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The maps and diagrams were drawn by The ArtWorks.
The cover was designed by Ann Aldred Associates.
On the cover, the photograph at top-right was taken by Phil Williamson, and won the President's Photographic Prize ar the 2008 Challenger Society Conference in Bangor.

Message from the Editor

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A future for sea fisheries?

Sidney Holt

An Icelandic professor of economics, and two fishery scientists, each from the Department of Fisheries and Aquaculture of FAO, Rome, and the Agriculture and Rural Development Department of the World Bank, Washington DC, have made a remarkable attempt to estimate what the global biologically sustainable catch of wild marine fishes and shellfishes would be if biomasses of all stocks were brought – by adjusting fishing effort – to levels of maximum economic yield (MEY); in their terms, the 'EY' is the difference between the market value of the entire catch and the cost of taking it. Phew!

Ragnar Arnason, Rolf Willmann and Kieran Kalleher, backed by the two prestigious international organizations, have courageously attempted the near impossible, with impressive results. Their work has been published by the Bank as a booklet with a clever cover (fish images conjured from bank-notes) – under the striking title *Sunken Billions: the Economic Justification for Fisheries Reform*. Their first conclusion is that the present global recorded landed catch of about 100 million tonnes is worth about 5 billion dollars less than the cost of taking it – hence the current need for subsidies. Their second conclusion is that if over-fished stocks were allowed to recover, and the few remaining under-fished stocks fully exploited, a sustainable MEY catch of around 80 million tonnes could be taken with about half the present fishing effort and with a net profit of about 50 billion dollars/year. Wouldn't that be nice!

There are some snags. One is that the authors assume that resource depletions are perfectly reversible when fishing pressure is relaxed. Some scientists doubt that, particularly with respect to the species composition of the exploitable marine biomass – large species being replaced by smaller ones (so-called 'trophic cascades'), jellyfish replacing anchovies, and so on. Still, reversibility, might not be an unreasonable starting assumption; we have many examples now of stock recoveries.

Another snag is that the authors assume that the discount rate for investment in vessels, etc. (i.e. the interest rate a central bank charges depository institutions that borrow reserves from it) is zero. Ever since the Canadian economist–mathematician Colin Clark demonstrated the consequences of non-zero discount rates on the exploitation of renewable resources (for instance he showed it could even be economically optimal to exterminate whales) we have known that such an assumption leads to over-optimistic results. So, with non-zero discount the 'sunken billions' could be fewer than the Bank and FAO suggest, other things being equal. Ah, there's the rub – they're probably not equal. Let me try to explain.

Estimating the costs of fishing is pretty straightforward, though tediously complicated. I'm not competent to comment on it, but I recommend that others, more competent, look closely at the methodology. However, estimation of the present states of wild fish stocks and of how they might be expected to respond, overall, to changes in the fishing regime is intellectually extremely challenging. I have made a first critique of the Bank/FAO approach which has been published in the April 2009 issue of *Fisheries Science,* entitled 'Sunken Billions: But how many?' I have reached different conclusions: First that the MEY could well be *bigger*, not less, than the current catch, and could be taken with *less* than half the present effort. That means that the 'sunken billions' could be substantially more than the 50 billion dollars/year estimated by the Bank/FAO authors. My conclusions are of course tentative, and I haven't yet done all my homework. So I'm more optimistic than The Bank/FAO – I think that optimizing managed fishing to secure MEY might result in a bigger global catch than at present, as well as a sustainable one.

Their conclusions – and at this point mine too – rest on an assumption that the rate of increase of the total biomass of traditionally exploited kinds of living marine resources (i.e. it's assumed that we shan't all become krill-eaters) – is a simple density-dependent function of the total biomass. Arnason, Willmann and Kalleher make two alternative assumptions using the Pella–Tomlinson equation employed in many fishery assessments. One is the simple 'logistic', S-shaped curve with the biomass level for MSY being 50% of the biomass before exploitation began ('carrying capacity') and the other is with the sigmoid curve skewed, and MSY at 37% of carrying capacity. But researchers have commonly believed that the MSY biomass level might be significantly *higher* than 50% of carrying capacity. This is all a bit 'number of angels on the head of a pin' stuff, but still it's fun looking at the possible consequences of different versions of the angels' dance. The relative beauties of symmetry or skewness may be said to be in the eyes of the beholder.

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The next step is to scale the adopted Pella–Tomlinson model – that means essentially estimating the MSY from data. The Bank/FAO authors adopt FAO's conclusions that 25% (by number of stocks) of all currently exploited stocks are over-fished, even depleted, though some might be recovering under more enlightened management; 50% are being 'fully utilized' and the remaining 25% are under-exploited or moderately exploited. With some sleight-of-hand our authors conclude that the present reported global catch is roughly the same as the MSY of the ocean biomass – that is, at the inflexions of the Pella–Tomlinson curves.

I think they are wrong, for several reasons. One problem is that very large *unreported* catches have not been taken into account. The Bank/FAO authors realize this but feel unable to take it into account because of the uncertainties in the data. Unreported catches are thought by some researchers to be at least half as much again as the reported ones. Another problem is that the FAO statements about percentages of fisheries in certain states refer merely to the *numbers* of stocks, but some stocks are enormously bigger or more biologically productive than others, and the bigger and smaller ones are not evenly distributed among FAO's three categories. For instance, more of the biggest are probably in the over-exploited or fully utilized categories than in the under- or moderately exploited collection.

It is perhaps worth saying that successful efforts to reduce global fishing effort substantially will surely have the side-effect of proportionately reducing incidental killing and injuring of non-target species, some of them listed as 'endangered' – such as whales and dolphins, seals, turtles and seabirds – as well as young fishes.

Whatever the dynamics of this great ecosystem, it is clear that returning to a more productive overall state will be painful, economically and socially, and must entail some risk that our assessments might be substantially in error. The Bank/FAO authors have only touched lightly upon the assessment of options for a transition from a generally poor state to an optimal one. Some computer simulations of transition scenarios must obviously be done if this approach to global fisheries policy is to be pursued. The Bank/FAO authors' approach is not an alternative to trying to make/keep fisheries for cod, herring, tunas, plaice etc. productive, but tries to put that diversity into a comprehensive perspective. It gives a view of the question: is it worth trying to manage fisheries for high sustainable production of human food, or must we accept – as I think many people are beginning to think – that sea-fishing will in a few decades or maybe a century become a historic curiosity?

I am corresponding with a specialist group of scientists about the next steps to be taken, and any interested readers are invited to join the 'conversation'. My *Fisheries Research* paper is available in digital form (pdf) so anyone seriously interested in this exercise without ready access to that journal can email me.

Sidney Holt is well known for his seminal work with Raymond Beverton on the theory of fishing. Now, in retirement, he wears many hats, but is currently Adviser to a UK charity, Global Ocean. Email: sidneyholt@mac.com

News and Views

Sea-level, shelf seas and CO_2

As the last glacial period ended, and the ice-caps began to melt, sea-level rose and the continental shelves were increasingly flooded. This had the effect of expanding the scope of the biological pump, whereby carbon dioxide taken up by phytoplankton may 'exported' to deeper waters in organic debris, and so removed from contact with the atmosphere. It is thought that that much of the carbon is eventually carried into the neighbouring deep ocean (below the thermocline) in cold dense water flowing off the continental shelf – the overall mechamism is known as the the 'continental shelf pump'.

As coastal waters are well supplied with nutrients from the land, it might be thought that all temperate shelf seas are areas of net uptake of CO_2. This is indeed the case for waters that are deep enough to become seasonally stratified as a result of warming in spring and summer, but areas that are well-mixed all year are observed to be sources of CO_2 to the atmosphere. Thus the deeper northern part of the present-day North Sea is a significant carbon sink, whereas the shallower southern part, which is well-mixed from top to bottom all year, is a weak source.

In a recent modelling study, researchers from Bangor and Kyushu investigated how the uptake of CO_2 by shelf waters in the north-eastern Atlantic changed during the first 21 000 years of the present interglacial period. The models had to take into account the changing areal extent and topography of the growing submerged area (complicated by the fact that as the ice-sheets melted, the land-masses and continental shelves experienced isostatic rebound).

In shelf seas, tidal currents provide ~95% of the energy for mixing, with winds playing a only a minor role. Tidal velocities generated by the palaeotidal model were used to determine the positions of tidal mixing fronts between stratified and well-mixed shelf waters. Perhaps surprisingly, comparison with modern situations showed that the influence of meltwater/ice cover did not affect the ability of the model to predict positions of the tidal mixing fronts. Furthermore, changes in the positions of fronts over time were supported by palaeodata, such as foraminiferal assemblages in shelf sediments.

Significantly, the modelling studies showed that as water levels rose, and the positions tidal mixing fronts moved, the area subject to seasonal stratification increased proportionately faster than the area of shelf sea as a whole. While this recent work confines itself to considering the effect of increasing shelf areas since the last glacial period, it suggests that flooding of shelf seas should not be ignored in predictions of what will happen to atmospheric CO_2 concentrations as sea-level continues to rise. At present, about 80% of the shelf waters off north-western Europe are seasonally stratified, and this percentage will grow as sea-level rises.

See Rippeth, T.P., J.D. Scourse, K. Uehara and S. McKeown (2008) *Geophysical Research Letters*. **35**, L24604, doi: 10.1029/2008GL035880.

US may ratify UNCLOS

The UN Convention on the Law of the Sea (UNCLOS) was concluded in 1982, and came into force in 2004. At the present time, 157 countries and the EC are parties to the Convention. Amongst the 22 countries that have signed but have yet to ratify the Convention is the US, but the tide of opinion in the Senate is changing.

The US already generally acts in a way consistent with the Law of the Sea (see pp.23–31) but some US legal experts worry that, without ratification, the US will lack influence on the ongoing codification of maritime law. Furthermore, American businesses want legal certainty so they can compete with foreign companies for marine resources, and the US military is looking for a guarantee of safe passage through all seaways.

However, opponents to UNCLOS fear that it could force the US to comply with as yet unspecified environmental codes, and some regard the International Seabed Authority's aim to distribute access to/profits from sea-bed resources as 'communistic'.

Are there seal-like mammals yet to be discovered?

Most biologists consider that all extant marine mammals have been scientifically described, but a recent article in the journal *Historical Biology* suggests that as far as pinnipeds ('wing-footed' animals) are concerned, there may well be a small number of species as yet undiscovered.

Modern-day pinnipeds – seals, sealions and walruses – are found worldwide, in tropical, temperate and polar latitudes, in the open ocean and in coastal seas, and even in land-locked lakes (e.g. Lake Baikal). Altogether, 36 species have been identified, in 18–21 genera (depending on the favoured taxonomy). These fall into three groups: the so-called 'true seals', which are sausage shaped and have visible earholes (the Phocidae); the 'eared seals' – fur seals and sealions, which have ear flaps, and are generally more slender and more mobile on land (the Otariidae); and the walrus and its extinct relatives known only from the fossil record (the Odobenidae).

Despite their wide-ranging distribution, at first sight it seems unlikely that any seal-like animal would remain undiscovered in the 21st century, not least because, as marine mammals, they breathe air and therefore frequently need to come to the surface. Furthermore, they are very noisy, and all known species rest, moult and/or give birth on land. However, since 1900, no less than eight species of pinnipeds have been scientifcally described for the first time – though it should be said that most of these have turned out to be synonymous with other species or were known about before the 20th century. Three that were definitely described for the first time post-1900 are the Galápagos fur seal, *Arctocephalus galapagoensis*, the Galápagos sealion, *Zalophus wollebaeki*, and the Hawaiian monk seal, *Monachus schauinslandi,* described in 1904, 1953 and 1905, respectively.

Even larger marine mammals have come to light during recent times. The Lesser beaked whale, *Mesoplodon peruvianus* (also known as the Bando-lero beaked whale, or Peruvian whale) was described in 1990 on the basis of a skeleton and a rotting carcass; interestingly, prior to that there had been 20–30 sightings of a kind of whale now believed to be the same species. Perrin's beaked whale (*Mesoplodon perrini*) and Omura's whale (*Balaenoptera omurai,* a close relation of the Blue whale) were both discovered during the late 1970s. These events, combined with the discovery of the 5–6 m Megamouth shark in 1976 (plus another possible new species of large shark in 2004), and the Indonesian coelacanth in 1998, do indicate that it is possible for large marine vertebrates to remain hidden even in today's increasingly crowded ocean.

Challenges for cryptozoologists

Cryptozoologists aim to clarify the identities of organisms that are known only theoretically – e.g. anecdotally or through cultural/historical references or through some other indirect way (or some combination or those). The term cryptozoology was coined by the Belgian zoologist, Bernard Heuvelmans, known as the Father of Cryptozoology.

There are obvious problems in describing/identifying animals that at best have been seen only briefly, and whose details have been recorded as quick sketches, often from memory, or as poor photographs. Even when newly found animals can be closely observed, it can be hard to determine their relationship with known species. Species believed to be newly discovered may in fact already be known about, with the 'new species' perhaps being a juvenile or a differently coloured variant. In some cases, the newly observed species is eventually classified as subspecies of an existing species; this was the case for the fur seals *Arctocephalus doriferus* (described in 1925) and *A. tasmanicus* (described in 1926) which are now considered to be subspecies of the Australian fur seal, *A. pusillus*, named in 1775.

Choosing taxonomic names is in itself problematic, as without a specimen of the animal to examine closely, its characteristics and taxonomic relationships to other known animals cannot be determined, and applying the detailed rules laid down by the International Commission on Zoological Nomenclature is problematic. Heuvelmans proposed that scientific names of putative new species be dealt with in the same way as the names of animals known only from their trace fossils (footprints or other marks) in the geological record.

Sadly, questions of identification are sometimes intimately related to ongoing extinctions, with some species going extinct before their status as a separate group has been determined. It has recently been established genetically that the Japanese sealion (named *Zalophus japonicus* in 1866) is a separate species from the closely related Californian sealion and Galápagos sealion. The Japanese sealion was effectively hunted to extinction in the 1950s – it is possible that individual animals have been sighted since, but they may be juveniles or escaped Californian sealions.

Despite the continual addition to the tally of known species, cryptozoologists struggle to be be taken seriously, and tend to be regarded as 'on the fringe' by most mainstream scientists. Scientific discussion of the subject is hampered by the fact that although there is a lively sharing of ideas within the community of cryptozoologists (particularly via the internet), articles rarely appear in peer-reviewed journals. The journal *Cryptozoology* published peer-reviewed articles until 1996 but is now defunct.

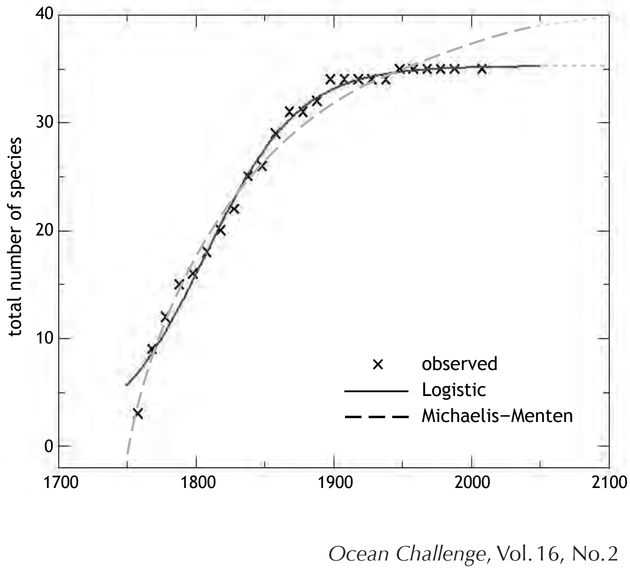

Figure 1 *Plot showing the cumulative increase in described pinniped species over time, along with two fitted regression curves. The full line is a logistic curve, the dashed line is the Michaelis–Menten curve; dotted lines are extrapolations (see text). (This method cannot be used for species-rich groups like sharks, where the points would show a lot more scatter.)*

Statistical approaches

In their recent *Historical Biology* article, Michael Woodley and colleagues use statistics to estimate the rate of discovery/description of new pinnipeds. They fitted two different theoretical regression curves to a cumulative plot of numbers of newly described pinniped species over time (Fig. 1). The curves attain a near-plateau where the likelihood of further discoveries has not yet become statistically negligible. By extrapolating this last part (dotted in Fig. 1), and determining the difference between the current number of species and the number corresponding to the eventual flat part of the curve, they could estimate the number of species yet to be discovered.

The two curves fitted are known as the Michaelis–Menten function (often used in descibing the kinetics of enzymes) and the logistic (S-shaped) regression. The former suggested the presence of as many as 15 new species, and the latter a number closer to zero. In fact, neither curve fits the data perfectly, and the prediction from the Michaelis–Menten curve is considered an overestimate. On this basis, and bearing in mind the observational/anecdotal evidence, the authors consider that there may well be a small number of pinnipeds yet to be discovered.

Similar analyses of discovery rates of larger marine animals, including cetaceans, all concluded that at least ten large marine animals await discovery, with the upper limits from some analyses being 15, 16 or even 51.

Some possible 'hidden' pinnipeds?

Perhaps the most well known kind of 'cryptic' animal is that with a long neck and other traits reminiscent of plesiosaurs – the most famous of course, being 'Nessie'. Most people assume that Nessie and her cousins are reptilian, but for these animals Heuvelmans proposed the name *Megalotaria longicollis,* which means 'big sealion with long neck'. A good proportion of the 48 sightings that he regarded as 'certain' related to animals with pinniped characteristics, including the presence of hind flippers, fur and a dog-like head with whiskers. Interestingly, some pinnipeds known only from the fossil record had a much greater resemblance to plesiosaurs than do modern pinnipeds (e.g. in the case of the 'swan-necked seal', *Acrophoca longirostris*, the neck made up ~20% of the vertebral column).

Whereas *Megalotaria longicollis* is based on sightings alone, a number of mysterious animals thought to be pinnipeds have been identified on the basis of remains. For example, in the 18th century, a 'long-necked seal or sea calf',

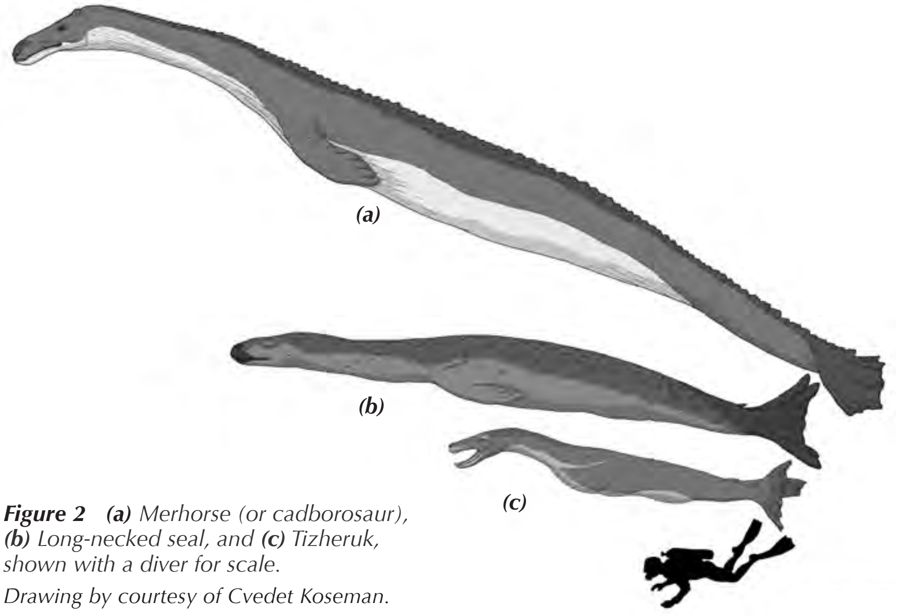

Figure 2 ***(a)*** *Merhorse (or cadborosaur),* ***(b)*** *Long-necked seal, and* ***(c)*** *Tizheruk, shown with a diver for scale.*

Drawing by courtesy of Cvedet Koseman.

with an otter-like head, was considered to have been observed in 'diverse countries' (Fig. 2(b)).

Merhorses – so named because of their horse-like head, long neck and, often, a mane – have a much longer pedigree, and have been alluded to since ancient times. Heuvelmans believed merhorses – which he named *Halshippus olaimagni* – to be a kind of pinniped.

