The Oceans

scientific certainties and uncertainties

Oceans cover almost three-quarters of the Earth's surface, and hold over nine-tenths of the planet's water. We use and exploit them for food, energy and materials, and they have a crucial role in regulating global climate.

Changes in the movements, volume and chemical composition of the ocean are already underway. Although many uncertainties surround the future state of the seas, these changes will inevitably alter ocean productivity, the global carbon cycle, atmospheric composition, weather patterns, and coastal landscapes.

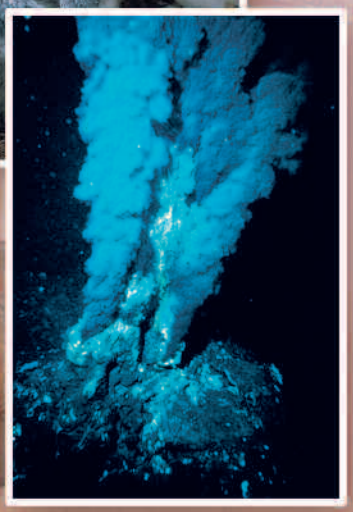
Our understanding of marine ecology and biodiversity lags well behind our knowledge of biodiversity on land: the full genetic diversity of the ocean (mostly microbial) is largely unknown.

Here we discuss what scientists know with a reasonable level of certainty and what we still need to find out. The information draws on work funded by the Natural Environment Research Council, as well as a wide range of other published sources.

NATURAL ENVIRONMENT RESEARCH COUNCIL

WHY?

Why do the oceans matter?

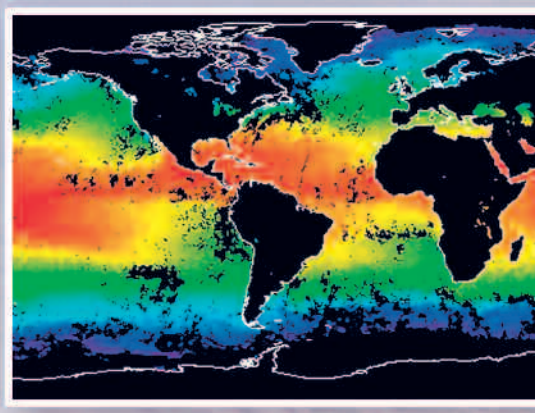


- Planet Earth is really planet ocean: the sea covers 71% of the globe's surface with an average depth of more than four kilometres.
- The ocean is the planet's heat pump: it is the main method of distributing the sun's heat from the equator towards the poles and around the globe.
- Together with seafloor sediments, the oceans are home for a biomass and biodiversity at least as great as that on land.
- Intensive fishing removes around 130 millions of tonnes of fish from the oceans each year.
- Worldwide, people dump thousands of millions of tonnes of waste and agricultural run-off into the oceans each year.
- Most climate change models predict that the Atlantic thermohaline circulation, the current system which carries heat northward and gives us our mild climate, will slow down. A slowing or shutdown could happen over a few decades, and may bring 3-4°C lower winter temperatures to the UK and northwest Europe.
- Parts of our coastline are eroding, particularly in the east of England. Extracting materials, such as aggregates, and dredging port approaches may exacerbate this problem.
- New energy sources are urgently needed to achieve drastic reductions in fossil fuel consumption. The UK is well-suited to developing marine renewables (wind, wave and tidal power).
- Sustainable fishery management requires joined-up, interdisciplinary science and policies.
- UK estuaries and coastal marshes are internationally important for many species of wading birds and migratory wildfowl.

WHAT? What we know?

Marine science is now moving from description to prediction. Researchers from different fields combine their knowledge to help us understand how the living and non-living elements of the marine environment interact and how the atmosphere, ice and land interacts with the oceans. Some of the main topics scientists understand with reasonable certainty are:

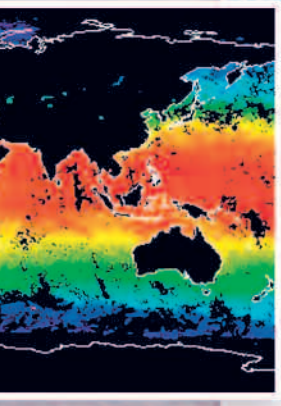
- the main patterns of present-day ocean circulation, particularly for the upper ocean and shelf seas
- approximately how much carbon, nitrogen and sulphur the oceans contribute to the world's present budgets of these chemicals, and the importance of trace elements such as iron and iodine
- how mid-ocean ridges on the sea floor create the Earth's crust
- how sea levels, sea ice and sea surface temperatures have changed over the last century
- how to predict tides and storm surges accurately
- how the oceans' biological productivity depends on tiny plants and animals (plankton) at the base of the food chain, and how productivity is distributed across the globe
- the basic ecology and population dynamics of many fish (mainly harvested species), seal, whale and sea birds

