



British Ecological Society

The *Bulletin* March 2009



Marine Ecology: Special Issue

Edited by Tom Webb and Alison Holt

Editorial

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Tom Webb & Alison Holt

The UK is an island nation where it is hard to be more than an hour or so from the coast. Our territorial waters cover more than three times the area of our land, and the myriad habitats are of exceptional ecological importance. Over 8000 marine species have been recorded to date in UK waters, and this number continues to grow as surveys sample ever deeper and farther from our shores. And of course the marine environment provides us with multiple goods and services, from the delights of a Pembrokeshire sunset to the bustle of Grimsby fish market. It seems wholly appropriate, then, that the BES should recognise the marine environment as one of its four areas of policy priority.

To date, however, this priority does not seem to have been reflected in the scientific output of the Society. For instance, by a rough count the BES journals published between 0 and 13% marine-themed articles in 2008, and only about 3% of the talks at the annual meeting in London could be classified as marine. Several marine ecologists have complained that when they have in the past turned up to such meetings, they end up in a single 'marine' session, regardless of the ecological content of their talk. Certainly such issues are not unique to the BES: one of us suffered from the 'marine session' pigeonholing at the ESA annual meeting last year, and it is well documented that the marine component of the published record in various subdisciplines of ecology (including macroecology, conservation biology and biodiversity science more generally) hovers at around 10%.

There are many reasons for this, including the departmentalism of UK science which places most marine ecologists within separate buildings from their more typical 'BES'-ecologist colleagues, and encourages them to attend specialist marine conferences and to publish in dedicated marine journals. This separation begins early, as there is little overlap between degree courses containing the keyword 'ecology' and those listed as 'marine' on the UCAS website (www.ucas.ac.uk). The extent to which most ecology students learn any marine ecology is therefore entirely dependent on the interests of whoever ends up teaching them.

This disconnect between marine and 'mainstream' ecology is unfortunate because marine ecology in the UK is thriving. Programmes such as NERC's Oceans 2025

scheme (www.Oceans2025.org) have ploughed money into centres of excellence in marine research, most of which support substantial ecological investigation. The British Oceanographic Data Centre (www.bodc.ac.uk) has logged almost 600 research cruises involving 73 different vessels on a biological or fisheries theme since 2006. And those marine studies that do seep through into the general ecological consciousness often prove to be particularly influential.

We have dedicated a large part of this issue of the *Bulletin*, then, to a celebration of ecological research into marine systems. Much of this research originates in the UK, but we have cast the net wider too to bring stories from around the world. We begin with contributions that capture the spirit of exploration still present in much marine ecology. The deep seas are especially good for this, with staggering rates of discovery of new species and continual breaking of physiological records. But we also bring stories from the surprisingly rich waters of the Antarctic, and highlight the phenomenal long-term records present in the archives of the Continuous Plankton Recorder survey. We then turn to some of the problems currently facing the marine environment, including biodiversity loss, ocean acidification, and the history of exploitation in our coastal seas. Finally, we bring you contributions that highlight some issues common to all ecologists, including how we value our ecosystems, and how ecological collaborations between the developing and the developed world should proceed.

We also bring regular features, several of these also with a marine theme. For instance, Callum Roberts contributes a Field Notes from the Philippines. But as Martin Angel commented, 'places in the open ocean all look rather similar at the surface!' Because it can therefore be events rather than places that inspire marine ecologists, we include his 'ship's log' of extraordinary happenings off the west coast of Africa.

Traditional *Bulletin* fare is also on offer in this issue: Society news is covered, with an announcement of the plenary speakers at the 2009 Annual meeting, reports from Society officers, and news from the Specialist Groups. In addition to our regular essayists there is a piece by Andy Clarke, who asks What makes a good ecology paper? Sheila Abrams reports on the joys and challenges of life as a mature student, and there is a good look at the lighter side of ecology. We hope there's something for everyone in this issue!

The *Bulletin* circulates exclusively to members of the Society. It carries information on meetings and other activities, comment and other topical items. Unsigned commentaries are the responsibility of the Editor and do not necessarily represent the views of the Society.

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COVER: Cape Wrath from Baknakeil Bay, N.W. Scotland. Photograph Tom Webb and Alison Holt.

Marine Ecology: Exploring the Marine Environment

The search for life at extreme depths

Alan Jamieson



(From left) Toyonobu Fujii, Alan Jamieson, Martin Solan and Asako Matsumoto on board the German Research Vessel 'Sonne'

The Hadal zone (6000-11000m) remains the most poorly understood large marine habitat on Earth. This habitat comprises deep trenches caused by tectonic subduction situated mostly around the rim of the Pacific Ocean. This unique environment accounts for 45% of the total Earth's depth range but only constitutes about 1% of the volume of the oceans. From a biological standpoint it creates intrigue due to its remoteness from surface-derived food supply, the extreme topography and the ever increasing hydrostatic pressure with depth. At the deepest point on Earth, Challenger Deep in the Marianas Trench, the pressure exceeds 1 ton per square centimetre. However, despite all these extreme conditions, life is known to exist and indeed flourish at even the greatest depths although due to the technological challenges of sampling at these extreme depths very little is known the organisms living there.

In 2006 a joint project between the University of Aberdeen's Oceanlab and the University of Tokyo's Ocean Research Institute was funded by the UK's Natural Environment Research Council and the Nippon Foundation in Japan. The project, entitled HADEEP, aimed to explore these extreme depths using 12000m rated free-fall baited cameras and traps. The objectives were to observe hadal-fauna in its natural habitat and to investigate what lives where, at what depths, and whether there are any physiological or behavioural adaptations to life at extreme depths.

The first stage was to construct the vehicles needed to carry out the autonomous operations. Oceanlab constructed two landers initially: Hadal-Lander A and B. Hadal-Lander A is a high resolution video system looking vertically down at a height of 1 metre, focussed on bait. Hadal lander B takes high resolution still photographs. Both landers are equipped with temperature, salinity and pressure sensors, and water sampling devices.

In July 2007, the team embarked on the German Research Vessel Sonne to the Tonga and Kermadec Trenches that lie between Samoa and New Zealand in the South West Pacific. There they deployed the lander to 6000, 7000, 8000, 9000 and 10,000m deep. On top of the success of achieving a 10km free fall deployment there were three interesting biological finds. The first was an increase in small amphipods with depth, with literally thousands of individuals swarming around the bait at 10,000m. The second find was quite unexpected: decapod crustaceans, previously thought not to exist deeper than 5500m, were found at both 6000 and 7000m. These decapods were penaeids, and not small ones either, some were as long as 35cm. Perhaps the most prominent result was finding a snailfish called *Notoliparis kermadecensis*, an endemic fish only ever caught once in 1952 and never before seen alive.



Snailfish, amphipods and soft shelled whelks from 7700m

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A few months later the team went back out to the Pacific on board the Japanese vessel *Hakuho-Maru*. The system was deployed to 7100m in the Japan Trench where they observed, again for the first time alive, another endemic snailfish called *Pseudoliparis amblystomopsis*. Also, bizarrely enough, they saw the macrourid *Coryphaenoides yaquinae*, known to inhabit the abyssal plains but never previously thought to enter the trenches. Two weeks later, on board the research vessel *Kairei* the team saw these macrourids on the abyssal plains of the Marianas Region to the South and to their surprise photographed a giant amphipod.

The most spectacular discovery to date came in October 2008 whilst back on board the *Hakuho-Maru* in the Japan Trench. They deployed the video system to 7700m assuming this was the limit of the snailfish habitat and felt they would be lucky to find fish at this depth. To the contrary they found a large aggregation of these fish – up to nineteen in a single shot at one stage. The fish, ranging from juveniles to large adults of >30cm, remained in view of the camera for about 7 hours.



Aggregation of 19 snailfish at 7700m – the deepest a fish has ever been seen alive

The next expedition is scheduled for March 2009 where the team will deploy the landers at 6000, 7000, 8000, 9000 and 9500m in the Izu-Ogasawara trench (also known as the Izu-Bonin Trench) that runs South of the Japan Trench.

Alan Jamieson is a post-doctoral research fellow at Oceanlab, University of Aberdeen. Video footage of the fish is available as an online supplement to Jamieson et al. (2008) Proc. R. Soc. Lond. B, DOI: 10.1098/rspb.2008.1670

Islands in the Deep Sea



Jon Copley

Islands have long held a fascination for naturalists, from Darwin's observations in the Galapagos to MacArthur and Wilson's models of island biogeography. One might therefore think that islands have been thoroughly picked over by ecologists and the days of tripping over new species on previously-unexplored archipelagos are long gone. But for those of us working in the deep ocean, that golden age of discovery is still a reality.

Thirty years ago marine biologists were astounded by pictures from a newly discovered phenomenon on the ocean floor: deep-sea hydrothermal vents. These undersea volcanic springs, first found 2500 metres deep in the Pacific, were home to abundant populations of new animal species. Such islands of life in the otherwise sparsely populated abyss are supported by local chemosynthetic primary production, where microbes use sulphide and methane gushing from the seafloor as an energy source to fix inorganic carbon.

