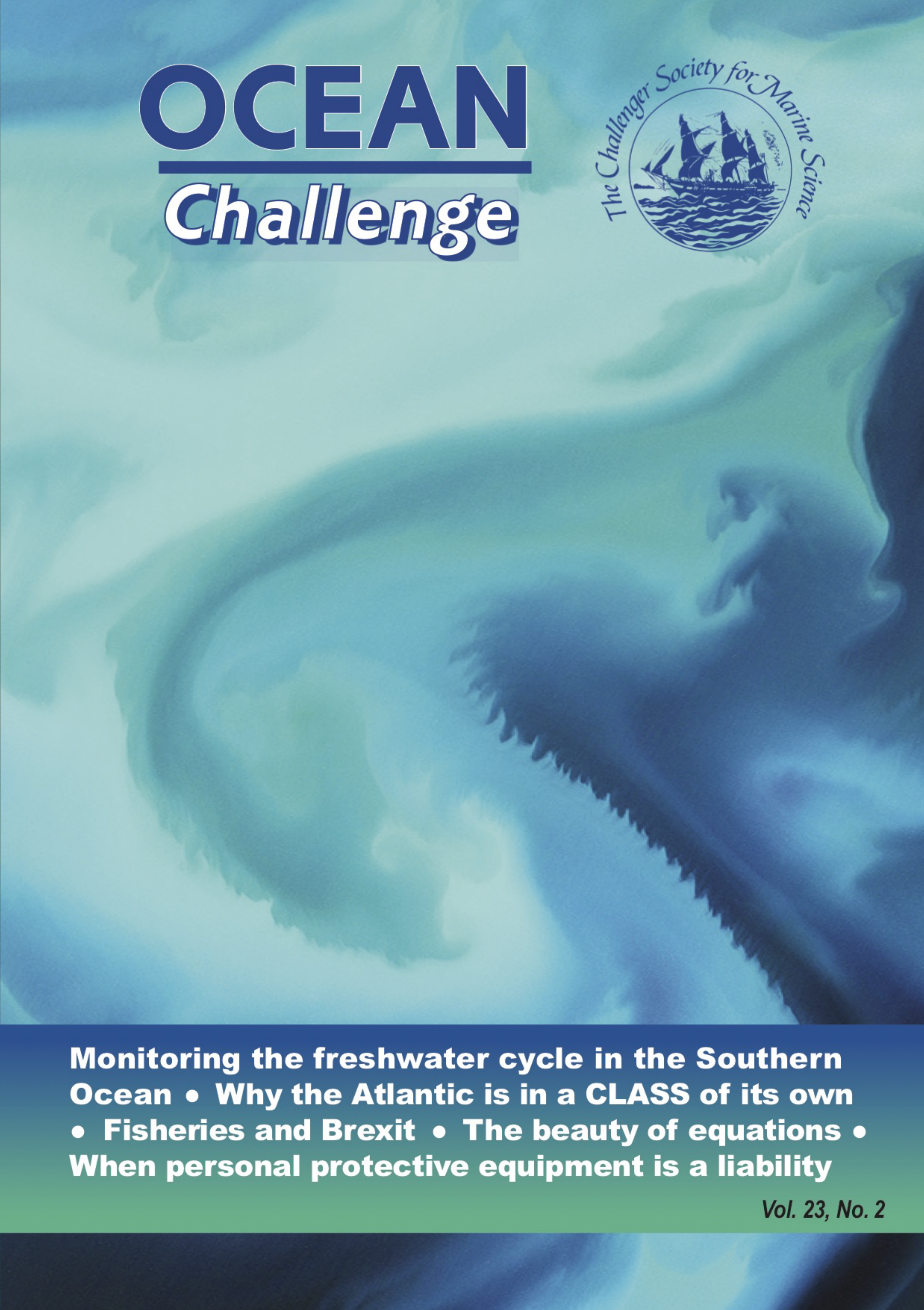
OCEAN Challenge

The Challenger Society for Marine Science



Monitoring the freshwater cycle in the Southern Ocean • Why the Atlantic is in a CLASS of its own • Fisheries and Brexit • The beauty of equations • When personal protective equipment is a liability

Vol. 23, No. 2

OCEAN Challenge

The Challenger Society for Marine Science

Volume 23, No.2, 2017
(published 2019)

SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and the rest of Europe. By covering the whole range of marine-related sciences in an accessible style it should be valuable both to specialist oceanographers who wish to broaden their knowledge of marine sciences, and to informed lay persons who are concerned about the oceanic environment.

NB *Ocean Challenge* can be downloaded from the Challenger Society website free of charge, but members can opt to receive printed copies.

For more information about the Society, or for queries concerning individual or library subscriptions to *Ocean Challenge*, please see the Challenger Society website (**www.challenger-society.org.uk**)

INDUSTRIAL CORPORATE MEMBERSHIP

For information about corporate membership, please contact Terry Sloane Terry@planet-ocean.co.uk

ADVERTISING

For information about advertising, please contact the Editor (see inside back cover).

AVAILABILITY OF BACK ISSUES OF OCEAN CHALLENGE

For information about back issues, please contact the Editor (see inside back cover).

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

To advance the study of marine science through research and education

To encourage two-way collaboration between the marine science research base and industry/commerce

To disseminate knowledge of marine science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management

To contribute to public debate and government policy on the development of marine science

The Society aims to achieve these objectives through a range of activities:

Holding regular scientific meetings covering all aspects of marine science

Setting up specialist groups in different disciplines to provide a forum for discussion

Publishing news of the activities of the Society and of the world of marine science

Membership provides the following benefits:

An opportunity to attend, at reduced rates, the biennial UK Marine Science Conference and a range of other scientific meetings supported by the Society. Funding support may be available

Receipt of our electronic newsletter *Challenger Wave* which carries topical marine science news, and information about jobs, conferences, meetings, courses and seminars

The Challenger Society website is
www.challenger-society.org.uk

MEMBERSHIP SUBSCRIPTIONS

The annual subscription is £40 (£20.00 for students in the UK only). If you would like to join the Society or obtain further information, see the website (given above).

ADVICE TO AUTHORS

Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references.

For further information (including our 'Information for Authors') please contact the Editor:
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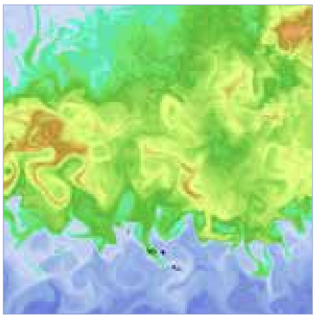

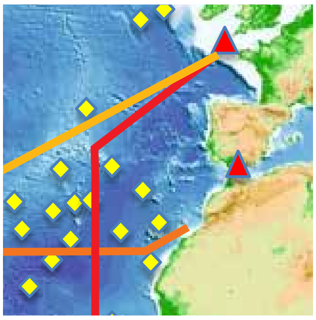

Most of the maps and diagrams were drawn by The ArtWorks.

The cover and heading graphics were designed by Ann Aldred.

The cover image is a true-colour image of the Barents Sea, obtained though the Sentinel satellite mission, by courtesy of ESA.

CONTENTS

Message from the Editor

The 2018 Challenger Society Conference concluded with an address by His Serene Highness Prince Albert II of Monaco, and a talk by the Challenger Medallist, Mike Meredith. Inspired by the first, this issue of *Ocean Challenge* contains an article explaining Monaco's long connection with oceanography (p.36), while in a feature article expanding on his talk, Mike discusses the global importance of the Southern Ocean, with particular focus on the freshwater cycle.

If you are an early-career scientist in need of funding, do take a look at 'Stepping Stones to a successful career' (pp.4–9) where past recipients of the Challenger Society Stepping Stones Bursary explain how it helped their career. Other articles cover the impact of marine plastics on people, monitoring carbon capture, Brexit and fisheries, large-scale and global obervational programmes, and the beauty of equations.

Finally, you may remember that in March, NASA had to cancel its first all-female spacewalk because of a shortage of spacesuits of the right size; to find out what this has to do with life on a modern research vessel, read 'Does my bum look big in this?' on p.12.

Angela Colling

Meeting of the Challenger Society Special Interest Group on Ocean Modelling

9–10 September 2019, University of Edinburgh

incorporating

the 2019 Challenger Society AGM

12.00–1.00 on 10 September

The Institute for Global Change of the University of Edinburgh School of GeoSciences is pleased to host the Annual Meeting of the Challenger Society Special Interest Group for Ocean Modelling, and the Challenger Society's AGM.

The meeting will be held at the Edinburgh Centre for Carbon Innovation, University of Edinburgh. The ECCI is in the City Centre, adjacent to the Royal Mile and 6 mins walk from Waverley Station.

We invite the submission of abstracts for oral presentations covering the full breadth of ocean modelling, including physical, biological and chemical oceanography, and from idealised process studies to regional and global simulations.

All members of the community are welcome, and we specifically encourage early-career scientists to present their work. The aim of the meeting is to provide an informal forum for discussion, and presentations will be limited to a maximum of 10 minutes.

The meeting will cost £20–25 which will include lunch on both days of the meeting, as well as breakfast on 10 September and coffee/snack breaks. However, fees for Ph.D students will be reduced, thanks to support from the Global Change Institute. (Exact costs will depend on the number of attendees.)

The Conference Dinner will be held at Howie's Edinburgh, 10–14 Victoria Street.

For further information,
please contact the convener, Daniel Goldberg dan.goldberg@ed.ac.uk
or co-convener James Maddison j.r.maddison@ed.ac.uk

To register, go to https://www.geos.ed.ac.uk/homes/dgoldber/challenger.html
by July 21

This meeting is supported by the Challenger Society for Marine Science,
and by the Scottish Alliance for Geoscience, Environment & Society (SAGES)

ADVANCES in MARINE BIOGEOCHEMISTRY

University of East Anglia

AMBIO IX:
Biogeochemistry Across Boundaries
a celebration of Professor Tim Jickells

24–27 June 2019, UEA

On the occasion of AMBIO's 9th biennial meeting, we are delighted to celebrate the immense contributions of Professor Tim Jickells. Tim's career has touched the full breadth of marine biogeochemistry, where he has personally pioneered transformative research and championed support for many of us in diverse roles of marine biogeochemical research, teaching and governance at local, national and international scales.

A celebratory dinner will be held on Wednesday 26 June.

An outline programme is available under Latest News at https://www.challenger-society.org.uk

Confirmed keynote speakers

Professor **Robert Duce**, Texas A&M University
Assnt. Professor **Laura Bristow**, University of Southern Denmark
Professor **Richard Sanders**, National Oceanography Centre
Dr **Sian Henely**, University of Edinburgh
Professor **Tim Jickells**, University of East Anglia

Registration AMBIO offers subsidised registration rates for members of the Challenger Society, and further subsidised registration for student members. Please register your attendance at AMBIO IX before 10 June 2019 via the UEA conference-booking site https://store.uea.ac.uk/conferences-and-events/faculty-of-science/env

Further information
https://www.challenger-society.org.uk/Advances_in_Marine_Biogiochemistry
For online booking help please email: online.registration@uea.ac.uk
Socal media connections: #AMBIOIX #JicklingZone Twitter: @ChallengerAMBIO

Convenors
Alex Baker and Matt Humphries (UEA)
Amber Annett (Southampton)
Will Homoky (Oxford)

Supported by
Planet Ocean Ltd
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Stepping Stones to a successful career

Reasons to apply for a Challenger Society Research Bursary

The Stepping Stones Bursary scheme is designed to support career development for members of the UK marine science research community currently without employment. The scheme can provide modest amounts of support (up to £1000 per grant) for activities which could enhance career prospects. Bursaries can be used for research-related activities including, but not limited to, travel, collaborative visits, laboratory time, fieldwork and conference participation. For more information, see p. 9 and the Challenger Society website. Below, four recent beneficiaries of the Award explain how they used their bursary and how they benefitted as a result.