In 1987 William Hagelund published *Whalers No More*, a book in which were reproduced some intriguing photographs taken in 1937 on a whale flensing platform at Naden Harbour, Queen Charlotte Islands, Canada. These photographs show an unusual long-bodied carcass, reportedly recovered from the stomach of a sperm whale. The carcass appears to be of an animal with an elongate body, a long head (somewhat camel-like) and a symmetrical fluked tail with a central series of knobs that appear to correspond to vertebrae. There appear to be pectoral flippers.

In 1995, Canadian marine scientists Edward Bousfield and Paul LeBlond formally described this animal as a new species, *Cadborosaurus willsi* (Fig. 2(a)). On the basis of observations of the carcass and eyewitness reports, they proposed that *Cadborosaurus* might represent a surviving plesiosaur.

Heuvelmans, however, believed that reports of *Cadborosaurus* were of merhorses – pinnipeds, not plesiosaurs. Michael Woodley and colleagues consider that what is known about the Naden Harbour animal – maximum flexibility in the vertical plane, hair, pectoral flippers, fused hind flippers, tolerance of cold, etc. – is more compatible with it being a pinniped. However, they concede that if the merhorse *is* a pinniped, it is an unusual and bizarre one.

What of the merhorses's intriguing mane? Ivan Sanderson, a colleague of Heuvelmans, speculated that it might have functioned as an auxiliary respiratory organ, enabling direct gas exchange with seawater. A more prosaic explanation is that the animal exhibits sexual dimorphism, and that the manes are equivalent to those of male sealions, for example.

The identification of the Naden Harbour carcass remains uncertain. Apart from the photograph, nothing of it survives, although it is thought that parts of the carcass were retained and forwarded to the Pacific Biological Station at Nanaimo and/or the Royal British Columbia Museum, Victoria.

No remains have been found of the Tizheruk, or Pal-Rai-Yk – a large snake-like creature that, according to Inuit folklore, inhabits the waters near Key Island, Alaska (Fig. 2(c)). It is described as having a 2 m head, and a tail with a flipper. It is reported to be voracious and to have snatched people off piers. Some believe that it could be the Arctic equivalent of the leopard seal, one of the Antarctic's fiercest top predators.

Whether or not new species of pinnipeds come to light, it seems likely that the number of large marine vertebrates will continue to grow, particularly as a result of projects within the Census of Marine Life (CoML).

For more information, see Woodley, M.A, D. Naish and H.P. Shanahan (2009) How many extant pinnipeds remain to be described? *H*istorical Biology, iFirst article, doi:10.1080/08912960902830210. We are very grateful to Michael Woodley and the other authors for their help with this article.

13th Challenger Society Conference for Marine Science, Bangor

The Challenger Society's biennial conference, held in Bangor in September 2008, was a hugely enjoyable affair. Hilary Kennedy and her colleagues worked tirelessly to see that everything ran well, despite deadful weather which played havoc with some of the excursions.

As always, the breadth of marine science covered by the conference was enormous. The sessions were highly interdisciplinary, with an emphasis on ocean cycles and climate change. Presentations were given in the grand Main Arts Theatre and Powis Hall. The latter will long be remembered by delegates for the striking and somewhat gloomy mural which could not be ignored however enthralling the speaker.* In addition to presentations and posters there were a number of lively workshops, addressing a range of topics: the legacy of the International Polar Year for young scientists; the challenge of ocean forecasting; the need for a UK Marine Science strategy; and communicating research and education at the European level. Frustratingly, it was difficult to attend more than one of the workshops!

There was also a public lecture by Harry Bryden on 'Monitoring the Atlantic Overturning Circulation at 26°N'. Attendance by local people was impressive, despite the specialist topic.

Prizes and awards

As always, there were a number of prizes awarded on the basis of the deliberations of two panels of hard-working judges. This year there were two poster prizes, the Cath Allen Prize for the best poster, and the newly established Sarah Jones Prize for the best poster or talk relating to 'particles in the sea' (see pp.12–13 for a tribute to Sarah, who died in July 2008). The former prize was awarded to Jonathan Sharples (Proudman Oceanographic Laboratory) and the latter to Tom Rippeth (Bangor University).

The Norman Heaps Prize is awarded for the best presentation by an early-career scientist. Because of the difficulty of establishing a clear winner when there are parallel sessions, a separate prize was awarded for each session. The winners were: Biological, Physical and Chemical Processes and Interactions, Patrick Martin (National Oceanography Centre, Southampton, NOCS); Observing and Modelling the Oceans, Emily Venables (Scottish Association for Marine Science); Ocean, Atmosphere and Biogeochemical Cycling, Claire Hughes (University of East Anglia); The Oceans in Past and Future Climate Change, Alberto Naveira Garabato (NOCS).

The Society's most prestigious award is the Challenger Medal, presented biennially to a distinguished UK marine scientist or other person who has made a major or sustained contribution to the development of marine science, or whose innovation has opened up new perspectives. Appropriately, the 2008 Challenger medallist was Bangor's John Simpson, who has been instrumental in developing interdisciplinary research of shelf seas. Earlier in 2008, Professor Simpson was awarded the Fridtjof Nansen Medal by the European Geosciences Union.

The Society also awards biennially up to four Fellowships to early-career marine scientists for their achievements and promise in a branch of marine science (marine biology, marine chemistry, marine geology or marine physics). The recipients of Challenger Fellowships were Angela Hatton (Scottish Association for Marine Science), Helen Johnson (Oxford University), Maeve Lohan (University of Plymouth) and Claire Mahaffey (University of Liverpool).

Of sea and sky

The subject for entries to the competition for the President's Photographic Prize was 'Sea and Sky'. Phil Williamson's beautiful winning photo is shown below, and can be seen in colour on the cover.

The topic of 'Sea and Sky' was chosen as close to the heart of retiring Challenger Society President, Peter Liss, who until recently chaired the Scientific Steering Committee for International SOLAS (SOLAS = Surface Ocean – Lower Atmosphere Study). A seemingly impromptu light-hearted session was held to celebrate Peter's substantial contribution to UK marine science, and acknowledge that he was – officially at least – retiring from the University of East Anglia.

Peter's contribution to science was officially recognized in May 2008 when he was elected Fellow of the Royal Society, and he has since been awarded the CBE.

At the Society's AGM, Peter handed the role of President over to Carol Robinson, who – given her close involvement with the 2002 Challenger Conference held in Plymouth – appreciated as well as anyone present the huge amount of work that goes into making a successsful conference. *Eds*

'Crossing the Dee estuary', by Phil Williamson', winner of the 2008 President's Photographic Prize. It was taken on an excursion to the observatory on Hilbre island, during the Challenger Conference held in Liverpool in September 2004.

*For those who were intrigued, the mural, painted by Edward Povey in 1992, is entitled 'The Hall of Illusion' and depicts a man's journey through life.

Return to the Challenger Conference – a personal reflection

Tim O'Hare

It's probably not the most sensible thing for a member of the Challenger Society Council to admit, but my attendance at the Marine Science 2008 conference in Bangor in September was my first full engagement with the Society's biennial conference since it was held in Stirling in 1994. So as I headed up to Bangor on the train for the meeting I was not quite sure what to expect. I was in for a surprise. What I found was that whilst the conference retained the same general feel, my reaction to it and my sense of its value were both greatly changed.

My history at Challenger Conferences dates back to the 1988 meeting at the University of East Anglia. I attended this event as I came towards the end of my MSc. in Physical Oceanography at what was then the University College of North Wales, Bangor, and presented my first ever poster display. This was my first taste of a conference experience, and I have to confess that I remember little of the talks but plenty of being led astray by my more senior Ph.D and post-doc colleagues from UCNW. I recall playing five-a-side football in the grounds (oh to be able to move like that now) and going on a trip to a vineyard somewhere in the depths of the Norfolk countryside, and I do remember the conference dinner.

In 1990 the conference passed to Plymouth and I was now in attendance as a 'two-year old' Ph.D student (still at UCNW). This was my first experience of a conference as a speaker, as I gave a talk on my Ph.D work. I must have done a reasonable job because I had the good fortune of walking away with the Norman Heaps Prize for the best presentation by a young scientist.* I recall delivering the talk in one of the Babbage lecture theatres (with which I am now horribly familiar) and can picture my hand-drawn overhead projector slides – all glorious technicolour in ultra-neat handwriting. I can recall having a script but having rehearsed so many times that it was not needed, and I know that I spent the entire talk extending and compressing a telescopic pointer (tip to new presenters: keep your hands still). I still have my prize certificate although it is a little ruffled having spent the hours immediately after the conference dinner rolled up in my jacket pocket as I had my one (and only) foray into Plymouth's 'famous' Union Street. My other clear memory from this conference was an excursion walk along the coastal path from Plymouth to Rame Head that involved stops at multiple hostelries and an impromptu treatise on the science of wind-surfing from John Simpson, who had just discovered the joys of this pursuit.

The Challenger Conference in 1992 was held in Liverpool and again, my recollections from the meeting are minimal, the main one being of a tortuous minibus journey up from Plymouth (my new home) that involved a detour to the University of Warwick in Coventry to drop off a friend of one of the passengers. I don't think I presented anything at that conference, but once again I can remember the excursion, this time to the Albert Dock and the maritime museum. Then, in 1994, the conference was in Scotland at Stirling University, home of a nice lake, a golf course and close neighbour to the William Wallace memorial.

Taken as a whole, these four conferences were all about attending as part of a group of young(er) scientists from my institution. They were about being part of the crowd and enjoying the social experience. I think that the scientific component was probably rather secondary.

After 1994, I stopped attending. I'm not entirely sure what brought about this change but 1996 coincided with me being a new father, and burgeoning demands of my role as a lecturer at Plymouth. Whatever, 1996 passed, 1998 passed, 2000 passed and I had slipped out of Challenger Conference mode and slipped into a professional role in which I was managing a large number of courses in the then Institute of Marine Studies at Plymouth, with my research activity hitting its lowest point.

I was almost rescued and drawn back into the Challenger fold in 2002 when I was kindly volunteered as the University of Plymouth representative on the Local Organizing Committee for the 2002 Conference. However, having done my bit, I flew off to Genoa for a European project meeting and missed all but the very start of the event. It was so near but yet so much further than ever before (hundreds of miles further in fact) and my golden opportunity to reconnect with the Challenger Conference was gone.

2004 passed and 2006 passed. Why would I break the habit of a (recent) lifetime and attend those meetings? I had managed perfectly well without them for over ten years, and from the perspective of someone with a research interest in coastal processes, based within a group that has an international reputation for its work, the national and deeper (though not necessarily deep) oceanographic focus of the conferences seemed of limited value in an already hectic schedule.

Then, in 2007, something changed. A request for new members of Challenger Council came round and, perhaps surprisingly, my instinctive reaction was not to hit 'delete', but rather to put my name forward. My nomination was accepted and my relationship with the Challenger Society moved from being a bystander to being close to the centre of the action, and with a Council meeting scheduled to coincide with the 2008 conference in Bangor I could hardly not attend.

And so I travelled back to Bangor for the conference and enjoyed lots of talks on topics that had only limited direct relevance to my own research but set all sorts of sparks firing in my mind. I discovered a UK marine science community that is very much looking north and south to polar regions. I was fascinated to learn more about the novel instrumentation drifting through the world's oceans. In my book of abstracts I have comments in the margins – 'nice talk' next to Laura Bristow's (UEA) abstract on 'Tracing nitrogen flows across the southern North Sea', Clare Jones's (Sheffield) abstract on 'Modelling the climatic impact of the glacial Barents Ice Sheet collapse', Peter Miller's (PML) abstract on 'Validation of multiple ocean shelf models against EO data using automated front detection' (this one gets an 'interesting idea' as well) and Emily Venables's (SAMS)

*As winner of the Norman Heaps Prize, Tim was invited to write an article for *Ocean Challenge*. Past issues of *Ocean Challenge*, going back to 1989, will shortly be available on the Challenger Society website, www.challenger-society.org.uk. Tim's article, on 'Bragg reflection and sand bar formation' was published in Vol.2, Summer/Autumn 1991, pp.43–8.

abstract on 'Observations of turbulent energy dissipation rate in the Wyville Thomson basin'. Rosalind Rickaby (Oxford), 'Back to basics: evidence for elevated pH in the glacial Southern Ocean', got an 'excellent speaker' note so her ability to deliver her scientific work to the audience clearly made a positive impression on me. And, in fact, although my margin notes don't always reflect it, there were many, many other 'nice talks' and 'excellent speakers', all of whom had interesting ideas, were making stimulating contributions to UK marine science, and set me thinking in a multitude of different directions.

On the Wednesday evening of the Bangor Conference, having spent a most enjoyable afternoon being wind-blown around Cwm Idwal under the superb guidance of James Scourse, I found myself on Bangor Pier having a chance encounter with the Editors of *Ocean Challenge*, which culminated in us sharing a meal at the nearby Italian restaurant. Our conversation ranged around topics such as the Challenger Society of Marine Science, the European Federation for Marine Science, the challenge of entraining new members into the Society and of encouraging participation (we did talk about some interesting things too) and I found myself reflecting on the conference and my return to the Challenger Conference fold. So, what were my thoughts?

At a basic level, my two key reflections were a sense of disappointment, even regret, that I had allowed six Challenger Conferences to pass me by and a sense of embarrassment about my non-participation. There is a view that the Challenger Conference isn't that important, and that there is little value in attending it because it is not the home of the cutting edge in any given subject area and is rather broad in scope; that it is national rather than international. Seeing the Conference with a fresh, more thoughtful eye has shown me that whilst this view may hold some truth, to subscribe to it and to act on it is to miss the point. The Challenger Conference provides a snapshot of the UK's marine science community – of its people, its places, its foci, its sense of purpose. You may be able to get this snapshot in other ways, but I am not so sure. Attending the Conference provides an opportunity to see the emerging scientists alongside the old hands and to witness the gradual shifting balance of influence, and the directions in which UK marine science is heading; it lays out before you the organizations, institutes, departments and research groups. But, just as importantly (in fact, I feel this is my *most* significant reflection), all is laid out before everyone else. So, an individual, a research group or an institution that does not embrace the Challenger Conference loses visibility and connectivity to the UK Marine Science community and leads a greatly impoverished existence as a result.

Returning to Bangor, and returning to the Challenger Conference was a revelation for me and I am relieved that I made the step before I had become a stranger within the community. The conference was a chance to renew some old acquaintances, to reconnect a little more with the marine science family and to begin to make some new friends. So whoever you are and whatever the strength of your existing relationship with the Challenger Conference – whether you are a first-timer, an early-career builder for whom the conference is still perhaps a slightly novel experience; whether you are a maybe/maybe not sporadic attender (interannual variability?); whether you are a firm believer and never-misser, a serial non-attender or a lapsed attender like I was – make no mistake, the Challenger Conference is good and the Challenger Conference is strong. You *may* not learn much of direct relevance to your own research but you *will* gain a sense of belonging to a strong, supportive and happy family and see a broader horizon and a clearer, more sweeping vision of your home subject area. You *will* gain a more distinct picture of 'who' and 'what' and 'where' and even 'why', and 'who' and 'what' and 'where' will gain a clearer picture of you and your home institution.

It may not have been pretty, but I haven't danced like I did to the Mersey Beatles for years, so take it from me, if you are far down in the cold deep ocean it's high time that you upwelled and joined in the interaction that is going on at the open ocean surface.

See you all in Southampton in 2010 …

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Memories of Mike Fasham

I did so enjoy the tribute to Mike Fasham in Vol.16, No.1 of *Ocean Challenge*, and thought readers might care to hear my own most enduring memory of Mike.

We were on a *Discovery* cruise, probably in the late 1960s, and either in the North Atlantic or Mediterranean, when during one of the night watches somebody brought a tiny, shivering and exhausted bird into the Plotting Office, having found it out on deck. None of us knew what species it was, but somebody suggested that Mike would know. Mike had turned in, but he was awakened and appeared in the Plotting Office a few minutes later, bright-eyed and full of interest, not in the least minding being awakened. He identified the wee bird, which I think was a shearwater but might have been a storm petrel, many of which we used to see when working on deck at night with the floodlights on, as they swooped down just outboard of the platform from which we handled gear. I think we were all impressed by Mike's dedication to birds – just another facet of this talented and humane person.

Pam Draper
Culbokie

EFMS at Bangor

The EFMS – the European Federation of Marine Science and Technology Societies – is made up of marine science societies from across Europe. At the Bangor conference, the EFMS hosted a workshop addressing the role that the EFMS might play in facilitating communication of marine research and education in Europe.

On the Friday after the conference, resentatives of marine science societies from a number of European countries came together for the 'General Assembly' which is open to all members of all the EFMS member societies. There were various reports of EFMS acitivities during the previous year, but in some ways the most useful part of the discussion came when delegates considered the common problems that face both the EFMS itself and the national societies, notably budgeting, running websites, keeping track of members and determining how best to serve them – work nearly all done on a voluntary basis.

For more on the EFMS see www.efmsts.org

‘Bright Sparks’ set sail from Galway

Emmett Clarkin

In early September 2008, I had the opportunity to take part in my first ocean-going cruise onboard the Marine Institute’s RV *Celtic Voyager*. This opportunity arose from an award known as ‘Bright Sparks’, a component of funding secured by the Marine Institute for the Integrated Marine Exploration (IME) Programme under the Irish Government’s Strategy for Science, Technology and Innovation (SSTI). The aim of this annual competition is to provide students with the chance to experience life onboard a research vessel and provide practice in the preparation and submission of a research proposal, design, planning and execution of scientific surveys, and final report writing.

Our winning proposal –‘Rafts, plankton and jellyfish: what is their value as biological indicators of different water masses?’ – was a collaboration between Queens University Belfast, the National University of Ireland, Galway, and University College Cork. As one of five students from the three institutions, I spent five days at sea off the south-west coast of Ireland getting first-hand practical experience in a fantastic location.

The first day in Galway started out beautiful, with *Celtic Voyager* nestled against the dock within the city itself, making a fantastic sight for anyone taking a stroll around town. We boarded early in the morning to beat the outgoing tides and set off out into Galway Bay to begin our first transect. Starting just south of the Aran Islands, we set out due west to meet and cross over the Irish Shelf Front.

Each of us students had various interests on the cruise. Triona and Cathal were interested in biogeochemical cycling at the shelf edge and ocean acidification, so at set locations we stopped the ship to deploy a CTD probe (CTD = conductivity (for salinity), temperature, and depth) to determine the physical properties of the shelf water, and get water samples to measure concentrations of carbon and nutrients at various depths to better understand the carbon processes in this region. Jessica was interested in gelatinous zooplankton and the functional role of jellyfish in marine ecosystems, with a particular interest in the relative abundance of particular species and their association with specific water masses. Conor’s remit was to determine the abundance and distribution of cetaceans and other megafauna such as sea turtles and oceanic sunfish in the Irish offshore area, whilst my own particular focus was to assess the abundance and distribution of macro-algal (seaweed) rafts and their role in the dispersal and distribution of marine invertebrates around Ireland.

It was immediately apparent that the weather wasn’t going to be on our side, with poor forecasts for later that night, so after the first six sample stations we decided to skip a few and take the most westerly station on the transect as it was the deepest and most important for Triona and Cathal’s work. After this night-time station the wind began to strengthen markedly so we made for the coast through the night and sought shelter in Dingle Bay further south (off County Kerry); when the weather improved we could then go directly to the most southerly transect on our cruise, which would take us further west and into deep water.

After a few surveys in the bay we docked in Dingle harbour for a night and a day. Of course, we were disappointed not to be out at sea carrying out our work, but any chance you get to see Dingle you need to make the most of, so a few Guinness were a must, giving me a great chance to have a bit of craic with my fellow shipmates. It wasn’t until the next evening that we finally left the harbour and with a short wait for the weather to improve we headed out of Dingle Bay just after midnight on 7 September to start our southerly transect a couple of hours later.

