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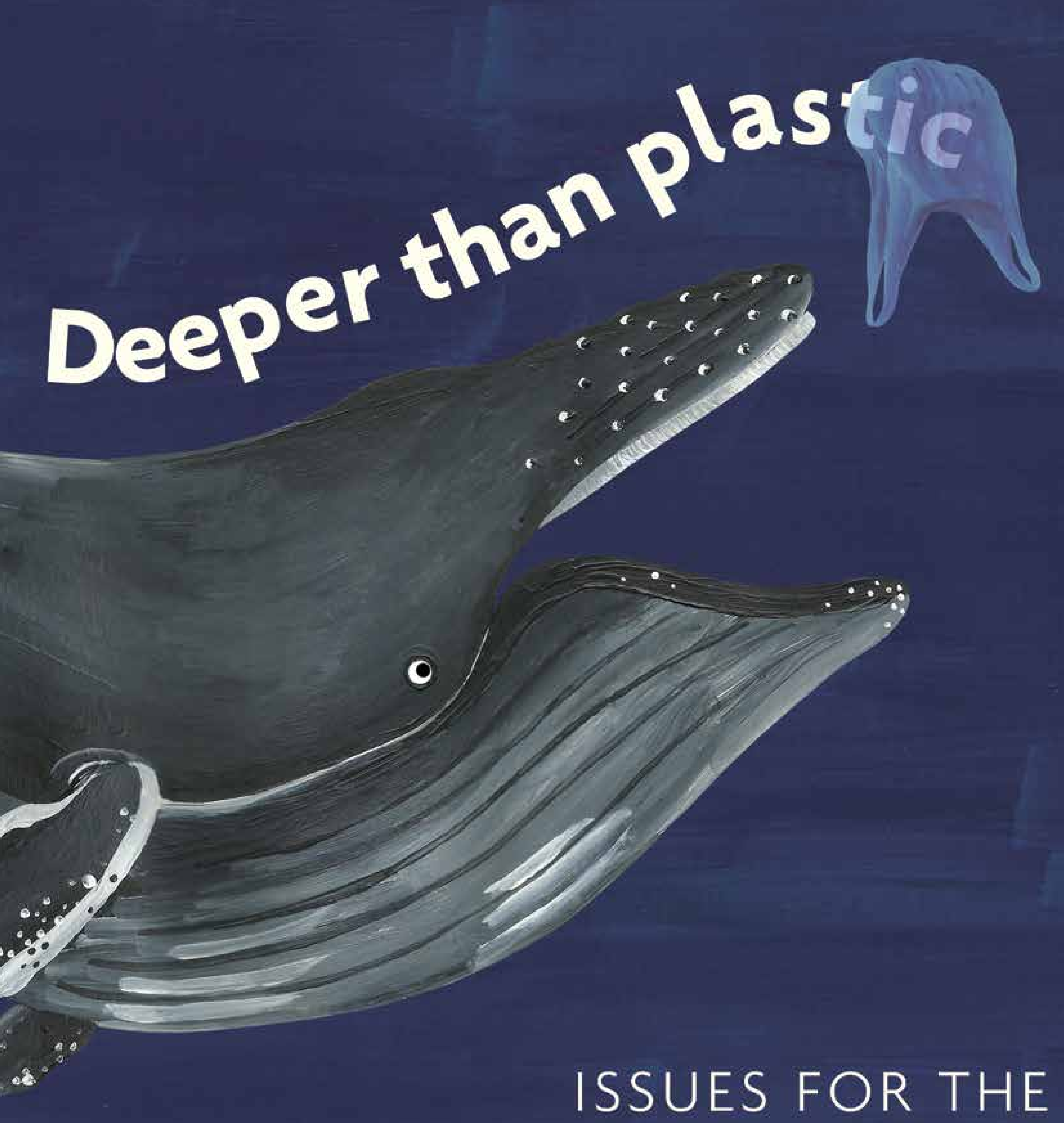

ISSUES FOR THE
MARINE ENVIRONMENT

EDITORIAL

How and why are the oceans changing?

The number of people living on Earth will grow to nine billion by 2050, with the population rising fastest in low-lying coastal plains and cities. Driven by growing public and political awareness, attention is turning urgently to the ocean and coastal regions to provide security for people and economic infrastructure against the sea's dangers, including maritime accidents, extreme weather, flooding and submarine geohazards. At the same time, there is a focus on the sea's ability to provide food, clean energy and minerals, whilst protecting and restoring the marine ecosystems upon which 90 per cent of marine economic benefits depend.

Making sense of the global changes and variability in the ocean, such as warming, acidification, oxygen depletion and the shifting of many marine species, will enable us to unravel the causes and help our search for solutions. The problems are fearsomely complex, not least due to cumulative effects over time and space and multiple feedbacks. All of these are driven by a mix of economic incentives, policies, governance, human behaviours and natural processes. So some marine systems are particularly stressed or vulnerable:

- coastal zones squeezed by sea level rise and competing demands;
- coral reefs, which cover just 0.1 per cent of the ocean's area but are home to 25 per cent of marine species;
- polar regions, where the most rapid environmental change is occurring whilst becoming ever more accessible to human activities; and
- the deep sea, a scientific, technological, economic and geopolitical frontier with vast economic potential but fragile ecosystems.

The challenge now is to move beyond identifying problems to creating solutions. A key dimension that frames solutions is the need for long-term perspectives, due to the scales of change and variability, and the commitment, infrastructure and investment demanded in the marine realm. Added to this, integrated cross-sectoral approaches in businesses and governments can bring about changes through influence and participative processes, as much as by legislation and by an integrated vision of the land–sea interface. Finally, there is a need for appropriate, smart financial and policy instruments to de-risk investment in sustainable activities and recover the economic potential of industries eroded by past ecosystem degradation.

Systematic, geospatial, continuous data from the ocean is needed to raise our awareness of the basin–decadal context of ocean change and to monitor the effectiveness of management interventions. Technology revolutions in big data, artificial intelligence and marine autonomous and robotic systems will have a major impact in developing the ocean economy. And, as with space science, many innovations originally developed to explore the deep sea are now ready to be brought into everyday use for marine operations.

This collection of papers explores these complex questions through specific examples and looks beyond the problems to possible solutions.

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Guest editor: Carolyn Roberts is a water resource management consultant and a Vice President of the IES. She was the first Frank Jackson Professor of the Environment at Gresham College, formerly Director of the Environmental Sustainability Knowledge Transfer Network at the University of Oxford and currently Entrepreneur-in-Residence at Keele University.

Cover design & internal illustrations: Lexie Mac is an illustrator working in London, she has a passion for the environment which is explored in her work. She is also part of the IES administrative team and is currently writing and illustrating an educational childrens book on ocean plastics.
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CONTENTS

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INTRODUCTION

What do we know about our effect on the oceans?

Carolyn Roberts shows how much we still have to learn about the Earth's largest ecosystem.

Environmental scientists are finding increasing evidence of human-induced damage to oceans at vast scale – the destruction of fish and coral ecosystems, massive gyrating pools of plastic refuse. Almost all the plastic ever produced is still with us, and according to research at the University of the Highlands and Islands, an additional 8 million tonnes of plastic litter enter the ocean each year. The effects are that about 100,000 marine mammals and a million seabirds per year are killed by eating plastic or becoming entangled in it – this includes fishing nets, which make up 10 per cent of the litter. Australian research published by the USA's National Academy of Sciences in 2015 found that 90 per cent of all seabirds had ingested plastic, and it took up 10 per cent of their average bodyweight. Harrowing photographs show that the contents of seabirds' stomachs include cigarette lighters, toothbrushes and tampon casings. Plastic has also been found inside turtles, fish and dolphins, and wrapped around organisms, effectively strangling them. By 2025, there could be 1 tonne of plastic in the ocean for every 3 tonnes of finfish.

DEEP OCEAN DATA GATHERING

Oceans are the least well-known major component of the Earth's environment. Early exploration of the oceans depended upon imprecise ship surveys, done by dropping lead weights on ropes for depth measurement and trailing thermometers on cables. Painfully slowly, observations were built up into generalised maps. By the early 21st century, the complex configuration of abyssal plains, ridges and trenches reflecting the slow shifts of tectonic plates was sufficiently well known to appear on Google Maps. However, less than 10 per cent of the ocean's 1.3 billion km^3 has been fully explored, and marine scientists still have only a rudimentary understanding of anything below about 2 km.

The lack of progress is illustrated by the fact that, in 1960 when oceanographers Don Walsh and Jacques Piccard were lowered 11 km down into the Mariana Trench in a bathyscaphe they saw very little because disturbed sediment made the water milky; they thought they saw a halibut, but nothing else. The feat has rarely been repeated, despite Richard Branson's plan for *DeepFlight Challenge*r to 'fly' to the bottom of the trench in 2011; the trial was quietly abandoned in 2014 when the submersible proved unable to withstand the pressures at that depth and developed fractures. Even though we can walk on the Moon, human technology is not yet sufficiently good for scientists regularly to explore the ocean floor in person.

Conversely, data gathered by the equipment carried by robotic submersibles, long-distance drifters powered by wind, wave and solar energy, and sensors on satellites, have driven our knowledge forward dramatically. Autonomous vehicles can photograph and bring back sediment and mineral samples for laboratory analysis.

Sea-bed instruments report changes in temperature, current direction, salinity and algal content at increasing frequencies. Satellite-borne altimeters, in combination with drone vessels, drifters or wave gliders and buoys, are enabling us to understand far more about the nature of the ocean, and the way water of different characteristics moves around.

Additional information is coming in from Earth observation satellites that were previously turned off as they passed over the ocean in order to save energy. The newer ones, including microsatellites, are now recording sea levels, wave heights and water temperatures with astonishing precision in real time. For instance, the new *GOES-16* satellite from the USA's National Oceanic and Atmospheric Administration (NOAA) measures ocean meteorology from 36,000 km above the Earth, and other satellites look specifically at oceans, allowing heat exchange between air and ocean to be calculated along with other parameters such as biomass content. Our static picture of the deep oceans has morphed into video and data capture of day-to-day or even hour-to-hour changes. Whereas previously we could only map underwater volcanoes, now we can catch glimpses of basaltic or mineralised eruptions and discharges of superheated steam from vents as they occur.

DATA ON WATER MOVEMENTS

Recent oceanographic research has yielded some surprising results at the surface too, including 20 minutes of record-breaking 19 m North Atlantic waves in February 2013 – they were captured by an automated World Meteorological Organization buoy. The buoy is part of the network of marine automated weather stations that includes ships and satellites. Other networks, such as Climate Linked Atlantic Sector Science (CLASS), are also capturing data in real time, allowing scientists to gain more understanding of water–atmosphere fluxes of gases such as carbon dioxide.

We now know that the general water circulation of the oceans is dynamic, with a complex pattern reflecting atmospheric drivers and the location of major continents. The Gulf Stream is only one part of a global conveyor system where warm surface waters and cold deep waters swing around the planet. Focusing in on the Atlantic, it has also been suggested that rapid ice sheet melting in Greenland might interrupt the patterns more typical of recent centuries. We know, for instance, that the Atlantic meridional overturning circulation (AMOC), which brings heat from the tropics towards northern Europe, is highly seasonal and that it weakened dramatically between 2009 and 2010. We can see that it is sensitive and volatile. The decline was linked to an unprecedented and surprising rise in sea level on the eastern seaboard of the USA. Now the results have to be incorporated into our understanding of climate systems.

Not only do geological inputs influence the biosphere, but the converse is also true: animals influence chemical cycling in the oceans. Large mammals play a previously unknown role in recycling nutrients from ocean depths – as they swim, they stir up sediments with fertilising potential (including increasingly needed nutrients such as phosphorus) which allows them to disperse around the world. The activity of whales, dolphins and walruses is starting to be understood particularly as a result of tracking. The Environmental Change Institute at Oxford University, for instance, has recently established that the massive reduction in large oceanic mammals such as whales has reduced this capacity to a tiny fraction of what it was before these mass extinctions.

NEWLY DISCOVERED SPECIES

Humans may be unsuited to deep ocean exploration, but other creatures do have the ability to withstand the extreme pressure, cold and darkness. New discoveries are being made every month in this, the world's largest ecosystem. Deep-sea frill sharks and giant spider crabs are examples of larger organisms thriving in these conditions, and about which little was known until recently. The photographs of Alexander Semenov, for example, working out of the White Sea Biological Station near the Arctic Circle, show stunning and previously unknown worms, sea cucumbers, starfish, jellyfish and more types of fish than can readily be enumerated.

Oceanic food chains rest on microscopic organisms. New discoveries on the deep Pacific Ocean floor by Danish scientists include bacteria and the distinctive single-celled *archaea* that lack a cell nucleus and challenge our ability to grasp what 'being alive' is. Found in vanishingly small numbers, maybe a thousand in a cubic metre of clay, they have such a slow metabolism that it would take thousands of years for them to generate enough energy to reproduce. They perk up and divide when fed with a nutrient soup in the laboratory. Interestingly, the latest research suggests that *archaea*, in turn, are host to novel viruses and parasites about which next-to-nothing is known. These and other extremophiles living on the nutrients generated by geologically slow processes support the global ecosystem in ways we do not yet understand, but which must be critical to the planetary-scale carbon recycling system on which we all rely.

THE EFFECTS OF WARMING SEAWATER

More warm-water species such as dwarf sperm whales, striped dolphins and Cuvier's beaked whales are moving north into British waters than previously, at least insofar as fragmentary observations can confirm. However, the picture is made more complex by the fact that some northerly species are moving south, as evidenced by recent sightings of a beluga whale in the Thames estuary in 2018. Perhaps the increased southerly drift of pack ice from melting ice sheets is responsible.

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Increasing sea temperatures, together with increasing acidity from dissolved atmospheric carbon dioxide and sea-level change, are also putting pressure on the coral reefs. Many carbonate reefs (and there are now known to be silica reefs as well, recently found at 760 m in the Mediterranean, and a legacy of ancient organisms such as sponges) are experiencing bleaching and subsequent death. Bleaching can be part of the natural cycle of coral reefs, and is sometimes associated with natural aerosols emitted from volcanoes as well as the strength of the cycles of sea currents associated with El Niño. So it is sometimes difficult to establish that widespread bleaching on reefs such as the Great Barrier is definitely the result of water temperature change, but it seems likely.

Cold-water corals are also likely to be affected, including common North Atlantic species such as *Lophelia pertusa* and *Desmophyllum dianthus*, which have been shown to become more brittle with acidification – a type of coral osteoporosis. The collapse of the basic structural elements of a reef can initiate wider changes in the marine ecology, with new species arriving to replace some of the rarer incumbents. It may also leave coastal areas open to inundation at high tides and in storms. Clearly, some form of protection is required, but it cannot just be a locally based solution as in most cases this will not address the fundamental cause of the bleaching.

