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The Marine Biologist

The magazine of the marine biological community

Oceans of change

Prof. Callum Roberts on past and future seas

Also in this issue:

Ecosystem structure in a marine heat wave
Linnaean limitations
The tropicalization of the Mediterranean

THE MARINE BIOLOGICAL ASSOCIATION

Carbon credits | Declining phytoplankton | Ocean literacy | Sharing resources

The Marine Biologist
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Editorial Office

Editor Guy Baker
editor@mba.ac.uk
+44 (0)1752 633244

Executive editor Matt Frost
mafr@mba.ac.uk
+44 (0)1752 633334

Membership Alex Street
alexa@mba.ac.uk
+44 (0)1752 633337
www.mba.ac.uk/membership

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

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Submissions
Please contact the editor.

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Editorial

Welcome to the first issue of The Marine Biologist, a new magazine for the marine biological community, provided free to Marine Biological Association (MBA) members.

When we gaze out to sea, it's hard not to wonder what's going on under the surface: where are all the fish? How close am I to a shark or an enormous fan mussel? How do the different parts of the marine environment interact? These questions spur us to dive, catch fish or study marine biology. They also add to our internal lives; who amongst us doesn't imagine their own, personal "Google ocean"? For all the passion people have for the sea and its inhabitants, and the fact that marine biological research is providing insights into how a substantial portion of our planet works, it appears that no English language magazine exists purely for the broad interest of marine biologists. What an opportunity!

So, by way of an introduction I'd like to offer a whistle-stop tour of The Marine Biologist. We dive first into the 'Science letters' section which contains a view of the marine biological research scene from a top researcher and articles on current research. In this issue Professor Colin Brownlee, Director of the MBA, looks at the challenges and opportunities ahead.

'Environment & conservation' looks at ongoing issues such as climate change, ocean acidification, noise, fish stocks, marine planning/management, new legislation and conservation success stories. Fittingly in this first issue I am delighted to present an article on our changing seas by the thoughtful and erudite Callum Roberts. When the MBA was established in 1884 it was to provide policy advice and the cross-over between research and policy remains all-important. The section opens with a policy overview which in this issue highlights the need to provide decision makers with the context that turns information into 'evidence'. I hope this section will prove to be useful and influential to policy advisers, NGOs and scientists, and I welcome discussion or opinion articles.

Articles on all aspects of sharing knowledge and resources appear in the section entitled 'Sharing marine science'. The US has its Science Educator Associations, and the EU now has EMSEA (the European Marine Science Educators' Association). Find out how this new initiative is pushing for ocean literacy in school curricula across the EU, and sign up for the EMSEA conference in September.

My aim is to source material from the widest constituency, from the research community to consultants, fishers, amateur naturalists, or anyone who has something current and interesting to say about life in the sea. Please take that as an invitation to comment and contribute to future issues of the magazine.

I hope you enjoy this first edition of The Marine Biologist, please contact me through the website www.mba.ac.uk/marinebiologist where you can also leave comments about this issue and make suggestions for the next, which is due for publication in spring 2014.

Front cover: Striking and accessible marine life: this is something that a rockpooler or snorkeller could find from Shetland to the Mediterranean. Jewel anemones (*Corynactis viridis*) in Sark. **Back cover**: The blue jellyfish, *Cyanea lamarckii*. Images: Fiona Crouch.

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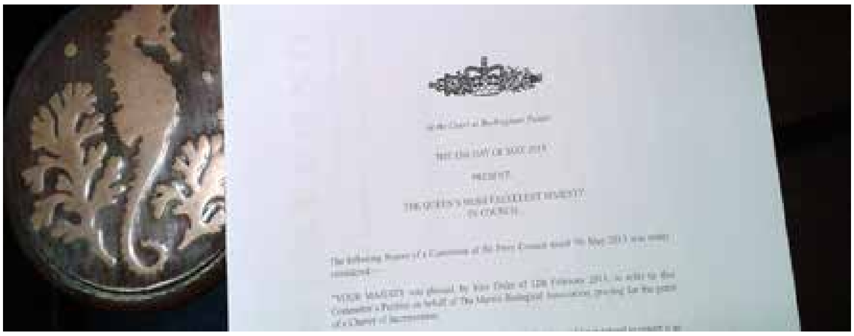
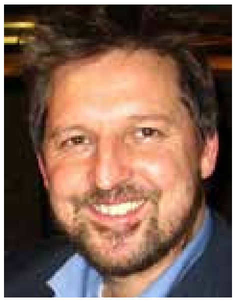
Around the Association

"The Marine Biologist" is launched at a time when the Association is seeing some of the biggest changes in its nearly 130 year history.



As members you will have been informed the MBA has recently been awarded a Royal Charter, which is "reserved for bodies that work in the public interest (such as professional institutions and charities) and which can demonstrate pre-eminence, stability and permanence in their particular field". In celebration of this award the next issue of The Marine Biologist will be a special edition looking at the importance and development of marine biology as a discipline. We will also be providing information on changes to the MBA's membership structure with exciting developments such as the implementation of a new MBA Fellows category and a new category of membership aimed at younger people (we often get enquiries from school pupils who have already decided they would like to become marine biologists!).

Whilst the changes being implemented above have taken a lot of work the MBA has continued to be active in supporting and giving voice to the marine biological community; notices for members are on page 35 and policy input is included in the policy update on page 21. In summary, this is a very exciting time and it is important that the recognition provided to the Association by the award is used to raise the profile of marine biology and the marine environment.



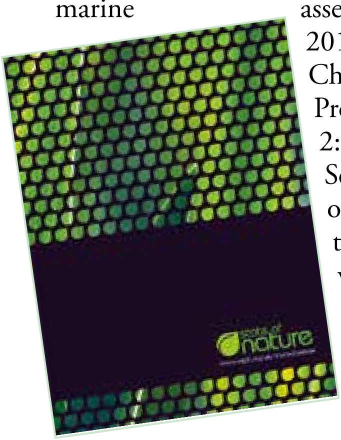
Dr Matt Frost

Find out more at www.mba.ac.uk/membership/FAQ

News

State of Nature report

The assessment of marine nature in the UK State of Nature Report briefly covers seabirds, seals, skates and rays, commercial fish species and plankton. This coverage reflects less a bias in favour of terrestrial and freshwater species, rather that the UK's marine environment already had its own comprehensive marine assessment in 2010 (see: Charting Progress 2: State of Seas (CP2)) of which the MBA was lead author on the Healthy and Biologically Diverse Seas feeder report. Therefore the State of Nature Report referred largely to CP2; its findings were still up-to-date and relevant and as such were used as the basis for the Marine Strategy Framework Directive Initial Assessment in 2012.



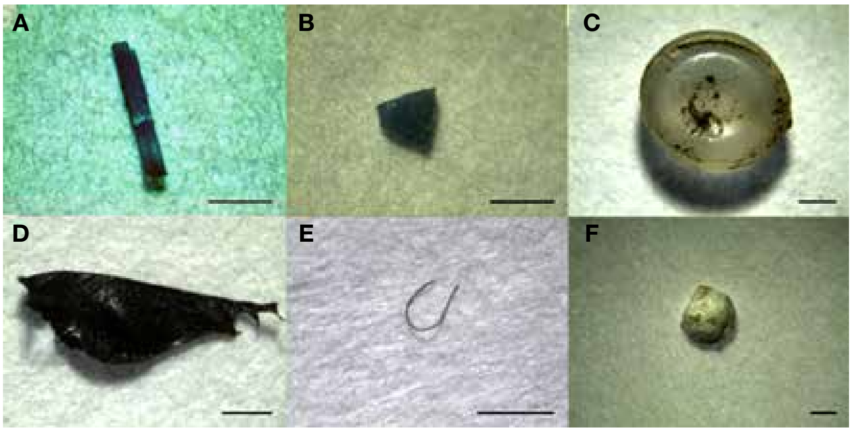
The MBA was however pleased to see marine included in the State of Nature Report as it may encourage more interest in the considerable challenges faced in the UK marine environment. Despite being a much larger component of the UK natural environment than the terrestrial and freshwater parts, it suffers from being 'out of sight – out of mind'.

Marine Science Review

In late 2012 the UK House of Commons Science and Technology Committee undertook a review of marine science. This review covered a range of topics from funding for marine science through to progress on implementation of UK Marine Conservation Zones. The committee reported in March 2013 with the government publishing its response to the report's recommendations in June. The key outcome from the review is that a full implementation plan for the UK Marine Science Strategy will be developed with a focus on a detailed plan for the first 18 months. A number of other recommendations from the committee's report were accepted by UK government such as the need to provide clarity on management measures for Marine Conservation Zones.

Welcome to the plastisphere (1)

Microplastics in the sea are colonized by microorganisms and



Photographs of microplastic debris found in surface waters of the Tamar estuary, UK. Fragments identified as (A) polypropylene, (B, C and D) polyethylene, (E) nylon, (F) polystyrene. Scale bar represents 1 mm. Images: Saeed seyed Sadri.

are now being viewed as novel ecosystems in their own right.

A team of scientists from Woods Hole, Massachusetts examined plastics from seawater samples and found at least 1000 different types of bacterial cells, many of which have yet to be identified. The assemblage, identified by scanning electron microscopy and gene sequencing, differed from those found on natural flotsam.

Tiny pits and cracks observed on microplastic particles suggest that microbes may be degrading the plastic. "When we first saw the 'pit formers' we were very excited, especially when they showed up on multiple pieces of plastic of different types of resins," said Linda Amaral-Zettler from the Marine Biological Laboratory (MBL), Woods Hole. "Now we have to figure out what they are by sequencing them and hopefully getting them into culture so we can do experiments."

This vast 'plastisphere' raises questions about its effects on microbial populations, not least how it will change where microbes – including pathogens and the algae that cause harmful algal blooms – will be transported in the ocean. www.whoi.edu/news-release/plastisphere

Small marine labs feel the pinch

One of the U.S.'s most distinguished marine research institutions has formed an affiliation with the University of Chicago.

Woods Hole Oceanographic Institute faced financial pressures in recent years due to a considerable drop in revenue. In the UK Port Erin Marine Laboratory closed in 2006 after 114 years of research and more recently it was announced that the Marine Biological Station at Millport in Scotland would no longer operate as a university linked research centre. On 1 January 2014, ownership of the Station will pass from the University of London to the Field Studies Council.

These reports are confirmation of the fact that there are considerable challenges being faced by marine laboratories worldwide as a result of the current funding climate.

Welcome to the plastisphere (2)

A recent study of demersal and pelagic marine fish in the English Channel revealed microplastics in the gastrointestinal tracts of over a third of all fish examined.

In a recently published study of Hawaiian waters, 58 percent of small-eye opah and 43 percent of big-eye opah had ingested some kind of plastic debris.

A landmark for shark conservation

Researchers record damatic declines in populations of pelagic sharks.

Shark fins are regarded as traditional and valuable food at Asian weddings. The shark fin trade is a global business revolving around Hong Kong where about 50% of all fins end up. The trade is supplied by over 80 countries and Europe delivers about one third of the fins.

The catch and trade of shark fins, meat and other body parts is largely uncontrolled. This year however, the future of some endangered and commercially important shark species may not be so bleak. At the world's largest wildlife summit of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 178 nations voted for strict controls on trading oceanic whitetip, porbeagle and three species of hammerhead sharks. This is a notable achievement; earlier attempts to implement trading controls failed.

China has banned shark fin soup from state banquets and New York recently became one of the last US states to ban shark fin sales.

Blue sharks are thought to be the most frequently caught shark species in the north Atlantic, with population declines of up to 80% in some regions since the 1980s.

Links to these news stories can be found on The Marine Biologist website. Scan the QR code to view the web page.

For the latest news from the UK marine science community subscribe to the Marine Ripple Effect or follow on Twitter **@MarineRipple**

For marine events, see the **UK Marine Science Events Calendar** at **www.mba.ac.uk**

A leading researcher takes a look at the challenges and opportunities in marine biology. In issue 1, Professor Colin Brownlee writes

from the crow's nest

Challenges – urgent and unforeseen?

We are witnessing an unprecedented rate of change in the global environment, the likely consequences of which are largely unknown. This statement is based on the weight of hard scientific evidence relating to ocean temperature, acidification, destruction of habitats and over-exploitation of resources. Consideration of challenges and opportunities must be made in the context of this changing landscape.

Dealing with complexity

Why are the oceans important in understanding climate? Heat and gas transfer between the oceans and atmosphere play a critical role in climate regulation. The melting of polar ice and consequent disruption of ocean circulation patterns has the potential to cause long lasting changes in marine ecosystem structure. The huge complexity of linkages between organisms, processes, communities, trophic levels, and ecosystems ensures that it is difficult, often impossible, to study a single environmental factor in isolation. Indeed, understanding connectivity and complexity at a vast range of scales, from viruses to multicellular organisms and their complex interactions at the ecosystem level, is arguably the most momentous challenge in marine biology.

From the very small ...

The problem is compounded by the need for simplification in order to develop quantitative models of ecosystem processes. How can we begin to integrate fragmentary information from laboratory experiments with larger scale *in situ* studies of complex processes? The advent of 'omics approaches, coupled with detailed physical and chemical metadata is increasingly allowing "who does what" studies to be applied to marine ecosystems.

More data than we can handle?

Collecting large volumes of data in many different forms, including physical, chemical, telemetry, imaging and 'omics to list a few examples, has become the norm. Curating, analysing and distributing vast amounts of data has itself become a major challenge, requiring resources that are not widely available.

The advent of 'omics approaches is increasingly allowing "who does what" studies to be applied to marine ecosystems

Major drivers of ecosystem change in the seas include temperature, acidification and hypoxia. These in turn affect a host of other parameters. It is clear that stressors do not act in isolation and consideration of the combined impacts of multiple stressors will be required to understand how regimes may shift to new stable or unstable states. Identifying and monitoring key sensitive ecosystems, such as those associated with coral reefs and polar regions, and co-ordinating data through networks of observatories, including long-term time series and archives will become ever more critical.

Responses to change

We also face the problem of trying to predict impacts whilst having insufficient knowledge of basic life processes. There is increasing evidence that extreme short term events can have profound and long lasting impacts on coastal and reef marine ecosystems (see article on marine heat waves, page 12). Current evidence suggests that such extreme events are likely to occur with increasing frequency as global temperatures increase. The ability to tolerate rapid extremes of temperature (both behaviourally and physiologically) may be one of the most important factors that will determine survival and community composition in the short term. It is therefore critical to understand the roles of short-term physiological responses and plasticity that will determine responses of key vulnerable ecosystems to change.

Changes in the genetic structure of populations is fundamental to longer term responses, over decadal or centennial timescales, of populations and communities. Our knowledge of genetic diversity and understanding of key evolutionary drivers is only rudimentary for most marine organisms. The bulk of marine productivity is brought about by the phytoplankton. These microbial populations have very short generation times, massive population sizes and limited barriers to geographical spread, all of which make them likely to be more resilient to climate change in comparison with many larger organisms.

Opportunities for the future

Clearly, there is important work to be done, however, marine science has already achieved much in terms of fundamental scientific advances, in providing knowledge that may underpin sustainable use of marine resources, and in the discovery of new resources and products.

Marine biotechnology is one of the EU's target areas for development

We have made impressive advances in understanding the basic biology, behaviour and underlying principles that determine abundance and distribution of populations. This knowledge not only helps us to understand the impacts of rapidly spreading invasive species on ecosystem biodiversity, it is also vital to develop fishing strategies for long term sustainability. We have the opportunity to implement marine protected areas that will further ensure ecosystem stability and provide nursery grounds for young fish populations.