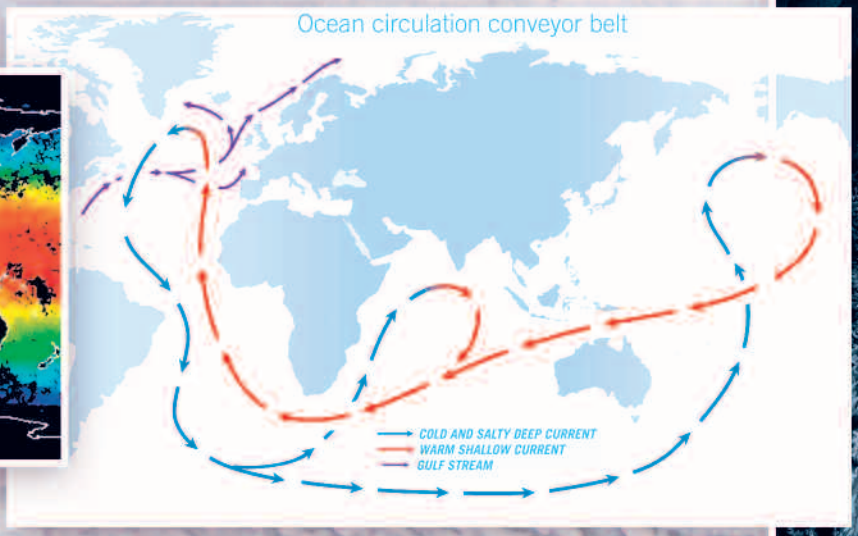


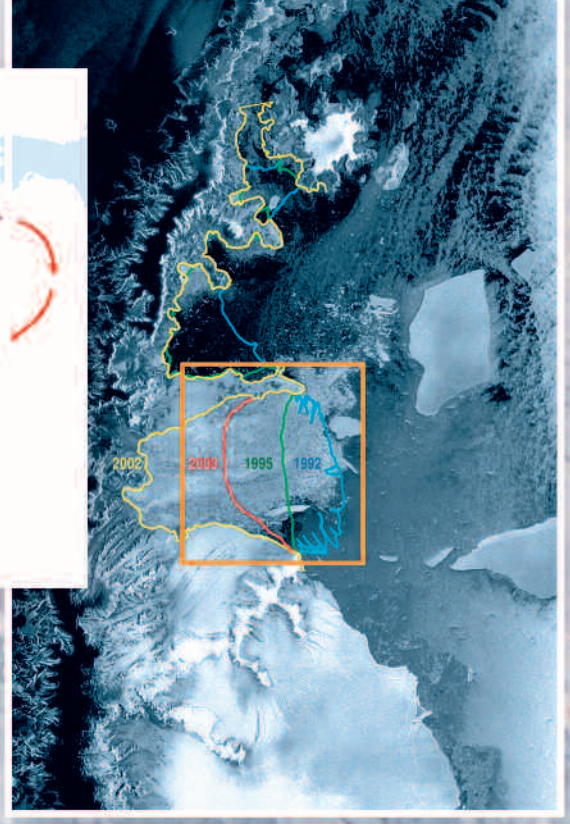
WHAT? What we need to know?

- How do marine viruses, bacteria and archaea* – together comprising the bulk of ocean biomass – interact with other organisms and affect marine ecosystem functioning, both in sediments and the water column?
- What is the scope for using new marine products, including genetic resources, in a sustainable way?
- How do the oceans and the atmosphere interact to determine our climate and weather, and how does this affect our quality of life?
- What causes the rapid and long-term changes in ocean circulation (such as the Atlantic thermohaline circulation) that dramatically affect climate, and can we predict future changes?
- How are polar ice sheets, ice shelves and sea ice patterns changing, and how will changes affect marine ecosystems and ocean circulation?
- How will the oceans' biogeochemical cycles, especially the carbon cycle, respond to climate change?
- How do organic pollutants interact in the marine environment, and how do persistent low levels affect marine organisms?
- What controls plankton populations, how do year-to-year changes affect fish stocks, and is climate change already bringing long-term changes?
- Will global warming melt vast stores of ice-like methane hydrates in marine sediments, potentially accelerating climate change or triggering tsunamis?

