Issue 14 April 2020
ISSN 2052-5273

Special edition: The UN Decade on Ecosystem Restoration

The Marine Biologist

The magazine of the marine biological community

Coral restoration in a warming world

Mangroves: the roots of the sea

A sea turtle haven in central Oceania

The Marine Biological Association
Est. 1884
Incorporated by Royal Charter

Climate emergency: are we heading for a disastrous future?
Tropical laboratories in the Atlantic Ocean | Environmental change and evolution of organisms

The Marine Biologist
The magazine of the marine biological community

The Marine Biological Association
The Laboratory, Citadel Hill,
Plymouth, PL1 2PB, UK

Editor Guy Baker
editor@mba.ac.uk
+44 (0)1752 426239

Executive Editor Matt Frost
matfr@mba.ac.uk
+44 (0)1752 426343

Membership Alex Street
membership@mba.ac.uk
+44 (0)1752 426347
www.mba.ac.uk/membership

ISSN: 2052-5273

We welcome submissions of original and relevant material, letters and responses to published articles. For guidance, please see the magazine website or contact the Editor.

www.mba.ac.uk/marine-biologist

The Marine Biologist is published by the Marine Biological Association, Registered Charity No. 1155893.

Editorial

Welcome to the latest edition of *The Marine Biologist* magazine, in which we celebrate the UN Decade on Ecosystem Restoration (2021–2030). This year promises much for nature as the UN's Gabriel Grimsditch explains in his introduction to this special edition on page 15. The first set of targets under Sustainable Development Goal 14 (the ocean SDG) will be due, and 2020 also marks the announcement of the UN Decade on Ocean Science for Sustainable Development.

Marine ecosystems are by their nature less accessible than those on land, and with much of the ocean being global high seas, it is harder to manage activities than it is for the terrestrial environment, which at least falls under national jurisdiction. Direct restoration interventions are therefore limited to coastal and shallow water ecosystems, and in this edition we look at mangroves, coral reefs, oyster beds, seagrass beds, and estuaries through the lens of ecosystem restoration. The restoration of remote, open-ocean and polar ecosystems is a task that we must tackle collectively by agreeing radical reductions in unsustainable use of resources and emissions of greenhouse gases (see page 10).

The UN can mobilize resources to enhance commitments and actions at all scales to restore ecosystems. If we are to protect and restore nature by 2030, clear, communicable, measurable, and science-based global targets will be needed and workable mechanisms must be put in place for implementation. As the decade unfolds, we will bring you updates on ecosystem restoration efforts.

The vision for the UN Decade on Ecosystem Restoration includes the phrase: 'the relationship between humans and nature is restored'. Here, I think our own imagination has a major role. We imagine our world into reality, but, as Rob Hopkins argues in his book *From What Is to What If*, many aspects of our developed, industrialized society actively erode our imagination, leaving us with impoverished or dystopian visions of what the future holds. Initiatives such as the UN decade and the Commonwealth Blue Charter can shift our collective ideas of what can be, enabling us to envision futures that are more equitable, and that work with the grain of nature. Such shifts can be powerful drivers for change. Hopkins quotes Susan Griffin: 'let us begin to imagine the world we would like to inhabit'. I would love to hear what your future marine world looks like.

As always, I invite you to send me your views and comments on the magazine or on marine life in general. If we receive enough letters and emails we can publish them here—so do put pen to paper and start a conversation!

Guy Baker

The Marine Biological Association
Est. 1884
Incorporated by Royal Charter

www.mba.ac.uk

@thembauk

We welcome your articles, letters and reviews, and we can advertise events. Please contact us for details or see the magazine website at www.mba.ac.uk/marine-biologist

Front cover: Deploying ceramic shapes bearing settled coral as one of many types of intervention to restore coral reefs. Great Barrier Reef. © Australian Institute of Marine Science / Andrea Severati SECORE.
Back cover: Trindade Island and Martin Vaz Archipelago © Lucas Nunes.

Contents

Issue 14, April 2020

Top: Surveying the benthic community of Brazil's oceanic islands. © Sergio Floeter. Middle: Mangroves and rice growing together, Rufiji delta, Tanzania. © Dominic Wodehouse. Bottom: Masked boobies on Tongareva atoll, South Pacific. Image © Michael White.

Metal-Organic Framework material is a potent pollutant extractor

Researchers in Spain have developed a new material that can soak up pollution from water.

The substance can remove microplastics, dyes and other pollutants from water, and could find applications in detecting and monitoring pollution. It is a type of metal-organic framework (MOF), an organic-inorganic hybrid crystalline material with a porous, cage-like structure and an enormous surface area (in the case of some MOFs more than 7,000 square metres per gram). Its magnetic properties allow it to be extracted from water along with adsorbed contaminants. It is chemically stable and easy to clean and reuse.

A team of chemists led by Gemma Turnes at Mallorca's University of the Balearic Islands (UIB) synthesized the substance, and published their results in the journal *ACS Applied Materials & Interfaces*.

Those hoping for a magic clean-up of our seas may be in for a bit of a wait: Dr Turnes said 'These are preliminary results and the material has not been tested on real samples yet. We are most focused on its use as an adsorbent for solid-phase extraction to be applied to monitoring of pollutants'.

Ocean acidification affects shark denticles

Increasing ocean acidification could be having corrosive impacts on the denticles of shark scales. Shark skin is covered in tiny tooth-like scales called dermal denticles which create minute vortices, reducing hydrodynamic drag and enabling sharks to swim faster and more quietly, contributing to their efficiency as predators.

A recent publication in *Scientific Reports* found that exposing puffadder shysharks (*Haploblepharus edwardsii*)—a species of catshark native to cooler waters off South Africa—to more acidic water over a period of eight weeks caused an average of 25 per cent denticle damage compared to 9 per cent found in the normal seawater control group over the same period.

The puffadder shyshark (*Haploblepharus edwardsii*). © Peter Southwood (CC BY-SA 3.0).

Shark denticles have a hard coating of calcium phosphate (bio-apatite), and the laboratory study found that concentrations of calcium phosphate were significantly reduced after exposure to acidic water. This denticle damage was found to alter the swimming behaviour and in turn, the foraging activity of the sharks. The extent of the impacts of denticle corrosion on shark physiology and behaviour is considered to vary between species.

The effects of ocean acidification on other calcium-building organisms have been investigated but this is the first study to show clear negative effects on elasmobranchs. *Via Nature Scientific Reports*

Lydia Tivenan

Pillar coral (*Dendrogyra cylindrus*), a species highly susceptible to stony coral tissue loss disease (SCTLD). Image © Keith Hiscock.

Stony coral tissue loss disease continues to plague the Caribbean

Stony coral tissue loss disease (SCTLD) has been ravaging multiple Caribbean reefs since its first appearance off the coast of Florida in 2014.

Thought to be caused by waterborne bacteria, the particular pathogen and disease processes are yet to be confirmed, as is the exact mechanism for this prolific spread—although it is suspected that ballast water from passing vessels has contributed to the spread of the disease.

The reefs of the Turks and Caicos Islands are the most recent to be affected by this devastating disease, with infected coral colonies seen across four of six islands. SCTLD causes rapid and extensive tissue damage and loss, and the International Coral Reef Initiative reported that 'SCTLD affects over 20 of the 45 species of Caribbean reef-building coral species'.

In Turks and Caicos, a local NGO has been given government go-ahead to begin coral treatment through the administration of antibiotics, a process which in itself can be problematic, but which has been used in Florida to minimize the spread of the disease within infected colonies. Mote Marine Laboratory has started its new Florida Keys Coral Disease Response & Restoration Initiative, which includes creating a gene bank of corals, rescuing coral colonies from vulnerable areas yet to show signs of SCTLD, and implementing extensive coral restoration in the Florida Reef Tract. *Via Mote Marine Laboratory and BBC News*

Lydia Tivenan

North Sea fisheries feed millions of seabirds

Each year, global fisheries discard over 10 million tonnes of fish, with the North Sea one of the largest discard-producing regions. A recent study estimated that 30–40 years ago, North Sea fisheries discards supported around 6 million seabirds. However, between 1990 and 2010 changes in discard policy, including the introduction of the EU's landing obligation, resulted in a 48 per cent decline in seabirds supported by North Sea fisheries to 3.5 million.

The study looked at eight species of seabirds, finding the largest declines in northern fulmars and black-legged kittiwakes. The extent to which seabirds rely on discards often depends on prey availability. Interestingly, the study found that during this period, seabird diet shifted from around 80 per cent roundfish, which are easy to swallow, to less easily ingested flatfish (around 50 per cent).

Other studies discovered that the biomass of scavenging seabirds remained steady when discards were gradually reduced, as many species are opportunistic and able to switch their prey diet. This raises concerns over the ecological impact of abrupt changes in discards, which will be exacerbated by climate-mediated declines in forage fish abundance. Declines are expected in scavenger species unable to find substitute food sources, whilst successful species are likely to be brought into greater conflict with humans. Currently, no global estimates exist for the number of seabirds that could be supported by fisheries waste, but considering the global biomass of discards this is likely to be substantial. *Via University of Exeter*

Kellyanne Batchelor

Albatross as ocean sentinels to detect illegal activity

In the open ocean, many fishing vessels 'go dark' when their on-board automatic identification systems (AIS) stop sending signals to report their location. In some cases, a faulty system may be to blame. However, many vessels intentionally switch off their AIS to mask illegal activity, which often occurs in off-limit areas such as marine protected areas.

Like many seabirds, albatross are attracted to fishing vessels and the discards thrown overboard. Researchers have devised an ingenious method of recruiting the help of albatrosses to patrol the ocean expanse and track down vessels engaged in illegal fishing.

Attached to these birds, GPS loggers—which weigh as little as one per cent of the bird's body weight—are able to detect radar signals within 5 km of a vessel and transmit this information to satellites.

During a six-month period, 169 wandering (*Diomedea exulans*) and Amsterdam (*Diomedea amsterdamensis*) albatrosses patrolled an area of 47 million km in the southern Indian Ocean, detecting radar signals from 353 different vessels. What's more, researchers discovered that 37 per cent of boats in international waters and nearly 26 per cent of boats within countries exclusive economic zones (EEZs) transmitted no AIS signal. The proportion of these involved in illegal activity is yet to be confirmed.

Due to the sheer size of the ocean this method cannot detect all 'dark' vessels, but when used in conjunction with other detection methods albatross may provide a valuable tool to detect boats involved in illegal fishing activity. *Via Proceedings of the National Academy of Sciences*

Kellyanne Batchelor

Wandering Albatross (*Diomedea exulans*). © JJ Harrison (CC BY-SA 3.0).

Grim end to the decade for Endangered shortfin mako sharks

As we transition into a new decade, the future for oceanic sharks remains uncertain after 2019 ended with extremely poor news for one of the world's most threatened shark populations. The globally Endangered (IUCN Red List, 2018) shortfin mako shark, *Isurus oxyrinchus*, which is highly sought-after for its meat and fins, failed to receive urgently needed protections at the annual meeting of the International Commission for the Conservation of Atlantic Tunas (ICCAT) in November. Ten countries, led by Canada and Senegal, proposed a full retention ban for the declining North Atlantic population, which is particularly vulnerable to overexploitation due to limited spatial refuge from longline fishing fleets operating in the region. However, two years after this population was initially described as 'overfished', the EU and US disregarded ICCAT scientific advice and obstructed a consensus by voting against the ban and refusing to give up on exceptions for hundreds of tons of the species to be landed.

This will allow status-quo fishing at unsustainable levels to continue and has sparked comments of hypocrisy as just a few months earlier, the EU co-sponsored the proposal to list mako sharks on the Convention on International Trade in Endangered Species (CITES) Appendix II. Although the Appendix II listing was an important step forward and obligates parties to regulate international trade, projections state that the probability of the population rebuilding by 2045 is only 53 per cent if all mortality ceases, and therefore stricter catch controls are the only way to safeguard the future of this Endangered species.

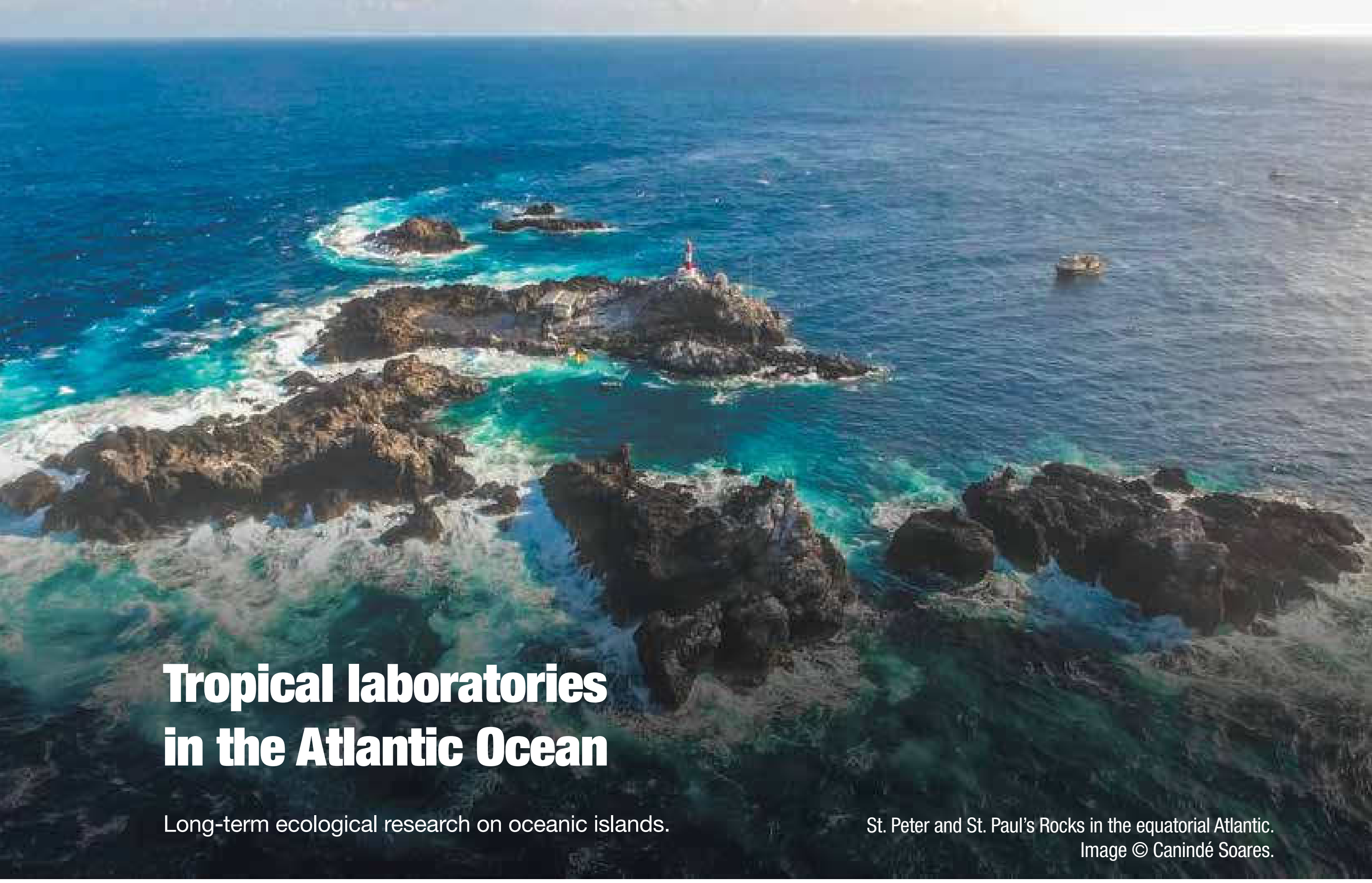
Sources: https://www.iccat.int/Documents/Meetings/Docs/2019/REPORTS/2019_SMA_SA_ENG.pdf
https://cites.org/sites/default/files/eng/cop/18/prop/060319/E-CoP18-Prop-42.pdf

Freya Womersley

New President of the Marine Biological Association

Dr Gill Rider, President of the Marine Biological Association.