FRAGMENTED RESPONSES

The evidence suggesting damage to the oceans is now so clear that moves are afoot to attempt to preserve some areas from plastic pollution, ocean floor mining and overfishing. However, responsibilities are fragmented, and despite the complex mixture of Marine Conservation Zones (MCZs), Marine Protected Areas (MPAs) and Integrated Coastal Zone Management (ICMZ) areas, there is little overarching international policy for ocean management. Rather, there are complex matrices for the protection of individual species and the prevention of land erosion, river pollution, overfishing and similar challenges. But the lack of political will for enforcement allows the degradation of oceanic natural capital to continue. In combination with the challenges emerging from climate change, there must be moves to generate a genuinely sustainable blue economy. **ES**

Carolyn Roberts is a Vice President of the Institution of Environmental Sciences; Professor of Environment Emerita, and Fellow, Gresham College, London; and is former Chair of the Society for the Environment. Carolyn is a water resource management specialist with many years of experience of research and consultancy work in the UK and overseas.

CASE STUDY

Climate Linked Atlantic Sector Science: A new UK marine science programme

Penny Holliday explains how sustained observations, the development of models and technological advances will provide essential knowledge of and robust predictions for the changing marine environment.

Starting in 2018, a new £22 million research programme will investigate the impacts of climate change and human activities on the Atlantic Ocean, from the surface to the seabed and from pole to pole, including its adjacent seas and shelves. Over the next five years, Climate Linked Atlantic Sector Science (CLASS) will deliver the knowledge and understanding of the Atlantic Ocean system required by stakeholders to make evidence-based decisions. Research will focus on understanding and quantifying climate regulation and ocean services, and predicting how the ocean will change as a result of climate change and intensified human exploitation. CLASS will build on sustained ocean observation, world-class model development and state-of-the-art technology. This research programme is funded by NERC national capability due to its scale and complexity.

The RRS *Discovery*, one of the UK oceanographic research ships used by CLASS. (© National Oceanography Centre)

▲ **CLASS scientists use a package lowered to the seafloor from research ships to measure currents, temperature, salinity, pressure, oxygen and fluorescence. The device also captures samples of water for chemical and biological analysis. (© National Oceanography Centre)**

The global ocean is vital to the functioning of our planet. It regulates global climate patterns by taking up 93 per cent of the Earth's excess solar heat and redistributing it in the Earth system, including through a surface-to-seabed overturning circulation driven by exchanges of momentum, heat and fresh water with the atmosphere. The Atlantic Ocean is central to driving and regulating the overturning circulation because half the global formation of deep waters occurs here. The global ocean also modulates key biogeochemical cycles by taking up about 30 per cent of anthropogenic carbon[1]. In the North Atlantic, large-scale flows make it a hotspot of carbon uptake, storing 23 per cent of anthropogenic carbon even though it comprises only 15 per cent of the global ocean surface area.

The inherent variability of Atlantic Ocean circulation is high and therefore the detection of anthropogenically driven change takes decades, but as we deploy new technologies to observe these dynamic processes, the impacts of human activities are becoming increasingly obvious and of growing concern. It is now clear that the ocean plays a pivotal role in climate change and this is having profound consequences for both regional weather patterns and marine ecosystems. Assessment of potential socio-economic impacts and the knowledge base to maintain resilient natural resources requires an integrated coordinated effort and detailed understanding of the natural variability of the basin-decadal scale ocean system (in other words, of the whole Atlantic Ocean over decades).

OBSERVATIONS, MODELS & TECHNOLOGICAL DEVELOPMENT

CLASS ocean observations are building on a long history of programmes to measure key properties over climate-relevant timescales (weeks to decades), and are part of globally coordinated programmes because observing the wide expanse and depth of the ocean is an enormous task. The essential ocean variables that CLASS is measuring are sea level, ocean heat content, ocean carbon storage and transport, surface marine climate temperature and carbonate chemistry, and surface plankton abundance and community structure.

CLASS is developing and running numerical ocean models for scientific analysis, predictions and scenario testing. We have a range of models for different uses, all with a high-quality ocean as a central component. The UK Met Office climate predictive systems use the CLASS ocean components, and the physics models form the basic framework for simplified ecosystem models and complex Earth-system models.

To reach all parts of the ocean we use a combination of research vessels, ocean-going robots and commercial ships that host or tow our instruments. Historically we have made great use of research vessels and measurements from commercial ships and satellite systems to learn about changes in the marine environment. In CLASS our activities are also developing the use of autonomous vehicles and new sensors to increase the spatial and temporal coverage of the ocean, and to increase the variables that our robots can measure. These vehicles give us options to access remote and difficult environments, allowing us to sample the ocean more widely and efficiently.

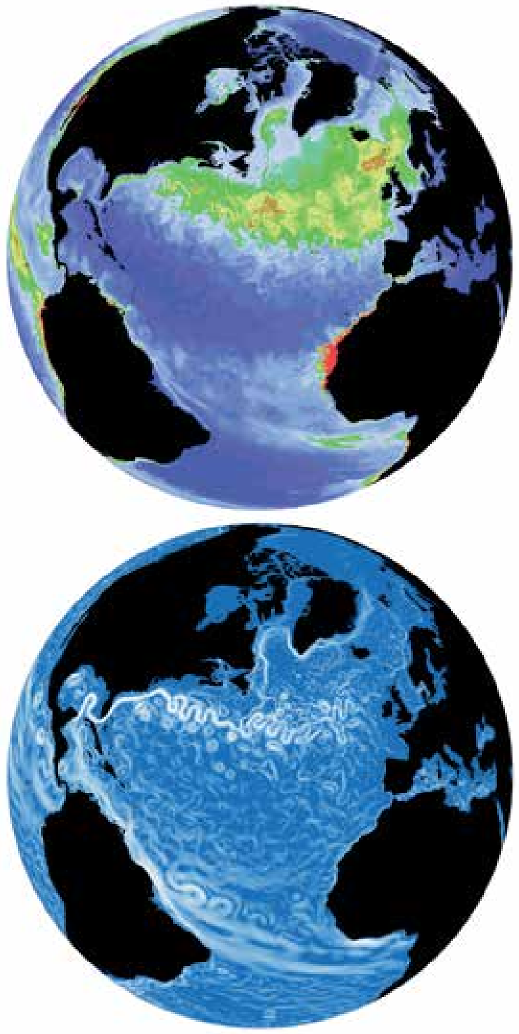
CLASS SCIENCE PROGRAMME

The Atlantic is hugely important for the citizens of northern Europe, including the UK, because the Atlantic Meridional Overturning Circulation (AMOC) transports heat northwards and keeps north-west Europe 3 °C warmer than comparable latitudes on the western margin of the Atlantic[2]. It also enables the North Atlantic to play a much greater role in the global carbon cycle than would be expected for its size. The AMOC's northwards supply of nutrients sustains high levels of biological productivity in the subpolar gyre, leading to a strong biological uptake of carbon[3]. The overturning's associated heat loss facilitates intense solubility-driven uptake of both natural and anthropogenic carbon and its transport to depth on climatically important timescales[4,5]. The Atlantic supports spatially and temporally diverse biological communities in the water column[6] and at the seafloor[7], which constitute biodiversity reservoirs, act to store carbon in the oceans, and underpin the marine food web – in essence, the ocean's natural capital.

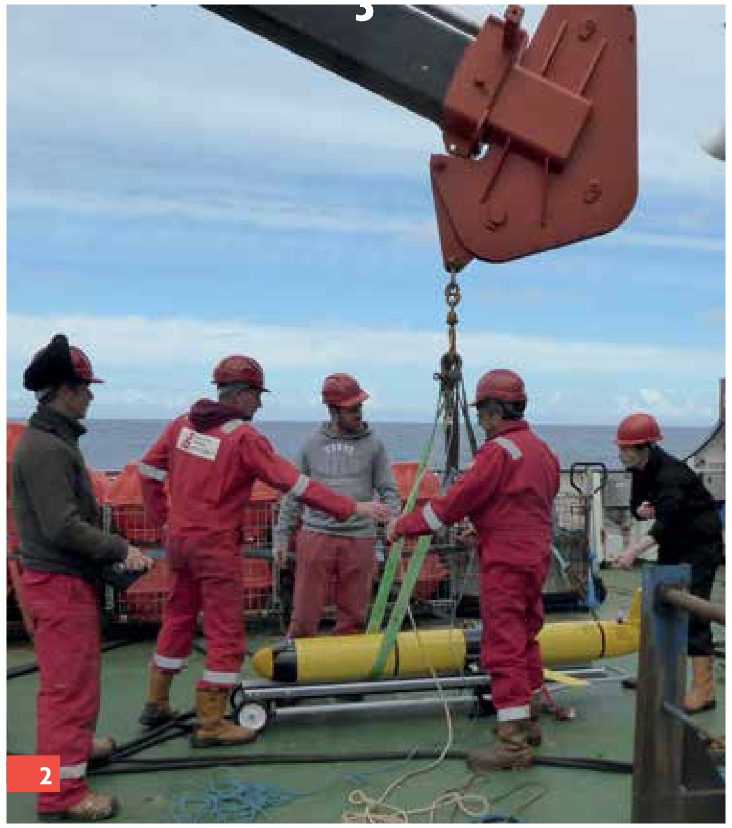
We now have abundant evidence that many features of the Atlantic Ocean and marginal seas are changing, including the strength of the thermohaline and wind-driven circulations, sea surface and interior temperature and salinity distributions, ocean heat content, air–sea CO_2 fluxes, primary production and nutrient fields. The reasons for these changes are complex, and include natural internal variability in the climate system and external time-varying anthropogenic forcing. Understanding and attributing these changes is often confounded by the difficulty of separating natural and externally forced variability, and by the positive and negative feedbacks between them. While global climate trajectories can be established with some confidence, climate trends at regional and seasonal-to-decadal scales can be masked by variability within and between basins. The natural variability in both circulation and biological properties is so large that distinguishing climate-change driven trends may require 30 or more years of data[8].

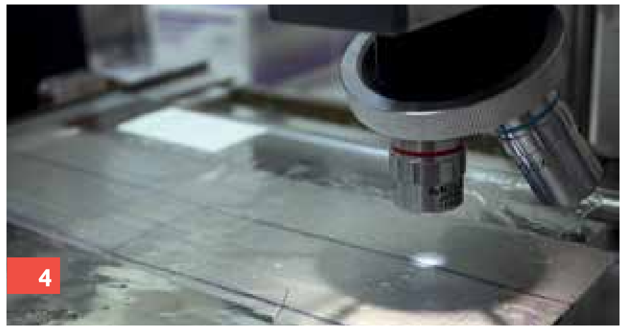
Changes in the Atlantic system have consequences for the climate regulation and ecosystem services the UK depends upon. How these services will evolve is uncertain, and numerical models show a wide range of future responses[9]. In some cases the link is clear (e.g. between anthropogenic emissions and ocean carbon storage). However, more complex linkages, such as how changes in ocean acidification may feed through to impacts on biodiversity in seafloor communities, are harder to elucidate. CLASS will address four inter-connected key knowledge gaps[10,11] related to ocean variability, biodiversity and the resultant functional capacity of the Atlantic sector:

- The evolving state of the hydrological cycle and how changes in ocean salinity may impact it in the future;
- How physical and biological uptake, transfer and storage of carbon in the deep ocean interact to determine the North Atlantic CO_2 sink, and the resultant effects on the production of other greenhouse gases, such as methane and nitrous oxide;
- How natural and anthropogenic drivers of basin and decadal changes are altering the Atlantic ecosystem, and the consequences for ecosystem functioning and services; and
- How the structure, diversity and productivity of seafloor biological communities are changing in response to abrupt or episodic disturbance events compared to long-term change.



▲ **Net primary production (top) and surface ocean velocity (bottom) from a high resolution global ocean–ice–ecosystem model. (© National Oceanography Centre)**





▲ **1: The aft deck of the RRS *Discovery*, full of oceanographic equipment, during an operation to lay a moored set of instruments that were left in the deep ocean for two years. (© National Oceanography Centre).**
2: Deploying an ocean-going robot (a glider) from a research ship. (© National Oceanography Centre).
3: Deploying a continuous plankton recorder (CPR) from a commercial vessel. The CPR is towed behind the ship, filtering surface water onto silk to capture plankton and other small particles in the water. (© Marine Biological Association).
4: Decades of manual examination of the CPR silks under have provided an 87-year record of plankton abundance and community structure in the North Atlantic. (© Marine Biological Association)

IMPACT

CLASS outcomes are intended to generate impact in a wide stakeholder community, ranging from international policy-makers to the general public. We will provide input to the Intergovernmental Panel on Climate Change (IPCC) and other global climate assessment processes. We work with the UK Met Office to communicate results directly to decision-makers through UK Climate Projections, and CLASS is supporting UK government decision-makers with key scientific evidence and expertise. We provide data and advice in support of implementing the Marine Strategy Framework Directive, marine spatial planning (e.g. for marine protected areas), fisheries policy and environmental assessment for offshore operations (e.g. marine renewable energy).

CLASS is also providing advice and strategic planning to international sustained programmes, and ensuring that all new observational and model data products are easily available to the international community. The large user community for the novel technologies we develop within CLASS will be:

- UK and international scientists in marine and non-marine environmental sectors;
- The international environmental observing community and operators, industry and government departments and agencies;
- Industries that are manufacturing technologies or providing services; and
- Academic and industrial technology developers.