Attending the 3rd International Symposium on Krill — Katrin Schmidt

Through the Challenger Society Stepping Stones Bursary I was able to attend the 3rd International Symposium on Krill, which took place in St Andrews, Scotland, in June 2017. At the conference there were ~70 participants from 15 countries, who had in common a passion for krill (euphausiids) – Antarctic krill, Pacific krill, Northern krill or Ice krill. In addition to a densely packed programme of scientific talks and poster presentations, there was the chance to meet stakeholders from non-governmental organisations (e.g. The Pew Charitable Trusts), regulatory bodies (e.g. the Marine Stewardship Council) and the fishing industry (e.g. Aker BioMarine).

Highlights of the social programme were the screening of the documentary *Licence to Krill* by David Sington and the late-evening 10-mile walk from the Kingsbarns Whisky Distillery back to St Andrews along the coastal path. The two convenors, Andrew Brierley and Keith Reid, did a great job at organising this conference.

The dual effect of Antarctic krill on phytoplankton blooms

For some time, I have been interested in the effect of zooplankton on phytoplankton blooms, both diminishing and fertilising them. For my talk, I compiled information on macronutrient depletion, ammonium accumulation, phytoplankton physiology and krill abundance / grazing activity to show that the Scotia Sea (north-east of the tip of the Antarctic Peninsula) is more productive than the often low chlorophyll-*a* concentrations suggest. This productivity is enabled by a tight coupling between autotrophic and heterotrophic production: krill exert a high grazing impact on phytoplankton, but at the same time they fertilise the remaining algae and prevent them from shelf-shading. Thus, primary production is high, but biomass rarely accumulates because it is channelled into the food web.

Left *Katrin during the Symposium excursion.*
Below *Krill at the sea bed.*
(Photo: Andrew Clarke and Paul Tyler)

I was very excited to present the results at the conference: they were a combination of my own new data and re-analysed published data, kindly provided by various scientists. My talk was very well received by the audience and led to a number of constructive discussions. Some of the data I presented are included in a paper recently published in *Biogeosciences* (see below).

The benefits of participating in the Symposium

At the time of the conference I had just been made redundant from SAHFOS, but the positive feedback on my talk, and on my previous work on Antarctic krill, gave me the confidence and enthusiasm to try to pursue a scientific career. Moreover, the conference gave me the opportunity to inform myself about new advances in krill research and to interact with scientists and stakeholders. I was able to discuss my research results with a knowledgeable audience, receive valuable advice for future work and funding applications, and to plan potential co-operations.

Many thanks to the Challenger Society for running the Stepping Stone Bursary, which can give a scientist at a sensitive stage of their career the chance to re-explore their interests, meet collaborators and gain motivation.

Schmidt, K., T.A. Brown, S.T. Belt, L.C. Ireland, K.W.R. Taylor, S.E. Thorpe, P. Ward and A. Atkinson (2018) Do pelagic grazers benefit from sea ice? Insights from the Antarctic sea ice proxy IPSO 25. *Biogeosciences* **15**, 1987–2006. doi: 10.5194/bg-15-1

Katrin is now at the University of Plymouth, working on a project to study food-web relationships as part of the Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC).
katrin7schmidt@gmail.com

Investigating feather stars in the Philippines

Angela Stevenson

I feel privileged to have been selected for the Challenger Society Stepping Stones Bursary, which allowed me to further develop my work on feather stars. Of foremost importance to my early career, the award allowed me to foster a new partnership with Marine Conservation Philippines (MCP) and strengthen existing collaborations with colleagues at the University of Michigan.

Why feather stars?

Feather stars, and their stalked cousins sea-lilies, are crinoids – among the few organisms on Earth with a well documented evolutionary, ecological and morphological history spanning half a billion years. Their fossil record contains abundant evidence of predator–prey interactions and many ecological and morphological changes over time.

In coral reefs around the Philippines, feather stars are the dominant large bottom-dwelling invertebrate, and are both abundant and species-rich from shallow (< 30 m) to mesophotic (30–150 m) depths, making this locality ideal for gathering data on interactions of feather stars with other coral reef organisms.

What we did

To answer fundamental questions about one of the oldest living fossils in the oceans, we did a lot of diving – twice a day, six days per week using a mix of technical and recreational diving at depths of 5–50 m.

Predator–prey interactions

When attacked by predators, feather stars self-amputate arms. We wanted to investigate how frequently feather stars are attacked by predators, how quickly their arms grow back, and whether arm growth-rates vary between species. To answer these questions we amputated arms from 64 feather stars of eight different species living at six depths, and then monitored their growth via image surveys conducted every month over a five-month period.

This was the most time-consuming part of the project as we had to relocate all 64 individuals while limited by bottom diving time, but it was also one of the most rewarding and interesting aspects of the work. To facilitate the task of relocating each individual, my dive team (Ashley Carreiro, Chase Byerly, Jim Gillespie and Tadhg O Corcora) and I first demarcated sites where amputations were performed. We recorded the bearings and made notes about the exact location of each marker. Once a month we would navigate underwater (using a compass) to our demarcated sites where we would relocate each individual feather star and prepare it for its photoshoot.

Left Stephanometra indica *with arms perfectly spread for an examination of arm regeneration.* ***Right*** Capillaster multiradiatus, *with arms being laid flat ready for its photo session. Arms regenerate more quickly in some species than others: less than two months have passed since* four *arms of this specimen were amputated (the regenerating parts are still very thin).*
(Photos: Angela Stevenson)

Depending on species, a feather star may have as few as 15 arms or as many as 200. Rates of arm-regeneration did in fact differ by species, and regeneration rate correlated with species' total arm number. Stay tuned for answers as we prepare the manuscript for publication!

Site fidelity

Feather stars can swim, but do they stay close to home? The quick answer is Yes! About half of the individuals were located again and in fact remained on the exact same perch for the whole five-month period. Others moved around to different locations, but never strayed more than 5 m from their original site. Those which disppeared and were never seen again, were probably carried to another location by strong wave action during a storm.

Do infesters impact predator–prey relationships?

Crinoids host a diverse biome of organisms known as 'infestors'. Infestors include fish and invertebrates such as gastropods, polychaetes and decapods, some of which have developed morphological adaptations for living uniquely within the arms of crinoids. The relationship between these infestors, their feather star host and fish predators is unclear, but has persisted through time, as revealed by interactions preserved in the fossil record.

It has been postulated that modern feather stars have biochemical properties which make them distasteful to fishes, suggesting that arm loss could be collateral damage, occurring during predation of infestors by fish (higher levels of predation in Paleozoic crinoids have been linked to infestors). In a separate survey conducted at multiple dive sites, we observed hundreds of feather stars and noted how many individuals were showing signs of a non-lethal predatory attack (e.g. had a missing or regenerating arm), and for those feather stars we quantified infestor diversity and abundance to try to detect patterns linking frequency of predatory attacks and the presence of infestors.

Fortunately, fossil crinoid expert, Prof. Tom Baumiller from the University of Michigan, visited and helped with data-collection for this part of the project. Tom and I spent almost three weeks photographing crinoids in shallow waters to get a sense of how many feather stars showed signs of predator attack (e.g. a missing or regenerating arm). Working alongside Tom was a great opportunity to learn new techniques, absorb his extensive knowledge about the taxon and benefit from his unique paleo-perspective on the work that we are conducting on these living fossils.

Tom and I surveyed over 500 individual feather stars in two sites. We noted the presence/absence of regenerating arms, as well as the presence/absence/type of infestors on each individual. Preliminary results suggest that arm loss is not linked to infestor occurrence, which goes against what we had previously believed.

Who lives where and on what?

Several technical considerations and a lot of dive planning went into this part of the project. Gathering data had to be done in a systematically rigorous manner, but also rapidly because at greater depths we were extremely limited by bottom time and worked under the influence of inert gas. To overcome this obstacle, we captured video surveys along a 50 m transect, every 10 m from the surface to 50 m using diver-operated camera. My team and I devised a very efficient technique for laying the transect and taking video – which we first mastered on land and then practised at shallow depths.

Angela hard at work recording the presence/absence of arm regeneration and infestors in the feather star population. (Photo: Aoibheann Gillespie-Mules)

As you can imagine, there was a lot work involved in analysing all 64 video transects collected. The transects revealed species-specific habitat, substrate, and bathymetric preferences, which were linked to certain aspects of feather star morphology.

Diving down to 50 m would not have been possible without the technical expertise and tremendous knowledge of the staff at Marine Conservation Philippines. MCP is a not-for-profit organisation that aims to spread knowledge of the ocean, embrace our connection to it, implement solutions to conservation problems, and bring about change before it is too late. They are also dedicated to facilitating diving for scientists like myself and my team, so that they may conduct the research necessary to inform conservation decisions. We continue to work with MCP today.*

Stephanometra indica *and two well camouflaged marine flatworms known as myzostomes, highlighted with red arrows. (Photo: Angela Stevenson)*

Spreading marine enthusiasm in the local community

Surrounded by like-minded people who shared my vision and passion for the ocean – my dive team, MCP staff, volunteers, interns, Tom – I felt energised and empowered to help the local community to connect with their marine environment. So, in between our hectic dive schedule, my dive team, and MCP staff, volunteers and interns helped me organise and run a 'Wild Postcard Project @Philippines' artwork competition. The Wild Postcard Project is a not-for-profit organisation that my friend Eileen Diskin and I founded in early 2016 as a way to improve knowledge of local biodiversity, and of organisations that research and conserve it, via an artwork competition for local kids and teens (aged 5–18), where winning artworks are published as postcards – a great way for local biodiversity to go global.

The competition we ran in the Philippines was a great success! We obtained over 1300 entries from 45 schools across Negros Oriental, from Dumaguete City to remote villages in the Siaton region. MCP is still working with participating schools to help kids learn about their local marine biodiversity and its conservation.

*For more about conservation work in the Philippines see the 'Coral Cay Conservation: and Citizen Science: How volunteers are contributing to marine conservation in the Philippines' by Tom Dallison and Tessa Dawson in *Ocean Challenge* **22**(1).

One last thank you

The Challenger Society was there for me throughout my doctoral work, supporting my research via travel grants, and is now there for me in my post-doctoral career, with the Stepping Stone Bursary, which helped me in more ways than I could have imagined. I feel immensely heartened and fortunate to be a part of the CSMS community and have their continued support, which I fully appreciate. A most sincere 'Thank you'.

For more about Angela's research see:

Baumiller, T.K. and A. Stevenson (2018) Reconstructing predation intensity on crinoids using longitudinal and cross-sectional approaches. *Swiss Journal of Palaeontology* **137**, 189–96. doi: 10.1007/s13358-018-0169-6

https://openexplorer.nationalgeographic.com/expedition/livingfossilsofthemesophotic

Angela is now based at the University of British Columbia, Vancouver. stevenan@zoology.ubc.ca

Winning entries of the 2017 Wild Postcard Project @Philippines artwork competition. (Photo: Angela Stevenson)

Studying sea-urchins in the mangroves *Coleen Suckling*

Thank you Challenger Society for the fantastic opportunity made possible through the Stepping Stones Bursary in 2016! It really allowed me to widen my experience and my network of collaborators, to develop new ideas that I could present in grant applications, and to produce data that colleagues and I could develop for publication in a peer-reviewed journal.

The grant allowed me to go from North Wales to Fort Myers in Florida to develop new links with scientists and instructors for three-and-a-half weeks. From the moment I arrived at the Florida Gulf Coast University (FGCU) I was kept busy. One of FGCU's outstanding technicians based at the Vester Field Station had already collected all of the organisms we needed by SCUBA diving. So we immediately started setting up the experimental laboratory in their excellent facilities (air temperature and photoperiod controlled) and began!