Once we were out in open water, the weather continued to improve and the swell steadily subsided, so by 10.30 that morning we had reached the Porcupine Sea Bight (~ 52° N, 12° E, depth 705 m). This part of the cruise reminded me of exactly why I have a passion for working in the marine environment. All around us, fin whales were advertising their presence with their characteristic blowhole spray. The wildlife spectacular did not stop there – as the day went on, the wind died and the sea became like a millpond. Sightings of common and bottlenose dolphins became regular, and many ocean sunfish were seen basking at the surface. At one point, a juvenile basking shark swam by – it couldn’t have been more than a metre-and-a-half long! There was a short lull in activity when suddenly someone shouted ‘Turtle!’ I couldn’t believe it – I was looking at a leatherback; the last time I saw one, I was working for a monitoring programme in Costa Rica and now finally I had the privilege to see one foraging in the open sea. We saw two more in the same area within the space of an hour – what a day this was turning out to be. I thought ‘OK that’s it, I’ve seen all that can be seen’. I was up on deck carrying out my normal survey for rafts, with Conor avidly keeping his eye out for cetaceans, when within just a few metres of us flew a black-browed albatross, a native to the Antarctic and thousands of kilometres from its normal range. We’ve made a few Irish birders jealous with that one, I think.

‘Bright Sparks’ was a fantastic opportunity for me to gain important research skills to use in the marine environment. I want to take this opportunity to thank the Marine Institute and my supervisor Louise Allcock for their help and support during this first class experience. We all managed to gather some valuable data that will hopefully provide a springboard for future research, and consolidate our plans for continued collaboration. So all in all, it was a great success and I have learnt a lot, not least to expect the unexpected.

The author* by* Celtic Voyager. *In the background are supervisor Louise Allcock (centre), with Triona McGrath, Martin White, Conor Ryan and Jessica Leahy.

*Queen’s University Medical Biology Centre, Belfast.

David Cushing's legacy for marine ecology in the 21st century

Joe Horwood

Our leading marine fisheries ecologist, David Cushing, died in March 2008 on his 88th birthday. He leaves behind a great corpus of science and literature, but as important is his legacy for today. This article draws upon the plenary lecture given in David's honour at the 2008 Annual Science Conference of the International Council for the Exploration of the Sea (ICES) held in Halifax, Nova Scotia.

Talking to his colleagues and students, I realized that David was best known to them for a variety of quite different things: as a pioneer in fisheries acoustics; as the father of the *Journal of Plankton Research*; for his books, readily accessible by students worldwide; and for his histories of climate and fisheries. But his key interests and contributions to marine science were in the dynamics of marine ecosystems and the functional relationship between adult marine fish and their young. When young fish are large enough to enter the fishery and be counted, they are often known as 'recruits', so this relationship is often known as the stock–recruitment relationship.

Increasingly, marine science is becoming compartmentalized into specialities so some readers may not know about the nature of the relationship between fisheries stock and recruitment. It works like this. A field of 10 cows is likely to produce about 10 calves, fields of 1000 cows, a thousand calves, but there will be an underlying density-dependence relationship where productivity (the number of calves produced per square metre of pasture) is greater at low cow numbers and less at higher numbers. It is different with fish. Over a large range of stock size, the production of young fish (termed the recruitment) is on average constant. Only when we have significantly depleted the parent stock does recruitment fall steeply to zero.

Figure 1 shows the relation between the number of young North Sea herring and the size of the parent stock in millions of tonnes. Only when the stock has fallen by about 90% do we see recruitment declining. We uncovered this relationship for science by overfishing and reducing the North Sea herring stock down to 99% of its former size (from 5 Mtonne to 50 ktonne). We hope not to do it again. But what is responsible for

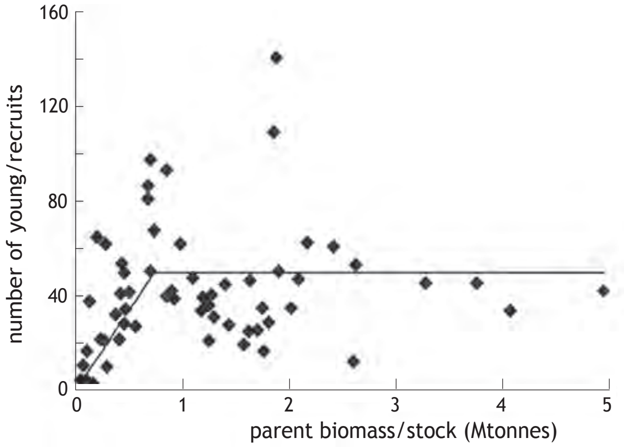


Figure 1 *The relationship between the number of young North Sea herring, and the size of the parent stock that produced them (in Mtonnes). Each diamond represents the young born in a given year, i.e. a 'year class', between 1947 and 2006. Note the on-average constant recruitment at higher stock sizes, the steep decline at low stock sizes, and the variability in recruitment at any one stock size.*

this extremely strong density-dependent relationship, wherein average recruitment stays constant even as we deplete the parent stock by nearly 90%? What population and ecological mechanisms are at work?

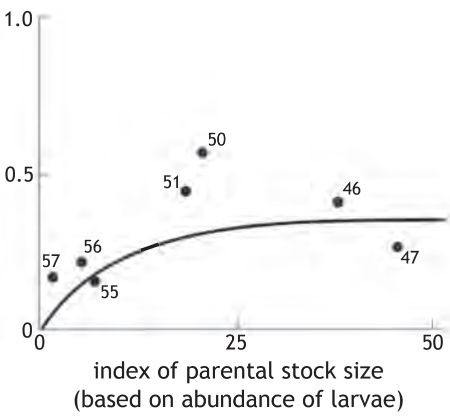
Further, the figure shows that at any one stock size, recruitment is suprisingly variable. We see differences of some 10 times from the lowest to the highest (e.g. for a parent biomass of 2 Mtonnes in Figure 1). These good year classes have a dramatic effect on the fisheries they support. But what causes them? Even more interestingly, each unfished cod will produce over 10 million eggs in its lifetime. If one in 6 million eggs survives to age 1, the population will remain stable. Given the huge number of eggs produced, only small fluctuations in the survival rate would produce large variations in terms of numbers. So, given the various factors that could affect survival rates why isn't the variability in recruitment much *greater* than 10 times? These are the puzzles of the stock–recruitment relationship: questions of fundamental ecology, and intimately related to the dynamics of the marine ecosystem. The two themes are strongly linked.

David Cushing was drawn early into the collapse of the North Sea herring in the 1950s. The issues were much as today. What is the extent of the problem, hidden to a degree by the increasing efficiency of the fishing fleets? What are the relative roles of the climate or environment compared with activities of human beings and fishing? To attack these questions David embraced most of fisheries and marine ecology.

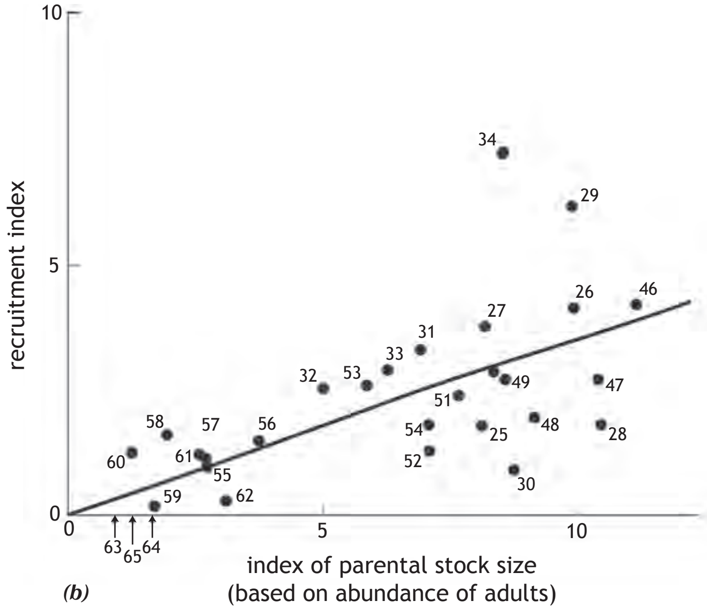
For the first time, for any fisheries, he drew out a relationship between young and parent stock (see Figure 2, opposite). The values on the axes are indices of recruitment and of parent stock, the stock index is based on a larval abundance in Figure 2(a), and on an adult abundance in Figure 2(b). For the first time we saw that production of recruits was impaired by low parent stock size (see data for the late 1950s and 1960s in Figure 2). He established that a cause of the decline of the Downs herring – those that spawn in the Southern Bight of the North Sea and in the English Channel – was insufficient parent stock caused by excessive fishing. The spiral of decline of low parent stock producing few young, which in turn produce even fewer parents, he termed 'recruitment overfishing'. We see it in cod stocks today.

He also explained, for our temperate seas, the variability in recruitment. This is caused by fish egg and larval production at a relatively fixed time of spawning, interacting with production of their algae and zooplankton prey, which is more variably determined by the weather and climate. This he termed the match–mismatch hypothesis of fish larvae and their prey.

The match–mismatch hypothesis does not explain the strong density dependence, and for this David turned to modelling the life of fish larvae. You would not think that fish larvae compete with each other – a single plaice larva, for example, has a space the size of a small office room to itself. But our modelling has found that there is a strong relationship between the feeding and growth of the larvae and



(a)



(b)

Figure 2 *David Cushing's relationships between the production of young North Sea herring and adult stock****, (a)*** *with index of parental stock size based on the abundance of larvae, and* ***(b)*** *with index of parental stock size based on adult numbers.*

In both diagrams, the figures on the data points correspond to year classes: e.g. the points labelled 57 relate to the young born in 1957. Note the decline in recruitment in the late 1950s and the 1960s.

that of their zooplankton prey. They must both be in balance. It is possible for the larvae to overwhelm the prey supply, resulting in domed-shaped stock–recruitment relationships.

These are the cornerstones of David Cushing's legacy but it goes further. He did not study these subjects in academic isolation, and as a result, two challenges to the science community are explicit in his works.

He needed to save the herring, and the industry and cultures that the herring supported. He felt deeply that science had not helped managers enough to manage these stocks. Science and scientists were in part to blame for managers' inaction over the herring. We still need more rigorous science to underpin the difficult decisions that fisheries managers have to make. And in particular we need to clarify the relative roles of environment and fishing in determining the fate of stocks.

To achieve the above we also need to understand how the marine ecosystem works. David considered that the stock–recruitment problem was at the heart of understanding the dynamics of the lower trophic levels. If we could focus on understanding the fate of individual larvae, through biological and physical observations and modelling, the dynamics of marine ecology would reveal themselves.

We all face the scientific challenges of climate change. In fisheries we have seen changes in distribution and abundance of stocks, and of their planktonic prey. Cod recruitment has been low for almost two decades. Cushing attributed the earlier increase in cod to improved production of *Calanus* and lower temperatures; this favourable situation has changed. Attributing changes in fisheries to anthropogenic global climate change is difficult. We have seen the large interannual variations in recruitment. But there are also decadal scale changes and longer period climatic variations influencing fisheries. David considered an historical knowledge of the fisheries essential to our understanding of the role of the environment on fish stocks. His books (see Further Reading) describe 1000 years of fluctuating fisheries. Studies of fish scales found in sediments take us back much further. The impact of climate change on fisheries returns us, in large part, to the determination of recruitment, and David's view that physical and biological scientists need to work together to solve the problem.

David Cushing – an iconoclast in fisheries science.

Further Reading

Climate and Fisheries (1992) (D.H. Cushing), Academic Press, London, 373pp.

Marine Ecology and Fisheries (1975) (D.H. Cushing), Cambridge University Press, 278pp.

The Provident Sea (1966) (D.H. Cushing), Cambridge University Press, Cambridge, 329pp.

Joe Horwood is Chief Scientist for the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and Defra's Chief Fisheries Science Adviser. He worked and published with David Cushing, and held David's former post at Lowestoft as Deputy Director of the Fisheries Division. He is currently President of ICES.

An appreciation of David Cushing may be found on p.5 of Ocean Challenge*, Vol.16, No.1.*

See p.32 for a review of *Dutch Herring: An environmental history, c. 1600–1860* by Bo Poulsen (2009), Aksant Academic Publishers.

Memories of Sarah Jones, Oceanographer, 1962–2008

Sarah Elizabeth Jones passed away at home in Menai Bridge, Anglesey, on 1 July 2008, following a two-year illness. While Sarah's loss has affected most acutely her husband, Colin Jago, and their children, Olivia, Alex and Melissa, and their family circle, it has also caused very great sadness amongst her colleagues and friends at the School of Ocean Sciences (SOS), Bangor University, as well as those who knew and worked with her in the wider oceanographic community. This appreciation by colleagues and research co-workers reflects not only the high regard, but also the very great affection, that was felt universally for Sarah. *AGD*

After leaving Friar's School in Bangor in 1980, Sarah went up to King's College Cambridge to read Natural Sciences, graduating in Physics in 1984. Later the same year she returned to North Wales to take up a Ph.D studentship with Colin, in the then Department of Physical Oceanography, on the geophysical properties of surficial marine sediments. From that point on, Colin and Sarah's social, personal and professional lives were inextricably linked with, and devoted to, the newly renamed School of Ocean Sciences. Not simply partners, they were the closest of professional collaborators, often sharing weekends and evenings in the lab to get projects finished or proposals in by deadlines. As Colin said so movingly at Sarah's funeral, 'Colin & Sarah' effectively became one and the same person. This partnership and collaboration has been one of the defining elements of SOS over the past 24 years.

Sarah went on to complete research assistantships in the School, and was appointed to a Lectureship in Geological Oceanography just prior to the award of her Ph.D in 1991. She quickly progressed to a Senior Lectureship in 1994. Through this period, and after, Sarah's distinctive scientific persona developed into a reputation of the very highest standing in UK marine science. She contributed significant research outputs and supervised ten Ph.D students.

James Scourse

As a creative, multidisciplinary, sea-going researcher, and a highly successful teacher, Sarah exemplified what SOS aspires to be all about. She worked selflessly for the School for more than 20 years, for example in contributing to the recruitment effort and then keeping a friendly eye on successive cohorts of students. Not only did she become a role model for female oceanographers in the UK, but she was also a delightful person, serious-minded, with a great sense of humour. If one were to define the colleague of one's choice, this would surely closely approximate Sarah.

Alan G. Davies

Sarah's introduction to the wider oceanographic community occurred during her extensive participation in the year-long North Sea Project cruises in 1988–89. At that time, many male scientists and ships' crews were still coming to terms with women at sea. However in the cramped confines of Challenger*, Sarah's warm and generous spirit rapidly eroded such prejudices, and her quiet tact was often used to de-fuse on-board disputes and mollify belligerent crew. With many oceanographers coming late to interdisciplinary shelf-sea research, such cruises proved ideal opportunities to draw on Sarah's skill in providing insightful explanations of obscure dynamical processes.*

By these means, Sarah moved seamlessly from being a student to being an established scientist whose name automatically appeared on crew-lists for almost any shelf-sea cruise that required monitoring of sediments. Her professionalism in all aspects of research – technical preparation, diligent observation, careful analysis and prompt reporting – set an example to all. Subsequent stages in her career encompassed designing, developing and evaluating instruments, and the associated thoroughness and honesty were widely appreciated. Her broad network of close colleagues enabled her to impact widely on technical through to theoretical aspects of sediment behaviour in coastal waters. The extent and incontrovertible validity of the many datasets collected by Sarah and her collaborators provide benchmarks that widely challenge both modellers and remote-sensing specialists. Recent significant advances in her long-standing interest in the aggregation and disaggregation of flocs (via innovative combinations of observations and modelling in the sea and in flumes) indicate her wide-ranging technical, theoretical and community-forming contributions.

David Prandle

I got to know Sarah in the late 1980s both in the School of Ocean Sciences and during long conversations over food and wine with her and Colin, about cosmology and music, and – as befits oceanographers – about ships and sealing wax and string. It was an interdisciplinary time in SOS, with biologists and geophysicists trying to understand interactions between the sea-bed and water column. In one of the deeper folders of my hard drive, repeatedly copied from older computers, there is a file about 'microbiology, physical transports, optics and particle dynamics in vertical process models' to which Sarah was contributing the particle dynamics. It was started circa 1992 and has remained an ongoing project for a decade and a half; now I see, sadly, that it won't ever be completed. But it did at least contribute to a joint paper on the coupled physical–microbiological PROWQM model in 2002.

One of the things that I liked about Sarah was her ability to combine theory and practice: to wrestle, despite her slight build, with giant sedimentation columns on the lurching deck of a ship whilst explaining the maths needed to calculate particle sinking rates. This memory is from Charles Darwin *93, one of the Shelf-Edge Study cruises to the Malin shelf break in 1995. Sarah caused a stir at NERC on a later SES cruise when she was several months pregnant with her second child. The traditionalists at NERC had barely come to terms with the notion of women at sea, let alone pregnant women; so Sarah was initially banned. She was incensed at what she regarded as institutionalized misogyny, and she terrorized the poor Principal Scientist until he was able to get the decision rescinded.*

The children, of course, brought about changes. Revisiting SOS some years after this, and having previously been used to Sarah working late in the department, I was struck by her saying that, although she had to leave promptly, she found that this had made her use her time more effectively. Surprisingly enough, I hadn't considered this aspect of parenthood myself, but I remember it now, having occasional duties to tend to grandchildren. This is how those who have gone, go on influencing us.

Another other example of what I learnt from Sarah was in the matter of parameterization. When I wanted to include particulate resuspension in my water column models, I initially used the customary parameterization, which requires that bed stress exceed a reference value before anything happens. Sarah showed me that such a discontinuity was unnecessary and ugly, and that it was simpler, and more elegant, to resuspend particles from a finite 'fluff' layer as a power function of bed stress. Complex environmental processes can be susceptible to alternative descriptions, making it good to try several ways of looking at things before settling on a final mathematical representation. Sadly, there is no longer the possibility of any more such insights from Sarah.

Paul Tett

Sarah's combination of intelligence, conscientiousness and kind-heartedness made her a great asset as a teacher in SOS. Shortly after her appointment as a lecturer, she developed a PC-based role-playing game for the geological oceanography students, where they formed oil companies and competed against each other to maximize profits. The whole exercise epitomized Sarah in so many ways. She devised the tasks and wrote the programmes in a matter of days. Like many academics, she sometimes had to specialize in the just-in-time mode of delivery but, in this case, it was unclear to most of her colleagues how the feat was achieved so quickly! The exercises made the students think in a really practical way and did much to break down barriers between students and staff; in retrospect one realizes that they actually brought the fun of fieldwork into the laboratory.

Given her physics background, Sarah was also keen to ensure that students had the academic know-how to be successful in their studies and, to this end, she played a pivotal role in the development of the 'key skills' module in Ocean Sciences. Those with any experience of key skills will appreciate the resilience, imagination and eternal optimism needed to even contemplate delivering such courses (as well as a touch of foolhardiness, of course). Sarah set about creating modules for oceanographers which covered the quantitative and computing skills that were to stand the students in good stead for the rest of their studies and, hopefully, their careers.

Typically, her tenaciousness meant that even whilst suffering from the symptoms of her illness, Sarah was committed to and heavily involved in the development of key skills. There were a myriad of other courses that Sarah organized and delivered, but throughout, her intelligence, knowledge, empathy and kindness made her a natural teacher. She will be remembered by very many students, including those who took part over the years in the summer field trip to Laugharne, in South Wales.

Dei Huws

Many thanks to Colin Jago for checking, and in places purifying, the text and to David Roberts (SOS) for his work on the photographs.

Manatees

Ancient Marine Mammals in a Modern Coastal Environment

Katie Tripp

Modern manatees have inhabited the coastal waters of Florida for more than a million years. They have no natural predators, but they were hunted by paleo-Indians and later by members of the Seminole tribe; however, they are now facing their greatest challenge – living alongside modern Floridians, with their boats, development, pollution, and consumption of natural resources. The majority of Florida's human residents inhabit narrow ribbons of land along the state's 1926 km of coastline, and the manatees' occupation of a coastal habitat has placed them in direct contact with certain human user groups. On the positive side, the fact that manatees are a coastal species has facilitated their study in recent decades, but there are still important questions to be answered about how they are are faring in a rapidly changing coastal environment.

Manatees are marine mammals. The 3300 manatees (*Trichechus manatus latirostris*) that live around Florida are a subspecies of the West Indian manatee (*Trichechus manatus*). The Antillean manatee (*Trichechus manatus manatus*), a second subspecies, inhabits the Caribbean region including Mexico and Belize (Figure 1). There are two additional manatee species: the Amazonian and West African manatees. Manatees and dugongs (found in the Indo-Pacific region) belong to the Order Sirenia. Another sirenian, Steller's sea cow, once lived in the Bering Sea but was hunted to extinction within 27 years of its discovery in 1741.

