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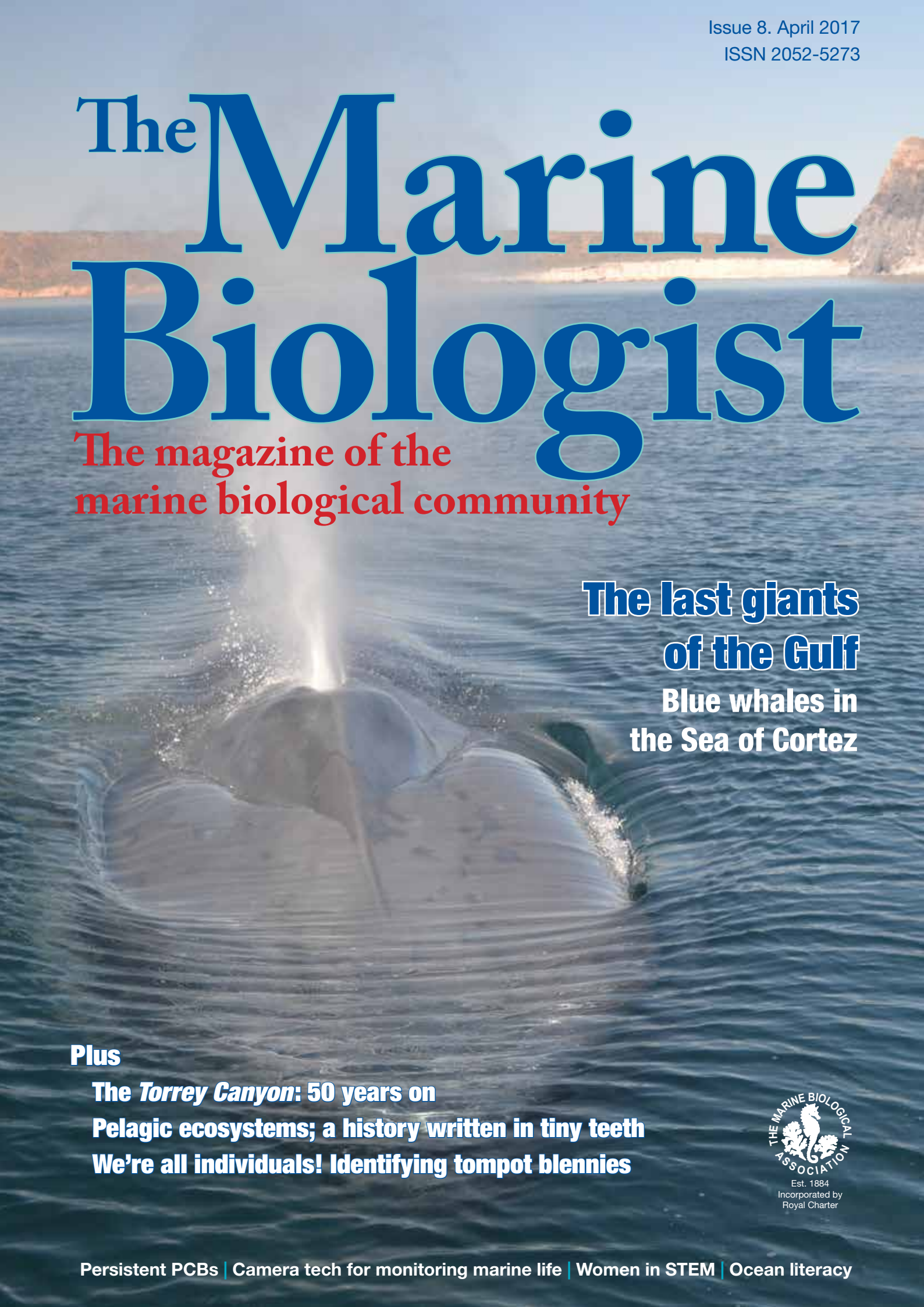
The Marine Biologist

The magazine of the marine biological community



The last giants of the Gulf

Blue whales in the Sea of Cortez

Plus

The *Torrey Canyon*: 50 years on

Pelagic ecosystems; a history written in tiny teeth

We're all individuals! Identifying tompot blennies

THE MARINE BIOLOGICAL ASSOCIATION
Est. 1884
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Persistent PCBs | Camera tech for monitoring marine life | Women in STEM | Ocean literacy

The Marine Biologist
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We welcome submissions of original and relevant material, letters and responses to published articles. For guidance, please see the magazine website at **www.mba.ac.uk/marine-biologist** or contact the Editor.

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Editorial

A warm welcome to *The Marine Biologist* magazine. Our cover story in this issue is an evocative and beautifully illustrated account of fieldwork from the Gulf of Mexico, concerned with conservation of the elusive blue whale.

50 years ago the *Torrey Canyon* ran aground off Cornwall, southwest England. Eve Southward was there at the time and recounts the MBA's response to the oil spill. If there was a silver lining to this disaster it was that MBA scientists had surveyed rocky intertidal sites in south west England for a long period prior to the spill. As well as being able to determine how long it took for shores to return to a pre-spill state, they were also able to assess the toxicity of the dispersants and provide the science that informed the way spills were dealt with subsequently.

From its establishment to the present day the MBA has taken the long view. We have the history and experience to recognize the importance of long-term science and of vital areas of research that are perceived as less charismatic. Taxonomy is an area of marine biology that is suffering a shortage of qualified people. There are many reasons for this 'taxonomic impediment' (see 'Where have all the taxonomists gone?' p. 24), not least a lack of career pathways for systematic scientists. It is also worth remembering that the standard academic route is not the only way in to the subject (see Waking up to Wakeham, p. 19).

As a member of the Marine Biological Association, you are more likely than most to be conscious of human impacts on the marine environment. However, this awareness needs to spread to all parts of society. Ocean literacy is a global movement addressing that need, helping citizens to better understand the ocean's influence on us and our influence on the ocean. Find out more about ocean literacy and how a major European project is making a sea change in our attitudes to the ocean (p. 20).

In a new feature (p. 22) we are plundering the MBA archives for images of famous people, places and events that capture a moment in marine biological history. I hope younger readers in particular will enjoy this edition, and if you have any comments about which parts you liked or disliked I'd love to hear from you.

Please have a look at our new website www.mba.ac.uk/marine-biologist where you will find dozens of articles from back issues of the magazine and much more.

As ever I am grateful to all our contributors for the fantastic content, which makes this (probably) the best association magazine in the world.

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

Front cover: A blue whale (*Balaenoptera musculus*) photographed in the Gulf of California, Mexico. Image: Michael Fishbach.
Back cover: The eye of a Greenland shark (*Somniosus microcephalus*). The eyes of almost all individuals of this species bear a parasitic copepod. Image: Julius Nielsen.

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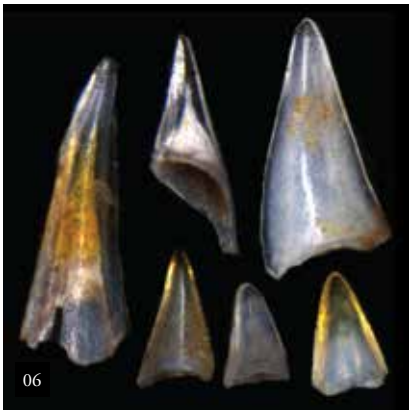

Top: Fish microfossils, Elizabeth Sibert.
Middle: Blue whale breath at sunset, Michael Fishbach.
Bottom: Oiled shore Porthleven, UK, 1967. A.J. and E.C. Southward.

The Greenland shark *Somniosus microcephalus*. Image: Julius Nielsen.

Capture Our Coast

Capturing Our Coast is a UK-wide project investigating the species that live in our seas and how we can protect them. The project involves Citizen Science, where members of the public contribute to scientific knowledge and discovery by collecting data, or by analysing and interpreting findings. The responsibility for protecting our seas and wonderful marine biodiversity belongs to all of us and at 'CoCoast' we believe that members of the public should be empowered to contribute in meaningful ways, sharing their skills and enthusiasm.

We have seven Regional Hubs around the UK including The Marine Biological Association in Plymouth, University of Newcastle, University of Hull, University of Portsmouth, University of Bangor, Scottish Association for Marine Science and the Marine Conservation Society. At these hubs you can find out more about this project and take part in training led by marine biologists. We aim to share best practice and work with other organizations leading related marine projects, achieving a co-ordinated marine survey effort that will benefit the marine environment.

Scientific aims of Capturing Our Coast include providing detailed distribution maps of marine species, exploring how climate change and other human impacts are affecting our seas, studying how species interact, tracking marine invasive species, investigating if conservation policies are effective, and exploring local issues on the coastlines of the UK. If you would like to be involved, contact us at: cocoast@mba.ac.uk www.capturingourcoast.co.uk/ Twitter: @CapturingRCoast

Nova Mieszkowska

Volunteers receive training to carry out marine surveys. Image: CoCoast / MBA.

Radiocarbon dating suggests centuries of longevity in the Greenland shark

While the thought of having to wait approximately 150 years to reach sexual maturity may seem far-fetched, it appears that this is ordinary life for the Greenland shark *Somniosus microcephalus*. A recent study carried out by Julius Nielsen of the University of Copenhagen's Department of Biology in close collaboration with an international team, and published in *Science* provides evidence to suggest that Greenland sharks are the longest living vertebrate on the planet.

Inhabiting close to freezing temperatures in the deep waters of the Arctic and North Atlantic Ocean it is understandable that much about the Greenland shark remains unknown, and determining their age has proven challenging.

Counting growth bands from the vertebrae is a widely recognized technique used to age fish. However, due to the absence of calcified tissues in the Greenland shark skeleton, Nielsen and his team used radiocarbon dating of the metabolically inert eye lens tissue instead to determine age. Using samples from 28 sharks between 81 and 502 cm in length, the study suggests the oldest shark is with 95% probability somewhere between 272-512 years old.

An unfortunate side effect of such slow growth and reproduction rates is extreme vulnerability to human impacts such as fisheries by-catch. Understanding more about these unique animals will therefore be essential to sustaining a healthy future population.

Alice Walsh

A major new practical guide to plankton biology

Over fifty experts worldwide have collated their knowledge in an effort to provide a detailed account of the marine plankton found across the North Atlantic ocean. Claudia Castellani, co-Editor of the book writes: "*Working on this project has been challenging but a very rewarding and life-changing experience. I sincerely hope that the vast knowledge and expertise it encapsulates will be useful to many future generations of marine scientists*".

Marine Plankton: A practical guide to ecology, methodology, and taxonomy is published by Oxford University Press. Access a 20% online discount when you

order directly via www.oup.com/academic using promotion code ACFLYP8.

How do sea urchins make their spines?

Marine organisms often use calcium carbonate to build their hard parts. Although calcium is relatively abundant in seawater, it has to be transported to the site of calcium carbonate formation, which is isolated from seawater in order to create a specific chemical environment, but also to accomplish the sophisticated morphogenesis of, for example, mollusc shells or sea urchin spines.

Professors Lia Addadi and Steve Weiner of the Weizmann Institute of Science looked at how the purple sea urchin (*Paracentrotus lividus*) makes its calcium carbonate spines. Using fluorescent dyes, they tracked calcium ions within developing urchin larvae. They then imaged thin slices of live larval cells and reconstructed the images into three dimensions enabling them to visualize how calcium ions move in live cells. In this way the researchers observed two mechanisms at work in the cell: the active uptake of calcium ions through the cell membrane, but unexpectedly that larval sea urchin cells also obtain calcium by vacuolization—the invagination of the cell membrane and eventual formation of a vacuole (a tiny pocket) inside the cell. These techniques also revealed that calcium is collected and concentrated in a network of vesicles until the mineral is required for building the urchin's spines.

The scientific debate over which of the two mechanisms occurs in a particular organism has been running for many years. Foraminifera are thought to take up calcium by vacuolization, whereas coccolithophores and urchins are thought to use transmembrane transport. This research adds to the evidence that many biomineralizing organisms use both mechanisms.

Hidden blooms

In July 2011 a major phytoplankton bloom was observed in a region of the Chukchi Sea beneath Arctic sea ice—something scientists had previously considered impossible. A new study suggests that because of thinning sea ice, light conditions rare 30 years ago are now common in the Arctic Ocean.

Arctic scientists examining sea ice and melt ponds in the Chukchi Sea, Arctic Ocean. Image: NASA.

Phytoplankton blooms are difficult to observe under sea ice and scientists use indirect methods to estimate biological activity in polar regions. A previous study which used ecosystem models to evaluate trends in sub-ice primary productivity found a small decrease over the past 30 years.

The modern Arctic is undergoing a strong decrease in sea ice cover and thickness, particularly in summer when it is increasingly covered in melt ponds. The new study in *Science Advances* incorporates melt ponds into the model which, being less reflective than ice, allow more light to penetrate into surface waters below.