From model organisms to a biotechnological revolution: risks and opportunities

The seas also present enormous potential for scientific, economic and social advance. Historically, marine organisms have provided many key models for the study of cell biology and evolutionary processes, with many potential biomedical and biotechnological applications. Examples include modern comparative biology, driven by the rich resources of the marine biota, and underpinned by long-standing classical taxonomy. The rapid march of whole genome sequencing projects is heralding a new era of functional and comparative genomics studies that will substantially improve our knowledge of basic biological mechanisms and their evolution.

... to the very large. The need to understand interactions at a wide range of scales is one of the key challenges for marine biologists. Images: Colin Brownlee.

What is needed to realise the potential of marine organisms for biotechnological advances? A recent European Marine Board position paper[1] identified target areas for development with a particular emphasis on biotechnological potential. Amongst these are: systematic sampling and genomic analysis of microorganisms, algae and metazoans; development of new technologies for culture of marine organisms; improvements in bioreactor technology; and identification of new model organisms.

But without adequate investment in infrastructure, the foundation for these advances is at risk. Fostering international networks and infrastructures is vital to ensure that opportunities for collaboration at the boundaries between disciplines – essential for major advances in technology, modelling and understanding processes – are maximised (see article on the European Marine Biological Resource Centre, page 32).

Society needs the knowledge gained through marine biology. A significant challenge for the marine biological community is to communicate this with some urgency at national and international levels in order to ensure support for the major undertakings required.

Professor Colin Brownlee is the Director of the Marine Biological Association

1 Querellou, J. *et al.* (2010) Marine Board Position Paper 15. Marine Board-ESF, Belgium.

Net-caught native and alien fish from the shallow waters of Rhodes (July 2009). Aliens (*Siganus* spp., *Lagocephalus sceleratus* and *Fistularia commersonii*) make up more than 70% of the total catch. Image: HCMR archives.

Biological invasions and climate warming

Maria Antonietta Pancucci-Papadopoulou and colleagues examine the tropicalization of the Mediterranean

The ever-increasing arrival of alien marine organisms is evident in the whole Mediterranean Sea, but is particularly pronounced in the eastern Mediterranean, primarily due to oceanic warming.

The coasts of the Dodecanese Islands (south-eastern (SE) Aegean Sea, Figure 1) receive westward flowing Levantine water masses, and are close to the route of intense maritime traffic using the Suez Canal. The area therefore represents the gateway for dispersal of Red Sea alien species westwards into the rest of the Mediterranean. Indeed, a significant increase in aliens' diversity along the Dodecanese coasts has been documented over the last three decades, while marine temperature data show that the area has undergone a remarkable warming.

Given this apparent connection, we attempted to link temperature alterations with new tropical species arrivals. Comparison between the regional satellite-derived sea surface temperatures (SST) with the whole northern hemisphere temperatures (NHT) dataset of the Hadley Centre since 1985, clearly revealed that the SE Aegean Sea is going through a substantial warming (Figure 2a). The significant relationship between the Dodecanese water temperature and that of the northern hemisphere illustrates that this warming signal is not a regional phenomenon, but part of the global warming and climate change trend (Figure 2b).

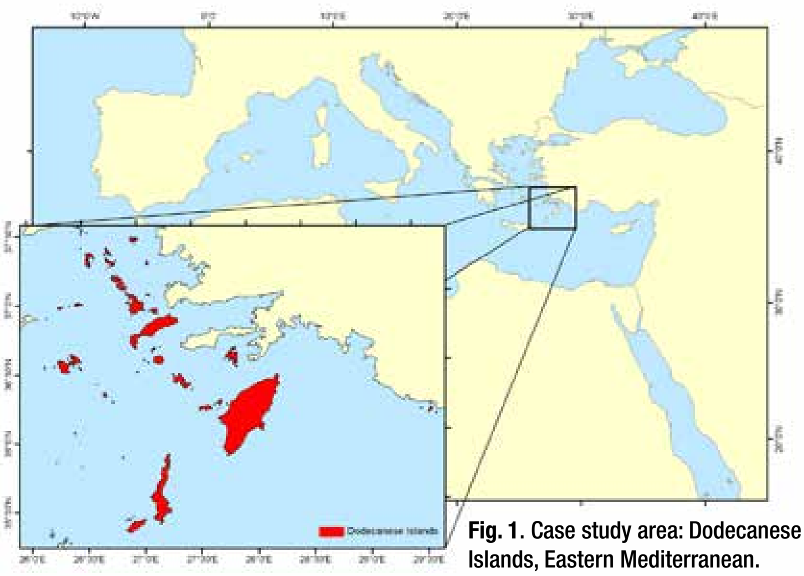


Fig. 1. Case study area: Dodecanese Islands, Eastern Mediterranean.

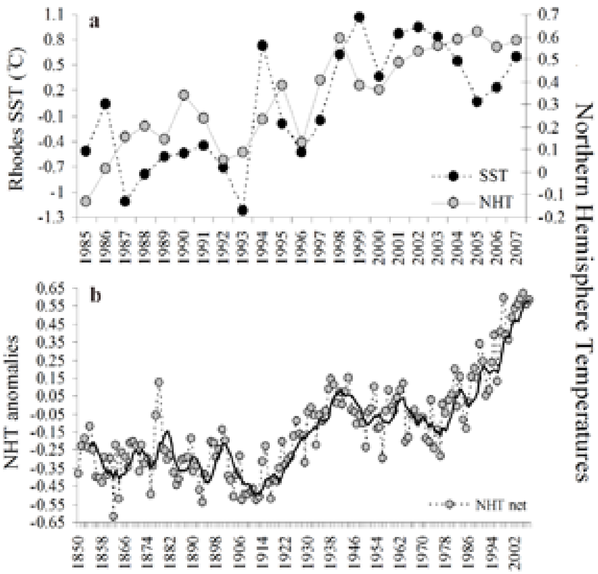


Fig. 2. Long-term relationships between global and regional temperatures: (a) satellite derived sea surface temperature (SST) (1985–2007) for the south-eastern Aegean Sea (Rhodes Island) against northern hemisphere temperature (NHT); (b) NHT anomalies (1850–2007). The solid black line corresponds to the 5 year mean.

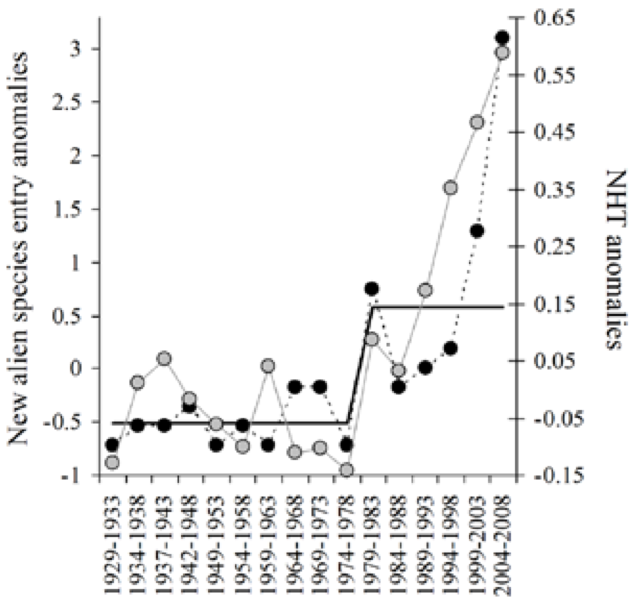


Fig. 3. Long-term 5 year averaged alien species against northern hemisphere temperature (NHT) anomalies (1929–2008). The solid black line represents the statistically significant shift for alien species (●, alien species; ●, NHT data).

As evident from the NHT, the temperature rise of the last 30 years, encompassing the abrupt shift in the mid-1990s, is the warmest period since 1850. Based on the SST means, the Dodecanese temperature difference between the two decades (pre-shift [1985–1997] and post-shift [1998–2007]) is 0.85°C.

To see if global warming has influenced the rate of new alien species arrival, the NHT was plotted against the local alien species data (Figure 3). The 80 years (1929–2008) period showed a significant parallel between the introduction rate of alien species in the SE Aegean Sea and increasing marine temperatures. The period 1929 to 1980 showed a stable neutral trend in both temperature and alien species arrivals. From the 1980s until present an abrupt parallel increasing trend can be observed (Figures 2b & 3).

Forty-three per cent of the 239 known alien species in Greek seas are found along the Dodecanese coasts, and nearly all (98%) are of warm/tropical origin. Eighty-four per cent of these alien species arrived via the Suez Canal (see Figure 4).

The first alien species recorded in the area were the seagrass *Halophila stipulacea*, and the macroalga *Hypnea cornuta*, both found in Rhodes in 1894. Over the next 50 years nine fish species and four algae of Indo-Pacific origin were introduced with consequent alterations to native communities and local fisheries. Indeed, soon after its introduction in 1925, the marbled spinefoot, *Siganus rivulatus* was commercially targeted. Between 1951 and 1980 another 18 (16

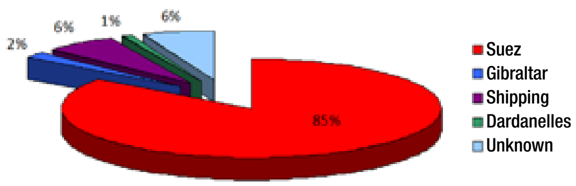


Fig. 4. Pathways for introduction of alien species in the study area. The percentage of aliens entering through the Suez Canal confirms the importance of the area as a crossroad for tropical species expansion.

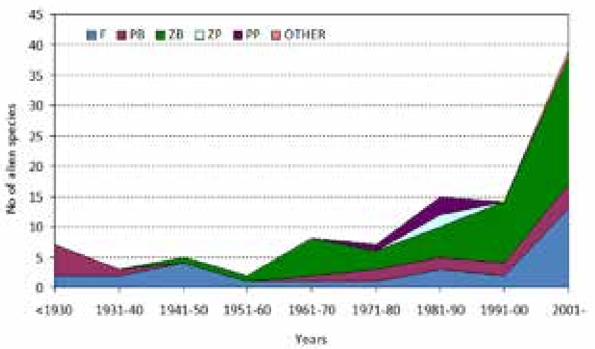


Fig. 5. Temporal trend of introduction of alien species in the study area (F, fish; PB, phytobenthos; ZB, zoobenthos; ZP, zooplankton; PP, phytoplankton; other, cyanobacteria). The unprecedented increase since 1980 is particularly evident in zoobenthos (46%) and fish (32%).

tropical) species were recorded. After almost a century of gradual colonization, the introduction rate of Indo-Pacific biota assumed the character of an invasion, with the addition of 68 new species from 1981 to date (see Figure 5).

Concern about the future tropicalization of the Mediterranean is increasing. The Suez Canal, until now a barrier to many species due to its high salinity, is to be widened and deepened. Furthermore, the Canal salinity is decreasing while that of the Eastern Mediterranean is increasing. While earlier introductions were limited to euryhaline (species tolerant of fluctuations in salinity) and littoral species, the door is now open to deep-water species.

The Dodecanese Islands belong to the 'Lessepsian Province', the sub-tropical character of which explains the very high percentage of warm/tropical alien species in the alien biota. Scientists predict that lessepsian immigrants will expand further west if the climate warms up further. Although the Indo-Pacific biota is mostly confined to the eastern Mediterranean, recent findings show that climate warming is enabling alien species to spread to the western-most part of the Mediterranean.

Acting together, stressors such

Fig. 7. *Fistularia commersonii* dwelling along the coasts of Rhodes. Image: HCMR archives.

as climate change, human impacts and alien species invasions may have unexpected and irreversible consequences for native communities and for fisheries. Owing to their very recent and rapid expansion, there is insufficient evidence to assess the real impact of aliens on native biota; however, many instances of ecosystem changes in the study area have been observed. The observed and potential impacts of four invasive species living along the Dodecanese coasts are presented below.

The blue cornetfish, *Fistularia commersonii* (Figure 7) is considered one of the most successful invasive fish species in the Mediterranean

Fig.8. Dredging in the shallow waters surrounding Rhodes revealed a huge population of *Strombus* (*Conomurex*) *persicus*. Image: HCMR archives.

Sea. Within just a few years of its arrival its range expanded not only along the Levantine coasts and up to the Aegean Sea, but also westward, reaching the eastern coast of the Iberian Peninsula within a few years. Since its first appearance in the SE Aegean Sea in 2001, it has become established on sandy-muddy bottoms and *Posidonia oceanica* meadows around Rhodes. Regularly present in Dodecanese

Fig. 9. *Caulerpa racemosa* var. *cylindracea* in *Posidonia oceanica* meadow. Image: HCMR archives.

fisheries as by-catch, the commercially useless blue cornetfish may have serious economic and ecological impacts, since it feeds mainly on several commercially important small native fish.

Within a few years of its introduction, the gastropod *Strombus* (*Conomurex*) *persicus* (Figure 8) became one of the most important components of the epibenthic fauna of the Dodecanese. It is currently locally marketed, and could potentially become a commercially exploited species throughout the Mediterranean Sea.

Since its first observation in 1993, the green seaweed *Caulerpa racemosa* var. *cylindracea* (Figure 9) has expanded extremely rapidly along all Greek coasts. It is considered a marine pest as it is able to overgrow other macroalgal species. Along the south-east coast of Rhodes Island, it makes up 30% of the total macroalgal coverage. The speed of spread is alarming, as *C. racemosa* is responsible for changes in the structure and function of native ecosystems in the Mediterranean.

Perhaps the most formidable

Fig. 10. *Lagocephalus sceleratus*: juveniles in the Aquarium of the Hydrobiological Station of Rhodes. Image: HCMR archives.

invader is *Lagocephalus sceleratus* (Figure 10), better known as the pufferfish, or fugu. The pufferfish has spread rapidly, occupying all Aegean coastal waters between 15 and 16.25 °C, and even advancing into the region limited by the 14°C isotherm. Its feeding strategy, anti-predator adaptations (inflation of the body and toxicity) and the probable absence of competitors and predators in the invaded coastal habitats are the main factors contributing to the success and abundance of the pufferfish in the area. Nor is control by commercial exploitation an option; owing to the high content of tetrodotoxin (TTX) in its tissues, it has been declared not marketable by the Greek authorities.

The public health danger and an anticipated rearrangement of the food chain are exacerbated by the already evident negative socio-economic impacts of pufferfish: a large number of fishing hauls have to be discarded, with consequent loss of working hours, fuel, etc., and native, commercially valuable stocks of invertebrates (mainly cuttlefish and octopus) are being depleted through intense predation, resulting in higher market prices.

The increase in alien species numbers in the SE Aegean parallels the substantial warming that began at the beginning of the 1980s and accelerated towards the end of the 1990s. Further sea warming may provide tropical invasive species with a distinct advantage over native Mediterranean biota and, if the present hydrographic characteristics of the south Aegean persist, significant changes in the composition and structure of the local biota are inevitable.

The gradual tropicalization of the Mediterranean is already apparent. The accelerating rate of introduction and spread of alien species leads us to believe that the tropical alien species so apparent in the eastern basin will gradually colonize the rest of the Mediterranean.

Maria Antonietta Pancucci-Papadopoulou (apan@hcmr.gr) is a Senior Researcher at the Hellenic Centre for Marine Research, Institute of Oceanography. Dionysios E. Raitsos and Maria Corsini-Foka are at the same institution.

FURTHER READING

Bianchi C.N. (2007) Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiology* 580, 7–21. DOI: 10.1007/s10750-006-0469-5.

Fritsch C. (1895) Uber die Auffindung einer marinen Hydrocharidae im Mittelmeer. *Verhandlungen der zoologisch botanischen gesamten Wien* 45, 104–106.