OPPORTUNITIES FOR GETTING INVOLVED

As well as delivering world-leading research, datasets, facilities and advice, CLASS activities will form the basis of new research projects. We encourage you to get in touch if you have ideas to develop into proposals with CLASS researchers. We are supporting the UK science community by providing opportunities for early-career researchers (including graduate students) to work with us, our data and our models in the research centres and on oceanographic research expeditions. Find out more by signing up to our email bulletins on the website. You can also contact us by email or Twitter. **ES**

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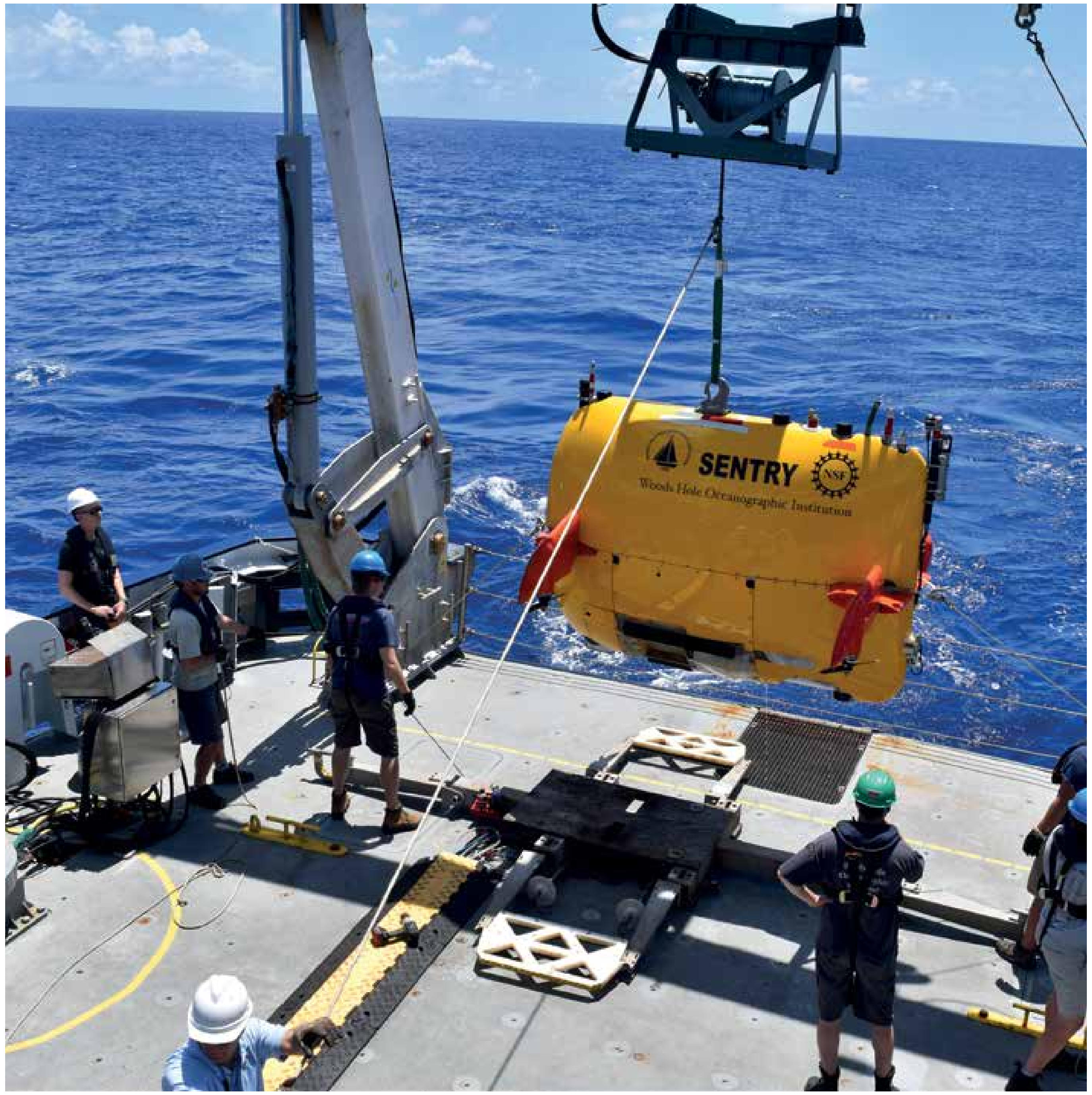
REFERENCES

1. Rhein, M., Rintoul, S.R., Aoki, S., Campos, E., Chambers, D., Feely, R.A., Gulev, S., Johnson, G.C., Josey, S.A., Kostianoy, A., Mauritzen, C., Roemmich, D., Talley, L.D. and Wang, F. 2013 Observations: Ocean. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds.)]. Cambridge, UK and New York, NY, USA: Cambridge University Press.
2. McCarthy, G., Gleeson, E. and Walsh, S. (2015) The influence of ocean variations on the climate of Ireland. *Weather*, 70 (8). doi:10.1002/wea.2543.
3. Sanders, R., Henson, S.A., Koski, M., De la Roche, C.L., Painter, S.C., Poulton, A.J., Riley, J., Salihoglu, B., Visser, A., Yool, A., Bellerby, R. and Martin, A.P. (2014) The Biological Carbon Pump in the North Atlantic. *Prog. Ocean*, 129, pp.200–218.
4. Khatiwala, S., Primeau, F. and Hall, T. (2009) Reconstruction of the history of anthropogenic CO2 concentrations in the ocean. *Nature*, 462, pp.346–349.
5. Khatiwala, S., Tanhua, T., Fletcher, S.M., Gerber, M., Doney, S.C., Graven, H.D., Gruber, N., McKinley, G.A., Murata, A., Rios, A.F. and Sabine, C.L. (2013) Global ocean storage of anthropogenic carbon. *Biogeosci.* , 10, pp.2169–2191.
6. Beaugrand, G., Edwards, M. and Legendre, L. (2010) Marine biodiversity, ecosystem functioning, and carbon cycles. *PNAS*, 107, pp.10120–10124.
7. Galparsoro, I., Borja, A. and Uyarra, M.C. (2014) Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean. *Front. Mar. Sci.*, doi.org/10.3389/fmars.2014.00023.
8. Henson, S., Beaulieu, C. and Lampitt, R. (2016) Observing climate change trends in ocean biogeochemistry: when and where. *Glob. Change Biol.*, doi:10.1111/gcb.13152.
9. Menary, M.B., Hodson, D.L.R., Robson, J., Sutton, R., Wood, R.A. and Hunt, J.A. (2015) Exploring the impact of CMIP5 model biases on the simulation of North Atlantic decadal variability. *Geophys. Res. Lett.*, doi:10.1002/2015GL064360.
10. MCCIP (2014) Marine Climate Change Research Priorities 2014 ‹www.mccip.org.uk/media/1478/researchpriorities_feb14_final.pdf›
11. National Research Council (2015) *Sea Change: 2015–2025 Decadal Survey of Ocean Sciences.* Washington, DC: The National Academies Press. doi.org/10.17226/21655.



▲ **The autonomous underwater vehicle, *Sentry*, being lowered into the ocean. (© Kenneth Rubin)**

Exploring submarine volcanoes

Ken Rubin describes our changing view of the seabed and its inhabitants, as we discover more about underwater volcanoes.

Earth is a restless planet, constantly renewing its surface by one or another geological or hydrological process, with the added impacts of human activities. Volcanism is one of the most dramatic forms of natural activity, rapidly changing landscapes and impacting local and global environmental conditions. Although we see many of Earth's most active volcanoes in places such as Hawaii, Iceland, Italy and Japan, by far the greatest number of volcanoes on Earth is under the sea, most being under many kilometres of water. This great depth makes active submarine volcanoes difficult to discover and to observe. But humans are up for the challenge, and like space explorers going to other worlds, oceanographers and marine geologists have been devising evermore innovative ways to study submarine volcanoes, with dramatic improvements in the last two decades or so.

Submarine volcanologists distinguish volcanoes occurring in the deep ocean (deeper than 500–1000 m) from those in the shallow seas, because the effects of hydrostatic pressure dramatically change the style of volcanism with increasing depth and the tools needed to study them. Shallow submarine volcanoes generally erupt near land (e.g. Surtsey, off the coast of Iceland) and often the eruption is visible at and above the sea surface. Deep eruptions, on the other hand, cannot usually be detected from the surface and occur further from land, requiring specialised tools to detect and respond to them. This article focuses on deep eruptions, which are more difficult to detect and study.

The methods submarine volcanologists use include *in-situ* observations by human-occupied submersibles, robotic vehicles (some with direct human intervention and some running pre-programmed missions), photography, water sampling by surface ships, satellite observations, and remote monitoring by hydrophone listening stations. All of these are reliant on computers, modern methods of navigation and geo-location (e.g. GPS) and basic geological, geophysical, ecological and/or environmental knowhow. In addition, just like other environments, submarine volcanoes are studied by scientists from many different disciplines, from microbiologists and macrofauna ecologists, to hydrothermal vent fluid chemists, mineralogists, geophysicists, structural geologists, physical oceanographers and volcanologists. The range of studies includes active eruptions, steady-state non-eruptive venting of fluids and ecosystem support, ore prospecting and geological hazards (e.g. earthquakes, tsunami generation, landslides).

HISTORY

The latter part of the 19th century brought many scientific and technological innovations. Two of these (the first true oceanographic expedition, on the HMS *Challenger*, and the laying of the first trans-Atlantic telegraph cables) recovered volcanic rocks from a structure we would later call the mid-Atlantic Ridge, and started the study of submarine volcanoes. It was not until after World War II that modern oceanography really started, in part because of the advent of sonar mapping (echo sounding), which made it much easier to determine seabed depth and the shapes of submarine landforms. This was when the extent of the global mid-ocean ridge system (now known to be more than 60,000 km long) was first discovered and the vast number (many thousands) of mid-plate seamounts revealed. Nearly all of the seamounts are volcanoes.

With the advent of human-occupied vehicle (HOV) missions in the 1970s came the discovery of submarine hydrothermal systems, first as low-temperature vents on the Galapagos Spreading Centre, followed by high-temperature 'black smoker' vents on the northern East Pacific Rise a couple of years later. These discoveries opened the door to simultaneous geological, ecological and geochemical studies, each needing the development of specialised instruments and tools to measure environmental parameters and take samples in ways that preserved their integrity. HOVs are not for the faint of heart. In addition to the limited driving speed and bottom time (due to battery life and life-support limitations), they are generally small (most outfitted for deep-sea exploration are 2 m spheres), cramped and uncomfortable, with two or three people aboard and no toilet. They bob up and down in the currents during deployment and recovery in ways that make many passengers ill. Yet HOVs still provide the maximum manoeuvrability in an immersive situation, and are by far the author's preferred means of exploring and working on the deep seafloor.

The advent of multi-beam echo sounders for seabed mapping and hydroacoustic listening stations in the 1980s gave scientists the ability to locate and map active volcanoes in greater detail. Both of these types of instrument had been in naval use for quite some time before they were approved for civilian use, but once accessible, the numbers of scientists studying submarine volcanoes and participating countries increased dramatically.

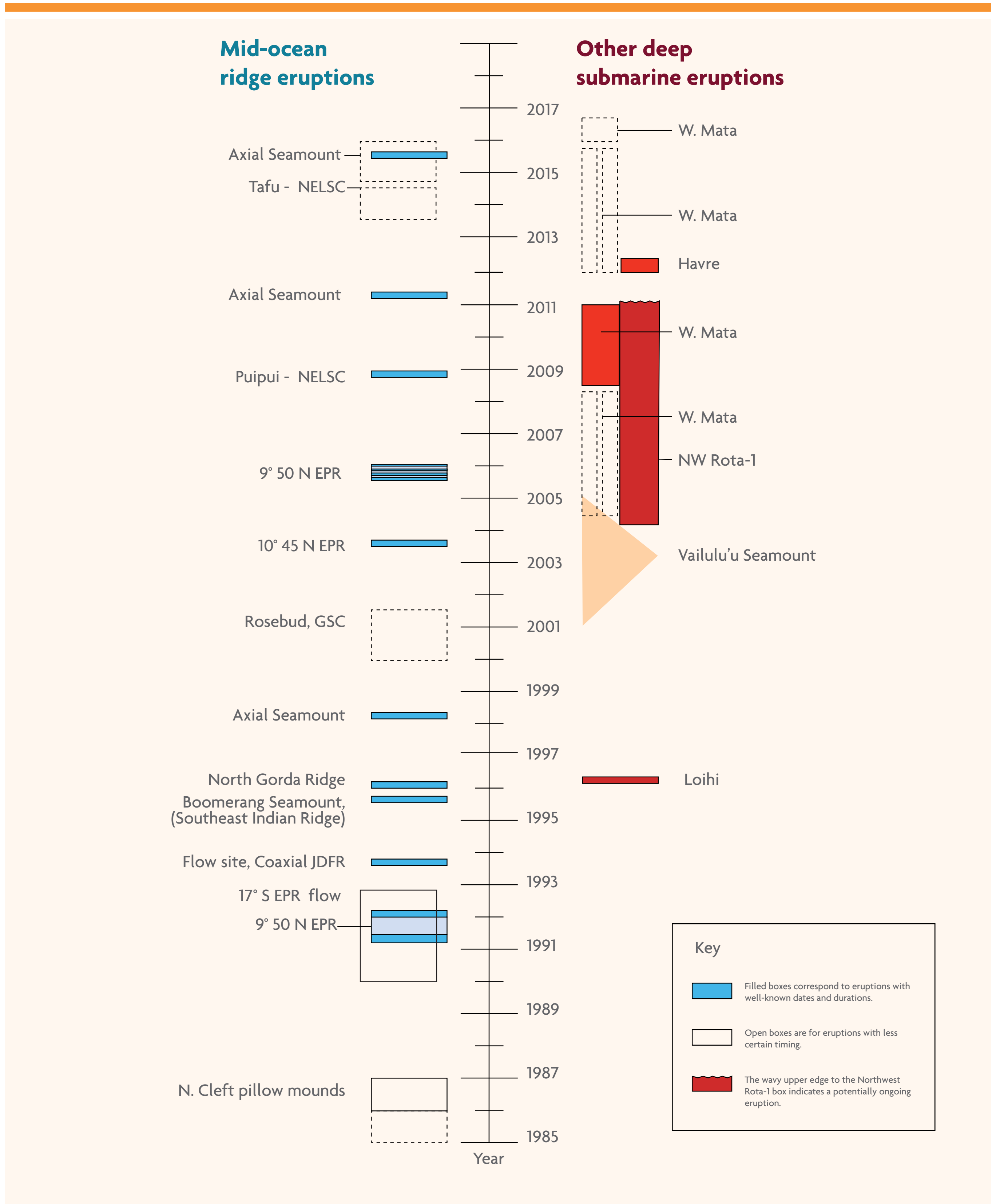
Three more military technologies came to the scientific community in the 1990s and transformed the study of submarine volcanoes:

- The global positioning system (GPS) of satellites;
- Remotely operated vehicles (ROVs), which are operated by pilots from a surface ship to remotely control the cameras, lights and sampling tools of a robotic vehicle on the seabed; and
- Autonomous underwater vehicles (AUVs), which are pre-programmed autonomous robots that run subsea mapping and sampling missions and then return to the sea surface for collection.

▲ **Ken inside the human-operated vehicle, *Alvin*. (© Kenneth Rubin)**

In addition, the application of transponder navigation (networks of stationary sound beacons) allowed scientists to precisely locate and revisit small features on the seafloor, so that they could begin to make time-series measurements and ecological transects.