On the basis of their model, the authors say that light conditions conducive to sub-ice blooms existed over almost 30% of the Arctic region during July over the past decade. They point out that massive, unseen primary productivity in ice-bound parts of the Arctic Ocean casts doubt on our estimates of carbon fluxes over the past two decades.

The State of European Cetaceans Report

ORCA, the International Fund for Animal Welfare (IFAW) and Plymouth University have released their 'State of European Cetaceans Report'. The report outlines and explains 10 years of data on the distribution Europe's cetaceans, collected from 376 surveys by ORCA and its army of trained volunteer 'Marine Mammal Surveyors'.

After analysis, the information provided key details on populations and identified specific areas of interest. ORCA are calling for the Bay of Biscay to be designated as an Important Marine Mammal Area as it topped the list for species diversity with 16 out of 22 species sighted. Devon and Cornwall waters were also recognized and named a Key Cetacean Area.

Important sightings included the elusive beaked whale, spotted in four of the nine surveyed sea regions, and 3,000 strong superpods of common dolphins. Unfortunately not all the news was positive and the coastal harbour porpoise was listed as the most threatened, due to its high risk of entanglement and by-catch from fishing. More widely, threats to cetaceans persist and include whaling, overfishing, ship strikes and marine pollution (see the article on PCBs on p. 14).

This report demonstrates the need for ongoing monitoring programs and the evidence they provide to make informed decisions on the future protection of cetaceans in European waters. Read the full report at: www.orcaweb.org.uk/uploads/Our_Work/ORCA-The_State_of_European_Cetaceans_(2006-2015).pdf

***Pylopagauropsis mollymullerae* at Bonaire dive site "Something Special". Image: Ellen Muller.**

New hermit crab species described

The candy striped hermit crab, *Pylopagauropsis mollymullerae*, found off the coast of Bonaire in the Southern Caribbean is a new species of hermit crab and the 20th species (second in the western Atlantic) in its genus.

Characterized by a scoop-like claw (chela) on the right arm (cheliped) this species lives up to its name with red and white striped appendages—a typical trait of fish-cleaning decapods. As a nocturnal crab it was discovered by photographer and naturalist Ellen Muller during evening and night SCUBA dives at depths of around 12 m.

As this species has been observed and photographed inhabiting crevices associated with broad banded moray eels (*Channomuraena vittata*) and flaming reef lobsters (*Enoplometopus antillensis*) the authors speculate that *P. mollymullerae* is either the cleaner for these species (a symbiotic relationship more commonly associated with fish and shrimps) or scavenges their food remains in a 'den commensal' living arrangement.

More detailed investigation into *P. mollymullerae's* behaviour and ecology will no doubt follow to test the validity of these interpretations.

References and links for these stories can be found on *The Marine Biologist* website. With your smartphone, scan the QR code below 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**

Evolution of the pelagic ecosystem: a history written in tiny teeth

By **Elizabeth Sibert**.

Modern humans have been around on the Earth for about 200,000 years, a blink of an eye in the 4.5 billion year history of the planet. In the past 85 million years and beyond, the Earth has experienced profound and extreme climatic, tectonic, and biological events that make the ice ages seem small, each leaving its mark in the geological record, and changing the course of evolution on the planet. While none of these events is a perfect analogue for the modern anthropogenic global change, by studying the Earth's past, palaeoceanographers and palaeontologists can find patterns in how life on the planet has responded to global change, to better understand the mechanisms driving the evolution of life on the planet.

The microfossil record

Deep below the ocean floor is a time capsule, in the form of ancient mud and ooze, that preserves snapshots reaching back millions of years into Earth's past. Preserved in the mud, and often comprising the mud itself, are tiny microfossils, so small that thousands can fit on the head of a pin, but which, together with geochemical signals and isotopes preserved in the sediment, reveal a fascinating history of how life, climate, and the ocean environment have coevolved through time.

While the most abundant deep-sea microfossils are the calcareous or siliceous remains of unicellular plankton, other members of the ocean ecosystem, such as fish, are also represented. The majority of a fish's body comprises soft tissue, and thus rarely preserved after death, but their teeth are particularly durable, and preserve well in the corrosive waters of the deep sea. These isolated teeth, together with dermal scales of sharks, called denticles, and occasional fragments of bone, comprise one of the most complete fossil records of vertebrates in the world. Together, these microfossils, which are composed of calcium phosphate (bioapatite), are called "ichthyoliths", which literally translates to "fish stones" (Fig 1). Because a single chunk of sediment may contain several hundred or thousand ichthyoliths, ichthyolith assemblages preserved in tens or hundreds of metres of deep-sea sediment core can reveal patterns of both fish abundance and fish community structure through time.

Three pelagic ecosystem states

The modern open ocean has many vertebrate consumers: fish, sharks, whales, and other charismatic megafauna. A typical modern ichthyolith assemblage has hundreds of teeth, and a smattering of denticles, perhaps one in 50. However, it has not always been this way. In the last 85 million years, the pelagic ecosystem has existed in three distinct stable states, each lasting 10s of millions of years, with abrupt transitions between them (Fig 2).

Stepping back 85 million years, to the Cretaceous Period, ichthyolith

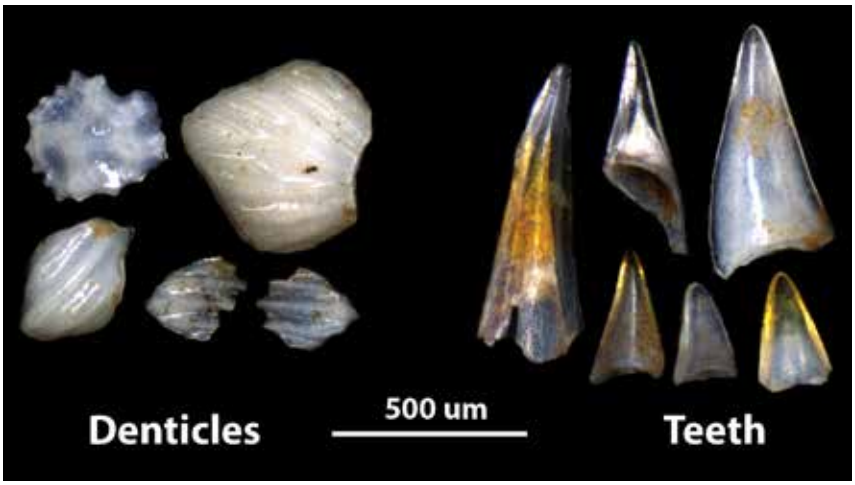

Figure 1. Example ichthyoliths from the South Pacific gyre, from the Eocene (~45 million years old). The scale bar is 500 µm. Images taken by the author using the Hull Lab Imaging System at Yale University.

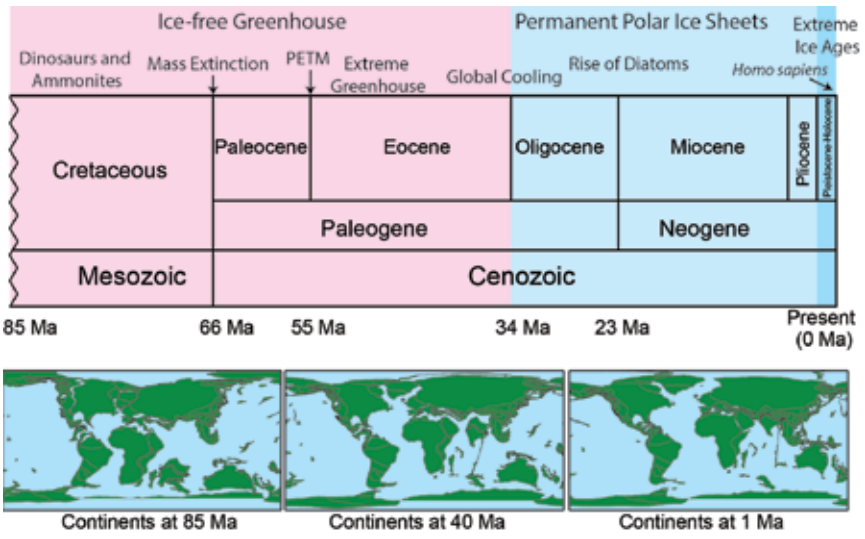

Figure 2. A geological time scale showing some major events and transitions in Earth's history (above) and continental configurations for the same time period (below). Maps modified from the Ocean Drilling Stratigraphic Network Plate Reconstruction Service (odsn.de).

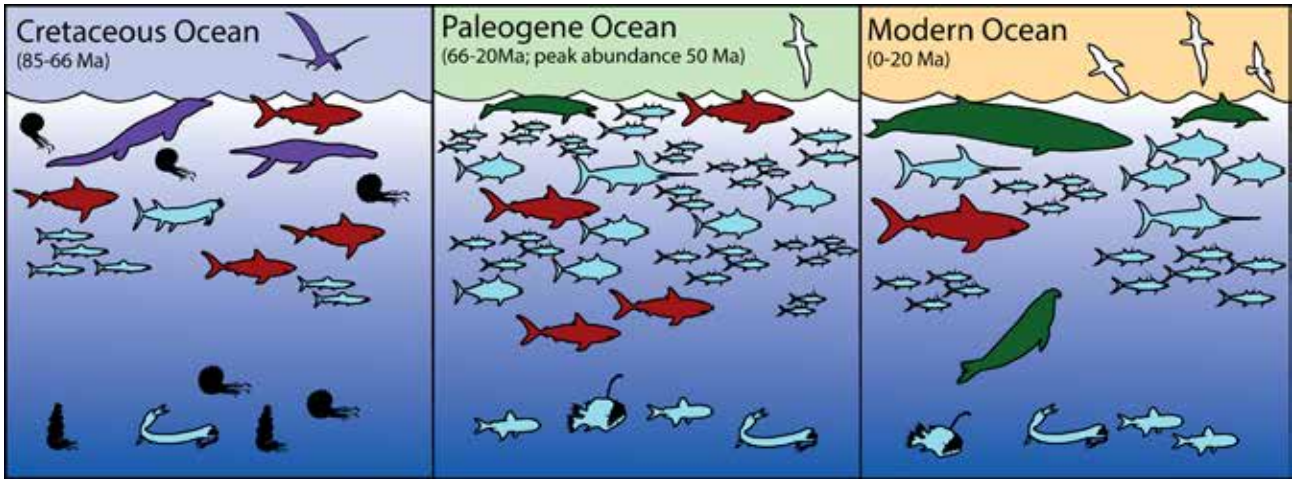

Figure 3. A cartoon schematic reconstructing the marine consumers present in each of the three ecosystem states discussed in this article. Purple are marine reptiles, black are ammonites, red are sharks, light blue are bony fish, green are mammals, and white are seabirds. Image reproduced from Sibert *et al* 2016, *Proceedings of the Royal Society. Series B.*

assemblages are considerably different from the modern. In the Cretaceous, denticles outnumber teeth in most assemblages, and are considerably more abundant than they are in modern assemblages. While teeth were present, they were relatively rare, and did not come close to reaching modern levels of abundance. This suggests that in the Cretaceous, sharks had a much larger role in the open ocean, and while fish were present, they were not as significant—sharks and other marine consumers were likely relying on ammonites and other Cretaceous mesopredators as their main source of prey. An asteroid impact, 66 million years ago (Ma) ended the stable Cretaceous ecosystem, allowing bony fish to take over newly vacated ecological niches. While sharks did not decline in absolute abundance, the post-extinction Paleogene ecosystem yielded ichthyolith assemblages with 5 times as many teeth as denticles. Indeed, this 5:1 ratio of teeth to denticles remained stable for the next 45 million years. Extreme swings in climate, correlated with changes in absolute ichthyolith abundance, with both ichthyolith types increasing and decreasing multiple times throughout the Paleogene period. Indeed, the highest abundances of ichthyoliths observed in the past 85 million years, nearly 10 × Cretaceous levels, were observed during the warmest part of the record, about 52 Ma, while the ratio between teeth and denticles remained constant.

However, this stability was once again interrupted, at 20 Ma, with the near complete disappearance of denticles from the open ocean. While there is no major climate change event, nor any obvious mass extinction at this time, two clues to the cause lie in the fossil record. First, many other marine predators began to diversify and spend time in the open ocean during the early Miocene, including seabirds, marine mammals, and even large schooling fish such as tuna. Second, there is a considerable increase in variability of both export productivity and ichthyolith abundance beginning with the Miocene, at about 23 Ma. While these changes do not align perfectly with the 20 Ma shift in the ichthyolith assemblages, it is possible that increasing variability in primary production, and increasingly patchy food supply, drove pelagic consumers towards more migratory ways of life, driving sharks to spend less time in the gyres, and thus leaving fewer denticles behind. As the shift from Paleogene to Modern ecosystem state occurred rapidly, it is likely that a critical threshold in variability was reached, causing a collapse of the formerly stable ecosystem.