Galil B.S. (2008) Alien species in the Mediterranean Sea—which, when, where, why? *Hydrobiologia* 606,105–116. DOI: 10.1007/s10750-008-9342-z.

Golani D. (2010) Colonization of the Mediterranean by Red Sea fishes via the Suez Canal—lessepsian migration. In Golani D. and Appelbaum-Golani B. (eds) Fish invasions of the Mediterranean Sea: change and renewal. Sofia/Moscow: Pensoft Publishers, pp. 145–188.

Kalogirou S. and Corsini-Foka M. (2012) First record of the Indo-Pacific Champsodon nudivittis (Ogilby, 1895) (Perciformes, Champsodontidae) in the Aegean waters (eastern Mediterranean Sea). *BioInvasions Records* 1, 229–233.

Minos G., Ismiridou A. and Economidis P.S. (2012) First record of Terapon theraps (Terapontidae) in the Aegean Sea (Greece). *Cybium* 36, 401–402.

Pancucci-Papadopoulou M.A., Raitsos D.E. and Corsini-Foka M. (2012) Biological invasions and climatic warming: implications for south-eastern Aegean ecosystem functioning. *Journal of the Marine Biological Association of the United Kingdom* 92, 777–789. DOI:10.1017/S0025315411000981.

Por F.D. (1978) Lessepsian migration—the influx of Red Sea biota into the Mediterranean by way of the Suez Canal. Ecological Studies 23. Berlin/Heidelberg/New York: Springer-Verlag.

Por F.D. (1990) Lessepsian migration. An appraisal and new data. *Bulletin de l'Institut Océanographique de Monaco* 7, 1–10.

Raitsos D.E., Beaugrand G., Georgopoulos D., Zenetos A., Pancucci-Papadopoulou M.A., Theocharis A. and Papathanassiou E. (2010) Global climate change amplifies the entry of tropical species into the Mediterranean Sea. *Limnology and Oceanography* 55, 1478–1484. DOI: 10.4319/lo.2010.55.4.1478.

Reinbold T. (1898) Meeresalgen von der Insel Rhodos gesammelt von Lehrer J. Nemetz. *Hedwigia* 37, 87–90.

Theocharis A. (2008) Do we expect significant changes in the thermohaline circulation in the Mediterranean in relation to observed surface layers warming? In Briand F. (ed.) Climate warming and related changes in Mediterranean marine biota. CIESM Workshop Monographs 35, 25–29. [Monaco: CIESM Publisher.]

Zenetos A., Katsanevakis S., Poursanidis D., Crocetta F., Damalas D., Apostolopoulos G., Gravili C., Vardala-Theodorou E. and M. Malaquias (2011) Marine alien species in Greek seas: additions and amendments by 2010. *Mediterranean Marine Science* 12/1, 95–120.

Too hot to handle?

Ocean heat waves, marine biodiversity and ecosystem structure

Dan Smale looks at an ocean heat wave that may have long-term consequences for a regional ecosystem.

Heat waves pose problems for human health and infrastructure, ravage crops and livestock, and have wide-ranging impacts on the natural world. What is less obvious, however, is that heat waves in the sea can impact marine organisms and alter the structure of entire ecosystems.

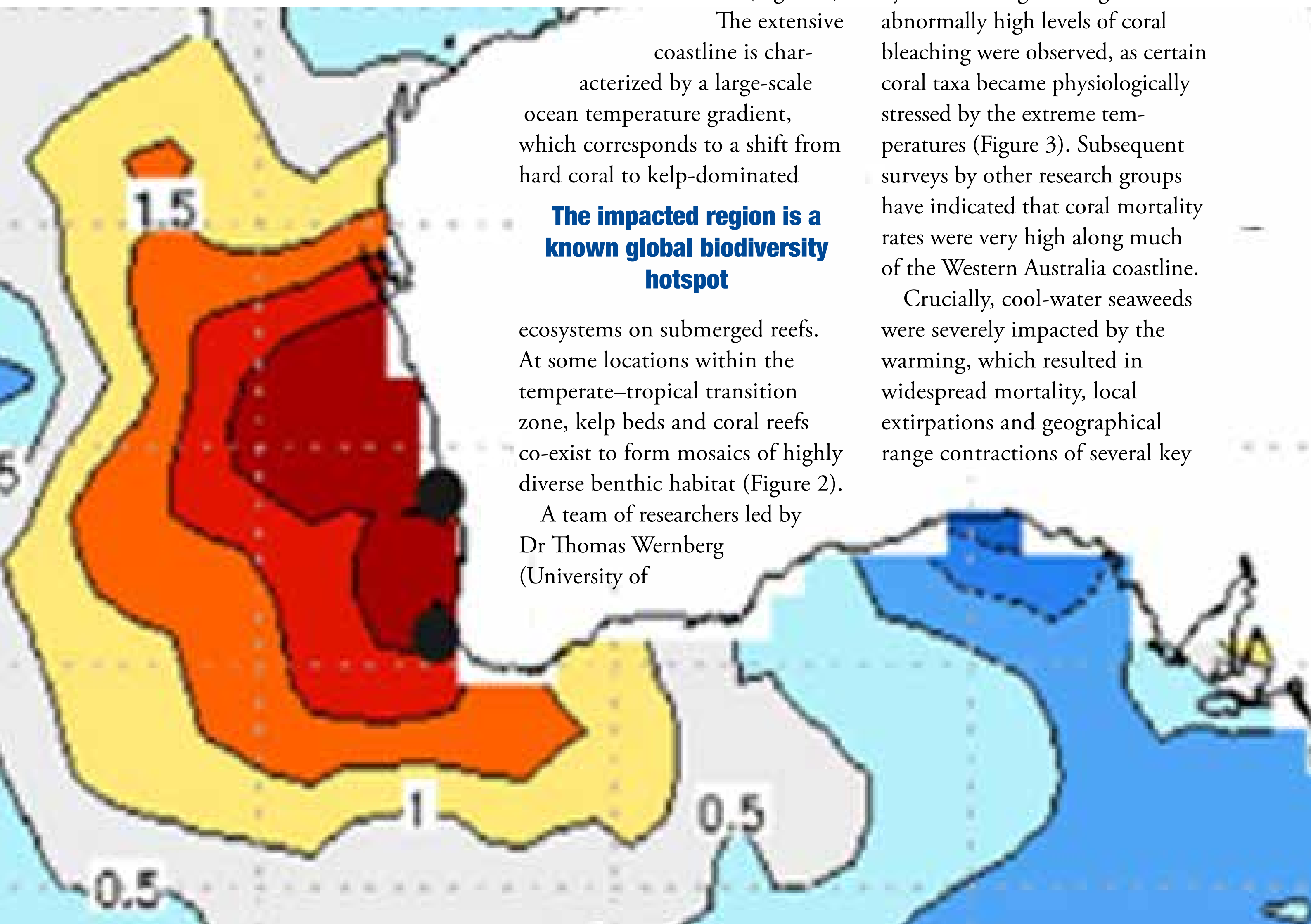
In early 2011, the coastal waters off Western Australia warmed to unprecedented levels, with temperatures soaring to up to 5°C above the long-term summer average (Figure 1). Sea surface temperature records dating back over 140 years indicated that the warming was the highest-magnitude on record. Temperature anomalies of 2–5°C persisted for more than 2 months along over 2000 km of coastline; the heat wave was both spatially and temporally extensive (Figure 1). Oceanographers have shown that the heat wave was caused by unusually strong La Niña conditions, which enhanced the poleward flow of warm, tropical water into cooler temperate regions.

The impacted region off south-west Australia is a known global biodiversity hotspot, with very high levels of diversity and endemism for seaweeds, reef-associated fish and some invertebrate taxa (Figure 2). The extensive coastline is characterized by a large-scale ocean temperature gradient, which corresponds to a shift from hard coral to kelp-dominated ecosystems on submerged reefs. At some locations within the temperate–tropical transition zone, kelp beds and coral reefs co-exist to form mosaics of highly diverse benthic habitat (Figure 2).

A team of researchers led by Dr Thomas Wernberg (University of Western Australia) and Dr Dan Smale (Marine Biological Association) have investigated the ecological effects of the extreme warming event. Using SCUBA divers and remotely operated technology (e.g. autonomous underwater vehicles) the team resurveyed historical sites to examine how key populations and assemblages of seafloor organisms were impacted by the warming. During the event, abnormally high levels of coral bleaching were observed, as certain coral taxa became physiologically stressed by the extreme temperatures (Figure 3). Subsequent surveys by other research groups have indicated that coral mortality rates were very high along much of the Western Australia coastline.

Crucially, cool-water seaweeds were severely impacted by the warming, which resulted in widespread mortality, local extirpations and geographical range contractions of several key

The impacted region is a known global biodiversity hotspot



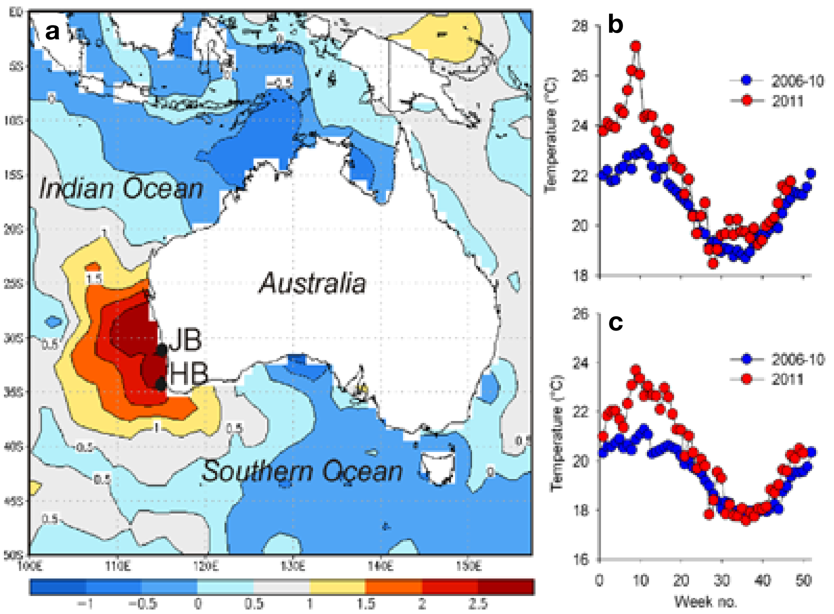


Fig. 1. The 2011 heat wave in the southeast Indian Ocean. a, Blended sea surface temperature anomaly map for March 2011 (relative to a 1971–2000 baseline), indicating a warming anomaly of >2.5°C along the southwest coast of Australia. The key study locations are also shown (Jurien Bay, 'JB', and Hamelin Bay, 'HB'). Plots show weekly temperature anomalies during 2011 (relative to means of the preceding five years) generated from in situ measurements at 10m depth at the study locations, Jurien Bay (b) and Hamelin Bay (c).

habitat-forming species (Figure 3). In the most impacted locations, the spatial coverage of canopy-forming seaweeds plummeted by more than 60%. Loss of seaweed canopies has led to large patches of bare, open reef habitat which has been partially colonized by turf-forming 'weedy' algae. The loss of dense seaweed canopies, which provide complex structural habitat and food for a myriad of other plants and animals, will likely have far-reaching ramifications for the structure and functioning of the seafloor ecosystem.

Dr Smale said; "We've been overwhelmed by the magnitude and extent of the ecological impacts. Species have retracted their geographical ranges by more than 100 km in a matter of months, whole kelp beds have been restructured, and sensitive coral reef habitats were hard hit too". Understanding whether kelp beds will eventually recover towards a pre-impacted state remains a research priority. "Kelp ecosystems in other regions, such as California, have undergone rapid deforestation in recent decades due to climate variability, but these systems often recover. However, the oceanography of the region, combined with the life histories of the most impacted seaweeds, suggest that this might not happen in Western Australia. Instead, we could be seeing a step-wise shift towards a different ecosystem state, but only time will tell", Dr Smale remarked.

Over the edge

As well as changes in seaweed populations, the team also observed a proliferation of several warm-water fish species after the warming event (Figure 3), but the mechanisms underpinning this response remain unclear. What is clear, however, is that extreme events can impact a variety of marine life, from seaweeds to fish to birds. There is mounting evidence to suggest that the frequency and magnitude of discrete warming events may increase as a direct consequence of anthropogenic climate change. In fact, the number of days characterized by extremely high sea temperatures has increased along 38% of the world's coastlines in the last 30

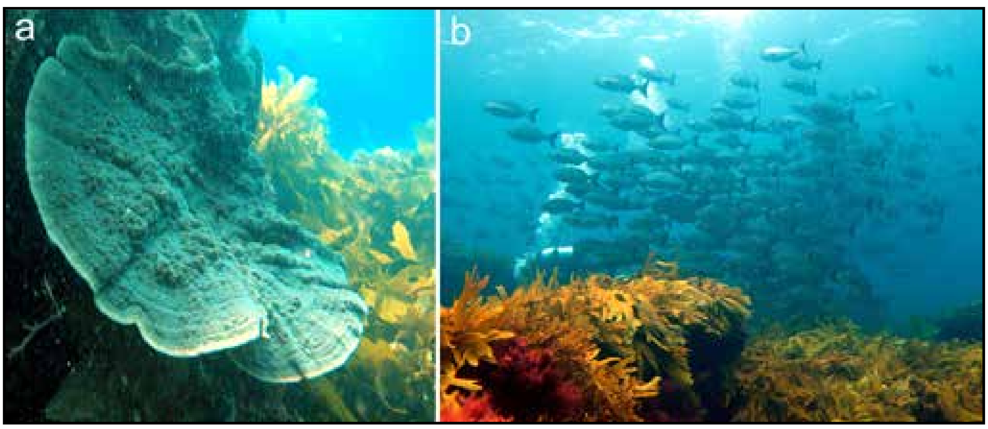


Fig. 2. Benthic marine biodiversity along the West Australian coastline. a; Kelp beds and hard corals co-exist in the temperate-tropical transition zone, forming highly diverse seafloor habitats. b; submerged rocky reefs off the southwest coast of Australia support dense kelp forests, which provide food and habitat for a wealth of marine plants and animals. Image: Dan Smale.