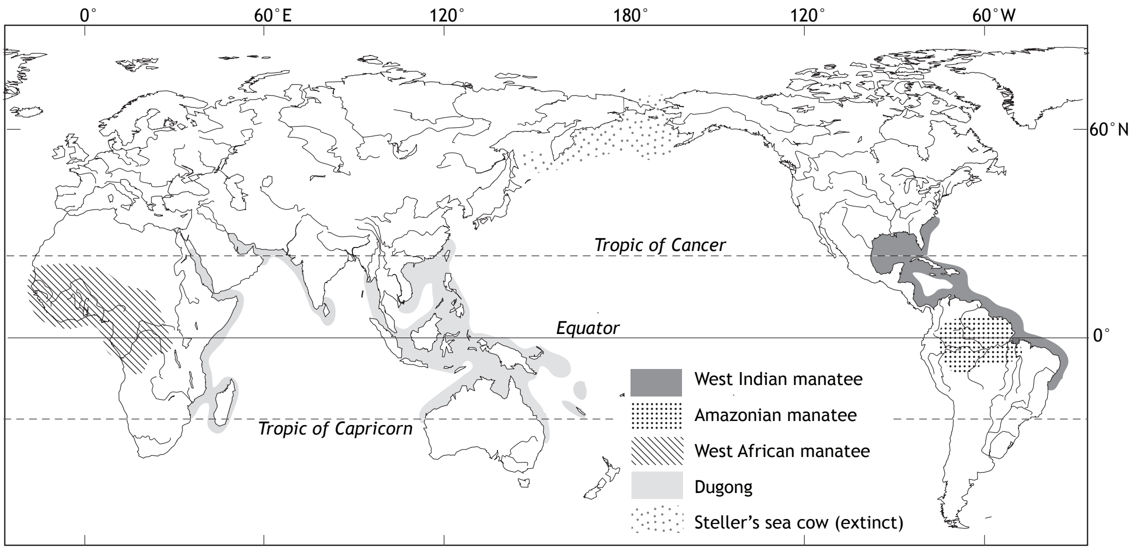
Although a manatee's natural life-span may exceed 60 years, many modern-day manatees are dying much younger. A manatee's age is determined post-mortem via histological analyses of a specific region of the ear bone, where a pattern of 'rings' develops over the life of the animal; these rings are counted much like the rings of a tree, to determine age. Manatee ear-bone data gathered from carcasses in the 1990s have suggested that manatees are dying at an average age of 7.7 years, and that 73% of females only survive long enough to produce one calf. It has been suggested that first-time manatee mothers may be less successful at raising calves, and if this is true, the survival rate of calves could be decreasing along with the birth rate, which would further limit the growth potential of the species.

Major threats

Florida manatees face both natural and human-induced threats, including habitat loss, collisions with watercraft, the effects of red tides, entanglement with fishing lines, and harassment.

Figure 1 *Global distribution of sirenians, living and extinct.*

Manatees and dugongs live in warm coastal water and rivers



Manatees breathe through two small nostrils on their snout. At rest, they can remain submerged for up to 20 minutes, but when active, they typically surface every few minutes

Figure 2 *A Florida manatee swims in one of the state's freshwater springs. Manatees use their large paddle-shaped tail to propel them through the water and utilize their front (pectoral) flippers to help steer. Manatees typically swim at a rate of 1–2 m s^{-1} but can move in short bursts of up to 7 m s^{-1}.*

Photo by courtesy of Patrick M. Rose.

Loss of habitat

Soon after Florida was purchased from Spain in 1821, a long process of ditch, levee, lock and dam building began as Florida's wilderness was tamed to accommodate development. 'Swamp' was perceived as valueless and in the eyes of would-be developers, couldn't be drained fast enough. The slow trickle of water through the Everglades and other natural waterways which used to purify the water was channelled into fast-flowing conduits out to the coast.

While some regard for Florida's natural systems has emerged in recent decades, the environment is increasingly affected by the soaring human population, which has risen from 12.9 million in 1990 to more than 18 million today, with a projected population of > 28.5 million by 2030. The remaining natural bodies of water – springs, lakes, rivers and streams – are being depleted to supply residential water demands and those of agriculture. Some springs have already ceased to flow.

Historically, the pricing structures from US utilities have not reflected the true cost and value of water resources, resulting in unsustainable practices. Currently, the average Floridian uses 160 gallons of water per day (the national average is 100 gallons per day). In addition, irrigation of Florida's 14.3 million acres of agricultural land accounts for about half of Florida's groundwater and surface water withdrawals. Public supply demands are expected to exceed agricultural demands in coming years and by 2020, Florida's total daily water demand is expected to reach 9.3 billion gallons per day. These pressures, coupled with pollution of groundwater and surface water resources, threaten the health of the lakes, rivers, and coastal waters that make up manatee habitat.

Water managers are working to identify and develop alternative water sources, including surface water withdrawals from reservoirs, and use of reclaimed water for irrigation, which has been the most common form of alternative supply. Seawater desalination along Florida's coasts is being mentioned with increasing frequency by water managers, but the energy demands of running a 'desal' plant, the potential consequences of aquifer contamination as a result of leaky pipes, and the discharge of concentrated brine back into the marine environment, have not been fully evaluated.

The quantity and quality of Florida's natual waters are degraded. Stormwater runoff from the adjacent urban landscape introduces high quantities of nutrients such as nitrate and phosphorus to the aquatic ecosystem, and at least 30% of Florida's surface waters are affected by nutrient enrichment.

Point source pollution also threatens the manatee's aquatic habitat. Each day for more than a

Figure 3 *An aggregation of manatees involved in a mating herd in shallow waters adjacent to coastal development on Florida's Gulf of Mexico coast.*

Photo by courtesy of Ken Arrison

Numerous males may congregate around a single female for days in hope of mating

decade, six ocean outfall pipes off the coast of Palm Beach, Miami-Dade and Broward Counties in south-east Florida have transported 300 million gallons of minimally treated domestic wastewater (sewage) into the Atlantic Ocean, offshore from beaches, and adjacent to coral reefs.

These outfalls have been recognized as representing a tremendous loss of water that could be treated and used for irrigation (see ealier), and a bill was passed during the 2008 Florida legislative session to limit the waste of water and the associated pollution. However, more intensive treatment of wastewater is not required until 2018, and while the bill calls for at least 60% reuse of wastewater in the region (which currently only reuses about 6%), it doesn't require that this standard be met until 2025.

Coastal development is working its way northwards, and has had unquantifiable cumulative impacts on manatees and their habitat. The remaining natural landscapes are being converted into prestigious coastal communities, resorts and marinas. As wetlands and natural landscapes are paved over for development, stormwater runoff and pollutant loads into the aquatic environment increase, which further degrades manatee habitat.

Damage to seagrass beds

Manatees are herbivorous, with the main component of their diet consisting of seagrass. Changes in freshwater flow can directly affect the health of seagrass stands, which require a delicate balance of salinity; reduced flows create detrimental hypersaline conditions, and stronger flows create equally damaging hyposaline conditions. Fluctuations in salinity have resulted in seagrass die-offs in areas including Florida Bay in south-east Florida (cf. Figure 4), and Faka Union Bay in south-west Florida. This threat to the manatee's food source is also recognized in the US Fish and Wildlife Service's Florida Manatee Recovery Plan.

Seagrass beds are not only an essential food resource for manatees, but also provide many other important ecosystem functions. They serve as a nursery ground for juvenile fish and invertebrates, produce oxygen, and trap sediment stirred up by boats or during storm events, which would attenuate light if left suspended in the water column.

Mitigation banking of seagrass (whereby seagrass in one area is allowed to be compromised for development in exchange for preservation or replanting of seagrass in another area) has recently been proposed as a conservation tool to offset development impacts in Florida, and a reference to mitigation banking was added as an amendment to an important seagrass protection bill during Florida's 2008 legislative session. However, environmental groups demanded that the bill be vetoed as it provided no assurance that the quality and significance of the proposed mitigation areas would be commensurate to that of the seagrass beds lost to development, and would ultimately have caused great harm to Florida's seagrass resources.

In certain areas of Florida, 'No Motor Zones' are proposed to mitigate the effects of projects such as dredging, which result in the destruction of seagrass and other benthic resources. Additional damage to seagrass is caused by boat propellers operating outside of channels, in the shallower areas, and propeller scarring is visible in most of Florida's seagrass beds. Boats-users are required to use a trolling motor or pole when navigating these shallow waters, in order to protect the submerged vegetation. Also, to protect seagrasses and other resources, a system of Aquatic Preserves, where certain development activities are limited, has been established.

The need for warm-water habitat in winter

As marine mammals, manatees are warm-blooded, and cannot tolerate exposure to water below 20 °C for extended periods. They have an extensive digestive tract that generates heat during the digestion process. This helps them stay warm in colder water. If manatees cannot find sufficient forage material in winter and this heat-generating digestion slows or stops, they become susceptible to a life-threatening condition known as cold stress syndrome. Cold-stressed manatees develop visible lesions on their skin and their immunity becomes compromised. In winter, when coastal water temperatures around Florida may drop to 13 °C or below, manatees seek out warm water. Thus although they are normally a solitary species, in the colder months they may be found in aggregations of 100 or more (cf. Figure 4 opposite).

Warm-water springs

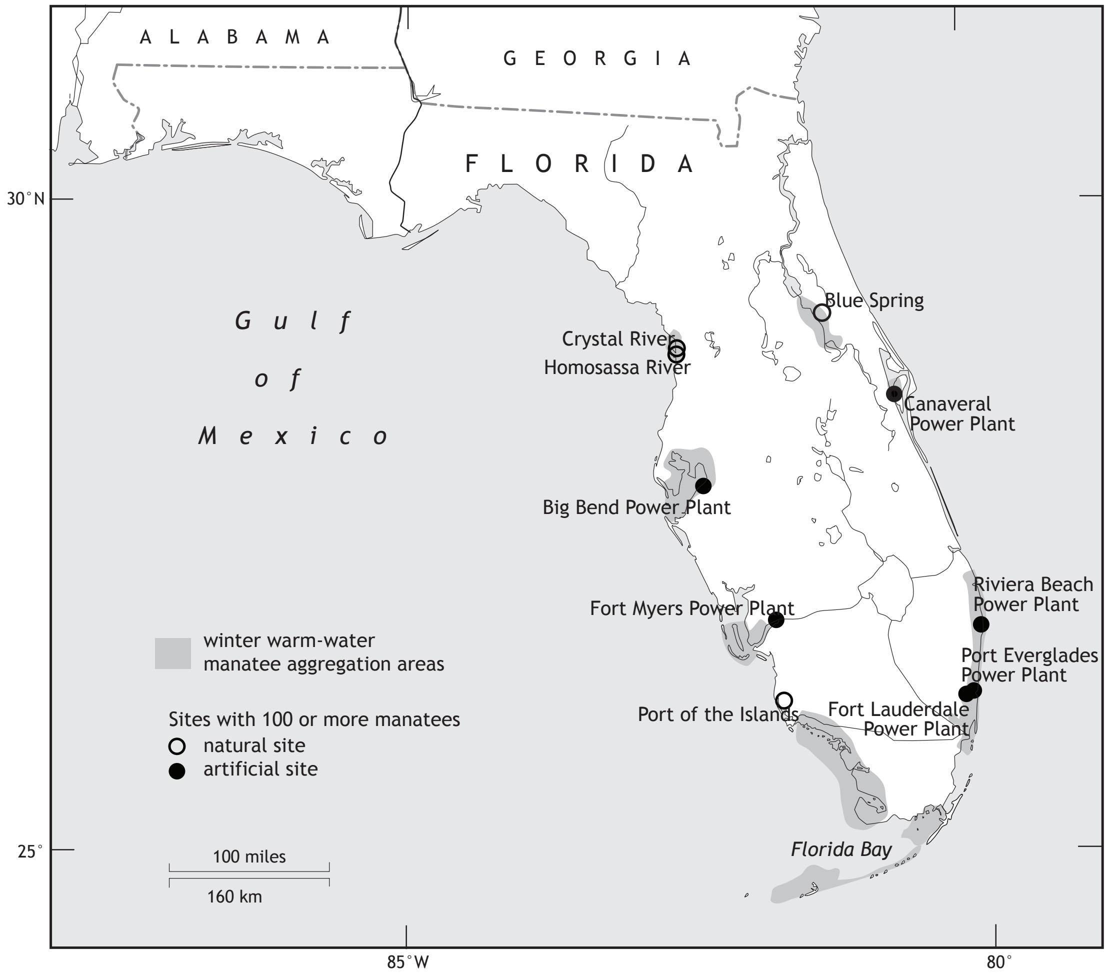
Florida has 700 known natural springs, where groundwater flows to an opening in the substrate and mixes with surface waters. Because of their relatively constant year-round temperature of ~22 °C, several of Florida's largest springs serve as critical winter habitat to a large number of manatees. However, as a result of the pressures on water mentioned above, many of these springs are declining, with decreases in water quality and/or a decreases in flow rate. Other springs historically used by manatees have been made inaccessible by dams and other construction.

The availability of natural springs is becoming more important than ever for manatees, as their second source of winter warmth faces an uncertain future (see below).

Artificial refuges

The second type of warm-water winter habitat is associated with power plants situated adjacent to coastal waters. Such plants take in water to cool the system, then expel the water back to its source. At plants that employ a once-through cooling process, waters are returned at an elevated temperature. Outfalls of ten power plants situated throughout Florida are used by approximately 60% of the state's manatee population during cold weather. These facilities (some of which are shown on Figure 4) provide refuge for a large number of manatees during extremely cold weather. For example, 434 and 588 manatees respectively have been counted in a single day at the Florida Power and Light Company's Fort Myers and Cape Canaveral plants.

Over time, manatees have come to rely on these plants as essential components of their habitat. All were constructed between the 1940s and



In winter, manatees exploit both natural and artificial sources of warm water to protect them from the cold

Figure 4 *General winter distribution and warm-water manatee aggregation sites around Florida.*

early 1970s and are reaching the end of their planned operational life. The increasing age of these facilities, coupled with other economic and environmental factors, led to discussions of possible shutdown. Among the environmental considerations driving talk of shutdown was the fact that discharges are a source of thermal pollution to the aquatic environment. Provisions made by the Environmental Protection Agency (EPA) in 2004 would prohibit newly constructed power plants from discharging warm water, and eliminate once-through cooling at existing power stations. The high cost of retrofitting aging power stations caused companies to consider closing plants. However, circumstances changed again in 2007 when the EPA published a notice that it was suspending its Cooling Water Intake Structure Regulations for large existing power plants. The EPA's rule remains suspended, which has given Florida's power companies the opportunity to repower their facilities, thereby increasing capacity and efficiency and lowering emissions of harmful air pollutants, without addressing warm-water discharges.

While plants selected for repowering may ultimately remain reliable sources of warm water for manatees, normal discharges will be interrupted during the repowering process, which could expose large numbers of manatees to cold-water conditions if planned interim measures are not successful. The Fort Myers plant has already been repowered. At this facility, temporary portable boilers provided warm water for hundreds of manatees within a semi-confined canal area. However, there are different dynamics at some other plants, which are further north within the state and are therefore subjected to lower temperatures. Additionally, some plants discharge into an open lagoon and not into a confined canal area, which could provide an additional challenge.

The long-term future of artificial warm-water sites is currently uncertain. Comprehensive strategies to address the loss of these sites have not yet been developed, but are crucial, particularly in light of human alterations to the environment that have affected natural manatee winter habitat. It is imperative that sufficient, alternative habitat is available to protect manatees from mass winter mortality before eliminating any critically important sources of artificial warm water on which manatees have become dependent. Of equal importance is ensuring that manatees are protected during the repowering process. Mistakes at key locations could result in the deaths of hundreds of manatees from cold stress syndrome, and permanent plant shutdowns could lead to catastrophic mortality. Many manatees will not leave a discharge canal even in the absence of warm water if it is the only refuge they know.

Nearly all adult Florida manatees bear scars from boat collisions

Figure 5 *An adult female manatee with deep, fatal propeller wounds inflicted by a pleasure boat.*

Photo by courtesy of Tracy Colson.

The dangers posed by watercraft

Manatees consume 10–15% of their body weight daily. With an average mass of 1000 pounds, this translates to a daily consumption of 100–150 pounds of aquatic plants. Their high food demands mean that they spend 6–8 hours per day feeding, typically in shallow seagrass flats adjacent to boating channels.

When a manatee hears an approaching boat, it has only seconds assess the direction from which a vessel is approaching, judge the degree of threat it poses, and decide how to react. Slower boats buy manatees more time, while faster boats steal precious seconds. A manatee's response to a vessel perceived as posing a threat is to swim in the direction of deeper water and dive. Unfortunately, the deeper water is typically in the boating channels, so their response may place them directly in the path of oncoming watercraft.

Slower boats allow manatees more time to decide the safest course of action

Figure 6 *Florida boater Angie Greico holds up one of the Save the Manatee Club's 'Please Slow, Manatees Below' banners, to alert other boaters of the presence of manatees.*

Photo by courtesy of Michael Greico.

The scars and fatal wounds manatees bear are a testament to their avoidance strategy. Propeller cuts across the body indicate that a manatee attempted to roll away from an oncoming boat, while damage to the caudal half of the body and tail indicate that a manatee was diving, trying to escape harm, when it was struck.

In 2007, there were more than one million registered vessels in Florida waters, and by 2060 it is expected that 1.8 million trailered boats alone will seek access to Florida's waters. Nearly all Florida manatees bear scars from boat collisions, with as many as 50 distinct scar patterns documented on an individual manatee. In fact, distinct watercraft-inflicted scar patterns are used to identify individual manatees. External injuries from such trauma may include a superficial linear scrape from a boat hull or propeller skeg, or deep cuts from propeller blades (Figure 5), while internal trauma may include a fractured skull, broken ribs, punctured lungs, or a severed spinal cord.

Boats and personal watercraft of all types, shapes, and sizes, moving at a variety of speeds, are capable of injuring or killing manatees, and while propeller blades do kill manatees, blunt force trauma from hulls and propeller skegs can be even more deadly. Manatees have been known to survive horrific injuries, but over the past 10 years, an average of 79 manatees have died annually as a result of collisions with watercraft; the record year was 2002 when 95 manatees were documented to have died from this cause. In 2008, 90 manatees were confirmed to have been killed by watercraft in Florida. The chronic effects of sub-lethal impacts on manatee health and reproduction are unknown, making a simple body count inadequate for measuring threats to the species. Furthermore, watercraft injuries may make manatees more susceptible to other causes of death, such as cold stress or red tide (see later).

In many Florida counties, boat speed zones have been created as an aid to manatee conservation. Speed zones have prevented the rate of watercraft mortality from increasing drastically in response to skyrocketing numbers of vessel registrations and of vessels that visit Florida annually. Without speed zones and other state and federal protections, the annual death tolls would undoubtedly be much higher. However, not all counties inhabited by manatees have protective speed zones, and collision with watercraft remains an unacceptable yet preventable cause of mortality. Efforts to reduce watercraft-related mortality include the development of manatee avoidance technology for watercraft and the funding of on-water law enforcement patrols to help ensure compliance with posted speed zones.

While speed zones can be a valuable tool for manatee protection, such zones require compliance by boaters and enforcement by appropriate authorities to be most effective. Unfortunately, the state's wildlife agency, which is one source of enforcement, sees high staff turnover due to low wages, and vacancy rates have been increasing, leading to complaint-driven enforcement efforts instead of standard manatee patrols. Furthermore, budget cuts led to a 2008 proposal to cut

66 positions from the state's law enforcement programme. Save the Manatee Club and others were able to lobby to keep these positions, but such cuts are likely to be proposed again in the future to address budget shortfalls. Some Florida counties are looking to marina and boat owners to help fund enforcement and education through annual manatee conservation fees.

Although there are more human deaths from boating accidents in Florida than in any other US state, there has been no mandatory boater education programme. While there are a multitude of educational signs, brochures, and kiosks to assist voluntary education efforts, mandatory education is the key to raising speed zone compliance and making the waters safer for both humans and manatees. Together, enforcement and compliance represent an integral component of manatee protection.