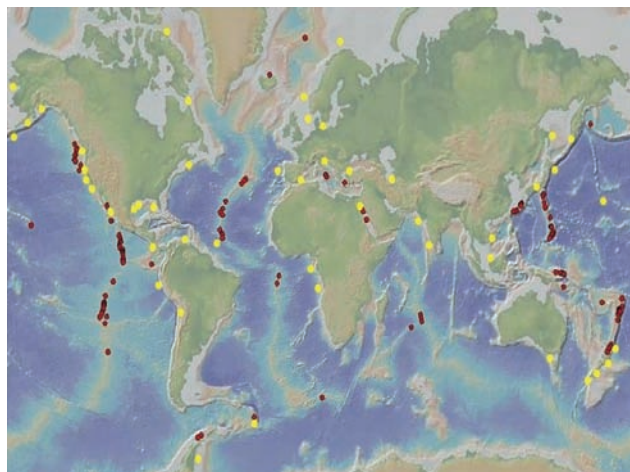
After the discovery of hydrothermal vents came that of cold seeps, another category of chemosynthetic island on the ocean floor driven by a variety of other geological processes. And we now know that whale carcasses also support islands of chemosynthetic life during the degradative succession of their skeletons. So deep-sea chemosynthetic islands are far more widespread than originally realised, in settings such as volcanic vents, brine pools, mud volcanoes, whale falls, gas hydrate beds and asphalt seeps.

Physiologists have rushed to understand the adaptations to these environments, from the symbiotic relationships between some animal species and chemosynthetic microbes, to the solutions evolved by many species to the problems of high sulphide conditions. But the development of our ecological understanding has arguably been much slower, while we gradually obtain prerequisite data on species distributions.

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More than 600 new animal species have been described so far from vents and seeps, which is an average of one new species every three weeks. And those are just the large, obvious megafaunal species such as the metre-long red-plumed vestimentiferan tubeworms that have become the poster child of hydrothermal vents. Our investigation of the smaller meiofauna – animals typically smaller than 1 mm, such as nematodes – has only just begun. When you encounter an animal at a depth of more than 3000 metres, there is a 50% chance that it will be a new species.

What is now beginning to emerge, however, is an appreciation of biogeographic patterns in chemosynthetic environments, thanks to efforts such as the International Census of Marine Life's ChEss (Chemosynthetic Ecosystems) programme. We are at last piecing together a global jigsaw puzzle of species distributions in these islands on the ocean floor. Eastern Pacific vents, for example, are dominated by vestimentiferan tubeworms and chemosynthetic mussels. But while mussels are also known at Mid-Atlantic vents, no tubeworms have been found there so far. Instead, some deep Mid-Atlantic vents are dominated by dense aggregations of shrimp that are highly adapted to the vent environment. Similar shrimp are present at vents in the Indian Ocean, first visited in the early 2000s. But many gaps remain, as only a tiny fraction of the ocean floor has been explored. The challenge now is to understand the processes that shape the emerging global patterns of biogeography at vents and seeps – and solving that puzzle should advance our understanding of patterns of marine life in general.



Global distribution of hydrothermal vent (in red) and cold seep (in yellow) sites discovered so far. The gaps represent where no one has looked yet! Image courtesy of Census of Marine Life ChEss programme, www.noc.soton.ac.uk/chess/

Patchiness in vent ecosystems

Individual vent and seep sites are small features on the ocean floor, each typically the size of a couple of football pitches. And they can be tens to hundreds of kilometres apart. Within each island, the environment is very patchy. At hydrothermal vents, temperature can vary by tens of degrees C over tens of centimetres – and temperature is a good proxy for the mixing between acidic, anoxic and sulphide-rich vent fluids and surrounding seawater. Although cold seeps by definition lack such temperature gradients, they exhibit similar sharp gradients in features such as sulphide and oxygen concentrations.

This patchiness and these gradients have consequences for the distribution of animals at individual vent and seep sites. Population distributions at vents and seeps often follow zonation patterns on similar scales to those of rocky shores. The patchiness can also affect processes such as reproduction, with zonation of brooding crustaceans around sites and patchiness in the reproductive development of some less motile species.

As well as being very patchy environments, they are also highly dynamic. Motile vent shrimp seem to vary their distribution on a tidal timescale in response to tidal fluctuations in the flow from vents, even at a depth of 3600 metres. And some polychaete species at vents appear to have reproductive cycles on lunar timescales – a frequency unprecedented elsewhere in the deep sea – again possibly linked to tidal cues.

Several other vent and seep species exhibit seasonal reproduction, despite plenty of food all year round from chemosynthetic primary production. These seasonal-reproducing species produce planktotrophic larvae, which feed on phytodetrital material as they develop away from vents and seeps. Reproduction in these species appears to be timed so that larval release coincides with the end of spring blooms of phytoplankton in sunlit waters far above – a hitherto overlooked link between the ecology of chemosynthetic and photosynthetic ecosystems.

With their sharp physical gradients and dynamics, chemosynthetic environments have been described as deep-sea analogues of the intertidal zone. The development of ecological understanding of these environments is following similar lines to those followed in the history of intertidal ecology. Vent and seep ecology is progressing from considering the role of solely physical factors in determining zonation patterns, for example, to also recognising the

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importance of biological interactions. Devising and executing field experiments on the ocean floor to demonstrate interactions such as competition, however, requires considerable practical and logistic ingenuity. But despite their remoteness, these islands may offer a similar sandbox to the intertidal for testing and developing ecological ideas.



A 'black smoker' vent chimney in action, at the TAG hydrothermal vent site on the Mid-Atlantic Ridge at 26 degrees N and a depth of 3600 m

Vent and seep biogeography

On a larger scale, deep-sea chemosynthetic environments are not only insular, but also ephemeral. Vent sites become clogged by mineral deposits, buried by lava flows, or have their underlying plumbing in the oceanic crust cut off by earthquakes. Along the sections of the mid-ocean ridge that are most volcanically active, a vent site may only last a few decades, while in less active regions one may last centuries. Cold seeps, meanwhile, sow the seeds of their own demise. The flux of sulphide at cold seeps is usually produced by the reduction of seawater sulphate by microbes in seafloor sediments, coupled to the oxidation of methane. Another by-product of this process is biogenic carbonate rock – and over a few centuries enough of this rock forms in the sediments that it caps further seepage of methane and sulphide to the surface at that site.

When venting or seeping stops, most of the animal populations at that island are doomed. Few adult forms can migrate to another vent or seep site. Many vent and seep species, such as the vestimentiferan tubeworms, as sessile as adults. Even for those species that are motile as adults, it can be hundreds of kilometres to the next chemosynthetic island, across an impenetrable desert in terms of productivity. Yet clearly the species that populate these islands have some means of

overcoming this apparent problem. Understanding dispersal in these environments – and its consequences for gene flow, population differentiation, speciation and biogeography – is currently a key question in vent and seep ecology.

For many animals, the answer lies in their larval forms, which often seem adapted for island-hopping. Vestimentiferan tubeworms, for example, produce lecithotrophic larvae that cannot feed but are provisioned with energy reserves. The larvae eke out their reserves as they are carried by ocean currents, because their metabolism ticks over very slowly in the cold deep waters away from vents. But even so, a vent tubeworm larva can only survive for around forty days in the wilderness before its reserves are spent. Fortunately that lifespan is sufficient to ensure that some are carried from vent to vent in their eastern Pacific, where vents are quite close together as a result of more intense volcanic activity at the mid-ocean ridge in the region.

In contrast, the vent shrimp found on the Mid-Atlantic Ridge and in the Indian Ocean produce planktotrophic larvae that can feed while away from the vents. Consequently these larvae may be more capable of dispersal across the larger distances that separate vents in those oceans. Chemosynthetic islands therefore offer an ideal system in which to study the roles of life history strategy and larval ecology in shaping patterns of population differentiation and biogeography in the marine environment.



Typical vent fauna: aggregations of the vent shrimp *Rimicaris exoculata* and the vent crab *Segonzacia mesatlantica*. From the TAG hydrothermal vent site on the Mid-Atlantic Ridge at 26 degrees N and a depth of 3600 m.

The future of vent and seep research

As I write this my colleagues and I are aboard a ship in the Southern Ocean, on an expedition looking for vents and seeps around Antarctica. This region is one of the missing pieces of the global jigsaw puzzle. Will life at chemosynthetic

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environments around the Drake Passage, between the Antarctic Peninsula and South America, be similar to that of the Pacific, or the Atlantic, or completely different to both? We have an onboard sweepstake about the animals we may find. A safe bet is that there may be mussels – the most geographically widespread taxon found so far at vents and seeps. Their wide distribution may in part be attributed to their planktotrophic larvae.

Shrimp may be another good bet for the same reason, though cold water temperatures can have a narcotising effect on decapod crustaceans, which has excluded them from Antarctic waters further south. I am hedging my bets on tubeworms, however, because of their lecithotrophic larvae. Based on our geological knowledge, the likely spacing of vents in this area may be around the threshold for tubeworm larvae to be able to hop from island to island with their limited food reserves. But the deep sea always contains surprises. Technology and weather permitting, within the next four weeks we should get our first glimpse of life at vents down here.

Another missing piece of the global jigsaw puzzle may lie at the bottom of a rift in the seafloor of the Caribbean. This rift, known as the Cayman Trough, contains the world's deepest undersea volcanic ridge, 6000 metres beneath the waves. This ridge has been volcanically active for at least 50 million years. Before the Isthmus of Panama closed between 10 and 3 Mya, vent species could have dispersed from the eastern Pacific to the Trough. Today, however, a deep ocean current links the Trough with the Mid-Atlantic.

So if geological history is a key feature determining biogeographic patterns at deep-sea vents, then we expect to find species in the Cayman Trough with affinities to those at the Pacific vents. If modern-day hydrography is a key factor, however, then we may find Atlantic-type vent fauna. The Trough could also be so isolated that it hosts its own unique fauna to some degree, which would tell us something about the scale and type of isolation required to produce distinct biogeographic provinces in the marine environment.