The animal used in this study was a warm-water species of sea urchin, *Arabacia punctulata*. In the coastal area of Florida these sea urchins experience variations in salinity on a seasonal basis, and it is known that urchins are osmoconformers, i.e. they match their bodies' osmolarity to their environment. We would therefore expect the urchins to show some level of short-term physiological stress in such conditions. I also wanted to determine whether suspended microplastics (from freshwater sources and disturbances of the sea bed) would provide further physiological problems for the animals and hence have ecological impacts on the coastal areas of Florida. We therefore carried out an experiment which assessed the short-term physiological responses of these urchins to lowered salinity, suspended microplastics and a combination of the two, in comparison to a control. The animals were placed into independent replicate aquaria and starved and cleaned daily for 10 days. Then, prior to determining their metabolic rates via closed chamber

Florida Gulf Coast University's Vester Field Station situated amongst the mangroves, alongside one of the channels that feed through to the open waters of the Gulf of Mexico. (Photo: Coleen Suckling)

oxygen optode techniques, animals were exposed to different stressor treatments for 48 hours to reflect short-term alterations experienced in the field (salinity field data came from NOAA and various Florida State water boards). We gained some interesting data which indicate that the animals show good levels of tolerances and we are therefore to investigate this further through collaborative efforts. This work is now being compiled into a short manuscript, in which we will ensure that the support from Challenger will be acknowledged.

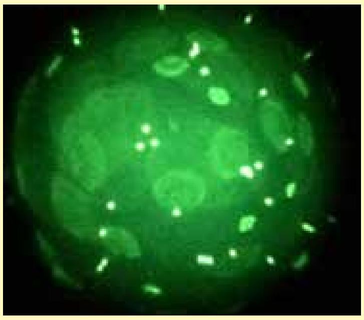
The sea urchin Arabacia punctulata, *with its mouth visible in the centre (Photo: Coleen Suckling)*

Following the practical work with FGCU (and using the savings I made by transporting equipment across the Atlantic as excess luggage rather than by courier) I took the opportunity to hire a car and visit various facilities and people around the state to discuss potential ideas and disseminate work I had previously carried out in the UK. I visited the Florida Keys where there is a government-funded field site which may be available for use for teaching purposes in my future employment. I also travelled to Fort Lauderdale to visit deep-sea specialist Dr Rosanna Milligan (Nova Southeastern University) to discuss climate change, deep-sea biology, and meta-analytical techniques which she uses in her area of research. I was hoping to see some experts in nearby Tampa to discuss aquaculture research, but the visit was cancelled because Hurricane Colin caused major disruption in that area.

Coleen enjoying the Florida Keys while investigating a field site that could be used for teaching purposes

My trip to Florida ended with some excellent meetings with geneticists and physical oceanographers based in FGCU, which further developed some of my ideas into potential grant-capture proposals. I also had useful discussions with Dr Joelle Richard, an ecophysiologist I worked with on the sea urchin experiment, about the potential of developing a field teaching exchange in the near future.

Microplastic particles being made to fluoresce so that it is easier to identify and count them (Photo: Coleen Suckling)



My experience in FGCU was an incredibly positive one with everyone there making me feel very welcome and being very encouraging about the ideas I shared with them. The experience also gave me insights into the US higher education system which have proved valuable in my current post.

The closed chamber oxygen optode technique is described in:

Suckling, C.C., M.S. Clark, J. Richard, S.A. Morley, M.A.S. Thorne, E.M. Harper and L.S. Peck (2015) Adult acclimation to combined temperature and pH stressors significantly enhances reproductive outcomes compared to short-term exposures. *Journal of Animal Ecology,* **84** (3), 773–84.

Coleen is now Assistant Professor in Sustainable Aquaculture, Fisheries, Animal and Veterinary Science at the University of Rhode Island.
coleensuckling@uri.edu

Joining a research cruise to the eastern tropical Pacific *Anna Belcher*

I was awarded the Challenger Society Stepping Stones grant to allow me to collaborate with a group of American scientists and join their research cruise to the eastern tropical North Pacific. The cruise, on RV *Siquliaq,* was led by scientists from the University of Washington, Seattle, and brought together researchers interested in the degradation of sinking particles. I was fortunate enough to be invited to join Prof. Rick Keil's group and help with particle-trapping and *in situ* incubations, to determine bacterial respiration through changes in oxygen concentration, as well as collecting pumped water samples.

The ship left from Manzanillo in Mexico on 28 December, and we immediately began prepping the floating PHORCYS* sediment-trap incubators and making sure we were all ready for the first set of deployments. It was great to learn more about the techniques being employed and the tracers that we would be using to monitor different reactions in the incubators. We were working in the oxygen-minimum zone off Mexico, so were particularly interested in the anaerobic reactions. After the usual couple of days getting everything working correctly we were catching lots of particles for everyone to use for their experiments. The research cruise lasted just over two weeks, and we deployed a total of 42 traps and 60 water pumps, a great achieve-

*PHORCYS = PHOtosynthesis, Respiration, and Carbon-balance Yielding System.

ment for the whole group. It was really interesting to be able to learn about the different experiments going on onboard the ship, and it was a great chance to network with some amazing scientists from the US and Mexico.

Working at night to deploy and recover the sediment traps, we escaped the intense heat of the day and got to enjoy concocting for ourselves the curious meal known as 'mid-rats' where pretty much anything goes, from cereal, to curry, to ice cream! We'd start the shift with breakfast, and finish with dinner, overlapping with the rest of the scientists on board and getting the chance to chat about what they were working on. It was a great opportunity to learn more about American institutions and the process of getting post-doc positions in the US, as well as just getting some great career advice from those who'd been in the game a long time. Despite becoming creatures of the night and only seeing a little daylight, we were treated to some beautiful sunrises, sunsets and moonsets. Check out the cruise blog at hohohomz.wordpress.com to find out more about life on board and the science we were doing.

Deploying the sediment-trap incubators (Anna is on the far left)

(Photo: Rick Keil)

Taking in one of the incredible sunsets

(Photo: Anna Belcher)

It was an incredible three weeks, and I really want to thank the Challenger Society for helping me to form these strong networks and to enable me to learn lots of great new skills that I can apply to my own research and share with others in the UK. It opened the door for possible future collaborations/post-doctoral positions with the US team, and I know that, having formed such firm friendships with my shipmates, I will always be able to seek their advice in the future.

I'd really encourage everyone to apply for the Stepping Stones grant as it is a great way to help you boost your career and explore your oceanographic interests, hopefully setting seeds for a long scientific career.

Anna currently holds a post-doctoral position at the British Antarctic Survey, working as an ecological biogeochemist in support of the DIAPOD and COMICS projects. annbel@bas.ac.uk

How to apply for a Stepping Stones Early Career Bursary

Stepping Stones bursaries are designed to support career development for members of the UK marine science research community currently without employment. Applications are not accepted from researchers holding permanent positions, but those on fixed-term contracts may apply up to three months before the end of their contract.

Individuals are eligible to receive only one bursary in any three-year period and the maximum amount that any individual can be allocated in any one funding round is £1000. The bursary cannot be used to pay salary.

The Society aims to fund four bursaries per year, and applications will be considered quarterly (deadlines: 15 February, 15 May, 15 August and 15 November).

The application form and full guidance notes for applicants can be found on the Challenger Society website.
https://www.challenger-society.org.uk/Stepping_Stones
Applications should be sent to Sophie Wilmes (s.wilmes@bangor.ac.uk).

Physical oceanographer Yueng-Djern Lenn discusses polar opposites in life and work

Yueng-Djern Lenn is a physical oceanographer working in the School of Ocean Sciences at the University of Bangor. Here she chats with Bangor colleague Katrien Van Landeghem about how she came to be working in polar environments, and about some of the highlights of her scientific life.

Hi Yueng, thanks for taking the time to conduct this interview for* Ocean Challenge*. For readers who don't know you, could you briefly introduce yourself?

Yes, sure, I am a polar oceanographer and senior lecturer at Bangor University. I grew up in Singapore, and first moved away from home to complete my first degree, an MA in experimental and theoretical physics, at Cambridge University. I followed that with an MSc. in Medical Radiation Physics in University College London. After a brief time working as a medical laser physicist in Singapore's National Cancer Center, I returned to university to pursue Ph.D work on Antarctic oceanography at Scripps Institution of Oceanography, San Diego. I have since continued a career in scientific research, more recently focussing on the physical processes that contribute to the ocean overturning in both polar regions and how these impact our climate.

So you went to Scripps following your MSc. in medical sciences? Why did you decide to change your field of expertise?

I was already intrigued by the idea of a research career when I completed my first physics degree, but at that time, I lacked confidence in my academic ability and was also uncertain that my curiosity was sufficient motivation to persevere through a Ph.D with all its ups and downs. So taking on the MSc. in medical radiation physics was a way to gain some practical skills in a field in which there would always be demand. But that degree and the medical working environment (somewhat resembling a class system with doctors at the top and everyone else working in service to them) persuaded me that I did indeed have the motivation to pursue a research career of my own, but it would be crucial to identify a field that really inspired me. I began looking for Ph.D programmes in geophysics as I had enjoyed that element of my undergraduate degree very much. I also focussed my search on the USA as admission to a graduate programme also means the admitting department is able to fund your study. Scripps appeared at the top of the hit list and further exploration of the options there led to me learning about the field of physical oceanography to which I was immediately drawn, as I had a long-standing love for the sea, as befits a person from a small island nation. So began my journey as physical oceanographer.

Do you think studying these various different physical sciences benefitted your career?

My background in physics has been critical for being a physical oceanographer seeking to understand the physics of the oceans. Perhaps not surprisingly, the medical radiation physics knowledge has also translated well into my understanding and my teaching about remote sensing techniques for measuring the ocean. So yes, it turns out all of my academic background has found application in my current research and teaching.

How did your interest in polar oceanography begin?

I come from a small prosperous country in the tropics where my parents cultivated a spirit of adventure and exploration in my brother and me. They were – and still are – principally interested in experiencing new cultures, their foods and places. In me, this spirit of adventure has manifested itself in me wanting to know more about the regions that are the farthest from what I knew growing up. Who can deny the allure of these mysterious places after all? And then once I started my research, these polar regions turned out to be the most sensitive to climate change for several very important and intriguing reasons, that keep me engaged to this day.

How are you currently engaged in that field of research?

I was successful in capturing funds from NERC's Changing Arctic Ocean programme to lead a project titled 'Primary Production driven by escalating Arctic nutrient fluxes?' otherwise known as PEANUTS. In this project, we will make new measurements of how phytoplankton respond to turbulent nutrient fluxes from the deep waters up into the productive surface layers throughout full annual cycles in two different locations along the Arctic continental slopes. These measurements, together with historical data, will be combined with numerical modelling to estimate primary productivity in order to evaluate how this has changed over the last decade.

And recently, a study was published by my Ph.D student Ben Barton, about how the warming, salinifying Barents Sea's Polar Front has become the main limiting factor on the southwards growth of winter sea-ice there. This has major repercussions for air–sea fluxes of heat and freshwater, and consequently, water mass transformation and ocean stratification and circulation. The paper was very well received and was recently highlighted by the US's National Snow and Ice Data Centre that essentially curates and distributes all the main sea-ice products used for research.

Scientific research involves working with people from a wide range of backgrounds. Do you enjoy that?

Higher education is a fantastic multi-cultural and international environment, in which we get wonderful opportunities to find commonality with people of vastly different backgrounds from ourselves (indeed often polar opposites), through the medium of our science. This is hugely stimulating and makes opportunities to go on fieldwork with lots of these people really precious. The whole process gives you faith in humanity, makes you open to new cultures, although of course science communities can be as biassed as any other human society about some issues. But I for one find it inspiring that we are all engaged in the pursuit of truth and understanding and that, by and large, in oceanography at least, this progresses with relatively little rancour and few lapses in integrity. Through both research and teaching, I've worked with, or got to know, people from UK, US, Germany, Norway, Turkey, Indonesia, Tanzania, South Korea, Singapore, Malaysia, Japan, China, France, Canada, Mexico, Chile, Belgium, Denmark, Sweden, Russia, Poland, Finland, Australia. I'm sure this is an incomplete list.

What's been your most memorable work-related experience?

Gosh, this is hard to say and there are a few candidates, really. I will never forget experiencing the majesty of the Antarctic for the first time, for instance. But equally, it was thrilling when I published my very first paper. Other very memorable moments were when my first Ph.D student graduated, and I won't forget successfully dragging for and recovering a mooring we feared was lost. So all very different experiences, which probably tells you all there is to know about being an academic, I suppose!

Being an academic is demanding – ever wished you had a 9 to 5 job?