Anthropogenic impacts

While "climate change" typically comes to mind as the major human impact on the environment, the ichthyolith record suggests that extreme and rapid changes in ocean temperature, even on the order of 4–8°C (7–14°F) of warming or cooling, were not responsible for pelagic ecosystem restructuring. Far more detrimental to the ancient fish communities, were rapid shifts in predator–prey interactions. Indeed, while anthropogenic climate change alone probably would not have had a major effect on the structure of the pelagic community, other human impacts on the ocean, particularly overfishing and removal of top predators such as sharks, large fish, and whales, could mark the beginning of a new, profoundly different open ocean ecosystem regime.

Elizabeth Sibert, PhD (esibert@fas.harvard.edu) is a Junior Fellow in the Harvard Society of Fellows, Harvard University. This work was done in collaboration with Professor Richard Norris, at Scripps Institution of Oceanography, at University of California San Diego.

Further reading

Sibert, E., R. Norris, J. Cuevas and L. Graves (2016). Eighty-five million years of Pacific Ocean gyre ecosystem structure: longterm stability marked by punctuated change. *Proceedings of the Royal Society of London B: Biological Sciences* 283 (1831).

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"We're all individuals!"

How identifying individuals can shine new light on fish behaviour. Words and pictures by **Paul Naylor.**

Fish are often regarded as rather anonymous and characterless animals, but this changes when we get to know them. Recognizing individual fish provides valuable insights into their behaviour and excellent opportunities for education and public engagement.

Bold, inquisitive, impressively territorial and photogenic, the tompot blenny (*Parablennius gattorugine*) has the perfect characteristics for such observations. It is well known by the divers and snorkelers of northern Europe, who see it peeking out from rocky holes and crevices, but its biology and behaviour have received little attention.

My study of individual tompot blennies originated from realizing that the intricate pattern of markings on their scaleless skin created the exciting possibility of recognizing them and tracking their behaviour through photography.

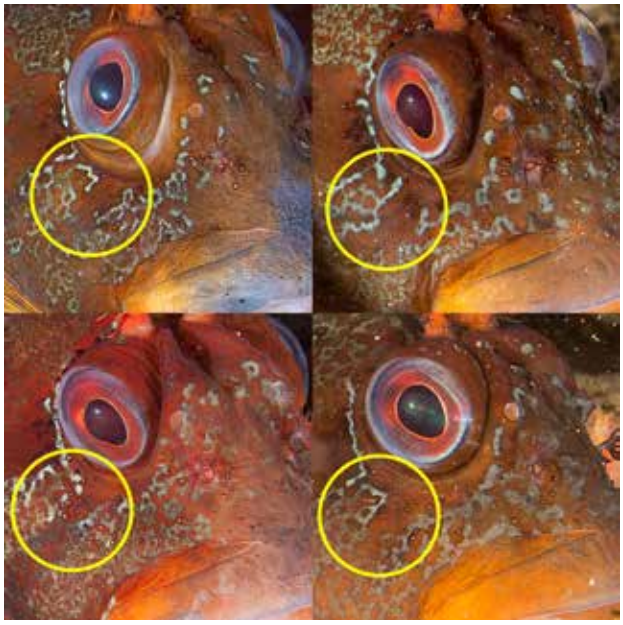

Figure 1: Distinctive markings on 4 tompot blennies. The angle from which photographs are taken varies with the blenny's position in a crevice so markings close to a fixed reference point on its body (such as the eye) are most helpful.

Male tompot blennies guard crevice territories that the females visit to lay eggs. I initially used individual recognition to ascertain the length of time, previously unknown, over which these territories were held. As the recognition technique developed, visiting females could also be identified, and this enabled interpretation of other interactions. For example, blennies being chased away by male territory holders were not generally rival males (as might have been assumed) but were often females that had entered male residences to breed at other times. The gender of a tompot blenny is difficult to determine in the wild unless a female is seen laying eggs or a male's large anal glands are visible.

My early findings on male tompot blenny territory retention have been published with more to follow. Other fish in which recognition of individuals by their markings has enabled study of behaviour include rays, groupers and wrasse.

A Wildlife Trusts press release about the tompot blenny recognition paper prompted The *Guardian* and *Daily Express* to describe the tompot blenny as "the small fish with a big personality", and "looking like a clown but nobody's fool". These articles, and others in local media, highlighted the surprisingly colourful nature of UK marine life and the vital importance of its protection. So, in addition to fascinating and perplexing us with its behaviour, the tompot blenny's individuality makes it an excellent ambassador for the marine environment!

Video clips of tompot blenny (and other marine animal) behaviour can be viewed via: vimeo.com/paulnaylormarinephoto

Paul Naylor (paul@marinephoto.co.uk)

- Males retained the same crevice territory for up to three consecutive breeding seasons. They defended territories against rival males, sometimes receiving (then recovering from) fighting injuries.
- Up to two years before being observed guarding a territory, recognized males had 'stand-offs' with territorial males or resided temporarily in one of the territories.
- Recognized females were seen in the same area of reef over a period of up to three years and, while more mobile than males, favoured particular hiding places.
- Consistent with expected blenny behaviour, female tompot blennies made egg-laying visits to more than one male residence in a breeding season and males hosted more than one female visitor.
- More surprisingly, males occasionally hosted two females (three on one occasion) simultaneously.
- Unexpectedly, the same females that made visits to males in the breeding season approached males outside this period and then quickly retreated or were chased away by the males. These approaches often involved the female lying partially sideways in an apparently submissive posture in front of the male.
- The same females that made 'submissive' approaches to males appeared to elicit similar postures in smaller females and chased them away, suggestive of a hierarchy.

Further reading

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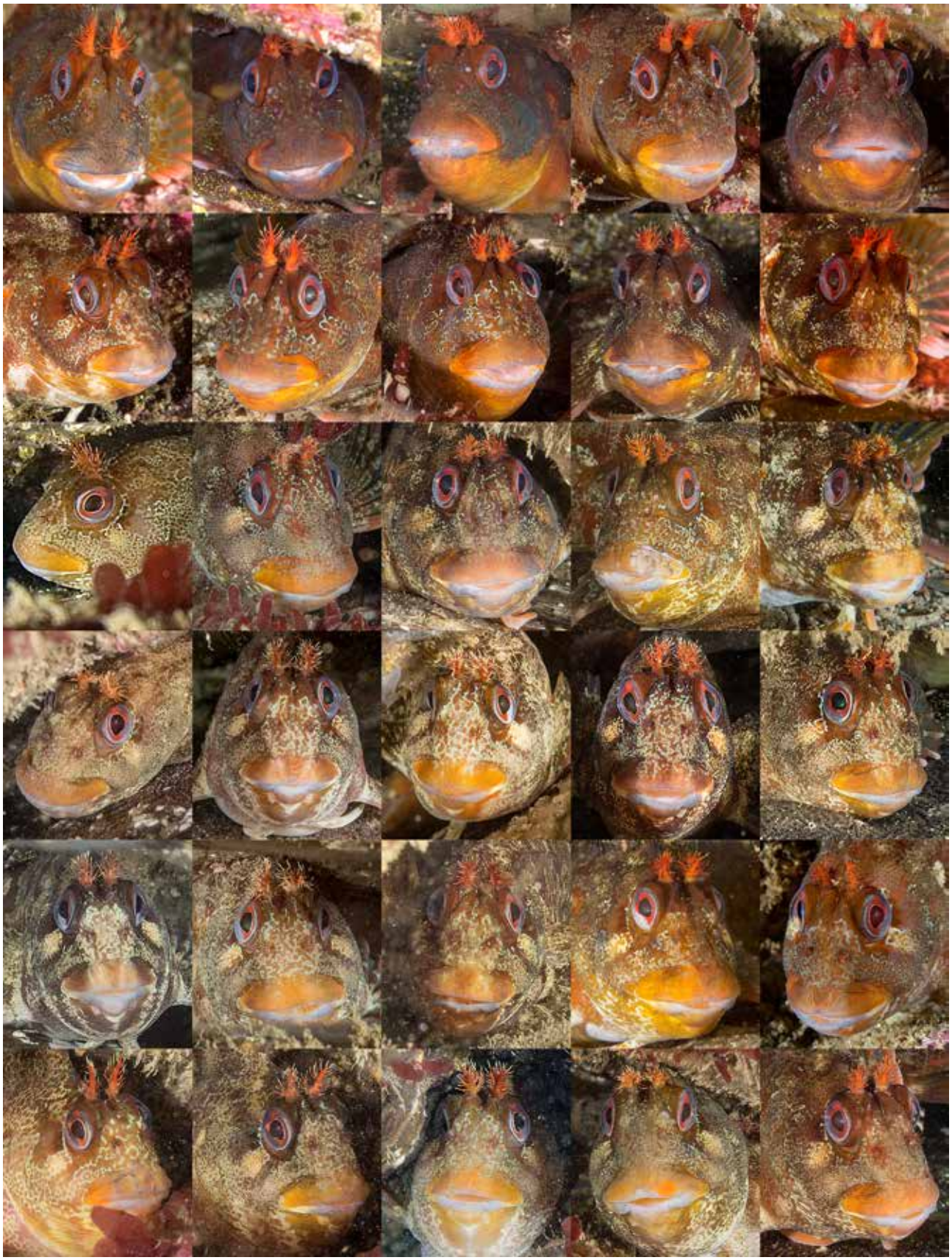

Figure 2: They're all individuals! The 10 male territory holders (top 2 rows) that were identified on a small, 15 m^2 area of Devon, UK reef between 2011 and 2016, along with 20 females (lower 4 rows) that visited the resident crevice of at least one male in the breeding season (March to June).

THE LAST GIANTS OF THE GULF

Words and pictures by **Michael Fishbach**.

A blue whale glides effortlessly through the waters of the Gulf of California (GOC) also known as the Sea of Cortez, off Mexico's famed Baja California Peninsula. This almost one thousand mile long, narrow, rugged piece of land protects these waters from the vast openness of the Pacific Ocean. It is here beneath towering, jagged peaks and next to a myriad of sub-tropical islands that the mightiest of

all animals can be seen in some of the calmest seas.

I have been coming here for the past 21 years both to get to know individual blue whales and to understand some of the countless mysteries that surround their lives. I was first brought here by the father of modern blue whale research Richard Sears in the mid 1990s, and this cactus-studded land where the desert meets the sea instantly captivated me, and has now become a second home to my family and me.

'White Eyes', easily identified by the distinctive markings on his tail fluke, is a regular visitor to the Gulf of California.

This is a land of little water and few people, a dry place that has the sea, and in the wintertime it is a rich sea at that.

Here is one of the very few places on Earth where at sub-tropical latitudes baleen whales can come to nurse their calves and feed voraciously at the very same time. It is also one of the safest places left for blue whales, far away from any shipping lanes and the massive vessels that blue whales in particular seem unable to learn to avoid. It is a rare pleasure to watch these mammoth whales swim along while they feed, care for their calves, and even engage in courting behaviour, all with little but raw nature being part of any view.

Blue whales used to number in the hundreds of thousands, their population perhaps even half a million strong. But when whalers figured out how to catch them, a ruthless slaughter commenced. The industry appeared unable to stop itself even as it became increasingly difficult to find any more blue whales and at the time of the commercial whaling ban in 1986, there were just a few thousand left. Today, they are a highly endangered species, remaining only in genetically poor remnant populations. The size of the current population is believed to be between eight and 15,000 animals, whilst an IUCN estimate puts the number at 10–25,000.

The gulf is a fabulous area for observing mother and calf blue whales

The Northeast Pacific population, of which the Baja Blue whales are a part, is believed to be the largest sub-population left on earth. Globally, the population level seems to be showing little or no recovery, although there are areas, for example the Southern Ocean, where it is apparent that a rebound from disastrously low numbers is occurring.

Researchers can identify individual blue whales in the calm waters of the Gulf.

In the Northeast Pacific the blue whales range from the coast of California south to both sides of the Baja Peninsula and beyond to an area of upwelling called the Costa Rica Dome. It is here that we find individuals at the beginning or end of their annual migration. One easily recognizable individual is named 'White Eyes' after one very bold white patch on each lobe of his massive tail fluke. We have seen White Eyes in 11 of our Baja field seasons. He is a regular whenever we have a film crew on board, and he has been observed vertical lunge feeding, chasing a wide array of females, and moving slowly along the shore 50 metres off the cliffs in a rare Baja thunderstorm. White Eyes is usually very easy going, offering us views of his massive body and unique tail. This whale provides us with a fabulous example of habitat preference too, as he habitually returns to the same portions of a vast sea.

I am usually able to identify about 50 individual blue whales in a season, but that number can vary between 35 and 60. It depends on the year and how long the whales that are present stick around; the longer that individual blue whales stay in the GOC, the lower the turnover of individuals and the lower the overall count in any one season. In some years individuals stay no more than a few days, then move on only to be replaced by a new group. This can happen again and again, offering us the chance to capture many individuals on our cameras. Last year (2016) this was not the case and we struggled to record 30 individuals. But some whales were observed on as many as 14 different days and stayed feeding in our working area for as long as a month and a half.