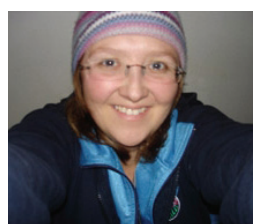
Any vents on the very deepest reaches of the ridge in the Cayman Trough could also be unlike any we have seen before, theoretically erupting water as hot as 550 deg C with a unique chemistry as a consequence of the higher pressure at greater depth. The microbial processes and physiological adaptations in such an environment are a tantalising prospect. Right now we are waiting to hear when the ship that we need will be scheduled for our first expedition to the area.

Although our expeditions will collect samples for molecular phylogenetics and population genetic studies, our first-order measure of gene flow between different sites is the presence / absence of species – much the same as that used by nineteenth century naturalists. And we share the same excitement that they experienced when visiting previously unexplored islands. Just as they rushed to peer through telescopes from the ship's rail or upper yards for the first sight of the inhabitants of new shorelines, so we cram around video monitors as our underwater vehicles arrive at newfound vent and seep sites.

In the three decades of exploration at vents and seeps, our view of these islands has changed from considering them a mere footnote in marine ecology to recognising them as widespread features of our planet's largest landscape, the deep ocean. As we start using them as "natural laboratories" to examine interactions between biogeography, evolution, genetics and ecology in determining patterns of marine life, I hope that they will eventually warrant more than just a passing mention in ecology textbooks of the future.

Jon Copley is a lecturer in marine ecology in the School of Ocean & Earth Science, National Oceanography Centre, Southampton.

CenSeam: a global census of marine life on seamounts



Mireille Consalvey

Seamounts are undersea mountains. Globally it is estimated there could be 100,000 seamounts exceeding 1 km high, and many more of lesser elevation, making them a ubiquitous deep-sea habitat. Ecologically important, they can act as oases in the ocean and play an important role in patterns of

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marine biogeography. They have the potential to support high biodiversity and unique biological communities. Seamounts can also be highly productive ecosystems, and feeding grounds for fishes, marine mammals, and seabirds. They host significant commercial fisheries in many parts of the world, and are attracting interest for deep-sea mining.

However, biological research on seamounts has been limited, and we have a poor understanding of seamount biodiversity on a global scale. To date, less than 200 seamounts have been studied in sufficient biological detail. Recognising it is not feasible to sample all of the world's seamounts, research efforts needed to be coordinated to assess the current state of knowledge, fill critical knowledge gaps and target understudied regions and seamount types. Under the umbrella of the Census of Marine Life CenSeam aims to (1) co-ordinate and expand existing and planned research (2) identify priority areas for research, and foster scientific expeditions to these regions (3) synthesize and analyze existing data and (4) communicate the findings through public education and outreach.



Seamount community, Macquarie Ridge. Courtesy National Institute of Water and Atmospheric Research (NIWA)

Two overarching priority themes have been defined:

- 1) What factors drive community composition and diversity on seamounts, including any differences between seamounts and other habitat types?
- 2) What are the impacts of human activities on seamount community structure and function?

These themes have been addressed through community workshops, committee meetings, and two working groups – Data Analysis (DAWG) and Standardisation (SWG). These

working groups operate in tandem to strengthen sampling design, ensure comparative data are collected, carry out subsequent analyses, and publicize results. Each group acts as a 'vehicle' which other scientists are invited to join (e.g. to contribute expertise and advise on particular subjects).

Spotlight on CenSeam research: Assessing the vulnerability of deep-sea corals to fishing.

In collaboration with another Census project, FMAP, CenSeam used Environmental Niche Factor Analysis to map the potential global distribution of deep-sea corals on seamounts, and compare this to global seamount fisheries (e.g. alfonsino, orange roughy). The results were a world first and highlighted a broad band of the southern Atlantic, Pacific and Indian Oceans where there are numerous seamounts at fishable depths, and high habitat suitability for corals. The results were published by UNEP-WCMC as a report which was tabled at the United Nations General Assembly and received publicity around the world. Subsequent analyses will be published in the *Journal of Biogeography* in 2009 (Tittensor *et al.*).

CenSeam mini-grants have been used to add value to other research programmes. Since commencing in 2005 CenSeam has served to bring together more than 300 seamount researchers and CenSeam linked scientists have participated in over 20 voyages. CenSeam researchers have augmented sampling efforts and analyses in the well studied Southwest Pacific and Northern Atlantic. CenSeam has also identified three key undersampled regions: the Indian Ocean, the South Atlantic, and the Western and Southern Central Pacific and researchers are working towards securing funding to sample these regions. To answer the core research questions of CenSeam it is essential to ensure as many data as possible are available. Our database SeamountsOnline continues to expand its data holdings, with several thousand new records added in 2008, including data from over 30 new seamounts, and several thousand more in the quality-control process. At present SeamountsOnline holds 17283 observations from 246 seamounts.



Seamount profile, Brothers, New Zealand. Courtesy National Institute of Water and Atmospheric Research (NIWA)

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As we move towards the end of the first Census of Marine Life CenSeam has enabled the “seamount community” to undertake improved analyses, strategically design national and international research programmes, erect new paradigms for seamount structure and function, work towards an improved understanding of the extent and impacts of fishing and mining activities and to develop and design global seamount MPAs to maximize efficacy of conservation networks.

For further information or to become involved with the CenSeam programme, including data contributions to SeamountsOnline, please contact project coordinator Mireille Consalvey (m.consalvey@niwa.co.nz). See also CenSeam website (<http://censeam.niwa.co.nz/>) and SeamountsOnline (<http://seamounts.sdsc.edu/>). The Census of Marine Life is a global network of researchers in more than 80 nations engaged in a 10-year scientific initiative to assess and explain the diversity, distribution, and abundance of life in the oceans. The world’s first comprehensive Census of Marine Life – past, present, and future – will be released in 2010.

Analysing Change in Southern Ocean Ecosystems

Eugene Murphy

Each summer more than four million fur seals, seven million penguins and many millions of other seabirds form vast breeding colonies across the Scotia Sea in the Atlantic sector of the Southern Ocean. The Sub-Antarctic Islands within this region provide these land-based breeders with safe habitats and access to an abundant food supply consisting primarily of Antarctic krill (a euphausiid crustacean).

Like much of the Southern Ocean, the Scotia Sea experiences major inter-annual fluctuations in both the physical and biological components of the system. In the Scotia Sea this is related to the dynamics of krill populations. The life-cycle of this crustacean is closely linked to the formation of sea ice that encompasses the Antarctic continent during the winter months. This sea ice provides a feeding habitat and a refuge from predators and is especially important for krill larvae. During the spring and summer months the sea ice retreats and krill are dispersed in ocean currents over large

distances (> 1000 km) to areas where they become available to predators. Climate related fluctuations in winter sea-ice cover, ocean temperatures and circulation patterns can all affect the population and dispersal dynamics of krill thereby generating major inter-annual fluctuations in the regional operation of the ecosystem. More systematic changes are also occurring on decadal time scales, but unlike the Arctic where winter sea ice is reducing across the whole ocean, in the Southern Ocean the changes are regional. The effects of these changes are, however, large-scale and dramatic and occur across some of the central regions of the krill population and affect species at every trophic level. Krill are also the target of a commercial fishery so understanding the controls on their dynamics is crucial both in terms of sustainable harvesting and in understanding the impacts of ecological change across trophic levels in these large-scale oceanic ecosystems.

Understanding the effects of variability and change in this ecosystem requires integrated scientific analyses across the whole ecosystem linking biological and ecological studies of key species and food webs, with analyses of the physical dynamics over a range of scales. The task is urgent; rapid changes are already occurring in the Southern Ocean driven by climate related processes and in addition harvesting impacts are likely to increase. The British Antarctic Survey’s (BAS) interdisciplinary marine ecosystem research programme brings together ecologists and biological, physical and chemical oceanographers. The aim of the programme is to develop the integrated analyses required to determine how these systems operate and respond to variability and change.



Deployment of pelagic net on RRS James Clark Ross

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The BAS programme undertakes interdisciplinary studies linking aspects of ocean mixing and circulation, biogeochemistry and plant productivity, relating these to the life-cycle dynamics of key oceanic and higher predator species. These studies include oceanographic analyses of the controls on primary production and biogeochemical cycling, which utilise oceanographic station sampling methodologies from ship-based studies. Under-way sampling provides wider physical, chemical and biological spatial context to interpret the station-based studies. Analyses of zooplankton (copepods and krill) and nekton (fish and squid) community and population dynamics are undertaken using net and hydro-acoustic sampling systems. Laboratory-based analyses provide information on vital rates, such as feeding, growth, development and mortality. New technologies are changing the scale at which sampling of oceanic systems is possible, for example we are utilising moored hydro-acoustic systems to provide year-round estimates of plankton abundance. Our predator studies are focused at Bird Island, South Georgia, where we monitor foraging and breeding performance of a range of penguin, albatross and seal species. In these studies we use satellite-based tracking systems and activity recorders to analyse foraging patterns, which also allows us to focus our ship-based studies on crucial foraging regions. Our field-based studies are underpinned by a programme of analysis and modelling aimed at developing integrated models of the life-cycles of key species and the operation of the whole ecosystem. Long-term monitoring has been underway for about 30 years and has provided invaluable data to examine the factors generating fluctuations in these large-scale ecosystems. Work in this area is developing very rapidly and new projects include, for example, combined analyses of population dynamics and genetics of key species, and analyses of the links between ecosystem structure, function and biodiversity.



Marking fur seals *Arctocephalus gazella* at Bird Island Research Station.

