

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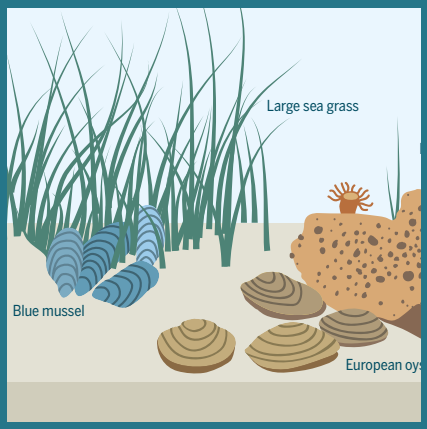

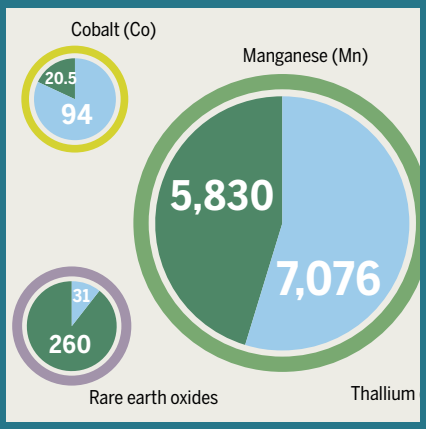

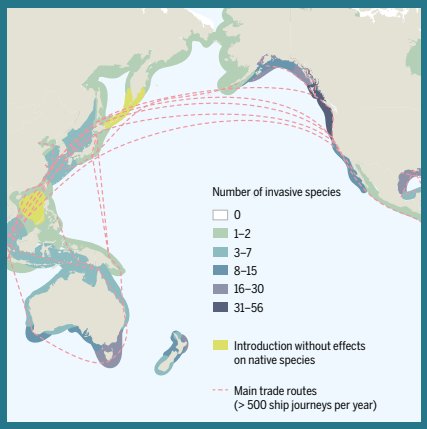

We are far from achieving the goal of designating 10% of the ocean as natural protection areas by 2020.

From: TOWARDS A NEW GOVERNANCE OF THE OCEAN, page 44.

People who live in coastal regions are especially endangered—and their number is growing.

From: LIFE IN THE DANGER ZONE, page 26.

A 20,000-square-kilometer dead zone has formed in the Gulf of Mexico.

From: FERTILIZER FOR THE DEAD ZONES, page 14.

Without the ocean, climate change would progress faster and more radically.

From: HOW THE OCEAN SLOWS CLIMATE CHANGE, page 22.