The GOC is a fabulous area for observing mother and calf blue whales. We usually see between 1-4 cow/calf pairs per season. The calves are quite young at this time of the year but grow quickly gaining over 200 pounds per day while nursing on the world's richest milk. Some years back we saw four cow/calf pairs in the same area at the same time, a sight none of us will ever forget.

Left: Whales stimulate phytoplankton blooms via the release of essential nutrients such as iron in the fecal plumes. Right: Whale faeces being collected for studies by the author.

Some of the old-time blue whales have not been seen for a number of years now. We suspect they can live for 70–90 years, but we cannot know what age any of the GOC blue whales were when they were first observed, unless they were seen as calves. It is not rare for an individual to drop off our radar for a decade or so, suddenly to return, leaving us to wonder about their whereabouts for all those years we did not encounter them.

Six years ago, I started the Great Whale Conservancy (GWC), a non-profit organization dedicated to conservation of the world's great whales with special emphasis on the blue whale, and annual fieldwork off Baja helps to keep me in tune with these mysterious giants. Not only does the GWC aid in efforts to minimize the impact of ship strikes and entanglements, but also in understanding in more depth how these animals help to fertilize the essential plankton blooms that sustain all life in the ocean as well as on land. Phytoplankton photosynthesis is responsible for half of the oxygen in our atmosphere and blue as well as other great whales stimulate these blooms via their mineral-rich faecal contributions. A return of the great whales to their pre-whaling numbers is therefore important in aiding the earth's response to the threat of global climate imbalances.

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The spout of a blue or fin whale lit by early morning sunshine, Baja California, Mexico.

Where next for camera technology?

Advances in camera technology are allowing us to monitor marine life and our impact on it in a multitude of ways. **Dr Anthony Bicknell** reviews some of these novel applications.

We have all been captivated by television wildlife documentaries that provide breath-taking video images of the previously unseen marine world. Although these may rely on the expertise of an experienced camera operator, camera technology has advanced to such an extent over recent years that even the most inexperienced operator (a seabird for example) can provide stunning video and pictures. As human activities in the marine environment increase it is important we understand how this might be impacting animals and habitats, and cameras are now playing an essential role in helping towards this goal. We recently reviewed how remote (i.e. not handled by a human operator) cameras are being used to address important issues relating to human activity in marine ecosystems and give you a taster here of what we found (with >180 published studies in the reference list you can understand why I say taster).

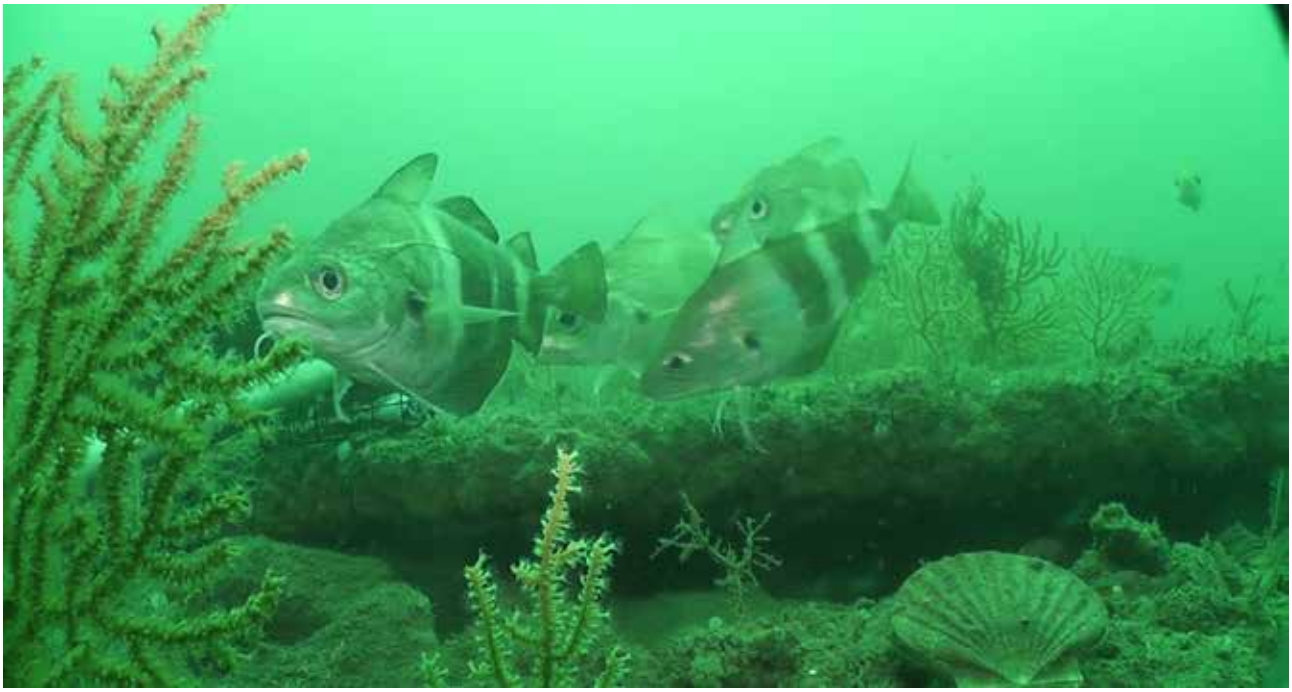
At the ecosystem- or population-level

One of the prerequisites of understanding change in natural systems is to collect long-term observations or samples. As you might imagine, due to the hostile properties of water to the human respiratory system (and other parts of the body in deeper water) this can be particularly challenging in the marine environment. Traditional techniques, such as seabed grabs from boats, fishing trawls and diver surveys can be costly, destructive or unsuitable in some locations (e.g. deep water). Remote camera systems offer a non-destructive method that either complements, or replaces these techniques often at much lower cost, plus the ability to access any marine location. This has seen their use increase dramatically over the last 30 years, notably to help assess the impacts of marine protected areas and fishing activities.

Protection of marine areas from destructive or disturbing activities, such as fishing, is a conservation practice that has been used around the world for many years. Although the benefits may seem obvious they need to be demonstrated and cameras are providing cost-effective long-term sampling for national agencies and researchers. For example, static cameras baited with dead fish and positioned on the seabed, known as "BRUVS" (baited underwater video systems, see Fig. 1), have been important in revealing the positive effects of no-take reserves on the abundance and size of target fish species compared with fished areas in tropical and temperate reef systems around Australia and New Zealand. Similarly, a high definition camera system towed on an underwater flying sled by Plymouth University (no, there aren't any reindeers involved) has provided detailed footage (Fig. 2) of seabed habitat and organisms that have allowed assessment of the extent and recovery of habitats within the Lyme Bay protected area in the UK.

We know that some fishing methods are extremely destructive for seabed habitats, and that poorly managed fisheries can deplete fish stocks to unsustainable levels; however, fishing represents a major source of livelihood and food for millions of people globally and so is an important

Figure 1. Still frame from baited underwater video footage taken in Lyme Bay, Devon, UK. Image: Dr Emma Sheehan, Plymouth University.



industry. An example we found where cameras are being used to help manage fisheries to reduce the latter impact is through video-based electronic surveillance, or electronic monitoring systems (EMS). Closed-circuit cameras, a Global Positioning System (GPS) receiver and weighing sensors are installed on fishing vessels and effectively monitor catch and discards, providing a permanent data record that can be collected and scrutinized (an improvement as compared with traditional logbooks). Compliance to catch and bycatch regulations (whether national or local) is a crucial part of a sustainable fishery and camera systems such as these offer another tool for management organizations. Such systems have already been successfully implemented in some US, New Zealand, Australian and European fisheries.

Figure 3. A northern gannet *Morus bassanus* taken by a miniature camera attached to the back of another northern gannet as part of the Celtic Sea fisheries interaction study. Image: Dr Stephen Votier, University of Exeter.

At the individual level

Studying individual wild animals was revolutionized with the development of animal-borne remote sensor equipment in the 1980s. The first integrated camera system was attached to a loggerhead turtle in 1987 as part of National Geographic project that created CRITTERCAM, which went on to provide pictures and video from both marine and terrestrial animals. With the integration of a GPS, time-depth recorder and accelerometer (recording an animal's position and acceleration) it has been possible to gain novel perspectives on how animals behave and where they go. A study in Australia provided video footage of green turtle eating habits (more than just seagrass) and where they were feeding. Without this it would not have been possible to identify new foraging habitats and change the approach to conservation of key areas.

Initially, the combined size and weight of the equipment limited its use to larger animals but miniaturization allowed attachment to smaller and eventually air-borne animals. An example from the Celtic Sea used camera pictures (Fig. 3) and GPS data from northern gannets to show how often individuals followed fishing vessels to feed on discarded fish (known from their diet). The fact that gannets follow fishing vessels was not disputed but the extent to which they do was unexpected and important to know when considering how fisheries management reform, such as a ban on discards in Europe, may affect animals that extensively use these food resources.

Figure 2. A still frame from the high definition video taken by the flying sled used in the Lyme Bay Marine Protected Area study. Image: Dr Emma Sheehan, Plymouth University.

Emerging and future applications

As technologies have become more sophisticated the opportunities to apply cameras to marine ecological research has increased considerably. Unmanned aerial vehicles (UAV) and autonomous underwater vehicles (AUV) are just two currently popular examples that provide novel perspectives and applications for cameras. They have been used successfully to survey marine animal populations (e.g. Pacific walrus and dugong) and for large-scale seabed habitat mapping, which would probably not be possible using other methods. A very novel use we found of cameras installed on an AUV was a technique to control the invasive crown-of-thorns sea star in the Great Barrier Reef in Australia. The camera footage is used to visually identify individuals in real time and a robotic arm subsequently administers a lethal injection of bile salts. What will they think of next?

From ecosystems to individual animals, remote camera imagery is being used to reveal the effects we are having and helping to understand how best we can sustainably manage the marine environment. The opportunities for the use of camera imagery are many, but they are only one part of the jigsaw to understand our impact on the marine environment, although an exciting and visually stimulating one.

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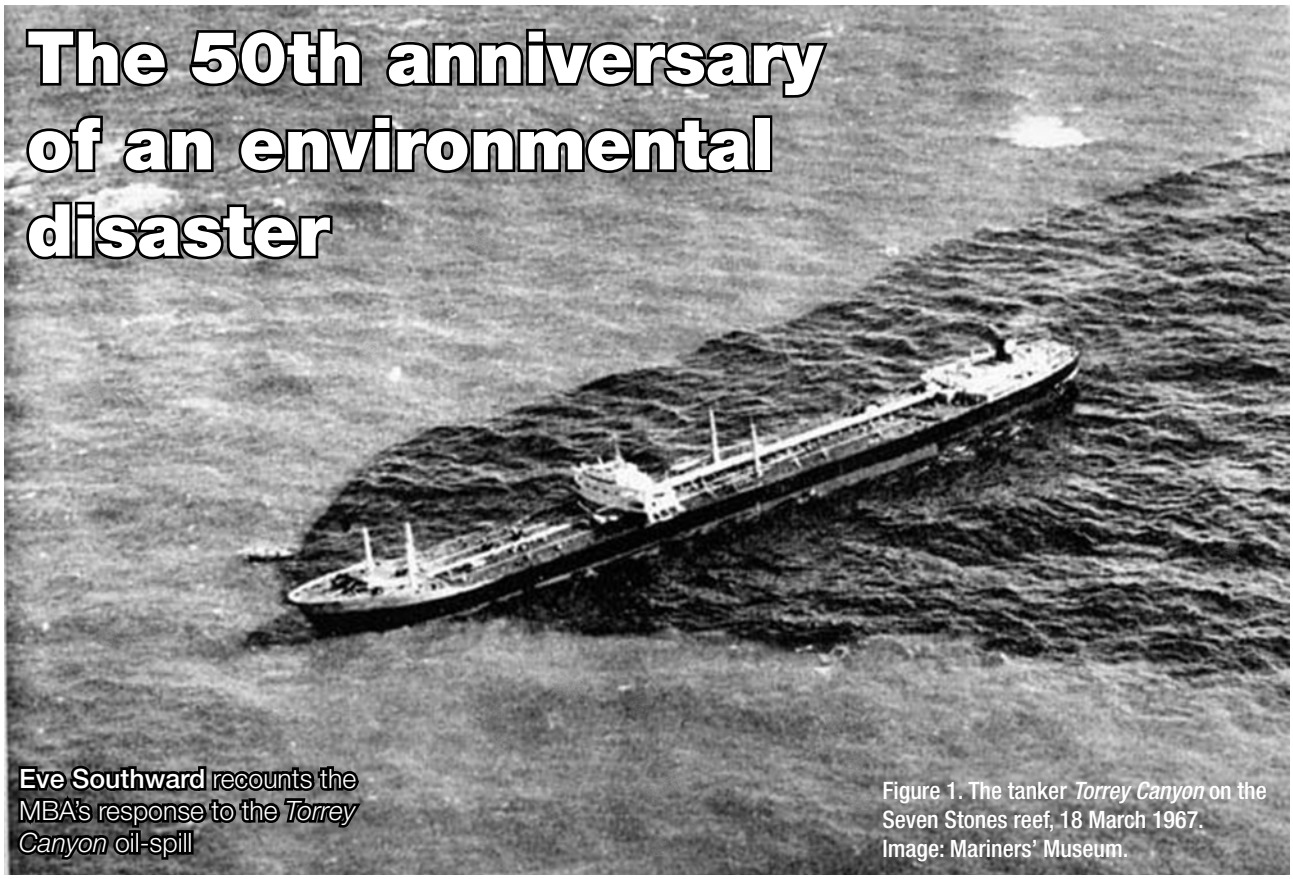
The 50th anniversary of an environmental disaster



Eve Southward recounts the MBA's response to the *Torrey Canyon* oil-spill

Figure 1. The tanker *Torrey Canyon* on the Seven Stones reef, 18 March 1967. Image: Mariners' Museum.