Analyses of the operation of large-scale oceanic ecosystems require not only an integrated scientific approach, but also a major internationally coordinated effort. The highly connected nature of the Southern Ocean ecosystems and the hemisphere-scale impacts of climate variability in this region mean that localised views of ecosystem operation are insufficient for understanding their responses to change. Fortunately many national programmes operate in different regions of the Antarctic and the Southern Ocean, providing data that collectively give a view on the operation of a large part of the global ocean. As there are no political boundaries in the Southern Ocean, fisheries management is conducted at a circumpolar-scale under the auspices of the Commission for Conservation of Antarctic Marine Living resources (CCAMLR), which is part of the Antarctic Treaty system. As a signatory nation, the UK has management and scientific obligations to fulfil in this area. CCAMLR science is based on an ecosystem approach to management. Development of this approach in the Southern Ocean also requires wider system analyses such as the role of the Southern Ocean in the physical climate system and in global biogeochemical cycles. This integration is being developed through a new international programme – ICED – Integrating Climate and Ecosystem Dynamics (www.iced.ac.uk), which is part of the International Geosphere Biosphere Programme called Integrating Marine Biogeochemistry and Ecosystem Research programme). As part of this coordinated international scientific effort, emphasis has also increased on developing understanding of polar ecosystem operation in general, encompassing Arctic and Antarctic ecosystems. In recognition of this we're planning a polar ecosystem thematic session (marine and terrestrial) for the next BES Annual Meeting in September 2009. The scale of the questions being addressed in polar marine ecology has fundamentally changed in the last few years and the science is advancing rapidly. This is an exciting, if somewhat daunting, time in polar science generally. These systems are changing rapidly and we are being asked to predict how these systems will change in the coming decades. We hope the BES community can play an active role in developing a wider polar ecological community in the UK that can generate the large-scale integrated analyses required to address such issues.

Eugene Murphy is Ecosystems Science Leader at the British Antarctic Survey. BAS is part of the Natural Environment Research Council. BAS ecosystem science provides the basis for developing advice for UK input into CCAMLR through the Foreign and Commonwealth Office.

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The Continuous Plankton Recorder

Abigail McQuatters-Gollop, David Johns and Martin Edwards

The Continuous Plankton Recorder (CPR) survey is one of the longest running marine biological monitoring programmes in the world. Started in 1931 by Sir Alister Hardy, the CPR has provided marine scientists with their only measure of plankton communities on a pan-oceanic scale. Today the CPR survey is operated by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), located in Plymouth, UK. Uniquely, the CPR survey's methods of sampling and plankton analysis remain unchanged since 1948, providing a spatio-temporally comprehensive > 60 year record of marine plankton dynamics

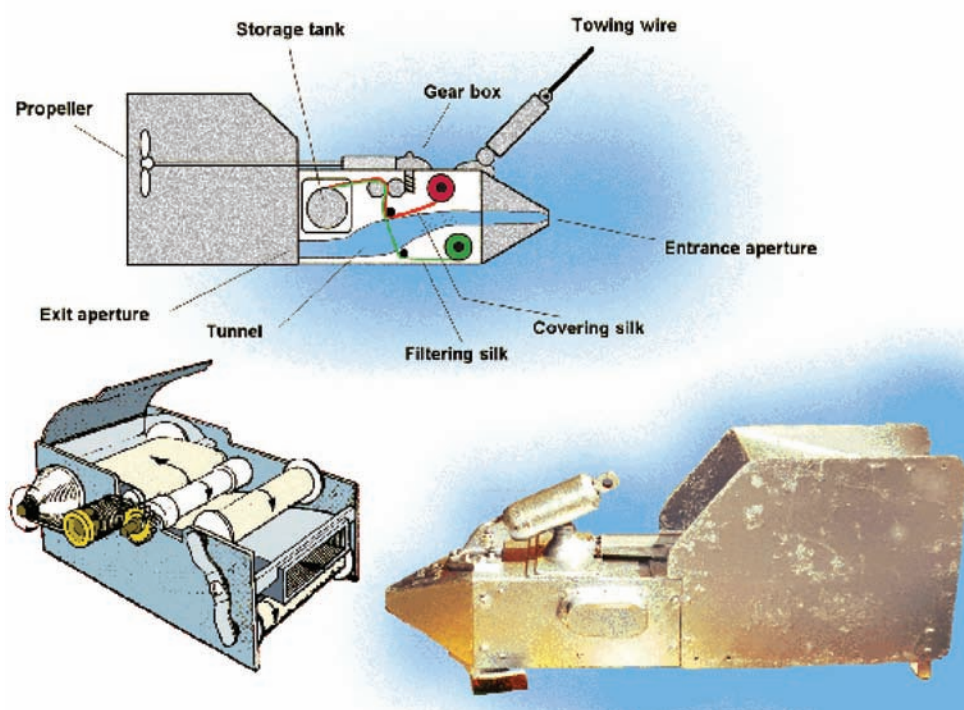
Sampling and analysis

The CPR is a plankton sampling instrument designed to be towed from merchant ships, or ships of opportunity, on their normal sailings. CPRs have been towed a total of over 5.5 million nautical miles by 278 ships since the survey's inception. Recorders have been towed in all oceans of the world, the Mediterranean, Baltic and North Seas and in freshwater lakes. However, SAHFOS CPR sampling primarily focuses on the northwest European shelf and the Northeast and Northwest Atlantic, with these regions undergoing monthly sampling; regular sampling is also now carried out

in the North Pacific. Additionally, sister CPR surveys, not conducted by SAHFOS but using similar methodology, are operated from USA and Australia.

The CPR is towed at a depth of approximately 10 metres. Water passes through the CPR and plankton are filtered onto a slow-moving band of silk (270 micron mesh size) and covered by a second silk. The silks and plankton are then spooled into a storage tank containing formalin. On return to the laboratory, the silk is removed from the mechanism and divided into samples representing 10 nautical miles of tow.

CPR samples are analyzed in two ways. Firstly, the Phytoplankton Colour Index (PCI) is determined for each sample. The colour of the silk is evaluated against a standard colour chart and given a 'green-ness' value based on the visual discoloration of the CPR silk produced by green chlorophyll pigments; the PCI is a semiquantitative estimate of phytoplankton biomass. In this way the PCI takes into account the chloroplasts of broken cells and small phytoplankton which cannot be counted during the microscopic analysis stage. After determination of the PCI, microscopic analysis is undertaken for each sample, and individual phytoplankton and zooplankton taxa are identified and counted. Over 500 phyto- and zooplankton taxa have been identified on CPR samples since 1948.



A cutaway view of the CPR, the plankton filtering mechanism, and a photograph of the instrument

Marine Ecology: Exploring the Marine Environment



Retrieval of a CPR from the Pride of Bilbao

Ecological research

Due to its long time-series, comprehensive spatial coverage and methodological consistency, the Continuous Plankton Recorder survey is a unique ecological dataset which has provided invaluable insights into numerous aspects of plankton dynamics and ecology. Key areas of research include:

- 🕒 Climate change
- 🕒 Biodiversity and biogeography
- 🕒 Eutrophication
- 🕒 Harmful Algal Blooms (HABs)
- 🕒 Fisheries investigations
- 🕒 Plankton ecology
- 🕒 Taxonomy
- 🕒 Regime shifts
- 🕒 Non-indigenous species

For more information see the SAHFOS website, www.sahfos.ac.uk

Marine Ecology: Human Impacts on the Sea

The carbon crunch



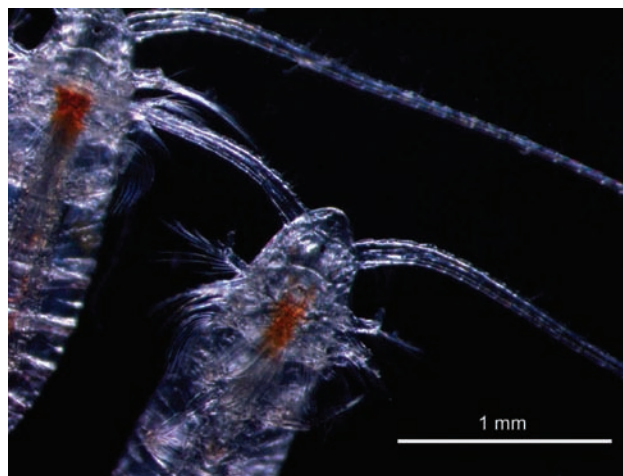
Daniel Mayor

Combustion of fossil fuels has caused the atmospheric concentration of carbon dioxide (CO₂) to increase by more than 35 % over the past 200 years, and emission rates continue to grow by approximately 3 % each year. The global financial implications of climate change, resulting from the continued release of CO₂ and other greenhouse gases, have highlighted the necessity for mitigation strategies to be swiftly implemented. One such strategy is carbon capture and storage (CCS), in which CO₂ is captured at the point of production and subsequently stored in isolation from the atmosphere. This apparently fantastical concept is actually a reality, and > 10 million tonnes of CO₂ have already been stored beneath the seabed in the northern sector of the North Sea. The successes of trial marine CCS projects have highlighted this technology as a promising tool for helping to tackle mankind's effect on the global climate. Indeed, the London Convention, which governs the disposal of waste at sea, has recently been amended to allow the disposal of CO₂ in sub-seabed geological formations.

But what if it goes wrong? Results from a time-lapse seismic survey indicate that sequestered CO₂ does stay put in the short-term (5 years), but nothing is known about the long-term stability of these reservoirs. Carbon dioxide readily dissolves in seawater, forming a weak acid; an abrupt failure of a marine geological CO₂ storage facility could lead to severe acidification of the surrounding seawater. The concept of 'ocean acidification' due to the dissolution of CO₂ in seawater is not a new one, but its effects on marine organisms and ecosystem services have only recently been studied in earnest. Potential impacts span from altering nutrient regeneration and coral reef growth rates in coastal environments to changing the way in which the oceans naturally export large quantities of CO₂-rich minerals into the abyss.