By the 2000s, most of the primary technologies used to study deep-sea volcanoes had been established, setting up a period of improvements in payload, manoeuvrability, power consumption, and the addition of highly specialised sampling tools. The transition from analogue to digital photography and video, and the subsequent increase of resolution, along with new forms of LED lighting systems made possible the documentation of seabed features for repeat viewing, paving the way for the current situation, which is that most seabed studies are conducted by ROV. Live tele-presence (streaming video, commentary and vehicle navigation data) has democratised this type of science, to the extent that tele-presence-enabled operators such as the NOAA Office of Ocean Exploration and Research, the Ocean Exploration Trust and Schmidt Ocean Institute (to name a few) can bring seabed science to many tens of scientists and thousands of public participants around the world in real time.



▲ **Timeline of verified historical deep submarine eruption discoveries (observed in action, dated radiometrically and/or detected by repeat sonar surveys). See data sources and methods in Rubin, K.H., Soule, S.A., Chadwick, W.W., Jr, Fornari, D.J., Clague, D.A., Embley, R.W., Baker, E.T., Perfit, M.R., Caress, D.W. and Dziak, R.P. (2012) Volcanic eruptions in the deep sea. *Oceanography*, 25 (1) pp.142–157. ‹dx.doi.org/10.5670/oceanog.2012.12›**

FEATURE

▲ Ken operating the remotely operated vehicle, *SuBastian*, from the control room. (© Kenneth Rubin)

MODERN METHODS

The specialised methods for studying the deep-sea volcanic environment include all the standard environmental tools for compositional analysis, genomics, mapping and GIS. However, the deep sea presents unique challenges in terms of sampling technologies, *in-situ* sensors, real-time monitoring and rapid response for capturing transient signals after an eruption. Only a very few sites on the seafloor are monitored in real time. The best monitored and observed submarine volcano is called Axial; it sits on the Juan de Fuca ridge off the western coast of the USA. It erupted in 1998, 2011 and 2015, and the last eruption occurred while the submarine observatory was coming online, demonstrating the utility of this real-time monitoring capability with earthquake locations, seabed depth changes and water temperature measurements.

The following methods or environments are given as examples of those that have specialised tools used to map and sample deep-sea volcanoes.

REPEAT SONAR MAPPING

Repeat mapping by surface ships and AUVs in a tightly constrained geospatial context allows detection of seabed depth changes of tens of metres and decimetres, respectively. AUVs achieve higher depth resolution by using higher-frequency sonar and by flying closer to the seabed than surface ships, avoiding a lot of the sonar noise and sound velocity aberrations of the shallow ocean, but they cover much less ground because of vehicle speed limitations to achieve the best-quality data. Such methods have been used at active volcanoes to identify new eruption deposits and then map their volume and aerial extents. For instance, in one of the author's study areas in Tonga, as many as 10 new eruption deposits over the last 15 years or so have been discovered by this method at just one small volcano known as West Mata, including one detected in December 2017 that had occurred within the preceding 18 months. Repeat decimetre-resolution AUV sonar mapping before and after the 2011 and 2015 eruptions allowed unprecedented views of lava distribution systems.

PLUME MAPPING

Submarine volcano-hosted hydrothermal systems produce plumes of persistently venting fluids and particles over submarine volcanoes, and eruptions produce transient plumes that are larger and shorter lived. These are mapped using computer-controlled towed packages of CTD (conductivity, temperature and depth) and nephelometry (light scattering) on a sampling rosette fitted with computer-triggered bottles to take water samples for analysis on the ship.

BIOTRANSECTS

Just as on land, biologists will place markers at sites of interest and use repeat visits to study benthic community composition, structure and stability in relation to possible changes in chemosynthetic energy sources from diffuse- and focused-flow hydrothermal venting. They also deploy colonisation experiments (e.g. preformed blocks of rock) to examine settling and recruitment of microbes and macrofauna larvae.

WATER SAMPLING

Tools to sample hot hydrothermal fluids and to preserve their integrity include titanium samplers fitted with valves, a long sampling tube and devices to draw in the hot fluids (up to 400 °C) activated by a submersible manipulator (robotic arm). Other similar devices are used to sample fluids for gas analysis, a key parameter in volcanology. These devices maintain the sample at *in-situ* pressure during the trip back to the sea surface and are chemically inert to keep fluid compositions intact. Some *in-situ* sampling devices can take multiple samples at once, and even carry out radioactive labelling experiments for *in-situ* metabolic or bioactivity analysis.

ROCK AND SEDIMENT SAMPLING

Volcanic rocks hold many keys to unravelling volcanic eruption styles and durations, as well as conditions in the magma leading up to an eruption, via their chemical and textural make-up. Additionally, geological mapping of individual volcanic eruption deposits is critical for assessing the frequency and duration of individual eruptions at submarine volcanoes. Like geology on land, such studies are conducted by visual observations and physical sample collection. Rocks are generally sampled with a manipulator or scoop. Sediments are sampled with long tubes capped on one end (pushcores) or special scoop bags designed to preserve the fine particles as well as coarser ones. Most of the analyses of these specimens happen on shore.

ERUPTIONS OBSERVED IN REAL TIME.

Early in the era of *in-situ* volcano studies, several submarine eruptions were detected either by chance or hydroacoustic monitoring. In most of these cases, repeat sonar mapping of the seabed revealed new rock deposits, which were subsequently studied along with the hydrothermal venting and resident ecosystems. In the mid- to late 2000s, the holy grail of submarine volcanology was reached, with the *in-situ*, real-time observation of a glowing hot pyroclast ejection at Northwest Rota-1 seamount (near the Marianas Islands) and the eruption of pyroclasts and molten lava flowing across the seabed at West Mata volcano in Tonga. To date these remain the only two deep submarine eruptions caught in the act. They have provided a wealth of observational data revealing how deep-sea eruptions occur, how volcanic materials are distributed into the landscape, and how eruptions perturb the local water column and seabed ecosystems.

The quality of information that can be determined during and after submarine volcanic eruptions depends on technology and human resources as well as weather and sea state. The future of the discipline is focused on whole-ocean monitoring, inexpensive and easy-to-deploy sensor networks, autonomous vehicles with greater deployment duration and functional capabilities, automated response capabilities, and *in-situ* biological and chemical analysis. To really learn about volcanic impacts in the deep ocean, such studies need to take place in many locations around the globe. This can be a challenge given the vastness of the world's oceans. ES

Ken Rubin is a professor and former department chair of Earth sciences at the University of Hawaii Manoa, with research interests in volcanology and sea-level change. In his 26 years in Hawaii he has participated in 25 human-occupied submersible dives and 100 ROV dives in sites around the Pacific Ocean. He holds a bachelor's degree in chemistry from the University of California, San Diego, and masters and doctoral degrees in oceanography and Earth sciences from Scripps Institution of Oceanography, UC San Diego.
@kenhrubin

ANALYSIS

Improving air quality: How ports can help

Michael Bull outlines the sources of air pollution around ports, and the solutions being proposed and implemented.

It should be no surprise that a location such as a port, which concentrates shipping and road transport into one area, should be considered a prime target for actions to improve air quality. This is reflected in the UK government's latest draft Air Quality Strategy, in which one of the proposals is that major ports in the UK will be required to develop air quality strategies to reduce emissions from both shore-side and shipping. Though this would appear to be a sensible action that could achieve air quality improvements, when UK ports are examined in more detail, it is questionable just how big an impact they have on air quality.

© Peel Ports

UK ports certainly involve the operation of vessels, vehicles and equipment, all of which emit pollutants into the atmosphere. However, the ports themselves have very little control over most of these sources. They do not own or operate the ships visiting the ports, nor do they operate the road vehicles used to transport goods and passengers using the ports. In some cases they are essentially only the landlords of the site, with the main port-related activities being carried out by their tenants. Most UK ports only operate a limited amount of machinery used to load, unload and transport cargo around the docks, and a small number of vessels such as tugs and pilot craft.

AIR QUALITY AROUND PORTS

The UK Major Ports Group (UKMPG) recognised that air quality was going to be an environmental issue their members would have to take into account and therefore commissioned and published (in September 2018) a study examining air quality around ports that also assessed mitigation measures that could be applied within each port's air quality strategy[1]. In this study, the recent trends in air quality around three example ports were examined and, where data was available, the contribution of the shipping and ports' activities to local pollutant concentrations was assessed. Two of the example ports were located in cities and the other was in a relatively rural location. Generally the air quality trends in nitrogen dioxide concentrations around ports were no different to those in other parts of the country near roads or in a city centre. Concentrations have been relatively stable or showing a slight decline in the last five years. In nearly every location examined, the main source of NO_x near ports was the local road network, but no port had detailed traffic information available to allow the contribution from vehicles using the port to be isolated, although clearly in some locations they would be responsible for the majority of the HGVs on the road links.

Emissions from the ships themselves were interesting. In a national context, domestic shipping is responsible for some 21 per cent of the total UK NO_x emissions from transport. This is a significant contribution, but in terms of local air quality, these emissions are often released in locations where they have little impact on pollutant concentrations. The Pollution Climate Mapping (PCM) modelling carried out on behalf of the Department for Environment, Food and Rural Affairs (Defra)[2] does give some useful information. The contribution of shipping to the regional background NO_x concentration is usually low, less than 1 $\mu g/m^3$. More locally to ports, the contribution of shipping to urban background pollutant concentrations can be higher, in some cases greater than 20 $\mu g/m^3$. The higher concentrations are only found close to where the ships berth or operate and usually the contribution declines a few hundred metres from the activity.

Looking at the activities within the ports, such as the machinery used for loading and unloading or moving goods and passengers within the ports, their contribution is very small. A study was carried out recently to examine a proposed Clean Air Zone in Southampton, including a detailed emissions inventory for the port and a detailed source apportionment for road links near to the port. Even very close to the port entrance, the contribution to local NO_x concentrations was less than 1 per cent of the total local NO_x concentrations.

Clearly the focus of air quality improvements near ports needs to concentrate on road traffic and to a lesser extent, shipping emissions.

THE ROLE OF PORTS

Nevertheless, ports can also play a role and have taken action to reduce their impact on air quality. They can act as important influencers and facilitators for other parties involved, such as the ships' operators. This influence can help to drive environmental improvements in the marine environment.

Some ports, notably the Ports of London and Southampton, have already published air quality strategies that detail the measures they are taking and propose to implement in the future. These either include or propose green tariffs, which are cost reductions for vessels that meet certain standards. In the case of the Port of London, the tariff will give up to a 5 per cent discount if the vessel scores above 30 on the Environmental Ship Index (ESI; a way of identifying ships that emit less NO_x, sulphur dioxide and greenhouse gases than are currently required by the International Maritime Organization)[3].

Some ports are also examining the use of lower-emission vessels (that use either fully electric

▼ **Cranes and vessels at the Port of Cardiff. (© Associated British Ports)**

ANALYSIS

▲ **Port of Cardiff, drone view. (© Associated British Ports)**

or hybrid technology). Although this is at a small scale at present, they act as important examples of what can be achieved and assist in driving forward technological improvements for the whole industry.

Other ports have already taken action to reduce their impact as a result of the air quality management process being carried out by local authorities. In one case at Felixstowe, an Air Quality Management Area (AQMA; where the area is put on notice to improve its air quality) was revoked as a result of measures largely taken by the local port operator.

MITIGATION MEASURES

In terms of port operations, it is often difficult to identify any measure that would have a significant impact without making major changes to the activity or reducing it. However, for several UK ports, there is one such measure that can significantly reduce the numbers of vehicles travelling to and from the site, and consequently result in reductions in local emissions and local air quality improvements. This is the use of rail to transport freight. Many ports have good rail connections and already use rail, while others are expanding their facilities. At one of the study ports, nearly 40 per cent of the freight in containers was moved by rail in recent years. The use of rail is a choice made by customers but has been supported in recent years by government freight subsidies. Unfortunately, these have begun to drop and the impact of these reductions can be clearly seen, with the proportion of freight moved at the study port reducing from 39 per cent to 32 per cent in the last two years – in this case this was the equivalent of nearly 100,000 HGV movements a year. Given that the greatest need to reduce pollutant concentrations is over the next two to three years, an increase in the support grant would be a simple measure that could result in a significant reduction in emissions.

The second measure that has received a lot of attention is the use of shore-side power. When vessels are at berth in a port, they source power from auxiliary generators on board ship. For some vessels these generators are sizeable: a cruise liner's auxiliary generator can typically generate around 12–14 MW of power. Where several vessels are berthed, the power generation could be over 50 MW. This level of generation, usually using oil as a fuel, can be seen as a significant source of pollutants and consequently shore-side power (also called 'cold ironing') is often proposed. The berthed vessels receive power from the grid instead of generating it themselves, thus reducing local emissions. This measure clearly removes a source of pollutants, although where data is available, the impact of these emissions on local air quality is relatively small. Installing shore-side power requires quite substantial infrastructure, but ports such as Southampton have a target to implement this measure while noting that, at present, only about 20 per cent of cruise ships can use this facility. In many cases, the current grid connection cannot provide sufficient power and an upgrade would be required. However, it is more widely applied to smaller vessels and most ports will use shore-side power for their own smaller vessels.

Managing vehicle movements at ports is important to ensure that they are not delayed, and many ports use vehicle booking systems to manage their vehicle arrivals. Although air quality improvements are not necessarily the primary purpose, reducing queuing and idling means emissions reductions are a secondary benefit.

Actions to improve air quality around ports can, in some cases, have wider air quality improvements, particularly those that relate to reducing emissions from ships themselves. Such actions are largely applied at a national or international level by government agreement. The MARPOL[4] convention resulted in the establishment of Emission Control Areas (ECAs) which included parts of the UK. This convention was mainly aimed at reducing sulphur dioxide emissions but also covers other pollutants such as NO_x. ECAs have been very successful in reducing sulphur dioxide concentrations at some UK ports such as Dover, where an AQMA was revoked.

The full report prepared on behalf of the UKMPG examines several other mitigation measures and provides a toolkit for UK ports to assist them in developing their air quality strategies. In recent years, many UK ports have themselves been examining ways to reduce their air quality impacts, and the proposed requirements in the draft Air Quality Strategy will no doubt accelerate these initiatives. ES

Michael Bull is a Director of Arup's Environmental Consulting business, and has over 30 years of experience in air quality assessment, mainly examining the impacts of transport infrastructure. He was the Project Director for the work carried out for UKMPG and one of the principal authors of the research report and Vice Chair of the IAQM.