We are delighted to announce the appointment of Dr Gill Rider CB, PhD, CCIPD as President of the Marine Biological Association. Look out for an interview with our new president in a future issue.



Tropical laboratories in the Atlantic Ocean

Long-term ecological research on oceanic islands.

St. Peter and St. Paul's Rocks in the equatorial Atlantic. Image © Canindé Soares.

Less exploited and less studied than the continental coast, Brazil's beautiful Atlantic islands are the subject of long-term ecological research. By **Lucas Nunes** and **Sergio Floeter**.

Brazil has one of the longest coastlines in the world, encompassing environments such as mangroves, sand beaches, and biogenic and rocky reefs. Among these marine environments, Brazil's oceanic islands stand out as the least exploited and least studied examples. These isolated tropical islands hold a distinctive fauna and flora, including several endemic species and a large biomass of pelagic fishes, thus offering a great opportunity for marine scientists to explore scientific questions and test ecological hypotheses.

Formed mostly by volcanic activity, oceanic islands are isolated from the continental shelf and often possess water transparency greater than 50 metres. These unique environments are a kind of marine 'oasis' with abundant food resources, breeding areas, and refuges in which reef organisms can thrive in a vast, otherwise oligotrophic (nutrient-poor) ocean. Another singular characteristic of oceanic islands is their high number of endemic species (those only found in a particular location). These islands are perhaps the last 'pristine' marine environments that we have on Earth, being the only places where large biomass of fishes and apex predators, such as sharks, still abound (Fig. 1).

In the Atlantic Ocean, four tropical oceanic islands belong to Brazil (Fig. 2). Their distance from the continental landmass makes them less affected by human impacts, such as pollution and overfishing, but it also makes them less known by the human population. Each of these islands has different characteristics, and, in 2013, the Long-Term Ecological Research of Brazilians Oceanic Islands[1] (PELD-ILOC) was set up to study these tropical 'laboratories'. Through long-term monitoring of fish, benthic organisms and coral (see Fig. 3), PELD-ILOC plays a fundamental role in understanding the processes

Figure 1. The lemon shark (*Negaprion brevirostris*) in a nursery site on Rocas Atoll. Image © Lucas Nunes.

1 http://peldiloc.ufsc.br

and dynamics in these relatively pristine ecosystems.

Each year, a small group of Brazilian researchers have the opportunity to visit these beautiful islands, where they sample different organisms and collect data. The adventure starts in the laboratory with detailed expedition planning, and then, after a boat journey of several days, we arrive in the warmth and sunshine of these paradise islands. Each island has a scientific station equipped with accommodation and research facilities, but in general potable water and food supply must come from the continent.

Long-term monitoring enabled us to record a coral bleaching event during 2016 due to water temperature anomalies (Fig. 4). The same event was responsible for massive coral bleaching in several coral reefs worldwide including the Great Barrier Reef in Australia. We can also detect fluctuations in fish populations over time. Dr Carlos Ferreira said, 'We are seeing that the population size of some reef fishes seems to be correlated with warming years, some species declining and others increasing after an 'El Niño' warm season, but many times these changes have a delay of one or two years before they are detectable.' In addition, sharks that are highly exploited by fisheries on the coast are thriving in these isolated islands, where nursery sites are protected.

Dr Sergio Floeter said, 'Together, the four Brazilian oceanic islands harbour 24 endemic reef fish species. Despite their isolation from each other, the islands are more connected among themselves than with the coast, mainly due to shared characteristics such as temperature, productivity, and high-water transparency. For example, the small and remote St. Peter and St. Paul's Rocks share endemics with Fernando de Noronha and Rocas Atoll, as well as with Ascension and St. Helena oceanic islands, in the Mid-Atlantic Ridge.'

In addition to this focus on research, the mission of PELD-ILOC is to increase awareness and interest among Brazil's population. Thus, for the future, we hope to continue the sampling effort and look forward to greater interaction between the population, scientists and the government to preserve the biodiversity of these unique marine ecosystems.

Lucas T. Nunes (nuneslteixeira@gmail.com)
Professor Carlos E. L. Ferreira (carlosferreira@id.uff.br)
Dr Sergio R. Floeter (sergiofloeter@gmail.com)

The PELD–ILOC is led by Prof Dr Carlos Ferreira with the participation of a large team of marine scientists of the Brazilian marine biodiversity network SISBIOTA-Mar see: http://www.sisbiota.ufsc.br

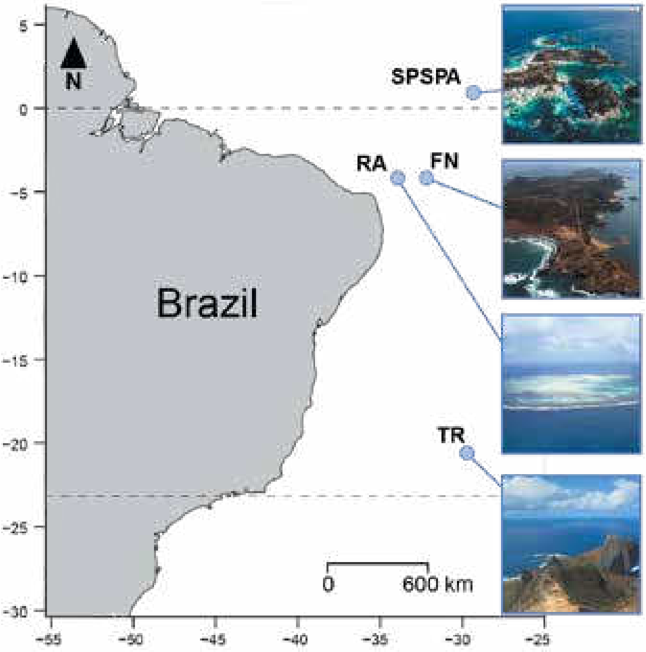


Figure 2. Brazil's oceanic islands. SPSPA: St. Peter and St. Paul's Archipelago © Canindé Soares; FN: Fernando de Noronha Archipelago © Sergio Floeter; RA: Rocas Atoll © Brazilian Navy; TR: Trindade Island and Martin Vaz Archipelago © Lucas Nunes.

Figure 3. Sampling the benthos for laboratory analysis. Image © Sergio Floeter.

Figure 4. Bleached coral colonies after the bleaching events of 2016. Image © Natalia Roos.

How does environmental change influence the development and evolution of organisms?

Using a cosmopolitan sea squirt as a model, **Atsuko Sato** investigates the paradox of developmental stability and adaptation to change.

Why is life so diverse? Much discussion of this fundamental question in evolutionary biology has focused on the direct operation of natural selection on the effect of random mutations, but the interaction between genes and development significantly complicates this picture. Organismal development remains surprisingly stable in the face of environmental fluctuations and variations in genetic background. However, to make new forms, development has to change. To explain this paradox, the famous British developmental biologist Conrad Hal Waddington proposed the idea of developmental buffering. Since development is a dynamic process in time and space (Fig. 1), he hypothesized that developmental buffering (which he clearly distinguished from general homeostasis that routinely maintains cell conditions stable) keeps development on track in the presence of genetic or environmental perturbations. Because of developmental buffering, mutations can be accumulated in the genome without affecting the form of the completed organism, but when the environment changes, the hidden mutations can be exposed to evolutionary processes as novel forms.

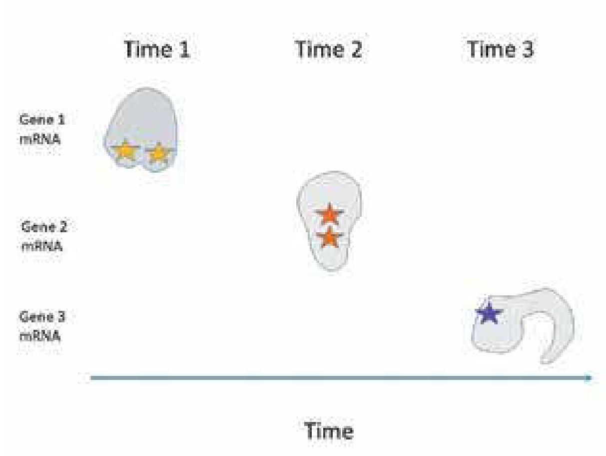


Figure 1. Development is a dynamic process in time and space. Different genes (gene 1 – gene 3) are expressed in different parts of embryos at different times.

I investigated the molecular basis of developmental buffering using a natural population of a solitary sea squirt, *Ciona intestinalis. Ciona intestinalis* lives in all the world's oceans, and has been one of the major model chordates in developmental biology for over a century. However, comparative genomic studies have revealed that several cryptic species of *C. intestinalis* occur in different seas; for example, one lives in the Mediterranean Sea, Japan, and the West coast of the US, whereas the other is limited to the North Atlantic. Plymouth lies in a special area for the study of the *C. intestinalis* species-complex, since the English Channel is the only known region where these two species are found together. By comparing over 500 specimens, it was possible to identify morphological differences that distinguish the two species in the field (Fig. 2). The two species are now referred to as *C. robusta*, originally described from Japan, and *C. intestinalis*, described by Linneus from the Atlantic Ocean.

Since the seawater temperature reaches only 17˚C in the North Atlantic but 28˚C in the Mediterranean Sea, I hypothesized that the two species are adapted to different thermal environments: the species adapted to warmer environment has a higher level of developmental buffering. I have tested this hypothesis by exposing developing embryos to increased temperature from the neurula stage to early-tailbud stage, when all the chordate characteristics appear, and examined developmental buffering levels by estimating the proportion of normal larvae after hatching. I found a pronounced difference in developmental buffering levels between the two species of *Ciona* (warm water species having higher buffering levels). Moreover, a maternal effect in the buffering levels was identified, that is to say, hybrid offspring show the same level of thermal tolerance as the maternal species.

Figure 2. *Ciona intestinalis* (left), *Ciona robusta* (top) and the hybrids (right). Image © Atsuko Sato.

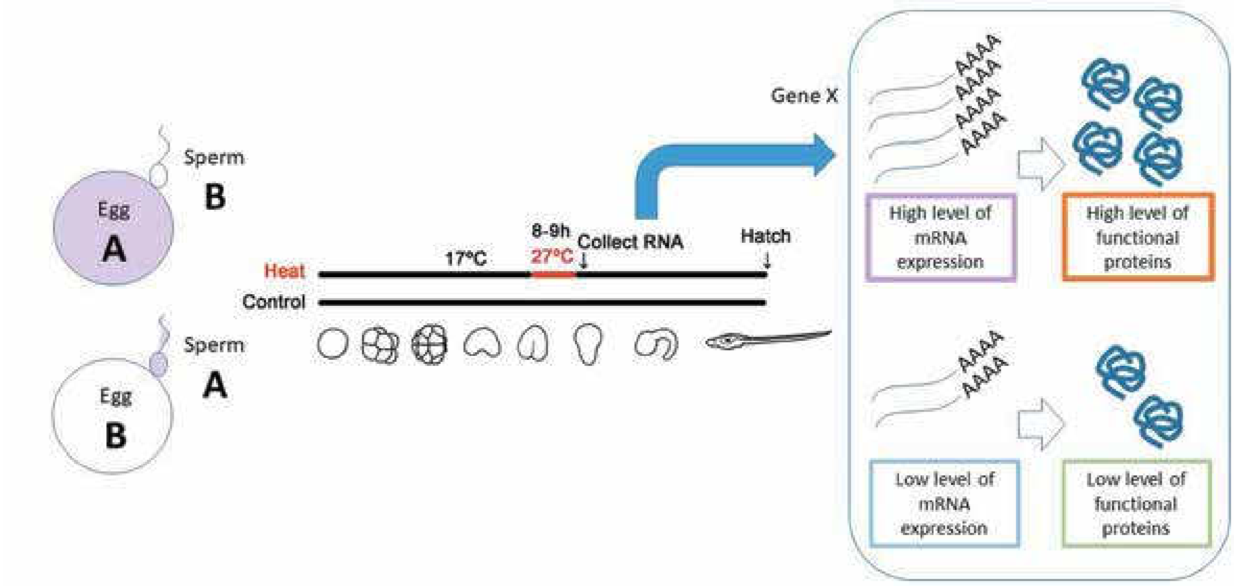


Figure 3. Experimental design comparing cross hybrids at the molecular level. I identified genes in which observed levels of mRNAs are correlated to buffering levels. If an activated gene is expressed, we observe mRNAs that are translated to functional proteins in a cell.

Comparing hybrids of *C. intestinalis* and *C. robusta* at the molecular level led my co-workers and me to doubt whether general homeostasis is as stable as Waddington thought. To identify the molecular basis of developmental buffering, I undertook a large-scale analysis of the correlation between gene expression levels of each activated gene and levels of developmental buffering against thermal stress (Fig. 3). The genes thereby identified as correlated with the level of developmental buffering are involved in protein quality control or metabolism in a cell, playing an important role in homeostasis. Like Waddington, we tend to think of physiological homeostasis as a stable process. If this is true, genes that correlated to the level of developmental buffering must have been different from those of general homeostasis. However, my data showed that homeostasis and developmental buffering are controlled by similar sets of genes, indicating that homeostasis can also be dynamic, underpinning development in time and space.

Our next question is to address whether thermal stress during development later impacts on the developmental buffering levels of eggs that the grown individual produces. We hypothesize that increased levels of buffering in the developing egg would allow the accumulation of mutations in later generations, thereby leading to long term evolutionary changes. Thanks to the kind support of two Plymouth marinas, Queen Anne's Battery and Sutton Harbour, and to the long-term collaboration and friendship with John Bishop and Christine Wood at the MBA, I have made transgenerational cultures of heat-treated *Ciona robusta* and collected gametes of the third generation. In collaboration with Manuela Truebano at Plymouth University and the Oxford Genomics Center at Oxford University, I will analyse the quantity and quality of maternally provided RNAs in the eggs at an extraordinarily high resolution, looking at each single egg. This has been painstaking research over several years, but I believe that the outcome will give us important information on how environmental change affects the evolutionary trajectory of species, in ways beyond just limiting the habitats species can occupy or driving them to extinction.

Atsuko Sato (pterobranch@gmail.com) Assistant Professor at Ochanomizu University and Tohoku University in Japan, and a Ray Lankester Investigator at the Marine Biological Association.

Further reading:

Waddington C.H. (1957) *The strategy of the genes*. London, George Allen & Unwin.

Sato *et al*. (2012) *Marine Biology,* 159: 1611-1619

Brunetti R. *et al*. (2015) *Journal of Zoological Systematics Evolutionary Research* 53: 186-193.

Sato *et al*. (2015) *Scientific Reports* 5: 16717

Image © Guy Baker.

Are we heading for a disastrous future?

The ocean is central to regulation of the Earth's climate. **Chris Reid** calls for urgent action on emissions.

Through climate change (CC), population growth and overexploitation of the Earth's resources, humans are at war with the world—a climate war that we cannot win. Of all challenges facing humanity at this time, CC is the greatest, and yet governments, businesses, and the public have failed to recognize the urgency and seriousness of the problem. Decades of negative campaigns and lobbying by fossil fuel industries, the countries that back them and climate deniers have confused the public and blocked policies to tackle global warming.

At present our global economy is intrinsically linked to carbon and continuing growth (Gross Domestic Product, GDP). The GDP of almost all countries in the world follows a curve that is correlated with CO_2 emissions per capita and strongly reflects the fossil fuel base of the current world economy. Most greenhouse gases as carbon dioxide equivalent (CO_2e) derive from the production, distribution, and sale of oil, gas, and coal.