The tanker *Torrey Canyon* struck the Seven Stones Reef off Land's End, Cornwall in south west England, on 18 March 1967 and the cargo of about 119,000 tonnes of Kuwait crude oil started to escape from the damaged ship immediately (Fig.1). The government and armed forces took charge of clean-up operations after attempts to tow the wreck off the reef failed, and oil dispersants (detergents) were sprayed on the oil slick from Royal Navy ships and others. Ten days after running aground, the wreck was bombed by the RAF and some of the cargo was burned but the fires went out and leakage continued until, towards the end of April, the empty wreck sank. The floating slick was moved by wind and tide (see Fig. 2) and the oil fouled the shores of west Cornwall between 24 and 29 March, and the Channel Island of Guernsey on 7 April. North Brittany (France) was finally reached on 10–12 April.

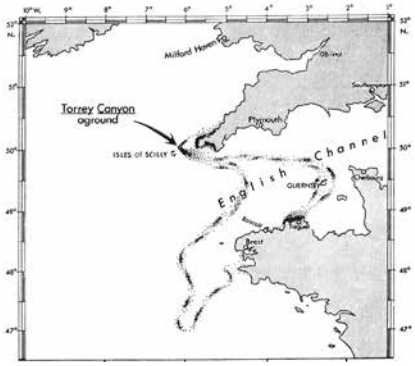


Figure 2. Approximate track of the oil from the *Torrey Canyon* and the places where it came ashore. Reproduced from Smith (1968).

Thousands of sea birds were the first victims of the oil but this spill became notable for the enormous amount of oil-spill dispersants that were applied in the Cornish marine environment. They were first used at sea to try to disperse the floating oil and were also sprayed (usually diluted with water) on the oily rocky shores and sandy beaches. The toxicity of such dispersants was not fully understood at the time of the disaster and they had a devastating effect on the fauna and flora.

Many official and voluntary bodies became involved in the subsequent clean-up and its consequences. As soon as the large-scale use of detergents became known and the pollution of large stretches of the Cornish coastline was seen to be inevitable, it was decided to divert the entire resources of the MBA laboratory to study the effects of oil and detergent pollution on intertidal and offshore marine life in the area. Work started on 26 March and continued until mid-June – although some at the laboratory continued for much longer. A report was completed by mid-September and published as a book in spring 1968.

On 28 March the MBA's research vessel *Sarsia* (Fig. 3) set off from

Figure 3. The *Sarsia,* the MBA's research vessel at the time of the spill.

Plymouth to take samples of water, plankton, and fish in Mount's Bay and the Seven Stones area. Gerald Boalch, the Chief Scientist on the cruise remembers: "*When we steamed west on* Sarsia *the first thing we noticed before we saw the oil was the dreadful sickening smell. When we did reach the oil it was like a thick rust-red layer on the surface. Local boats were out spraying the oil with detergent and the oil was obviously being broken up and dispersing. We realized that the detergent was breaking up the oil but was probably making it more accessible to the marine life. At that time we had no information on the toxicity of the detergent. We sampled the plankton in the area where the oil was being treated and under the microscope could see that some species of the plankton were being killed.*"

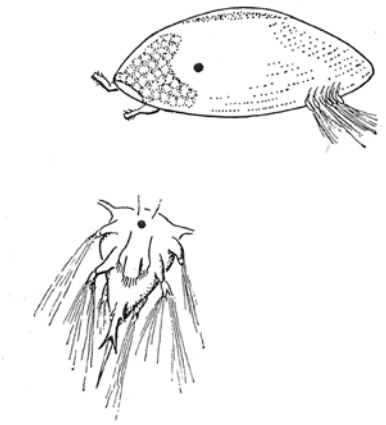


Figure 4. Drawings of barnacle larvae copied from Smith 1968.

Local people were also involved in attempts to deal with the spill, but frequently felt that their knowledge and suggestions were ignored by the 'experts'. When interviewed in 2011, members of local communities commented on the nauseating smell and the brown colour of the incoming oil on the sea. They feared for their livelihoods and the likely effect on the 1967 tourist season.

My own involvement began with exploratory experiments – with Alan Southward and Eric Corner – on the toxicity of the detergents on the larvae of a common intertidal barnacle, *Elminius modestus*. We tested four brands of detergent employed at the time, in comparison with the laboratory detergent Teepol and with samples of Kuwait crude oil. All four brands were more toxic than Teepol or Kuwait crude. The relative toxicity of the various brands depended on the types and quantities of organic solvent components. Other researchers found similar effects on other types of planktonic larvae and phytoplankton species in culture.

Alan and I then turned our attention to the effects of oil and detergent on the ecology of the Cornish rocky shores, for which we had some 10 years' earlier data. MBA workers visited 65 sites between mid-March and mid-May; 18 main sites were obviously heavily polluted and most of these were 'cleaned'. It was difficult to find a shore that had been oiled and not cleaned, however, the shore at Godrevy Point (close to a seal colony) was patchily oiled and not directly treated with detergent because of objection by the National Trust. This became our control site in future years. On heavily detergent-treated shores tufts of bleached seaweeds and empty shells could be seen. The rocks looked clean, even white. In the absence of most grazing animals ephemeral green algae could settle and grow, turning the shore green within the first year, and the green algae were succeeded by a heavy settlement of brown algae. At Godrevy Point, most of the limpets survived under a light coating of oil, there was no greening and the shore returned to normal within two to three years. The recovery of dispersant-treated shores to 'normal' took 5 to 10 years (see Fig. 5).

Up to 50 years' follow-up observations, including photographs, are now available for five of the major *Torrey Canyon* sites, showing the extent of the recovery phases and later natural fluctuations in algal cover and animal populations.

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Figure 5. Cape Cornwall intertidal rock platform, before and after the *Torrey Canyon* oil spill and clean-up. Images A.J. and E.C. Southward.

Further reading

Smith J.E. ed. (1968) *'Torrey Canyon' Pollution and Marine Life.* Marine Biological Association of the U.K. and Cambridge University Press. 196 pages.

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Corner, E.D.S, Southward A.J. and Southward E.C. 1968. Toxicity of oil-spill removers ('detergents') to marine life: an assessment using the larvae of the intertidal barnacle *Elminius modestus*. *JMBA* 48: 29–47. Link to JMBA vol 48?

Southward, A.J. and Southward, Eve C. 1978. Recolonization of rocky shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. Symposium on Recovery Potential of Oiled Marine Environments. *Journal of the Fisheries Research Board of Canada* 35, 5: 682–706.

PCBs – an unresolved marine mammal problem

By **Robin Law** and **Paul Jepson**

Polychlorinated biphenyls – or PCBs – are man-made industrial chemicals which were used extensively from the 1930s until their environmental persistence and toxic potential led to them being banned and/or their use strictly controlled, primarily in the 1980s. They were listed as Persistent Organic Pollutants (POPs) for elimination in the initial phase of the Stockholm Convention deliberations. Their primary use was in electrical transformers and capacitors, but they were also used as flame retardants, in paints and lacquers, in joint sealants and caulks for buildings and a number of other uses. They were recognized as an environmental problem after their discovery in fish from the River Viskan in Sweden around 1980. PCBs bioaccumulate in marine food chains with concentrations rising as animals higher in the food chain are encountered. Apex marine predators, such as marine mammals, can accumulate particularly high levels of these lipophilic (fat loving) contaminants due to their fat-rich diet and high-fat milk, exacerbated in some cases (e.g. some killer whales) by consumption of other marine mammals with already elevated levels of PCBs.

The EU ban on PCB use/manufacture was followed by declines in concentrations of PCBs in many species. This included grey seals, otters and white-tailed sea eagles in Swedish waters, species which were badly affected by PCB-related reproductive abnormalities in the 1960s and 1970s. Most avian marine top predators, including herons, gulls, ospreys, petrels and skuas, are no longer listed as threatened on the IUCN Red List, following declines in their body burdens of organochlorine contaminants, including PCBs.

Evidence that this is not the case for UK marine mammals comes from the Defra-funded Cetacean Strandings Investigation Programme, begun in 1990. This programme investigates the causes of death of stranded and bycaught marine mammals from UK coasts, and also collects tissue samples for, among other things, contaminant analysis. The primary species of study is the harbour porpoise, as this is the only cetacean species which occurs around the whole UK coastline. Repeated analyses have allowed us to investigate time trends in concentrations of contaminants, including PCBs, organochlorine pesticides, butyl tin compounds and brominated flame retardants over periods of around 20 years with high degrees of significance statistically. This has shown that, whilst all other contaminant concentrations have shown continuing and significant declines, the initial falls in PCB concentrations have stalled and the trends have been flat since the mid/late 1990s. For harbour porpoises, around 40 per cent of animals studied each year have PCB concentrations in their blubber above a toxicity threshold associated with an increased risk of death due to infectious disease. This is indicative of, but does not prove, immuno-suppression. The risk also increases as the blubber PCB concentration rises, indicative of a dose–response relationship.

Harbour porpoises are relatively small and short-lived cetaceans, but there are other species which accumulate higher body burdens of PCBs and which may therefore be at higher risk of toxic impacts. In a separate study, we looked at PCBs in bottlenose dolphins, striped dolphins and killer whales from the UK, the Iberian Peninsula and the Mediterranean Sea. All of these species had the highest PCB concentrations globally. In the case of the killer whales these were much higher than in other species or regions, and are still widely associated with long-term population declines and low or zero rates of reproduction, consistent with severe PCB-induced populations-level effects. A small pod of killer whales currently residing off the Hebrides, for example, is doomed to extinction as they have stopped reproducing completely. Populations of killer whales and bottlenose dolphins originally present in the North Sea disappeared in the 1970s, at the likely peak of PCB usage. An accessible summary

Apex marine predators such as killer whales can accumulate particularly high levels of contaminants and may be at higher risk of toxic impacts. Image: CSIP/ZSL

of this work is given in the 2015 report of the Zoological Society of London.

In order to protect marine life, marine mammals in particular, further stringent efforts are required to reduce PCB inputs to the marine environment.

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1 Centre for Environment, Fisheries and Aquaculture Science (Cefas).

2 Institute of Zoology, Zoological Society of London.

Further reading

2015 report of the Zoological Society of London.

Policy view

Waking up to Wakeham

Matt Frost looks at the Wakeham review and why biology and environmental science graduates are losing out in the jobs market.

There are a wide range of career options within marine biology including policy, industry or, as pictured above, the media. Image: MBA.

Governments play a key role in education policy, determining the way education is provided from the youngest schoolchild to post-graduates. It is governments who decide everything from what levels of funding are provided to the education sector as a whole through to what subjects should be included in the national curriculum for state schools.

The importance of training and education for the next generation of marine scientists is an issue that has come to the fore recently, and one which was highlighted by the Wakeham Review of STEM Degree Provision and Graduate Employability (May 2016). This review, commissioned jointly by the UK Government's Departments for Education (Dfe) and the Department for Business, Energy and Industrial Strategy (BEIS), focused on science, technology, engineering and mathematics graduates, seen as key to 'economic success' and to the successful implementation of the UK government's Science and Innovation Strategy (2014). A key report finding was how poorly both Biological Sciences and Earth, Marine and Environmental Sciences fared with an above average unemployment rate for graduates and high proportions of graduates working in non-graduate and/or low paid roles being reported. The area of 'Aquatic and Marine Science' was one of the areas highlighted where 35% or more of employers expressed concern about graduates having the skills to meet the needs of employers. The findings were considered concerning enough to warrant further investigation.

Notwithstanding the caveats around this type of review, most of us know from our own experience that marine biology can be a tough field in which to carve out a career. I wouldn't want to put anybody off pursuing marine biology as it can be incredibly rewarding to be employed to do what for many of us is a lifelong passion. I often find myself however talking to eager new students and treading a fine line between encouraging their enthusiasm and injecting some realism about the challenges ahead.