Extreme acidification events, such as that anticipated to occur in the event of a catastrophic reservoir failure, pose a

potential threat to the reproductive success of invertebrates that sit near the bottom of the food chain. A keystone species of copepod, a water flea-like crustacean (pictured), suffers a ten-fold reduction in egg hatching success when exposed to an extreme concentration of CO₂-acidified seawater. This is of particular concern for fisheries, as the abundance of many commercial fish species is dependant upon a plentiful supply of these creatures. The extent to which invertebrate reproduction will actually be impaired in the event of a major CO₂ leakage from a geological reservoir remains to be seen. Nonetheless, the potential for this to occur highlights the necessity for careful planning and the appropriate assessments of risks associated with any commercial-scale marine CCS initiative. Any such risks must be weighed against the benefits of reducing CO₂ emissions and their effects on the global climate, although more research into the realistic environmental impacts of marine CCS initiatives, and their long-term stewardship, is required before any such cost-benefit analysis can be meaningfully undertaken.



Calanus finmarchicus, one of the most abundant copepods in the northern North Sea and North Atlantic

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Marine Ecology: Human Impacts on the Sea

The consequences of marine biodiversity loss on ecosystem properties



Jasmin Godbold

A major contributing factor to the unprecedented rates of extinction we are currently witnessing is, and will continue to be, human activity (e.g. over-exploitation, pollution, habitat destruction, climate change) which is extensively altering ecosystems and biodiversity on a global scale (Sala *et al.* 2000). As a result there has been great concern over the consequences of biodiversity loss on ecosystem properties (e.g. plant biomass production, nutrient and water cycling), which subsequently affect the provision of ecosystem goods and services (e.g. food, water and shelter), and ultimately affect human well-being (Diaz *et al.* 2006).

Since 1990, 1315 peer reviewed articles have been published that either directly or indirectly consider the concepts surrounding the relationship between biodiversity loss and ecosystem properties. The majority of these studies (empirical and theoretical) have, however, been based in terrestrial systems with less emphasis on freshwater and marine systems. This bias is worrying, considering that estuaries, coastal seas and ocean ecosystems have been focal points for resource use and human settlement throughout history (Jackson *et al.* 2001) and continue to be of fundamental importance

for the provision of goods and services to society. Indeed, a recent synthesis on ecological change in marine ecosystems shows that the whole of the marine environment is affected by human influence, with 41 % of marine areas strongly influenced by multiple human drivers (Halpern *et al.* 2008). As marine ecosystems harbour tremendous biodiversity (e.g. of the 29 non-symbiotic animal phyla that have been described so far, 28 have living representatives in marine ecosystems and 13 of these are endemic to the marine habitat; Snelgrove 1999) the consequences of species loss for marine ecosystem properties are likely to be of global significance.

Recent syntheses reveal that, irrespective of the system under study, increased biodiversity tends to have a positive effect on ecosystem properties although the pattern of response may vary depending on the ecosystem and species investigated. The high degree of experimental control required and the short time periods under which studies are conducted means, however, that the environmental variation and biological interactions that occur in natural marine systems are largely not realised. As a result, greater environmental and biological realism has been incorporated into experimental designs by, for example, connecting aquaria to the real world using flow through systems, using real assemblages in the laboratory, doing in-situ manipulations (Figure 1) or by incorporating multiple trophic levels. Despite increasing the complexity of studies in this way, there is still a fundamental difference between demonstrating the importance of biodiversity effects under experimental conditions and showing that such effects are just as strong and important in natural systems.

Innovative use of observational studies using natural and anthropogenic gradients of disturbance may aid in bridging the gap between experimental and theoretical studies and their applicability to real marine systems. Such gradients are particularly well studied in marine benthic environments, where sequential changes in community composition have



Figure 1. In-situ experimental plot in the Ythan Estuary, consisting of mesocosms (insert) containing communities of benthic invertebrates at different levels of species richness to investigate the effects of changing consumer diversity on ecosystem properties (algal decomposition) (Godbold *et al.* 2009).

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been documented alongside concurrent changes in the physico-chemical properties of the benthos and thus offer an opportunity to determine the relative importance of biodiversity in mediating ecosystem properties in natural systems. If we are to accurately predict the ecosystem consequences of marine biodiversity loss and estimate the long term effects on human well-being, a challenge for marine ecologists will be to provide this type of information in the short term.

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Jasmin Godbold, Mark Solan and Steve Widdicombe will chair a themed session on 'The Effects of Ocean Acidification' at the BES Annual Meeting at the University of Hertfordshire in September.

Past Lives – Piecing together the ecological history of coastal ecosystems can inform today's marine management

Heike K. Lotze and Catherine Muir



Cities around the world have many common elements—pollution, skyscrapers, and traffic jams probably come to mind—but an often overlooked feature of many of the largest cities around the globe is their geographical setting. For example, most New Yorkers today are probably unaware that their urban jungle is located at the mouth of the Hudson River, one of North America's largest estuarine environments. In fact, estuaries and coastal seas have been hubs for human settlement throughout history, and today, over half of the world's largest cities are located around estuaries.

The importance of estuaries is sometimes overlooked, even in the realm of ecology. Terrestrial ecosystems such as rainforests are more likely to make headlines in environmental news than marine ecosystems, and when the focus is on oceans, coral reefs typically receive the most attention. Yet the disastrous tsunami that wreaked havoc in Southeast Asia in 2004, and 2005's Hurricane Katrina in Louisiana, USA, brought the world's attention to the catastrophic impact that storms can have on coastal settlements and ecosystems. The severe effects of the tsunami and hurricane were made worse by historical losses of wetlands and mangroves that reduced available floodplains.

Estuaries have been essential to sustaining both human and marine life since earliest times. Teeming with species diversity and productivity, estuaries support abundant human and animal consumers. They also provide protective habitats for human settlement and animal spawning, nursery and foraging grounds, and link human transportation and animal migration routes between rivers and the sea. Looking down from an airplane on an estuary, this is not hard to imagine. These bountiful environments have, over time, attracted

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hunters and fishers, settlers and farmers, traders and industries alike, which together have changed the land- and seascape of estuaries around the world.

Today, we look back on a long history of human-induced changes such as overexploitation, habitat transformation, and pollution that underlies the current state and future of estuarine ecosystems and their surrounding cities. This raises two important questions: First, how big and severe have these human-induced changes been? And second, if we want to restore estuaries, what do natural or pristine estuaries actually look like?

In 2002, a group of ten ecologists, historians, paleontologists, and archeologists set out to reconstruct the magnitude and range of historical changes in 12 major temperate estuaries and coastal seas in Europe, North America and Australia from the onset of human settlement until today. Four years and more than 800 analyzed sources of information later, the study was published in the journal *Science* in June 2006.

The results were surprising. Although different in their physical, biological and human history, all 12 estuaries showed similar patterns of degradation. Only the timing was different: severe degradation first occurred during Roman times (~2500 years ago) in the Mediterranean Sea, Medieval times (~1000 years ago) in Northern Europe, and in the wake of European colonization (~150–300 years ago) in North America and Australia. Increasing demands from growing human populations, developing markets for luxury items such as furs, feathers and ivory, and the commercialization and industrialization of resource use were the major drivers causing the depletion and destruction of marine life and habitats.

Some economically important species suffered the most. For example, oysters, highly valued during Roman times, were overexploited in Italian waters ~2000 years ago, and soon had to be imported from the North Sea. There, centuries of overexploitation brought about the collapse of the oyster fishery in the early 1900s, and with the loss of oyster banks an important habitat disappeared. Sturgeon, one of the most valued fish in Medieval Europe, was already in decline in the 12th century due to high demand and degradation of river habitats. It was still fished in the Rhine and Elbe River estuaries until the early 20th century, when this prized fish became scarce and essentially vanished in these waters.



Drawing of the sturgeon fish market in Hamburg Harbour, 1884, by Hans Peterson

The *Science* study found that today, on average more than 90% of formerly important species have been depleted, over 65% of seagrass and wetland habitats have been eliminated, and water quality has been degraded 10- to 1000-fold in the



*Map showing the locations (in pink colour, left) of the former banks of the European flat oyster, *Ostrea edulis* (right) around the island of Sylt in the North Sea. The oyster banks disappeared in the course of destructive and over-fishing in the early 20th century*



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estuaries studied. Only in the 20th century have some negative trends been turned around through increasing conservation efforts, so far mostly benefiting seals and birds.

Although many people are aware of human-induced changes on coastal environments, only recently have marine scientists started to look into the past in an attempt to determine historical reference points and evaluate the magnitude of change underlying the state of today's ecosystems. Knowing the past is important to set sound restoration and management targets for the future.

This new research field of Marine Historical Ecology uncovers a variety of fascinating data sources: descriptions of early naturalists exploring the New World; lists of species sold at fish markets in times gone by; taxes paid to a reigning monarch for the amount of fish caught; historical cookbooks; maps and logbooks of whalers; animal bones and shells left behind by hunter-gatherer tribes; and layers of sediment in cores taken from the seafloor (Figure 3).

Our studies and others on estuaries and coastal ecosystems have brought to light the vital importance of coastal environments to human development throughout history. Estuaries act as sources of marine biodiversity, habitats for commercial fish, a resource for our economy, and a buffer against natural disasters. The health of these ecosystems should therefore be a management priority.

As human influences today spread rapidly from the coasts to the continental shelves, from shallow waters to the open ocean and deep seas, an increasing part of the blue ocean is at risk from depletion and degradation. However, we can and should learn from past failures and successes in coastal waters to better manage our activities in the global ocean, now and in the future.