This article aims to emphasize the urgent need for all countries to decarbonize rapidly and reduce the speed of growth in their economies to prevent further increases in temperature: an unpalatable option to politicians, and at present to the public. 'Climate Action' is only one of 17 United Nations 'Sustainable Development Goals' to be reached by 2030, but all the other goals are dependent on the success of this action.

The media also gives a low profile to CC and some papers still run pro-fossil-fuel articles and retain columnists who have this view. This is despite knowing about the greenhouse effect and the role of CO_2 in the atmosphere since the 19th century, frequent warnings by scientists of the dangers over the same period, and many thousands of pages of scientific reports outlining the potential consequences.

Machta in 1972 accurately predicted the concentration of atmospheric CO_2 by the year 2000, and Hansen the same in 1989 for global temperature in 2015. Many subsequent models of greater sophistication are now used by the International Panel on Climate Change (IPCC). Why should we question the results of these models given the accuracy of past predictions?

As terrestrial beings, few people are aware that the ocean, covering over 71 per cent of the surface of the Earth, is the beating heart of our planet (Fig. 1) and a key factor in CC, absorbing over 90 per cent of the excess heat from the greenhouse effect and around 30 per cent of CO_2 generated by human activities. Until the last Assessment Report (AR5), even the IPCC did not give the importance of the ocean the recognition it deserved.

humans are at war with the world—a climate war that we cannot win

Over the last four decades, warming of the world has accelerated in both the ocean and on land, especially over northern hemisphere land, with amplification of warming over the Arctic region (Fig. 2).

The main greenhouse gases (GHGs) are water vapour and carbon dioxide (CO_2). The concentration of water vapour in the atmosphere is dependent on the warming caused by CO_2 and other GHGs. Warmer air can hold more water vapour and further amplify the warming as a positive feedback. Emissions of CO_2 are continuing to track the high emission scenarios of the IPCC, which would lead to a mean world temperature rise of around 3°C and possibly higher. Mean temperature over the land mass of Eurasia would be even greater.

The increasing impacts that are evident and attributable to global warming are occurring for a world that is 1°C warmer than it was in pre-industrial times (Fig. 3). Mean global warming above 2°C is considered by many as 'dangerous climate change' (see UNFCC 1992, Article 2). All Earth systems are responding to the accelerated warming. They include: increasing plant growth and poleward expansion of plants and animals; sudden, step-like regime shifts in the environment and ecosystems; and pronounced deterioration of coral reefs. The frozen world has been especially impacted, with rapidly reducing glaciers, melting of the Antarctic and Greenland ice sheets (Fig. 4), disappearance of sea-ice and snow cover, melting permafrost and methane release. Meltwater from ice sheets and glaciers, along with thermal expansion of seawater, has contributed to sea levels rising much more rapidly than expected. Without adaptation, catastrophic flood impacts are now likely, even for the lowest level scenario for sea-level rise, severely impacting coastal cities and regions where most of the world's population lives, with estimated costs potentially running into thousands of trillions of US$ (Fig. 5). There is a 17 per cent chance that sea level might reach 2 m above global mean sea level (GMSL) by

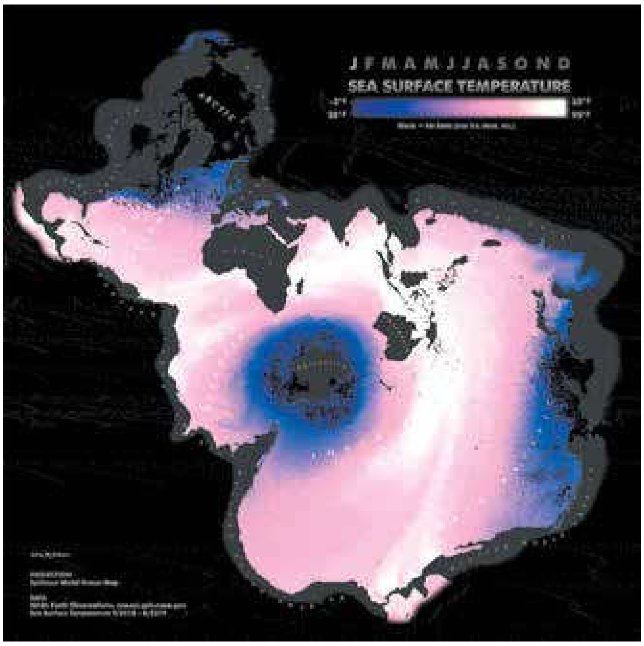


Figure 1. The ocean is the beating heart of the world. Image © Spilhaus Ocean Map 2019 Sep. ArcGIS. David Burrows and Bojan Šavric, cartography John Nelson. NASA SST 9/2018 – 8/2019.

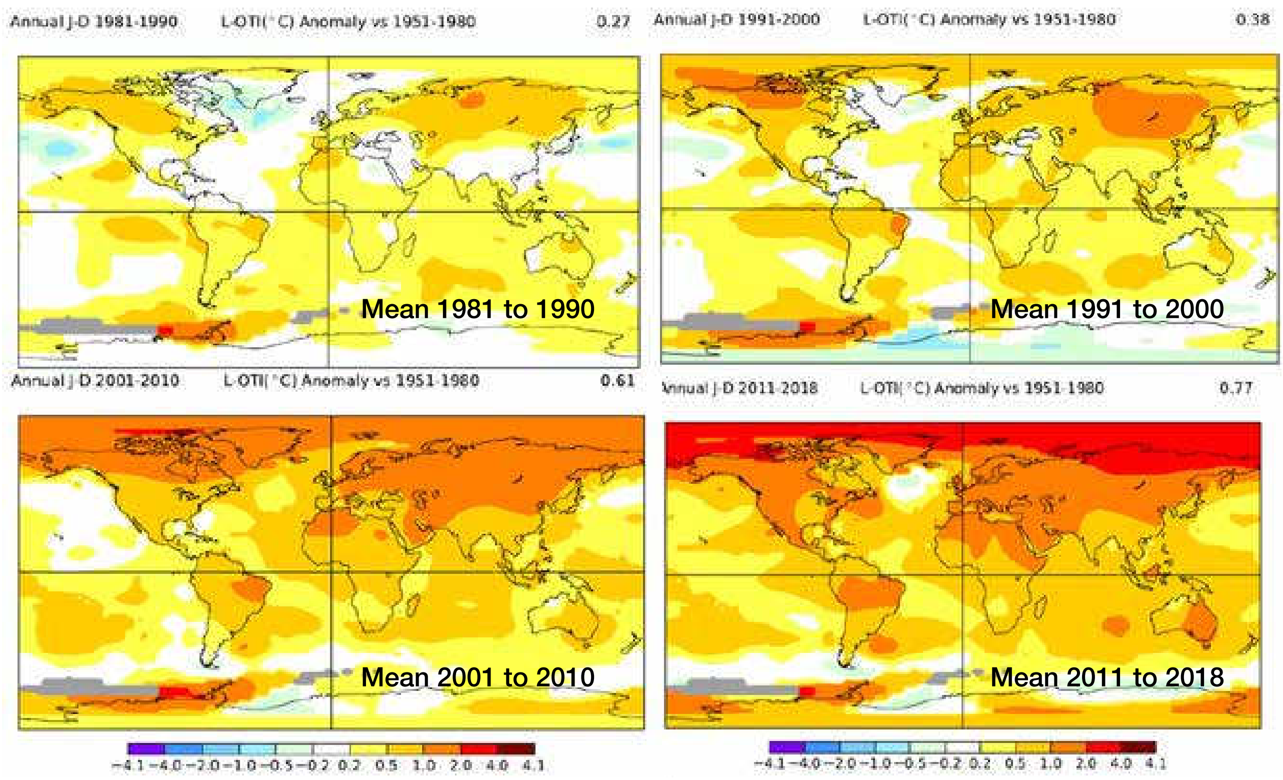


Figure 2. Surface temperature anomalies (°C). Image © GISTEMP Team, 2020: GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies. Dataset accessed 2019-12-20 at https://data.giss.nasa.gov/gistemp/

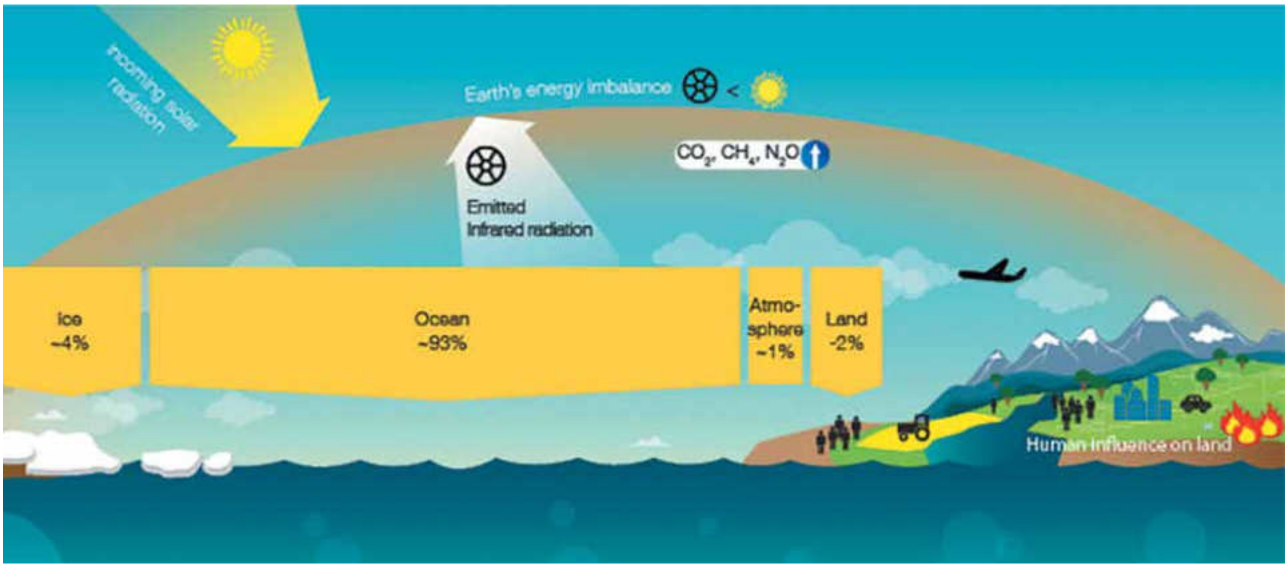


Figure 3. Earth's Energy Flow and Storage. The Earth's energy imbalance (EEI) is 0.83 ± 0.11 Watts per Meter[2]. The mean temperature of the Earth's surface between 1951 and 1980 was 14°C. Now it is around 15°C. Image redrawn and modified after von Schuckmann *et al.* (2016).

2100 for a high emission scenario. Undercutting and destabilization of the Antarctic ice sheet by incursion under ice shelves of warmer water from Circumpolar Deep Water has the potential to lead to very rapid increases in sea level well above 2m.

There is clear evidence for an increase in the severity and frequency of natural disasters. Extreme temperature events (heatwaves) are occurring more frequently and lasting longer, leading to mortality of wildlife and humans, and wildfires. If we continue on the present emission trajectory, tropical parts of the world could become uninhabitable for much of the year by 2100, as they would be above dangerous levels of combined temperature and humidity for humans and many animals.

Warnings of the seriousness of CC were flagged by the IPCC in the last Assessment Report (AR5) with a series of special topic reports in 2019 including 'Global Warming of 1.5°C' prior to the next major 6th Assessment in 2021. Nevertheless, governments around the world have taken little action, the Kyoto Protocol has been fudged and we are well off target to meet the requirements of the successor Paris Agreement: major emitters e.g. Saudi Arabia, Russia, and Australia are prevaricating and the USA has initiated a withdrawal from the agreement.

Between 1990 and 2017 total UK territorial emissions as CO_2e reported to the UNFCC showed a 42 per cent reduction. The reductions were primarily achieved through the expansion of onshore and offshore wind and the use of solar panels for electricity generation. Kyoto and Paris only require countries to reduce their territorial emissions, not the emissions produced in the manufacture and transport of goods imported from elsewhere. In the change from a manufacturing-dominated to a service economy, the UK in 2016 imported 57 per cent more consumption based CO_2 compared to territorial emissions, and is the largest net importer of emissions of all G7 countries—a highly materialistic society. Furthermore, the reduction in territorial emissions achieved does not take into account the large historical emissions by the UK as the first industrialized nation in the world. When consumption and historical emissions are also taken into account, the UK is falling well behind in reducing its carbon footprint.

How can individuals effect change? Governments, through policy change are the main way by which adjustment to a low carbon economy can be implemented rapidly—so lobby your MP. The UK is fortunate to have

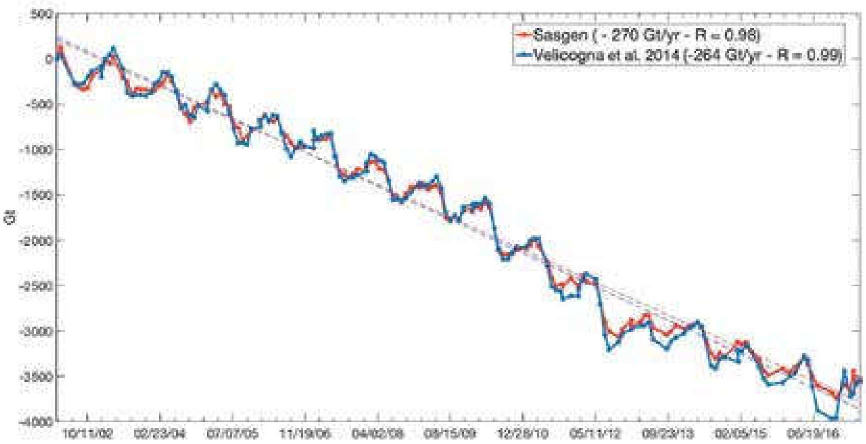


Figure 4. Greenland and Antarctica coastal basal melting. Tedesco *et al.* 2017 [in Arctic Report Card 2017], http://www.arctic.noaa.gov/Report-Card

Figure 5. A graphic representation of the Belgian coast with a 1 metre rise in sea level. Image © Glynn Gorick.

an independent and proactive 'Committee on Climate Change' (CCC) that has provided excellent advice to the government. The United Nations through its ActNow campaign, the Organisation for Economic Co-operation and Development (OECD) by its 25 Actions, and a 2019 report to the CCC by Carmichael, identify and promote ways in which individuals can reduce their carbon footprint. A paper by Wynes in 2017 evaluated 148 actions and calculated that having one fewer child per family would have the highest impact.

For the sake of our grandchildren we need to prepare for the future by adapting and changing our consumption and energy use patterns .If we do not, by 2100 the world will have become a dangerous place in which to live. Becoming more self-sufficient as a country should be a priority, with a move away from a throwaway society, the development of clean manufacturing and waste recycling technologies, and reduction in imports from abroad by encouraging purchase of products 'made and grown in the UK'. We need a government that places CC at the top of national and global agendas, encourages research and monitoring, especially in ocean science, supports the development and application of new technologies and green energy production, and promotes sustainable farming practices. As a nation we would benefit enormously economically if we took this route and provided proactive global leadership on CC issues, including finance and investment in new technologies. We are stewards of the world for future generations and need to act NOW by changing the way we live at all levels.

the UK is the largest net importer of emissions of all G7 countries

Philip (Chris) Reid (pchrisreid@googlemail.com) is Professor of Oceanography at the University of Plymouth and Honorary Lankaster Fellow of the MBA.

Further reading

www.mfe.govt.nz/climate-change/we-all-have-role-play/what-you-can-do-about-climate-change

www.activesustainability.com/climate-change/6-actions-to-fight-climate-change/

www.un.org/en/actnow/

www.bbc.com/future/article/20181102-what-can-i-do-about-climate-change

www.oecd.org/stories/climate-25-actions/

Meeting international obligations and the World Congress of Marine Stations

In our regular update on marine policy, **Matt Frost** looks at how marine stations can support the 'ocean decade'.