The outcome of the next stage of the review, and the government's response is, as yet, unknown. The MBA will continue to highlight the need for adequate funding for marine biological research so there are more opportunities, but what else can we do as a community? One possibility would be to shift the focus from the standard academic route (university degree, post-graduate study, post-doctoral research and so on) and look at all options available to contribute to the field of marine biology. A focus on a much wider skill-set aimed at a wider range of career options would mean that marine science graduates would be better prepared to go into areas such as policy, media and industry. The MBA's recently established MBA Fellow category for example was designed not just to reward academics but also those who have contributed to marine biology through their involvement in media, industry, education, policy and others. The new Associate Member category was established to recognize that some individuals can become involved in and contribute to marine biology without undertaking formal academic training.

Increased support and funding for marine research and education, a stronger voice for marine biology as a discipline, and clearer information on the wide range of possibilities for a marine biological career may go some way to ensuring any future reviews have more positive outcomes.

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What is Ocean Literacy?

And how the Sea Change project is promoting ocean literacy in Europe

To understand the ocean's influence on you and your influence on the ocean is what it means to be ocean literate. The ocean not only supports a wealth of life but provides most of the oxygen we breathe whilst regulating our climate, so it seems obvious that we should appreciate its value. However, in 1996 ocean and aquatic science had almost no mention in the US National Science Education Standards (NSES), which influenced materials, textbooks and assessments for the school curriculum. Dismayed at this virtual absence of teaching resources, in 2004 marine scientists and educators decided to tackle the issue by developing the Ocean Literacy Network (OLN). Over a number of years organizations, educators and scientists developed the seven fundamental principles which are the foundation for learning about the ocean. This ongoing process endeavours to provide a consensus for what should be taught (and the relevant resources) to become an ocean literate citizen. In order to support the improvement of ocean literacy, evidence is also being gathered to influence the development of science standards by local educational agencies, state departments of education, and professional societies and associations.

The US is not alone; ocean sciences have largely been neglected in European high school syllabi. In 2011, European marine educators attended an international meeting at the National Marine Educators Association (NMEA) conference in Boston, MA. At this meeting a new network, the European Marine Science Educators Association (EMSEA), was born. EMSEA provides support for EU marine educators in the form of workshops and conferences, and training and teaching materials. It also fosters dialogue with scientists and educators outside the EU.

Each of the seven principles of ocean literacy—ideas scientists and educators agree everyone should understand about the ocean (see Box 1)—generates a number of fundamental concepts that are used as the basis for formal and informal education.

Box 1. The seven Ocean Literacy principles

1. The Earth has one big ocean with many features
2. The ocean and life in the ocean shape the features of Earth
3. The ocean is a major influence on weather and climate
4. The ocean made Earth habitable
5. The ocean supports a great diversity of life and ecosystems
6. The ocean and humans are inextricably interconnected
7. The ocean is largely unexplored

These principles are expressed differently for the various curriculum stages. For example, the first concept for principle 5 talks about the diversity of life in the ocean. For KS 2 this is expressed as "There is a great diversity of organisms in the ocean" At KS 4 it is: "The diversity of ocean ecosystems allows for many lifeforms and adaptations of ocean organisms".

Sea Change

Sea Change, a major EU ocean literacy project, was launched in 2015. Coordinated by the MBA and with 17 partners across Europe including EMSEA, the aim of Sea Change is to improve ocean literacy in Europe by 2018.

Amongst its key aims (see Box 2), Sea Change is focusing on two areas that reinforce OL Principle 6. One is to promote responsible behaviour of citizens towards the ocean and its resources. The project calls on citizens to take action to reduce their impact on the ocean and proposes pledges that they can make related to marine litter, ocean acidification, pollution, and depletion of fish stocks. The other aim is to enhance the link between human health and the health of the ocean, in order to improve decision-making and policy development. An animation produced by the project (Fig, 1) explains the importance of our ocean for various goods and services, including human wellbeing. The beneficial effects on both physical and mental health of living near the coast, visiting the beach or even an aquarium —collectively known as the blue gym effect—are increasingly recognized.

The National University of Ireland, Galway (NUIG), is a Sea Change partner and here innovative methods are being explored to change behaviour and tackle social problems. Christine

Domegan is leading one aspect of the project's work to apply Social Innovation Participation Processes (SIPPs) to develop new ways of thinking about and behaving towards the ocean. Christine explains "*Co-creation is when different parties come together to work towards a mutually valued outcome. We have been using this participatory approach to enable citizens to make a Sea Change happen through their everyday choices and behaviours*".

The 'Think Big Think Ocean' Ideas Challenge asked European Union citizens to submit a video on a concept or event that they thought would increase people's awareness of the ocean. The winning ideas from each of the eight countries that participated in this co-creation initiative will be used as the foundations for a number of Sea Change public events that will be held in 2017. For example in the UK the winning video highlighted the issue of marine litter, and in partnership with the creator, Alicia Fullerton, the idea is now being developed into a community event. Events in Spain, Belgium, Sweden and Portugal will focus on different ocean issues all of which will help to raise awareness and increase ocean literacy amongst European Citizens.

Sea Change is not limited to Europe. Ocean literacy is one of the research themes within the Galway Statement on Atlantic Cooperation; European Union–Canada–United States of America Research Alliance. To support its transatlantic efforts Sea Change has an International Advisory Group made up of experts from both sides of the Atlantic.

The introduction of ocean literacy has been a pioneering process, providing a coherent framework and an increasingly global focus for teaching about the sea. The collaboration between scientists and educators continues, inspiring projects such as Sea Change, publications for teaching (e.g. *Life on an Ocean Planet*, 2005), a range of collaborations for informal teaching, and even literacy frameworks in other fields (e.g. Climate Literacy).

Figure 1. Screen grab from a short film explaining the importance of our ocean in sustaining our lives.

Box 2. The six key areas of Sea Change

1. EMPOWER educators, students and educational communities to help integrate and promote Ocean Literacy principles.
2. PROMOTE responsible behaviour of citizens towards the ocean and its resources.
3. ENGAGE in a dialogue with key actors of the international marine governance system on the link between human health and the health of the ocean in order to improve decision-making and policy development (both in Europe and the transatlantic context).
4. COLLABORATE with transatlantic partners in order to bring about a global approach to protecting the planet's shared ocean.
5. ENSURE that efforts to sustain an Ocean Literate society in Europe continue beyond the life of Sea Change through codes of good practice, public campaigns and ongoing community activities.
6. CREATE a resource relating to the links between the planet's ocean and human health.

Fiona Crouch (ficr@mba.ac.uk), Katharine Clayton (katharine.clayton@students.plymouth.ac.uk) and Jon Parr (jparr@mba.ac.uk).

Sea Change is a three-year European Union H2020-funded project. The Sea Change partnership includes major networks (World Ocean Network, UNESCO-IOC, Ecsite and EUROGEO) that are helping to disseminate the project's work.

Further reading

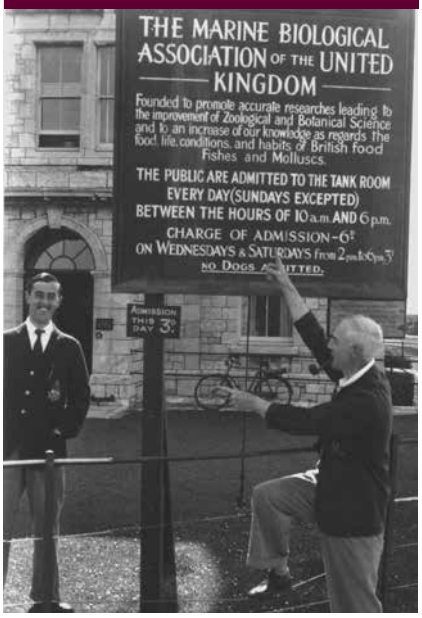
Sea Change website
www.seachangeproject.eu

Ocean Literacy
www.oceanliteracy.wp2.coexploration.org

Figure 2. Alicia Fullerton (second from right) winner of the Sea Change video competition, pictured alongside the MBA's research vessel *Sepia*, Plymouth, UK. Image: MBA.

Marine biological miscellany

From the archive



The MBA holds thousands of images, old and new. Here we have a charming photograph of Dr D. P. Wilson (left) and Dr E. Ford outside the MBA's Citadel Hill laboratory. Note the aims of the MBA (at the time) and times of public access to the tank room.

The smart attire, brilliantined hair, Dr Ford's pipe and the classic style of the sign are evocative of a bygone era. The picture was taken in the 1930s (exact year unknown) by G. M. Spooner.

Look out for more images from the archive in future editions of the magazine.

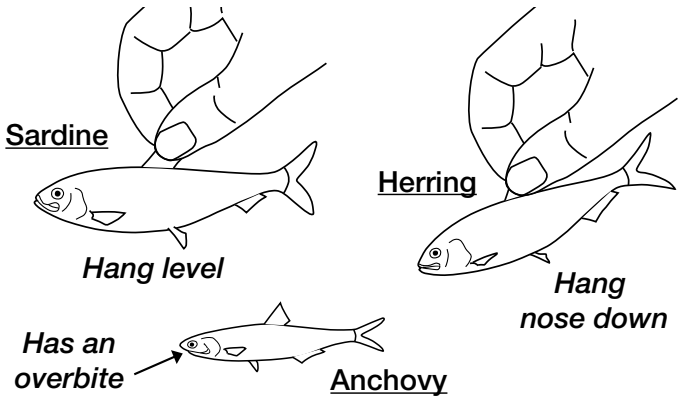
MYTH or REALITY?

Do sea-squirts really eat their own brains?

Like of lot of marine invertebrates, sea-squirts start life as a swimming larva, resembling a tiny tadpole with a strong muscular tail. But the larva soon attaches to a solid surface where the adult animal will grow, and live the rest of its life without moving away. Despite being much simpler in construction, the larva's body has a basic layout that qualifies sea-squirts as members of the Chordata, the same major animal group (phylum) as ourselves. In particular, the 'tadpole' larva shares with the other chordates a hollow nerve chord that runs along its back. At the front end of this hollow nerve chord is a widening incorporating a ganglion (referred to as a 'brain vesicle') accompanied by sense organs that enable the swimming larva to respond to the direction of light and gravity while locating a site to settle on. Once attached, the larval tail is pulled in and the body undergoes a fairly profound metamorphosis to create the initially small, juvenile, attached animal. Since this stage does not travel, the larval sense organs are not required and they are resorbed along with the tail and its dorsal nerve chord and recycled into the adult organ systems; the swollen anterior end of the nerve chord ('brain vesicle') of the larval nervous system is largely resorbed and makes at most a limited contribution to the adult brain, the cerebral ganglion. The adult has a reduced, rather basic nervous system, different from the larval nervous system, dominated by a simple ganglion between the two water siphons that governs the animal's limited behaviour, with nerves running to other parts of the body, but no dorsal nerve chord. So the larval 'brain' (anterior central nervous system) and dorsal nerve chord does not survive to adulthood; it is resorbed (figuratively, but not literally, 'digested') or rearranged, or some combination of the two, and the pre- and post-metamorphosis nervous systems are distinct structures as required by the contrasting life styles of the larva and juvenile/adult.

Dr John Bishop (jbis@mba.ac.uk)

The larva of a sea-squirt resembles a tiny tadpole. Image: John Bishop.



Identification corner

There you are, minding your own business with a handful of small, pelagic fish, and someone comes along wanting to know exactly what species you are holding. Our simple pictorial guide means you need never be put on the spot again!

Sardines also have larger scales than herrings and radiating lines on the posterior part of the gill cover, which herring lack. (With thanks to Peter Rendle, MBA Laboratory Steward.)

Women in marine science

In honour of women's history month (March), **Katharine Clayton** looks at the positive changes women have made in marine science through the lens of MBA staff and members past and present.

Science is one of the four pillars of STEM (Science, Technology, Engineering and Maths). Although plagued with gender inequality, efforts spanning a century have led to the participation of more women in STEM in recent years.

At the turn of the 20th century, botany was commonly chosen by the few women able to study or research marine biology. This arose from the fashionable pastime of seaweed collecting by women during the Victorian era, and these early phycologists provided valuable information regarding anatomy, taxonomy and cultivation of algae. Much of this information is preserved in the herbarium in the archives of the National Marine Biological Library (NMBL) at the Marine Biological Association (MBA), where six out of the eight major contributors were women. Initially assembled by Dr Mary Parke in the 1940s the herbarium consists of 3,300 specimens with material dating back to 1830.

Some women broke free from botany and pursued other avenues. Dr Molly Spooner, for example, was a pioneering scientist who coined the term 'meiofauna'—used to describe small benthic invertebrates in marine or freshwater ecosystems—and who travelled the world investigating the impacts of oil spills.

Since the 1970s we have seen the emergence of a new breed of women marine scientists, a prime example being Dr Sylvia Earle, award-winning marine biologist, explorer, author, lecturer and MBA Honorary Fellow.