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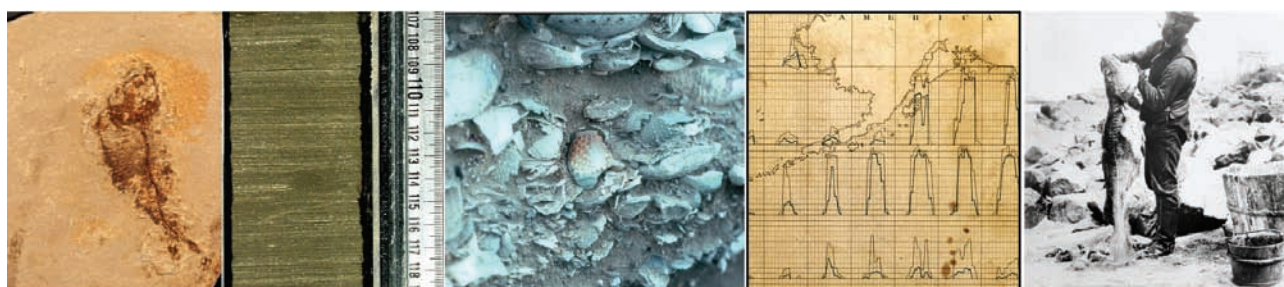


Illustration of the variety of data sources used in marine historical ecology (L-R): Sardine fossil from the Santa Barbara Basin, California, ~11 million years old (courtesy Richard D. Norris); Profile of a sediment core from South America (courtesy Richard D. Norris); Section of an archaeological shell midden site at San Miguel Island, California (courtesy Jon M. Erlandson); Section of M. F. Maury's Whale Chart from the Gulf of Alaska, 1852; Photograph of a fisherman from Monhegan Island, Maine, with a large codfish in the 1880s (courtesy Robert S. Steneck).

Marine Ecology: Human Impacts on the Sea

Crossing system divides: broadening the biodiversity and ecosystem functioning debate



Thomas Davies

As an undergraduate student my enthusiasm for studying the natural sciences was almost exclusively restricted to the marine environment. This is perhaps unsurprising given that I was undertaking a degree in Marine Biology and Oceanography at the time. Since completing my undergraduate studies I have broadened my academic horizons by undertaking cross disciplinary postgraduate studies at masters and now doctoral levels. The culmination of my experience to date is that I would no longer consider myself to be exclusively a marine biologist, but first and foremost to be an ecologist.

In my PhD I am attempting to demonstrate a link between the extirpation susceptibility of species and their contribution to the functioning of key ecosystem processes such as primary production, nutrient cycling and organic matter decomposition. It quickly became apparent that such a broad theme deserved a broad experimental approach. I have therefore diversified my research by working on as many different marine communities as is practicable, including sub-tidal fouling communities, intertidal macroalgal communities and saltmarsh communities. This provides a broad spectrum of ecosystems in which to explore the role functional and phylogenetic diversity in the maintenance of ecosystem services. Indeed, I would expand my work into terrestrial ecosystems but for my time already being stretched.

The approach reflects the biodiversity and ecosystem functioning debate as a whole. It is just one example of how the collaborative efforts of marine, terrestrial and freshwater biologists can provide a stimulating environment in which to broaden our understanding of the mechanisms which shape the natural world. Yet the research efforts of terrestrial ecologists contribute disproportionately to the biodiversity debate. In one recent assessment Hendriks and Duarte (2008) showed that 72.3% of papers published on the subject of biodiversity between 1990 and 2004 were contributed by terrestrial biologists, while aquatic biologists contributed 17.3%.

Accepting that certain imbalances might be expected from a logistical perspective, this skewing in the literature appears to suggest a need for aquatic biologists to increase research output in these broader context areas. So why is this the case? There is little doubt that marine biologists took to the notion of biodiversity regulating ecosystem functioning with less enthusiasm than their terrestrial counterparts. Perhaps on the basis that this notion conflicts with the traditionally held perspective that resource availability determined biodiversity. However those historical divisions which reflect the boundaries between land, river and sea may also have inhibited the communication of ideas among terrestrial, freshwater and marine ecologists. In either case recent years have seen an explosion in the number of marine contributions to the BEF debate and any reservations which may have existed have been overcome. Much can be gained from marine research playing an integral role here. A huge variety of model ecosystems are available, representing a wide range of phylogenetic diversity. To add to this the marine environment is suffering from anthropogenic pressures at an accelerating pace on both global and local scales, and the need to quantify the consequences of biodiversity loss for our ecosystem services is increasingly urgent.

In 2007 I participated in an international conference where the majority of the conference delegates were from marine backgrounds. A small contingent of freshwater biologists presented their work in one freshwater biology session, despite the context of the work fitting in perfectly with other session themes in the conference. This is perhaps a reflection of our propensity to focus research according to particular habitats or species and that is no bad thing. Indeed our ability to conserve the environment would almost certainly be compromised if we all addressed only the broader ecological questions, leaving gaps in our specialist fields. But, on those broader themed questions, the collective knowledge of experts working in different ecosystems can provide greater context to the discussion and it is here that I think we benefit most by approaching the table first and foremost as ecologists.

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Application of ecosystem service valuation to policy and management



Stephen Mangi

Valuation of ecosystem services and change has become one of the most significant and fastest growing areas of research in environmental and ecological economics. One motivation for valuation studies has been to generate a better and more comprehensive information base for policy formulation and the decision making process. Such studies have used a variety of valuation methodologies to estimate values of the ecosystem services provided by marine biodiversity and indicate how these values change (e.g. Beaumont et al. 2008). These methods include economic valuation, socio-cultural valuation, biological valuation and the development of decision support systems.

Economic valuation methods are quantitative in nature and use both direct (market values) and indirect (revealed and stated preferences) techniques to express a utilitarian or instrumental value of direct and indirect use, or non-use value of an ecosystem service. Using direct market values to value ecosystem services is relatively straightforward since data are easily available and understood by the general public. However, direct market methods only assess the producer surplus and do not consider consumer surplus and other externalities. Revealed and stated preference techniques, on the other hand, estimate values attached to ecosystem services that are not directly tradable in markets. These techniques generate monetary values but are subjective as the values are based on good information and respondents' preferences.

Ecological valuation methods enable the development of a unified index of biological importance of marine biodiversity so that areas can be spatially mapped with an indication of their intrinsic value. This method is useful in informing decisions on the selection of areas to protect or locate various

infrastructure such that damage to valuable ecosystems is minimised. However, the intrinsic values obtained are not directly related to human welfare and arguments persist on whether this is a valuation method.

Socio-cultural valuation uses Q-methodology to analyse discourses resulting in the delineation of various stakeholder perspectives (Q Methodology is a research method used to study people's 'subjectivity', that is, their viewpoint). This method allows for similarities across stakeholder groups to be uncovered, increasing the likelihood of resource managers to see agreement or discord. This valuation method therefore provides insight on how various categories of stakeholders value ecosystem services, but does not generate spatially explicit indicators of value.

The values of ecosystem services generated from these methodologies have been used to inform policy and management of resources on their own or combined to produce decision support systems. Decision support tools support the decision-maker in making trade-offs and choices between resources and their use. The integration of the values obtained from the different valuation methods is an important element in the development of decision support systems. Approaches such as multi-criteria analysis are able to mix apples and oranges to help multiple stakeholders make trade-offs between their multiple objectives, needs and use of resources. Some decision-support tools have been developed for use in situations where there are limited data and the degree of uncertainty surrounding the data is substantial e.g. Bayesian belief networks. While these approaches overcome the uncertainty relating to the available data, considerable uncertainty remains about the outcomes of the models and the models themselves. Further, it has been a challenge to integrate the various valuation methods in decision support systems to effectively inform policy measures. More research is needed to explore how the different valuation methods can all be captured in decision support systems.

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How much for a pound of nature?



Odette Paramor

Trying to describe the relative merits of intertidal mudflats to friends and relatives has always been difficult. They never seemed to get past the fact that mud smells, it gets them dirty and when I've taken them out to help me with fieldwork, it also has a mildly amusing habit of retaining their wellies...

Recently though, I have been involved in a study which used an economic approach to place a value on marine habitats, including mud, in terms of the 'ecosystem services' they supported. These types of studies are continually being touted as a way of allowing non-scientists to understand the 'worth' of nature and to allow politicians, policy makers and managers to compare the value of some of the more unprepossessing (and inedible) habitats and species with variables they are more likely to understand such as employment figures and the monetary value of a harvest.

Since Costanza *et al.*'s famous 1997 *Nature* paper in which the global value of ecosystem services was estimated at $\$33,268 \times 10^9 \text{ yr}^{-1}$, the use of environmental economics has been employed to address important global matters such as climate change (Stern Review, 2006) and other issues likely to affect human well being (UN Millennium Assessment, 2005).

However, compartmentalising nature into the 'ecosystem services' and assessing the value of those services in monetary terms is an uncomfortable concept for many ecologists. Strong arguments have been made that it 'commodifies' nature and that nature conservation should be a moral, not an economic, issue. In the mean time, there have been some spectacular cases of management failing to protect anything at all, neither nature nor society, so perhaps it is time actively to engage with politicians and the governance system in terms they actually want and understand.

The evaluation of natural systems in monetary terms is still a bit of a pioneer zone though. There are heated debates about the methodologies, interdisciplinary teams always take a while to figure out what its various component disciplines are actually taking about, and this all occurs in the face of colleagues who view your work with suspicion because it does not feel quite right to put a pound sign in front of their favourite animal/plant/habitat.