REFERENCES

1. Ove Arup and Partners Ltd (2018) UK Major Ports Group (UKMPG) Air Quality Study Research Report.
2. Defra, UK Air Information Resource. Air modelling for Defra. ‹uk-air.defra.gov.uk/research/air-quality-modelling?view=modelling›
3. International Maritime Organisation. International Convention for the Prevention of Pollution from Ships (MARPOL). ‹www.imo.org/en/About/conventions/listofconventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx›
4. World Ports Sustainability Program. Environmental Ship Index ESI. ‹www.environmentalshipindex.org/Public/Home›

FEATURE

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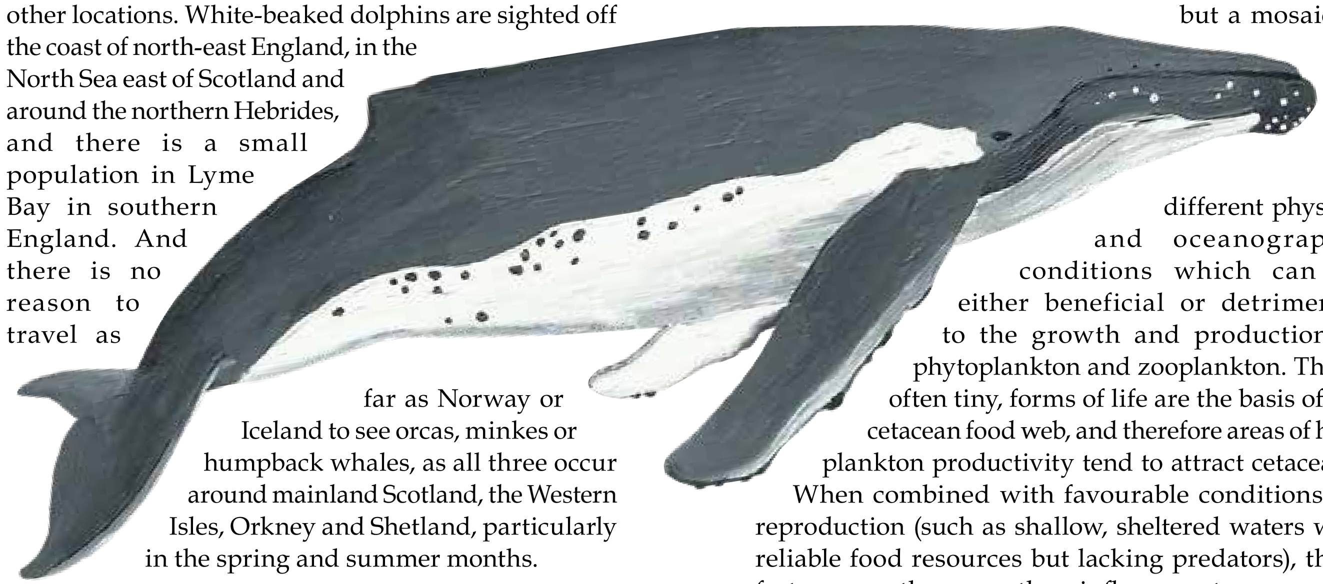
The cetaceans of the British Isles and a changing marine environment

Chiara Giulia Bertulli and **Peter Evans** describe ongoing shifts in abundance and distribution.

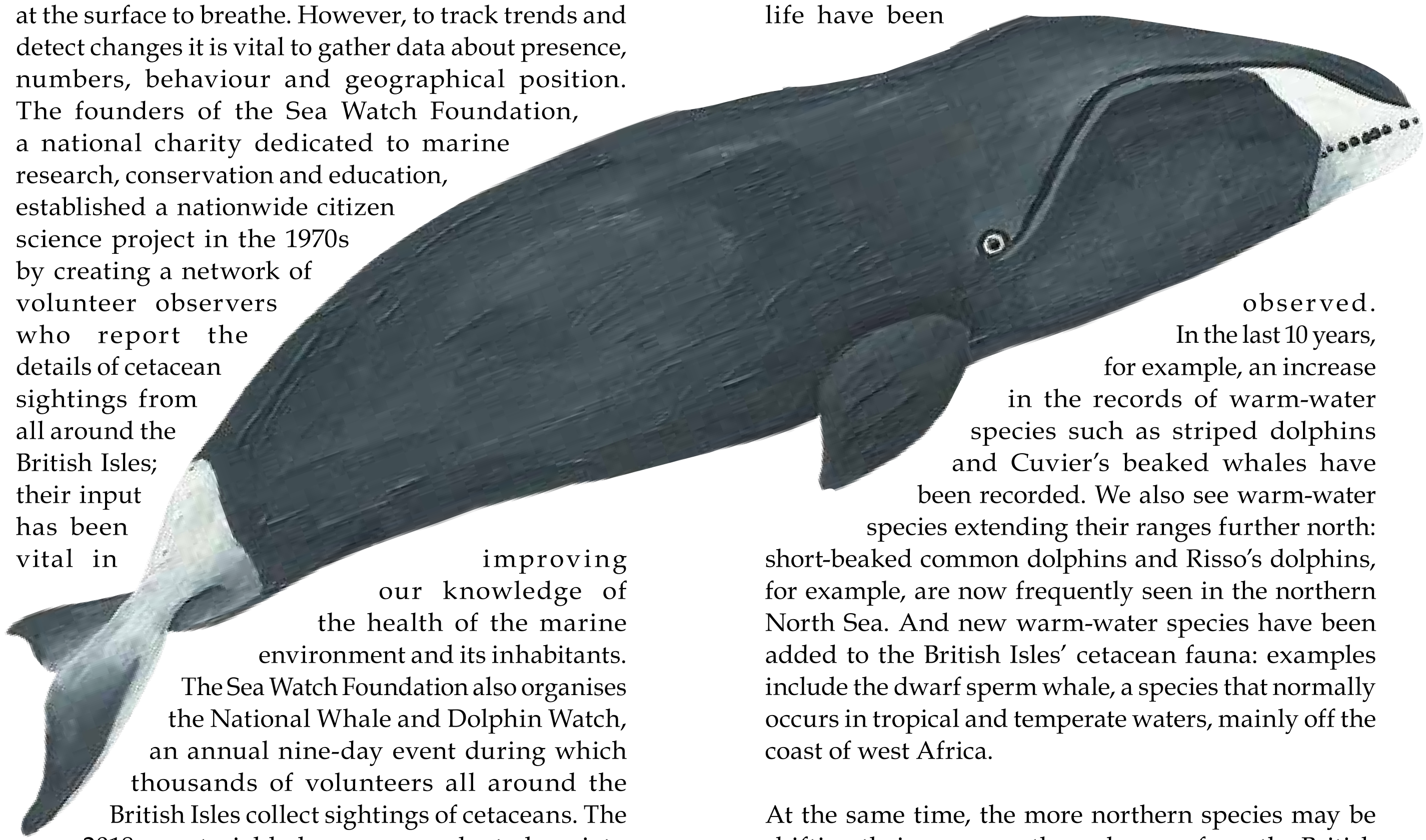
The waters around the British Isles hold many important sites for whales, dolphins and porpoises (collectively called 'cetaceans') to feed, give birth or raise their young. In total, 29 species have been recorded, almost one-third of the 90 species found worldwide, which highlights how rich our waters are for these magnificent and treasured animals. Harbour porpoises are the most common and widespread – they can be spotted almost anywhere around the coast.

Bottlenose dolphins are seen almost daily from places such as New Quay on the Welsh coast and Chanonry Point in the Moray Firth, and less often from several other locations. White-beaked dolphins are sighted off the coast of north-east England, in the North Sea east of Scotland and around the northern Hebrides, and there is a small population in Lyme Bay in southern England. And there is no reason to travel as far as Norway or Iceland to see orcas, minkes or humpback whales, as all three occur around mainland Scotland, the Western Isles, Orkney and Shetland, particularly in the spring and summer months.



COLLECTING DATA

Gathering information about population sizes, movements and distributions of cetaceans is challenging: they travel long distances and spend most of their time underwater, with only brief appearances at the surface to breathe. However, to track trends and detect changes it is vital to gather data about presence, numbers, behaviour and geographical position. The founders of the Sea Watch Foundation, a national charity dedicated to marine research, conservation and education, established a nationwide citizen science project in the 1970s by creating a network of volunteer observers who report the details of cetacean sightings from all around the British Isles; their input has been vital in improving our knowledge of the health of the marine environment and its inhabitants. The Sea Watch Foundation also organises the National Whale and Dolphin Watch, an annual nine-day event during which thousands of volunteers all around the British Isles collect sightings of cetaceans. The 2018 event yielded an unprecedented variety of cetaceans, possibly because of the stable high temperatures, which may well have created ideal conditions for plankton fronts to develop, attracting shoals of fish and in turn whales and dolphins.



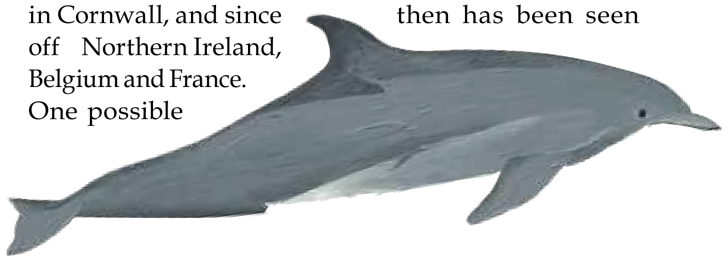
CHANGING DISTRIBUTIONS

The reason why whales, dolphins and porpoises occur in certain areas is because our oceans are not uniform, but a mosaic of different physical and oceanographic conditions which can be either beneficial or detrimental to the growth and production of phytoplankton and zooplankton. These, often tiny, forms of life are the basis of the cetacean food web, and therefore areas of high plankton productivity tend to attract cetaceans. When combined with favourable conditions for reproduction (such as shallow, sheltered waters with reliable food resources but lacking predators), these factors more than any others influence cetacean spatial and temporal patterns of distribution.

With recent records of increased sea temperatures in the waters around the British Isles, alterations in the distribution and abundance of many species of marine life have been observed. In the last 10 years, for example, an increase in the records of warm-water species such as striped dolphins and Cuvier's beaked whales have been recorded. We also see warm-water species extending their ranges further north: short-beaked common dolphins and Risso's dolphins, for example, are now frequently seen in the northern North Sea. And new warm-water species have been added to the British Isles' cetacean fauna: examples include the dwarf sperm whale, a species that normally occurs in tropical and temperate waters, mainly off the coast of west Africa.

At the same time, the more northern species may be shifting their range northwards away from the British Isles as a result of rising sea temperatures – white-beaked dolphins have become scarcer in the southernmost North Sea, probably in response to changing distributions of their prey, and are now mainly seen in the central and northern North Sea, around Orkney and across to north-west Scotland. In previous decades, Atlantic white-sided dolphins were frequently seen west of Ireland. Nowadays, the British Isles and Ireland represent the southernmost edge of their range, with the species appearing to be shifting northwards.

However, some unexpected changes in the opposite direction have also been observed. A bowhead whale, a species largely confined to the Arctic, was sighted off the Isles of Scilly in February 2015, more than 3,000 kilometres from its normal range. The same species (possibly the same individual) was re-sighted a year later close to shore at Marazion near Penzance, in Cornwall, and since then has been seen off Northern Ireland, Belgium and France. One possible explanation is that ice melt is causing the ice to fragment, allowing icebergs and pack ice (with which these species closely associate) to drift south from the Arctic. The welcome increase in the size of the West Greenland population of bowhead whales may also be a contributory factor. The other arctic species sighted in the waters around the British Isles in recent years is the beluga (also called the white whale). Belugas were seen on multiple occasions in 2015 off the coast of eastern England and Northern Ireland, and the one in the Thames Estuary in 2018 represents one of the most southerly records of the species in Europe.



MULTIPLE THREATS

But the threats to cetaceans do not relate only to rising sea temperatures as a result of global climate change: they face many other threats. Harbour porpoises suffer entanglement in bottom set gillnets, common dolphins get caught in pelagic trawls; high levels of marine pollutants such as PCBs can disrupt reproduction and affect the immune systems of all marine mammals; noise from a range of human activities can disturb whales from their feeding grounds; and overfishing can leave porpoises dolphins short of food and put them under threat of starvation.

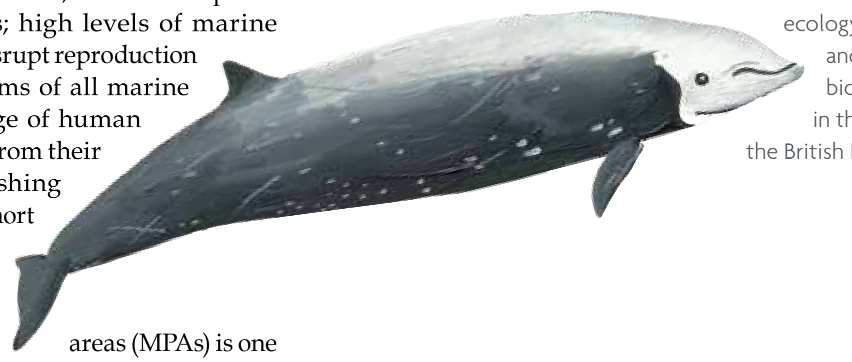
Establishing marine protected areas (MPAs) is one way to safeguard cetaceans from a range of threats. The great advantage of designating such areas is that they successfully protect not only that particular cetacean species but many other species occupying the same environment. The Sea Watch Foundation provided the basic information that led to two parts of Cardigan Bay being designated as Special Areas of Conservation (SACs; the Southern Cardigan Bay SAC and the Pen Llyn a'r Sarnau SAC) for bottlenose dolphins as they are important mating and calving grounds for this species. They also contain important feeding areas for the dolphins – observations of live and stranded individuals provide evidence that they eat a wide range of fish and crustaceans.

In the long term, there are going to be more warm water species expanding their distribution further north and therefore, an increase in the number of species sighted. However, we might lose species such as the Atlantic white-sided dolphin and maybe the white-beaked dolphin. All the tropical and warm temperate species entering the seas around the British Isles are likely to face a much wider range of human pressures along the industrialised coastlines of northern Europe, and the effect of these on cetaceans will need to be closely monitored.

ES

Chiara Giulia Bertulli is the Sightings Officer at Sea Watch Foundation. She holds a PhD in marine biology from the University of Iceland. Before joining Sea Watch she spent eight years leading a citizen science project focusing on the conservation, demography, social structure and health status of minke whales and white-beaked dolphins in Iceland.

Peter Evans established Sea Watch Foundation (formerly the Cetacean Group of the Mammal Society) in 1991 and is the charity's Director. He has worked on cetacean research for 40 years and oversees the national cetacean monitoring scheme of the British Isles. He is Honorary Senior Lecturer at the School of Ocean Sciences, University of Bangor, and his field research concentrates on the ecology, behaviour and conservation biology of cetaceans in the waters around the British Isles.