Nevertheless only 28% of the world's science researchers are women[1]. Although there is no silver bullet to tackle the inequality faced by women in the 21st century, organizations across the world are challenging the status quo. Books and films have helped shape perceptions and promote the value of women in STEM roles whilst the growth in social media has been a key factor in connecting women, allowing them to share advice and experiences with each other more easily than ever before. Women in STEM events such as conferences and workshops enable networking and interaction with inspirational women too; for more information search for your local Women in STEM hub.

Dr Molly Spooner exhibiting her water colour paintings in the MBA Common Room, 1985. Image: MBA.

"Women have made strides in careers that were once the exclusive province of men. But biases and challenges persist, especially for women in the sciences."
Dr Sylvia Earle

It is through perseverance that women across the world will eventually have equal access to education and STEM opportunities. The momentum generated so far must be maintained however, as the changing political climate threatens to undo the vast strides taken in recent decades.

We caught up with prominent scientists at the MBA for their thoughts and advice.

Dr Eve Southward (MBA Lankester Honorary Research Fellow) "*Knowledge helps! Read books, talk to people and don't believe everything you read on Google".*

Dr Nova Mieszkowska (Lecturer in Earth and Ecological Sciences and MBA Research Fellow) "*Marine biology is a career that requires a lot of initial higher education training (Bsc, MRes/MSc and PhD). Try to study slightly different subjects for each degree to broaden your skills and knowledge base, this will increase your employability.*"

There are so many women in marine science (past and present) that only a few could be mentioned here. For more information on the MBA's history please see the NMBL website www.nmbl.org

Katharine Clayton
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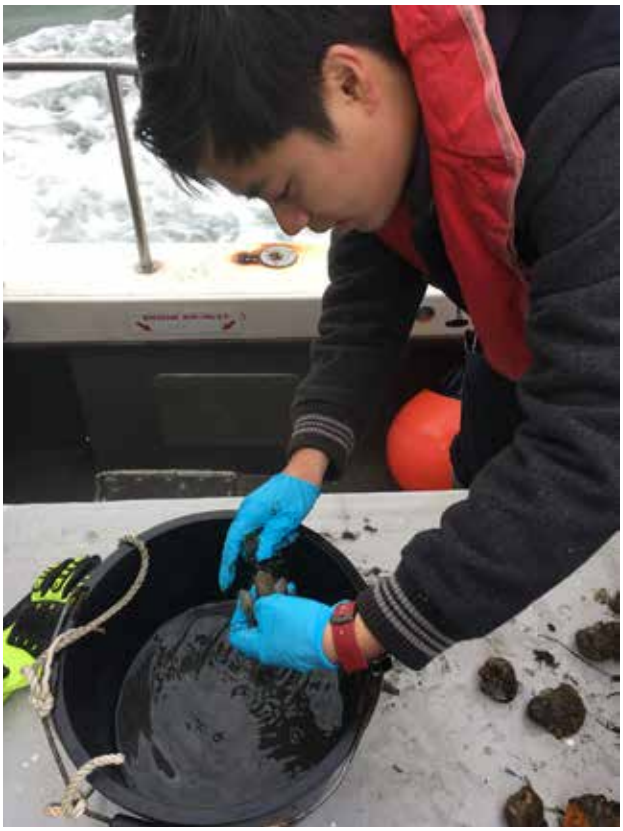
Dr Mary Parke. Image: MBA.

1 UNESCO Institute for Statistics, October 2015.

Where have all the taxonomists gone?



It has been over 300 years since the birth of Carl Linnaeus, the renowned Swedish botanist who set forth the foundations for a system of naming and classifying biological organisms known as taxonomy. The past 250 years of taxonomical research has allowed us to identify approximately 1.9 million different species on earth, with the most recent estimations of total species reaching 8.7 million according to the Census of Marine Life. This has led to the creation of large accessible online databases such as the World Register of Marine Species, providing extensive lists of all known marine organisms. Despite this exciting opportunity for scientific discovery, there seems to be consensus within the scientific community that there is a current shortage in professionally trained taxonomists.

There are a number of reasons that may be contributing to this, with the main misconception being that taxonomists spend their days placing animals into dusty collections at the back of a natural history museum. While establishing collections is no doubt an important part of taxonomical research, it seems that taxonomy needs to take advantage of novel molecular techniques such as DNA barcoding. The ability to identify a species by analysing a small proportion of their genome will help identify new and separate cryptic species (see box). The application of molecular techniques to identifying organisms will not only increase the rate at which species are discovered, but will help bring interest from a younger generation of scientists who want to incorporate new scientific techniques into their career.

Cryptic species: one of two or more morphologically indistinguishable biological groups that are incapable of interbreeding. Examples range across a plethora of taxa; for instance the scalloped hammerhead shark (*Sphyrna lewini*) which is morphologically similar but genetically distinct from the Carolina hammerhead shark (*Sphyrna gilberti*).

Students from Portsmouth University identifying marine organisms—who says taxonomy is not fun? Images: Ellis Moloney.

However, it seems a better education in the subject at A-level and undergraduate level is needed in order to get young scientists interested in this career path. This should not only focus on the basics, but also on the relevance taxonomy has today in a number of areas including conservation and understanding how climate change is affecting biodiversity. Taxonomy represents a perfect example of what has underpinned scientific discovery for centuries and that is —to borrow a phrase coined by Richard Dawkins—an appetite for wonder. Nowhere is this more applicable than in the marine environment, especially the deep sea, an area of harsh extremes where new species are constantly being discovered.

However, efforts to inspire future scientists into pursuing a career in taxonomy need to be met with adequate funding if this valuable scientific skill and area of research is not to become extinct itself.

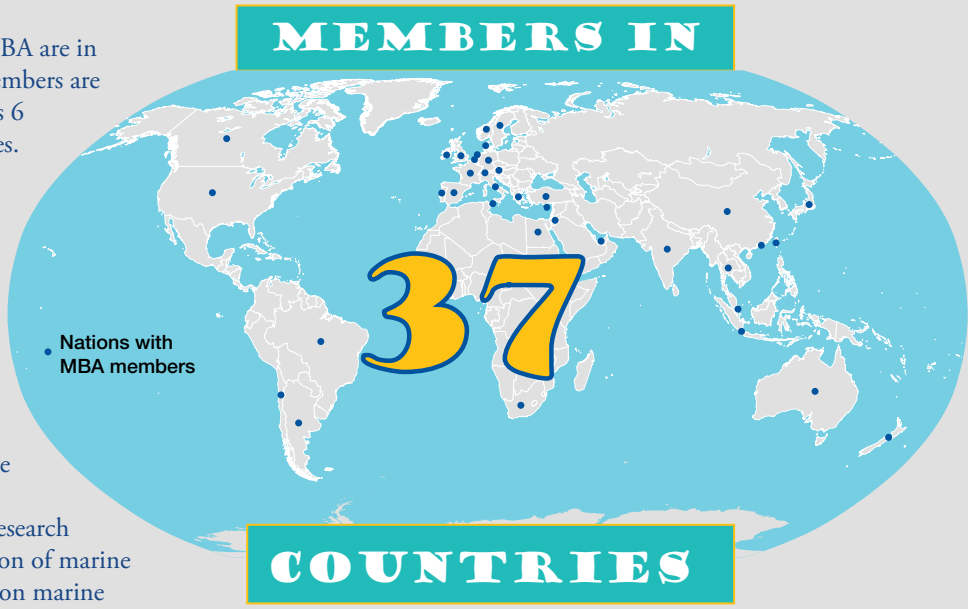
Ellis Moloney (ellis.moloney@myport.ac.uk)

Who are we? A look at the MBA membership

The membership is at the heart of the Association and it is only by liaising with, and speaking on behalf of, our members that we can have a real impact and claim to be the voice of the marine biological community. Did you know that it is the members who have the ultimate say in the way the MBA operates including, for example, the make-up of the Board?

Where are we?

The headquarters of the MBA are in Plymouth, UK but our members are currently distributed across 6 continents and 37 countries. Our vision is to see membership increase both in the UK and internationally, with the Association providing a focus for discussion and collaboration. It is not just about sharing information and ideas but also strengthening our collective voice to call for adequate resources to fund marine research and train the next generation of marine biologists, as the pressures on marine ecosystems continue to rise.



AROUND 1,500 MEMBERS

58% of MBA members are male

42% are female

Ways to be a member of the MBA

The granting of the Royal Charter was the ideal opportunity for the MBA to increase the geographical spread of its membership and to make membership more accessible by adding new categories.

The Young Marine Biologist (YMB) category allows those too young to have embarked on training or career to become members, whilst the new MBA Fellows category recognizes those who have already made a significant contribution to marine biology in one form or another. And if you are passionate about marine biology but have no formal background then Associate Membership may be for you.

See www.mba.ac.uk/membership for more information.

9,500 followers

@thembauk

The MBA's social media community

15,000

fans, followers and subscribers

4,400 likes

1,300 followers

The 51st European Marine Biology Symposium

Marine scientists from around Europe (and in some cases from much further afield) gathered on the island of Rhodes, Greece in September 2016 for the 51st European Marine Biology Symposium (EMBS). The Marine Biological Association has a long-standing connection with this symposium as it fits well with the MBA's aims in supporting marine biological research, particularly with its focus on encouraging the next generation of marine researchers to come and present alongside esteemed names in marine science. In addition to publishing conference presentations in a special issue of its journal, the MBA also provides a joint prize (along with the MARS Network) for best poster presentation given by a student. First prize at the 51st EMBS went to Paul Kotterba for his poster 'Predator impacts on inshore Baltic herring (*Clupea harengus*) larvae: Lions, tigers and bears – but where?' The full list of winners including runner up prizes can be found at www.marinestations.org/embs

proud winners of the EMBS prize receiving their magazine. Image: nnanev.com

The Symposium also focused on some of the key marine policy issues of our time including the impacts of climate change and invasive species and the development of marine indicators—a key tool in the science-policy interface. The social programme allowed us to see part of the beautiful island of Rhodes and, for some, the chance to put on a mask and snorkel and observe a few of the non-native species (mainly Lessepsian migrants) we had heard about in the presentations! The link between the local environment and marine biology was also made in a fascinating talk by Professor Eleni Voultsiadou entitled "Aristotle as a marine biologist: Aegean biodiversity 2400 years ago". The organisers, Professor Artemis Nicolaidou (University of Athens) and Dr Sofia Reizopoulou (Hellenic Centre for Marine Research) are to be thanked for organising such a fascinating conference.

Finally, the EMBS Committee was delighted that Professor Tasman Crowe of University College Dublin accepted the nomination to take over as EMBS President. The committee also offered warm thanks to Professor Herman Hummel for his successful tenure at the helm of the EMBS.

The 52nd EMBS will be held in Piran, Slovenia, 25 - 29 September 2017. For further details see www.embs52.org/information

Matt Frost (matfr@mba.ac.uk)

And the winners were ...

MBA student bursary awardees report on how the grants have helped them develop their careers.

Biennial Challenger Conference, Liverpool, UK

With help from the Marine Biological Association Student Bursary, I was able to attend the Biennial Challenger Conference in Liverpool, UK. The four-day conference gathered approximately 400 delegates, many UK-based, however, some travelled from mainland Europe, the US, and even New Zealand to share and discuss research in marine oceanography. The conference was filled with icebreakers, early career networking and training sessions, special-topic discussions, and presentation and poster sessions all focused around current topics in marine science.

This was the first scientific conference I have attended, and I was even lucky enough to be given the chance to present my master's research,

Brittany Visona at the Challenger Conference in Liverpool.

'Sandeels and top predators: Effects of bio-physical coupling on predator-prey aggregations'. This was the first time I presented my research to a large scientific audience, including many of the researchers whose papers I cited throughout my thesis. Even though the presence of many highly regarded scientists made presenting a bit intimidating, it was a great opportunity to showcase my work.

Over the four days, I was able to speak to many scientists and become immersed in vast array of topics including internal waves, the effect of renewables on ocean processes, using stable isotopes in spatial ecology, and the role of society in marine science. Being more of a biologist than an oceanographer, I left the conference

with knowledge of the latest findings in marine oceanography, and having formed many connections in the marine industry. All in all, it was a superb educational experience.

Brittany Visona
(brittanyvisona@gmail.com)

The 12th International Seagrass Biology Workshop, Nant Gwrtheyrn, North Wales

Nestled between the Irish Sea and Snowdonia national park, Nant Gwrtheyrn hosted over 170 seagrass scientists for the 12th International Seagrass Biology Workshop (isbw12.org).

Under the conference theme 'Securing a future for seagrass', delegates discussed their research, new ideas and ways forward. As a PhD student from Stockholm University, Sweden, I presented a project which investigated movements of juvenile Atlantic cod within coastal shallow-water environments (seagrass included) in the North Sea. My presentation was part of the faunal ecology session, whilst other interesting sessions included seagrass resilience, blue carbon, physiology, genetics and restoration. Workshops were held in the afternoons to bring together knowledge and expertise from a wide range of backgrounds to discuss all things seagrass, from stressors and ecosystem services through to ocean optimism.