As pointed out in Gabriel Grimsditch's article (opposite), this is an exceptionally busy year for the international marine science community as we seek to engage with a host of initiatives, which together have seen 2020 labelled as a 'super year' for the oceans. A key element in delivering on the various high-level objectives and goals, including those articulated in the UN Decade of Ocean Science for Sustainable Development, is making the most of current resources and working together at a global level. In the April 2019 edition of *The Marine Biologist* I emphasized the importance of moving forward with the full establishment of a World Association of Marine Stations (WAMS). This is now a step closer to reality, with a 'World Congress of Marine Stations' being held in Moscow in October 2020.

This congress is bringing marine station and marine station network representatives together from around the globe to discuss how WAMS can be used to support the Ocean Decade. The meeting will provide the first comprehensive overview of marine stations at a global scale and their role in delivering a range of services, from monitoring to education and fundamental research. There will also be an option on the third day to meet as regional or national networks, or to hold meetings on potential international collaborations (a meeting between UK and Russian scientists to discuss Arctic marine science is already planned).

Early bird registration for the World Congress is now open (see link, left) and the early bird registration deadline is 30 April. More details are being sent out and posted on the website as the programme continues to be updated, but in the meantime, please register or pass on this information to others who may be interested.

More detail on WAMS and the World Congress can be found on the website at www.wcms2020.com In the meantime please email the conference organizers at info@wcms2020.com or contact me directly at matfr@mba.ac.uk

Dr Matt Frost (matfr@mba.ac.uk) WCMS Committee is MARS President, MBA Deputy Director and Head of Policy and Knowledge Exchange.

The UN Decade on Ecosystem Restoration

Gabriel Grimsditch of UN Environment introduces this special edition, which celebrates the UN Decade of Ecosystem Restoration (2021–2030).

The United Nations Environmental Programme (UNEP) headquarters in Nairobi. Image © Gabriel Grimsditch.

2020 is the year where we have an unprecedented opportunity to redefine our relationship with our natural environment. Environmental concerns are expected to top many global agendas as crucial international meetings are being organized on climate change (the 26th Conference of the Parties of the United Nations Framework Convention on Climate Change in Glasgow) and biodiversity protection (the 2020 Biodiversity Conference in Kunming). Several other important conferences that are especially relevant to marine ecosystems are also taking place in 2020, including the UN Oceans Conference in Lisbon, the Our Ocean Conference in Palau, the 14th International Coral Reef Symposium in Bremen, the IUCN World Conservation Congress in Marseille, and the 14th International Seagrass Biology Workshop in Chesapeake Bay.

But this is not just a year of conferences. Global awareness is increasing on the myriad of challenges that our marine environment faces, and communities around the world are increasingly willing to take action against ecological degradation. There has never been a more urgent need to restore damaged ecosystems, and nature-based solutions are being recognized as critical for addressing global sustainable development goals and national priorities, from climate change mitigation to food security.

In recognition of this urgency, the United Nations General Assembly in March 2019 proclaimed 2021–2030 as the **UN Decade on Ecosystem Restoration**[1]. On land, this involves the restoration of at least 350 million hectares of degraded landscapes by 2030, realizing up to US$9 trillion in net benefits and alleviating poverty in many rural communities. A target for coasts and oceans has yet to be set, and this presents an opportunity for target-setting for education, awareness-raising and investments in the restoration of marine ecosystems from government, civil society and private sectors.

> The potential for ecological restoration in the coastal space is huge and can provide benefits to societies

Globally, we have lost approximately half of live coral cover, a third of seagrass meadows, a third of mangrove forests, 40 per cent of saltmarshes and up to 85 per cent of oyster reefs since the early 20th century. The potential for ecological restoration in the coastal space is huge and can provide benefits to societies. The IUCN estimates that up to 812,000 hectares of degraded mangrove area globally show potential for restoration, with over 500,000 hectares considered highly restorable. This would not only lead to increased carbon sequestration, as mangroves are among the most carbon-rich ecosystems globally, but also to increased fisheries productivity and shoreline stabilization. Coral reefs are another valuable ecosystem where advances are being made in restoration techniques. A United Nations Environmental Programme UNEP analysis showed that healthy coral reefs would deliver economic benefits of $34.6 billion and $36.7 billion between 2017 and 2030 in the Mesoamerican Reef and Coral Triangle regions respectively. Urgent action on climate change, coupled with investments in protecting resilient coral reefs from localized stressors can deliver a healthier future for coral reefs and the economies that depend on them.

Challenges still exist around the cost-efficiency and scalability of restoration; however the UN Decade on Ecosystem Restoration provides a great opportunity to catalyse investments and prioritize the restoration of coastal and marine ecosystems for governments, private sector and civil society around the world.

Gabriel Grimsditch (gabriel.grimsditch@un.org), Programme Management Officer for Marine and Coastal Ecosystems Branch, Ecosystems Division, UN Environment

1 https://www.decadeonrestoration.org/

The roots of the sea

Large scale, 'traditional' hand-planting approaches to mangrove restoration suffer an unacceptably high rate of failure. Here, **Alfredo Quarto** and **Ibrahima Thiam** describe a community-based ecological approach that improves the success of mangrove restoration.

'Mangroves sustain the people who sustain the mangroves'

Pisit Charnsnah, Founder and Director of Thailand's Yadfon Foundation.

Mangroves are a cornucopia of life—a rainforest by the sea—inhabiting intertidal zones of tropical and sub-tropical regions. Passing through a healthy mangrove forest has long inspired me. Over the last 26 years, I have wound through countless branching waterways that cut through the tangle of mangrove roots and branches. I have watched the roosting egrets and spoonbills, kingfishers and herons in the arching canopy. I've seen mudskippers fight mini battles for territory, and monitor lizards race across the glistening surface of mudflats towards the safety of deeper pools.

I have also walked in the mud at low tide, losing more than one sandal to the thick ooze of the mangrove substrate that can sink you thigh-deep in places. I've seen fresh footprints of Bengal tigers in mud channels in the Sundarbans of Bangladesh, proboscis monkeys peering from trees in Malaysia, and immense sea crocodiles launching themselves from primordial shores towards our boat in emerald enclaves of India's Bhitarakanika sanctuary.

All of this I have witnessed and

Main picture. Mangrove crabs on mud around a mangrove trunk.
Figure 1 (right). Red-billed hornbill (*Tockus erythrorhynchus*), Senegal. Images © Dominic Wodehouse, MAP's Team CBEMR Trainer.

more on the shores of Asia, Africa and the Americas, but I've also seen and felt the loss of mangroves too often in too many places.

Mangroves are the markets for traditional communities, providing food, tannins, fuel wood, medicinal remedies, and building materials (see Box 1). Despite this, they are one of the most threatened habitats, with an annual loss of nearly 1 per cent, outpacing other tropical rainforests. An estimated 15 million hectares remain: less than half their original area. Their disappearance is primarily due to over-harvesting for timber (Fig. 2b) and charcoal, urban expansion, pollution, coastal road construction, and industrial developments. Cleared forests and ruined wetlands are turned into shrimp ponds, oil ports, tourist hotels, golf courses, and marinas.

One of the gravest threats to the remaining mangrove forests and the wildlife and communities they support is the rapidly expanding shrimp-aquaculture industry, fuelled by voracious consumer demand in the US, Japan, and Europe. Millions of hectares of coastal wetlands, including mangroves, have been cleared to make room for shrimp ponds. The Philippines and Thailand have lost over 65 per cent of their mangroves, while Ecuador, Indonesia, Cambodia, India and Bangladesh are close behind.

One village chief in Thailand told me in 1992 that the shrimp mafia had murdered his father because he'd opposed their cutting mangroves. He spoke with deep emotion: 'If there are no mangrove forests, then the sea will have no meaning. It is like having a tree with no roots, for the mangroves are the roots of the sea.'

His words inspired the creation of the Mangrove Action Project (MAP), and I've not stopped working for the mangroves since. Today, approximately 450,000 hectares of abandoned ponds exist, closed by disease and pollution—telling signs of the boom-and-bust shrimp industry. The Mangrove Action Project has been working with local communities and other local NGOs to halt this destruction of mangroves and promote their sustainable use and restoration.

Several organizations are now supporting mangrove conservation and restoration efforts globally: we are collaborating with Mangrove Watch from Australia, the IUCN's Mangrove Specialist Group, the

Box 1: What have mangroves ever done for us?

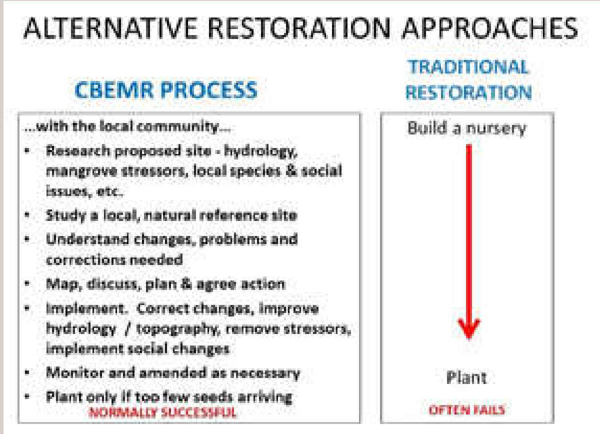
Mangrove forest wetlands are vital for healthy coastal ecosystems in many regions of the world. They support an immense array of marine and coastal life, serving as vital fish nurseries, nesting and feeding grounds for migratory shore birds, last stands for Bengal tigers and lemurs, and a wide variety of other mammals including manatees and proboscis monkeys. They sustain a myriad of insects, amphibians and reptiles, including sea turtles. Mangroves also support the health and productivity of coral reefs and seagrass beds. They are crucial for countless coastal communities and indigenous peoples who depend on them for life and livelihoods. Mangroves now are recognized for their important role in reducing climate change, storing up to five times more carbon in their peat soils than other forest ecosystems, for hundreds, if not thousands, of years. They prevent silt and polluted runoff from reaching fragile coral reefs and seagrass beds, and are living buffers against the forces of storms and waves that can otherwise devastate a coastline.

Figure 2. The Rufiji Delta, Tanzania. There is a lot of biodiversity in the delta (a), but Jim is standing next to the very edge of a huge pile of confiscated mangrove poles (b), one of the real problems facing the TFS and the delta. Images © Dominic Wodehouse, MAP's Team CBEMR Trainer.

Figure 3. In parts of the Rufiji Delta, Tanzania, the challenge is clearance of mangrove for rice cultivation. Farmers clear the mangroves and plant rice, and the government replants the mangrove trees. Farmers then plant rice around the feet of the mangroves until the canopy closes. Image © Dominic Wodehouse, MAP's Team CBEMR Trainer.

Box 2: The CBEMR approach

CBEMR involves a methodological ecosystem approach, incorporating natural mangrove dispersal and ecological recovery. The key is in the restoration of the hydrology of the area being considered for restoration, and subsequently working with nature itself to help facilitate regeneration of the area's naturally occurring mangrove species. At each site monitoring and evaluation follow to assess progress, and indicate the corrective action to be taken to ensure success and replicability. CBEMR is based on principles of community engagement and empowerment, recognizing that sustainable restoration requires the active participation of the affected local communities.



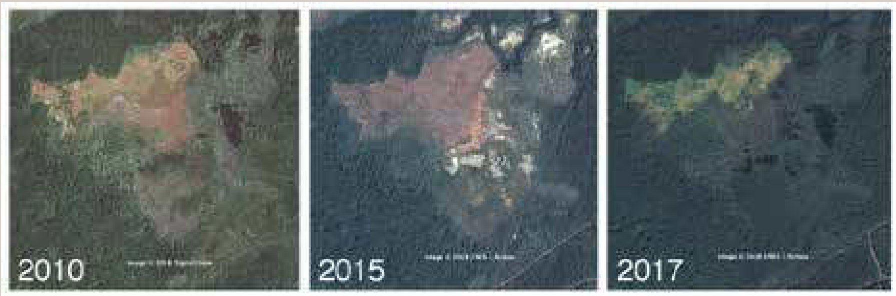


Photo sequence of a successful CBEMR project that MAP helped initiate in El Salvador resulting in good mangrove recovery after the blocked hydrology was restored by volunteers from the resident communities. Image © Asociacion Manglar/ Eco-Viva, El Salvador.

Zoological Society of London, The Nature Conservancy, and Mangroves For the Future, to name just a few. We have also recently become a member of the newly created Global Mangrove Alliance, which is steered by the 'big five' of the environmental movement—IUCN, Conservation International, The Nature Conservancy, Wetlands International, and WWF.

In 2017, Sri Lanka announced plans to be the first nation to give full protection to mangroves. This will require much work to realize, but the hope is that Sri Lanka's ambitious and welcome initiative will inspire a growing, broad, and cooperative world movement to protect and restore coastal wetlands. However, this cannot be done without establishing a set of basic best practices that better assure the success of future mangrove restoration efforts. Presently, traditional approaches to mangrove restoration around the globe suffer a 75 to 80 per cent failure rate. This is not acceptable considering the urgent need to mitigate sea level rise and counter climate disasters. The Mangrove Action Project strongly supports a best practice approach via our established Community-Based Ecological Mangrove Restoration (CBEMR) method (see Box 2 and Fig. 4). We are currently running intensive CBEMR training workshops in various regions in Asia, Africa and the Americas, involving local communities, community-based NGOs, local government, and educators in this process of conserving and managing their coastal resources.

Figure 4. MAP's CBEMR Training in the Saloum Delta, Senegal emphasising stage one of the CBEMR process—thoroughly researching a restoration site, including interviews with local people, pH testing, salinity measures and careful observation of what nature is revealing. Image © Dominic Wodehouse, MAP's Team CBEMR Trainer.

Just as mangroves are the 'roots of the sea', it is hoped that this expanding network of partners and projects will continue to strengthen and spread its roots throughout the world.

Alfredo Quarto (mapexecdir@gmail.com), Program and Policy Director of the Mangrove Action Project.

Further reading:

Brown, B., (2008) 6-Steps to Successful Ecological Restoration of Mangroves. Yogyakarta: Mangrove Action Project, Indonesia.

Cintrón, G. and Shaeffer-Novelli, Y., (1992) *Ecology and management of new world mangroves*. Pp. 233–258 in: Seeliger, U. (ed.), Coastal Plant Communities of Latin America. San Diego: Academic Press.

Lewis, R.R., (2005) Ecological engineering for successful management and restoration of mangrove forests. *Ecological Engineering* 24, 403–418. Online at: http://www.mangroverestoration.com/Ecol_Eng_Mangrove_Rest_Lewis_2005.pdf.

Lewis *et al.* (2006) *Ecological Mangrove Restoration*.

Seeking global sweet spots for marine farming

Kellyanne Batchelor asks: can restorative aquaculture feed a growing population and restore our marine ecosystems?

Aquaculture, defined as the cultivation of aquatic organisms under controlled conditions, is one of the most rapidly growing forms of primary food production, valued at US$243 billion globally. Along with this growth have come image problems. In 2000, the UK daily paper *The Telegraph* reported that nutrients discharged from Scotland's 350 salmon farms had ecological impacts effectively greater than the sewage produced by the country's population of 5.1 million people. Multiple news outlets have also raised concerns over capturing masses of wild fish for consumption by farmed fish.

Unlike fed aquaculture projects, such as salmon or shrimp farms, unfed systems extract resources from the environment. Evidence shows farming unfed organisms, specifically seaweed and bivalve molluscs (mussels, clams, and oysters), can have benefits for both humans and the environment (Fig. 1). This intentional cultivation to yield positive ecosystem and economic outcomes is known as 'restorative aquaculture'. Shellfish aquaculture can provide nurseries for commercially valuable species, as well as habitat for many others, whilst seaweed aquaculture can mitigate the local (kilometre-scale) effects of ocean acidification. Bivalve molluscs and seaweed species also assimilate nutrients from surrounding waters, improving water quality and lowering the risk of algal blooms and associated problems such as hypoxia. Benefits to people include increased food security and employment opportunities in coastal regions where unemployment is high (Figs. 2 & 3).