Manatee speed zones and other protective measures have been opposed by some individuals, and a contingent of boaters, developers, and others with marine interests are against speed restrictions and limits on coastal development. Such individuals appear indifferent to the fact that manatee mortality statistics reflect the deaths of living creatures, and that these animals suffer as a result of human carelessness. Overcoming such human apathy may be the single greatest challenge faced by manatees.

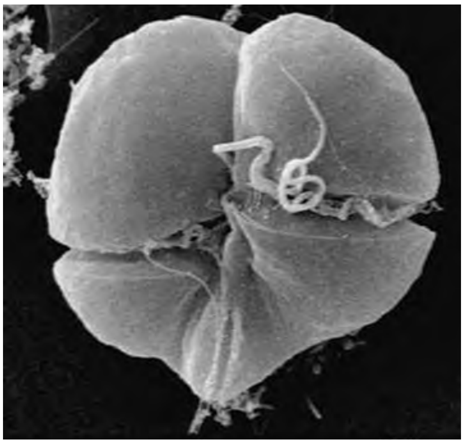
Red tides

Red tides – areas of water discoloured a browny red – are caused by blooms of the dinoflagellate *Karenia brevis*, which produces toxins that can kill manatees and other animals (Figure 7). Red tides are not a new phenomenon, but their frequency and duration may be increasing, particularly in the Gulf of Mexico, along Florida's west coast. Since manatee mortality statistics were first recorded in the early 1970s, red tides resulting in manatee mortality have been observed in the early 1980s, and in 1996, when 151 manatees died. An apparent surge in red tides began in 2003 when 98 manatees died, followed by 93 red tide deaths in 2005 and 62 in 2006; in 2007, there were 52 red tide manatee deaths along the Atlantic coast.

Red tide acts as a neurotoxin, causing seizure-like symptoms in manatees. Manatees may inhale red tide in an aerosol form when they surface to breathe, or ingest the toxin via tunicates, which are sometimes incidentally ingested during feeding. During seizures, manatees often become disoriented, cannot surface to breathe, and drown. If a manatee is observed exhibiting signs of red-tide toxicity and can be removed from the water by personnel from the state wildlife agency, the symptoms will decline as the animal is able to breathe. In addition to acute exposure, red tide may be absorbed by seagrass and other plant material and persist for several weeks, resulting in an additional danger for manatees as they feed.

There are several different hypotheses about what causes red tide. One idea is that the nutrient pollution that feeds red tides is caused by runoff resulting from heavy rain events like hurricanes. The long-term consequences to manatee survival of exposure to, and subsequent recovery from, red tide, are unknown. The South-West management region, which is most heavily affected by red tide, contains 41% of the state's manatee population. The population in this region is believed to be in decline, due in part to red tide mortalities.

Figure 7 *Scanning electron micrograph of* Karenia brevis*, the dinoflagellate that causes red tides in Florida waters. (Image about 30 μm across.)*
Photo by courtesy of the Florida Fish and Wildlife Conservation Commission.



The toxin produced by* Karenia brevis *can kill fish and birds, as well as manatees

Entanglement

Manatees consume a large range of aquatic vegetation, which they grasp using their upper lip and flippers. Monofilament fishing line and hooks are often discarded after becoming snagged in vegetation within seagrass beds, and feeding manatees may accidentally swallow the line or get it tangled around their flippers. Hooks can become embedded in a manatee's lips, mouth, throat, stomach, or intestine, leading to fatal infections. Line entanglements can also cause infections, either internally within the digestive system, or externally around the body, tail stock (peduncle), or pectoral flippers. In the case of pectoral flipper entanglement, severe injury may lead to self-amputation of the flipper, or a manatee may need to be rescued and transported to a critical care facility where its infected flipper can be surgically removed.

Crab traps can be another danger for manatees, as they may become entangled in the ropes that connect the traps to floating marker buoys. Entanglement in rope alone may cause serious injury, but entanglements involving ropes still attached to crab traps can be particularly harmful. Manatees often drag these traps for miles, and wound infections may lead to flipper amputation or death. Such entanglements can also interfere with a manatee's ability to swim and forage, which further compromises its health. Since 2000, 124 manatees have been rescued with various types of entanglement injuries, 16 of which occurred in 2008 alone.

Recently, Florida's Fish and Wildlife Conservation Commission proposed a rule that would allow for temporary closures of the blue crab fishery, which currently operates year-round in Florida waters. The closures, of up to ten days in duration, would provide an opportunity to collect derelict crab traps in Florida's coastal waters, which currently pose a serious entanglement threat to manatees.

Since 2000, 124 manatees have been rescued after getting entangled with rope or fishing lines

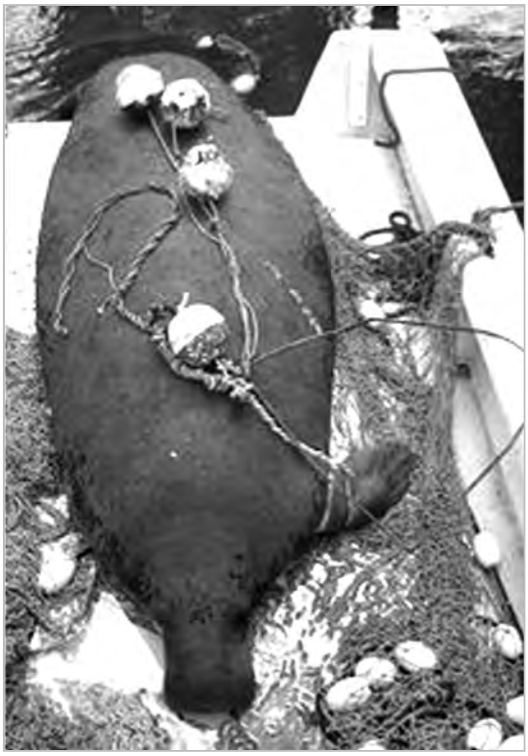


Figure 8 *Manatee rescued after being discovered entangled in crab trap lines and buoys. (The net in the boat was used to catch the manatee.)*

Photo by courtesy of the Florida Fish and Wildlife Conservation Commission.

The Entanglement Working Group (EWG) was established in 1999 and consists of personnel from various agencies and environmental groups, including Save the Manatee Club. The EWG has worked to offset incidents of wildlife entanglement in Florida and has educated the public about the dangers associated with discarded fishing line and debris. The EWG encourages proper disposal of monofilament through a network of collection bins at boat ramps, public access docks, and other locations throughout Florida, and also coordinates monofilament clean-up events.

Harassment

As a state and federally listed endangered species, and a marine mammal, manatees are legally protected from harassment. Within the Marine Mammal Protection Act (MMPA), harassment is defined as 'any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal ... in the wild; or has the potential to disturb a marine mammal ... in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering'. However, manatees are commonly fed lettuce, given fresh water from a hose, touched, ridden, or otherwise disturbed.

Most harrassment occurs in marinas and/or near boats, which encourages manatees to approach the vessels that can cause their injury or death. People seeking a positive interaction with manatees are actually training them to behave in a way that could bring them into danger, especially as there may be individuals who purposely seek to harm manatees.

In Crystal River (cf. Figure 1), as many as 100 000 people visit the National Wildlife Refuge each winter to snorkel and dive with manatees that gather in local springs to survive low winter temperatures (Figure 9). Manatees often tolerate being surrounded and touched in order to remain within their warm water refuge, but in extreme situations, they may leave. During such disturbance manatee mothers may become separated from their calves, placing the calves at extreme risk if the two are not reunited.

Figure 9 *Snorklers surrounding a manatee at a spring in the Refuge in Crystal River, Florida.*

Photo by courtesy of Tracy Colson.

A novel experience for divers may result in a stressful experience for manatees

Save the Manatee Club has set up a partnership with a local kayak tour operator in Crystal River to sponsor 'Do Not Disturb' kayak tours for Club members. These tours are based on the principle of passive observation, whereby humans observe manatees, but do not enter the water or touch them. Passive observation allows people to witness natural manatee behaviour and share their environment in a positive, low-impact way.

The politics of manatee protection

In the United States, there are both federal (nationwide) and state laws for protection of wildlife. In Florida, manatee protection is a cause of conflict, and between 2001 and 2007, a debate was conducted to determine whether manatees met the state's criteria for endangered status. Critics of manatee protection claimed that their population had grown, without noting that in certain parts of the state the numbers of carcasses were increasing faster than the population was increasing Various marine interest groups pushed for a change in state listing status, hoping that it would lead to a lowered federal status. After six years, the Florida Fish and Wildlife Conservation Commission decided to indefinitely defer downlisting the endangered status of manatees, due in large part to the efforts of Save the Manatee Club.

Attempts to weaken federal protection

Despite successes for pro-manatee groups at the state level, attacks on protective measures for manatee and other endangered species have also been waged federally. In the last eight years, numerous attempts have been made to undermine the federal Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA).

In 2003, a military budget was proposed to Congress that would have exempted the military from five environmental laws, including the ESA and the MMPA, even though there was no evidence that they had interfered with military operations. The proposal would have also weakened the definition of harassment under the MMPA. Then, in 2005, Representative Richard Pombo (California) introduced the *Threatened and Endangered Species Recovery Act*, which was intended to replace the ESA. Among its provisions, it would have changed the definition of conservation so that species might be protected to some extent, but not necessarily enough for populations to recover. Pombo's bill also included an amendment by US Representative Adam Putnam (Florida) that would have exempted manatees from protection under the MMPA, in regard to granting permits for dock-building.

Further attempts to weaken conservation measures occurred in 2007 when the Department of the Interior proposed to protect listed species only in those areas of their range where their survival was threatened, in contrast to the ESA, which currently requires that species be protected throughout their range.

Most recently, in August 2008, changes were proposed by the administration through the Department of the Interior, which would eliminate independent project reviews carried out by the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). Currently, projects authorized, funded or built by federal agencies (e.g. wetland-modifications, real estate development, and oil and gas drilling) require independent reviews to assess potential impacts upon 1353 listed plant and animal species and their critical habitat. Such reviews have been conducted since the Act's inception 35 years ago, and are imperative in rapidly developing states such as Florida. Under the proposed changes, agencies could undertake their own evaluations of the potential impacts of their projects on listed species and critical habitat, even if their staff lack knowledge of wildlife and ecosystem biology. Supporters of this proposal claimed that eliminating much of the independent review process will allow efforts to be focussed on the most menacing projects, but for species such as manatees the cumulative impacts of the numerous smaller projects can be as damaging as single large projects, or even more so. Fortunately the new US president, Barack Obama, is working to reverse these changes.

The ESA has been a strong protector of manatees and other wildlife. Its right to request modification of a project, or to refuse it altogether, is one of its main strengths in helping to ensure species protection. It is also what has made the ESA a target for pro-development forces.

State protections

In addition to a state list of imperiled species, Florida has developed various other strategies to help manatees and humans coexist. Guidelines have been created to help developers and local governments site marinas and docking facilities so that interactions between boats and manatees are minimized. State-approved manatee protection plans (MPPs), with guidelines for siting boat facilities, educational requirements, and other strategies to protect manatees, have been mandated and completed for 13 Florida counties, and several additional counties have developed MPPs. Unfortunately, there is no single set of standards and there is considerable variation in the quality and content of these MPPs. Some cannot guarantee minimal adverse impacts on manatees or their habitat, as intended.

There are counties in Florida that lack MPPs altogether, and some counties with MPPs are now working to undermine these documents and the manatee protection that they provide. Permits for docking facilities and other coastal developments must consider impacts on manatees, but very few of these projects are ever blocked, and there is no consideration of cumulative impacts associated with a number of development projects in a given area. As Florida's human population continues to grow, development pressures will intensify, and manatees and their habitat will decline if strong protective measures are not upheld conscientiously.

The role of advocacy

Save the Manatee Club is a membership-based national non-profit organization based in central Florida and works actively in all areas of the state where manatees are found. The Club also funds and supports international efforts related to manatee conservation. Save the Manatee Club's primary funding is derived from a unique 'Adopt-a-Manatee®' programme. The Club uses its funding to support public awareness, education, research, and rescue and rehabilitation of manatees, along with advocacy and legal action to protect manatees and their habitat. Founded in 1981, this organization has served as the voice for manatees for 28 years.

Conclusion

Manatees represent the 'real Florida' and are a conservation symbol within the state. This species represents an endangered aquatic ecosystem that requires protection, and measures that conserve manatees will preserve this entire ecosystem. Hundreds of thousands of acres of Florida's coastal environment and their associated species of flora and fauna receive protection, at least in part, because of manatees. Florida has experienced unprecedented changes in the last century, which may be surpassed in scope only by what is yet to come. Human presence in Florida has altered the status of manatees so that their fate is interconnected with our own. As a people, we must decide if we will value and protect manatees and their habitat or if we will allow their demise as an acceptable consequence of 'progress'. There are opportunities for humans and manatees to co-exist, but only if sound growth management and conservation strategies are utilized.

As Floridians look to the future, it would be wise to consider that the qualities of Florida that have served manatees – the crystal clear springs, shallow lagoons, calm lakes, and splendid coasts – are the same qualities that have attracted 18 million humans to live in the state. If we create a landscape of polluted waters congested with boat traffic and littered with human debris, no longer suitable for manatees, we must question if it will be suitable for us.

Further Reading

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One of Florida's manatees surfaces to breathe

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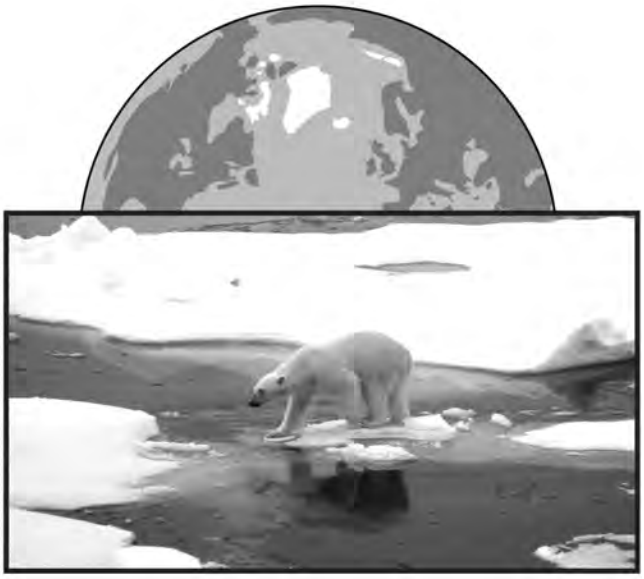
The Arctic

A Race for Resources or Sustainable Ocean Development?

Tavis Potts and Clive Schofield



The Arctic Ocean is a semi-enclosed sea surrounded by five coastal states: Canada, Denmark (Greenland), Norway (Svalbard), the Russian Federation and the United States of America (Figure 1). Since the planting of a Russian flag on the sea-bed at the North Pole in August 2007 there have been renewed efforts by the other Arctic Ocean littoral states to reinforce their claims in the region. This, combined with the dramatic decrease in the extent of summer sea-ice, means that the Arctic has become a focus of global media, scientific and government attention. Much of this Arctic narrative has been decidedly alarmist, not to say misleading, featuring tales of a 'scramble' or 'race' for the Arctic, and talk of an Arctic 'land-grab' or 'gold rush'. Underlying the expectation of resource-driven competition between nations staking claims in the Arctic is the perception that the Arctic represents a potential scene for geopolitical confrontation or the basis for a new Cold War.

Current activities in the Arctic

Despite its remote location, the Arctic has long been affected by a variety of human influences, including exploitation of its resources (notably hunting and fishing, reindeer husbandry, forestry and mining), and activities such as dumping and navigation. Hunting of species such as whales, seals, walrus and polar bears has been practised by indigenous communities and people from outside the Arctic for hundreds of years. Arctic and especially sub-Arctic waters are known for their highly productive fisheries, with several important fish stocks exploited for commercial gain since the mid-20th century. Europe remains an important market for Arctic fisheries, with stocks of Arctic cod, herring, capelin, haddock and shrimp of commercial importance. Perhaps surprisingly, about half the fish consumed in the EU comes from the European Arctic.

In recent decades, oil and gas resources have also been exploited in the Arctic, though predominantly onshore north of 60° latitude in Russia, Alaska, Canada and Norway; there will be a concerted move offshore as technological advances facilitate the exploitation of sea-bed resources in deeper waters and harsher environments. Mining has been a significant activity in the terrestrial Arctic, for gold, nickel, lead, zinc, diamonds and coal. Mining and associated infrastructure has led to increased wealth and investment in remote parts of Canada, Alaska, Russia and Svalbard, but has had a range of environmental and social impacts.

Because of its proximity to human populations, the Arctic has long been a recipient of hazardous material. Pollutants such as radionuclides, heavy metals and persistent organic pollutants are transported over long distances to the Arctic in air masses originating over Europe, Russia and North America. Most pollutants result from the manufacture, use and storage of industrial agricultural chemicals or are by-products of industrial activity.

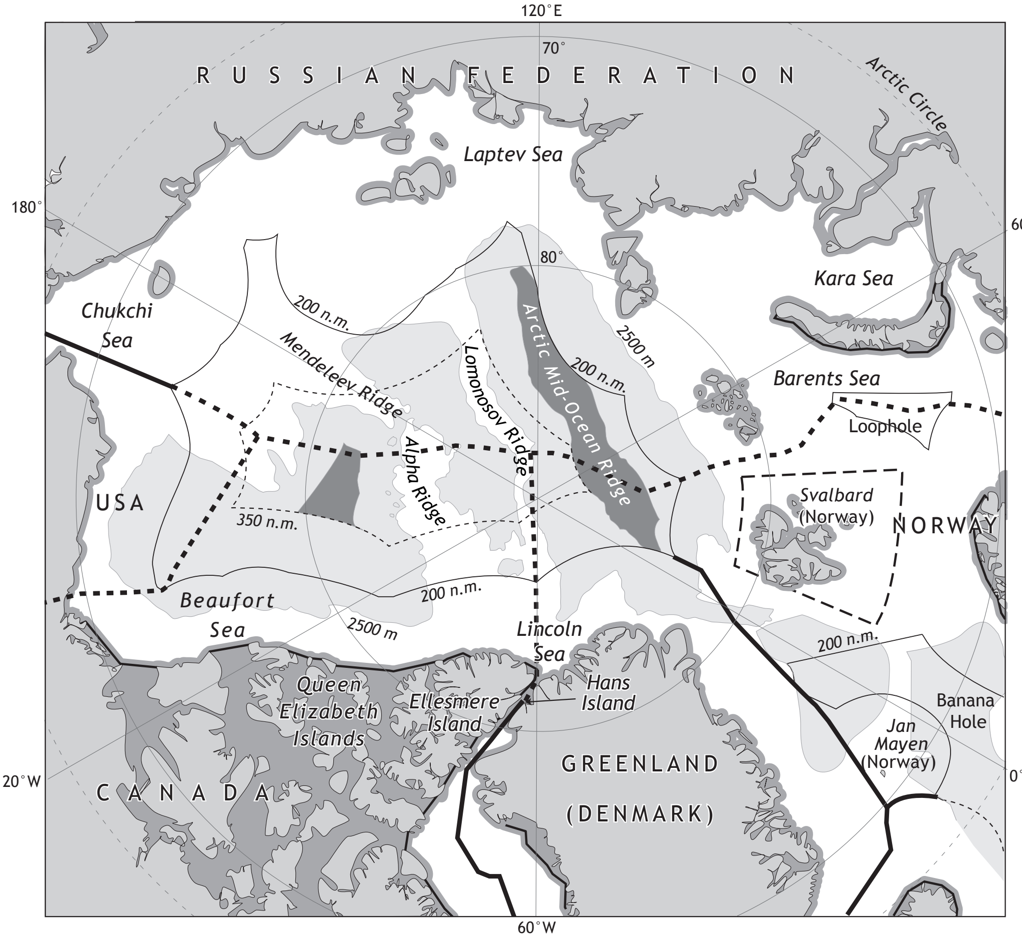
Pollutants are present in a range of Arctic flora and fauna. Indigenous communities are particularly susceptible to pollutants, and public health concerns have been identified, particularly for communities who have a traditional diet based on fish and marine mammals at the top of the food chain, which bio-accumulate pollutants.