We also had the chance to explore the surrounding land- and seascape through excursions which took us to, amongst other places, the local eelgrass meadow where delegates could partake in a survey of the seagrass itself and of animals found within these important marine habitats.

As well as all the science talk, there was plenty of opportunity to immerse ourselves in the local culture and even enjoy a local pub quiz—in Welsh of course!

After 6 days it was time to go our separate ways and leave our new and old seagrass friends behind, whilst looking forward to the future where we will reunite for the next meeting in sunny Singapore, 2018.

Thomas Staveley
(tom.staveley@su.se)

5th International EcoSummit Conference

I attended the 5th Annual EcoSummit Conference in Montpellier, France from 29 August to 1 September 2016, joining over 1,500 delegates from more than 75 countries to present and discuss ecological sustainability.

Thomas Staveley attended the International Seagrass Biology Workshop, Nant Gwrtheyrn, North Wales.

Kathryn O'Shaugnessy at the 5th Annual EcoSummit Conference in Montpellier, France.

At the event I presented some of my PhD work with the World Harbour Project on ecological engineering of coastal infrastructure in Plymouth. The World Harbour Project is a global initiative to create ecologically resilient urbanised harbours through international research and collaboration. There are 24 partner cities worldwide, and Plymouth is proud to be the only one in the UK. Following this I also presented my past research conducted in South Carolina, USA on restoring coastal oyster reefs with the Coastal Oyster Recycling and Restoration Initiative (CORRI). During this project I helped CORRI build more than 20 shell reefs in 10 tidal inlets in the Greater Myrtle Beach area, as well as test the ability of these shell reefs to functionally mimic natural reefs. I am honoured to have been awarded the conference's Outstanding Early Career Researcher Poster Award for this poster presentation.

It was important that I attended the EcoSummit, as I was able to form meaningful relationships with the World Harbour Project organisers from Sydney, Australia. I would like to thank the Marine Biological Association for their generous funding.

Kathryn O'Shaugnessy (kathryn.oshaughnessy@plymouth.ac.uk)

Christina Thiele presenting at the European Conference on Echinoderms in Sopot, Poland, September 2016.

The 9th European Conference on Echinoderms (ECE), Sopot Poland

I was awarded a student bursary from the Marine Biological Association to attend the 9th ECE in Sopot, Poland in September 2016. Reflecting on this event, it has been a great opportunity in many ways for me as an early career scientist.

The ECE series is a specialist gathering of echinoderm researchers. While my future lies in marine microplastic research, I conducted a behavioural ecology experiment on the common starfish *Asterias rubens* for my MSc thesis. Even though echinoderms do not feature in my research anymore, I greatly enjoyed learning about other scientists' research and networking with senior but also fellow early career researchers.

Not only did I obtain useful feedback on my research but listening to other scientists' talks and studying their posters has been a valuable opportunity to improve my own presentation skills. I am very grateful to my former supervisor, Professor David Bowers from Bangor University, and the conference organizer, Tomasz Borszcz from the Institute of Oceanology of the Polish Academy of Sciences, for encouraging me to give a talk rather than prepare a poster. As an undergraduate student I dreaded presentations but this negative feeling subsided to some extent during the taught part of my Master studies. However, this has been the first presentation I had actually been looking forward to and I thoroughly enjoyed the experience. I believe that presenting at the ECE has been an important stepping stone in my career as a scientist.

Last but not least, this meeting has also allowed me to try new things: during a pre-conference field trip to the cliffs of Gdynia, I had the opportunity to learn how to find and extract fossils on the beach. A small brachiopod fossil and a fossil imprint of an echinoid spine in a pebble now sit on my desk at home as a reminder of this conference. I would like to thank the Marine Biological Association again for providing me with this student bursary.

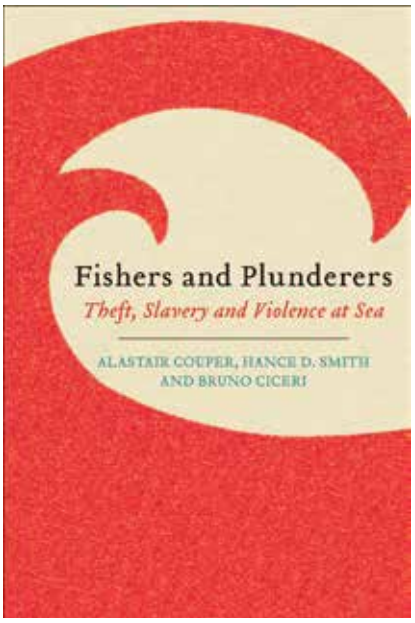
Christina Thiele

Reviews

Fishers and Plunderers. Theft, Slavery and Violence at Sea

Authors: Alastair Couper, Hance D. Smith and Bruno Ciceri
ISBN: 978 0 7453 3591 9
Published by: Pluto Press, London.

This book gives the reader a concentrated dose of human misery and misdeeds. The main theme of the book is description of the multiple ways humans can mistreat fish stocks and each other.



Consequently I cannot recommend the book for anyone looking for inspiration and hope that someday humans might exploit the sea sustainably. As the authors write in their introductory chapter 'The main purpose of this book is to raise concerns about the deaths, dangers and deplorable conditions experienced by fishers who earn a living from the sea, and also about the communities that depend on them (p. 1)'.

There are two aspects to the problem which are dealt with in turn; Part I, The fishing industry and the race to fish and Part II, The plight of the fishers. As the section heads imply the first part describes how fishers use illegal, unreported and unregulated (IUU in much of the literature) methods to over-exploit fish stocks. In many cases, fish that are caught by these methods have to be 'laundered' as does money obtained by criminal activity. Its origins must be disguised and in a world where the source of fish is now of greater interest to consumers, particularly in developed countries, skilful methods have to be employed to hoodwink the system.

The practice of IUU fishing creates the opportunities for the outrages against human rights and dignity described in the second part of the book. This contains many reports of the ways in which fishing crew are recruited from poor communities, particularly in South East Asia, and lured onto fishing boats as crew. Once on board they might be at sea for months, experiencing beatings and poor living conditions and at the end of the trip be cheated of much of their pay by unscrupulous skippers and boat owners. These abused people find it very difficult to obtain redress for the crimes committed against them as families have often paid a surety for them which is lost if the crew member absconds or misbehaves. As might be expected these conditions sometimes lead to mutiny and murder, as recounted in the book.

The book appears to have been sponsored by two organizations whose brief is to help disadvantaged fishing crew; Seafarers' Rights and The International Transport Workers' Federation. The

Executive Director of the former has written the foreword. I think that as a result of this the remedies proposed by the authors are focused very much on legal measures designed to protect crew and prevent IUU. Although this approach is fairly typical of how problems created by the violation of human rights and overfishing are approached, the analysis leaves out the causes of the behaviours recorded. Why do people resort to such behaviour?

The basic reason for the smash and grab approach to fisheries is the shortage of fish relative to the demands of a rapidly expanding human population. A further potential cause is the globalization of the fishing process. Human social systems are characterized by a willingness to co-operate with strangers but such a system leaves the way open for those who wish to cheat. Rules and regulations have to be devised so as to control cheating. In small scale local fisheries, fishers know each other, interact regularly and are better placed to deal with cheats in an effective way. This book would have been enhanced by such considerations.

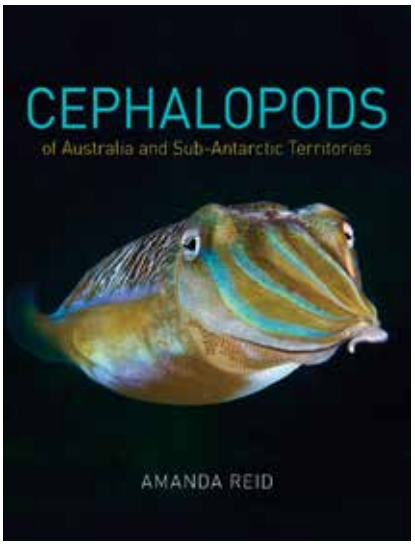
I can see this book being a useful source for those working to improve the plight of exploited fish stocks and fishers but it makes for dark reading which depresses rather than inspires.

Paul J.B. Hart, University of Leicester (pbh@leicester.ac.uk)

Cephalopods of Australia and Sub-Antarctic Territories

Author: Amanda Reid
ISBN: 9781486303946
Published by: CSIRO Publishing

Despite the fact that cephalopods are both highly ecologically significant and of considerable biological interest, there is a lack of up-to-date, comprehensive handbooks suitable for experts and amateurs alike. Amanda Reid, a taxonomist from the Macquarie University in Sydney with a particular interest in Sepiida and Sepiolida, identifies this as one of her main motivations for producing a thorough guide to the 226 species of cephalopod found in Australian waters.



The result is a wonderfully detailed description of the cuttlefish, squid, octopus and nautilus occurring off mainland Australia, Tasmania and offshore islands including sub-Antarctic islands and the Australian Antarctic Territory. Given the results of recent studies showing increasing abundance of cephalopods (likely due to overfishing of finfish) and their importance as both keystone predators and a commercial fishery resource, this is a particularly timely publication which will serve as a good basis for fisheries management or identifying potential future research projects.

The book contains a brief overview of general cephalopod biology including life history, physiology, evolution and behaviour as well as short sections on fisheries and climate change. However the book is primarily intended to be an identification guide – readers wanting a complete synopsis of cephalopod biology should look elsewhere. There is a useful glossary with clearly annotated drawings of the anatomical structures used for identification. Following this are keys and species descriptions with diagnostic features, habitat, biology, size, distribution, images and references. Whilst there is limited information on juvenile and paralarval forms (which is to be expected given that these aren't yet described for most species) and no information about cephalopod beaks (which is thoroughly covered in Xavier and Cherel's *Guide to Southern Ocean Cephalopod Beaks*), there are detailed distribution maps and diagnostic drawings throughout, and many excellent colour photographs of fresh specimens or live individuals, especially for the more commonly encountered species. There is also a very useful section covering fixation and preservation methods including anaesthetization, tissue sampling, karyology and making parasite smears.

Richly illustrated and extensively referenced, this book will be invaluable for any cephalopod researchers or fisheries experts working in Australia, as well as to keen naturalists and divers looking to identify specimens in the wild.

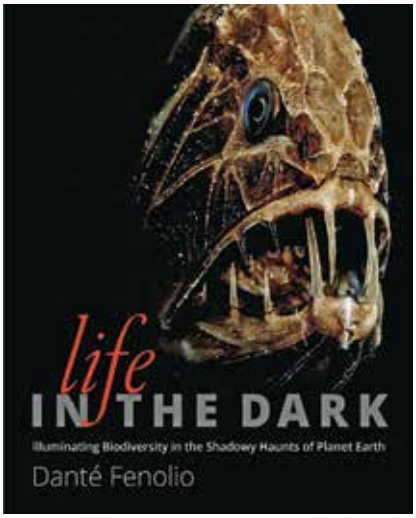
Alix Harvey (alilec@mba.ac.uk)

Life in the Dark: Illuminating biodiversity in the shadowy haunts of Planet Earth

Author: Danté Fenolio
ISBN: 978-1421418636
Published by: Johns Hopkins University Press

This fascinating book is intended to shed light on the private lives of the mysterious creatures that have never themselves seen sunlight: inhabitants of the oceanic abyss, caves, subterranean habitats, the murky waters of tropical rivers and other dark environments. The author has achieved this by devoting his long scientific career to the study of species interactions in microhabitats with emphasis on biology, ecology and conservation of cave fauna.

The book is richly illustrated by more



than 200 stunning photographs of bizarre creatures taken by the author during his numerous expeditions. He also provides abundant references for further reading.

The story begins with an introductory chapter describing the animals that live in shadowy surroundings and how the environments beyond the reach of daylight shape their lifestyles and body features. One of the main chapters is dedicated to extraordinary denizens of the deep seas, which in spite of living in perpetual darkness still rely on their eyesight in everyday activities because of omnipresent bioluminescence. The author reveals the different ways that this bioluminescence is used by fish and invertebrates for communication, hunting, same-species recognition, hiding and defence.

Another principal chapter, which is perfectly illustrated by an amazing set of photographs, concerns subterranean life. It tells numerous stories of the hidden realm of cave dwellers. To a lesser extent, the book also deals with twilight freshwater habitats that harbour diverse blind and semi-blind fish as well as the fossorial wildlife—animals that burrow and live below the ground both on lands and in seas. The final group that the author addresses are parasites, represented on a few pages again containing stunning photographs.

The volume concludes with a chapter regarding the conservation of these fragile habitats and their vulnerable residents. I hope that the wealth of information in this unique book will be properly appreciated and enjoyed by a wide range of lovers of natural history.

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