Figure 1. Chesapeake Bay floating oyster aquaculture. Image © Andy Lacatell.

> farming seaweed and bivalve molluscs can have benefits for both humans and the environment

It appears that seaweed and shellfish aquaculture systems can help address a host of global environmental challenges and societal issues, but where should these systems go? Recent research published in the journal *PLoS ONE* revealed potential zones where aquaculture could benefit both people and nature. Researchers developed a novel index and conducted a global spatial analysis, which mapped oceanographic and geographic suitability and overlaid key environmental, socioeconomic, and human health factors. Their analysis ruled out highly polluted regions or those with poor wastewater treatment, or where aquaculture production may be compromised by failures to implement and enforce sound regulations and policies. Conversely, restorative aquaculture 'sweet spots' are those locations where favourable ecosystem and societal factors coincide. These are where, the authors of the research say, governments, international development organisations, and investors should push and drive changes in public policy and business planning to unlock the benefits of seaweed and shellfish aquaculture.

Regions boasting the most potential were found throughout Europe, North and South America, Asia, and Oceania. No regions scored 'full marks', demonstrating the counterbalance of opportunity and associated risks. For instance, the North Sea region had the highest opportunity for restorative aquaculture to combat issues like habitat loss and elevated trawl fishing pressure, but with a history of harmful algal blooms, high microplastic concentrations and elevated persistent organic pollutants, it received a borderline human health score.

The authors point out that developing restorative aquaculture in these zones does not guarantee ecosystem recovery or provision of ecosystem services, as factors such as farm design and characteristics of the environment or culture species are highly influential. For example, unsustainably managed, intensive cultivation of bivalve shellfish could produce enough waste (as pseudofaecal and faecal carbon), beyond the carrying capacity of the local environment, to lead to localized benthic hypoxia.

The majority of high-potential zones were found in areas where seaweed and shellfish aquaculture are already established. Here, a proper assessment of the practices used is needed to identify modifications to improve ecological benefits. Given the scale of these systems, and with China being the world's largest producer of aquaculture shellfish, small steps towards ecosystem-orientated improvements could provide substantial benefits.

Aquaculture clearly needs to be correctly managed to reap ecosystem and societal benefits, and studies using large global datasets are key to forming guidance. Dr Seth Theuerkauf, lead author of the *PLoS ONE* study and aquaculture scientist with The Nature Conservancy said, 'This study is the first of its kind to aggregate global scale datasets, providing an objective, data-driven method for evaluating where opportunities for restorative aquaculture are greatest—indicating that there are high opportunity locations across the world. By collaborating with key partners, including shellfish and seaweed farmers, government agencies, and academic partners, we are leading further scientific research to better understand the specific conditions where aquaculture can provide the greatest benefits, including evaluation of different farming methods'.

Figure 2. Seaweed aquaculture off South Cornwall, UK. Image © Sophie Corrigan.

Figure 3. Seaweed harvest. Image © Robert Jones.

The Nature Conservancy is currently piloting projects to develop aquaculture as an alternative livelihood for fishers whilst providing environmental benefits for communities in coastal hotspots from the US to Belize and Indonesia.

Although illuminating, global studies using large data sets have their limitations. In the study highlighted here, areas scoring poorly were generally found in Southeast Asia, Africa, and the Middle East. Data for these areas, and many island nations, is notably lacking, meaning a proper assessment of the potential benefits of restorative aquaculture is currently unavailable to many low to middle-income countries. Where analyses show only moderate potential for these nations, the underlying challenges must be understood to ensure solutions are effective and sustainable in the long term. For example, the regions next to India and Bangladesh have promising prospects for habitat provision and alleviating nutrient pollution, but logistical issues and human health concerns knock down their score. This highlights the need to improve governance alongside addressing other core social challenges.

Studies like this not only highlight data gaps, illustrating the importance of data sharing, they also provide methods that can be translated to other habitat restoration projects like mangroves or coral reefs. Future studies must also be conducted at regional and local levels. This combination of information, at all scales, can guide aquaculture development and assist policy-makers to support the provision of benefits for ecology, economics and society.

Kellyanne Batchelor
(kellyannebatchelor@gmail.com)

Further reading

Theuerkauf, S.J., Morris Jr, J.A., Waters, T.J., Wickliffe, L.C., Alleway, H.K. & Jones, R.C. (2019) A global spatial analysis reveals where marine aquaculture can benefit nature and people. *PLoS ONE*, 14(10).

www.nature.org/en-us/about-us/where-we-work/united-states/massachusetts/stories-in-massachusetts/aquaculture-oyster-restoration/

Restoring native oysters to European seas

Formerly a food for the masses, native oysters have declined around Europe. **Alice Lown** and **Tom Cameron** describe the widespread restoration efforts that are now underway.

The decline of the native oyster (*Ostrea edulis*) has been attributed to a range of factors including overfishing, loss of habitat, pollution, disease and non-native predators and competitors. Alongside losses of the oysters themselves is the loss of the habitats oysters can create, and the ecological functions those habitats could support. Much of the research on shellfish ecosystem function and services is based on intertidal rock oysters (*Crassostrea gigas*) but there is evidence emerging of biodiversity gains, greater carbon storage potential, improvements in water quality, and contributions to nutrient cycling that could all come from the restoration of native oysters.

Plans to restore native oysters

With the native oyster previously abundant in the shallow seas around Europe, plans to restore this species are now widespread (Fig. 1). As there are so many restoration projects, and more projects on the sustainable fishing and production of oysters, it is essential for best practice to be shared in order to progress the restoration of this species. To facilitate knowledge transfer and promote collaboration, the 'Native Oyster Network UK & Ireland' was established in 2017.This network continues to grow with members including oyster growers, interested coastal communities, NGOs, academics, conservationists and a range of philanthropists and companies working together to restore the native oyster.

Restoration: a case study

Among the remaining strongholds of native oysters are the Essex estuaries. Here, oysters are ingrained in the culture with the livelihoods of many generations depending on this species. Research by the Essex Wildlife Trust and the University of Essex resulted in the designation in 2013 of England's largest inshore Marine Conservation Zone, the Blackwater, Crouch, Roach and Colne Estuaries MCZ. Spanning 284 km^2, this area is designated not just to protect, but also to restore the native oyster and its habitats.

Mersea Island oystermen wanted to do something to restore their

Figure 1. Map showing the distribution of projects involved in restoration or production of the UK native oyster registered with the Native Oyster Network UK & Ireland. For more information see https://nativeoysternetwork.org/restoration-projects-partnerships/

beloved shellfish, giving rise to the Essex Native Oyster Restoration Initiative (ENORI). Working with Natural England and Kent & Essex IFCA, ENORI established a 2 km^2 Blackwater Restoration Box, where trials of active habitat restoration have begun. In Essex the focus of restoration is to improve the habitat for the settlement of juvenile oysters. To achieve this, tonnes of cultch (shell and gravel) were laid on the seabed in spring 2019 (Fig. 2), along with 12,000 adult oysters, as spat (newly settled oyster larvae) are known to be attracted to live conspecifics (Fig. 3). This project represents one of the first of its kind, with a Marine Licence solely for the purpose of shellfish restoration. Results from this experiment should guide further restoration at larger scales.

Bringing the North Sea together

Projects are taking place across Europe under the umbrella of an international network, Native Oyster Restoration Alliance (NORA), which was established in 2017. Laboratory and pilot field studies are indicating benefits to biodiversity and water filtration (Fig. 4) but moving forward, we face challenges in upscaling these trials, streamlining the marine licensing process and, not least, securing funding. The benefits of oyster restoration have long been understood in the USA, with projects such as the Chesapeake Bay Oyster Program investing many millions of dollars to improve coasts for people, for wildlife and for access to a great food source. This is what we now need to achieve across Europe.

Dr Alice E. Lown (aelown@essex.ac.uk) and Dr Tom C. Cameron (tcameron@essex.ac.uk). School of Life Sciences, University of Essex.

Further reading

The Native Oyster Network UK and Ireland (NativeOysterNet). Contact: Celine Gamble, nativeoyster@zsl.org or visit nativeoysternetwork.org/network

The Essex Native Oyster Restoration Initiative (ENORI). Contact: Matt Uttley, matt@bluemarinefoundation.com or visit https://essexnativeoyster.com

Allison, S., Hardy, M., Hayward, K., Cameron, T.C. & Underwood, G.J.C. (2019) Strongholds of *Ostrea edulis* populations in estuaries in Essex, SE England and their association with traditional oyster aquaculture: evidence to support a MPA designation. *Journal of the Marine Biological Association of the United Kingdom*. 1-10

Native Oyster Restoration Alliance (NORA) please visit https://noraeurope.eu/# or contact Philine zu Ermgassen at secretariat@noraeurope.eu

Figure 2. (Top) Cultch (shell and gravel) being laid into the Blackwater Restoration Box in Essex to promote the settlement of native oyster larvae. Image © Matt Uttley.

Figure 3. (Middle) Oyster spat (circled) on a small oyster. Image © Alice E. Lown.

Figure 4. (Bottom) Some of the species associated with the native oyster include starfish, whelks, sea urchins, and various crab species. Image © Alice E. Lown.

Restoring meadows, marsh and reef

Ben Green introduces an initiative that aims to restore England's lost estuarine habitats.

Figure 2. Steart Marshes, Somerset: a managed realignment completed in 2014 that created 277 hectares of new intertidal habitat.

A hundred years ago, a walker along the shoreline at the mouth of many of England's estuaries would have encountered seagrass beds, native oyster beds or saltmarshes. These vital marine habitats have undergone a significant decline over the past two centuries. Saltmarshes have decreased in extent by 85 per cent in England, native oyster reefs by 95 per cent. Along with the loss of habitat, there is the associated loss of ecosystem services: the flood and storm protection provided by saltmarshes; the carbon sequestration and fish nursery site potential of seagrass (Fig. 1); the water quality improvements provided by native oysters. All three provide complex habitats that can increase biodiversity.

The Environment Agency (EA) are coordinating the 'Restoring Meadows, Marsh and Reef' initiative (ReMeMaRe) with Natural England and other Defra agencies, with a vision that estuarine and coastal habitats will be restored for the benefit of people and wildlife. This aligns with the UN Decade of Ecosystem Restoration. We want to reverse centuries of decline and our ambition is to restore at least 15 per cent of the current extent of our lost habitats. However, restoration is a complex process, and funding and regulatory issues only increase this complexity further. ReMeMaRe will work with Defra partners, NGOs, industry, and academia with the aim of streamlining the regulatory procedures for restoration projects, and providing support and coordination to attract investment. Restoration cannot be financed entirely from public funds; a blended approach with private funding can be used to attract investors and to engage community-led approaches.

Figure1. Subtidal seagrass (*Zostera marina*) beds off the west coast of the Isle of Wight. Intertidal and subtidal seagrass beds have declined significantly over the last century.

The climate crisis has increased the profile of habitat restoration in the media and the public sphere. Whilst much of the coverage is around rewilding and the reintroduction of lost species to forests and uplands, the potential to restore our estuaries and coasts is beginning to be recognized. The EA have the Regional Habitat Compensation programme that creates saltmarsh lost due to flood and coastal defence construction (e.g. through managed realignments such as Steart Marshes, Fig. 2). Compensation is not restoration though, and we want to go beyond this to support the creation of saltmarsh, seagrass beds and oyster beds purely for restoring biodiversity and for their associated ecosystem benefits. Some organizations are already doing this: the UK and Ireland Native Oyster Network (NON), and the European Native Oyster Restoration Alliance (NORA) provide oyster restoration leadership, whilst seagrass restoration is being pioneered by Project Seagrass and the Natural England-led ReMEDIES project.

Our ambition is to restore at least 15% of the current extent of our lost habitats.

We want ReMeMaRe to build capacity and share knowledge with our partners. We're working with NON and the Zoological Society of London to produce oyster restoration guidelines, including setting out biosecurity recommendations. Seagrass and saltmarsh guides are also in development.

Following the success of the Restoring Estuarine and Coastal Habitats in the NE Atlantic (REACH) conference in July 2019, the EA and Natural England are co-hosting REACH 2 on 14 July 2020. This conference will build on the growing network of restoration practitioners and enable people to share progress and inspire greater restoration activity in our estuaries and coasts. We hope you'll be able to attend!

Dr Benjamin Green (ben.green@environment-agency.gov.uk) Senior Advisor, Estuary and Coast Planning

Note: REACH 2 conference details and call for abstracts will be available online shortly. Please contact Roger.Proudfoot@environment-agency.gov.uk to register your interest in advance.

Tongareva Atoll: a sea turtle haven in central Oceania

Figure 2. A rescued green turtle hatchling. Image © Michael White.

MBA Fellow **Michael White, Ru Taime**, and **Marangi Taime** describe how a community on a remote Pacific atoll is planting trees to save turtles.

Tongareva is the largest and remotest atoll in *Kuki Airani* (the Cook Islands). It is a haven for biodiversity, especially seabirds (*manu* in the local language, Fig. 3d) and sea turtles (*honu*). The human population is around 180 people leading a mainly subsistence way of life, gathering resources directly from nature.

The atoll is 77 km in circumference, and the lagoon has an area of 233 km^2 (see Fig. 1). The *motu* (islets) are traditionally owned by extended families but are uninhabited and used for resource gathering. Forests are mostly coconut trees and a few hardwoods, such as Pacific mahogany, Pacific rosewood, and tepuka. Hardwoods tend to grow more slowly, but can reach substantial heights and provide important habitat for birds.

Figure 1. Tongareva Atoll (09º South; 158º West) in the central South Pacific Ocean. Image Google Earth. Data SIO, NOAA, U.S. Navy, NGA, GEBCO Image © 2020 Maxar Technologies

This important maritime ecosystem was near-pristine, but is now badly impacted by climate change. Impacts include: considerable tree loss, death of giant clams (*Tridacna maxima*) and coral bleaching, and pollination failure. In addition to this, oceanic plastics and industrial fishing-gear litter all shorelines and pollute our food supply.

Hakono Hararanga Incorporated is Tongareva's Community Environmental Society. It monitors our biodiversity year-round, and records all marine sightings and animal behaviour (see Fig. 3c). The Society also conducts community education—running field days for the school and beach cleans—and undertakes extensive tree planting. We also promote low-carbon living, including solar-charged electric vehicles and outboard motors. Our intention is to create an abundant, sustainable and biodiverse future for our atoll.

Endangered green sea turtles *Chelonia mydas* (Fig. 2) are present in Tongareva throughout the year, while critically-endangered hawksbills *Eretmochelys imbricata* have only been observed five times since 2012.

In most places around the world, including Palmerston Atoll, green sea turtle nesting is distinctly seasonal, but at Mangarongaro motu we have observed successful nesting *every month* since August 2014. This is the most important green sea turtle rookery in the central South Pacific. All sea turtle nesting occurs on the ocean side of the atoll, and juvenile development occurs year-round in the lagoon and on outer reefs. Mating is often observed in Taruia Passage and at Omoka wharf.

Reef-top gaps or *ava* provide opportunities for turtles to emerge from the sea. Large waves can carry turtles to

Year	2014	2015	2016	2017	2018	2019
Nests	534	555	565	1,374	1,767	1,030+†

† The 2019 tally was until mid-September, when our research was disrupted due to logistical challenges.

Table 1: Annual green sea turtle *Chelonia mydas* nest totals at Mangarongaro, 2014–2019.

the back of the beach, where good quality nesting sand is found a short crawl away. The habitat is highly dynamic and often steeply sloping; at times all the sand is stripped away and the honu then go into the forest and dig nests there. Egg predation is absent, so clutches tend to be successful. We stay off the beach at night allowing the honu to nest undisturbed: nesting has steadily increased (see Table 1).