Often – every time I am tired at night or stressed about anything at work and can't let it go mentally! I am mother of two and I am sure that tiredness from stress/overwork etcetera does nothing good for our family life. But in contrast, there are many ways in which my work actually enriches my family life as well, and these are sufficient to outweigh the complaints. As one example, apart from being a researcher and a lecturer, I am also an active promotor of STEM – which supports science, technology, engineering and mathematics in the UK – and I act as a liaison between my university department and local schools. I test out many of the STEM activities on my own young children at home, and their reactions, and those of school children I interact with, give me hope that these activities will inspire them to consider STEM careers. This is especially true for the girls who visit the School of Ocean Sciences, as women are still very under-represented in STEM.

Is there a key message that you have been glad to have passed on during your STEM outreach events?

One example struck me most: a visiting teacher thanked us in particular for convening a STEM careers panel discussion, during which we all talked about our setbacks in life and work and how we were able to press on regardless. She thought this was really valuable to her students who struggle with low self-esteem. So despite all the work that went into preparing for the practical activities of that day, it was this low-prep aspect of the school visit that was the most impactful. I certainly learnt that STEM outreach is more than making practical science look exciting, and that boosting the self-confidence of young people is a key aspect of STEM outreach.

And finally, if you could choose anyone from past or present to work with, who would it be?

I'd like to work more with Mary Louise Timmermans. She is a fantastic polar physical oceanographer at Yale University at just at the top of her game at the moment. Happily, though female oceanographers are still outnumbered by male scientists, we do have several wonderful role models to choose from, but even amongst them Mary-Louise stands out for the breadth and depth of her contribution to Arctic oceanography. Furthermore, she has been an excellent mentor to her students and post-docs and is also great fun to be around.

Yueng at the Polish Henryk Arctowski station on King George Island, off the Antarctic Peninsula, where all signposts except one point North!

Does my bum look big in this?

Gender bias in personal protective equipment (PPE)

Gillian Damerell

An XL immersion suit, flanked by Kirsten Macsween (left) and the author (right). These suits are for use in emergencies only, to be worn if forced to abandon ship. Many ships only carry the larger sizes.

(Photo: H. Griffiths)

Picture the scene: the start-of-cruise safety briefing, and we're all invited to try on an immersion suit. A suit is handed to the smallest woman on board (let's call her Marie), and when she puts it on we all laugh – it is ridiculously, absurdly too big for her. The ship only carries Large and XL sizes. She laughs as well, and asks when she gets her red nose and clown shoes. It's all part of the good-natured joking which goes to create the sense of camaraderie on board which will sustain us all through a long cruise.

This is a scene repeated on research ships around the world, and one I'm sure all sea-going marine scientists have experienced. But is it really funny? In a real emergency a too-large immersion suit would be positively dangerous: a lot of air would be trapped in the suit and that air could go anywhere. When Marie is found floating in the ocean with her feet held up by the air in her suit and her head down, will we still find it amusing? When I ask about this, people shrug and say it's better to just have the larger sizes that anyone can wear, so time isn't wasted in an emergency matching people to suitable suit sizes. Err, OK, so you're saying that the average speed at which people can get a suit on is more important than whether the suits will be dangerous for short people? Are the lives of short people less valuable?

I'm writing this on a research ship currently in the Southern Ocean, and the extreme environment means there's a lot of personal protective equipment (PPE) in daily use, as well as the immersion suits for emergencies. Today we're going out to deploy equipment through the ice. I put on my thermal long-johns, noting that there's a slit in the front so that a man can pee without stripping off. The warm, padded, all-in-one snow suit which goes over it also has a double-ended zip all the way down to the groin, so men won't need to take that off either. Meanwhile the female scientists on board tell each other not to drink too much water before going on the ice so we won't need to pee. The legs and arms of the snow suit are, of course, far too long. The legs I manage to roll up, otherwise they'll get under my boots and trip me up. I fail on rolling up the arms, though – the padding makes them too stiff – so I'll just have to keep pushing them out of the way while we work.

__Left__ Snow suits are worn when working outside for several hours, e.g. on the sea- ice. They are very warm and quite comfortable – if they fit! __Below__ Gloves for giants? The brown and yellow gloves are padded and warm with good grip, useful when working with equipment in the cold. The orange gloves are warm and waterproof, and are used for wet/muddy work. (Photo: Y. Wang)

The gloves we've been supplied with also don't fit – the fingers extend 1–2 cm beyond the ends of my fingers, which would make my hands too clumsy to work with the equipment. Luckily I brought my own. They're not as warm as the gloves supplied, but it'll be warmer than taking the gloves off every time I need to do anything. The final, ridiculous straw is the sunglasses – the arms are too long and I'll have to keep pushing them up my nose every two minutes. I improvise a cord round my head to hold them on.

I could go on. The overalls we have for working on deck, the fleeces, warm jackets, salopettes (warm waterproof dungarees), are all designed around the shapes and sizes of men's bodies. Of course, some of the clothing fits some women perfectly well, and some of the men have ill-fitting clothing too – but not nearly as many men as women. For the smaller women on board, everything is too big because the sizes just don't go small enough. One woman tells me that even the hard hats don't fit – they cannot be adjusted tight enough for her head so she has to keep pushing them back as they slide around. And women with larger chests have to choose between squashing their breasts uncomfortably or wearing clothing which is much too big everywhere else.

Life jackets, by the way – those most fundamental pieces of life-saving equipment – don't fit many women. The larger your breasts, the more the life jacket rides up until it wedges under your chin, which is very uncomfortable and can severely restrict your range of motion. After wearing a life jacket for about 30 minutes during the sea-survival training compulsory before embarking on UK research vessels, there is a chafed patch on the bottom of my chin which is sore for days afterwards. And the awkward positioning of the life jacket makes it noticeably more difficult for larger -chested women to climb from the water into a life raft.

Why, in the 21st century, is it still acceptable to leave women at increased risk of dehydration, hypothermia, frostbite, snow blindness and drowning? Is the cost of PPE designed for women really so prohibitive? Even discounting emergency situations, which I must admit are pretty uncommon nowadays, why must we suffer ill-fitting PPE which renders us slower and clumsier, contributing to the still-present, though largely unspoken, belief that women are less effective field scientists? These problems will, of course, also affect women in marine industries such as oil and gas, and similar issues will exist for women working in other dangerous environments.

Ironically, I'm writing this on Friday 8 March, International Women's Day, a day when we celebrate the achievements of women and the progress towards gender equality. But even in 2019 there are still too many issues that have not been addressed – or even recognised as issues which should be addressed. PPE has always been like this, I am told, women just learn to work around it. It's not a real issue. But wouldn't it be better if female scientists didn't need to 'work around' the clothing and equipment which is supposed to help us conduct research safely?

Further Reading

Invisible Women: exposing data bias in a world designed for men (2019) Caroline Criado Perez, Chatto.

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Memories of John Harvey

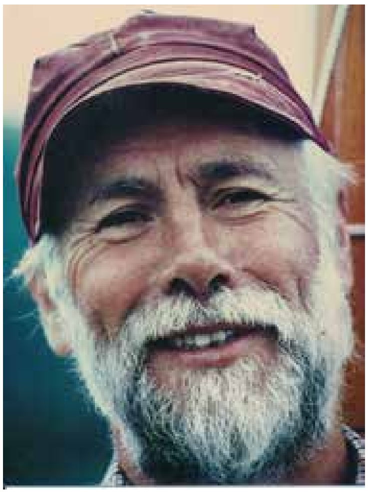
Peter Liss

My friend and colleague John Harvey, who has died aged 80, was not only an expert in ocean physics, but also a keen climber and outdoor activity leader.

In 1968 John was among the first group of lecturers in the interdisciplinary School of Environmental Sciences at the recently established University of East Anglia (UEA) in Norwich. There he taught physical oceanography to generations of students.

He wrote a remarkable book, *Atmosphere and ocean: our fluid environment*s (1976), which was ahead of its time in introducing students to the idea that the two should not be studied as single subjects, but needed to be viewed as interacting parts of the global system.

John carried out expert research into the circulation of the North Atlantic, which showed how Atlantic water masses could be identified by their temperature and salinity characteristics, with different water types showing up as particular areas of the temperature–salinity (*T*–*S*) diagram. Some regarded this as a rather traditional approach, but within a decade it was back in vogue in interpreting the findings of the major international global survey carried out as part of the World Ocean Circulation Experiment.



John was brought up in Irby on the Wirral peninsula by his parents, Eddie Harvey, a manager's secretary with the Blue Funnel Line shipping company, and his wife, Marjorie (née Ward), a teacher. After attending Dawpool school and then Birkenhead school, John studied geography at Liverpool University, and then took a job as a physical oceanographer at the Fisheries Laboratory (now Cefas) in Lowestoft, Suffolk.

After a few years he was appointed a lecturer at the Marine Science Laboratories on Anglesey, a part of the then University College of North Wales, Bangor (now Bangor University), where I first met him while participating in a summer school on oceanography that he was teaching. He inspired me to take up a career in marine science.

In 1989 John took early retirement from UEA to embark on another challenge, leading outdoor activity holidays (mountaineering, navigation and sailing), with his wife, Chris, from the centre they established overlooking Loch Lomond. They both also led walking holidays in Europe and John additionally led some bridge and skiing holidays. John was an accomplished hill walker and climber, having scaled all 282 of the Munro mountains in Scotland, completing the challenge in 2003. He was also a keen sailor and, again with Chris, circumnavigated the British Isles. On their return to East Anglia in 2004, to Brooke in south Norfolk, John was an active and enthusiastic orienteer who liked to enthuse others. Latterly he assisted with running local health walks.

During the last decade of his life John suffered from myeloma and faced its treatment with typical fortitude. He is survived by Chris (née Evans), whom he married in 1961, their sons, Robert and Michael, and grandchildren, Kate and David.

This appreciation first appeared in the Guardian *online 'Other Lives' section for 7 February 2019.*

From HMS Challenger *to* Argo *and beyond*

Judith Wolf and Colin Pelton

In November 2018, a meeting on this topic (jointly organised by the Royal Meteorological Society and the Challenger Society, and sponsored by OSIL) was held at the National Oceanography Centre, Southampton (NOCS). Judith Wolf and Colin Pelton were there and provide their personal impressions below.

Profiling the ocean

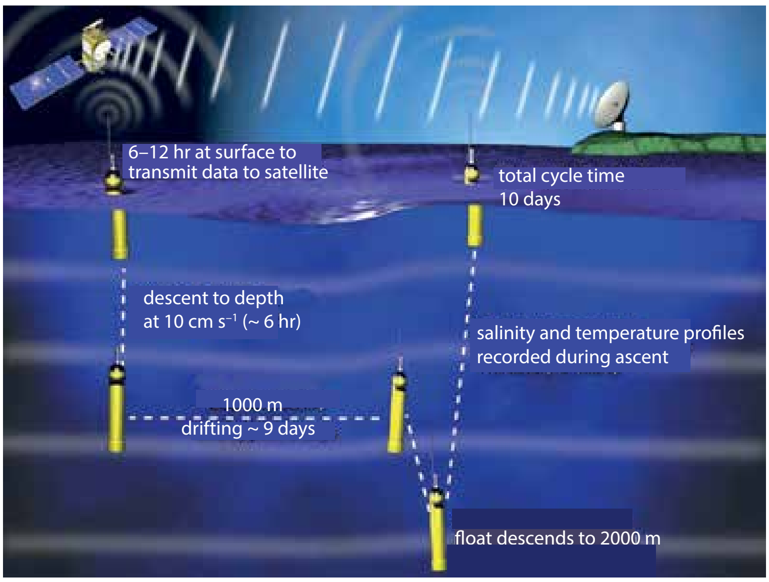
Not being a deep-sea scientist or working with *Argo* data, I attended this meeting out of general and historical interest in the science of physical oceanography and I was not disappointed. Although there were students present, it did feel rather to be a meeting of the 'old guard' – retired and semi-retired scientists were much in evidence. It was a bit of a luxury for me to take the time to attend this type of meeting, and I did so because a number of factors converged for me, not least that I have just started partial retirement and can follow up things for pure pleasure, and scientific interest. It is a sign of our times that the increasing pressure on all of us to do purely funded work means that there is no time for the free-wheeling thinking and making of connections that can be so fruitful when you step outside your own field. There were about 50 attendees on the day – I wouldn't like to guess what the average age was, but it was a great learning experience for me, so hopefully we are never too old!