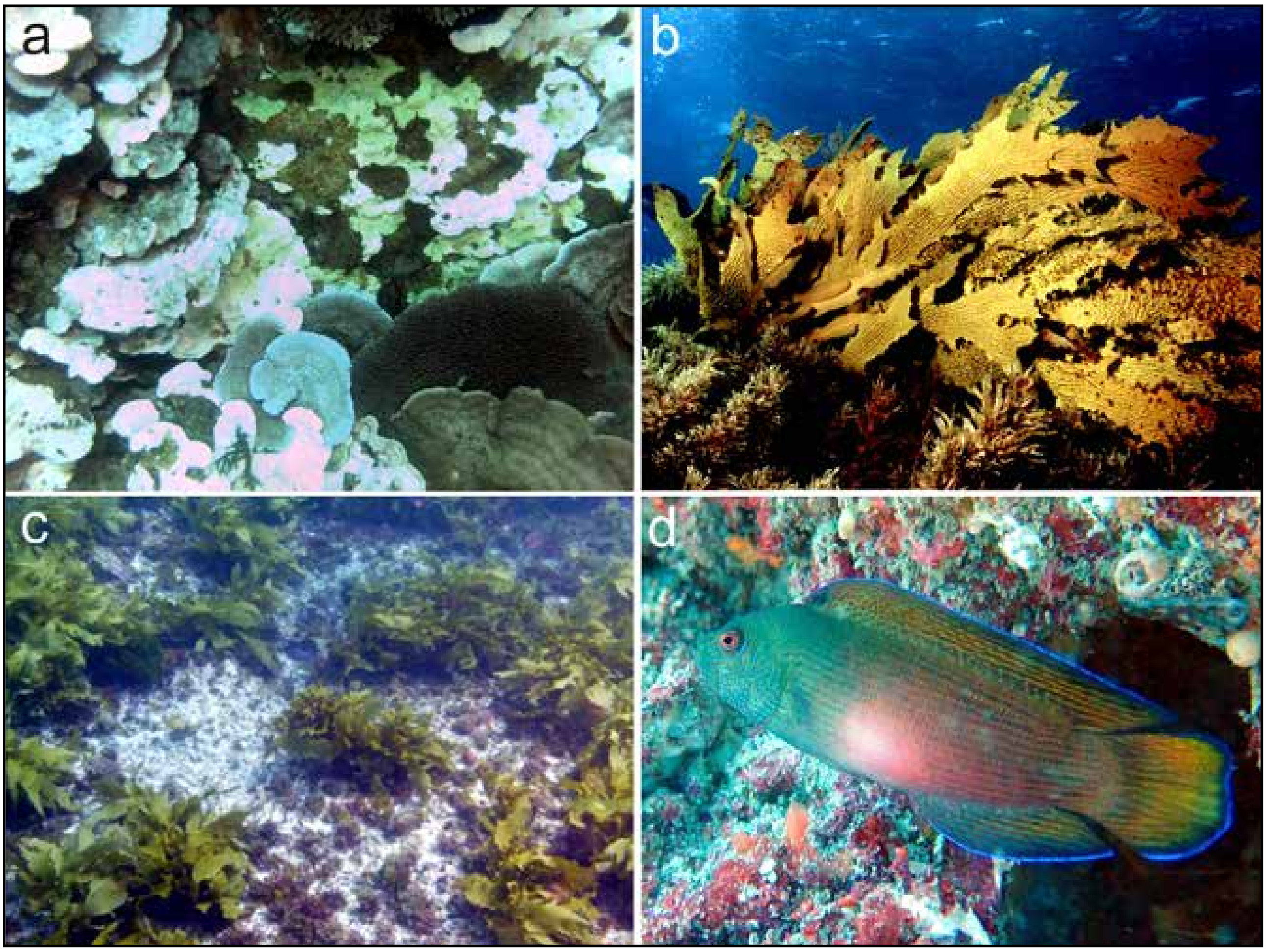


Fig. 3. Marine organisms impacted by the warming event. a; High levels of bleaching of hard corals, such as *Montipora* spp., were recorded during the marine heat wave. The warming event caused local extirpations and range contractions of key habitat-forming seaweeds, including the kelp *Ecklonia radiata* (b) and the fucoid *Scytothalia dorycarpa*. High mortality rates led to a decreased seaweed canopy cover and large patches of bare reef (c). The abundances of some warm-water fish species, such as *Labracinus lineatus* (lined dottyback, d), increased immediately after the warming event and caused a 'tropicalization' of fish assemblages. Images: Dan Smale (a), Thomas Wernberg (b, c) and Timothy Langlois (d).

years. These events will subject organisms to acute thermal stress, which may interact with chronic stressors such as gradual warming, eutrophication and pollution. In consequence, organisms, populations and communities may find themselves pushed 'over the edge' as they struggle to deal with rapid environmental change.

Thomas Wernberg at the University of Western Australia concluded: "It is well known that marine life is responding to long-term gradual climate change, in Australia and elsewhere, through shifting distributions or changing behaviours. But this marine heat wave has demonstrated how quickly species and entire ecosystems can be impacted by increased temperature. We've been studying this system intensively for over 10 years, and we thought we were beginning to understand its ecology. But we now need to divide our data and understanding into two parts; before the heat wave and after the heat wave".

Dan Smale is a research Fellow at the Marine Biological Association. dansma@mba.ac.uk

FURTHER READING

Feng, M. *et al*. (2013) La Niña forces unprecedented Leeuwin Current warming in 2011. *Scientific Reports* 3:1277

Smale, D.A., Wernberg, T. (2012) Ecological observations associated with an anomalous warming event at the Houtman Abrolhos Islands, Western Australia. *Coral Reefs* 31:441

Moore, J. et al. (2012) Unprecedented mass bleaching and loss of coral across 12° of latitude in Western Australia in 2010–11. *PLoS ONE* 7:e51807

Wernberg, T., Smale, D.A., et al. (2013) An extreme climatic event alters marine ecosystem structure in a global biodiversity hotspot. *Nature Climate Change* 3:78-82

Smale, D.A., Wernberg, T. (2013) Extreme climatic event drives range contraction of a habitat-forming species. *Proceedings of the Royal Society B: Biological Sciences* 280: 20122829

Lima, F.P., Wethey, D.S. (2012) Three decades of high-resolution coastal sea surface temperatures reveal more than warming. *Nature Communications* 3:704.

Microalgae systematics: can we still fit a square peg in a round hole when new evidence says it is a triangle?

The genomic era may seriously challenge our quest to pigeonhole biological entities into species, write **El-Mahdi Bendif** and colleagues.

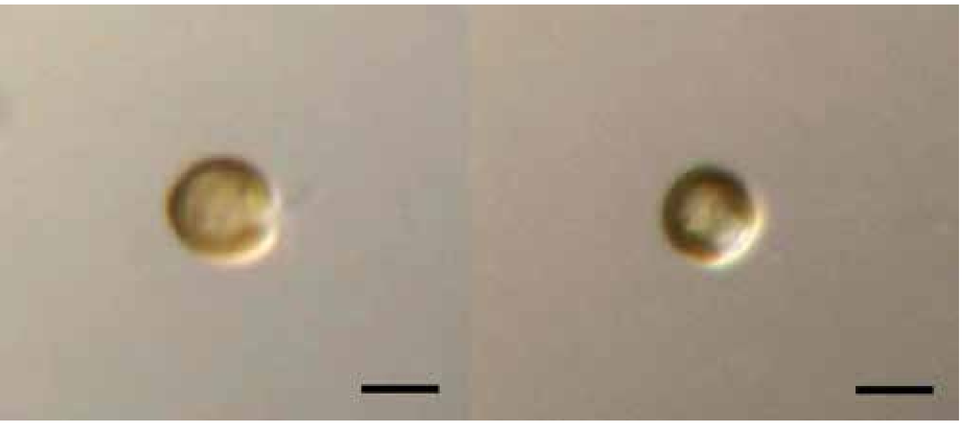


Fig. 1. Light micrographs of *Isochrysis galbana* (left) and *Tisochrysis lutea* (formerly *Isochrysis* aff. *galbana* or T-iso). Scale bar = 5 um.

We have an innate desire to pigeonhole life which is largely due to our ability to communicate in various ways, thereby necessitating a system that ensures we can define what it is we are referring to. An inevitable outcome of defining an item is giving it a name. In biology, taxonomy sets out the rules defining what makes something unique, while nomenclature applies a set of rules or codes for naming. For plant life, this delineation started with Carl Linnaeus' *Species Plantarum* of 1753. To this day the fundamental principles of Linnaeus remain—a specimen is selected as the basis for the description, this being referred to as the 'type' specimen. Any individual considered to match this description is considered to be a member of the species. Linnaean genus and species names together with names for other ranks (such as family, class, etc.) can and should serve to express a great many viewpoints as to relationships between taxa, i.e. systematics.

Like other groups of organisms, the taxonomy and systematics of microalgae have historically been based almost exclusively on comparison of morphological criteria. Nowadays, microalgal systematics is greatly influenced by data derived from DNA extracted from nuclei, mitochondria and chloroplasts, leading to the discovery of many cryptic species that demonstrate a decoupling between morphological conservatism and genetic variability. On balance, it is our opinion that molecular-based systematics should now be considered more of an exact science than the traditional morphological based taxonomy, but there is as yet no consensus on how to integrate this new knowledge in the most informative yet practical manner into the Linnaean nomenclatural system. Here we outline a few recent examples that illustrate this important issue in different ways.

A haptophyte culture strain assigned to *Isochrysis* affinis *galbana* (Tahiti isolate, commonly known as 'T-Iso') is widely used in aquaculture due to its exceptional lipid content and thus high nutritional value. Despite seemingly being morphologically identical to type material of *Isochrysis galbana*, comparison of conservative (slowly evolving) genetic markers has demonstrated that T-Iso is clearly genetically distinct from this taxon (Figure 1), with the genetic distance being equivalent to that commonly found between different genera within the haptophytes. It has therefore been classified in a new genus, *Tisochrysis*, as a new species, *T. lutea*. The creation of a new genus based on genetic data reflects the fact that this is a fairly extreme example of cryptic species, but the practical consequence is that the Linnaean names no longer convey unique information on morphology and any organism identified by microscopy as fitting the morphological description cannot be assigned to one or other of the species without DNA sequencing.

There are numerous examples of less extreme, but nonetheless significant genetic diversity occurring within morphospecies. *Karenia mikimotoi* (Figure 2) is a widespread toxic HAB dinoflagellate taxon, but morphometric plasticity within clonal isolates and between specimens assigned to this species (or to *Gymnodinium nagasakiense* or *Gyrodinium aureolum*, two species generally regarded as conspecific with *K. mikimotoi*) has caused notorious taxonomic confusion. In 2011 Manal Al-Kandari and colleagues at the Marine Biological Association applied a combination of nuclear and chloroplast gene markers to positively discriminate between isolates collected from Europe, New Zealand and Japan. Whilst isolates from all of these geographical localities exhibited similar morphologies (Figure 2), genetic evidence indicates distinct cladistic features. The European and New Zealand isolates have more in common with each other than the Japanese isolates, and only the Japanese isolates were shown to produce harmful toxins Gymnocin A & B+. Al-Kandari chose to distinguish the two genetic clades that they identified within *K. mikimotoi* as sub-species, termed *K. mikimotoi mikimotoi* and *K. mikimotoi aureolum*. In other cases where significant intra-morphospecies genetic diversity has been discovered, terms such as 'clade' (for the dinoflagellate *Symbiodinium microadriaticum* or the prasinophyte *Micromonas pusilla*, for example) or 'ecotype' (for the cyanobacterium *Synechococcus*) have been used. Use of an epithet such as 'clade' with a Linnaean name has the advantage of conveying information on both morphological similarity and genetic differentiation of cryptic taxa, but does not provide a clear idea of the investigator's opinion of where species boundaries lie.

In fact, this might actually be considered an advantage in light of the large-scale genomic information that is becoming increasingly available. A key member of the haptophytes is the iconic calcifying coccolithophore *Emiliania huxleyi* that is classified in a separate genus from another very common coccolithophore, *Gephyrocapsa oceanica*, due to a highly visible, but structurally extremely minor difference in the form of the calcite crystals making up the calcite scales (coccoliths) that cover the cells (Figure 3). *Emiliania huxleyi* is a very young morphospecies in evolutionary terms, palaeontological evidence suggesting a recent divergence from *G. oceanica* around 291 thousand years ago. Genetic studies indicate that they are very closely related species that should at least be classified in the same genus. Despite its recent emergence, significant genetic diversity has been detected within *E. huxleyi* using both mitochondrial and a nuclear-encoded marker, this diversity corresponding to either biogeography or minor morphological variations in the degree of calcification of coccoliths, respectively. The full genome sequence of one strain of *E. huxleyi* and large-scale sequence data from 13 other strains have recently been published and these data reveal that members of the *E. huxleyi* morphospecies exhibit a 'pan genome': reflecting extensive genome variability (as much as 25% variability in gene content between different *E. huxleyi* strains) and different metabolic repertoires. *Gephyrocapsa oceanica*, as well as other *Gephyrocapsa* species, are likely genetic variants of the *E. huxleyi* pan genome. The taxonomic implications of such observations are not yet clear, but it seems evident that as the genomic era progresses, our current quest to pigeonhole biological entities into species will be seriously challenged.

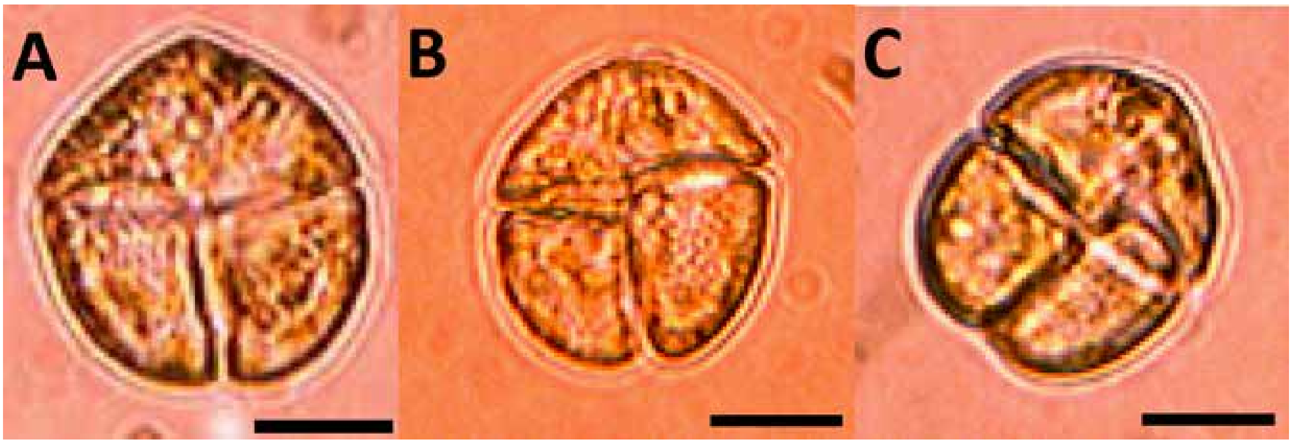


Fig. 2. Light micrographs of the ventral view of *Karenia mikimotoi* isolated from three geographical locations: United Kingdom (A), Japan (B) and New Zealand (C). Scale bar = 10 um.

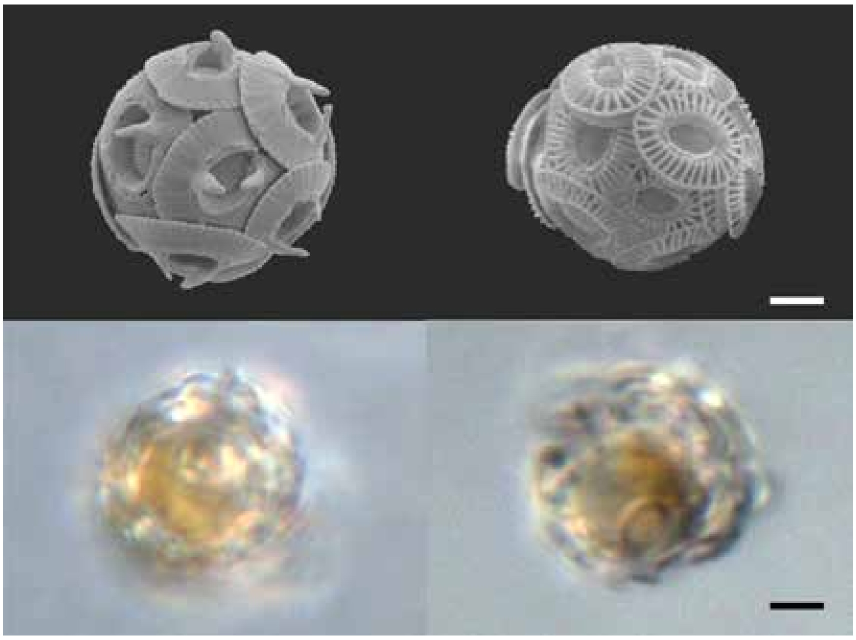


Fig. 3. Typical morphologies of *Gephyrocapsa oceanica* (left) and *Emiliania huxleyi*. They can be clearly distinguished by the resolution of scanning electron microscopy (top panel); while under light microscopy they are indistinctive. Scale bar = 1 um.