**Marine archaea are little studied, because they are near-impossible to identify or to grow in the laboratory. They look much like bacteria, but genetically are as different from them as we are.*







DISCOVERIES

Recent discoveries

- The Atlantic thermohaline circulation, which gives us our mild climate, appears to have slowed by nearly a third since 1992. NERC has set up a pilot scheme to permanently monitor the circulation. First results from the scientific array show the circulation has slowed – but little is known about the circulation's annual or decadal variability.
- Human activities are raising ocean temperatures. Natural changes are not enough to explain the warming seen over the last 40 years. Only models that include gases and other emissions from human activities can accurately simulate the change.
- Arctic sea-ice cover in late summer has decreased by around 30% since 1978, when satellite records first began. Submarine measurements indicate that ice thickness is also rapidly reducing.
- In the Antarctic, the abundance of shrimp-like krill has declined five-fold from the 1970s, probably caused by changes in ice cover. Krill are the main food for penguins, seals, albatrosses and whales.
- In the North East Atlantic, the range limits of many zooplankton and fish have moved northwards by 500-1,000km. The net effect is detrimental, since the warmer water species tend to have lower abundances and biomass.
- Expendable free-drifting floats – Argo buoys – provide worldwide temperature profiles for the top 2km of ocean. The data are used for climate modeling and to improve long-range weather forecasts.
- The oceans are becoming more acidic – ocean acidity has increased by 0.1 of a pH unit over the last 200 years. The rate of change is around 100 times faster than has occurred naturally.
- Wind-blown desert dust provides essential trace nutrients, such as iron, to the open ocean. A lack of iron limits biological productivity, affecting carbon dioxide draw-down from the atmosphere.
- Marine microbes are much more abundant and diverse than previously thought. One of the commonest organisms on the planet – the bacterium *Pelagibacter ubique* – was unknown a few years ago.
- Virus infection plays a major role in marine nutrient cycling and productivity; it can also result in the release of dimethyl sulphide, a gas that promotes cloud formation.
- Bacteria that live on underwater surfaces and in marine sediments use chemicals for sophisticated communication and defence. Such processes could be used to help control biofilms (important for many diseases, as well as ship biofouling), and to develop new drugs.
- Even the least volcanically-active of mid-ocean ridges release heat and fluids from hydrothermal vents. The total movement of hydrothermal fluids into the oceans approaches 20% of the total river input, significantly affecting seawater chemistry.
- A 430 metre sediment core collected near the North Pole showed that ice has covered the Arctic Ocean for around 15 million years. The Arctic basin was formed around 45 million years ago; before then, local conditions were sub-tropical.

Issues of global concern

ISSUES

Climate change

Climate change, accelerated by human activities, is causing huge disruption in ocean ecosystems.

- In the North Atlantic, increasing hurricane frequency and intensity are linked to warmer sea surface temperature.
- By the end of this century the oceans will be more acidic than they have been for 25 million years. This is because of increased carbon dioxide in the atmosphere. This could shift the oceans' ecological balance, with big potential ramifications for marine life, socio-economics, and even further climate change.
- Climate change may disrupt important ocean currents. Scientists are not yet sure exactly what will happen, nor the implications for people, but we can get some idea from El Niño's economic impact. In this frequently-occurring natural phenomenon, a Pacific Ocean current suddenly rearranges itself. The 1997/98 El Niño caused severe droughts, forest fires and air pollution in some parts of the world, while floods and storms devastated others.
- Global sea level rise is accelerating – it is predicted to rise 10-90cm this century. It rose 10-20cm in the last century. Most sea level rise is caused by thermal expansion, the other component is melting glaciers and ice sheets. Sea level rise is likely to be one of the most serious and expensive consequences of global warming – around half the world's population live near the sea.

Fisheries

- Most of the world's sea fisheries are over-exploited. Over-fishing leads to fish stocks collapsing, changing the ecological balance for other marine organisms.
- Escaped farmed fish could out-compete native species. Genes from genetically-modified farmed fish and shellfish could contaminate wild populations.
- Certain fishing techniques, such as bottom trawling and dredging, damage seabed communities and coral reefs. Other methods, such as gill-nets, catch large numbers of non-target species, including marine mammals, turtles and seabirds.
- Salmon farms are blamed for increasing numbers of parasites in wild fish populations.
- Deep sea fish species and ecosystems around seamounts are now being exploited without regulatory controls and with insufficient knowledge of their abundance and basic biology.