Across the globe, about 4000 *Argo* floats continuously collect data on the physical state of the ocean. Once deployed, the floats dive down to 1000 m, drift with the ocean currents for several days, then sink an additional 1000 m before slowly rising to the surface while collecting temperature and salinity data. At the sea surface, they transmit the data via satellite before diving down again. They repeat these data dives every 10 days, operating autonomously for four to five years on battery power. Since the first *Argo* float was deployed in 1999, the programme has produced nearly four times as many profiles as all other ocean observing tools combined, and the two millionth profile has recently been collected (http://www.weathernationtv.com/news/argo-program/achieves-milestone-with-two-million-ocean-measurements/).

The meeting was introduced by Chris Folland (Emeritus Professor at the Met Office), co-organiser of the meeting with John Gould (NOCS). The introduction was followed by a talk by the latter on the history of measuring temperature and salinity in the ocean. This took us back over 150 years to the sparse measurements made in the late 19th century with limited instruments using a sounding wire. I learned about these methods in my undergraduate degree at Bangor nearly half a century ago, but how many young scientists now know about these pioneering measurements when every data point was a challenge and the subject of much thought and contrivance?

Brian King (NOCS) brought us up to date by describing the present-day *Argo* programme. I was fascinated to learn that over 3000 research papers have used *Argo* data, and about 75% are by authors who were not involved in the data-collection programme. This reminds us of another lesson: how valuable observational data are and how they can be used in many kinds of investigations not originally envisaged. I was interested to learn through break-time discussions that the global *Argo* programme costs about £25M per year, with the UK contribution being approximately £1M, provided by the government Department of Business, Energy and Industrial Strategy, through the Met Office Hadley Centre, NOC and BODC. Each year UK *Argo* is dependent on finding the money to continue, sometimes through underspend on other projects. I'm not sure this is an ideal way to proceed, but I am sure the results are invaluable.

Launching an Argo *float from Australia's RV* Southern Surveyor.
(Photo: Alicia Navidad, CSIRO)



The Argo *float operational cycle*

Viktor Gouretski (Institute of Atmospheric Physics, Beijing) gave a presentation on bias correction methodology for temperature and salinity profiles. This work can allow us to recover older data and leads into a fruitful discussion area for climate science. If we do not make use of older data, we will not be able to discern signals of change, despite being totally swamped by modern, accurate data, with much better spatial coverage than could ever have been dreamed of by the early pioneers.

After lunch, we had three excellent talks on the use of *T* and *S* data from young Met Office scientists: Rachel Killick, Matt Palmer and Leon Hermanson. Rachel discussed the EN4 database, comprising quality-controlled temperature and salinity profiles, together with objective analyses, provided since 1900 (see https://www.metoffice.gov.uk/hadobs/en4/). The growth of the EN4 dataset has been remarkable: in January 1900 there were 159 profiles, in January 1960, 6522 profiles, and in January

2018, 20 335 profiles.* The increasing coverage of the oceans was naturally a recurring theme during the day. There was also reference to the HadIOD Integrated Ocean Database, which includes EN4 plus COADS, i.e. both subsurface and surface observations (see Atkinson *et al.*, 2014).

Matt talked about ocean profiles and their contribution to the understanding of ocean heat content and climate change. A breakthrough was made when we achieved closure of the sea-level budget versus the individual process contributions, published by Church and colleagues (2011).

Leon discussed seasonal to decadal variability, and the increased provision of climate services through understanding of patterns of environmental change, leading to seasonal predictions for operational purposes. As we know, the ocean, with longer time scales than the atmosphere, is very important for decadal prediction.

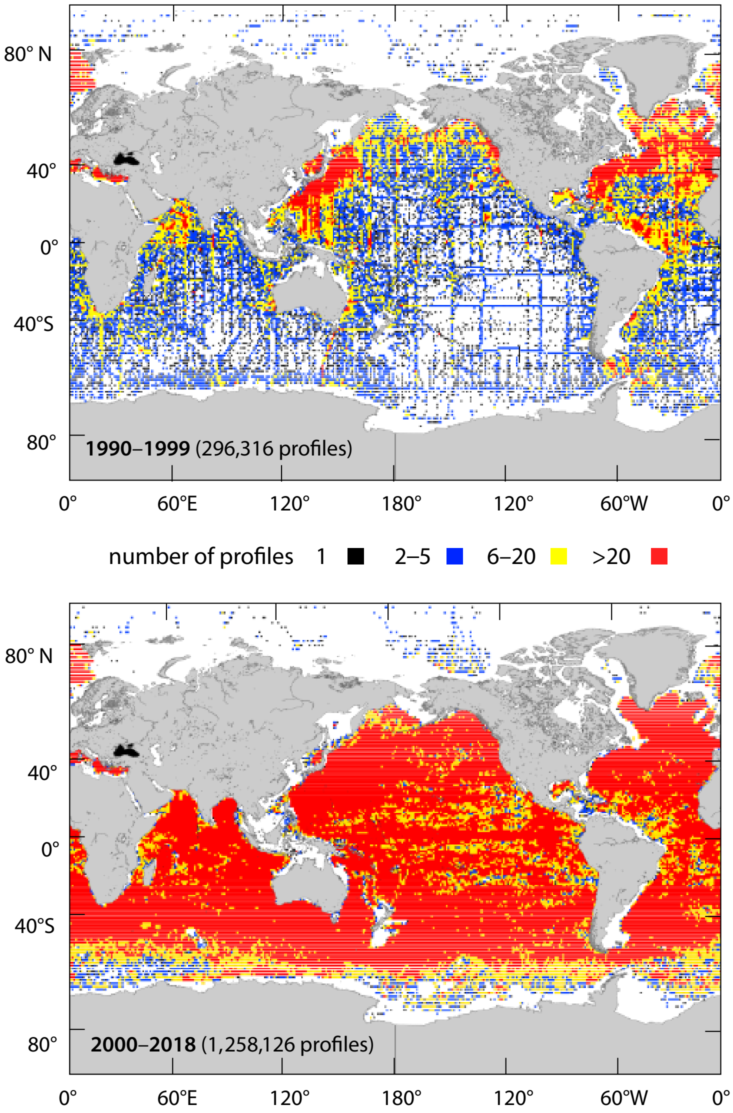
Katy Hill (World Meteorological Organisation) described some large-scale programmes of ocean observation, from TOGA (1985–1994), WOCE (1983–2002), OceanObs'99, OOPC and CLIVAR and IMBeR, to name but a few. The framework for the JCOMM *in situ* Observations Programme Support Centre (JCOMMOPS: www.jcommops.org) provides for collection of Essential Ocean Variables (EOVs),† allowing us to better understand climate cycles of water, carbon and energy. The Global Ocean Observing System (GOOS) has panels which deal with physics, biogeochemistry and biology. We look forward to the UN decade of Ocean Science for Sustainable Development 2021–2030.

Karen Heywood (University of East Anglia) summarised the day, pointing out some challenging regions for *Argo*: close to the coast, in polar waters, in boundary currents and under ice. She talked about some new ways of closing the data gap in polar regions, notably tags on seals and other marine mammals. Sensors and *Argos* satellite transmission are now cheap, and can provide continuous data in regions with sea ice, but the tags record only 18 levels in the vertical, with limited accuracy (cf. the MEOP-CTD database – Marine Mammals Exploring the Ocean Pole to Pole, http://www.meop.net/database/). Karen referred to 'The Slocum mission', a sci-fi article by Henry Stommel, which predicted the present-day glider programme. The new Unmanned Surface Vehicle, *AutoNaut*, propelled by surface waves, will undertake its first mission in 2020, and so the exploration of the ocean continues with new technology.

*EN4 has since been updated, and in March 2019 included 25 156 profiles.

Argo profiles per 1° x 1° box over two decades: ***Upper*** *1990–1999* ***Lower*** *2000–2018*

(Argo website)



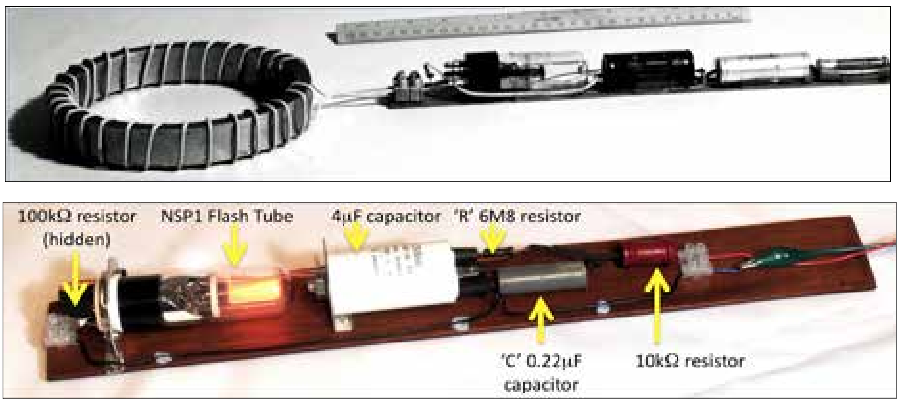
†EOVs are quantities derived from field observations, which contribute significantly to assessments of the state of the ocean.

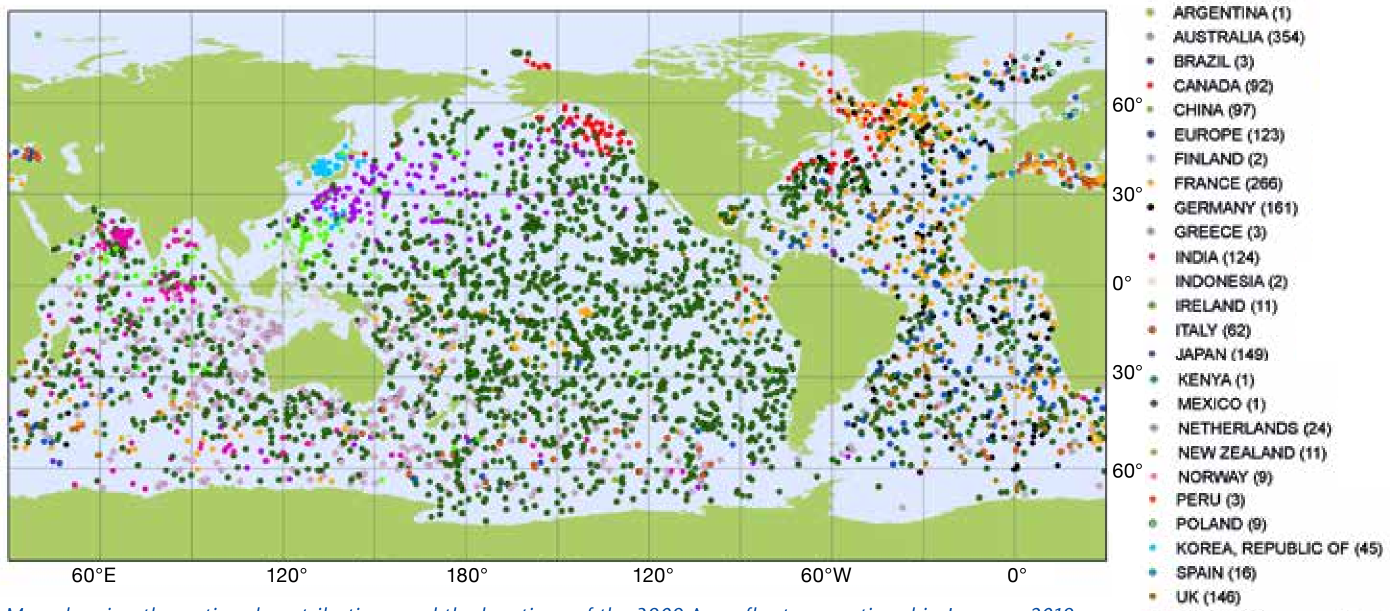
The discussion session focussed on data archaeology, crowd-sourcing and the need to archive historical material *now*. Finding resources for these activities is a huge challenge, and debate about this must continue.