We might do well to attempt to devise and code a nomenclatural system that focuses on conveying a much broader range of standardized and complementary information than at present; without necessarily having the pretention of ring-fencing (and typifying) species, and potentially with more emphasis on describing strains and shared features between strains, such as pan genomes. Linnaean names could obviously be an integral part of such a system, for example if there is general agreement that their use should be restricted to conveying morphological information only. These examples add to the ever-growing body of evidence of molecular schemes challenging morphological assumptions in many different ways. But alas, change does not come easy. Taxonomic changes impact the nomenclature of well-known organisms that is often deeply entrenched in academic and societal usage, a factor that tends to lead to resistance to the adoption of new descriptions and names (let alone a new nomenclatural system). Nonetheless, taxonomy is a classification science and therefore by its very nature is subject to evolutionary processes based on advances in the state of knowledge about groups of organisms. Carefully defined names are and will remain a powerful means to convey the state-of-the-art of this knowledge.

El-Mahdi Bendif[1](elmben@mba.ac.uk), Manal Al-Kandari[2], Ian Probert[3] and Declan C Schroeder[1](dsch@mba.ac.uk)
1. The Marine Biological Association
2. Kuwait Institute for Scientific Research
3. UPMC/CNRS Station Biologique de Roscoff

GLOSSARY

Microalgae Microscopic unicellular photosynthetic life forms.

Morphospecies Species that are morphologically almost identical but genetically different.

HAB Species that cause Harmful Algal Blooms.

Plasticity Morphological variability related to changing environment.

Coccolithophore From greek: coccos or kokkos= berry, lithos= stones, i.e., cells covered by calcium carbonate.

Pan genome a set of core genes plus genes distributed variably between strains.

FURTHER READING

Al-Kandari M., Highfield A., Hall M., Hayes P. & Schroeder, D.C. 2011. Molecular tools separate Harmful Algal Bloom species, *Karenia mikimotoi*, from different geographical regions into distinct sub-groups. *Harmful Algae doi*:10.1016/j.hal.2011.04.017

Bendif E.M., Probert I., Schroeder D.C. & de Vargas C. 2013a. On the description of *Tisochrysis lutea* gen. nov. sp. nov. and *Isochrysis nuda* sp. nov. in the Isochrysidales, and the transfer of *Dicrateria* to the Prymnesiales (Haptophyta). *Journal of Applied Phycology* (in press):10.1007/s10811-013-0037-0

Bendif E.M., Probert I., Carmichael C., Romac S., Hagino K. & de Vargas C. 2013b Genetic delineation between and within the world plankton morpho-species *Emiliania huxleyi* and *Gephyrocapsa oceanica* (Haptophyta, coccolithophores). *Journal of Phycology*. (in review)

Hagino K., Bendif E.M., Young J., Kogame, K., Takano, Y., Probert, I., Horiguchi, T., de Vargas, C. & Okada, H. 2011. New evidence for morphological and genetic variation in the cosmopolitan coccolithophore *Emiliana huxleyi* (Prymnesiophyceae) from the cox1b-ATP4 genes. *Journal of Phycology* 47:1164-1176 -

Read B. A., Kegel J., Klute M. J., Kuo A., Lefebvre S. C., Maumus F., Mayer C., Miller J., Monier A., Salamov A., Aguilar M., Claverie J-M., Frickenhaus S., Gonzalez K., Herman E.K., Lin Y-C., Napier J., Ogata H.i, Sarno A. F., Shmutz J., Schroeder D., de Vargas C., Verret F., von Dassow P., Valentin K., Van de Peer Y., Wheeler G., *Emiliania huxleyi* Annotation Consortium, Dacks J. B.,. Delwiche C. F, Dyhrman S. T., Glöckner G., John U., Richards T., Worden A. Z., Young J., Zhang X. & Grigoriev I. V. 2013 *Emiliania*'s pan genome drives the phytoplankton's global distribution. *Nature* doi:10.1038/nature12221

Schroeder D.C., Biggi G. F., Hall M., Davy J., Martinez Martinez J., Richardson A., Malin G. & Wilson W.H. (2005) A genetic marker to separate *Emiliania huxleyi* (Prymnesiophyceae) morphology. *Journal of Phycology*. 41: 874-879.

The question of a global decline in phytoplankton is hotly debated. **Abigail McQuatters-Gollop** weighs up the evidence.

Are marine phytoplankton in decline?

Phytoplankton produce half of the world's oxygen, comprise the base of the marine food web, and play an important role in carbon cycling and climate regulation. Changes in phytoplankton communities impact climate processes and all trophic levels of marine ecosystems, from zooplankton to fish to whales.

In 2010 research scientist Daniel Boyce and colleagues at Dalhousie University created an index of phytoplankton biomass by combining records of water transparency with *in situ* chlorophyll concentrations to create a dataset spanning a >100 year time period. This new time-series showed a worrying decline in global marine phytoplankton biomass of approximately 1% per year over the last century.

Boyce's results, however, were not in agreement with research using data from the Continuous Plankton Recorder (CPR) survey—the world's largest marine macroecological dataset (Figure 1). The CPR survey, coordinated by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in Plymouth, UK, has sampled the surface waters of the North Atlantic since 1931, collecting plankton with a high-speed recorder. In addition to identifying and counting ~500 phyto- and zooplankton taxa, CPR analysts also produce an index of chlorophyll: the Phytoplankton Colour Index (PCI), a visual estimate of phytoplankton biomass (see Box). More than

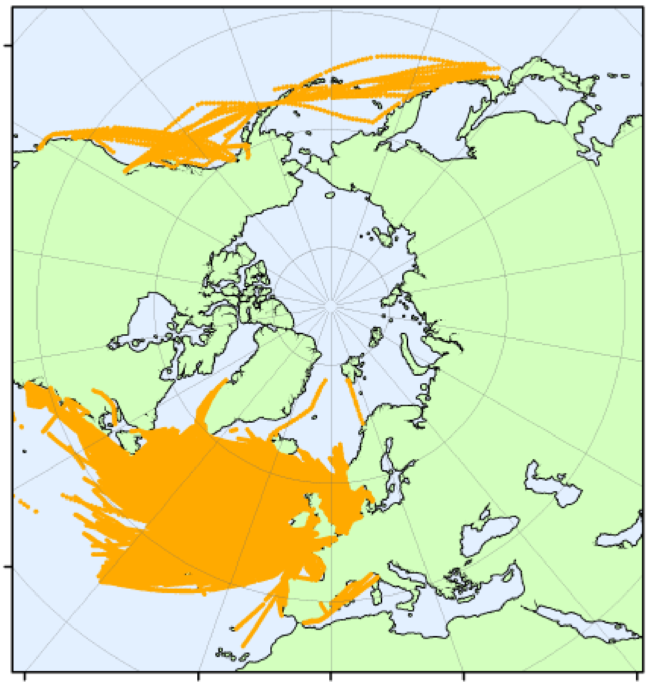


Fig. 1. The Continuous Plankton Recorder (CPR) was developed by Sir Alister Hardy (left) as a way to collect information on food for fish stocks. The CPR's current design is virtually the same as the model used in 1931, which makes the CPR dataset one of the world's longest and most spatially extensive macroecological time-series, with over 6 million nautical miles of ocean sampled (right—each orange dot is one sample). Uniquely, CPR data are collected using ships of opportunity, such as cargo vessels and ferries, rather than expensive research vessels. The ships' crews tow the CPRs as a greatly-appreciated gesture of goodwill which has enabled the survey to cost-effectively collect data for the past eight decades.

five decades of PCI data show a clear increase in phytoplankton biomass in both the north-east and north-west Atlantic basins (Figure 2). The 1980s saw a rapid increase in phytoplankton biomass in the North-east Atlantic. We now know this dramatic change was part of a regime shift—a climate-driven stepwise change in the structure and functioning of the north-east Atlantic marine ecosystem. Cuts in funding resulted in the loss of CPR routes in the north-west Atlantic in the 1980s but they were resumed in the 1990s revealing that, as in the north-east Atlantic, PCI had increased. Post-2000 most North Atlantic regions have higher PCI than in past decades, the open ocean included.

The above CPR findings contradict the decline in phytoplankton biomass described by Boyce *et al.* this could be due to differences in the consistency of the phytoplankton biomass datasets used to estimate the long-term trends. For the first 50 years of the Boyce *et al.* time-series most of the phytoplankton biomass estimates were derived from measurements of water transparency collected using a Secchi disc; later, chlorophyll sampling became a standard oceanographic procedure and after 1980 most of the data were from chlorophyll measurements. The 'mixed' dataset of Boyce *et al.* does not take into account that the relationship between water transparency and chlorophyll concentration may vary geographically or temporally, and may therefore be biased. Additionally, throughout the world's oceans, even in regions with low productivity, water transparency is influenced by sediment and other non-living suspended particles and by dissolved organic matter, not only by phytoplankton chlorophyll. Therefore, water transparency measurements may not accurately reflect the amount of phytoplankton biomass in the water. In contrast, since 1931 the PCI has been derived for more than 6 million nautical miles of ocean (> 250,000 analysed samples) which have been directly sampled by ships of opportunity towing the CPR. The virtually unchanged methodology and consistent long-term time-series makes the CPR survey a robust source of plankton data.

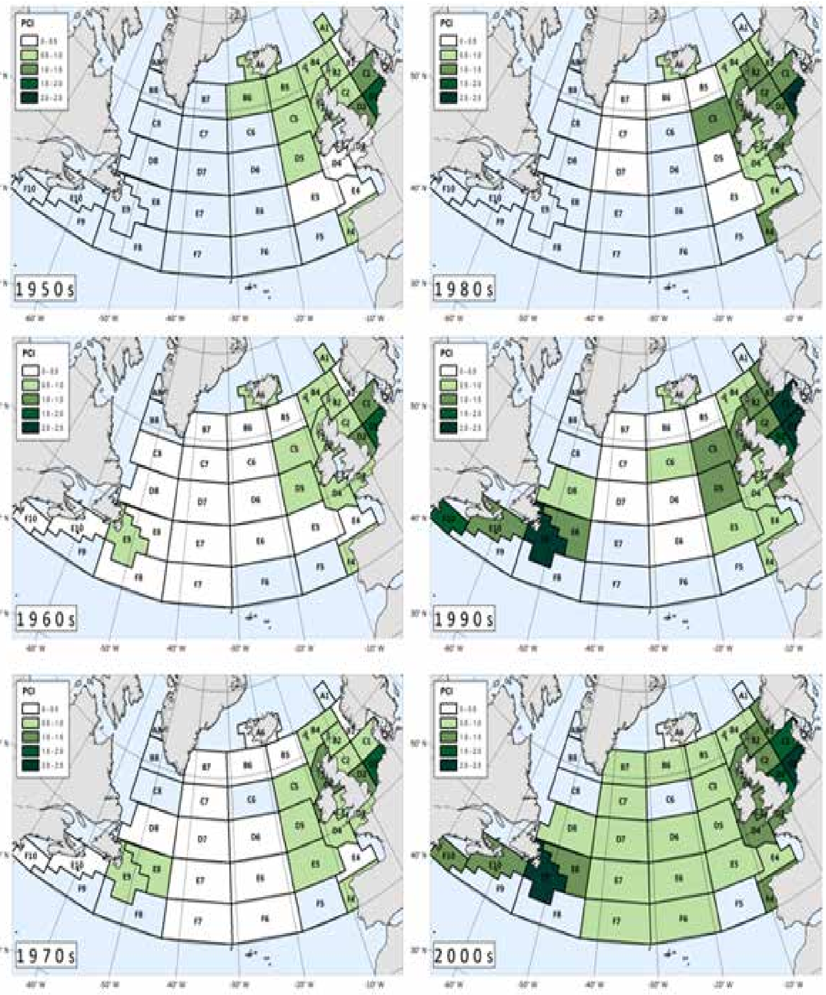
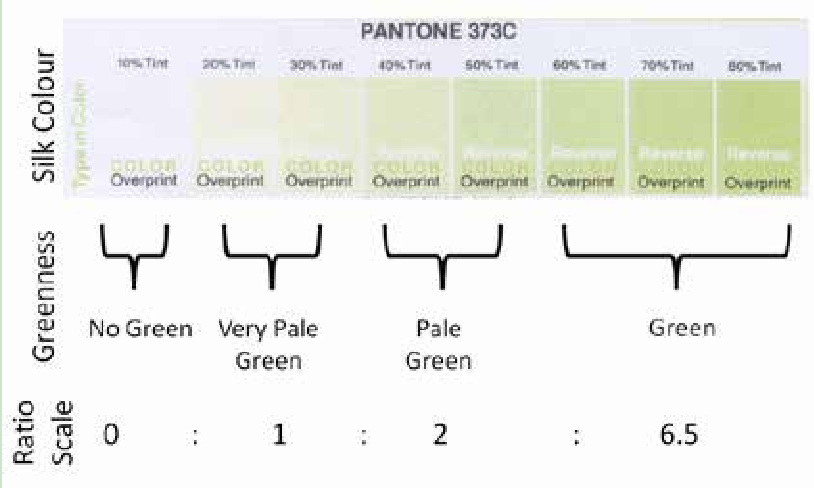


Fig. 2. Since the 1950s the Phytoplankton Colour Index from the Continuous Plankton Recorder survey has shown a clear increase in phytoplankton biomass throughout much of the North Atlantic basin.

The increase in phytoplankton biomass observed by the CPR is supported by data from other long-term time-series, including the Hawaii Ocean Time-series (HOT), the Bermuda Atlantic Time-series (BATS), and the California Cooperative Oceanic Fisheries Investigations (CalCOFI) which also show increased phytoplankton biomass during the last 20–50 years. This considerable body of data contrasts with the results presented by Boyce *et al.*, indicating that there is no strong evidence for a marked decline in global marine phytoplankton. Additionally,

What is PCI?



The Phytoplankton Colour Index (PCI) is a visual estimate of phytoplankton biomass derived from Continuous Plankton Recorder (CPR) samples; PCI is essentially a measure of silk 'greenness'. Chlorophyll in phytoplankton cells colour the silk, with high biomass samples stained dark green while samples with low biomass are pale in colour. Each CPR sample is compared to a standard colour chart with four values ranging from 'No Green' to 'Green'. PCI is semi-quantitative and has been successfully intercalibrated with measurements of both flourometric and satellite chlorophyll. Acetone extraction experiments revealed that the PCI colour categories equate to a ratio scale, with Pale Green silks containing twice the amount of chlorophyll as Very Pale Green silks, while Green silks are 6.5 times richer in chlorophyll than Very Pale Green silks.

Though the CPR's mesh size of 270 µm is considered large when it comes to plankton sampling, the device consistently collects small cells, such as coccolithophores, on the silk with recent work suggesting that the relative contribution of smaller size phytoplankton to the PCI is increasing in some regions. The PCI also accounts for fragile, broken and fragmented cells that contribute to phytoplankton biomass but are not morphologically identifiable.

remote sensing data suggest that changes in phytoplankton biomass are not globally uniform, with biomass increasing in some marine regions while remaining stable or decreasing in others. More work exploring regional changes in phytoplankton biomass, and the drivers behind these changes, is clearly needed. Investigation into which components of the phytoplankton are driving the regional increases or decreases in phytoplankton biomass could provide information about future responses to climate change or food web alterations. Continuous long-term time-series of plankton community composition are rare, but the CPR survey's extensive 80 year dataset can be used for analysis of North Atlantic phytoplankton community dynamics, including changes in individual taxa and functional groups, which may offer insight into observed changes in phytoplankton biomass. Long-term ecological time-series such as the ones mentioned here are crucial for filling scientific knowledge gaps about changes in our seas and for providing robust evidence to support decisions regarding the management of the marine environment.