Cetaceans in order as they appear: top left, humpback whale; bottom left, bowhead whale; top right, dwarf sperm whale; middle right, bottlenose dolphin; and bottom right, Cuvier's beaked whale. (© Lexie Mac)

FEATURE

New members and re-grades

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Christine Irvine – Renewables & Sustainability Project Officer
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Anna Kalasinska – Data Quality & Radiation Protection Supervisor
Benjamin Lewis – Environmental Monitoring Advisor
Roisin Lindsay – Principal Consultant
Stuart McAleese – Managing Partner
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Neil Martin – Senior Environmental Health Officer
George Onuoha – Regulatory Services Officer
Jo Osmond – Environmental Consultant
Cara Peers-Smallwood – Environmental Consultant
Julia Reynolds – Project Officer: Team Leader, Contaminated Land
Marc Ross – Contaminated Land Manager
Paul Sanderson – Environmental Scientist: Air Quality
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Katherine Stanger – Senior Air Quality Consultant
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Grace Biddle – Graduate
Katharina Cameron – Graduate
Thomas Clarke – Geoenvironmental Consultant
Howard Cross – Aquatic Ecologist
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Yohlanda Day – Graduate
Maddalena De Lorenzo – Air Quality Consultant Assistant
Cat Dixon – Environmental Consultant
Ian Dunkley – Geo-environmental Engineer
Dominic Ellerton – Graduate
Rachel Ellis – Graduate
Cameron Farr – Geotechnical Testing Engineer
Laura Fleming – Environmental Coordinator
Matthew Greenwood – Environmental Consultant
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David Hastings – Environmental Consultant
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Sarah Low Wanlin – HSE & Sustainability Advisor
Clare Lydon – Graduate
Guy Marsden – Environmentalist
Abigail Pepler – Graduate Researcher
Emilia Pruszkowski – Environmental Consultant: Air Quality
Taraka Rhodes – Graduate
Jessica Rimington-Cross – Graduate
Connor Rusby – Assistant Air Quality Consultant
George Taylor – Graduate
Victoria Thomson – Analyst Consultant
Annie Trevis – Graduate Air Quality Consultant
Steven Vallance – Assistant Environmental Engineer
Lee Weir – Security Officer
Daniel Wicker – Assistant Environmental Consultant

Affiliate is for individuals with an interest in environmental issues but who don't work in the field, or for students on non-accredited programmes.

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Thomas Fynn – Regulatory Scientist
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ANALYSIS

Focus on the coast

Natasha Bradshaw outlines the increasing need for integrated management of the coast to keep up with the emerging interest in and pressures on our oceans.

This article highlights the potential of collaborative governance mechanisms and participatory approaches to involve coastal communities in decision-making and help to promote coastal and ocean stewardship.

ANALYSIS

COASTAL ECOSYSTEMS AND COASTAL COMMUNITIES

Coastal habitats, the transition zones between land and sea, are among the most productive ecosystems in the world – they produce disproportionately more services relating to human wellbeing than most other systems. These ecosystem services include food, shoreline protection, water quality maintenance, waste treatment, tourism, social and cultural benefits[1]. Coastal economies also depend upon coastal habitats to provide spawning ground for fish, sand for beach tourism and construction and deep-water harbours for ports and navigation, amongst other uses. Over one-third of the world's population live in coastal areas, which are defined by the United Nations Environment Programme as inland from the coastline to a maximum of 100 km or 50 m elevation, whichever is closer to the sea[2].

As population density and economic activity in coastal zones increase, pressures on coastal ecosystems increase: multiple users place multiple demands on coastal ecosystems, so the competition for natural resources is often higher than inland or at sea, meaning that coastal habitats have become highly threatened.

A wide range of industries benefit from the use of land near ports and harbours, with accessible transport infrastructure in low-lying coastal areas. The agricultural sector benefits from nutrient-rich farmland near the mouth of rivers and estuaries. Individual and commercial interests in high-value land and property contrast with the open-access demands of beach users and the benefits of coastal recreation to a wide population. Activities such as beach tourism, hotel development, sand extraction and port construction risk damaging the quality and sustainability of the resources people value at the coast. The demands of communities, recreational users, fisheries, ports and aggregate industry as well as energy and other commercial users need to be carefully managed to avoid conflict. Strong user-groups representing these interests are often formed with sailing clubs, angling clubs, conservation groups, hoteliers and residents needing a say in decision-making.

CHANGES TO COASTAL COMMUNITIES

Local coastal communities are likely to experience increasing pressure to meet national or regional development objectives for nuclear power stations, offshore wind farms and aquaculture to redress losses to fish stocks. Many countries are now progressing marine plans[3] which will lead to the allocation of space to maritime industries, many of which will require coastal access land. Coastal tourism, water sports and the recreational health benefits of being by the sea have been recognised, but development proposals can often overlook the need to factor these into decision-making. Socio-economic activities such as beach tourism have mushroomed in recent decades. However, sand mining and large-scale aggregate dredging may threaten the very land on which coastal communities rely[4]. Due to climate change, the increased risk of storminess and sea-level rise makes coastal communities increasingly vulnerable to flooding and erosion. Over-exploitation of coastal land squeezes habitats such as mangrove, salt marsh and mud flats, undermining their ability to provide a natural buffer to protect land, property and the natural resources upon which coastal communities rely. The loss of beaches and coastal habitats can put high-value coastal property and transport infrastructure at risk, leading to escalating costs of artificial coastal protection schemes such as concrete walls, rock armour and beach replenishment.

The demise of small-scale inshore fishing in favour of larger commercial-scale fishing in many parts of the world is another example of how recent changes have made coastal communities more vulnerable in socio-economic terms. In future we are likely to see increasing competition for space from the aquaculture and renewable industry sectors. The potential for harnessing tidal energy and other renewables from the sea could be both an opportunity and a risk to coastal communities – a risk that the character and traditional uses of the coast are compromised by large-scale development, but an opportunity for socio-economic revival, particularly in areas where social deprivation has become an increasing challenge.

If competition for resources is not governed or managed well, the quality of the environment for people and wildlife deteriorates and along with it, the value of the ecosystem services.

DECISION-MAKING FOR COASTAL ZONES

Where land meets sea, there is no obvious management unit or ecosystem boundary as there may be for a mountain range, a woodland or a river watershed. The coastal ecosystem is rarely seen as a whole, with monitoring and compliance standards typically based on specific indicators (e.g. water quality, fish catches, or habitats and species occurrence). Shoreline units are sometimes identified using 'sediment cells' to inform coastal protection schemes but the need for integrated management goes beyond this.

Currently, decision-making is often undertaken on a project or case-by-case basis, with limited application of strategic planning or cumulative effects assessment[5] to take account of the health of the ecosystem. The assessment of environmental impacts from development decisions is often limited to narrow timescales for public consultation, rather than ensuring full engagement across sectoral interest groups and the engagement of coastal communities with local knowledge. Decision-making can be also be slow and lack transparency. With new development opportunities emerging (such as renewable energy and aquaculture) there is a need to increase accountability to stakeholders and update approaches to resource management to emphasise stewardship[6].

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LEGAL & POLICY APPROACHES TO COASTAL MANAGEMENT

A focus on planning and management of the coast has emerged in recent decades through legislation, policy and practice. Early European Community action programmes drew special attention to coastal areas leading to a European Coastal Charter in 1981, which underscored the need for integrated planning of coastal areas[7]. During the 1990s, the European Commission recommended the implementation of integrated coastal zone management (ICZM) in Europe[8].

In 1992 the UN Earth Summit called on coastal states to set up ICZM strategies[9]. The Organisation for Economic Co-operation and Development (OECD) adopted a recommendation on ICZM which stated that 'the coastal zone … is under severe and increasing pressure from rapid urbanisation, pollution, tourism development and continued development in hazard prone areas. Resource allocation conflicts are increasing'. It advocated the need for coastal zone legislation to define roles and responsibilities, meet environmental objectives for coastal ecosystems and legal arrangements to deal with property rights, arbitrate in disputes and enforce legislation[10]. Advice was provided on how countries could provide governance arrangements to encourage an integrated approach.

Legislation for coastal zones continues to be pursued in some countries. South Africa introduced an Integrated Coastal Zone Management Act (2009). In Europe, Mediterranean countries are pursuing the ICZM Protocol (2010) and countries such as France continue to pursue an active coastal policy[11]. To help achieve sustainable management, a voluntary framework for ICZM emerged in countries such as the UK[12]. However, implementation is proving challenging with or without framework legislation.

Global progress is being made towards marine planning[3] and the designation of marine protected areas (MPAs), with mixed experiences of how the coast and coastal communities are engaged in the planning process, but

ANALYSIS

the need to acknowledge the land–sea connection is recognised[13]. The European Commission is making attempts to promote integration between terrestrial and marine planning through Article 7 of the EU MSP Directive (2014)[14] which requires that 'in order to take into account land–sea interactions … Member States may use other formal or informal processes, such as ICZM'[15]. It remains to be seen whether this will progress integrated management of coastal ecosystems and the extent to which coastal communities are engaged in the process. The introduction of marine planning with an overlap between marine and terrestrial land use plans in coastal zones between mean high and low water does not necessarily secure an integrated approach.

TOWARDS COLLABORATIVE COASTAL GOVERNANCE

There is nowhere more challenging to manage our co-existence in shared spaces[16] than in coastal areas with a higher concentration of the population competing over shared resources. This challenge is felt whether a statutory or non-statutory framework exists for coastal policy, planning and management. Aside from the regulatory and advisory duties of government, there are often a multitude of industries, local clubs, user and interest groups keen to use and protect (their) coastal resources. Current governance arrangements lack emphasis on their role in decision-making. Participatory approaches to decision-making are not consistently supported due to the perceived costs of proper engagement with coastal communities or a lack of political will to ensure open and transparent decisions.

Statutory obligations towards the sustainable management of coastal resources may be limited in the extent to which they encourage stewardship through standard consultation mechanisms. Non-statutory activity tends to be more engaged with society, raising awareness of problems and mobilising voluntary effort towards stewardship. Participatory engagement mechanisms can bring together regulators, industry, scientists and citizens on an informal basis for a geographical area or ecosystem. Since the 1990s, voluntary coastal and estuary partnership initiatives have evolved at the local level for approximately 40 areas around the UK coast[17]. They facilitate collaborative governance and participatory engagement, setting sustainability targets and pursuing joint projects, often demonstrating stewardship as they mobilise stakeholder and public engagement.

The source of many of the problems we face resides in failures of governance – the failure of our political, social, economic and administrative systems. The ecosystem is not always seen as a whole, with monitoring and compliance standards typically based on specific indicators and limited timescales for public consultation. There are now more avenues to challenge governments' environmental performance through charities, trusts and NGOs, who can represent the environment to give it better legal standing[18]. Yet we are still experiencing significant losses to the coastal environment through overfishing and illegal fishing, land-use change and habitat loss, invasive species, eutrophication from pollution and the associated health impacts. Despite the work of NGOs and voluntary initiatives highlighting the challenges faced in coastal areas, the rate of change and increasing vulnerability calls for a more radical shift in the way we look after coastal ecosystems. Collaborative (and good) governance requires mechanisms that must represent the long-term public interest.

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CONCLUSION

The optimal mechanism for an effective governance framework for coastal ecosystems requires further research and testing at different scales. Over 40 years of ICZM has been driven through top-down direction and voluntary co-operation efforts from the bottom up, but significant challenges remain to bring these efforts together and implement an integrated approach that makes a difference to sustainable management. With the renewed focus on statutory marine planning and the need to consider land–sea interactions, there may be cause to review outcomes from this experience to enable new recommendations towards coastal stewardship. **ES**

Natasha Bradshaw has specialised in coastal and marine planning, management and governance for 30 years. She is currently researching for a doctorate at the University of the West of England (UWE) Bristol, focusing on collaborative governance mechanisms to enhance coastal stewardship in the UK. Prior to this she led the oceans governance programme and Celtic Seas Partnership for WWF-UK and campaigned for the UK Marine Act. Her current appointments include: Adviser to the European Coastal and Marine Union (EUCC), Marine Management Organisation (MMO) representative to the Devon and Severn Inshore Fisheries and Conservation Authority (IFCA); and Trustee/Director of the Severn Rivers Trust.

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For more information, see: www.lrfoundation.org.uk/www.

REFERENCES

1. United Nations Environment Programme (UNEP) (2006) *Marine and Coastal Ecosystems and Human Wellbeing: A Synthesis Report Based on the Findings of the Millennium Ecosystem Assessment*. UNEP.
2. United Nations Environment Programme (UNEP) (2006) The value of coastal ecosystems. ‹web.unep.org/coastal-eba/value-coastal-ecosystems› [Accessed 5th October 2018]
3. Carr, S. (2017) Marine Spatial Planning ten years later: A conversation with Charles 'Bud' Ehler Marine Ecosystems and Management Open Channels blog. ‹meam.openchannels.org/news/meam/marine-spatial-planning-ten-years-later-conversation-charles-bud-ehler› [Accessed 5th October 2018]
4. Pilkey, O.H. and Cooper, J.A.G. (2014) *The Last Beach*. Durham, NC: Duke University Press.
5. The Planning Inspectorate (2015) Cumulative Effects Assessment Advice Note. Bristol: The Planning Inspectorate.
6. Berkes, F. (2015) *Coasts and People: Interdisciplinary Approaches to Coastal and Marine Resource Management.* New York: Routledge.
7. European Commission. EU Policy on Integrated Coastal Management. ‹ec.europa.eu/environment/iczm/background.htm› [Accessed 18th September 2018]
8. European Commission. Coastal Zone Policy. ‹ec.europa.eu/environment/iczm/proprec.htm› [Accessed 1st October 2018]
9. United Nations (1992) Agenda 21. United Nations Conference on Environment & Development, Rio de Janeiro, Brazil, 3–14 June 1992.
10. European Council. (1992) Recommendation of the Council on Integrated coastal zone management. ‹ec.europa.eu/environment/iczm/pdf/OECD_Memorandum.pdf›
11. Living with a changing coast. Managing the coast in France. ‹www.licco.eu/changing-coastline/caring-for-the-coast/managing-the-coast-in-france/› [Accessed 18th September 2018]
12. Department for Environment, Food and Rural Affairs (Defra) (2008) A strategy for promoting an integrated approach to the management of coastal areas in England. PB13199. ‹www.southerncoastalgroup.org.uk/pdfs/DEFRA%20ICZM%20Strategy.pdf› [Accessed 5th October 2018]
13. Agardy, T. (2013) Integrated land-and-sea management: Examining three cases where marine practitioners are looking upstream. Marine Ecosystems and Management, 6 (6). ‹www.doc.as/oceans/wp-content/uploads/2013/06/MEAM31.pdf› [Accessed 5th October 2018]
14. European Commission (2014) Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning. ‹eur-lex.europa.eu/legal-content/EN/TXT/?qid=1460624697519&uri=CELEX:32014L0089› [Accessed 14th April 2016]
15. ICM is a more recent term used to describe ICZM where the use of 'zone' is not considered essential.
16. Healey, P. (1997) *Collaborative Planning: Shaping Places in Fragmented Societies*. London: Macmillan Press Ltd.
17. Stojanovic, T. and Barker, N. (2008) Improving governance through local coastal partnerships in the UK. The Geographical Journal. 174 (4), pp.344-360.
18. Stone, C.D. (2010) *Should Trees Have Standing? Law, Morality, and the Environment.* 3rd edition. New York, Oxford: Oxford University Press.