I found this a very rewarding day and certainly not just for revisiting history. A nice addition, however, was the display of historical instruments, including a reversing thermometer first used aboard SMS *Meteor* in 1925, and Gwyn Griffith's authentic reconstruction of the electronic circuit used by John Swallow in the first neutrally buoyant floats in 1955.

Judith Wolf

Upper *The electronic circuit used in the first neutrally buoyant Swallow floats in 1955.*
Lower *Gwyn Griffith's reconstruction of the circuit.*





Map showing the national contributions and the locations of the 3909 Argo *floats operational in January 2019 (*Argo *website)*

Global data-gathering through international co-operation

My attendance did little to lower the average age of the meeting as I now find myself one of the 'old guard'. One benefit of a long time series of corporate memories is that I can usually identify the key players at these events. This meeting and its many eminent speakers and attendees demonstrated the range of pioneering multidisciplinary skills that led to the *Argo* programme and the subsequent advances in global data-gathering. In hindsight I am very lucky to have worked in oceanography at a time when scientists were moving away from collecting costly, time-constrained and spatially limited shipborne measurements to global ocean observing with autonomous vehicles and floats. This well chosen programme of speakers explained clearly how these advances were achieved.

As mentioned by Judith, many of the presentations illustrated increases in global data-coverage over time. This highlighted an important point: some of the younger scientists present (and they were evident on both sides of the podium) could not have undertaken their current research using the limited datasets we had at our disposal in the 1970s and 80s, let alone those available in the late 19th century after HMS *Challenger* had sailed into scientific legend. As a former Information Officer at the Institute of Oceanographic Sciences in the mid 1980s, I can confirm that the access we had to global marine data was as described by the speakers: apart from scientific research cruises and coastal measurements, data coverage was limited mainly to areas which were of interest to those involved in shipping, oil exploration, coastal engineering or defence, and was focussed on shelf seas. Vast global datasets accessible via a mouse-click were unheard of. As a man who has spent many hours on data-management committees, I commend the drive to re-examine the treasure trove of older records in our archives and add these valuable datasets to the time series.

At a time when uncertainty with respect to both climate and politics is increasing, it is reassuring to hear that the international marine community is successfully collaborating on global science, and thousands of data-gathering floats are freely wandering our oceans. As a reminder of the robustness of marine technology, a deep ocean lander, which failed to surface on Christmas Day in 2013 in the Drake Passage, has recently washed up on the coast of Tasmania. It was recording pressure, temperature and salinity and some of its data were still recoverable (see https://www.noc.ac.uk/news/news-archive/201812?-search=).

Finally, special thanks should go, not only to the organising team for their sterling efforts, but also to NOCS which provided an excellent meeting venue and the space to socialise around examples of the latest autonomous data-gathering technology.

Colin Pelton

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Colin Pelton's long and wide ranging career in NERC led him from geological surveying and mapping in the days of the National Institute of Oceanography to heading up the information compliance unit in Swindon. He is now an active member of the Challenger Society History of Marine Science Group. col.51@icloud.com

The Atlantic is in a CLASS of its own

Climate Linked Atlantic Sector Science – a new UK programme

Penny Holliday

A £24 million research programme, which began in April 2018, is investigating the impacts of climate change and human activities on the Atlantic Ocean, including its adjacent seas and shelves, from north to south and from the surface to the sea bed. Over five years, Climate Linked Atlantic Sector Science (CLASS) will aim to deliver the knowledge and understanding of the Atlantic Ocean system that stakeholders need to make evidence-based decisions. Research will focus on understanding and quantifying climate regulation and ocean services, and predicting how the ocean will change as a result of climate change and intensified human exploitation. This research programme, funded by NERC, is delivered by the National Oceanography Centre, Plymouth Marine Laboratory, the Scottish Association for Marine Science, the Marine Biological Association and the Sea Mammal Research Unit.

The global ocean is vital to the functioning of our planet. It regulates global climate patterns by taking up 93% of the Earth's excess solar heat and redistributing it in the Earth system, including through the surface-to-sea-bed thermohaline circulation. The Atlantic sector of the ocean is key to driving and regulating the global overturning circulation because half the formation of deep and bottom waters occurs within it. The overturning circulation in the Atlantic is often referred to as the Atlantic Meridional Overturning Circulation or AMOC. Importantly for the UK, the AMOC transports heat northwards and keeps north-west Europe 3 °C warmer than comparable latitudes on the western margin of the Atlantic.

The global ocean also modulates key biogeochemical cycles by taking up about 30% of the atmosphere's anthropogenic carbon. The AMOC's northward supply of nutrients sustains high levels of biological productivity in the subpolar North Atlantic, leading to a strong biological uptake of carbon, and enabling the region to play a much greater role in the global carbon cycle than would be expected for its size: it stores 23% of anthropogenic carbon even though it makes up only 15% of the surface area of the ocean as a whole. The overturning's associated heat loss facilitates intense solubility-driven uptake of both natural and anthropogenic carbon and its transport to depth on climatically important time scales.

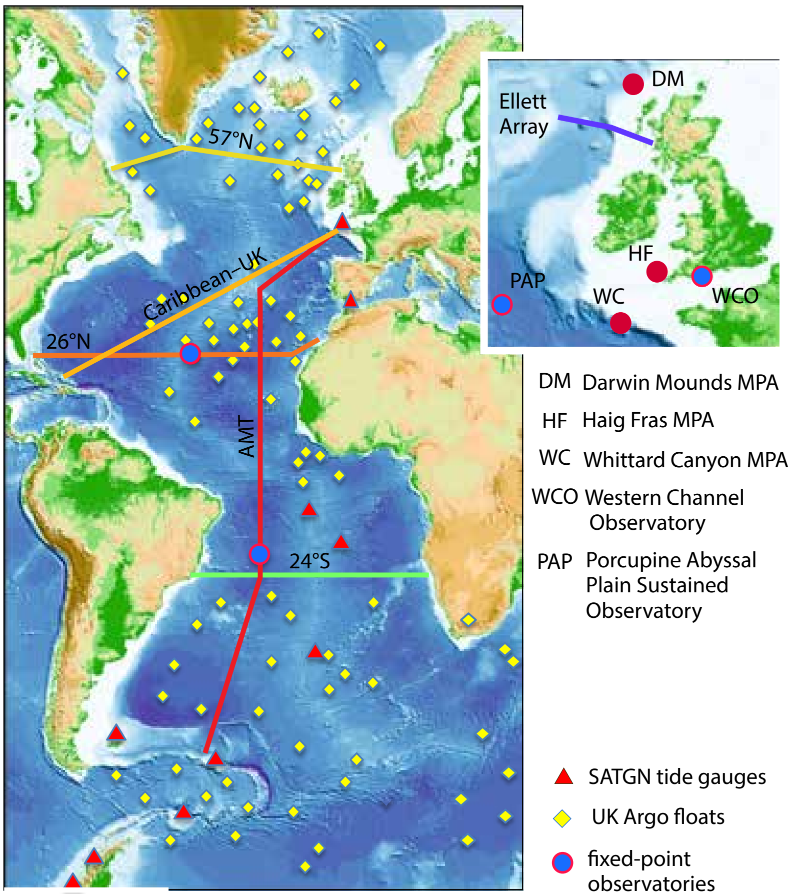
As far as marine life is concerned, the Atlantic supports spatially and temporally diverse biological communities in the water column and at the sea floor, which constitute biodiversity reservoirs, act to store carbon in the oceans, and underpin the marine food web – in essence, the ocean's natural capital.

The inherent variability of the Atlantic Ocean circulation is high, so detection of anthropogenically driven change takes decades, but as we deploy new technologies to observe dynamic ocean processes, the impacts of human activities are becoming increasingly obvious and of growing concern. It is now clear that the ocean plays a pivotal role in climate change, and this is having profound consequences for both regional weather patterns and marine ecosystems. Assessment of potential socio-economic impacts, and the knowledge base to maintain resilient natural resources, require an integrated coordinated effort and detailed understanding of the natural variability of the whole Atlantic Ocean over decades.

CLASS: observations, models and technological development

Observing the wide expanse and depth of the ocean is of course an enormous task. CLASS ocean observations are building on a long history of programmes to measure key properties over climate-relevant time scales (weeks to decades), and are

Figure 1 Ways in which long-term, large-scale observations, being used in CLASS, are being collected: hydrographic sections at 57° N, 26° N and 24° S; the Atlantic Meridional Transect (AMT), which includes two fixed-point observatories in the north and south oligotrophic (low-nutrient) subtropical gyres; a transect between the UK and the Caribbean which uses ships of opportunity to collect surface biogeochemical measurements; Argo *floats; and the South Atlantic Tide Gauge Network (SATGN).* ***Inset*** *Off the British Isles, there is the Ellett moored transport array, three Marine Protected Areas which are repeatedly surveyed, and two fixed-point observatories. the deep-water Porcupine Abyssal Plain Sustained Observatory and the Western Channel Observatory. These last two also contribute to ICOS, the Integrated Carbon Observation System.**



*ICOS is a pan-European research infra-structure that aims to provide the high-precision and long-term observations necessary to quantify and understand greenhouse gas fluxes over Europe and adjacent ocean regions.

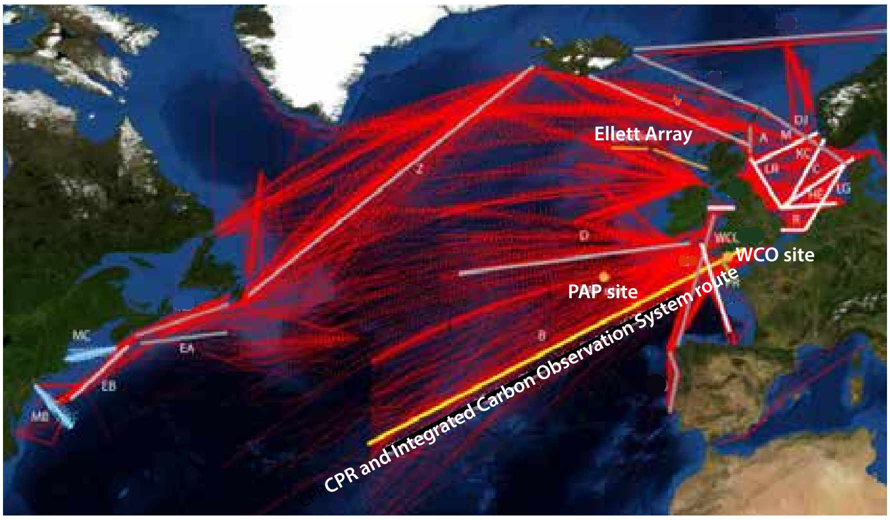


Figure 2 ***Left*** *Deploying a Continuous Plankton Recorder (CPR) from a commercial vessel, so that it can be towed.* ***Above*** *A compilation of CPR tracks over the last 60 years. The white lines are routes in operation today, and pale blue lines are routes for which funding is being sought. The yellow line is the CPR route dedicated to collecting data for ICOS (footnote on p.17). (By courtesy of the Marine Biological Association)*

also part of globally coordinated networks (Figure 1). The Essential Ocean Variables* that CLASS is measuring are sea level, ocean heat content, ocean carbon storage and transport, sea-surface temperature and carbonate chemistry, and surface plankton abundance and community structure

Data on plankton communities have been collected for nearly 90 years by means of the Continuous Plankton Recorder (CPR) survey, operated by the Marine Biological Association at Plymouth. CPRs, towed by ships of opportunity, collect plankton and small particles on a continually moving roll of silk gauze. Decades of microscopic examination of the CPR silks have provided an invaluable record of plankton abundance and plankton community structure in the Atlantic (Figure 2).

CLASS is developing and running numerical ocean models for scientific analysis, predictions and scenario testing. We have a range of models for different uses, all with a high-quality ocean as a central component. The UK Met Office climate predictive systems use the CLASS ocean components, and the physics models form the basic framework for simplified ecosystem models and complex Earth-system models (Figure 3).