Arctic jurisdiction and governance

Arctic maritime claims

The key international legal framework governing ocean affairs, including maritime jurisdictional claims and the delimitation of maritime boundaries, exploration for and exploitation of marine resources, navigation, and preservation of the marine environment, is provided by the 1982 United Nations Convention on the Law of the Sea (UNCLOS). UNCLOS came into force in 1994 and has gained widespread international acceptance. Four of the five Arctic coastal states are parties. The exception to the rule is the United States. The US does, however, generally regard UNCLOS as reflecting customary international law and therefore pursues a policy in accordance with it.

All the Arctic coastal states have made 200 n.m. maritime claims but a large area of the central Arctic Ocean lies seaward of these claims



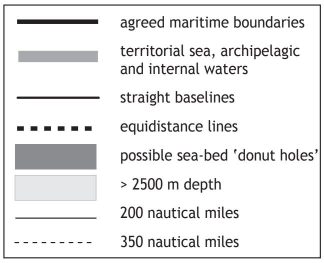


Figure 1 *Map showing maritime claims, agreed maritime boundaries and theoretical equidistance lines in the Arctic region. A large area in the central part of the Arctic Ocean lies beyond the 200 n.m. limits of the maritime claims of the coastal states. Two areas beyond 200 n.m. from the coast – the so-called 'Loophole' and 'Banana Hole' – also exist in the Barents Sea and Norwegian Sea. Most of the sea-bed of these areas is likely to be subject to submissions to the Commission on the Limits of the Continental Shelf (CLCS) on the part of the relevant coastal states (see Box opposite). However, the two grey-shaded 'donut holes' in the central Arctic Ocean are likely to lie beyond national jurisdiction and form part of the International Seabed Area. (Note that the breadths of territorial seas and EEZs are generally measured from the low-water line as marked on large-scale charts officially recognized by the relevant coastal state (UNCLOS, Article 5). However, where the coastline is deeply indented or there is a fringe of islands along the coast, states may instead use straight baselines, such as around Norway's northern coastline.)*

All of the Arctic littoral states, including the US, have advanced claims consistent with UNCLOS, notably 12 n.m.*-breadth territorial seas, within which states have complete sovereignty subject to the right of 'innocent passage' on the part of foreign vessels, and 200 n.m. exclusive economic zones (EEZs), within which states have specific sovereign rights and obligations in relation to living and non-living marine resources (see Figure 1). Otherwise, however, high seas freedoms, for instance over navigational rights, are retained within claimed EEZs. Under UNCLOS, states may also be able to establish sovereign rights over areas of 'outer' or 'extended' continental shelf, seaward of the 200 n.m. EEZ limit (see Box, p.25).

Wherever the maritime claims of the Arctic coastal states overlap, there is a potential maritime boundary. By no means all the maritime boundaries in the Arctic have been agreed, and there are a number of overlapping claims and boundary disputes, notably between Canada and the US in the Beaufort Sea, between Canada and Denmark (Greenland) in the Lincoln Sea, and between Norway and Russia over the status of the waters around Svalbard (Figure 1) and over maritime delimitation in the Barents Sea. Such disputes are hardly remarkable and reflect the incomplete nature of the maritime delimitation picture worldwide, with under 50% of potential maritime boundaries agreed. In fact, the Arctic region generally lacks major territorial disputes.

*1 international standard nautical mile (n.m.) is numerically equal to 1.852 km, which is equivalent to 1 minute of latitude ($^1/_{60}$ of 1° of latitude) at around 44° latitude.

The relatively minor (and arguably curious) exception is the dispute between Canada and Denmark over possession of Hans Island. Hans Island is a tiny (1 km^2) island located roughly midway between Canada's Ellesmere Island and Greenland. Although sovereignty over the island is disputed, the parties managed to define a sea-bed boundary through the strait by means of the innovative expedient of ignoring the island for the purposes of constructing the delimitation line of the continental shelf line: the boundary line stops just short of the island to the south and then continues from a point located just off the island's northern coast.

Article 76 of UNCLOS lays down a complex series of formulae through which the coastal state can define the outer limits of its continental shelf areas lying seaward of the 200 n.m. limit (see Box). In order to establish entitlement to outer continental shelf areas in accordance with Article 76 a coastal state is required to gather information related to the morphology of its continental margin as well as its geological characteristics and bathymetric information. This information is then submitted to a specialised United Nations technical body – the Commission on the Limits of the Continental Shelf (CLCS) – for assessment (see later). Arctic coastal states are therefore busy gathering the complex datasets needed to formulate submissions relating to their outer continental shelf claims.

Where law, geoscience (and politics) meet

Defining the limits of the outer continental shelf

Article 76 of UNCLOS states that the continental shelf of a coastal state consists of 'the seabed and subsoil of submarine areas' and extends beyond its territorial sea either:

- to a distance of 200 n.m. from relevant baselines (usually the low-water line, or, under certain conditions, straight baselines) (cf. Fig.1); or
- 'throughout the natural prolongation of its land territory to the outer edge of the continental margin'.

Where a coastal state is contiguous to a broad continental margin that extends beyond the 200 n.m. limit, Article 76 provides two entitlement formulae through which it can establish that such continental margin extends beyond the 200 n.m. limit. Both of these formulae are measured from the foot of the continental slope, i.e. where the steep continental slope becomes the more shallow continental rise, a point defined as 'the point of maximum change of gradient' unless there is 'evidence to the contrary'. They give rise to:

- The Gardiner Line – based on the thickness of sedimentary rocks overlying the continental crust; or
- The Hedberg Line – a line no more than 60 n.m. from the foot of the continental slope.

Once the existence of continental shelf beyond the 200 n.m. limit has been established, two maximum constraint or 'cut-off' lines are then applied:

- 350 n.m. from the relevant baselines; or,
- 100 n.m. from the 2500 m isobath.

The coastal state has the option of applying whichever of these entitlement formulae and constraints are most advantageous to it.

The outer limits of a coastal state's outer continental shelf are to be defined by 'straight lines not exceeding 60 nautical miles in length, connecting fixed points defined by coordinates of latitude and longitude'.

The problem of ridges

Article 76 also states that the 350 n.m. cut-off applies to 'submarine ridges' but that this constraint does not apply to 'submarine elevations that are natural components of the continental margin, such as plateaux, rises, caps, banks and spurs', which are sometimes described as ridges. Distinguishing between the various types of 'ridge' has proved to be problematic and contentious and has provoked considerable debate. Ridge issues are highly relevant to the outer continental shelf claims of the Arctic states. For example, Canada, Denmark and Russia in particular are keen to demonstrate that the Lomonosov Ridge is composed of continental crust, linked to their respective continental margins and thus legitimately part of their natural prolongations and outer continental shelf entitlements.

The changing Arctic

In 2004, the Arctic Climate Impact Assessment (ACIA) project observed changes in the Arctic climate over recent decades and investigated a range of future impacts on the natural and socio-economic structure of the region. The ACIA highlights that the Arctic is sensitive to climatic changes, and observed temperatures show that despite evidence of cooling in southern Greenland, the Labrador Sea and the North Atlantic, for the Arctic as a whole the trend is for substantial warming. Between 1954 and 2003, the mean annual surface air temperature rose by 2–3 °C in Alaska and Siberia with winter rises averaging 4 °C. Interestingly, the ACIA reports that indigenous perceptions and experiences of climatic warming in the Arctic match scientific observations, particularly as regards changes in biodiversity and ecology of Arctic flora and fauna, weather patterns, sea-ice and impacts on indigenous cultures.

The ACIA developed predictions for a range of future climate scenarios in the Arctic. The predictions were constructed on the basis of composites of five ACIA climate models based on the Intergovernmental Panel on Climate Change (IPCC) B2 scenario (global development on a path of environmental sustainability – a conservative emissions scenario). From 1990 to 2090, projected annual temperatures show a uniform warming of up to 4 °C. However, projected surface air temperatures in winter may rise by ~ 4–5 °C over land and potentially up to 8–10 °C over the Arctic Ocean and its coasts – a cause for serious concern.

In September 2007, the European Space Agency reported that the area covered by sea-ice had shrunk to its smallest summer extent since the initiation of satellite measurements 30 years ago. The United States National Snow and Ice Data Center (NSIDC) reported that the average five-day mean sea-ice extent in September 2007 was 4.13 km^2 million, compared to the 1979–2000 average of 6.74 km^2 million. The record 2007 sea-ice reduction followed the 2005 record minima of 5.32 km^2 million. The recent 2008 summer ice extent was closely monitored by the NSIDC and the media. The average September summer extent was recorded as 4.67 km^2 million, making it the second lowest on record. Compounding the issue of summer sea-ice extent is the thinning of winter sea-ice. Overall, the mean ice thickness within the central Arctic Ocean was reduced by 40% between the periods of two submarine ice-draft climatologies, for 1958–1976 and 1993–1997, as identified in Rothrock *et al.* 1999 (see Further Reading).

This dramatic loss can be viewed in the context of reductions in summer sea-ice cover over the last 10 years of approximately 100 000 km^2 per year, on average. Forecast models of summer sea-ice extent show a continuing downward trend, but scientific debate continues over how long it will be before the Arctic will be ice-free in summer. It remains to be seen whether the present summer sea-ice regime is part of a long-term cycle, or the system has switched into a new state of decline; however on the basis of the 2008 record, the NSIDC noted that the implications of the declining trend were 'enormous'.

The increase in temperatures, reduction of sea-ice and altered hydrology arguably presages a 'step change' in the nature of impacts on ecosystems and communities within the Arctic. The impacts on the environment include the shifting of vegetation zones and ecosystem-scale changes to Arctic habitats and species. Changes to migration and breeding behaviour, foraging ecology and the introduction of invasive species will lead to altered diversity, distribution and abundance of species. For the four million indigenous and non-indigenous residents, impacts from a warming climate include damage to infrastructure from melting permafrost, increased coastal erosion, impacts on health, water and food supply and economies. In addition, changes in species distribution, landscape, and a shift in economic drivers, will mean indigenous communities will have to adapt to a changed way of life and loss of traditional cultural practices.

Arctic opportunities

What of emerging and future uses of the Arctic Ocean? A substantial debate has been developing in the relevant literature regarding the range and extent of economic activity in the Arctic. While the extent and mix of socio-economic activities is open to conjecture and will differ at sub-regional scales, it is likely that in the Arctic, economic activity will grow as warming patterns evolve.

Fabled sea routes

While there is little doubt that navigation in Arctic waters is on the rise, led by developments in the oil and gas sector, increasingly in respect of fisheries and, particularly, through tourism, these developments are regional in character rather than involving inter-oceanic transits. Thus, for example, offshore oil and gas activities are concentrated in the Barents and Kara Sea, while ship-based 'adventure cruising', which has expanded considerably, tends to be focussed on the Nordic Arctic, especially Svalbard, although it has also been increasing rapidly in the eastern Canadian Arctic.

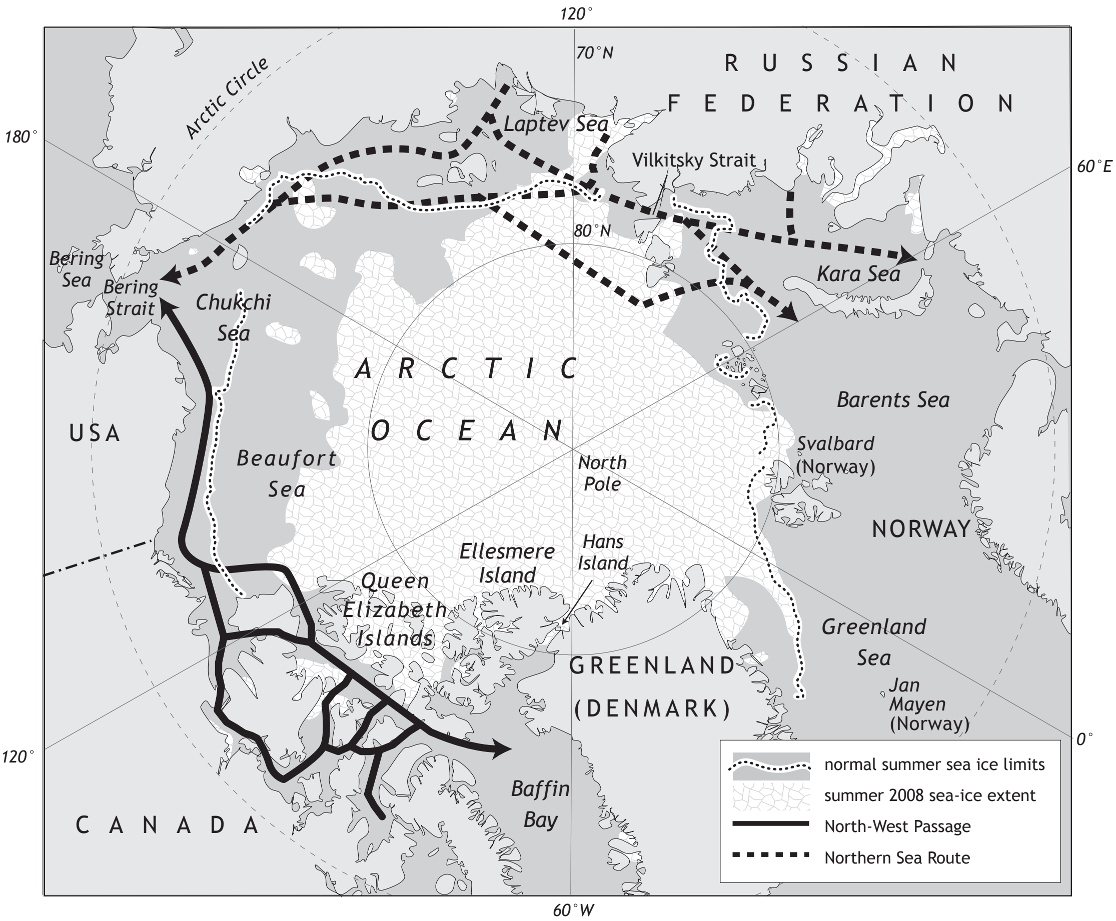
Nevertheless, the reduction in sea-ice has re-awakened dreams of the opening up of long-sought navigational routes across the 'roof of the world': the North-West Passage (aptly termed the 'Arctic Grail') and the Northern Sea Route (formerly known as the North-East Passage), both of which are a series of intertwined passages rather than a single route (Figure 2). There may also even be a transpolar route.

Satellite imagery from September 2007 shows the North-West Passage completely ice-free and the Northern Sea Route partially blocked. In 2008, the September minimum recorded by the NSIDC showed both the Northern Sea Route and North-West passage as open. Indeed, in October 2008 the research vessel *Polarstern* returned to its home port of Bremerhaven having completed a double transit of both the North-West Passage and Northern Sea Route without having to break any ice.

The prospect of the opening up of shipping routes in the Arctic, linking Europe to Asia, is certainly an enticing one for the shipping sector. Purely in terms of distances to be travelled, if navigable, the North-West Passage would offer a 9000 km (4860 n.m.) saving on the route between Europe and Asia via the Panama Canal, whilst the Northern Sea Route would entail distance savings of almost 40% on the transit between northern Europe and north-east Asia via the Suez or Panama

Figure 2 *Potential routes of the North-West Passage and the Northern Sea Route, shown in relation to the normal summer limit of sea-ice and the extent of sea-ice in 2008 (data from the United States National Snow and Ice Data Center).*

If open and safe to navigate, the Northern Sea Route and the North-West Passage could allow voyages between the Pacific and the Atlantic to be thousands of kilometres shorter than at present



Canal. The distance savings involved in a trans-Arctic 'over-the-top' route are, unsurprisingly, even more dramatic with, for example, a voyage between Hamburg, Germany, and Kobe, Japan, being cut from 11 225 n.m. (via Suez) to around 5000 n.m. – a saving of approximately 6225 n.m., or 55% of the distance involved. Small wonder then that possible navigation via Arctic routes has been the subject of considerable excitement and speculation.

However, pure distance savings do not tell the whole story. Even with reductions in ice-cover, increasing access and lengthening of the navigational window, ice will remain a hazard to shipping in Arctic waters. It is highly probable that there will still be some cold summers with, inevitably, heavy sea-ice conditions. Navigation through the Arctic will therefore necessitate the use of ice-strengthened vessels, which are significantly more costly to build, maintain and operate than conventional shipping. Additionally, the threat of sea-ice will in all probability translate to slow and cautious passages which may well require ice-breaker assistance (Figure 3) – all of which serve to undermine any savings in transit times and navigational costs implied by the enormous distance savings. It is also the case that finding insurance for ships and cargos undertaking Arctic navigation is likely to prove highly problematic given the inherent risks involved in navigating Arctic waters.

With regard to the North-West Passage, there are grounds for suggesting that even with a rise in temperature there will be only a marginal lengthening in the summer sailing season and, more alarmingly, that navigation through the North-West Passage may become considerably more hazardous rather than less. This is because the Canadian Arctic Archipelago, especially the Queen Elizabeth Islands, and the first-year ice that forms in the channels between these islands, tends to shield the North-West Passage from the concentrations of older and considerably harder sea-ice that builds up in the central Arctic Ocean (Figure 4) . The melting of first-year sea-ice therefore has the potential to lead to a greater intrusion of multi-year 'old ice' from the Arctic Ocean proper into the North-West Passage (cf. Figure 4). This tends to replace the ice that has melted, in effect 'filling up' the Passage with thicker ice and thus restricting any lengthening in the summer sailing season. This is likely to make navigation through these waters considerably more hazardous, even for ice-strengthened vessels and ice-breakers, especially as old ice is extremely hard, durable and potentially lethal for a vessel in the event of a collision. Furthermore, there are indications that the melting of first-year ice may result in the southern migration of pack ice in the Beaufort Sea, potentially blocking, or hampering access to the western entry/exit to the North-West Passage.

In contrast, the Northern Sea Route has, officially at least, been open for business since 1991. While this route, or series of routes, has certainly provided a crucial link to the outside world for Russia's Arctic settlements and allowed, for example, the export of ores and processed metals from the region, the Northern Sea Route's role as a potential transit route linking the Atlantic and

Figure 3 *A Russian ice-breaker operated by the Murmansk Shipping Company, photographed in the Vilkitsky Strait which links the Laptev Sea and the Kara Sea (and so is part of the Northern Sea Route).*

Photo by courtesy of Ben Powell.

A ship cannot be broader in the beam than the ice-breaker it needs to follow

Pacific Oceans is more questionable. It is perhaps significant that although the route has on occasion been used, for example by vessels such as the above-mentioned *Polarstern*, thus far there have been no regular commercial transits by non-Russian vessels.

The key obstacle to the use of the Northern Sea Route as an alternative to traditional navigational routes is that there are size restrictions on the shipping that can use it. These size restrictions are a function, particularly, of the shallow nature of a number of the straits lying between the mainland

Figure 4 *Melting sea-ice in Vilkitsky Strait. The thinner flat ice is first-year ice, the hummocks are the remains of old ice that over the years has been pushed together, rafted layer upon layer. Given that about 90% of the ice-volume is below the sea-surface, sailing through such an area of sea is very dangerous, even for ice-breakers.*

Photo by courtesy of Ben Powell.

Waters infested with sea-ice are dangerous, especially if some of the ice is old, hard ice

and islands offshore the Siberian coast, which restricts the draft of ships using the Northern Sea route to 12.5 m. Although, such depth limitations can be overcome by following a higher-latitude 'outer' route, this alternative is, inevitably, more ice-prone and thus hazardous and unreliable. Furthermore, the need for ice-breaker assistance due to unpredictable ice conditions along the route means that there is a requirement that shipping not be broader in the beam than the ice-breaker it needs to follow, which translates to a beam restriction of 30 m.

In combination, these draft and beam restrictions mean that the maximum size of vessel capable of using the Northern Sea Route is around 50 000 dead-weight-ton (d.w.t.). This compares unfavourably with the size of vessels plying the traditional Suez route which may be at least four times the size (currently 'Suezmax' class ships can be up to 200 000 d.w.t. with a draft of up to 19 m, but the canal is being widened and deepened in order to accommodate 350 000 d.w.t. vessels). This factor alone undermines the logic of using the Northern Sea Route because despite the impressive potential distance savings involved, the option makes little sense if three or four transits are needed to deliver the same volume of cargo as could be achieved by one voyage via a traditional route.