Sexual differentiation of sea turtle embryos is determined by nest incubation temperature: females hatch from warmer nests, males from cooler ones. Global warming will favour the production of females. Mangarongaro's beach faces west and receives full sun from noon until sunset, but climate change impacts had killed many trees just inland, meaning the rookery received full sun all day. In response, Hakono Hararanga has planted over 6,000 trees in the last 18 months (Fig 3a & b), the aim being to create canopy cover, which can shade the beach, provide local cooling and retain soil moisture in the forest.

Sea turtles are well adapted to life on our planet, having changed little in millions of years. Human activities are now their greatest threat, impacting directly—for example by building on nesting beaches, or taking sea turtles and eggs; or indirectly—for example through fishery bycatch, oceanic pollution, and now climate change. Our solutions must be holistic, addressing every aspect, if we wish to have a sustainable and biodiverse future.

Dr Michael White (crwban681@yahoo.co.uk) FMBA
Ru Taime
Marangi Taime

Disclosure

Michael is President of Hakono Hararanga, Ru the Chairman, and Marangi the Waste Manager.

We had a GEF-SGP grant for reforesting; an Australian High Commission (Wellington, NZ) DAP grant for oceanic plastics; and sponsorship for tree planting from Te Ara o te 'Onu (Rarotonga).

Further reading

White, M. (2014) Tongareva Atoll: The most important sea turtle habitat in the Cook Islands. *Testudo* 8: 19-37. http://library.seaturtle.org/8489

White, M. (2016) *Too hot in Paradise! The Marine Biologist, April 2016: 26-27*. The Marine Biological Association https://www.mba.ac.uk/marinebiologist/

http://library.seaturtle.org/9685

White, M. (2019) *Initial Assessment of a New Coral Bleaching Event at Tongareva Atoll in the Northern Cook Islands.* http://library.seaturtle.org/11235

Figure 3. a: Saplings are brought in to Mangarongaro's beach to replace trees lost due to global warming impacts. b: Saplings after one year. c: Tallying the eggshells. d: Masked booby (*Sula dactylatra*) on eggs. Images © Michael White.

Coral restoration in a warming world

Coral reef restoration is emerging as a strategy to combat the coral reef crisis, but, in an era of warming seas, is it a worthwhile endeavour? By **Ian McLeod** and **Maxine Newlands**.

The United Nations Decade of Ecosystem Restoration (2021–2030) is a clear sign that restoration is becoming a major priority on land; yet marine ecosystem restoration is contentious. Whilst land-based ecosystem restoration is well established, the science to restore our oceans' health at scale is less developed. Critics claim marine ecosystem restoration is expensive, has a high risk of failure, and distracts the conversation away from tackling global climate change.

Until recent decades, marine management has focussed on passive restoration by reducing stressors that caused the damage. Actions such as managing destructive overfishing through marine protected areas, or coastal pollution through improved land management, have led to major improvements in some areas. Despite these actions, many valuable marine ecosystems continue to decline and active restoration is increasingly being seen as an economically viable management option. Usually, active restoration can only be successful once the drivers of decline have been reduced or eradicated. For example, hundreds of hectares of oyster reefs are being rebuilt in Chesapeake Bay, US, because they could not recover on their own after destructive dredging ended.

Coral reefs are some of the most threatened ecosystems on the planet. They support the livelihoods of at least 500 million people through activities such as fisheries and tourism, and are worth an estimated US$375 billion per year. Reductions in coral reef health have been recorded in all major tropical oceans since the 1980s, with an average of 30–50 per cent reduction in coral cover globally.

Global climate change is the key driver of coral reef decline from associated bleaching events, disease outbreaks, and ocean acidification from warming waters. The Intergovernmental Panel on Climate Change forecasted the world's coral reefs would decline by a further 70–90% with a 1.5°C increase in global mean temperature. Recent bushfires, flooding, and coral bleaching are clear signs that climate change is impacting at scale. With climate models predicting that even

Figure 1. (main picture) Coral research in the Australian Institute of Marine Science's Sea Simulator. Image © Australian Institute of Marine Science / Christian Miller.

Box 1. What is coral restoration?

The earliest coral restoration projects involved direct transplantation of coral colonies, often away from areas of development such as pipelines. In the 1980s, coral gardening projects where coral fragments were grown in an intermediate nursery phase began. This allowed for a multiplication of fragments as corals could be grown and fragmented many times before outplanting. More recently, new methods to encourage coral recovery have been trialled. In Hawaii, teams of divers have been removing over-growing, invasive seaweed with the help of an underwater vacuum. In the Philippines, coral spawn has been captured and reared until ready to settle, with millions of larval corals then added to degraded reefs. In Indonesia, the pet food and confectionary company Mars, Incorporated has developed 'reef stars'; frames that are linked together and seeded with corals to consolidate areas of coral rubble.

if we stop all emissions of greenhouse gases today, warming will continue for decades, then why invest in coral restoration (see Box 1) if the stressor, climate change, has not been removed?

Recently, an international team of scientists looked at 362 cases of active coral restoration methods from 56 countries across four decades. Their study showed that over 200 different species of corals have been used and survival of restored corals was relatively high, between 60 and 70 per cent, demonstrating that it is possible to successfully grow corals at smaller scales. The research team also identified common issues in projects including a lack of clear and achievable objectives, or appropriate, standardized monitoring and reporting, along with many projects that were poorly designed in relation to their stated objectives.

Despite some of the recurring challenges in coral restoration projects, some nations are investing in coral restoration in a major way. In Australia, the federal government—through the Reef Trust Partnership—has invested close to AU$100 million into the Reef Restoration and Adaptation Program, seeking to scale-up and accelerate reef restoration and adaptation science to help protect the Great Barrier Reef (Figs. 1 & 2). The initial scoping and design phase has been completed and seven categories of interventions have been identified for the next five years of research and development (Box 2). These interventions include ways to protect corals by reducing their exposure to extreme temperature stress by making environmental adjustments that, for example, increase shade or cool the water. It could also include assisting coral populations to more rapidly build natural resilience to threats such as higher temperatures, through measures such as selective breeding or genetic engineering. Other interventions aim to accelerate natural recovery, for example, modifying reef surfaces to promote growth (Fig. 3), and producing and distributing coral larvae on a large scale (Fig. 4).

In the US, the National Oceanic and Atmospheric Administration (NOAA) and partners have developed an unprecedented, decades-long approach to restore seven iconic reef sites in Florida Keys National Marine Sanctuary. The project, Reef Icons, involves removing nuisance and invasive species, like seaweed and coral predators, before a rebuilding programme that includes planting clusters of a range of coral species, followed by the addition of urchins and crabs to keep seaweed under control.

Alongside these government-led initiatives, the Coral Restoration Consortium (CRC) is a rapidly growing network of coral restoration groups. The CRC is a 6,000-strong community of practice comprising scientists, managers, coral restoration practitioners, and educators with a focus on knowledge sharing and collaboration. A new report from the United Nations and the International Coral Reef Initiative (ICRI) found that nine ICRI member countries currently have or are developing best practice

Figure 2. Larvae are settled onto 3D printed shapes in the laboratory, and the shapes are then wedged into areas of the reef lacking live coral. Deployment shown here on the Great Barrier Reef. © Australian Institute of Marine Science / Andrea Severati SECORE.

Figure 3. Coral reef restoration using artificial reef structures: three-year time series of coral growth on coral tables in Pulau Hatamin, Indonesia. Photo by Martin Colognoli for Coral Guardian.

and policy guidelines for coral restoration projects. The average annual spend of ICRI members on coral restoration ranged between US$30,000 to US$1 million. These numbers are dwarfed by the amount that could be lost if reefs continue to degrade. A UN report estimates that if reefs continue to decline, their annual value could fall by US$3.1 billion in Mesoamerica and US$2.2 billion in the Coral Triangle by 2030, adding that measures to address this decline, from large and cost-effective investments in coral reef conservation and restoration will be necessary.

Box 2. Types of interventions being investigated through the Reef Restoration and Adaptation Program

- **cooling and shading** – reducing exposure of coral reefs to heat and light stress during acute events
- **stabilization** – adding reef structures and stabilization measures to facilitate coral recovery following disturbances (see Fig. 3)
- **coral seeding** – using natural coral larvae to enhance coral reproduction and reef recovery following disturbance
- **biocontrol** – managing coral predators and competitors to enhance coral survival
- **field treatments** – increasing coral survival and health following disturbance with probiotics, feeding, medicines or other treatments
- **seeding with enhanced corals from existing stock** – seeding reefs with corals from existing stock that have enhanced performance, to increase coral health and tolerance
- **seeding enhanced corals bred from engineered stock** – seeding reefs with corals that have enhanced performance derived from synthetic biology and gene editing approaches, to increase reef health and tolerance.

Where next for coral restoration?

This year and the next will be significant for coral reef conservation and restoration. In the political sphere, the implementation of the Paris Accord is hoped to reduce global carbon emissions whilst Australia and the US lead the way in reef restoration science, supported by the UN Decade on Ecosystem Restoration.

The UN Decade aims to massively scale-up restoration to combat the climate crisis and enhance food security, water supplies, and biodiversity. Most of the focus will be on land, through actions such as replanting trees. These efforts will help marine ecosystems in three ways. First, many coastal ecosystems are damaged by muddy water and pollution from degraded agricultural land, and this will be reduced if there is more plant cover. Second, restoring coastal wetlands and replanting

Figure 4. Larval restoration trials in the Great Barrier Reef. Image © Ross Miller.

mangrove forests will improve local water quality as they filter runoff from coastal land. Third, restoration could remove up to 26 gigatonnes of greenhouse gases from the atmosphere, helping to combat climate change, the most important threat for marine ecosystems such as coral reefs.

So what is the role of coral restoration in a warming world? First, whilst decades of warming are 'baked in', coral restoration and adaptation could help preserve more coral stock and biodiversity to help corals recover once, or if, temperatures stabilize. Second, in many areas such as popular tourism locations, local reefs are so valuable that it justifies the high cost of restoration. Third, all new science and innovation is contentious, but coral restoration allows for citizen scientists, divers and people who care to get involved in helping, and therefore gives hope. Lastly, coral restoration has largely been driven by passionate tinkerers, and involving high-technology and large investments into research and development offers opportunities for new solutions.

Some critics worry that an increasing focus on restoration will distract from meaningful action on climate change, and this is a valid concern. Without meaningful and rapid action to reduce greenhouse gas emissions the future for coral reefs is bleak. Conversely, by focussing so much on climate change as the driver of coral decline, there is a danger that decision-makers will give up on other actions to improve coral reef health, such as improving local water quality because they think reefs are doomed anyway.

Global climate change is the key driver of coral reef decline

The upcoming decade will be critical for the world, and for coral reefs. We are responsible for the destruction of much of the world's natural wealth in just a few lifetimes. Embracing the UN Decade on Ecosystem Restoration on land and at sea, along with urgent action to reduce greenhouse emissions, is an opportunity to turn the tide so the next generation can also experience the world of wonder we have had the privilege to enjoy.

Dr Ian McLeod (ian.mcleod@jcu.edu.au) and Dr Maxine Newlands (maxine.newlands@jcu.edu.au) at TropWATER, James Cook University, Australia.

Further reading

McLeod I.M. *et al*. (2019). *Mapping Current and Future Priorities for Coral Restoration and Adaptation Programs.* 44 pages. Available at www.icriforum.org

Boström-Einarsson L. *et al*. (2020) Coral restoration – A systematic review of current methods, successes, failures and future directions. *PLoS ONE* 15(1): e0226631. https://doi.org/10.1371/journal.pone.0226631

Reef Restoration and Adaptation Program website https://www.gbrrestoration.org/

Restoring Seven Iconic Reefs: A Mission to Recover the Coral Reefs of the Florida Keys https://www.fisheries.noaa.gov/southeast/habitat-conservation/restoring-seven-iconic-reefs-mission-recover-coral-reefs-florida-keys

The restorative properties of National Marine Parks

Lydia Tivenan descibes how National Marine Parks could extend the benefits of blue spaces to contribute to societal health and wellbeing.

The popularity of natural history documentaries and increasing attention on social media over the past few years has driven enormous public interest in the marine environment. Yet surveys around the globe continue to show that the wider public have a limited understanding of the marine environment. Time and again, knowledge has been shown to be a catalyst for behaviour change, a recent example being the rise in awareness of plastic pollution following the Blue Planet 2 series which led to policy changes on plastic pollution in many countries.

Born in the US, the concept of ocean literacy promotes a way to engage societies with the sea, and to increase our understanding of the ocean's influence on us and our influence on the ocean. A collective intelligence study found that lack of personal experience of the ocean and lack of opportunities to interact with the marine environment were preventing people from becoming ocean literate. If, as a society, we enable ways to nurture the relationship between humans and the sea, benefits could extend beyond the marine environment to improvements in physical and mental health.

The restorative properties of water have long been acknowledged, and a large body of research exists on the wellbeing benefits of blue spaces showing that people living near, or having views of the coast are healthier and happier. In Australia, volunteers who monitored Marine Sanctuaries through citizen science programmes said that participation made them feel both mentally and emotionally positive, increased their personal satisfaction, and created a desire to protect the marine environment.

Current UK marine protection designations are confusing and inaccessible to the public and there is no mandatory requirement built in for marine education or engagement. Could National Marine Parks (NMPs) be used as a way to engage and educate the public on the marine environment and connect citizens to our coastal waters in a way that current designations do not?

National Marine Parks may engage people in ways other designations cannot. Jewel anemones (*Corynactis viridis*) in Plymouth Sound, location of the UK's first National Marine Park. Image © Keith Hiscock.

The concept of marine parks received a notable reference in the UK Government's recently published *Landscapes Review: National Parks and AONBs*. In the UK, National Parks on land exist to 'conserve, enhance and promote the special qualities of the Parks'; aims which could be applied to National Marine Parks. Another possible model is Sweden's Kosterhavet National Park, where the key focus of the park is public engagement and tourism whilst also allowing for the sustainable use of natural resources and long-term conservation.

The UK's first NMP was recently designated in Plymouth Sound in 2019: could it pave the way for the UK to achieve a healthier, more ocean-literate society? It will most certainly be watched with interest as a proving ground for new approaches to balancing a complex mix of uses whilst delivering societal benefits.

In a world of mounting health problems and environmental degradation, the benefits of NMPs to people and coastal ecosystems appear achievable and desirable. If future NMPs are designed to be inclusive and accessible to all parts of society, the marine environment could become an essential and deeply beneficial presence in our lives.

Lydia Tivenan (lydiativ@hotmail.co.uk)

Further reading

McCauley, V., McHugh, P., Davison, K. and Domegan, C. (2019) Collective intelligence for advancing ocean literacy. *Environmental Education Research* 1-12.

Koss, R.S. (2010) Volunteer health and emotional wellbeing in marine protected areas. *Ocean & Coastal Management* 53(8), 447-453.

Kelly, C. (2018) 'I Need the Sea and the Sea Needs Me': Symbiotic coastal policy narratives for human wellbeing and sustainability in the UK. *Marine Policy* 97, 223- 231.

Sharing understanding of algae

Clare Marshall reports on the 68th British Phycological Society Meeting.

The New Year was ushered in with a celebration of all things algal, as over 130 delegates and speakers from around the world gathered in January in Plymouth, UK, for the 68th British Phycological Society (BPS) Meeting.

The intellectual work began with a keynote lecture from Grégory Beaugrand about phytoplankton responses to climate, using historical data collected by the Continuous Plankton Recorder (CPR) Survey. A great day of Manton Prize[1] talks, delegate talks and two-minute poster pitches followed, taken into the evening with a poster session, enabling those not giving a talk to share their work. Contacts were made and research shared, forging into 2020 with some great ideas. Amongst many stands, new microscope technology, algae cultivation, and biotechnology techniques were on display, and a local artist, Debby Mason, displayed her work.