Abigail McQuatters-Gollop (abiqua@sahfos.ac.uk) is a Science-Policy Researcher at the Sir Alister Hardy Foundation for Ocean Science (SAHFOS).

FURTHER READING

Boyce, D. G., Lewis, M. R. & Worm, B. (2010) Global phytoplankton decline over the past century. *Nature* 466, 591-596.

Reid, P. C., Colebrook, J. M., Matthews, J. B. L. & Aiken, J. (2003) The Continuous Plankton Recorder: concepts and history, from plankton indicator to undulating recorders. *Prog. Oceanogr.* 58, 117-173.

Edwards, M., Reid, P. C. & Planque, B. (2001) Long-term and regional variability of phytoplankton biomass in the Northeast Atlantic (1960-1995). ICES *Journal of Marine Science* 58, 39-49.

Head, E. J. H. & Pepin, P. Spatial (2010) and inter-decadal variability in plankton abundance and composition in the Northwest Atlantic (1958-2006). *Journal of Plankton Research* 32, 1633-1648.

Reid, P. C., Edwards, M., Hunt, H. G. & Warner, A. J. (1998) Phytoplankton change in the North Atlantic. *Nature* 391, 546.

Raitsos, D. E., Reid, P. C., Lavender, S. J., Edwards, M. & Richardson, A. J. (2005) Extending the SeaWiFS chlorophyll data set back 50 years in the northeast Atlantic. *Geophysical Research Letters* 32, L06603.

McQuatters-Gollop, A. *et al*. (2007) A long-term chlorophyll dataset reveals regime shift in North Sea phytoplankton biomass unconnected to nutrient levels. *Limnology and Oceanography* 52, 635-648.

Beaugrand, G. (2004) The North Sea regime shift: Evidence, causes, mechanisms and consequences. --> 60, 245-262.

McQuatters-Gollop, A. *et al*. (2009) How well do ecosystem indicators communicate the effects of anthropogenic eutrophication? *Estuarine, Coastal and Shelf Science* 82, 583–596.

Saba, V. S. *et al*. (2010) Challenges of modeling depth-integrated marine primary productivity over multiple decades: A case study at BATS and HOT. *Global Change Biology* 24, in press, DOI:10.1029/2009GB003655.

Kahru, M., Kudela, R., Manzano-Sarabia, M. & Mitchell, B. G. (2009) Trends in primary production in the California Current detected with satellite data. *Geophysical Research Letters* 114, C02004, DOI:10.1029/2008JC004979.

Gregg, W. W. & Conkright, M. E. (2002) Decadal changes in global ocean chlorophyll. *Geophysical Research Letters* 29, 1730, DOI:10.1029/2002GL014689.

Batten, S. D. *et al.* (2003) CPR sampling: the technical background, materials and methods, consistency and comparability. *Prog. Oceanogr.* 58, 193-215.

Leterme, S. C., Seuront, L. & Edwards, M. (2006) Differential contribution of diatoms and dinoflagellates to phytoplankton biomass in the NE Atlantic Ocean and the North Sea. *Marine Ecology Progress Series* 312, 57-65.

A look at current policy developments

The UK Department for Environment Food & Rural Affairs (Defra) ran a consultation from the 13th December 2012 to 31st March 2013 on proposals for the designation of Marine Conservation Zones. To quote Defra, the response was 'exceptional' with over 40,000 responses received (to get an idea of how exceptional this was, a consultation from March to June 2012 on proposals for Good Environmental Status under the Marine Strategy Framework Directive received a total of 77 responses). Even allowing for high profile campaigns boosting interest, it is clear that the issue of marine protected areas is one that stirs up a great deal of passion (for a scientific perspective see Professor Callum Roberts' article in this issue).

The response to the Marine Conservation Zones consultation was 'exceptional'.

On the same day that Defra was issuing a summary of responses to the UK consultation it was being reported that a meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) had failed to reach agreement on setting up protected areas in the Ross Sea and Eastern Antarctica. Russia wanted to 'establish the scientific case' but had blocked the proposals over various concerns including fishing restrictions. It is these same arguments over protection versus exploitation that are being played out in numerous situations around the world.

The challenge for scientists and scientific societies such as the Marine Biological Association (MBA) is that discussions around protected areas are not just restricted to issues of marine science. Take the example of the Chagos Marine Protected Area in the Indian Ocean. This is now the world's largest no-take marine reserve and the MBA stated in its comments to the UK Foreign and Commonwealth Office (FCO) in 2010 that from a scientific point of view the proposal for a reserve deserved support. We were, however, well aware that the whole debate over the Chagos proposal was taking place within the framework of broader disputes over rights of return for Chagos Islanders and disputes over sovereignty between the governments of the UK and Mauritius.

The job of marine scientists in all of this is to focus on the science: ensuring that those making decisions have the best scientific evidence available and, equally important, that they understand how to use this evidence base. In December 2012 the Association gave evidence to the UK House of Commons Science and Technology Committee[1] and made a plea for a realistic approach regarding evidence used to support policy. For example, it has been unfortunate to see phrases such as 'lack of evidence' and 'inadequate science base' being used as a reason not to implement marine protected areas in UK waters which are, relatively speaking, some of the best known and most intensively studied waters in the world. It will always be the case that unless our ability to map and understand the marine environment outstrips our capacity for exploitation (a highly unlikely scenario) the precautionary principle will need to be applied in order to ensure the best long-term outcomes for all parties. Meanwhile, the marine biological community needs to be at the forefront in providing evidence and filling gaps in knowledge with directed research, whilst at the same time helping decision makers understand the inevitable limits to understanding the > 99% (by volume) of the biosphere which is oceans and seas.

Long-lived branching sponges and sea fans in the Start Point to Eddystone Special Area of Conservation. Image: Keith Hiscock.

Matt Frost (mafr@mba.ac.uk) is MBA Deputy Director (Policy & Knowledge Exchange).

1 See the Committee's report on Marine Science at www.publications.parliament.uk/pa/cm201213/cmselect/cmsctech/727/72702.htm

Image: Guy Baker

Oceans of change

Callum Roberts takes the long view of our exploitation of the marine environment

The Marine Biological Association was founded in 1884, as many will recall given the recent 125th Anniversary celebrations. It was forged by an influential group of scientists on the back of the International Fisheries Exhibition held in London in 1883, at which Thomas Huxley had famously declared the great sea fisheries inexhaustible. Less strident voices, like those of the then 36-year old Professor Ray Lankester, begged to differ, believing they had seen signs of depletion. With precious little data on fish stocks and fisheries, neither position was easy to prove, as the contemporary Royal Commission of Enquiry into bottom trawling concluded in 1885. The new MBA was therefore to focus the lens of scientific enquiry on life beneath the waves.

I often wonder what we modern scientists would make of the sea if we were miraculously transported back in time to fill the shoes of our predecessors in their new laboratory overlooking Plymouth Sound. How different might our notions of the workings of marine ecosystems be? Coastal scenes of fishing in old photographs and engravings suggest fish were larger, much more abundant, and catches of big species more varied than today, but it has been hard to find data to underpin such anecdotes.

Fish were larger, more abundant, and catches of big species more varied than today

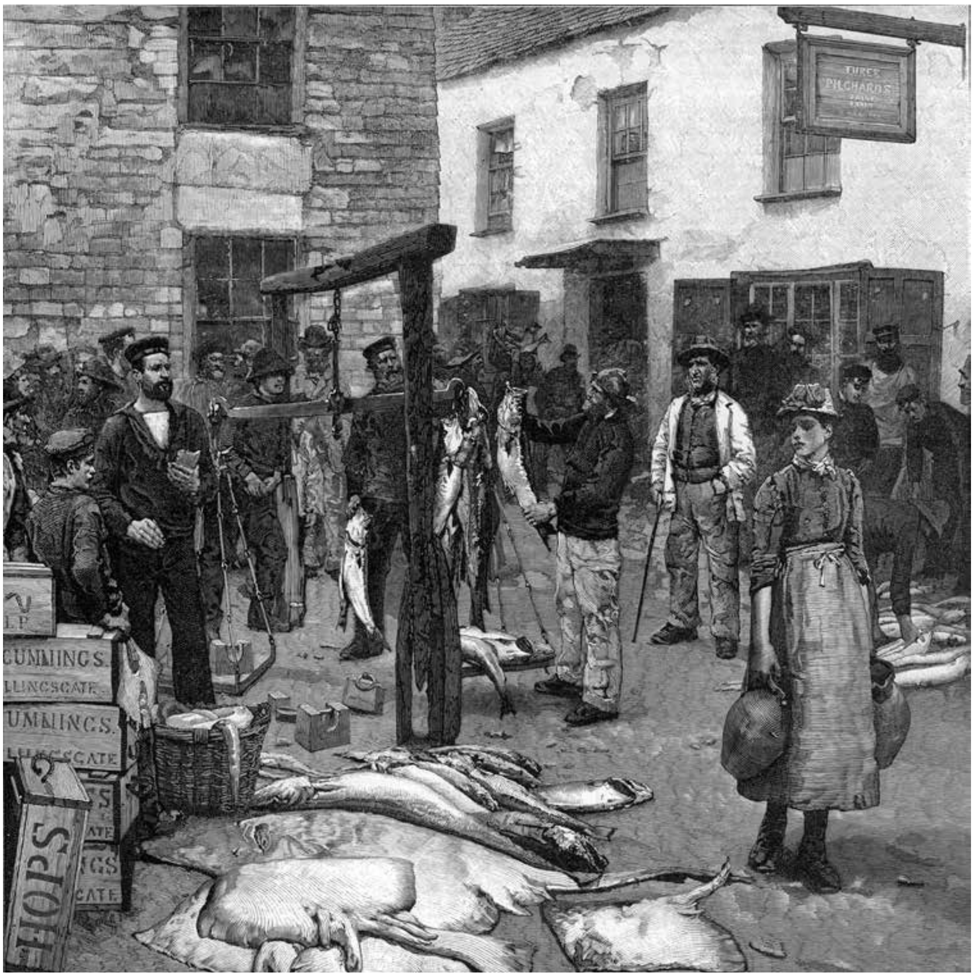
The most positive outcome of the 1885 Royal Commission was to initiate fisheries data collection in 1886, with nationwide rollout by 1889. Those data offer a bracing perspective on the current state of UK seas as my former student Ruth Thurstan recently discovered. Despite 118 years of technological advance, landings of bottom fish into England and Wales—from a largely sail powered fleet—were five times greater in 1889 than in 2007. Landings peaked around the outbreak of World War II at an astonishing 17 times greater than today. Of course, landings crashed during both World Wars, reminding us that relative fishing effort has a lot to do with these peaks and troughs.

To gain a sharper insight into the changing nature of marine ecosystems, we need to account for the effects of changes in fishing power. Here a lovely study by Georg Engelhard of the Centre for Environment, Fisheries and Aquaculture Science proved a godsend. He had forensically pieced together the changing power of bottom trawlers from the sailing vessels of the 1880s to the hi-tech boats whose banks of blinking screens suck vast streams of information from the deep to uncover the secret haunts of fish beneath. One steam trawler in 1898 was equivalent to eight sailing trawlers, for example, while a diesel trawler in 2000 could do the work of 50 sail trawlers. The records show how many boats of what type were at work so we can calculate a measure of total fishing power for each year.

When you divide landings by fishing power, 'peak fish' shifts backwards from the late 1930s to the very first year of data collection. In 1889, we landed 17 times more fish per unit of fishing power expended than we land today. As prolific as these figures confirm, the seas probed by the MBA's first scientists were not pristine. Hundreds of heartfelt testimonies by fishermen to Royal Commissions of Enquiry in the 1860s and 1880s reveal widespread bewilderment and anger at the falling productivity of fisheries. For example, a line fisherman from the north-east of Scotland said in 1885 '[7 years ago] boats here say they can have got half a ton, 12 cwt and as high as 14 and 15 cwt [of haddocks], but the highest catch we had last year was 5.5 cwt, at about, I may say, 6 miles further off than formerly'. A similar lament from the north-east of England went 'I have been going [to sea] 34 years … and when I commenced we would get 40 to 50 stone of fish, and now we cannot get over 4 or 5'.

The Royal Commission reports also included nuggets of data that enable us to trace fishing productivity backward to the middle of the 19th century. Fishermen in the 1860s landed a staggering 25 times more fish per unit of fishing power than today according to these numbers. Piecing together many statements from the 1866 enquiry on changes in fishing productivity, like the ones quoted above, we can push deeper into the early 19th century when sail trawling was mostly limited to the south coast. In the waters near the MBA's Plymouth headquarters, gnarled old fishermen recalled catch rates 2 to 5 times higher in the early 1800s compared to the 1860s. Those catches included species hardly seen in these parts today, such as massive skates and halibut, wolffish and ling.

From early on, fishermen also railed against the destructive tendencies of the trawlers, and their observations show that life on the seabed was also undergoing a transformation. Accounts provide vivid sketches of rich and varied habitats. An 1837 description of Ireland's Carlingford Lough noted that 'The middle of the Loch is deep … and the bottom occupied



Skate and hake or ling amongst the fish catch at Polperro, Cornwall in the 1860s.

Record cod catch. Lossiemouth, Scotland.

by an immense bed of oysters, of which vast quantities are taken to Dublin and other towns'. Charles Shore, a visitor to the Isle of Man was taken aback by the clarity of its waters in 1836: 'The southern coast of Man yields much seaweed which supplies the Island with good manure. It may be seen waving to and fro at great depth, so extraordinary is the clearness of the water; a perfect submarine forest'.

These habitats were progressively stripped by trawl and dredge throughout the 19th and 20th centuries. One trawl fisherman from Scarborough told in 1885 of how '[50 years ago] we used to go to the back of west rock, that is abreast of Filey, very often, and at that time we could not trawl more than an hour and a half or two hours in consequence of the shells, what we call the clam shells, some dead ones and others alive. Those dead shells had at that time white and brown thusks in them, and all among these shells the soles inhabited; and we by this small beam net […] could get 40 and 50 pair of soles in a tide […]. Well now, you could take the same coble, the same net, the same everything, and trawl over the same ground and where there are no shells, and I would think we would not get five pair of soles in a tide […]. They have trawled [the shell fish] away…'. In view of the obvious damage being done, many fishermen campaigned to have trawling banned or restricted, like the men of Youghal in Ireland in 1837, who petitioned 'The havoc and mischief occasioned by trawling is absolutely incalculable, as it tears up the ground ... the bag of the trawl often exhibiting one common mass of destruction ...'.