To reach all parts of the ocean we use a combination of approaches. Historically, oceanographers have relied upon research vessels and observations collected by commercial ships and satellite systems to learn about changes in the marine environment. In CLASS our activities are also developing the use of autonomous vehicles and new sensors to increase the spatial and temporal coverage of the ocean, and to increase the variables that our robotic vehicles can measure. These vehicles give us options to access remote and difficult environments, allowing us to sample the ocean more widely and efficiently (Figure 4).

The changing Atlantic

We now have abundant evidence that many features of the Atlantic Ocean and its marginal seas are changing, including the strength of the thermohaline and wind-driven circulations, sea-surface and

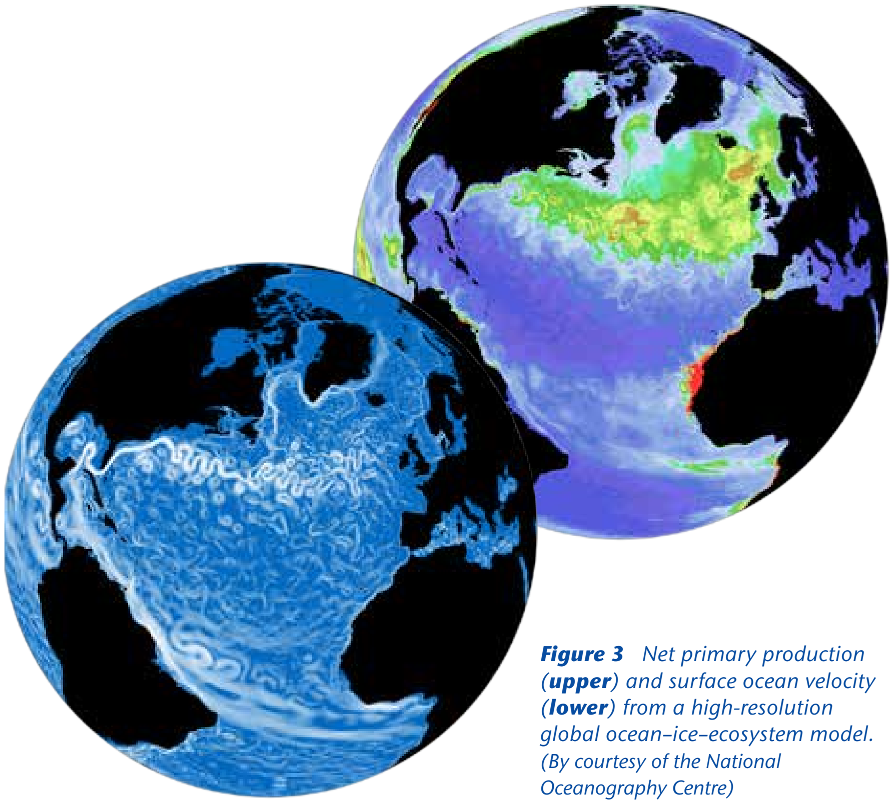


Figure 3 *Net primary production (**upper**) and surface ocean velocity (**lower**) from a high-resolution global ocean–ice–ecosystem model. (By courtesy of the National Oceanography Centre)*

*The Global Ocean Observing System has a focus on Essential Ocean Variables, which are quantities derived from field observations that have high impact on climate assessments and be feasible at the necessary spatial and temporal scales.

interior temperature and salinity distributions, ocean heat content, air–sea CO_2 fluxes, primary production and nutrient fields. The reasons for these changes are complex, and include natural internal variability in the climate system and external time-varying anthropogenic forcing. Understanding and attributing these changes is often confounded by the difficulty of separating natural and externally forced variability, and by the positive and negative feedbacks between various processes. While global climate trajectories can be established with some confidence, climate trends at regional and seasonal -to-decadal scales can be masked by variability within and between basins. The natural variability in both circulation and biological properties is so large that distinguishing trends driven by climate change may require 30 or more years of data.

Changes in the Atlantic system have consequences for the climate regulation and ecosystem services that the UK depends upon. How these services will evolve is uncertain, and numerical models show a wide range of future responses. In some cases the link is clear (e.g. between anthropogenic emissions and ocean carbon storage). However, more complex linkages, such as how changes in ocean acidification may feed through to impacts on biodiversity in sea-floor communities, are harder to elucidate.

CLASS will address four key interconnected knowledge gaps relating to ocean variability, biodiversity and the resultant functional capacity of the Atlantic:

- The evolving state of the hydrological cycle and how changes in ocean salinity may impact it in the future.
- How physical and biological uptake, transfer and storage of carbon in the deep ocean interact to determine the magnitude of the North Atlantic CO_2 sink, and the resultant effects on the production of other greenhouse gases, such as methane and nitrous oxide.
- How natural and anthropogenic drivers of decadal and basin-scale changes are altering the Atlantic ecosystem, and the consequences for ecosystem functioning and services.
- How the structure, diversity and productivity of sea-floor biological communities are changing in response to abrupt or episodic disturbance events compared to long-term change.

Figure 4 *Preparing to deploy an autonomous underwater glider from a research ship. (By courtesy of the National Oceanography Centre)*

How CLASS will serve stakeholders

CLASS outcomes are intended to generate impact in a wide stakeholder community, ranging from international policy-makers to the general public. We will provide input to the Intergovernmental Panel on Climate Change (IPCC) and other global climate assessment processes. We work with the UK Met Office to communicate results directly to decision-makers through UK Climate Projections, and CLASS is supporting UK government decision-makers with key scientific evidence and expertise. We provide data and advice in support of implementation of the Marine Strategy Framework Directive, marine spatial planning (e.g. for Marine Protected Areas), fisheries policy and environmental assessment for offshore operations (e.g. marine renewable energy).

CLASS is also providing advice and strategic planning to international sustained programmes, and ensuring that all new observational and model data products are easily available to the international community. The large user community for the novel technologies we develop within CLASS will encompass UK and international scientists in marine and non-marine environmental sectors, and the international environmental observing community and operators, industry and government departments and agencies. Developers of technology, both academic and commercial and industries that are manufacturing technologies or providing services and will also benefit.

Opportunities for getting involved

As well as delivering world-leading research, datasets, facilities and advice, CLASS activities will form the basis of new research projects. We encourage you to get in touch if you have ideas to develop into proposals with CLASS researchers. We are supporting the UK science community by providing opportunities for early-career researchers (ECRs), i.e. graduate students and postdocs, to work with us. CLASS research cruises have space on them for ECRs to collect samples and data and to gain training in making measurements at sea. CLASS also offers funded ECR Fellowships to support extended visits to the National Oceanography Centre and the Scottish Association for Marine Science, which could include joining a cruise. Find out how to apply for berths on cruises and CLASS ECR Fellowships, by signing up to our email bulletins on the website: proj.noc.ac.uk/class. You can also contact us by email (class@noc.ac.uk) or Twitter (@CLASS_URI).

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The beauty of equations

Tom Anderson

What makes something beautiful? Out of curiosity, I googled 'famous beautiful painting' and one of the images that came up was 'The Scream' by Edvard Munch. My wife saw the painting during a visit to Oslo and so I asked her if she thinks it is beautiful. She replied with a resounding 'No!', but maybe whoever paid $120 million for it in 2012 has a different opinion. A rather less extravagant example is provided by the postcard shown in Figure 1 which was posted in 1932 and shows the Sultan's palace in Selangor, Malaysia. I collect Malaysian postcards as a hobby and find this one particularly beautiful because, almost a century ago, producing colour cards of this kind took immense skill. Making this card involved printing in black using the collotype method (based on exposing gelatin to light passed through a photographic negative), in combination with hand colouring of individual printing plates by applying dots of different densities (stipple) using pen and lithographic ink. Its beauty, at least for me, lies not only in its appearance but also in the skill with which it was accomplished.

Figure 1 *Postcard of the Sultan's palace in Selangor, Malaysia (posted in 1932)*

Beauty, simplicity and usefulness

Simple things are often considered to be the most beautiful. For example (quoting Eleanora Duse), 'If the sight of the blue skies fills you with joy, if a blade of grass springing up in the fields has power to move you, if the simple things of nature have a message that you understand, rejoice, for your soul is alive.' Mathematicians often see beauty in simple equations because simplicity abstracts ideas into the purest dependencies between terms. The simpler the equation, the more evident is the nature of the dependency. Perhaps the most famous example is Einstein's $E = mc^2$. Furthermore, simple (and thereby beautiful) equations and theories are sometimes viewed as being closest to the truth. For example, the English chemist Rosalind Franklin remarked that Watson and Crick's discovery of the double-helix structure of DNA 'was too pretty not to be true'. The renowned physicist Paul Dirac even remarked that 'It is more important to have beauty in one's equations than to have them fit the experiment.'

Simplicity in equations, i.e. mathematical description using the purest dependencies, is likewise a virtue for me, but only when it is meaningful and can be usefully applied to further our understanding of the world that surrounds us. For example, here is a beautiful pair of equations that I derived some time ago to calculate the ratio of bacterial production (*BP*) to primary production (*PP*) in the ocean (at steady state):

$$\frac{BP}{PP} = \frac{\gamma + \phi_\infty}{1/\omega - \phi_\infty} \qquad (1)$$

$$\phi_\infty = \frac{\phi_1}{1 - (1 - \phi_1)\,k_c} \qquad (2)$$

The *BP* : *PP* ratio can be used to indicate the importance of microbial pathways as a sink for organic carbon in the ocean and depends on the supply of dissolved organic carbon (DOC) to fuel *BP* via phytoplankton and zooplankton. The calculation involves only four parameters: the DOC released by phytoplankton normalised to *PP* (γ), the fraction of carbon processed by zooplankton during a single grazing event that is transferred to DOC (ϕ_1), the zooplankton net production efficiency (k_c) and bacterial gross growth efficiency (ω).* Variable ϕ_∞ is the DOC released via grazers at successive trophic levels (ordered into an infinite series for practical application). I see beauty not only in the simplicity and elegance of the equations, but also in their underlying meaning and their consequent usefulness.

*Note that the model, as published, also had parameters for viral lysis which I have excluded here because calculated *BP*/*PP* was insensitive to them.

I nevertheless discount any necessary relation between simplicity, beauty and truth. Some of the assumptions and equations that go into marine ecosystem models are oversimplified, even 'dysfunctional', and such equations are in no way beautiful to me. Biological organisms and ecosystems are complex entities in terms of physiology, behaviour and interactions among individuals. Complex models that describe these processes and interactions may therefore be seen as beautiful, in the same way that a symphony involves harmony between many different musical instruments. Usefulness is the key. An interesting non-mathematical example is provided by Urhobo pottery. Most of us think of vases and other ceramics as beautiful if they have appealing shapes or are decorated with alluring

Figure 2 *Oni Oche pot of the Urhobo people. (By courtesy of Mansfield Ceramics, Gulgong, Australia)*

colours and motifs, such as Japanese Imari porcelain. For the Urhobo people of southern Nigeria, however, the beauty of a pot such as the Oni Oche (Figure 2) is not due to a pleasing shape or embellished appearance but, rather, it is expressed through its functionality in relation to the purpose for which it is made. This 'beautiful' pot was made for storing liquid, with a narrow neck and rounded belly that slopes gradually to the base.

The eye of the beholder

I suggest that we marvel at, and see beauty in, the wonders of the world such as the Pyramids and Taj Mahal, not only because of their appearance, but also because of the tremendous effort and skill that went into building them. The Danish author Isak Dinesen, best known for her book *Out of Africa*, once wrote: 'Probably one can say that all beautiful, noble, or brilliant works are of use, or that everything that proves to be useful or beneficial has its own beauty.' This may be so, but only in the eye of the beholder. For example, I consider the engine in my car to be most useful, but do not see any beauty in it. This is despite the fact that it is a feat of engineering that marks the achievement of thousands of people over many decades. It is simply not within my sphere of interest. In similar fashion, I do not expect you to necessarily see beauty in my equations for calculating *BP*/*PP*. For starters, I provided here only minimal ecological context with little about the assumptions behind the equations and, moreover, it may be that doing math is not your favourite pastime.