Marine pollution

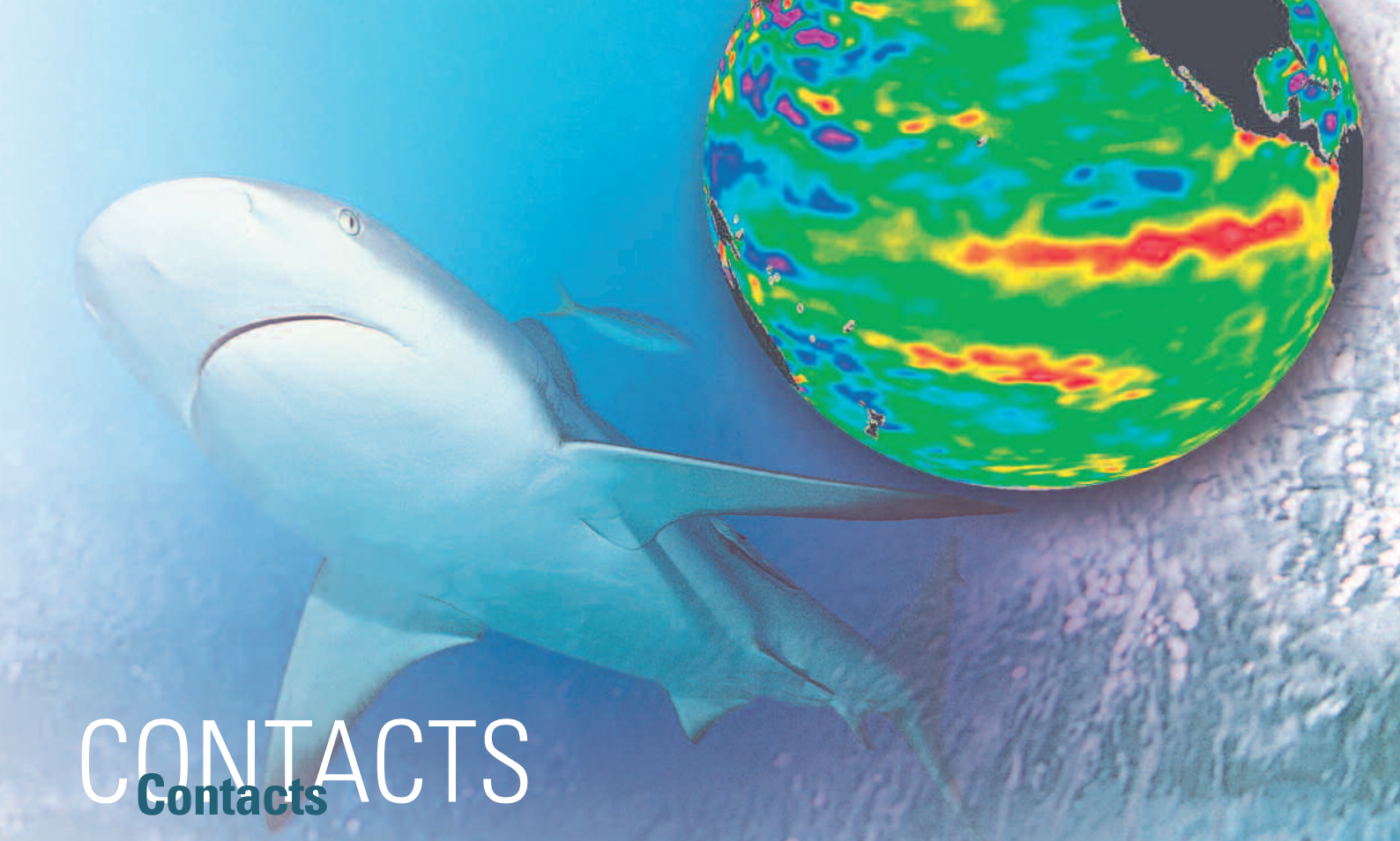
Pollution in the UK has reduced but shallow seas near highly-populated areas remain at risk from chemical contamination. Plastic litter and discarded fishing nets now affect every part of the global ocean.

- Changes in nutrient inputs from agriculture and human sewage can stimulate excessive or unusual blooms of marine algae. The algae may themselves be toxic, or their subsequent decay may use up oxygen, affecting seafloor communities.
- Some organic chemicals act as hormone-mimics, affecting the physiology and reproduction of invertebrates and fish.
- Offshore oil and gas exploration and production can release toxic chemicals into the oceans.
- Oil tanker spills cause acute pollution to coastal communities and chronic pollution to the marine environment generally.

Other problems include . . .

. . . more than 50 non-native species have been identified in UK waters in recent years; dredging and mineral extraction can seriously damage the seafloor; and tropical coral reefs are under multiple pressures, including temperature-induced bleaching.

Steven Kazlowski/Still Pictures



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NATURAL ENVIRONMENT RESEARCH COUNCIL

The UK's Natural Environment Research Council uses a budget of around £370 million a year to fund and carry out impartial scientific research in the sciences of the environment. We train the next generation of independent environmental scientists.

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