The Northern Sea Route might retain some attraction for the transport of smaller, high-value cargos, but another issue of concern is punctuality. Unpredictable sea-ice conditions allied to uncertainty over the availability of assistance from the large but ageing Russian ice-breaker fleet is likely to impact on punctuality – an issue of serious concern in an era when reliable, just-in-time deliveries are increasingly considered essential in international commerce. Despite these seemingly compelling drawbacks, it has nonetheless been reported that the German shipping company Beluga plans unassisted sailing using the Northern Sea Route from the summer of 2009.

Increasing navigation in the Arctic also equates to increased risks of maritime accidents, and brings into question the capacity of coastal states to deal with such an eventuality, both in terms of rescuing those involved and addressing the environmental impacts of, for example, a major oil spill. A recent series of accidents, involving tourist operations in both polar regions, serves to highlight the issue. In August 2007, the collapse of a glacier onto the *Alexey Maryshev* resulted in injuries to 46 tourists off Svalbard. In November 2007, the MS *Explorer* sank in the Antarctic, necessitating the emergency evacuation of 154 passengers and crew. Two more cruise ships, the MV *Ushuaia* and the *Ocean Nova*, ran aground off the Antarctic Peninsula in December 2008 and February 2009, respectively. While the *Ocean Nova*, carrying 106 passengers and crew, was freed by high tides, the 89 passengers and crew of the *Ushuaia* had to be rescued. It is clear that 'expedition cruising' in remote and potentially hazardous waters is growing, and it can be reasonably anticipated that this growth will continue.

Consequently, the coastal states are increasingly moving to assert their jurisdiction over navigation in Arctic areas. Article 234 of UNCLOS allows coastal states to adopt and enforce non-discriminatory provisions with the objective of preventing, reducing and controlling marine pollution from vessels in ice-covered areas of their EEZs, where severe climatic conditions and the presence of ice cover 'for most of the year create obstructions or exceptional hazards to navigation'. While Russia has long relied on Article 234 to justify its jurisdiction over the Northern Sea Route – requiring prior notice for vessels intending to use the Northern Sea Route and the submission of an application and set payment for services in support of passage (often termed the 'ice-breaker fee') – Canada has only recently signalled its intent to apply a similarly compulsory regime.

In August 2008, Canada announced that it would be extending the application of its Arctic Waters Pollution Prevention Act from 100 n.m. to 200 n.m. and would also be making use of its Arctic marine traffic scheme, NORDREG, mandatory. These moves – the logic of which seems self-evident given the risk of a major shipping accident in hazardous high-latitude waters, with the attendant threat to the fragile Arctic environment – are likely to prompt a renewed round of exchanges between Canada and the US in their long-standing dispute over the legal status of the North-West Passage. Indeed, in one of his final acts, outgoing US President George W. Bush signed a National Security Presidential Directive on 9 January 2009. The Directive notes the US's 'broad and fundamental' national security interests in the Arctic region, including in respect of freedom of navigation and overflight rights – something the Directive termed a 'top national priority'. For the first time the US also explicitly asserted that straits used for international navigation in both the North-West Passage and the Northern Sea Route are seaways to which the non-suspendable right of 'transit passage',* open to vessels of all nations, applies. The interpretation and application by states of Article 234 in the face of increasing shipping is therefore likely to remain a source of future legal debate.

*Under UNCLOS, transit passage permits 'the exercise ... of the freedom of navigation ... soley for the purpose of continuous and expeditious transit between one area of the high seas or an exclusive economic zone and another ...'.

Sea-bed resources – the 'last frontier'?

The Arctic has been portrayed as a major potential source, or 'last frontier', of sea-bed energy resources and, from a US perspective, as a potential 'strategic energy reserve'. The authority often cited to support this view is the United States Geological Survey's (USGS) 2000 estimate that the Arctic may hold as much as 25% of the world's undiscovered hydrocarbon resources. This view was elaborated and largely reinforced with the publication of the USGS's May 2008 *Circum-Arctic Resource Appraisal*. This assessment noted the existence of over 7 million km^2 of Arctic continental shelf areas under less than 500 m of water and advanced the view that these shallow continental shelf areas 'may constitute the geographically largest unexplored prospective area for petroleum remaining on Earth'. The USGS report went on to conclude that overall the Arctic may host around 22% of 'undiscovered, technically recoverable' resources globally, potentially consisting of 90 billion barrels of oil (13% of global undiscovered oil), 1669 trillion cubic feet of natural gas (30% of undiscovered gas), and 44 billion barrels of natural gas liquids (20% of undiscovered liquids). Significantly, the USGS appraisal suggested that 84% of potential resources were located offshore and that for most of the Arctic basins, it is about three times more likely that gas will be found than oil. Russian estimates regarding the potential energy resources of the Arctic have been similarly optimistic. On the basis of these figures it seems clear that the Arctic is potentially an enormously significant source of sea-bed oil and, particularly, gas.

There are, however, a number of factors that suggest that an Arctic hydrocarbon bonanza is unlikely, at least in the short term. There has been little serious exploration (i.e. very little in the way of seismic activities, let alone drilling) in Arctic waters proper (especially in the central Arctic Ocean) due to the presence of sea-ice coupled with severe environmental conditions. Indeed, as a consequence of the sparsity of available data, the 2008 USGS appraisal based its findings on a ‘probabilistic’ analytical methodology, emphasizing the inherent uncertainties associated with estimates of undiscovered oil and gas (Figure 5). A more conservative view is consistent with a recent (November 2007) report employing detailed geoscientific analysis of individual Arctic basins, backed by oil industry data on exploration wells and existing discoveries, the findings of which were considerably less optimistic than the estimates outlined above (3 million barrels of oil per day and 5 million barrels of gas equivalent per day at peak production).

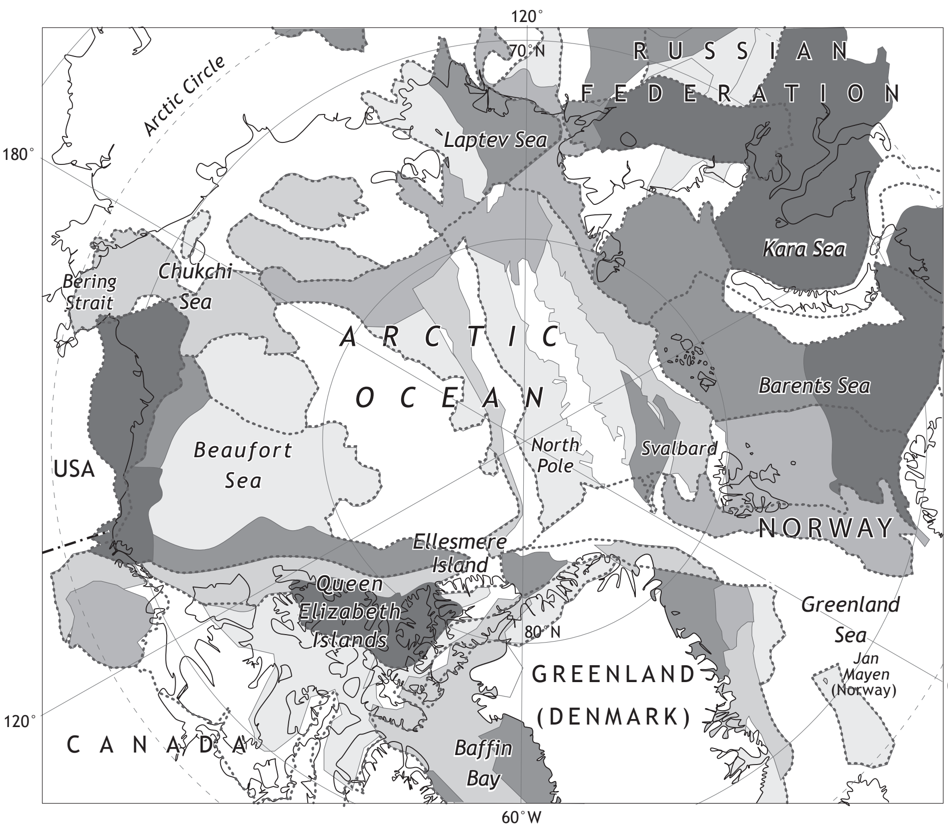
The conclusion contained in both this analysis and the 2008 USGS appraisal that the Arctic is predominantly ‘gas-prone’ has significant implications because gas is considerably harder to transport to markets, and the technologies that are required to achieve this aim (especially offshore) are still in their infancy, meaning that exploitation of a large portion of Arctic sea-bed resources is likely to be delayed until 2050 at least. Overall, the November 2007 report concluded that its findings were ‘disappointing from a world oil resource base perspective’ and call into question ‘the long-considered view that the Arctic represents one of the last great oil and gas frontiers and a strategic energy supply cache for the US.’

A further important point to note is that most if not all of the Arctic oil- and gas-bearing sedimentary basins that have been analyzed fall within 200 n.m. of the coast and thus within the declared EEZs of the Arctic littoral states (cf. Figure 1). This situation is at odds with the prevailing perception of a resource-driven race to the Pole in respect of potentially overlapping claims to outer continental shelf areas in the central Arctic Ocean.

This is not, however, to discount the idea that major oil and gas finds will be made in the Arctic – they will just not necessarily be on the same scale or in such a swift time-frame as some

Figure 5 *Map showing the likelihood of oil/gas being found in various areas of the Arctic Ocean, taken from the USGS's May 2008 Circum-Arctic Resource Appraisal. For each sedimentary basin, the intensity of the grey tone shows the probability that the basin contains at least one oil and/or gas field with recoverable reserves equivalent to > 50 million barrels of oil. Comparison with Figure 1 shows that the basins with a high probability of containing hydrocarbons fall mainly within the EEZs of the Arctic littoral states, rather than in the more contentious outer continental shelf areas.*

By courtesy of the US Geological Survey.



It is likely that most offshore hydrocarbon deposits discovered will fall within the EEZs of Arctic littoral states

optimistic reports may suggest. Furthermore, the strong perception that such sea-bed riches may exist is in itself a powerful factor in motivating claims to maritime jurisdiction. For example, in the above-mentioned US National Security Directive of January 2009, it is stated explicitly that 'energy development in the Arctic region will play an important role in meeting growing global energy demand' on account of the 'substantial portion' of global undiscovered energy resources thought to exist there.

It has also been suggested that the sea-bed of the Arctic Ocean may harbour substantial reserves of gas hydrates, which may be exploited in the future. While the potential may well be very large, the technologies required to exploit these resources, especially from such remote areas and in such hostile conditions, mean that their exploitation currently remains over the horizon.

Arctic living resources and biodiversity

The Arctic is a highly productive marine ecosystem and represents one of the few regions where fish stocks remain in a relatively healthy state (Figure 6). Fishing presents one of the more significant threats to Arctic marine biodiversity in the short and medium term. While the Arctic is host to several globally significant fisheries in the Bering and Barents Seas, there are potential opportunities and concerns relating to new fisheries in previously inaccessible areas, and changes in existing grounds. Key causes of concern include potential impacts from fishing gear, and from vessels that are able to exploit stocks in deep water, particularly in the case of high seas bottom trawling.

Climate-induced migration and population changes may further complicate fisheries management arrangements. The ACIA report notes how a changing Arctic environment will force major changes in species distributions, diversity and ranges, with consequences for dependent and associated species. For example, the 1987 climate-related collapse of the capelin stock in the Barents Sea had major impacts on seabirds in the region. Changes to ice algae and related changes in food-web dynamics are likely to impact on fisheries, but the extent of impacts are at this stage relatively unknown. Climate change may also prove to be positive factor in increasing the productivity of certain stocks. Moderate warming may increase the productivity of herring and cod stocks through providing increased habitat and increased productivity of prey. However, Arctic ecosystems are complex and not well understood in the context of changing climatic, ecological and oceanographic conditions, and while productivity may increase in some species, decreases could occur in other dependent and associated species.

Implications for fisheries

The migration of stocks is a factor that could complicate ecological relationships between stocks and their management. The migration, overfishing, collapse and rebuilding of the Norwegian herring fishery in the 1950s to the 1990s illustrates how the twin influences of climatic changes and management regimes are critical in determining fisheries sustainability. Recent studies have shown that populations of a number of commercially important fish species are shifting northwards as water temperatures increase. The ACIA reports that rising bottom-water temperatures in the Bering Strait are resulting in a northward shift in some fish stocks seeking colder and deeper waters, and this is affecting predator–prey relationships. In the North Atlantic, it has been reported that cod and haddock have shifted 60–70 km northwards.

Whether it is new stocks that migrate into Arctic waters and displace, or compete with, existing Arctic stocks, or shifts in the ranges of indigenous species, management arrangements for fisheries will become increasingly complicated. Fishing fleets may need to change gears and methods in order to catch new species, or may need to travel to new fishing grounds. It has been reported, for example, that Icelandic fishermen have been exploiting cod stocks in the Barents Sea 'loophole' (an area of high seas surrounded by EEZs: see Figure 1), in response to shifts in stock from

Figure 6 *Kittiwakes and humpback whales feeding off Bear Island, between Svalbard and Norway, at the western entrance to the productive Barents Sea.*
By courtesy of Finlo Cottier.

their home waters. This raises the challenge that from a management perspective, stocks could move across or straddle borders, prompting calls for the development and implementation of joint management regimes under the 1995 UN Fish Stocks Agreement. In light of the depletion of stocks elsewhere, especially in waters beyond the national jurisdiction of coastal states – the so-called 'tragedy of the commons' – new fishing opportunities in an ice-free Arctic will require strict management if they are not to be short-lived. This may require the extension of existing agreements such as the Norwegian–Russian Fisheries Commission or the North-East Atlantic Fisheries Commission. However, in light of broader ecosystem changes and pressures in the Arctic, and the critical importance of Arctic fisheries for European markets, consideration could be given to an Arctic Ocean-wide management regime. A possible model is the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLAR) in the Southern Ocean which has developed a wide-ranging ecosystem-based precautionary approach to fisheries. The key issue, however, is one of state sovereignty, and the political will necessary to negotiate regime reform. Despite this, in the future three things are relatively certain – there will be changes in the distribution and abundance of fish species, shifts in effort and capacity, and new players.

Genetic resources

In view of the region's unique environmental conditions, the Arctic may also prove to be a source of useful genetic material, raising issues about the preservation of biodiversity and the management of bioprospecting. A recent report from the United Nations University (see Further Reading) highlights the growing interest and commercial significance of bioprospecting for genetic resources in the Arctic. The report identified 43 commercially active companies that are engaged in research on, and exploitation of, biotechnology based on Arctic resources, as well as 31 patents on specific Arctic genetic resources. These resources are providing development potential for a range of commercial applications including anti-freeze proteins, bioremediation, pharmaceuticals, dietary supplements, other health applications, and cosmetics.

Arctic governance: challenges for a sustainable Arctic

It is clear that, in the Arctic, mineral resources are of strategic importance and under the jurisdiction of Arctic states. However, as this article has discussed, the extent of resource reserves and operational capacity is highly uncertain. Any future development must proceed with the mitigation of environmental impacts as its highest priority, and as part of a shared vision of the Arctic states. Considering the uncertainty over governance, impact mitigation, and the high stakes of any potential accident, it would seem appropriate to apply the precautionary principle to Arctic development.

The geopolitical aspects of claims to areas of outer continental shelf should not be discounted. Even though senior Russian officials have emphasized that Russia acted in accordance with international law, there is no doubt that the symbolic planting of the Russian flag at the North Pole served to alarm Russia's Arctic neighbours. It also did the Russian government no harm at home, as the flag-planting event was accompanied by a great fanfare in the domestic political context and was taken to represent a sign of Russia's more robust posture internationally.

A race to the Pole?

Concerning the question over a 'race to the pole' the answer is a highly qualified 'Yes' ... but mostly 'No'. Clearly a large area in the central Arctic Ocean lies beyond the 200 n.m. limits of the EEZ claims of the littoral states. It is in respect of this area that much has been written, especially following Russia's North Pole flag-planting escapade. However, while all the coastal states are engaged in a 'race' of sorts to gather scientific information on areas beyond their 200 n.m. EEZs, all have stated that they are doing so in strict accordance with the terms of UNCLOS.

Submissions will then be put to the UN Commission on the Limits of the Continental Shelf (CLCS; see earlier), which will provide recommendations on the basis of which coastal states will be in a position to declare final and binding outer continental shelf limits. For coastal states that were parties to UNCLOS prior to 13 May 1999, the deadline for submission to the CLCS is 13 May 2009, although in light of this looming deadline, the terms for meeting this requirement were considerably relaxed in June 2008. Both Russia (2001) and Norway (2006) have made submissions, and the CLCS has asked for additional supporting information from Russia. The deadline for submission from Canada is 2013, and for Denmark it is the following year. As a non-party to UNCLOS, no deadline has been set for the US.

A key uncertainty in this context, however, is how the Commission will deal with the question of ridges (see Box on p.25). This will be an issue of great concern to the Arctic coastal states given the presence of major ridges in the central Arctic Ocean, notably the Alpha, Lomonosov and Arctic ridges (Figure 1). Nonetheless, it has been suggested that the vast majority of the central Arctic sea-bed, perhaps with the exception of two 'donut holes' beyond national jurisdiction (dark grey in Figure 1), may be claimed by one or other of the Arctic coastal states. It is important to acknowledge, though, that the CLCS is a technical rather than a legal body. The Commission will therefore not resolve questions of overlapping claims. If such scenarios emerge, as appears likely, it will be up to the Arctic coastal states themselves to resolve them, either through cooperative approaches or, perhaps, by settling their maritime boundaries for areas beyond 200 n.m. with one another and then approaching the CLCS.

In fact, very little is known about the resource potential of the sea-bed in the central Arctic, though when queried about the resource potential of the North Pole area itself, USGS scientists have observed that the area did not appear 'very interesting'. Key factors likely to prevent the central Arctic yielding substantial oil and gas riches in the near to medium term include the fact that for the foreseeable future ice-cover is likely to linger in these areas, at least for much of the year, as well as the great depth of the waters involved – Russia used an unmanned deep-sea submersible to plant its flag in over 4200 m of water. Both these factors are likely to seriously compromise energy resource exploration and, particularly, exploitation activities in the central Arctic Ocean for the foreseeable future.

Resolving Arctic governance

UNCLOS clearly provides the international legal framework for maritime jurisdictional claims in the Arctic. Arguably, the same applies to the broader issues of governance in the Arctic. This appears to be the position of the Arctic coastal states.

In May 2008 Ministers from all five Arctic coastal states met in Greenland and issued the Ilulissat Declaration. This document emphasizes the 'sovereignty, sovereign rights and jurisdiction' of the five Arctic coastal states over 'large areas' of the Arctic Ocean and the 'unique position' this puts them in to address Arctic issues. The Arctic littoral states went on to note the existence of an 'extensive international legal framework' applicable to the Arctic Ocean including, notably, UNCLOS, which provides a 'solid foundation for responsible management … through national implementation and application of relevant provisions'.

The five Arctic coastal states went on to emphasize their commitment to 'this legal framework and to the orderly settlement of any possible overlapping claims' that might arise. Furthermore, they acknowledged their 'stewardship' responsibilities and agreed to cooperate amongst themselves to share information and to enhance search-and-rescue infrastructure. They also committed to continuing to work through existing 'soft law' mechanisms such as the Arctic Council but foresaw 'no need to develop a new comprehensive international legal regime to govern the Arctic Ocean'. Interestingly, other non-littoral Arctic states and indigenous groups such as the Inuit Circumpolar Council (ICC) were not included in discussions over the content of the declaration. The ICC responded in a recent press release claiming that the Illulissat Declaration 'completely ignores the rights Inuit have gained through international law, land claims and self-government processes'.

This national sovereignty and sovereign rights-oriented approach is at odds with the views expressed by leading environmental NGOs such as the World Wildlife Fund which has suggested that by itself UNCLOS 'is not enough'. More recently, in October 2008, the European Parliament passed a resolution calling on the European Commission to take a 'proactive role' in the Arctic, for instance by taking up permanent observer status on the Arctic Council. More controversially, the resolution went on to call for the initiation of international negotiations with the objective of the adoption of an international treaty for the protection of the Arctic, 'having as its inspiration the Antarctic Treaty'. Following the EU Parliamentary resolution, the EU Commission released a communication on the Arctic. The communication dropped any reference to adoption of an 'Arctic Treaty' but outlined a policy of systematic engagement in Arctic environmental protection, human rights, research and monitoring, sustainable resource development, and multilateral governance. Clearly the EU will be a significant player in Arctic affairs in the years to come.