FEATURE

Bringing oceans back from the brink

Louise Heaps discusses the conditions needed for achieving a sustainable blue economy.

As land-based resources are increasingly exhausted, the world is looking to the ocean for new opportunities to support economic growth. Huge advances in technology are now enabling us to explore and potentially plunder valuable mineral deposits even in the deepest parts of the ocean floor. According to the OECD[1], by 2030 the ocean economy, which is taken to include all economic sectors with a direct or indirect link to the ocean, is projected to double, outperforming the growth of the global economy as a whole in terms of added value and employment. With the total value

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FEATURE

of the ocean economy estimated to be US$24 trillion, providing annual benefits of at least US$2.5 trillion to our global economy[2], unprecedented development is expected in coastal tourism, infrastructure, energy, biotechnology, transport and food production.

However, over-exploitation and the growing threats facing ocean ecosystems means that many of the indicators of ocean health are now trending in the wrong direction. The cumulative impacts of unsustainable fishing, poorly planned coastal development, excessive land-based urban and agricultural pollution as well as climate change are all degrading the oceans' natural capital and rapidly eroding the resource base upon which healthy ocean ecosystems, communities and indeed our economic growth expectations depend.

"As the primary user of the blue economy, the private sector is critical to turning this vision into reality"

Coral reefs are a case in point. In only 30 years, the Earth has lost around half of its reefs due to a range of pressures. On current climate-change trajectories, scientists project that up to 90 per cent of the planet's coral reefs are likely to suffer bleaching and disappear by mid-century[3]. While they occupy less than 0.1 per cent of the marine environment, coral reefs provide habitat for at least 25 per cent of all marine species. Given that reefs also support essential food supplies and provide jobs and coastal protection to hundreds of millions of people, such losses would have serious social and economic ramifications.

THE RISKS OF BUSINESS AS USUAL

Despite these stark facts, the argument for the intrinsic value of our ocean – not to mention its vital life-support functions in terms of providing half of the oxygen we breathe, regulating our climate and buffering the effects of climate change – has not sufficiently motivated decision-makers to act. However, the social, economic and risk-reduction case for restoring and protecting ocean health is beginning to resonate with many governments and business leaders alike.

The World Economic Forum now ranks the following as its top risks over the next 10 years[4]:

- extreme weather;
- failure to adapt to climate change; and
- ecosystems collapse.

Fish stocks in some tropical areas are predicted to decline by an estimated 40–60 per cent due to climate change alone[5], with significant implications for the food security and livelihoods of many millions of people in developing coastal states. The estimated USD$83 billion losses in annual global revenue caused by overfishing[6] is also leading to a substantial leakage of value out of the ocean economy. Put simply, the current level of unsustainable economic activity in the ocean is already undermining ocean health and its ability to continue to deliver essential ecosystem services, with long-term consequences for all of us.

This of course runs counter to the ambitions of the Sustainable Development Goals (SDGs), in particular the ocean goal (SDG14), agreed in September 2015[7], which envisage 'a world in which poverty is eradicated, economies are transformed and development takes place within planetary boundaries[4].

Unsustainable investment lies at the heart of this degradation, facilitating levels of development that exceed the carrying capacity of our ocean and its ecosystems. Yet, if the ocean's natural capital was properly valued and mainstream finance was redirected towards its restoration, significant opportunities could be realised. Certainly, the World Bank[6] estimates that the global marine fish harvest could be 13 per cent higher if fisheries were managed more sustainably, and there is increasing evidence that up-front investments in fisheries recovery can generate substantial social and economic returns over time[8].

The question is: do we have the right combination of responsible governance, tools, innovation, resources and political will to achieve the healthy, diverse, productive and resilient marine ecosystems required to realise the substantial benefits that the ocean offers?

A FRAMEWORK FOR SUSTAINABLE INVESTMENT

The term 'sustainable blue economy' is slowly being adopted into global policy parlance, taken to mean the sustainable use of the ocean and its resources for economic development without compromising its integrity and health. Sustainable blue economy approaches aim to:

- build ocean resilience;
- maintain ecosystem integrity; and
- safeguard the livelihoods of those who depend on living oceans.

As the primary user of the blue economy, the private sector is critical to turning this vision into reality. Indeed, global businesses are becoming increasingly aware of the long-term risks of continuing with business as usual, not least in terms of the potential regulatory, market and physical risks resulting from unsustainable ocean activities[9]. By the same token, they are awakening to the benefits of sustainability, both in terms of improved investment prospects and the long-term viability of their companies[10].

Incentives and capital urgently need to be directed to a sustainable blue economy vision, and the finance and investment sector are at the centre of driving this transition. But in an environment that already carries significant business risk as a result of the complexity and inconsistency of the regulatory environment, information and data challenges, and the cumulative nature of impacts, there is limited available guidance on how to act. Whilst SDG14 offers a clear framework and a significant opportunity to address some of the biggest threats facing our oceans today, there is an urgent need for industry-specific targets, measures and guidelines, better integrated regulation and stronger incentives.

Without a framework to guide sustainable ocean-related investment and development policy, investors could see significant margin-diluting risks and a portfolio of stranded assets. To address this, a new set of voluntary sustainable blue economy finance principles specific to the sustainable blue economy have been developed by WWF, the European Commission (EC), the European Investment Bank (EIB) and the World Resources Institute (WRI) to act as a framework for sustainable mainstream investment and development policy decisions, underpinning the delivery of the SDGs.

"Fish stocks in some tropical areas are predicted to decline by an estimated 40–60 per cent due to climate change alone"[5]

These principles build on existing frameworks for this sector, including the Equator Principles[11] and the Principles for Responsible Investment[12], as well as WWF's sustainable blue economy principles[13]. They aim to ensure that ocean-related investment delivers long-term value without having a negative impact on marine ecosystems, on efforts to reduce carbon emissions, or on ocean-based businesses of all sizes and the livelihoods of people who depend on them. They were presented at the Our Ocean conference in Bali in October 2018, with an ambition of achieving widespread adoption by the finance, investment and insurance sectors.

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GETTING THE ENABLING CONDITIONS RIGHT

The true potential of the blue economy can only be realised if our ocean's health is secured. We must therefore invest in restoring, protecting and sustainably managing ocean assets. Whilst there is no shortage of investment capital globally, the lack of high quality, scalable and investable projects, coupled with an often-weak governance environment and data limitations on which to base investment decisions and measure impact[14] present real challenges. Certainly, the lack of debt or working capital to finance fisheries recovery at the pace and scale required is considered to be a significant obstacle to achieving sustainability in this sector[15].

There is a need to create an enabling environment that reduces the inherent risks associated with operating in the ocean environment. The public and private sectors have a critical role in achieving this by, for example, committing up-front investments and guarantees to address unfavourable governance conditions through the use of blended finance, defined as 'the strategic use of development finance and philanthropic funds to mobilise private capital flows to emerging and frontier markets'[14]. Tailored insurance products can also improve the risk profile of ocean-based projects, thereby strengthening investor confidence.

Several innovative financing mechanisms are also now starting to emerge, creating new forms of finance for development opportunities that fulfil the ambitions of a sustainable blue economy. These include mobilising domestic sources of income through payment for ecosystem services (PES) models, or addressing sovereign debt through debt-for-nature swaps. Blue carbon is also gaining traction and is leading to increased interest in mangrove and seagrass rehabilitation. In addition, a handful of emerging ocean private equity investment funds are also now looking to generate financial returns, including Althelia Ecosphere's Sustainable Ocean Fund launched in early 2016. The concept of blue bonds is also emerging, with the development of the Seychelles Blue Bond[16] which, during the 2018 Our Ocean conference, the Seychelles Government announced to support sustainable development and management of the Seychelle's marine resources. Nevertheless, many of these approaches are still untested and there is an urgent need to further explore, pilot and advocate them.

Reducing risk to secure investor confidence in sustainable blue economy projects will also require governments to substantially strengthen regulation and policies that build resilience and support the sustainable management and protection of natural capital. Emerging and well-established governance tools, regulations and approaches, if implemented effectively, could achieve this and improve long-term opportunities for growth. Marine protected areas (MPAs), for example, aim to protect fragile and representative habitats and species so that marine life is able to breed and mature, allowing the system to recover and become more resilient to human pressures. Not only have MPAs been shown to increase fish biomass[17], they make economic sense if effectively managed, potentially creating billions of dollars of benefits[18]. Yet, despite a global agreement to protect 10 per cent of our oceans by 2020, only about 7 per cent of our oceans are currently under some form of protection; and significantly less is under effective management[19].

At larger scales, marine spatial planning (MSP) is an emerging ocean governance tool fundamental to the delivery of the growth ambitions of many coastal states. MSP provides a tool for looking holistically across seascapes as well as facilitating the consideration of competing interests and the cumulative impact of all the activities taking place in that area. In doing so, it aims to reduce conflict and help ensure that there is a space for nature, so that marine ecosystem resilience is not compromised and the replenishment of natural resources is supported. MSP is already underway at scale in many countries, including the UK, and requires multi-sector collaboration and concerted action in ways that have not been attempted before. If our ambitions for sustainable development in our oceans are to be realised, the effective application and investment into tools such as MSP is essential.

OPPORTUNITIES FOR THE FUTURE

Achieving a sustainable blue economy is fundamentally about systemic change. This will require substantial shifts in political will, new forms of investment and strong engagement with private sector. Getting the

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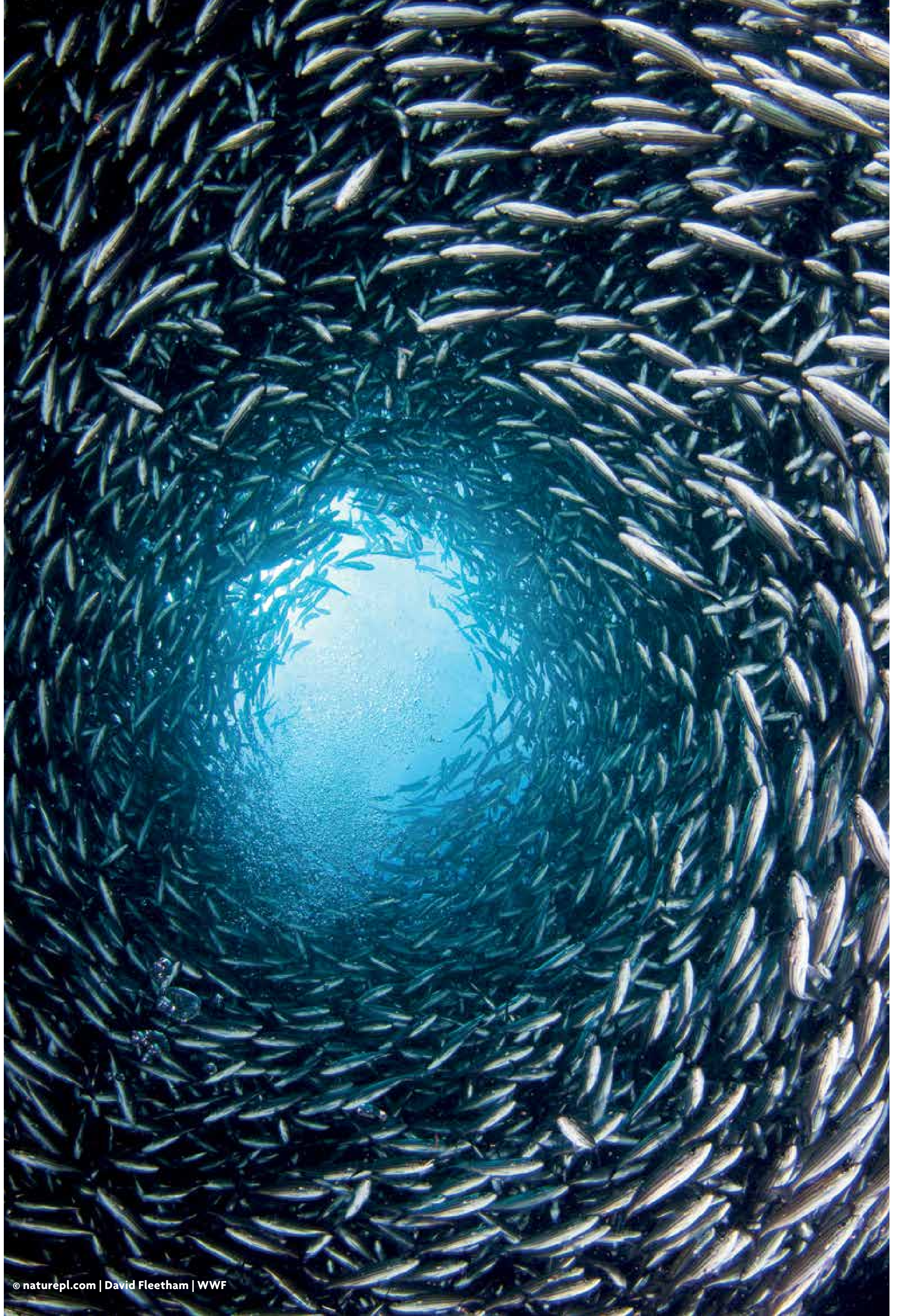
political traction and investment needed is challenging, but at the first UN Oceans Conference held in New York in June 2017 there was a real optimism for a sustainable approach to the blue economy; many small islands developing states (SIDS) in particular, including Fiji, Grenada, the Maldives, and the Republic of the Seychelles, are now framing their national strategies around this emerging approach. And with the blue economy becoming so prominent in political dialogues, the first-ever global conference on the topic will take place in Nairobi in November 2018.

If we are to steer the blue economy in a sustainable direction, active leadership and innovation are urgently needed across the public and private sectors. With the right kind of investment and supporting enabling environment, along with technological innovations, there is a momentous opportunity now to create a sustainable blue economy future – one that supports everyone's needs and in particular those fully dependent on the oceans for their wellbeing, long into the future. ES

Louise Heaps is WWF-UK's Head of Blue Economy and co-leads WWF's global sustainable blue economy initiative. She has worked in ocean conservation and management around the globe for over 25 years, spending five years in the Pacific Islands region. Louise also recently completed an MBA at the University of Exeter.