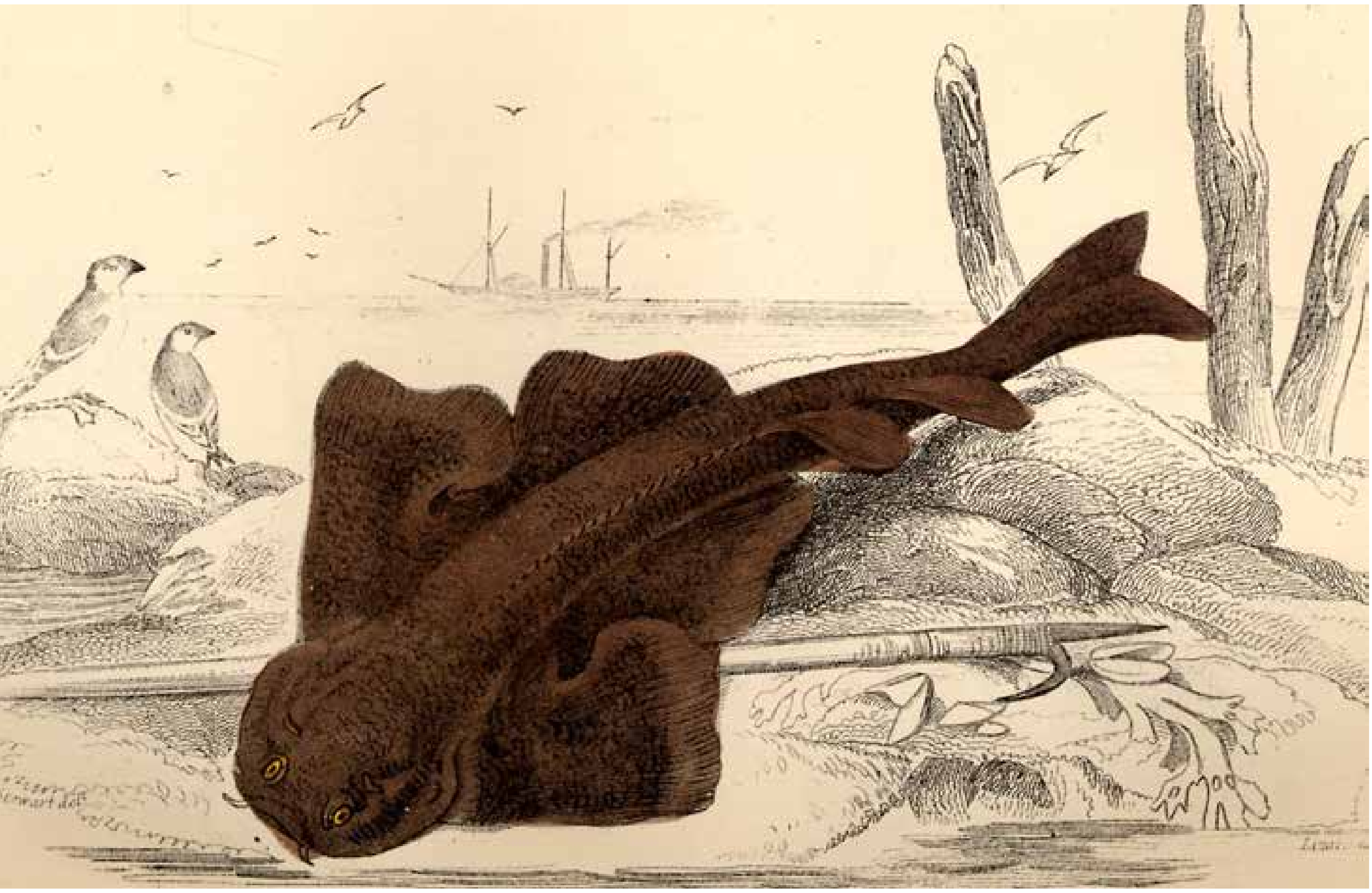
Without history, we can never make sense of the forces that govern life beneath the waves

What different theories might we have spun, what alternative scientific paradigms would these seas have yielded to the modern eye? If we really want to know how people have changed the world, the long view is essential. When I was at school, full of youthful hubris, history seemed dull and irrelevant to me. Fortunately, I shrugged off such foolishness later in life. A few years ago, I pieced together the effects of 1000 years of exploitation on the sea (*The Unnatural History of the Sea*, Island Press). Writing the book, I soon realized that the ghosts of past fishermen and hunters were with us everywhere, even to the greatest depths of the ocean (where nutrient shuttling between surface and abyss by whales and giant fish has dwindled to a trickle, if you are wondering). Without history, we can never make sense of the forces that govern life beneath the waves, nor understand how best to manage the sea. The emerging field of historical ecology is leading a renaissance in our understanding of the sea.

But while the ghostly hand of industry past still clutches the oceans around us, it is joined today by new forces unimaginable to the people who plied these seas long ago. Those forces have been unleashed by the extraordinary expansion of humanity across the globe, coupled with our increasing technological prowess. What would the MBA's first scientists make of Plymouth Sound today if they could be lifted from their graves and pressed back into service? They would find a world in the headlong grip of climate change and globalization. While many species familiar to them would have declined or disappeared from local waters, waves of new arrivals have ridden the spreading tendrils of warm water welling north, or jumped ship from distant ports. Perhaps the air would seem fresher to them, the stinking residues of sewage and refuse all but gone. But mud flats and beaches have gained grains of plastics, while synthetic chemicals lace the waters with effects unseen and hard to disentangle. The sea laps higher on the dockside and the waters turn litmus a shade brighter than before.

Would it shock them to find that people have become a dominant force shaping the sea, shifting the flow of currents, melting polar ice caps, greening the sea in some places while expanding ocean deserts in others, and choking life from vast tracts of seabed? The oceans still yield up catches to local fishermen, but nets are filled with smaller fry. And places like the Irish Sea, once noted for its huge fish, have been so raked and sieved by dredge and fine-mesh prawn trawl, that only prawns, scallops and small fish like dabs and red gurnard still thrive. The mice and cockroaches of the sea have usurped its elephants and lions.

Nobody willed it this way. Fishermen have not deliberately set out to destroy ocean life and undermine their own livelihoods. Their ingenuity and adaptability have simply outrun societal restraint. At every step-shift up in power—hook and line to sail trawl, sail trawl to steam, steam to diesel—marine life has shifted downward in abundance and variety. To keep the balance between fish and fishing, industrial power must be fettered and commercial



Once common around Britain, the angel shark has now virtually vanished and is considered to be extinct in the North Sea (IUCN, 2008). Image from *A history of British fishes* (Yarrell, 1836).

A level seabed harbouring soft corals such as pink sea fans (*Eunicella verrucosa*), and sponges. Such communities are vulnerable to physical damage and may take decades to recover. Image: Keith Hiscock.

fervour constrained. To be fair to the many who have tried, it is not easy, even if your only interest is in fishing. And we have only recently come to appreciate that it simply is not possible to balance nature conservation, healthy ecosystem functioning and fisheries profitability using the old regulatory toolbag of restrictions on gear and landings (some have yet to realize this). For that balance to be struck, we need something else: marine reserves.

Marine reserves put places off limits to fishing, other exploitation and harm. They provide refuges in which vulnerable species can thrive and habitats can begin the decades-long journey back to vitality. By allowing big fish to return and reproduce, they will supply surrounding fisheries with young fish; a point understood even in the 19th century, as a Sunderland fisherman noted in 1883: '... the Dogger Bank has been seriously affected by the trawling going on there; and we have looked upon the Dogger Bank as the principal reservoir of fish; and the mischief done to the Dogger Bank we look upon as [done to] the fountainhead'. With well found networks of marine reserves, fish can be exploited more intensively in other places, even with trawl and dredge. And with fish more abundant, they could be taken at lower cost by a more efficient industry.

Many have battled hard to see marine reserves established around the UK. England has a blueprint for an entire network and was on the cusp of turning around the state of its seas until this Government faltered and put forward less than a quarter for implementation. They said it was too expensive and blamed scientists for lack of evidence (there is plenty that marine reserves are sorely needed), while quietly shelving promises to apply the precautionary principle and use best available evidence. This is why 86 marine scientists recently wrote to the Prime Minister urging him to reaffirm the Government's commitment to a full network of protected areas and set out a clear timeline for its establishment, reminding him that the costs to society of further inaction greatly outweigh the costs of protection.

Callum Roberts (callum.roberts@york.ac.uk) is Professor of Marine Conservation at the University of York, and author of *Ocean of Life: How our Seas are Changing*. Penguin 2013.


Image: Jason Flower

Carbon Credits: the new face of coastal conservation?

Melissa Schiele looks at the mechanisms behind 'blue carbon' trading.

Climate change is affecting nearly all biomes on the planet. The degradation and deforestation of mangroves, seagrass beds and tidal marshes in particular could release up to a billion tonnes of carbon dioxide annually if something is not done soon (Pendleton, 2012). Some financiers, scientists and non-governmental organizations (NGOs) believe that conservation through carbon credit generation and sales (i.e. markets), is the answer.

Carbon credits are a market driven mitigation initiative which encompasses the production and sale of carbon credits, in what is known as the carbon credit market. A carbon credit represents a tonne of carbon dioxide released into the atmosphere and the idea is, that if an entity releases 1 tonne of carbon dioxide, purchasing or creating a carbon credit (for their own use) will cancel out their emissions.

The largest carbon credit trading forum is the EU Emissions Trading Scheme (EU ETS), an example of a compliance market, meaning that credits being processed are used by companies who are legally mandated to reduce their emissions (such as those in the EU). The EU ETS accepts credits generated from projects which have shown to reduce net emissions. An example would be a Clean Development Mechanism (CDM) project where an industrial company from the UK has built solar panels in India for a village, reducing the dependency on coal and consequently reducing the emissions by a certain amount per year.

There also exists a global voluntary market for carbon credits. The voluntary market is still in its infancy and is a refuge for those credits which do not meet the EU ETS credit prerequisites. Credit prices are affected by a lot of factors so if a company is able to create a lot of them from a particularly carbon rich site they may be able to increase the value of the credit if that site also has endangered species on it, hence the other term, corporate social responsibility (CSR) credits. The credits that fit into CSR/voluntary markets are often those from forest projects which come under the umbrella of UN REDD credits (United Nations Reducing Emissions from Deforestation and Forest Degradation) or IFM (Improved Forest Management). UN REDD has been in existence since the United Nation's Framework Convention on Climate Change's Kyoto Protocol. It is under UN REDD where new mangrove and seagrass bed conservation projects may appear in the coming years and that is where things get interesting for the marine science and conservation community.

The success of REDD forest projects relies heavily on the ability of the project to conserve forests and to avoid degradation and deforestation. The regrowth of the forest amasses carbon in the wood and roots and it is this sequestration that allows carbon credits to be formed. In short, as the forest grows, CO_2 is locked away for good or until the tree dies in several hundred years or so. It is this combination of offsets (avoided emissions from not cutting the forest) and sequestration that can be converted into carbon credits. The project must prove that without its presence, the forests would surely be cut down, something called additionality, and without it a project is void. The basic concept is that deforestation must be avoided in order to keep the project viable environmentally and financially.

This model is being developed in order for mangroves and seagrass beds to be conserved in a potentially more economically viable manner. It may soon be the case that investors begin to plough money into the companies which are doing these projects specifically for mangroves and seagrass beds and not just forests, as mangroves hold more carbon and thus generate more credits that can be sold. Countries where this could happen first are Indonesia and Brazil, which have the largest extent of mangroves in the world.

Mangroves, seagrass beds and wetlands are delicate and diverse ecosystems which are often subject to exploitation by local people for wood collection to aquaculture. They are at risk from rising sea levels but could also play an important role in climate change mitigation as carbon storage facilities. The ecosystem service of carbon storage is now being recognized by large NGOs and governments and much frantic research is going into clarifying the carbon sequestration rates of these coastal ecosystems and consequently, monetization mechanisms

Mangroves above and below the surface. Images: Jason Flower.

Zanzibar has many seagrass beds including those in the rural peninsula of Fumba. Image: Melissa Schiele.

are being created. With mangrove deforestation being three times more detrimental for the environment than regular deforestation, it is unsurprising that carbon credit generators are trying to find ways of capitalizing on them. Deforestation (including coastal system destruction) accounts for 8–20% of total global emissions. It is also important to realize that mangroves on average store at least twice as much carbon than most tropical rainforests, with certain sites in Micronesia (for example) holding around 70% of their carbon in the soils. Mangroves, seagrass beds or salt marshes are found on nearly all non-Arctic or Antarctic coastlines in some form and their carbon benefits are augmented by the biodiversity benefits and amenities that come with conserving such places, not least being protection against storms. NGOs and local governments in developing nations face a difficult challenge in conservation of coastal environments due to often poor funding and limited staff coupled to increasing populations. Paper parks (and Marine Protected Areas MPAs) can also be a hindrance to conservation efforts.

The effectiveness of the REDD projects varies greatly, however. Only a handful of projects have generated credits which have been validated by the Verified Carbon Standard (VCS). A REDD project has a lot of moving parts and as the industry is relatively new, many carbon credit companies are still trying to figure out how to monetize and even create the credits under the strict policy guidelines of UN REDD and also validating bodies such as the VCS. The projected returns on some of these projects can be staggering, but whether the market and demand holds up is yet to be seen. Governments in developing countries are often keen to get these investors on-board; it helps to reduce the country's overall emissions and shows that they are actively keen on development.

A carbon company (or NGO in partnership with one of these companies) which wishes to set up a REDD project must work closely with the local government, policy makers and stakeholders as well as maintaining a strong and fair relationship with the local inhabitants—at the end of the day, once a REDD boundary is delineated, that forest or costal area then becomes strictly off limits to the local people. This is where serious problems can arise. The media has been quick to highlight the actions of so called 'carbon cowboys' who have entered an area to make a quick buck and not taken into account the local people's needs or situations, ending in protests, violence and the risk of uprooted indigenous people losing their land (and of course disgraced politicians and governors). REDD projects require an element of positive net benefits for the local communities and to help projects quantify the effectiveness of their community engagement, as well as biodiversity in the local area

As well as storing carbon, seagrass beds (left) are home to a diverse flora and fauna. Sea cucumber, Fumba, Zanzibar (right). Images: Melissa Schiele.

and climate effects, a standard was created, known as the CCBA standard (The Climate, Community and Biodiversity Alliance). Project developers use this standard alongside their more technical carbon counting VCS standard to quantify the good work the projects have done. Many local people can find employment through REDD projects and often schools and places of worship are built in remote areas. An important issue for investors is whether deals with local communities are legally binding and strong enough to last the length of the project, which can be decades.

Of course the proper capital is also needed to pay for all outgoings; this is often funded by investors into the carbon company's core fund. There is a risk that if the market demand for carbon credits slides, the interest in these REDD projects may suffer also, with less investment happening and the chance of abandoned projects resulting in increased degradation and greenhouse gas emissions. But the likelihood of this happening is relatively low, as many companies and firms believe that climate change will affect them negatively in some way, and whether through buying CSR credits or investing in a project, they will want to get their share of the market.

Overall, REDD projects could be a good way for coastal conservation managers to guarantee the safety of their environments in a time where funding for regular conservation projects is hard to come by and support from governments in governance and enforcement may be minimal. Examples of successful projects include the Kasigau Corridor Project (Phases I and II) which has created thousands of credits for sale (visit the VCS project database for more information). REDD projects are labour intensive and risky (financially and socioeconomically) but if carried out with rigour and with an interdisciplinary team focused on good governance, conservation and social development then there are few reasons why they should not work.

Melissa Schiele (melissa.schiele@gmail.com) is Heritage Project Manager and a member of the Marine Biological Association.

FURTHER READING

Kauffman J.B., Heider C., Cole T.G., Dwire K.A. Donato D.C. (2011) Ecosystem carbon stock of micronesian mangrove forests. *Wetlands* 31, 343–352.

Pendleton L., Donato D.C., Murray B.C., Crooks S., Jenkins A.W., Sifleet S., Craft C., Fourguean J.W., Kauffmann J.B., Marbà N., Megonigal P., Pidgeon E., Herr D., Gordon D. and Baldera A. (2012) Estimating global 'blue carbon' emissions from conversion and degradation of vegetated coastal ecosystems. *PLOS 7*, e43542. DOI:10.1371/journal.pone.0043542.