These comments by the EU Commission fit an overall pattern of debate over the future of the Arctic and its mode of governance, and are concerned with whether the existing regime is sufficient to protect and manage the Arctic, or whether a new regime is required in the face of multiple pressures. Despite this debate, the paradigm in the Arctic is one of state sovereignty and cooperation via regional agreements – as evidenced by the Illulissat Declaration. In the medium term, it is likely that future economic activity driven by Arctic environmental changes will operate within this existing legal framework.

Domestic laws control development and environmental management in areas under national jurisdiction, but these laws are influenced by international pressures and commitments. International legal regimes concerning climate change, biodiversity, fisheries, trade and environmental protection are enacted by some or all of the Arctic states, but their application remains patchy, and many of the problems, such as climate change, require solutions stretching far beyond the Arctic. As Arctic states have opted to pursue a 'soft law' voluntary regime focussing on the coordination of scientific research, environmental management and sustainable development, efforts to protect and manage the Arctic can suffer from a 'lowest common denominator' effect, where a lack of action by one or more states can undermine or hinder the effective action of others. On the other hand, the current regionalist approach characterized by the Arctic Council has been moderately successful and realistic, although potentially due for reform as greater international attention is focussed in the region and external factors become increasingly important.

Possible future scenarios

We identify three possible scenarios for future governance: an existing or 'status quo' regime; a mixed reform regime; or a new binding international regime. The continuation of the existing and successful soft law regime in the Arctic is a likely scenario, particularly as Arctic coastal states are unlikely to relinquish their sovereignty to a binding international regime. The divergence of political opinion over the future use of the Arctic, together with continued geopolitical positioning, render establishment of a binding agreement difficult and lead to the idea of progressing within existing political frameworks. A 'flexible approach to norm building' within existing frameworks would appear to be a likely way to move forward on difficult issues and continue to improve regional environmental governance on issues such as monitoring and impact assessment, coordinating and harmonizing regulations, promoting cleaner production and reducing pollution.

A mixed reform regime would seek to reform the existing governance approach identified above. It would actively seek to address the inefficiencies of, and gaps in, the existing 'unambitious regime' and move toward addressing Arctic 'sectoral' issues where reform is needed (e.g. shipping, search-and-rescue). This could be a likely scenario where Arctic coastal states and other states with interests in the region move ahead on an issue-by-issue basis under international frameworks such as UNCLOS, particularly in the context of Article 123 on regional cooperation in enclosed and semi-enclosed seas. This approach would retain the principle of sovereign control in the Arctic but increase cooperation and move forward on difficult and emerging multilateral issues such as fisheries management and straddling and high seas stocks. Building in improved mechanisms to deliver ecosystem-based and precautionary based strategies, using existing instruments that are operational in the Arctic such the Convention on Biodiversity, would evolve under this scenario.

The final scenario of a comprehensive binding international regime, i.e. an 'Arctic Treaty', is an unlikely outcome. Reform is needed within the existing Arctic system, particularly clearly thought-out reform with established targets and the ability to address emerging transboundary problems. However, it is yet to be demonstrated that Arctic states have the political will or desire to move in this direction. It is therefore anticipated that efforts are more likely to be focussed on voluntary approaches. Several ideas have been discussed during consideration of a binding pan-Arctic Treaty mechanism loosely based on the 'Antarctic' model, but in the short term this is a highly unlikely development, despite the EU parliamentary resolution and lobbying on the part of some NGOs on the desirability of seeking such a treaty.

Overall, the future of the Arctic is subject to uncertainty and change. Change is coming from many directions – from the underlying physical and biological system driven by climatic warming, from geopolitical stances by the Arctic states, and in a resurgent interest in the potential or actual living and non-living resources of the region. Best international practice would develop and apply a precautionary and multilateral approach to the issues, backed by scientific research, an Arctic vision or Charter, and the political will to act on identified issues of concern, such as resource sustainability, ecosystem-based management and maritime jurisdictional claims. Whether the legal and governance regime in the Arctic evolves via a continuation of the status quo, through a mixed reform approach, or a new international regime, it is hoped that the future of the Arctic is one of sustainable development, peace and international cooperation.

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Book reviews

Restoring dynamic coasts

Beach and Dune Restoration by Karl F. Nordstrom (2008) Cambridge University Press, 187pp. £70 (hard cover, ISBN-13: 978-0-521-85346-0; ISBN-10: 0-521-85346-0; eBook format, ISBN: 978-0-511-42672-8).

Along many of the world's shorelines, it is now impossible to define what might be termed the 'natural' state as opposed to a state that is, at least partially, the result of human interference. At the same time, however, the ecological functioning of the coast is now recognized more than ever, as is the extent to which ecological functions add to the value of the coast for people. This new understanding leads to the rather challenging need to restore the 'natural' functioning of coastal ecosystems in the face of intense human pressures, such that the coast may fulfil its many varied functions, such as acting as a 'buffer zone' during storm events, providing 'accommodation space' for nationally and internationally important habitats, and retaining a certain resilience and adaptability to future environmental change. By 2020, 60% of the world's population is expected to live within 60 km of the coast and most of these people are likely to reside near sandy shores, as these types of coasts provide arguably the greatest economic potential through, amongst other things, opportunities for tourism and recreation. In this context, Karl Nordstrom's book on *Beach and Dune Restoration* is a timely and appropriate text.

The first chapter addresses precisely those issues that arise out of the intense human and environmental pressures on sandy shores on the one hand, and the recognition of the value of these habitats on the other hand. Throughout the discussion, the need to restore at least elements of the natural dynamism and resilience of sandy shores is recognized, as is the fact that 'natural processes cannot be relied upon to re-establish natural characteristics' (p.3). The book contains a comprehensive review of the concept of 'restoration' (as opposed to conservation) and its various goals and associated approaches, and recognizes that unprecedented challenges lie ahead. These include the need to set targets for restoration that allow adaptation to as yet often uncertain potential future environmental and socio-economic scenarios, rather than to define restoration by reference to historic baselines.

Karl Nordstrom's book focusses firmly on intensively developed coasts. The author discusses a multitude of practical approaches to beach and dune restoration, ranging from beach nourishment (artificial addition of sand, most commonly from offshore areas) to dune-building and measures aimed at restoring the specific ecological functioning of dune or beach environments, such as restoring dune slacks (low lying areas between the foredunes and main dunes, with highly characteristic vegetation communities) or replacing vegetation. The book recognizes that, in general terms, an increase in the dynamism of landforms leads to a greater probability that diversity and complexity are retained and the level of resilience raised – while the exact level of dynamism and complexity required to fulfil this function can only be determined at the site-specific level.

It is refreshing to see a book of this sort openly acknowledge the reality of the spatial and/or temporal restrictions that are often placed on restoration schemes that sit within complex social, political, legislative and economic frameworks. Chapter 5 of this volume addresses this issue particularly well, with its focus on spatially restrictive environments, where physical and/or ecological barriers necessarily lead to a fragmentation of habitats or a truncation of cross-shore gradients that have to be incorporated into the design of restoration schemes. In light of such apparently insurmountable conservation challenges, the book retains a positive and pragmatic tone, placing much emphasis on the need to change public perception to accept natural dynamism as an intrinsically necessary functional characteristic of sandy shores. Nordstrom repeatedly highlights the need to 'identify the advantages of letting wild nature occur' (p.105). Clearly implicit in such statements is the hope that the option of allowing landward migration of dynamic beach and dune environments will be chosen more frequently, particularly given the increasing 'appreciation of the intrinsic, recreational, and educational aspects of nature' (p.95).

Given the excellent framework and realistic approach to dune and beach restoration adopted in the first chapters, it is somewhat disappointing that the geographical focus of this volume remains largely North American. Although examples of schemes from the Baltic, Italy, Spain, and Australia are mentioned occasionally, the detailed review of local approaches to restoration is focussed on North America. Important lessons are clearly to be learnt from these projects, such as the usefulness of 'demonstration sites' in an attempt to address the previously identified need for altering public perception. The geographical bias, however, remains a little restrictive.

Ultimately, it may not be the correct application of scientific knowledge that leads to a restoration scheme's success, but rather the setting of realistic goals that are accepted by the various stakeholders with an interest in a particular coastal dune and beach environment. Nordstrom's final chapter illustrates this all too well, as it outlines the various standpoints that may be adopted by (and actions that may be taken to bring on board) municipal managers, developers and property owners, scientists, and environmentalists.

For many an environmental scientist, the impossibility of returning dune/beach environments of intensively developed coasts to something that might be called a 'natural' condition may be somewhat difficult to accept, as might be the inability to know what constitutes such a 'natural' condition. In many ways, however, Nordstrom's book guards against the danger of adopting a 'do nothing' approach in the face of this lack of certainty. The aim thus ought not to be to restore beach and dune environments to their 'natural' state, but to restore a more 'dynamic' state that is able to respond to external stimuli in more resilient ways. If this publication ensures that this message is delivered to those in charge of coastal management schemes around the world, it must be a big step forwards.

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War, politics and fish

Dutch Herring: An Environmental History, c. 1600–1860 by Bo Poulsen (2009) Aksant Academic Publishers, Amsterdam, 272pp. 35 euros (hard cover, ISBN-13: 978-90-5260-304-9; ISBN-10: 90-5260-3049).

At the beginning of the 17th century the Dutch herring fishery was the dominant producer of salt herring. Production declined from an estimated 60 000 tonnes in 1600 to 1000–2000 tonnes in 1700.

Throughout the 18th century production continued to decline gradually, but then increased dramatically post-1850. Throughout this era the fishing technology used by the fishery remained almost unchanged, and it was highly regulated. The College van de Grote Visserij, which was established in 1567 with representatives from 13 towns and villages, was granted jurisdiction over the entire Dutch herring fishery. It continued to hold this monopoly until 1857. The College regulated all aspects of the fishery, from the technologies used, to the fishing seasons and processing methods, distribution and marketing. Its principal aim was to maintain the highest standards of product quality. In typical Dutch fashion, it kept detailed records, and it is these records that have been analyzed by Bo Poulsen for his Ph.D, which was part of a Dutch–Danish cooperative research programme. Before undertaking the project, the author – who is Danish – first had to learn Dutch, and he then wrote up the results in English.

The records show the imprint of political events, such as the Anglo-Dutch wars and the War of Spanish Succession at the end of the 17th century, and later, the Napoleonic wars. Early on, piracy in the North Sea was a major problem; in 1625, 85 vessels were lost to pirates and a further 124 were lost in 1635. These losses represented nearly 10% of the total fishing fleet. Again in 1691 the Dutch government banned the herring fishery because privateers sailing out of Dunkirk were causing such havoc, and putting fishermen at risk. In 1694, a joint Dutch and British force attacked Dunkirk.

The main market for salted herring lay around the Baltic and continental Europe. The waxing of the (then Norwegian) Bohuslen herring fishery in the 18th century eroded the dominance of the Dutch in supplying salted herring in the Baltic region. More generally, there was a gradual decline in the importance of salted herring in the peoples' diets, and prices fell as demand waned.

I looked in the book for evidence of the 'Year without a summer' having an impact on the returns. Coming after a series of cold summers, 1816 had the third coldest summer on record following the eruption of Mount Tambora in Indonesia, which injected an estimated 83 cubic miles of dust into the atmosphere (hence Turner's wondrous sunsets). This event came immediately after the ending of the Napoleonic wars and the British blockade of the continent, and its effect may have been to slow the post-war recovery of the fishery.

Despite the statistical noise created by these external events, the College's detailed records provide useful insights into the fluctuations of the herring stocks in the North Sea. The wealth of data has allowed analysis of the activities of individual boats and captains. The driftnets were standardized in design, and the procedures for salting the fish were consistent throughout. Remarkably, the fishing fleet was serviced by hospital ships that carried replacement equipment, as well as caring for any injured or sick fishermen. Other vessels collected the barrels of salted herring from the fishing boats and rushed them back to the home ports in Holland. The vessels carrying out these services also provided a communications link within the fleet, and this sharing of information improved the overall catch rates. For those of you who are interested in foraging theory, there are some revealing data on distances sailed between net deployments: vessels moved greater distances when the catches were poor than when the fishing was good. Hence the movements of the fleet tracked the anticlockwise migrations of the herring shoals around the North Sea, despite having no other means of fish-finding.

Because the same technologies were employed throughout the 250 years analyzed, catches could be expressed as catch per unit effort (CPUE) and this showed a general decline. At no time did the exploitation rates ever approach levels that were unsustainable, so the changes in CPUE probably reflect the influence of climate changes on the herring stocks following the end of the 'mini-Ice Age' in the 17th century.

Having just read Kurlansky's recent book on *Salt: a World History,* I noticed that there was one significant aspect of the fishery that Poulsen did not explore: Where were the Dutch getting their salt? According to Kurlansky, in 1660 the Dutch Government gave incentives to their colonists in New Amsterdam to build salt works on Coney Island. Kurlansky also records that in 1652 the British Navy destroyed much of the Dutch herring fleet, which had been trained as an armed naval force when relations between the Dutch and the British were at an all-time low. This event shows as a blip in Poulsen's Figure 4.2 (the number of vessels in the Dutch herring fleet) but otherwise does not get a mention.

There is much of interest in this book, which extends records of fishery returns from the North Sea much further back in time than any other available data. However, each chapter tends to be written as a separate essay, so the book is not constructed as an entity and there is a lot of repetition. The book could also have done with more effective proof-reading – there are rather too many typographical mistakes and grammatical errors for comfort. Moreover, when drafting this review, I found a major omission in this otherwise nicely produced volume – there is no index. But putting these criticisms aside, this is a book that is well worth exploring.

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The book is based on the author's 2006 Ph.D thesis for which he was awarded the Dutch Hoogendijk prize. His research was sponsored by the History of Marine Animal Populations (HMAP) project of the Census of Marine Life (CoML), amongst others. For more on this topic, see 'The past is the key to the future – how marine historians are providing the long view of marine ecosystems' by Kira Paulli Pravato, in *Ocean Challenge*, Vol. 15, No.2, 26–31.

Chemical oceanography: at the heart of Earth Systems Science

Chemical Oceanography and the Marine Carbon Cycle by Steven R. Emerson and John I. Hedges (2008) Cambridge University Press, 468pp. £45 (hard cover, ISBN-13: 978-0-521-83313-4; ISBN-10: 0-521-83313-4).

The study of ocean chemistry is central to understanding the Earth's life support system. This is because the chemical composition of the oceans is determined by key climatic and environmental parameters including ocean circulation, continental weathering and sea-floor spreading rates. Furthermore, the oceans are a vast reservoir of the chemical elements that are essential for life. For these reasons, chemical oceanography is an essential component of most Earth Systems Science curricula, so it is perhaps surprising that there are few textbooks suitable for undergraduate courses. This new book, based on undergraduate courses taught by the authors, who are extremely well regarded in this field, is therefore a welcome resource for teachers and students alike.

The book is divided into two parts; the first part explores some of the basic controls on ocean chemistry. These include fundamental controls, such as thermodynamics and radioactive decay, as well as process-related controls, such as biogeochemical cycling and hydrothermal activity. The second part putatively covers more advanced topics, including molecular diffusion and reaction rates, along with broader discussions of organic geochemistry and the global carbon cycle.

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Each chapter follows the same general structure. At the beginning of the chapter is a discussion about why that topic is important in the wider context, new concepts are then explained and presented in a quantitative framework. Crucially, each chapter is packed with examples of real data (with references), which have informed our ideas and against which models can be tested. These range from the effect of hydrogen bonding on the boiling and freezing point of water, to ^{14}C-dating of marine sediments. This structure makes the book both easy to read and a useful reference. Moreover, the authors have taken particular care with their explanation of concepts they know students find difficult, pointing out where confusions can arise (for example, δ^{18}O of molecular oxygen versus the δ^{18}O of $CaCO_3$). Although no questions are provided to test the reader's understanding, there is plenty of material that could be utilized by teachers; in particular, I was delighted to see the inclusion of a Matlab program for calculating the concentrations of carbonate buffer species from measurements of alkalinity and dissolved inorganic carbon.

Overall, the book is well laid out with appropriate use of figures and tables. Figures are available to download, which is a nice touch for teachers. Sadly, in common with most textbooks, colour is restricted to eight plates and some of the figures would benefit from being larger – most notably the Periodic Table. A minor quibble is that the book largely sticks to discussing those aspects of marine chemistry that are relatively well established; personally, I would like to have seen more material on 'newer' areas of research, such as gas hydrates or the effects of iron fertilization.

In summary, this book makes an excellent undergraduate textbook, filling a notable gap in the marketplace. Its price (£45 hardback) is not unreasonable; the quantitative assessment of many of the key concepts in marine chemistry will ensure that the book will remain an invaluable reference guide for many years to come.

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Tsunamis, past and present

Tsunamis. The Sea: Ideas and observations on progress in the study of the seas, Vol.15 edited by Eddie N. Bernard and Allan R. Robinson (2009) Harvard University Press, 450pp. £80.95 (hard cover, ISBN-13: 978-0-674-03173-9; ISBN-10: 0-674-03173-3).

This is a very interesting and informative book covering a wide range of topics relating to tsunamis. It is a text that should certainly not be missing from a series covering the 'study of the seas'. Furthermore the book contributes to general education on tsunamis, at both an elementary and a research level. It can also be regarded as being dedicated 'to all tsunami victims', as stated in the preface of the book. It consists of contributions by eighteen well known scientists, who have successfully covered the thematic areas of their scientific fields, which have been nicely arranged and interrelated by the editorial advisory panel, assisted by the efforts of the eleven external reviewers.

The book is organized into 13 independent chapters: after an introduction, the remaining chapters are presented in a logical sequence that begins in the past and then looks into the future with an anthropocentric point of view. All the chapters are well organized in sub-sections, while the presence of a list of contents and a useful introduction at the begining of each chapter prepares the reader for what follows. Each chapter provides state-of-the-art information of high scientific quality and is accompanied by a comprehensive, up-to-date reference list. Sometimes the reader has the impression of reading a scientific paper and not a chapter of a book, yet the text is easy to read and comprehend and does not require the reader to have any specialized knowledge in the field of tsunami science.

In Chapter 1, the new trends in tsunami research are discussed along with recent findings, with extensive reference to the destructive tsunami of 26 December, 2004, which affected Indian Ocean coastlines causing 228 000 casualties. Chapter 2 presents data on historical tsunamis, including their magnitude, geographical and temporal distribution, and generation mechanisms. Relationships between tsunamis and structural geology are presented in Chapter 3, where tsunami deposits and related sedimentology are also discussed. Chapter 4 deals with the estimation of the probability of tsunami occurence, both empirically and computationally, including a discussion on the related uncertainties. Chapter 5 covers successfully and systematically all aspects of tsunami generation by earthquake shocks, while in Chapter 6 all other tsunamogenic sources are discussed.

Tsunami measurements (including post-tsunami surveys) obtained via *in situ* instrumentation and observational networks and their analyses are presented in Chapter 7, and Chapter 8 is an extensive presentation of the developent of numerical tsunami modelling, along with laboratory simulations. Chapter 9 is devoted to the simulation of tsunami propagation and the accurate prediction of the wave height, and time of arrival at the coast, while in Chapter 10 tsunami modelling is extended to calculation of the area of inundated coastal land and the development of hazard maps. In addition, the various processes affecting the impact of tsunamis on coastlines, and their mathematical analyses, are discussed in Chapter 11. Chapter 12 deals with tsunami forecasting, addressing the various goals and challenges and presenting the relevant state-of-the-art technology and existing forecasting systems; it also describes the outcome of tests and evaluations of forecasting methods. The final chapter is dedicated to the organization and performance of tsunami warning systems and includes aspects such as warning dissemination and emergency management response.

I would also like to to mention the high quality of presentation, especially of the figures, tables, diagrams and photographs, even though (with the exception of the colourful figures in Chapter 6) they have been printed in black and white.

In summary, this book covers the subject of tsunamis comprehensively and it should be very useful not only to scientists but also to the general public and those involved in integrated coastal zone management.

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Post Script If you haven't yet investigated it, take a look at the recently released **Google Ocean**. It is a great resource for both research and teaching, covering bathymetry (with side-scan and multibeam sonar images), submarine cables, magnetic declination, shipwrecks, global tidal predictions, marine biology .... and much, much more.