The study my colleagues and I did with the Environmental Economics group at the Scottish Agricultural College evaluated the economic benefits of introducing various networks of marine conservation zone to offshore UK marine waters compared to the existing management system (Moran *et al.*, 2008). We were funded by Defra. The numbers we came up with were enormous. We estimated that the added value of introducing networks of marine conservation zones ranged from between £8.7 billion and £19.3 billion! Our study has gained a great deal of interest from various government bodies, including the European Parliament, and there is obviously a strong demand to further develop this type of interdisciplinary collaboration in marine systems.

But what do these collaborative ecology-economics studies mean in practical management terms? For the moment, they do not impact on the day to day management of human activities in marine systems, but given the high level of interest from the people involved in government, it seems likely that they will play a role in the future. For this to happen, the ecological science to support these studies needs to be advanced massively. How do we measure ecosystem services at regional scales (and well beyond the scale of a laboratory)? How is their delivery affected by different human activities operating at different intensities?

A few approaches have been developed to measure ecosystem services at the larger spatial scales. These range from a simple measure of the service itself (e.g. nutrient recycling) to using a more sophisticated analysis of the biological traits of the biota present and inferring how these traits may affect the delivery of services.

Measuring the service itself will produce maps which will allow us to identify which areas are important for the delivery of that service. It will not provide any information on the underlying processes (or functions) involved in the delivery of the service or how human activities may affect its delivery. These are the really chewy science questions we need to address.

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One of the more promising approaches is the use of biological traits analysis which was developed in freshwater systems but which my colleagues at the University of Liverpool have been applying to marine systems for the last decade. It uses very detailed information on the life history, physiology and behaviour of biota and does go some way to investigate the ecological basis for the delivery of ecosystem services.

We have used this traits approach to investigate how fishing affects the functioning of benthic systems (Bremner et al., 2003; Paramor and Frid, 2008) and how it could be used to delineate Special Areas of Conservation (Frid et al., 2008). It is not perfect but it does attempt to show the direct link between the biota and the services they support.

Considering that there is so much interest from government quarters in developing ecology-economics collaborations, it has become increasingly urgent that we focus attention on the ecological science required to do these studies. It is a rapidly developing area and whilst we will often be working outside of our comfort zone, it is essential if we are to engage with future government policy.



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Giving proper feedback on overseas research: No lack of interest



Lizzie Tyler

When I arrived in Tanzania to conduct my PhD fieldwork I discovered that the marine park ranger assigned as my research assistant did not know how to SCUBA dive or want to learn. After asking around the local institution I found that in a country with nearly 4000 km² of coral reef, there were less than ten people trained to conduct underwater reef fish surveys using SCUBA. Despite wooing one of the best of these to work with me, he was in such high demand that I

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was left stranded mid-way through my first field season. With data collection pressures in mind, I simply flew out UK field assistants for my next two seasons.

Do we all start with good intentions to involve local people in our overseas research and then find the process too difficult under scientific pressure? In an ideal world, developing countries would conduct their own research programs. However, the startling difference between developed and developing countries in scientific funding, resources and expertise might lead many of us to believe that we should help to decrease this gap whilst enjoying access to the resources and organisms in developing countries. During my PhD, it was clear this wasn't being done. But given some of the difficulties I encountered, combined with lack of pressure from my host institution, I was not surprised.

It seems I am not alone. From a quick poll of ten researchers in the Animal and Plant Sciences department here in Sheffield, seven thought that the level of feedback from visiting researchers was 'not as good as it should be' (my wording) in the countries in which they worked (in Africa and South and Central America).

So what sort of feedback should we provide as visiting scientists? Actions that were achieved by most of these ten people included: Having a local research collaborator (8 people), sending back copies of papers or theses (7), employing local research assistants (7), leaving behind equipment or resources after a project has finished (7), giving a talk to the local institution (6) and co-authoring papers with a local collaborator (5). Interestingly, of these, the highest number of people thought that employing local research assistants was 'important, but not happening' (7).

It can be difficult to provide feedback. A lack of trained local researchers (4), bureaucracy at the country-level (beyond local institution) (3), lack of trained local research assistants (2) and lack of organization in the local institution (2), were limiting factors chosen by my ten respondents, who went on to add language problems, high turnover of staff, bad infrastructure, running out of time, lack of funding after a project has finished and lack of incentives to encourage such interactions.

What a list of challenges! Many of which are outside the hands of visiting scientists. But given that a lack of trained local researchers was the most common limiting factor and not employing local research assistants was the most

common omission, greater interaction between local and visiting researchers would surely help to alleviate this.

How can we encourage scientists to provide better feedback to host institutions? Funding bodies for medical science have stringent ethical guidelines. Should funding bodies for ecological science have similar guidelines for working in developing countries? Would these take the form of good practice procedures that could be adapted to suit a particular project or host institution or should certain actions be mandatory? I certainly believe something as basic as sending back copies of all the papers or theses produced from a project could be, yet even this was not always being done for my host institution in Tanzania.

Two of my ten-person team rightly pointed out that visiting researchers should not just prescribe, but ask local partners what they can do and think of it more as collaboration, rather than feedback. Certainly, it would be better if host institutions developed their own guidelines for visiting scientists. But in the absence of these, I believe we can do more than we are, and since 'lack of interest from local institutions or researchers' received a big fat zero as a limiting factor in my highly replicated and well designed questionnaire, it is worth a try.

Thanks to Tom Webb for encouraging me to submit an article, the ten people in APS who answered this questionnaire and Simon Queensborough for comments. I would be interested to discuss this topic further, please contact me on e.tyler@sheffield.ac.uk

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Marine Ecology: Field Notes

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Callum Roberts Palau



There are some places in the world that exert a mysterious grip on the imagination. Places that you find yourself returning to again and again in your mind. The Republic of Palau is such a place for me. Palau stands alone at the edge of the western Pacific Ocean. The Philippines, 800 kilometres west, are its nearest major landfall. It comes as little surprise then, that Palauans have a close affinity with the sea. In the 1970s Bob Johannes, at the time a mid-career fisheries scientist, spent several years working with Palauan fishers and was astounded at their detailed knowledge of fish life and habitats. His book, *Words of the Lagoon*, brought their understanding to world attention. It is the lagoon and its hundreds of exquisite 'Rock Islands', strewn like emeralds upon an aquamarine sea, that first captured my attention on the descent into Palau's airport.

I visited Palau in 1992 to count fish as part of a study of global differences in species packing on coral reefs. In terms of marine biodiversity, Palau lies just on the margin of the global centre of maximum species richness for reef organisms. Having most recently been fish counting on comparatively low diversity Caribbean reefs, counting fish in Palau came as a shock! I had used the stationary point count method in the Caribbean in which for a period of 15 minutes I would count fish within and passing through a 10m diameter cylinder of water. I noted each fish species seen on an underwater slate and estimated the number of animals present. On a Caribbean reef my lists typically reached 20-35 species in 15 minutes. Counting fish there was relaxing and by five minutes into the count you entered a wonderful state of calm in which it felt like you could leave the counting to your subconscious and the rest of your mind was free to enjoy the dive.

In Palau, I spent my counts scribbling furiously to try to keep pace with the throngs of fish that swirled about me. The abundance of fish was on average slightly higher than Caribbean reefs but the major difference was in variety. Where in the Caribbean I would count tens to hundreds of individuals of the same species, in Palau, it seemed at times as if every fish was different. By the end of 15 minutes my board was a blaze of abbreviated Latin and sketches of species I had not seen before. Most counts I went above 80 species, and in some reach 100. With around 1300 different species of fish in all, there was never time in Palau to tune out while counting and contemplate life.

Julie, my wife, unconstrained for once by the demands of science, was free to wander off and enjoy the reef as I struggled to comprehend the astonishing richness of fish. She was never alone for long, as Palau is a place that still has plenty of sharks, some of them large and decidedly curious. I still remember her swimming back to me goggle-eyed with fear having been buzzed by a huge shark and frantically gesticulating that I should stop counting and end the dive. Absorbed as I was in a count, I seem to remember thinking that she was just enraptured by the splendours of this reef. I waved briefly and suggested by gestures that she enjoy the reef in the other direction. Perhaps she sent the shark back to buzz me as well, but without the leisure to bother with anything more than five metres away, I didn't notice.



*Julie Hawkins
recovers from her
shark encounter
on Rock Islands,
Palau*

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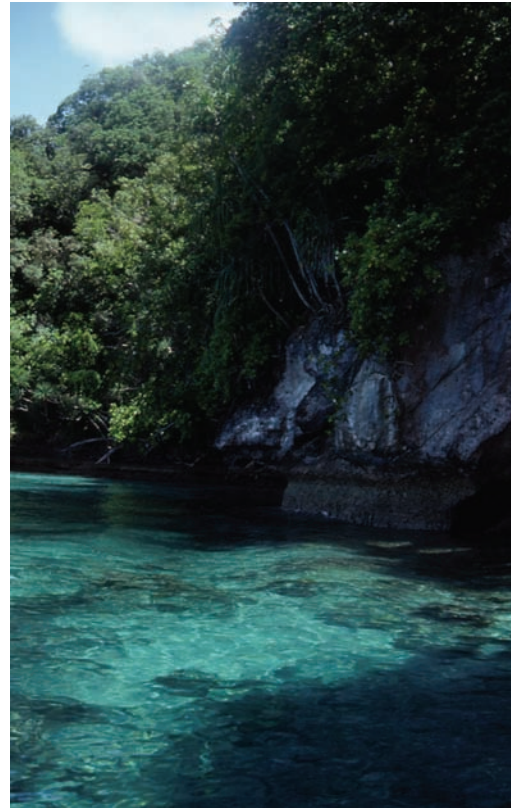
The demands of fish counting sometimes set you at odds with the sea. We were dropped onto the reef at a place called Ulong Channel one day, where a pass runs between lagoon and outer reef. There was a light current but nothing untoward, and I set up for my first count. By the second, the current had grown to the underwater equivalent of a hard blow. By the end of the third count, my mask was almost being torn from my face. Sensible people do Ulong Channel as a drift dive, and when Julie and I finally let go from my 'stationary' counts, we hitched a thrill ride into the lagoon on the flood tide.