VCS http://v-c-s.org/

UN REDD http://www.un-redd.org/

CCBA http://www.climate-standards.org/

REDD Monitor (unbiased whistle blower on REDD) http://www.redd-monitor.org/

Mongabay http://www.mongabay.com

European marine educators, unite!

Europe's quest for a more ocean-oriented society and economy.

Knowledge is an engine for sustainable growth in the interconnected global economy and improving knowledge about the seas and oceans is a key element to achieving that growth in the European Union.

A fundamental tenet of Ocean Literacy is that marine knowledge should reach not only young students but all age groups. The European Commission's Directorate-General for Maritime Affairs and Fisheries states in its 'Marine Knowledge 2020' initiative that public information is fundamentally a public good that can benefit a wide body of stakeholders. By improving marine knowledge, the initiative aims to improve the quality of public decision-making at all levels. A more informed and concerned public will better understand the need to manage ocean resources and marine ecosystems in a sustainable way, and indeed an ocean-literate person is 'able to make informed and responsible decisions regarding the ocean and its resources'.

However, the basic understanding about oceans and seas seems to be insufficient in Europe. There is still a gap between what scientists know, and what the general public understands, about the marine environment, despite the general quest for marine knowledge from the public. Ocean sciences seem to be left aside in most high schools syllabi. Unfortunately, there are only a few studies conducted on the subject of ocean knowledge and ocean education in Europe. This scarcity of information seems to be another indication that ocean knowledge is limited in most European countries.

In 2011, the College of Exploration initiated an international meeting at the annual National Marine Educators Association (NMEA) conference in Boston, Massachusetts, attended by several European marine educators. At this meeting a new network of marine educators was born, the 'European Marine Science Educators Association' or 'EMSEA'. EMSEA is Europe's own network of marine educators, a network that is closely affiliated with NMEA and the international ocean community. EMSEA's core business is to establish a platform for ocean education within Europe. Europe has much to offer in terms of valuable marine projects and educational materials, but the efforts are often poorly visible, and thus seldom used by others. EMSEA is therefore dedicated to facilitate the exchange of best practice in marine education, to provide a networking directory for marine educators and to organize annual conferences for educators throughout Europe.

While people the world over express serious concerns about the protection and the health of the ocean, Europe has yet to provide a structure to make Ocean Literacy its priority.

The position paper of the European Marine Board 'Navigating the Future IV', which outlines the most important marine thematic research priorities for Europe (2012–2106), clearly states the urge for a European consensus on Ocean Literacy. Questions such as what Ocean Literacy means for our continent and what people should know of the ocean to make informed and responsible decisions need to be debated. The position paper underlines the importance of understanding what people know, want to know and should know about the ocean. Through public surveys and meetings between European ocean scientists and educators, the aim is to agree upon overall essential principles, based upon those prepared in the US.

A major concern is that the diversity in languages, educational systems and ways of living with the sea across Europe will complicate the implementation of a future European Ocean Literacy plan. National characteristics and issues do not tell us all

Participants at the first European Conference on Ocean Literacy. Image: VLIZ (Hertz).

we need to know about the seas as a global system connected by shifting winds, seasonal currents and migrating species. Some issues addressed are similar at European or global level. This is where EMSEA steps in. Through EMSEA, European countries have the opportunity to define the purpose of ocean education for their economic and scientific challenges, and find ways to collaborate on ocean issues and stimulate a science curriculum reform.

As a pioneer in Europe, Portugal has made a concerted effort to place Ocean Literacy on the map for its science teachers. The Portuguese National Agency for Scientific and Technological Culture, Ciência Viva, launched in 2011 a version of the Ocean Literacy principles adapted to the Portuguese reality, linked to the Portuguese science curriculum: 'Conhecer o Oceano: Principios Essenciais e Conceitos Fundamentais' ('Knowing the Ocean: Essential Principles and Fundamental Concepts'). This effort certainly serves as an example and inspiration for other European countries.

The First Conference in Europe on Ocean Literacy (12 October 2012, Bruges, Belgium) brought together scientists, experts, educators and policy makers to explore how Ocean Literacy can improve the future of European seas. Highlighting the lack of ocean-related content in formal science education the conference emphasized how marine education projects and informal education efforts (e.g. aquaria, science centres, museums, NGOs etc.) were by necessity paving the way to more public involvement and active participation. There is no doubt the conference has been an important milestone in developing an ocean literate society in Europe. It has been critical in raising the profile of Ocean Literacy with European policy makers, notably with the European Commission DG Research and Innovation. The inclusion of Ocean Literacy as one of the themes for greater trans-Atlantic collaboration in the EU's Transatlantic Galway Declaration (24 May 2013) is clear evidence of major progress in this area. At the request of the European Commission a group of ocean education experts will deliver recommendations to the European Commission DG Research and Innovation on mechanisms and initiatives to better support marine science outreach and education in the Horizon 2020 Programme and beyond.

It is clear that the promotion of Ocean Literacy is still in its infancy in Europe. However, the resources are available, and EMSEA will make sure that these (often local) initiatives will be highlighted and promoted. Together these efforts will be the start of a more ocean literate Europe. Investing in Ocean Literacy on a European and global scale will no doubt have considerable currency for many years to come.

If this article sparked your interest, we will be honoured to welcome you at the next EMSEA conference which will be hosted by the Marine Biological Association on 3–5 September 2013 in Plymouth, UK.

Géraldine Fauville[1] (geraldine.fauville@loven.gu.se), Evy Copejans[2] and Fiona Crouch[3]
1. Sven Lovén Centre for Marine Sciences
2. Flanders Marine Institute
3. Marine Biological Association

FURTHER READING

Buckley P., Pinnegar J.K., Terry G., Chilvers J., Lorenzoni I, Gelcich S., A. Dudek A. and Arquati A. (2011) Report on European public awareness and perception of marine climate change risks and impacts. Deliverable 2.2. *Climate Change and Marine Ecosystem Research (CLAMER)*, 65 pp. www.clamer.eu/

Dee T. S. (2003) Are there civic returns to education? Working Paper 9588, National Bureau of Economic Research.

Chawla L. (1999) Life paths into effective environmental action *The Journal of Environmental Education* 31, 15–26.

Commission Europe (2020) A European Strategy for smart, sustainable and inclusive growth, 03.03.2010 COM (2010) 2020.

Commission of the European Communities (2007) An Integrated Maritime Policy for the European Union Brussels, 10.10.2007 COM (2007) 575 final.

Commission Marine Knowledge (2020) Marine data and observation for smart and sustainable growth; A better understanding of our seas and oceans to boost competitiveness and growth. Brussels, 8.9.2010, COM(2010) 461 final, SEC(2010) 999, SEC(2010) 998.

Copejans E. and De Doncker K. (2007) *Mare incognitum*. De Aardrijkskunde 31, 21–32.

COSEE, National Geographic Society, NOAA, College of Exploration (2005) Ocean Literacy: The Essential Principles of Ocean Sciences Grades K–12. Jointly published brochure. Available at: www.coexploration.org/oceanliteracy/documents/OceanLitConcepts_10.11.05.pdf.

Eggermont M. (2007) Upgrading basic knowledge of oceans and seas through secondary education. MSc thesis. Universiteit Gent; MARELAC: Gent. 103 + 1 cd-rom pp.

Hoeberigs T. and Seys J. (2005) Wat weten we over de zee? Een onderzoek naar de kennis en informatienoden bij jongeren en senioren [What do we know about the sea? A study of what youngsters and senior citizens know and want to know]. *De Grote Rede* 14: 2-5

McDonough N. *et al.* (2013) *Navigating the future V. ESF Marine Board Position Paper. European Science Foundation*. Ostend: ESF Marine Board: Ostend.

Pooling resources for marine science

The European Marine Biological Resource Centre

by **Nicolas Pade** and **Colin Brownlee**

Europe has a very long and distinguished history in marine biological research. Its coastal marine biological laboratories are among the oldest in the world, with many being established in the 19th century. The rationale behind the establishment of the early marine laboratories, notably promoted by A. Dohrn in Naples and T.H. Huxley in Plymouth was to increase knowledge of the seas and life therein—vital to understand the sustainability of the fishing industry. There followed a proliferation of marine laboratories around the world including many in the USA. These sites provided access to the sea, marine organisms and the facilities to collect and study them in key ecologically important locations. The marine laboratories have hosted many scientists over the years to carry out research much of which has led to ground-breaking discoveries in fields as diverse as biomedicine, evolutionary science, and chemical and physical oceanography.

The oceans represent the largest set of ecosystems on Earth and harbour exceptionally high biological diversity. Of the 36 recognized phyla of living organisms, only 17 occur on land, whereas 34 occur in the sea. Marine organisms present an extraordinary variety of structures, metabolic pathways, reproductive systems and sensory and defence mechanisms. Efforts to understand this biodiversity have led to discoveries with important implications for the sustainable development of human society, for example in relation to advances in biomedicine, biotechnology, gene technology, food security, environmental issues and general ecosystem health—the Ecosystem Services Concept.

A co-ordinated European marine biology infrastructure

Marine laboratories have been pivotal in uncovering the hidden potential of the marine environment through provision of platforms, equipment, expertise, resources and information. However, these marine laboratories have traditionally tended to operate rather independently as research infrastructures (RIs), providing stand-alone access to marine organisms, ecosystems and facilities for visiting and resident researchers.

There is an urgent need to better coordinate these activities at the European level in order to address future demands for marine resources, to seize the opportunities presented by better understanding of marine systems and technological advances and to meet the challenges of increasing uncertainties about the changing marine environment.

What is the EMBRC?

The EMBRC is a developing

Fig. 1 EMBRC partners

pan-European marine biological infrastructure that aims to provide coordinated access to ecosystems, data, resources and facilities for academic researchers and industry. EMBRC partners recognize the critical and increasing importance of large scale international collaborative efforts to address the future major challenges of marine science. The primary aim is to provide essential access beyond that which will be possible through future infrastructure capabilities defined at the national level. A coordinated system of access at the European level has been agreed by the participating organizations as the most cost-effective and scientifically productive means of accommodating the future infrastructure requirements in marine biosciences, as also demonstrated by the success of major European RIs in related fields.

The provision of services by EMBRC will be centred around four core themes: Access to Ecosystems; Aquaria & Culture; 'Omics technologies, and Mobility of Researchers and User Access. The EMBRC Scientific Strategy Report (www.embrc.eu) describes how this distributed infrastructure will come about, the standards and services that it will provide, and how it will operate and evolve to establish a single entry point to European marine research infrastructure. Throughout the preparatory and construction phases member organizations are formalizing national and European agreements, establishing a searchable EMBRC database of facilities, platforms, organisms and services, and are taking the first steps towards standardization of databases.

A one-stop-shop for marine biological research

EMBRC will provide access to ecosystems, model species, culturing and husbandry, large-scale facilities and platforms as well as e-infrastructure and bioinformatics support.

Overlap and complementarity with related programmes and infrastructures will be addressed whilst working towards a single entry point to ensure that applicants access the most relevant facilities for their work. Sharing of aquaria and culture expertise and best practice guidelines will be set up and disseminated throughout the partner institutes. The coordination of 'omics tools and capability throughout Europe, and establishment of standards for design and analysis will be facilitated to provide a framework upon which 'omics approaches will be developed throughout the infrastructure. As well as services and facilities for Europe's Horizon 2020 programme EMBRC will provide training for technical staff, early and established researchers and platforms for R&D SMEs.

EMBRC will be a major asset in making Europe an attractive and highly competitive centre for marine biological research.

Nicolas Pade (nipa@mba.ac.uk) is EMBRC Technical Development Officer (WP2), and Colin Brownlee is Director of the Marine Biological Association.

CURRENT EMBRC PARTNERS

CNRS/University of Paris Marie Curie, France; Alfred Wegner Institute (AWI), Germany; Sven Lovén Institute, Sweden; Sars Institute, Norway; Naples Zoological Station, Italy; Hellenic Centre for Marine Research, Greece and University of the Algarve, Portugal, plus the European Molecular Biology Laboratory (EMBL) in Heidelberg and its bioinformatics node at Hinxton, UK (along with the other UK partners). The current UK partners are the Plymouth Marine Science Institutes (led by the Marine Biological Association (MBA) and Plymouth Marine Laboratory (PML)); the University of St Andrews/Scottish Oceans Institute; and the Scottish Association for Marine Science (SAMS). EMBL will provide the link to ELIXIR (a pan-European research infrastructure for biological information) and the BioImaging RIs.

Hugh Miller is a marine biologist and cameraman with the BBC's Natural History Film Unit. He gives:

the view astern

The Marine Biologist: Hugh, what first got you interested in marine life?

Hugh Miller: Going rockpooling as a child on the coast of Scotland and realizing the world under the sea was much stranger than the one above.

TMB: The footage under the ice in the BBC Frozen Planet programme and the story of how you got it was fascinating. Do you think you will be seen as a pioneer of filming techniques in the future?

HM: No! [Laughs] Most of the techniques we use are modern versions of what has been done before. Today we benefit from much better cameras and kit but I do adapt the equipment to do what we want.

TMB: The water clarity under the ice was astonishing.

HM: The water has been under the Ross Ice Shelf in the dark for a long time and it circulates very slowly so nothing is growing in it by the time it flows past those sites. When summer comes and it's light there is a big plankton bloom and the visibility crashes. There was a sense of vertigo and floating in nothing when it is that clear. On one dive, the whole water column tipped below the freezing point. The water was twinkling with ice crystals and crystals were forming on the equipment. It was extraordinarily beautiful.

TMB: Thinking about the early Antarctic explorers and their copious notes and drawings, has technology completely removed the need for any 'analogue' recording or notes?

HM: Notes and drawings are an interpretation of what is observed, and that is true with digital technology. What you choose to point the camera at and how you compose the shot is an interpretation, and the technology itself also interprets reality.

TMB: What are you looking forward to in your underwater filming career?

HM: I'd love to film in the deep sea from a submersible, that's a real ambition. We are also on the brink of some exciting developments with ultra HD [high definition], filming in the dark, much more advanced camera grip and so on. Who knows, I'd like to film giant squid one day!

TMB: What is your most memorable marine life experience?

HM: The first time I swam in on a sperm whale in the Azores back when I was a camera assistant. We were way out at sea with the boat stood off and the cameraman and I were in a tiny tender with an electric motor which is quiet. I jumped in but didn't see anything, so I was making my way back to the boat when all of a sudden a mother and calf appeared in front of me. When she saw me she ranged me with her sonar and I felt my lungs shake!

TMB: If you had to be a researcher what would you specialize in?

HM: Probably either fisheries as it's important, but I would also like to look at vision and colour and how sea creatures see their surroundings.

TMB: Which marine scientist do you most admire?

HM: That's a hard one; I keep finding new scientists that I'm in awe of! Edie Widder would be one because of her work filming giant squid. I have huge admiration for people who make machines that allow us to explore the ocean in different ways so I'm going to pick the engineers, Piccard senior and junior. Auguste designed the bathyscaphe, *Trieste* that reached the Challenger Deep and his son designed and skippered the submersible *Ben Franklin* that drift-dived the Gulf Stream for a whole month in 1969. It was an extraordinary journey and a pioneering expedition and everyone involved has my admiration.

Upcoming news and events for members of the Marine Biological Association

- The MBA will be advertising for the **Anne Warner Fellowship** in September 2013.

Look out for job vacancies on the MBA website.

- The **EMBO Plymouth Microscopy Course** is planned for April 2014.
- **Bryozoan workshop** 27th September 2013.

For more information or to book a place on a course email: membership@mba.ac.uk

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