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REFERENCES

1. OECD (2016) *The Ocean Economy in 2030*. OECD Publishing, Paris. ‹doi.org/10.1787/9789264251724-en›
2. Hoegh-Guldberg, O., Beal, D. and Chaudhry, T. (2015) *Reviving the Ocean Economy: the case for action–2015*. Gland, Geneva: WWF International. ‹www.worldwildlife.org/publications/reviving-the-oceans-economy-the-case-for-action-2015›
3. van Hooidonk, R., Maynard, J., Tamelander, J., Gove, J., Ahmadia, G., Raymundo, L., Williams, G., Heron, S.F. and Planes, S. (2016) Local-scale projections of coral reef futures and implications of the Paris Agreement. *Scientific Reports*, 6, 39666.
4. World Economic Forum (WEF) (2015) *Part 1: Global risks 2015: Introduction*. ‹reports.weforum.org/global-risks-2015/part-1-global-risks-2015/introduction/›
5. Intergovernmental Panel on *Climate Change (IPCC) (2014) Climate Change 2014: Impacts, Adaptation and Vulnerability. Part A: Global and Sectoral Aspects*. UK: Cambridge University Press. ‹www.ipcc.ch/report/ar5/wg2/›
6. The World Bank (2015) *The Sunken Billions Revisited: Progress and Challenges in Global Marine Fisheries*. ‹www.worldbank.org/content/dam/Worldbank/Topics/Environment/Sunken%20Billions%20Revisited-web-2.pdf›
7. United Nations Deveopment Programme (UNDP) Sustainable Development Goals. ‹www.undp.org/content/undp/en/home/sustainable-development-goals.html›
8. Holmes, L., Strauss, C.K., de Vos, K. and Bonzo, K. (2014) *Towards investment in sustainable fisheries: A framework for financing the transition*. New York: Environmental Defence Fund, London: The Prince of Wales' International Sustainability Unit and Washington, DC: 50in10.
9. Research conducted by Accenture Development Partnerships for WWF; information not yet published.
10. Natural Capitalism (2013) *Sustainability pays: Studies that prove the business case for sustainability*. ‹mvonederland.nl/system/files/media/sust_pays-businesscase-reports.pdf›
11. The Equator Principles. ‹www.equator-principles.com/›
12. Principles for Responsible Investment. ‹www.unpri.org›
13. WWF (2015) *Principles for a Sustainable Blue Economy*. ‹wwf.panda.org/?247477/Principles-for-a-Sustainable-Blue-Economy›
14. World Economic Forum (WEF) (2015) *Blended Finance Volume 1: A Primer for Development Finance and Philanthropic Funders*. ‹www3.weforum.org/docs/WEF_Blended_Finance_A_Primer_Development_Finance_Philanthropic_Funders_report_2015.pdf›
15. Rangeley, R.W. and Davies, R.W.D. (2012) Raising the "Sunken Billions": Financing the transition to sustainable fisheries. *Marine Policy*, 36 (5), pp.1044–1046.
16. Richardson, P. (2016, January 24) Seychelles plans blue bonds to develop sustainable fisheries. *Bloomberg*. ‹www.bloomberg.com/news/articles/2016-01-24/seychelles-plans-blue-bond-sale-to-develop-sustainable-fisheries› [Accessed: 27th September 2018]
17. Worm, B. (2017) How to heal an ocean. *Nature*, 543, pp. 630–631.
18. Reuchlin-Hugenholtz, E., and McKenzie, E. (2015) *Marine protected areas: Smart investments in ocean health*. Gland, Switzerland: WWF.
19. Gill, D.A., Mascia, M.B., Ahmadia, G.N., Glew, L., Lester, S.E., Barnes, M., Craigie, I., Darling, E.S., Free, C.M., Geldman, J., Holst, S., Jensen, O.P., White, A.T., Basurto, X., Coad, L., Gates, R.D., Guannel, G., Mumby, P.J., Thomas, H., Whitmee, S., Woodley, S. and Fox, H.E (2017) Capacity shortfalls hinder the performance of marine protected areas globally. *Nature*, 543, pp.665–669.

Surfers against plastic

Paddy Fowler speaks to **Hugo Tagholm** about the crisis of plastic pollution in the oceans and on beaches worldwide.

Hugo Tagholm is currently the chief executive of Surfers Against Sewage, having previously worked with the organisation as an activist, regional rep and trustee. He is also, of course, a surfer.

We spoke to Hugo about his experiences in working to stem the flow of plastic that is being added to our environment and in raising awareness of the problems it causes.

Could you give a brief history of Surfers Against Sewage and how you became involved in the plastic pollution issue?
Surfers Against Sewage (SAS) was started as a movement and non-governmental organisation (NGO) back in 1990 and, as the name suggests, it was set up by surfers on the single issue of sewage. The focus then was particularly

on marine sewage disposal, which was causing chronic issues of water quality on the beaches around the UK. The focus on water quality in the first decade was in conjunction with sweeping new environmental legislation coming in from Europe: the Water Framework Directive, the Bathing Water Directive and many more. The game changer was the Urban Waste Water Treatment Directive, which put the responsibility onto the water companies, to make them stop pumping out sewage on a day-to-day basis all along the coastline of the UK.

Personally, as a supporter and member, I have been involved since the very early days when I met some of the founding members in 1991. After spending time working with Sarah Brown at her charity, Theirworld, and in a number of other charities, I took over as chief executive on the day of the financial crash in 2008. I wanted to reinvigorate SAS and give it a new structure, and so we built a programme of work on various issues:

- The ongoing work on water quality, particularly on real-time information about water quality;
- Climate change and its impacts on our oceans;
- Our recreational bathing waters, and
- Marine litter and plastic pollution.

We have been working on the plastic pollution issue for over a decade now and we have gone from mobilising around 500 volunteers a year in 2008, to working this year with the biggest beach-clean community in the UK: some 75,000 volunteers contribute around 225,000 hours of volunteering time to protect our beaches from plastic pollution.

But of course, we can't just litterpick our way out of the problem; we are working across the board around plastic pollution, particularly with interventions upstream. We do a lot of this through our all-party parliamentary group (APPG) in Westminster, which is the APPG in parliament that focuses on marine conservation. Here we bring together politicians, other NGOs, businesses and regulators to discuss policy, legislation and innovation in relation to various issues in marine conservation. Plastic pollution has been top of the agenda for a while now, and we have worked very successfully on campaigns such as the plastic bag charge, which has already reduced the number of plastic bags used in the UK by 10 billion.

We have also been one of the leading voices in the calls for a comprehensive deposit return system on beverage containers – cans and plastic bottles are found all too regularly in our rivers, across the countryside and on our beaches. A deposit return scheme is a proven method to trap that material in the economy rather than in the environment. Last year we delivered a petition of more than 30,000 signatures to Downing Street and now the government is committed to putting that in place; we will be looking at the design of the scheme over the coming months.

So we have been involved in plastic for a long time and in a number of ways. The abiding and ever-enduring characteristic of the organisation is that we represent perhaps the most authentic voice of the oceans in the UK in terms of the charity sector. We represent people who live and breathe the ocean, who have a really passionate connection with the ocean and often a daily physical connection. We amplify their voice through all of the work we do, from the beachfront to the front benches of parliament.

There is always a balance between consumer responsibility, producer responsibility and government regulation. Have we currently got the balance right?

Firstly, I would hesitate to call it a balance. I would look at it more as a set of links between the different actors. Currently the consumer is, in my opinion, taking on too much responsibility and the plastic pollution issue is all too often being characterised as a littering issue. It isn't just a littering issue, this is very much a plastic pollution issue. At the moment consumers are given products but not always the systems to recycle them effectively. That is something that the producers need to now step up to solve. The producers are putting this plastic in the hands of the public, and without the right systems in place those pieces of plastic are effectively weaponised. And even when those pieces of plastic do get recycled they may have already accumulated a huge number of recycling miles that are added to the footprint of that product. None of that is good enough.

Now the government needs to both incentivise and penalise producers, hopefully edging more towards incentivisation to do the right thing and move away from virgin plastics, reduce the amount of plastics they are using and use more sustainable alternatives, creating a truly circular economy with a domestic recycling economy infrastructure surrounding it. In my opinion, the rhetoric is all too often weighted on the consumer and the quite-often fictional character, 'the litterbug', that industry can use as a fall guy in the public space.

This is entirely a systems failure. There is more and more plastic being pumped out, yet we still have the same bins and recycling structure that we have had for years and years without much change. The bins in your park today are the same as they were 20 or 30 years ago. It is clear that the producers really aren't thinking about the full life cycle of the product, nor are they really wanting to take the financial hit to do so. Let's bear in mind that you and I – or, more accurately, the taxpayer – is paying for the end-of-life processing for a lot of these products through their council tax: the emptying of bins in our streets, our beaches and in other spaces, the street sweeping. Councils are dealing with the end-of-life cost that producers aren't taking account of, a second cost of the plastic products that consumers purchase through taxation.

What is the next step in the UK towards preventing plastic waste entering our oceans and what infrastructure changes do you see in the next 5–10 years?

Infrastructure will play a big part in it, but I think there isn't a silver bullet in all of this, as it isn't one single issue that needs solving. The current situation is the cumulative effect of plastic pollution over a number of years from a number of sources. One product taken in isolation can be made to seem very basic and dealt with simply, but the collective and compounded effect of lots of different products that are difficult to recycle and manage means that we are in a plastic pollution crisis. So we definitely need new systems, and the deposit return scheme, for example, requires national infrastructure to get bar coding on cans and bottles to be able to return them. We need the machines to be built and to know where they should be placed, as well as increasing numbers of recycling systems that give waste value in place to improve domestic recycling in other materials so that we don't ship our contaminated recyclate to far off places. And new systems need to be developed for people to manage the sheer volume of packaging that we are exposed to every day. Whether you are eating a sandwich or drinking a coffee, systems that truly work to capture the recyclate ready to be turned back into new food-grade packaging or other high-value products need to be put in place. That is really important.

> **"The producers are putting this plastic in the hands of the public, and without the right systems in place those pieces of plastic are effectively weaponised"**

But the government needs to play a big role in this. It needs to put the right legislation in place to push businesses to invest in the right areas. We are seeing some great leadership in terms of innovations from some companies at the moment. Companies such as Iceland are leading the supermarket charge and we see others trying to do more good and less harm. But we do need a full system change and we need the government to intervene in certain places, just as they have done in legislation that has driven some of the big changes we have seen with plastic bags. It wasn't just an overnight opinion change with consumers saying they didn't want a plastic bag, it was legislation that put the change in at the supermarket level and that's something that SAS campaigned for. We're now seeing the same legislation coming through on microbeads.

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We do need to legislate more around plastic, otherwise we may find that we do not have the systems in place that are suitable to really control plastic pollution. We need to create the toolkit of systems and processes that can really deal with this material in such a way that it can be conserved and valued.

The sources of ocean plastics differ greatly in reality to what the public imagines. Do you think that the fishing industry is being let off the hook?
No I don't, actually. Before the *Blue Planet* effect and the great public awareness around single-use plastics that we see today, Surfers Against Sewage was working as part of the Global Ghost Gear Initiative with great charities such as World Animal Protection to look at how to better control the loss of fishing gear. Ghost gear in our oceans kills so much marine life and the opportunity for industry to get together with the fishers, manufacturers, retailers and the charity sector to create a more efficient way of dealing with fishing gear is imperative. This pre-dated the great attention that we are seeing from government, the public and industry on single-use consumer plastics, so there has always been some heat there. There is a great understanding that fishing gear is one of the significant sources of marine plastic pollution and so changes in the system are coming too.

Bioplastics is a term that has been thrown around as a potential solution. What are your thoughts on this and other alternates to crude-oil-based plastics?
That's another really interesting question as it loops back to systems. Compostables or bioplastics, with the right systems to capture, recycle and reprocess or compost could be a really great part of the system. But we have to think of *all* of the impacts of any new alternative material. Currently, the problem is that if we put compostables and bioplastics into the recycling stream, they contaminate the traditional oil-based plastic recyclate, which complicates the recycling solutions. We have also got to think about land used for food balanced with our demand for bioplastics, so the jury is still out over the potential benefits on that front.

> **"We amplify their voice through all of the work we do, from the beachfront to the front benches of parliament"**

Surfers Against Sewage really believe that we shouldn't just be looking at replacements around plastics though. We have got to start by going back to the waste hierarchy and thinking more about where we can eliminate plastic, where can we reduce the resources we are using to package and market the products that we have in our world. Not just food, but other consumables and electronic goods, and the stuff you receive your online orders in, wherever we find plastic. We have got to think about elimination first and foremost, as there is clearly too much pointless plastic out there in our systems.

So there is obviously pointless plastic in our systems, but plastic is a very useful material, especially in increasing the shelf life of many foods, reducing food waste. Should our focus be on our better appreciation of plastic rather than removing plastic from our world?
I think we need to look at deposit return systems, they are part of a good circular economy. We have been talking to the Treasury about incentives for manufacturers to use more recycled content to wean themselves off of virgin plastics. We should look at the hierarchy of plastics from the pointless to the very useful, because plastic is a fantastically useful substance – it is important that we don't throw the baby out with the bathwater. But that's not to say that we should continue with business as usual, because we know there is a plastic pollution crisis in our oceans and that there is far too much plastic in every part of our environment. The reason it remains there is because plastic is such a strong and durable material, the very same properties that make it useful for wrapping things up and moving things around in. We have got to make sure we are using plastic in the right way, for the right products, with the right systems in place for the end of life so we can put it back into useful products.

The 10 most polluting rivers worldwide for plastic pollution carry around 90 per cent of all plastic contaminants, so how do surfers against sewage balance encouraging action at home versus tackling the problem in pollution hotspots worldwide?
First and foremost, I think the notion that those countries are polluting more than us, or the fact that they are, is often due to us exporting our contaminated and dirty waste to places because we haven't set up the right systems here. So their problem is in fact our problem, driven by our consumption and by the economic model that we have in place around that consumption. That isn't their wrongdoing, it's us passing the buck. Let's view their plastic footprint as our plastic footprint, and whilst we have to do more good here, we must encourage, help and support the implementation of the right structures to recycle and do more to control that plastic waste. Often there just isn't any recycling or waste management in place in these countries.

More to the point, with the global backlash against plastic pollution, we are seeing lots of leadership in developing countries – the banning of plastic bags and certain plastics ahead of developed countries, for example. Often progressive legislation is coming from those areas rather than from the tradition leadership in the west, so I think we should look there for inspiration to solve the issues at home, too.

We have got to work together as it is a global issue and we have got to have global solutions. Collaboration, innovation and legislation from across the world. We have to ensure those who are profiting most from the plastics are paying the most to stop their plastics polluting the world. ES

Paddy Fowler is the Publications Officer at the Institution of Environmental Sciences. He studied for an MSc in Science Communication before joining the IES in 2017. Paddy has a keen interest in aquatic conservation and an enthusiasm for communicating interesting sustainability innovations across the environmental sciences.

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