The special sessions included an insight into seaweed-microbe interactions and seaweed restoration projects from Alexandra Campbell of the University of the Sunshine Coast, Australia. The public lecture 'Thin films of Life and the challenges of changing environments' was delivered by Prof Graham Underwood.

BPS has a strong community ethos and a particular highlight of the week was the evening dinner. After Society business had been attended to, the Manton Prize winners were announced: Daniel Liesner (Alfred Wegener Institute) won the prize for best talk, and Nele Scimpf (Alfred Wegener Institute and University of Plymouth) for best poster. The Ceilidh band then fired up, providing musical delights and dancing, with most people giving it a go.

Delegates also had the opportunity to test their local seaweed identification

Clare Marshall representing the MBA at the 68th British Phycological Society Meeting. Image © Marine Biological Association.

skills at Plymouth University's Marine Station, whilst others thoroughly enjoyed a plankton sampling trip in Plymouth Sound on board *Wavedancer*.

The Marine Biological Association, The University of Plymouth, and Plymouth Marine Laboratory collaborated to deliver the event, and would like to say a big 'Thank you' to the BPS volunteers and events staff for all their hard work and enthusiasm.

Clare Marshall (clare.marshall@mba.ac.uk) CPR Plankton Analyst and Conference Chair of the BPS Volunteer Committee.

1 The Irene Manton Prize for the best oral paper by a postgraduate student, and the BPS Student Poster Prize, for the best poster by a postgraduate or undergraduate student. See https://think.taylorandfrancis.com/journal-prize-est-bps-manton-prize/

Delegates at the 68th British Phycological Society Meeting, Plymouth, January 2020. Image © Marine Biological Association.

Come to Essex, bring wellies

The beautiful Colchester campus is close to the Colne estuary, in Essex, UK. **Michelle Taylor** descibes a hands-on marine biology experience right by the water.

Figure 1. A new angle on student fieldwork. Image © University of Essex.

The sun is shining, the quadrats are out, and there is a student stuck at a seemingly impossible 45-degree angle in a mud flat (Fig. 1). This is our first-year student introduction to some of the local ecosystems within the Marine Conservation Zone found near our campus in Colchester. It's only week two and Essex believes in immersing its students in the marine environment (at least, knee-deep in the case of the student in the photo above), and as soon as possible.

Let's face it, when you say you are a marine biologist, most people's minds wander to tropical beaches, and snorkelling over coral reefs whilst counting colourful swarms of fish. Now, don't get me wrong, our Indonesia coral reef field course covers just such tropical loveliness (more on that later), but most marine biology field work, especially in the UK, involves wellies, waterproofs, and maybe Antarctic-grade thermals. The saltmarshes are later in the first month, and then there is a visit to rocky shores in Scotland, and that is just year one. That's not forgetting the third year field course to Greece, where we play with drones and boats to help monitor marine mammals, learn about microplastic pollution, and map seagrass for a week. Of course it's not the location that matters; field work and studying the marine environment is often about testing theory and answering questions. What dictates where different animals exist? How and why are there zones of different animals in these environments? If—or more realistically, when—the marine environment changes, will the animal communities change too? It's easier to answer such questions having seen the ecosystem in question. Even if you don't like the outside world very much (I have several very happy marine biologist friends who never venture beyond a lab or stray far from their computers), it is a valuable exercise to understand how raw marine ecological and biological data is collected.

> most marine biology field work, especially in the UK, involves wellies, waterproofs, and maybe Antarctic-grade thermals

Figure 2. Essex's attitude to fieldwork is 'the more the better'. Image © University of Essex.

Now you have a feel for Essex's attitude to field work (the more the better, Fig, 2), and given that the theme of this current edition is ecosystem restoration, I wanted to highlight Essex's links to Indonesia. Here, Essex undertakes teaching and environmental research that targets the world's ecosystem that is likely to be the first to collapse in the face of climate change: coral reefs.

Essex has been taking students to a tiny dot of an island called Hoga, Sulawesi, since 2002 (opulent sunset image of our students finishing the last dive of the day: see Fig. 3). Our very own Professor Dave Smith started Operation Wallacea (a volunteer research organization) there with colleagues at about that time. The shacks are still simple and the animal life on land and under the waves is still stunning. The internet connection is laughably bad but it is precisely this isolation (it takes two-and-a-half days to get there) that enables healthier coral and an experience like no other. And we have electricity until 10pm now, so what more could you need?

Our links to Indonesia go beyond a tropical marine biology field course; Professor Smith and the Mars organization have established an inspiring coral reef restoration initiative. The MARRS[1] (Mars Assisted Reef Restoration System) method involves installing continuous connecting sheets of 'reef stars', which have fragments of live coral attached to them, over

1 www.mars.com/news-and-stories/articles/coral-reef-rehabilitation

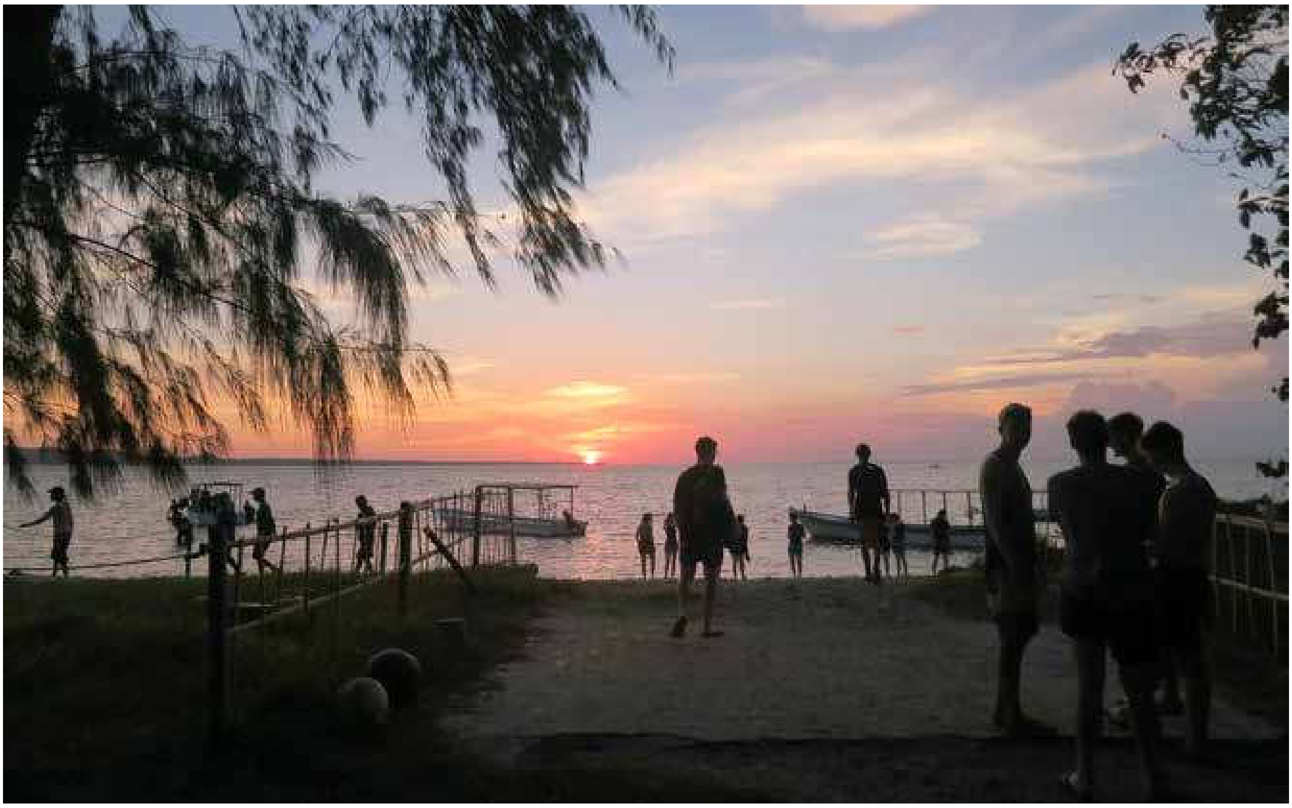


Figure 3. Opulent sunset image of Essex students finishing the last dive of the day, Hoga, Indonesia. Image © University of Essex.

rubble or dead coral areas to link living reefs together. 18,000 reef stars incorporating 270,000 coral fragments have been installed already, covering approximately 3 hectares; possibly the world's largest coral reef restoration project. The results are impressive and a much-needed good news story for the ocean.

Now, if the thought of field work alone can't tempt you to our campus, what about the plethora of fabulous research our internationally-recognized lecturers and post-docs pump out? Our marine biologists work on oil spill degradation, oyster restoration (the famed Mersea oyster is just down the road), ocean chemistry, global processes, and, of course, animal ecology. We work in both poles and from shallow to deep water: in fact there are not many marine ecosystems we don't study in some form or another and this experience is woven into our research-led teaching. To support this teaching we have a shiny new-STEM Centre with all the latest tech (Figs. 4 & 5), and we are investing £1 million in improving our student research and aquarium area. In addition we just bought another research boat!

We'd love to see you on campus, and would be happy to show you around, so drop me a line (pun totally intended) and get in touch.

PS The wellies survived to fight mud flats another day. Bring on the saltmarsh!

Dr Michelle Taylor (michelle.taylor@essex.ac.uk) at the School of Life Sciences, University of Essex.

Figure 4. The STEM Centre is the University's new £18 million facility in the heart of the Colchester campus. Image © University of Essex.

Figure 5. Students working with our new iPad integrated microscopes. Image © University of Essex.

Image from the archive of the Marine Biological Association

First Class of Experimental Zoology conducted by Dr Cresswell Shearer in 1911

Back row: Kathleen Haddon; Harold Munro Fox (previously H. M. Fuchs); F. M. Davis. Front row: Dorothy Jordan Lloyd; Dr. Creswell Shearer; John Tennant Saunders.

Dr Cresswell Shearer's (1874-1941) research interest was experimental embryology. From 1910, Shearer carried out research into the hybridization of echinoids at the MBA's Plymouth Laboratory. Shearer also had a profound knowledge of medieval Italian architecture and was a keen artist and photographer, which complemented his scientific and literary work.

Kathleen Haddon (1888-1961) was a British zoologist and photographer. Until 1947, women were not eligible to receive degrees from Cambridge University. Instead, Haddon worked as a university demonstrator in zoology from 1911 to 1914. She later received a degree in 1948.

Harold Munro Fox (1889-1967) worked on the genetics of sea urchin hybrids at the MBA from 1911-12. The following year, Fox was appointed lecturer in zoology at the Royal College of Science, London.

In 1911, F. M. Davies joined the staff of the Fisheries Department of the Ministry of Agriculture and Fisheries as an assistant naturalist. After the war, Davies investigated the fishing gear and methods employed by English and Welsh fisheries. Later he studied North Sea benthic fauna.

Dorothy Jordan Lloyd (1889-1946) studied the interactions of water with proteins, and was the first to propose that hydrogen bonds maintained the structure of globular proteins. She was also Director of the British Leather Manufacturers' Research Association: the only female scientist at the time in charge of an industrial research association.

Little is known about John Tennant Saunders, apart from the fact that he co-authored the *Manual of Practical Vertebrate Morphology*.

Interview

Dr Gerald Boalch is a marine phycologist and long-standing member of the Marine Biological Association.

How long have you been a member of the MBA?

I joined when I was a student in 1953; I've been a life member since 1960.

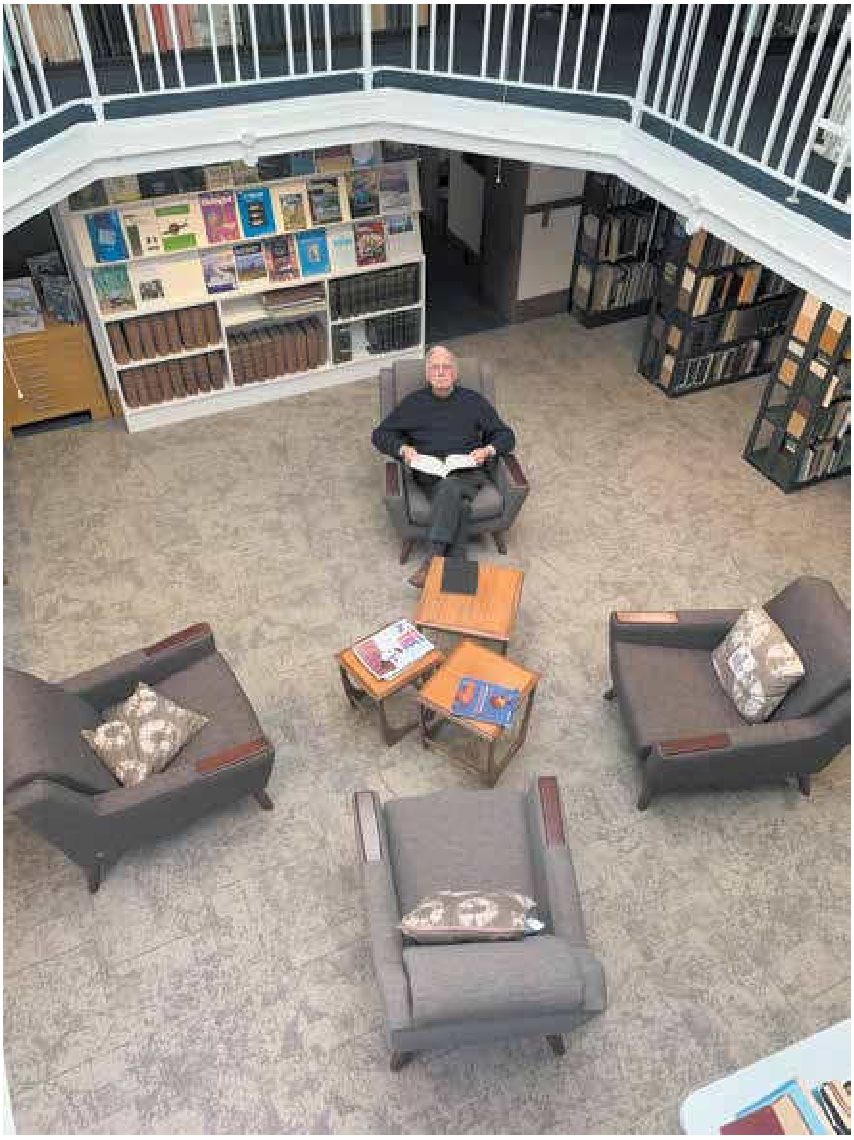
What has motivated you in your career?

As school children at Beer [on the South coast of Devon, England] during the war we were involved in collecting seaweed. The supply of agar from Japan had ceased, we had to find a substitute and *Gigartina* and *Chondrus* were used as alternatives. We were marched down to the beach at low tide and we spent the afternoon collecting seaweed. I realized there was more than one sort of seaweed and when I went to secondary school, we had a very enlightened teacher who taught me how to press seaweeds and from there on I was up to my neck in seaweeds.

What are the questions that you have tried to answer throughout your career?

The first thing of importance was my PhD work in London where I was the first to cultivate a *macroalga* in a laboratory under bacteria-free conditions. It was *Ectocarpus* and other people took it up afterwards as it proved to be a valuable source of viruses. We got rid of the bacteria, but we did not realize that the thing was full of viruses.

After I was appointed a research fellow at the MBA, I was told I had to take an interest in plankton, and I started working with Dr Mary Park who said to me, I'm doing the small stuff, you've got to do the diatoms and dinoflagellates, so that's what I specialized in. I published papers on the taxonomy of several genera of diatoms and dinoflagellates and I've been looking at samples for over 60 years.