Palauan reefs were magnificent and still are. We mostly dived along the western drop off. Getting there was better almost than the dives, certainly as wonderful. The boat left the capital city Koror early in the morning and we threaded our way among a maze of hundreds of limestone islets. The Rock Islands are the eroded remains of Miocene coral reefs exposed by coastal uplift. Thousands of years of weathering have left them pitted and craggy. The boat weaved its way among bleached rock cliffs sometimes blinding in the sunshine, at other times shadowed in hues of deep green and blue from the sea. The islets are capped with verdant forest and scrub. Some fifty of them have enclosed salt lakes, connected to the sea through a network of limestone cracks and passages. Each supports a unique ecosystem, assembled through processes of dispersal and chance. Perhaps the most extraordinary are the five jellyfish lakes. High nutrient levels and an absence of predators combine to allow jellyfish to reach incredible abundance. The water is thick with them and the experience of snorkelling in a lake surrounded by pulsing jellies unforgettable. Isolated from surrounding waters, the jellyfish in these lakes are slowly evolving in distinct ways.

Palauan reefs suffered a setback in 1998 when high ocean temperatures caused widespread coral bleaching and mass mortality. I understand from recent visitors that they are on the mend. Certainly Palau's reefs have benefited from the wisdom of the nation's inhabitants. President Tommy Remengesau issued the 'Micronesia Challenge' in 2005 calling on fellow Pacific Islands and more far flung nations to safeguard 30% of their coastal waters and 20% of their land area in protected areas by 2020. Palauans are well on their way and now have many marine protected areas in which fish and corals will hopefully continue to flourish.

Palau continues to inspire me in my work to gain protection for the world's seas. We in Europe have much to learn from their wisdom grown over thousands of years living by the

water's edge. In a nutshell, you can't eat fish if there are none in the sea, and there won't be much to catch if you don't care for their habitats.



*Rock Islands,
Palau*

Callum Roberts is Professor of Marine Conservation at the University of York. His research focuses on threats to marine ecosystems and species, and on finding the means to protect them. His latest book, *The Unnatural History of the Sea*, charts the effects of 1000 years of exploitation on ocean life. It was chosen by The Washington Post as one of their Best 10 Books of 2007 and won the Rachel Carson Environment Book Prize of the Society of Environmental Journalists in 2008. Callum is a Pew Fellow in Marine Conservation and winner of the Marsh Award for Conservation Biology. Web link: <http://www.york.ac.uk/res/unnatural-history-of-the-sea/>

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Ship's Log: Plankton, dust and bugs

Martin Angel



One of the black crickets *Gryllus bimaculatus* on the RV *Polarstern*

In November 2007 I was aboard the R.V. *Polarstern* which had left Bremerhaven to steam south to service the German Antarctic station. I was part of an international team of taxonomists with the mission to collect a series of very deep net tows under the aegis of the Census of Marine Zooplankton (www.cmarz.org). This programme has the ambitious aim of collecting all holoplankton species from the world's oceans by 2010 and to bar-code as many species as possible. Such is the state of global taxonomic expertise that the majority of those capable of identifying live bathypelagic and abyssopelagic zooplankton species are well past retiring age, and almost past their sell-by date.

On the morning of 8th November we were about 200 miles away from the Cape Verde Islands and well offshore of the African mainland. It was extremely hot and humid on deck. Visibility was down to a hundred metres and the air was foetid. Underfoot the decks were crunchy, thanks to a covering of fine dust. Were my eyes deceiving me, or was a grasshopper hopping across the deck? Then there was another and another and another. During the next day, vast numbers of insects continued to land on the ship, providing useful snacks for several land birds, which had joined at much the same time. The variety of insects was quite amazing. Several varieties of hawk dragonflies quartered the deck, and there were various species of the less powerfully flying damselflies. There were at least three species of butterfly, a host of different plant bugs and a large and spectacular neuropteran, as well as several desert locusts and many large black crickets *Gryllus bimaculatus* which scuttled across the deck. These last I had encountered at sea before.

In February 1972 RRS *Discovery* was working even farther offshore, about 500 nautical miles, and was boarded by hoards of these crickets. They caused quite a problem because they hid in every nook and cranny on the ship and

all night produced an ear-piercing cacophony of noise. The night watch-keepers were unable to sleep and there was nearly a mutiny. When we fished neuston nets (nets that sample the upper 10cm of the water) at night the lantern fishes (myctophids) we caught that had migrated up from daytime depths of 500m or so were gorged with crickets. Indeed, when we sampled these and other non-migrant fishes during the day at mesopelagic depths, their guts, too, were crammed with remains of the crickets.

So are our current organic flux studies in the deep ocean missing a trick? Probably in most oceans such events either do not occur or have a negligible impact. But in the North Atlantic oligotrophic gyre, might terrestrial exports of organic material be having a significant impact on the dynamics of the midwater ecosystem? A colleague recounts that when he was sampling off the eastern seaboard of the States in the 1960s, he encountered a similar phenomenon with swarms of ladybirds (but perhaps such events will have changed now the North American populations of 'ladybugs' have been largely replaced by harlequin ladybirds from Asia).

As a consequence of this cricket event I was designated to run suction traps at sea to sample what Alister Hardy had termed 'aerial plankton', but all I caught was soot particles from the ship's funnel! At the time the entomologists at the Agricultural Research Station at Rothamsted were actively engaged in tracking insect migrations; annually swarms of aphids arrive in the UK, which have been blown in from Europe and cause substantial damage to British agriculture. Movements of locusts have been of importance since biblical times, and still cause considerable damage to crops in sub-Saharan Africa. Maybe the recent increases in grain prices will rejuvenate interest in such migrations by insects.

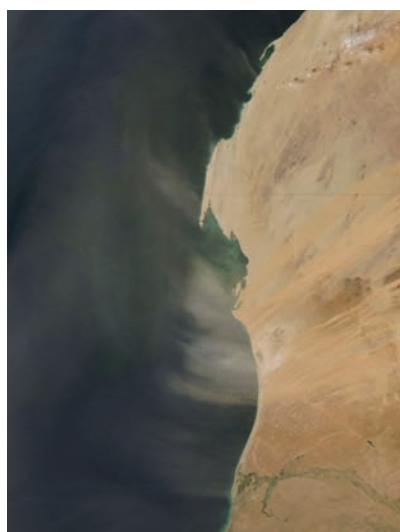
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Massed bugs on deck

Wandering around the decks of the *Polastern I* collected as many different types of insect as I could find, and soon accumulated over thirty species. In places on deck the corpses of thousands of plant bugs had to be hosed away by the crew to get the decks clean. The importance of Saharan dust events in increasing primary production in the North Atlantic by supplying iron has been well documented, and indeed our phytoplanktonologists observed a peak in surface chlorophyll coincident with the dust. But it is not only oceanographers who are actively interested in these events. The dust clouds cool the surface of the Atlantic, and hence reduce the frequency of Atlantic hurricanes. They are easily seen by Earth-observation satellites and our event was well mapped by the Total Ozone Mapping Spectrometer (TOMS). Images of the dust cloud over the Cape Verdes are available on the web on the Earth Observatory and Natural Hazards website (http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php?img_id=14619).



Satellite image of the dust storm off the west coast of Africa. Image courtesy of MODIS Rapid Response Project at NASA/GSFC

On the same website is an image taken on 7 November of extensive agricultural burning in Senegal and Mali, no doubt the foetid smell we experienced at sea came from these fires, which were contributing to the export of all sorts of 'interesting' chemicals. The same sensor also mapped locust swarms moving across the Sudan – could our locust have originated from much the same source? The dust was reported arriving in Guadeloupe on the 11th November where it persisted for four days and clogged the intakes of overflying aircraft. Saharan dust is thought to be an important source of nutrients for the Amazonian rain forests. Estimates of the quantities that are being transported annually range between 250 and 500 million tonnes, and over half is reported to come from a single location, the Bodélé Depression close to Lake Chad - with erosion at such a rate it is hardly surprising that it comes from a depression. The winds that give rise to such events are named as Harmattan winds, which carry fine mineral particles which induce respiratory and heart disease, these winds are considered important contributors to the 'African Burden of Disease'.

We observed a peak in surface chlorophyll coincident with the dust event. The North Atlantic is not iron limited because of inputs of Saharan dust, so should those who are conducting iron fertilization experiments pay greater note of the phrenology of these natural events? They occur over a far greater spatial scales than can be achieved in experimental fertilization experiments, and so offer much greater opportunity for understanding the longer-term and larger-scale impacts of such fertilization. Such observations will be particularly relevant in the context of commercial proposals to use iron fertilization of the open ocean as a way of off-setting carbon emissions.

Martin Angel 'retired' in 1997 after working at the Institute of Oceanographic Sciences and the Southampton Oceanography Centre (now the National Centre for Oceanography) for 32 years, eleven as head of the Biology Department at IOS and 25 as co-editor of the *Progress in Oceanography*. He has since returned to the study of the systematics and taxonomy of halocyprid ostracods.

The British Ecological Society

Founded in 1913, the British Ecological Society is the oldest society of its kind. The BES has 4000 members around the world, including research scientists, environmental consultants, students, conservationists, teachers, local authority ecologists and many others with an active interest in natural history and the environment.

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