Gerald Boalch in the Southward Reading Room of the National Marine Biological Library. Image © Marine Biological Association.

How do you see your work in relation to the big environmental challenges faced by society?

Sir Frederick Russell, Alan Southward, Ian Butler and I were studying the seasonal variation in herrings and pilchards, and we produced a paper in *Nature* on a 50-year cycle of cooling and warming in the western English Channel, going back to 1600. The cycle is still slightly evident now, but it is being drowned out by a much stronger effect which is presumably man-made. I think it's the longest long-term study ever published on the marine environment.

We could also mention the overuse of resources and the degradation of marine habitats.

This idea of having nature reserves in the sea or closed areas can be very difficult. In the Domesday book, Beer is listed as a fishing village and now the fishing has virtually stopped because they are not allowed to use any bottom gear. I think there should have been a more moderate system. If the order had said these areas can be used by small boats with just one or two men where everything is done manually, this would have been much more suitable, and would have allowed the small local boats to fish as they had done for generations.

In your science career what has been your greatest achievement, and what are you most proud of?

I think one of the most pleasing things was stopping the introduction of *Macrocystis* [giant kelp] to the English Channel. I went to a meeting of European phycologists in Roscoff where they were discussing the introduction of *Macrocystis*, thinking I was going to try and stop this. When I got there, my French colleague rather carefully said, 'Oh, Gerald you are in the chair for this meeting,' which meant that as chairman I couldn't join in with the discussions. Harry Powell from Millport was there and I told him not to worry: as I was in the chair, he would get the first questions. I said at the beginning, I am going to run this on the English system and no one is to speak until the chairman indicates, and although one or two of them got up, I said, sit down and wait! And Harry got the first questions in. During the lunch break there was this unhappy situation where I was talking to the professor from Caen who was pushing the *Macrocystis* introduction and I said, 'Look, we are going to be at war, you and I, over this, we must do something about it.' And she said, 'Well, in France we can't get grants for anything else except *Macrocystis*'. So I suggested that they put in an application for a grant with their government for work on a native species that I would countersign. She got the grant for local research and stopped working with *Macrocystis*, which I think is my greatest achievement. If we had *Macrocystis* in the Channel goodness knows what would happen.

I was also very proud when I was made President of the International Phycological Society at an enormous meeting in the US. Also, I was made an Honorary Professor in Marine Botany at the Universidad Austral de Chile at Valdivia, after giving a series of lectures there on marine phycology.

Which marine scientists or marine biologist do you most admire, and why?

Sir Frederick Russell, because he was Director of the MBA when I first came here. His scientific work was inspirational. His book *The Seas*[1] was 'gospel' reading.

What advice would you give to a young person who wants to be a marine biologist or someone who wants to be involved in marine biology in some way?

I think they should do what my professor said to me when I started research for a PhD: he said go away in the library, I don't want to see you for three weeks, read all you can about your subject. You will find that a lot of what you want to study is probably published but they may have misinterpreted it; so, look at it and think in a different light.

What are the most striking changes you have seen both in the sea and within marine biology as a profession?

Well, the funding is a lot more difficult now. When I first came to the MBA, we had three boats; we only have one now. When we had the RV *Sarsia* and later the RV *Sir Fredrick Russell*, we could get out almost regardless of the weather.

In the English Channel, the seasonal cycle (the spring bloom and autumn bloom) is no longer as distinct as it used to be. For example, November should be a quiet time over winter but the recent samples had quite a lot of phytoplankton in them. Species which I suspect have come around from Ushant. The sea temperature has gone up probably half a degree, so I don't know whether it is that or if the water currents have changed.

1 Russell, F.S., and Yonge, C.M. (1963) *The Seas; Our knowledge of life in the sea and how it is gained*. Frederick Warne & Co.

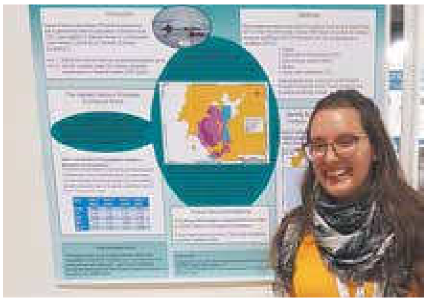
And the winners are...

Students who have won MBA bursaries or placements report on how this has supported them to develop their careers.

The World Marine Mammal Conference, Barcelona, December 2019

I felt very honoured to attend this four-day conference, with inspirational attendees, ranging from students to the pioneers of marine mammalogy.

Besides presenting a poster about my Bachelor research on identifying suitable habitats for harbour porpoises in Galician waters, I had the great opportunity to listen to, meet, and talk to researchers I admire. Sitting in one of Michael C. Fontaine's talks about his latest work was an unbelievable experience. Also, listening to Arctic researcher Kit Kovacs was a true inspiration. I also made connections and found a project for my MSc thesis.



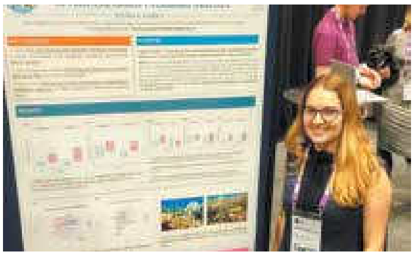
Tamara presenting her poster in Barcelona. Image © Tamara Narganes Homfeldt.

This conference has helped me to clarify the direction I want to take in my future career and I am grateful to everyone I met, as well as for the knowledge and inspiration I gained. I want to give a big thank you to the MBA for having made this great opportunity possible.

Tamara Narganes Homfeldt (tamaranarganes@web.de)

The British Ecological Society (BES) Annual Meeting 2019, Belfast, Northern Ireland

I was honoured to receive an MBA Student Travel Bursary to travel to the BES Annual Meeting. As an early-career ecologist beginning my search for PhD positions, participating in



Monica Gabell at the BES Annual Meeting in Belfast. Image © Monica Gabell.

such a large and prestigious conference was a great opportunity.

I presented a poster with my Master's thesis results on seasonality in fish assemblages in tropical canopy-forming habitats, and was glad to receive positive feedback and make new connections in my field.

I was fascinated by the vast number of delegates and research topics covered. These spanned all types of habitats, from the polar regions to the tropics, from the deep-sea to alpine mountains and deserts, and everything in between. And although many weren't directly related to my field, it was amazing to see all the different research being done around the world, much of which inspired me with new ideas that could be applied to aquatic systems.

I also got to attend a few different workshops, including 'Work-Life Balance' and 'Careers Outside of Academia', which were informative and stimulating. I left the conference with a better set of networking skills and an increased appreciation for the field of ecology. I feel more prepared to face my uncertain future as I seek new opportunities that will allow me to continue contributing to this amazing community.

Monica Gabell (monicagabell@gmail.com)

The International Conference for Young Marine Researchers (ICYMARE), Bremen, September 2019

Luka (on right) in Bremen. Image © Arianna Liconti.

Attending the ICYMARE conference was a great pleasure! Thanks to an MBA Student Travel Bursary, I was able to partially fund my trip to Bremen.

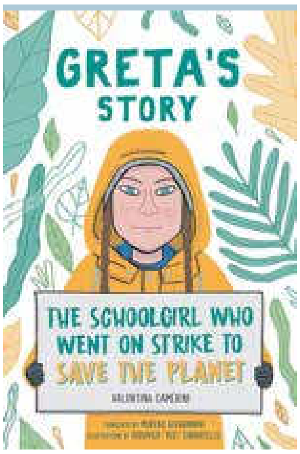
At the conference I presented a poster of some preliminary work from my dissertation project on the sequestration of carbon from *Laminaria* kelp forests in a changing climate. I was over the moon to win a prize for the best poster at the conference, especially with all attendees voting as the jury. As part of my prize I received a Springer book voucher, which will certainly come in handy. I will never forget this fun experience: for an aspiring marine scientist, the ICYMARE family is the perfect community to be a part of!

Over three years at university in Plymouth, I have spent a lot of my extracurricular time at the MBA: volunteering, revising, writing my dissertation, or just socialising. These experiences have certainly been a great asset to my education.

Luka Seamus Wright (luka.wright@students.plymouth.ac.uk)

Reviews

Greta's Story: The Schoolgirl Who Went on Strike to Save The Planet



Author: Valentina Camerini
ISBN: 978-1-4711-9065-0
Format: Paperback 144 pp.
Published by: Simon and Schuster

Greta's Story is an amazingly composed, moving, carefully thought about piece of writing, which gives a captivating tale of how Greta became inspired to do all she can for our planet and its future. It left me with a glowing feeling inside after reading it.

The writer has meticulously planned every word so it is easy to understand and really makes you feel like you are inside the book.

It is full of information about Greta's life, the problems she faced, and how she overcame them.

After the main story, there is a glossary, a timeline, and a 'WHAT CAN WE DO' section that really makes the reader feel involved.

Most of the books aimed at upper Key Stage 2 (Year 5–6) are just made up of text, so I was happy when I found out that there were illustrations, as they bring books to life. They enhanced my interest in the book and made sure that I was always engrossed in the content. I think this book—despite being aimed at children—can be appreciated by any age and would be an asset to anybody's home bookshelf or school library.

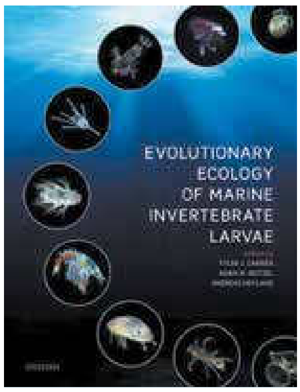
I would recommend this book to anybody who cares deeply about our environment and wants to do more to help our planet. It shows that—in the words of Greta Thunberg herself— 'No-one is too small to make a difference.'

Lily Hoare-Hambly (age 10)

Evolutionary Ecology of Marine Invertebrate Larvae

Edited by: Tyler J. Carrier, Adam M. Reitzel and Andreas Heyland
ISBN: 978-0-1987-8696-2
Format: Hardcover 354 pp.
Published by: Oxford University Press

Most shallow water marine invertebrates generate huge numbers of planktonic larvae that disperse in the water column then seek the adult environment and undertake rapid, radical metamorphosis. Such a life history pattern is subject to colossal selection

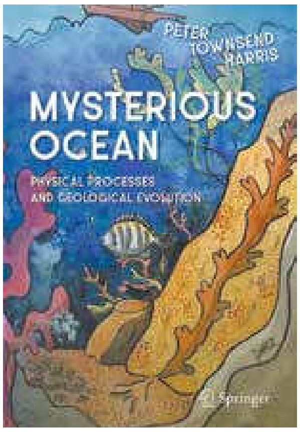


pressures over the early phases of development. This book sets out to understand the ecological and evolutionary consequences of this mode of development. It tackles this significant topic through expert reviews partitioned into sections covering evolutionary aspects, functional morphology, larval transport and settlement, and larval ecology in extreme conditions, including those generated by human activities. Individual reviews, and also each section, have useful brief summaries. The authorship team includes those with distinguished careers in the field and those at an earlier stage who are developing novel lines of enquiry.

The book concludes with an appreciation of some of the early discoveries in the field and an investigation of the potential of model species as tools for resolving outstanding questions. It describes major advances in the field since the publication of *Ecology of Marine Invertebrate Larvae* (McEdwards, 1995), while adding an evolutionary perspective. It includes an overview of the remarkable diversity of larval morphology more generously illustrated in the *Atlas of Marine Invertebrate Larvae* (Young & Sewell 2006), but neither book does justice to the spectacular recent advances in our understanding of internal anatomy provided by fluorescence microscopy. The diversity of settlement and metamorphosis patterns was described through a wide range of examples in *Settlement and Metamorphosis of Marine Invertebrate Larvae* (Chia & Rice 1978). Progress since then in our understanding of these crucial processes appears throughout the Carrier *et al*. volume, but the remarkable recent insights into the precise molecular cues for settlement and metamorphosis should perhaps have been covered in more detail. Nonetheless, this book is a major and timely resource for anyone interested in larval ecology and the evolutionary pressures to which the larval stages of invertebrates are exposed.

Simon Cragg
(simon.cragg@port.ac.uk)

Mysterious Ocean: Physical Processes and Geological Evolution



Author: Peter Townsend Harris
ISBN: 978-3-030-15632-9
Format: Hardcover 199 pp.
Published by: Springer Nature Publishing

Peter Townsend Harris has more than 30 years' experience in geological oceanography. His book is rich in reminiscences of his work and those of fellow scientists who have revolutionized our understanding of the physics and geology of the ocean. He leads the reader on a journey of discovery from the origin of the ocean more than 4 billion years ago to the present day.

Mysterious Ocean describes in detail the origins of the global ocean, the formation and movement of continents, and the geological features of the sea floor. The author also discusses the importance of seamounts and hydrothermal vents to marine life, and he touches on many contemporary issues related to the misuse and abuse of ocean resources.

Probably one of the most valuable features of the book is that the author shares not only his scientific successes, but also his failures. This gives any budding marine scientist an insight into the reality of research at sea.

Mysterious Ocean adopts a conversational style that reflects the author's desire to promote the cause he supports. Sometimes, his language appeals to the emotion as much as the intellect and some of the evidence is selective and overstated.

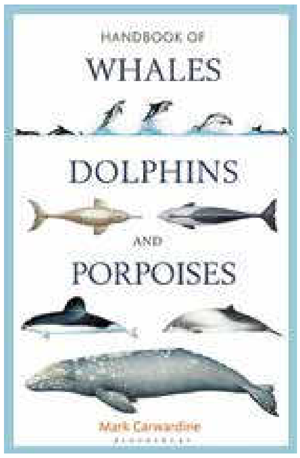
There is no glossary, some key terms are missing from the index, and a lack of sections and subheadings makes navigating the text difficult. But this is not a textbook; it is a sharing of a passion for the science of the sea, and a plea to better understand our ocean and to care for it more. For anyone wanting to be privy to the thoughts of an experienced physical oceanographer, *Mysterious Ocean* is a fascinating read.

Mike Kent
(rmike.kent@tiscali.co.uk)
MemMBA, FRSB

Handbook of Whales, Dolphins and Porpoises

Author: Mark Carwadine
ISBN: 978-1-4729-0814-8
Format: Hardcover 528 pp.
Published by: Bloomsbury

I remember the summer day of 1996 when a friend of mine gifted me the first edition of Mark Carwardine's *Handbook of Whales, Dolphins and Porpoises.* The book was already getting immensely popular both among amateur whale watchers and professional scientific observers working on board fishery and research vessels. Since then this book always accompanied me in my expeditions across the world's oceans being



probably the best available tool to identify cetaceans in the field, as well as giving a short but exhaustive summary of their ecology.

This new edition is the most comprehensive and easy-to-use reference to all existing species and subspecies of marine and fresh-water cetaceans; a kind of alloy of a visual identification guide and an encyclopaedia. The book contains more than a thousand detailed pictures illustrating not only the entire body—not normally seen by an observer—but details useful for species identification including relative size, blows, diving sequences, and flukes. Each species is provided with: a brief overview of its distribution and migrations, description of similar species with which it might be confused, description of characteristic behaviour, and common group size and structure. This identification information is topped up with concise summaries on ecology, estimated numbers, and conservation status.

Mark Carwardine is a zoologist, writer, and TV and radio presenter who has been working on cetaceans for more than 30 years. His book remains indispensable reading for anybody interested in the lives of these charismatic creatures.

Vladimir Laptikhovksy (vladimir.laptikhovsky@cefas.co.uk)

MBA academic publishing

The MBA publishes scientific journals in support of its charitable aims.
If you would like to publish original research or reviews in the MBA's journals, please contact the editor:

Journal of the Marine Biological Association: Professor Jane Lewis lewisjm@westminster.ac.uk
Marine Biodiversity Records: Dr Nova Mieszkowska nova@mba.ac.uk