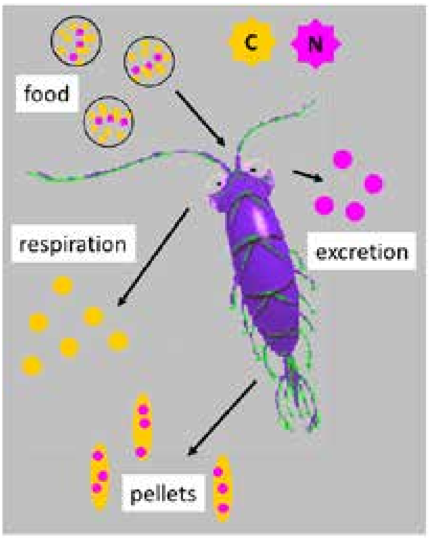
In many instances, beauty is an acquired characteristic, requiring time and experience, and we all have different interests in life. The best choice of venue for a day out with my wife, for example, would not be the Math Museum (Figure 3)! Models and equations are, however, an integral part of scientific research and it therefore behoves modellers, including myself, to make their models as transparent and accessible as possible to the rest of the scientific community. This need not require users to delve deeply into the equations and their derivation as it is exploring the concepts that matters most, along with their quantitative testing in the context of available data. Two great marine ecosystem modellers spring to mind in this regard: John Steele and Mike Fasham. Both enjoyed nothing more than reaching out to, and interacting with, biologists and ecologists, sharing ideas and, through the combination of observations and theory, advancing our understanding of the structure and function of marine ecosystems.

Figure 3 *Formula Appreciation Class (© Sidney Harris)*

The beauty of discovery

The role of equations and models in science is often not well understood. To some, modelling is about taking existing knowledge, formalising it mathematically and making predictions such as how marine ecosystems will respond to future changes in climate. Making these kinds of predictions is, of course, an entirely worthwhile and important activity. Modelling, however, can provide so much more in terms of contributing to knowledge and the advancement of science in general. Equations organise thinking, and models provide a framework for carrying out numerical experiments to rigorously test cause and effect. An obvious example that springs to mind is Mike Fasham's use of a simple ecosystem model to test various hypotheses about the factors that regulate the distinctive high-nutrient low-chlorophyll (HNLC) ocean ecosystems, including iron limitation, grazing and light. Models may suggest new observations and experiments – as elegantly put by John Steele: [By] 'forcing one to produce formulas to define each process and put numbers to the coefficients, reveals the lacunae in one's knowledge … to suggest further field or experimental work'. These experiments suggest new hypotheses and so the advance of science continues through the cycle of theory and observation.

Figure 4 *Cycling of carbon and nitrogen in food by zooplankton. (Adapted from a cartoon by the Zoology Dept, University of Guelph)*



As I wrote in a previous *Ocean Challenge* article, 'the beauty of science … is that it is a voyage of discovery, with the unexpected and unexplained lying in wait at every turn.' Models should surprise us, at least occasionally, and the equations involved are most beautiful when they contribute to this voyage. I recently developed a model that predicts how invertebrates, notably zooplankton, use the carbon and nitrogen in their food for growth and metabolism (Figure 4), and how this is influenced by temperature. My co-authors and I were surprised by its predictions. We had hypothesised that in a warming environment zooplankton will require increasingly carbon-rich diets because increasing energetic costs of metabolism will be mainly fuelled by compounds such as carbohydrates. In fact, however, we ended up concluding that the hypothesis is false, namely that 'the nutritional requirements of invertebrate consumers may change little, if at all, at elevated temperature'. I especially enjoyed pondering and discussing the results with my colleague in Southampton, Dan Mayor, and we couldn't but help remark that, with the model predictions in front of us, it all seemed so logical and beautiful.

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Tom Anderson is a senior research scientist in the Marine Systems Modelling group at the National Oceanography Centre, Southampton. His interests include Earth System science, marine biogeochemical cycles, stoichiometry, the microbial loop and dissolved organic matter, model complexity, and the methodology and philosophy of science.
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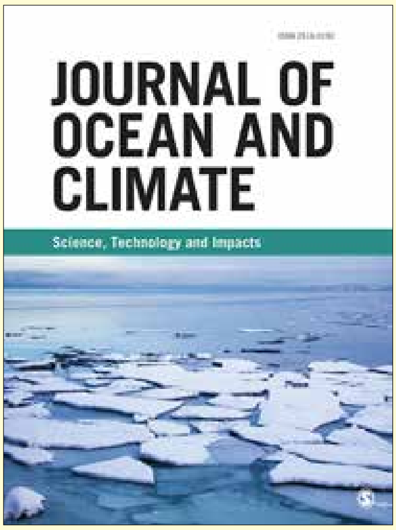
Special Collection of articles in *Journal of Ocean and Climate: Science, Technology and Impacts*

At the Challenger Conference 2018 a partnership was established with the SAGE peer-reviewed, open access *Journal of Ocean and Climate: Science, Technology and Impacts* (https://journals.sagepub.com/home/ocs). Authors of abstracts for the Challenger Conference are encouraged to submit a journal paper to form part of a Special Collection in the journal.



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The submission deadline is August 31, 2019.

MASTS Annual Science Meeting
Bold science to meet grand challenges

MASTS will hold its 9th Annual Science Meeting on 2–4 October 2019 (Wednesday–Friday) at the Technology and Innovation Centre, University of Strathclyde, Glasgow. Everyone is welcome.

This cross-disciplinary meeting will examine the science we need to meet the modern challenges which face our marine waters and seas. It will bring together members of the marine science community, with the aim of promoting and communicating research excellence and forging new scientific collaborations. The cross-disciplinary nature of the event as well as the high calibre of the selected talks means that scientists can broaden their knowledge in marine science as well as benefit from expertise and ideas gained in a range of fields other than their own.

Science presentations and e-poster sessions will take place on the first two days (Wednesday and Thursday, 2 and 3 October), together with plenary sessions and opportunities to network. On the third day, the venue will host a number of meetings and workshops.

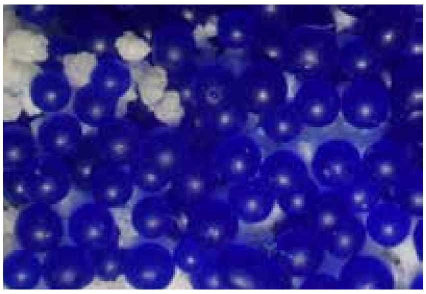
Please get in touch if you would be interested in running a special session on 2 or 3 October, hosting a workshop on 4 October, or exhibiting at the event.

How marine plastics affect people too

Bridie Kennerley

The impacts of plastic pollution on marine life are becoming increasingly well understood, but new research from Plymouth Marine Laboratory shows how much these marine plastics also impact people, costing us financially and damaging our health and wellbeing.

Plastics in the ocean, from plastic straws to abandoned fishing nets, can be lethal to a wide range of organisms living in the sea. Studies into the threats posed by entanglement, swallowed plastic and the widespread presence of microplastics have increased hugely in recent years and show that even the deep ocean is not immune. Public awareness has risen thanks to programmes such as Sir David Attenborough's BBC documentary series, Blue Planet II, wide news coverage and initiatives reducing the use of drinking straws, stirrers and cotton buds, and legislation banning plastic beads in cosmetics.



Although banned, microbeads from cosmetics will continue to pervade the marine environment (Photo: Kelvin Boot)

However, the effect of marine plastic pollution on natural capital – the goods and services that the marine environment provides to society – has been studied and discussed much less. Marine ecoservices have an enormously poitive effect on human health, providing food and oxygen, and regulating our climate and weather. They also have a significant effect on our wellbeing, not only as a source of food and income for many people in coastal communities, but also through recreation and leisure, and cultural and emotional connections with marine life.

The scale of damage to marine ecosystem services by plastic pollution has been investigated by a multidisciplinary team of scientists, led by Plymouth Marine Laboratory, in collaboration with scientists at the Universities of Stirling and Surrey in the UK, and the Arctic University of Norway. Their study reviewed global marine plastic research, scoring different organisms by the geographical extent and frequency of impact, and the reversibility of any damage. The findings, based on 1191 data points, showed global evidence of negative impact on almost all species covered, from zooplankton to marine mammals. Only bacteria and algae appear to benefit, by being able to colonise the surfaces of marine plastics, introducing the risk that they could be carried around the world to act as pathogens or invasive species.

This information was then translated to impacts on ecosystem services by scoring each organism on its potential to provide each ecosystem service, using the CICES ecosystem services classification (https://cices.eu). By combining this with the ecological impact results, the study found that all ecosystem services are impacted by marine plastics, leading to an overall estimate of a 1–5% reduction in the delivery of marine ecosystem services, based on 2011 levels of plastic pollution**.** Using previous research assessing the financial benefits of marine ecosystem services to society, the study estimated that this 1–5% decline in ecosystem services led to an annual loss of \$500–\$2500 billion, or \$3300–\$33 000 per tonne of marine plastic, in terms of reduced marine natural capital.

The provision of fisheries, aquaculture and agricultural materials, as well as recreation and tourism, were identified as being of particularly high value and at high risk. Beyond these more obvious economic impacts, the study also highlighted significant risks to heritage, culture and emotional welfare. People attach significant value to charismatic marine species such as seabirds, turtles and cetaceans, experiencing emotional wellbeing in the knowledge of such animals' existence now and in the future.

This study highlights the reality of the plastic problem in human terms, and will hopefully lead to this aspect of plastic pollution becoming part of the global conversation, with policy-makers and industry waking up to this previously overlooked issue.

Dr Nicola Beaumont, lead author and Environmental Economist at Plymouth Marine Laboratory, warned: '*Our calculations are a first stab at "putting a price on plastic". We know we have to do more research to refine them, but we are convinced that already they are an underestimate of the real costs to global human society.*'

Further reading

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For more about ecosystem services see https://oceanwealth.org/ecosystem-services/ *Useful articles are:*

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Plastic litter impacts on the goods and services that the ocean can provide, ultimately affecting us all (Photo: Kelvin Boot)

Brexit and UK fisheries

Choppy seas ahead?

John Shepherd and Joe Horwood

'*Managing fisheries is hard: it's like managing a forest, in which the trees are invisible and keep moving around.'*
One of us said this many years ago (http://jgshepherd.com/thoughts/), and both of us have said, on numerous occasions, that if the Common Fisheries Policy did not exist, we would have to invent it, or something like it. If the UK does eventually leave the EU, we shall indeed have to invent a new UK fisheries policy that can coexist with the CFP, which will of course continue in force for other member states. The present political declaration* on the future relationship provides little guidance. It just says *'the Parties should cooperate on the development of measures for the conservation, rational management and regulation of fisheries, in a non-discriminatory manner'* and '... *the Parties should establish a new fisheries agreement on,* inter alia*, access to waters and quota shares'*. In other words, the can has been firmly kicked further down the road, and none of the important detail has been worked out yet. In this article we shall try to explain some of the historical background, why fisheries agreements are hard to reach, why the CFP was (and is) not all that bad, why making that new agreement will not be easy, and why everyone is almost certain to be dissatisfied – not least the fishermen.

History

Once upon a time UK fishermen could fish pretty much wherever they pleased, including the rich fishing grounds off Iceland and the north-east coast of North America. In the later 20th century, their activities were conducted under the aegis of two international Conventions, implemented through the International Commission for the Northwest Atlantic Fisheries (ICNAF)† in the north-western Atlantic, and the North-East Atlantic Fisheries Commission (NEAFC), still in existence in the north-east. However, while these bodies did assess the state of their fish stocks, and sometimes proposed catch limits, those limits were not enforceable and were not divided into national quotas, and there was little or no attempt to enforce any restrictions other than so-called 'technical measures' such as limits on mesh sizes and minimum landing sizes, intended to prevent the exploitation of juvenile fish. However that all changed in the 1960s and 1970s, when Iceland (among other countries) unilaterally extended its fishery limits to 12, 50 and finally 200 nautical miles (n.m.) in 1976, leading to series of 'Cod Wars' in which Iceland prevailed.

Thereafter, UK fisheries were progressively restricted to home waters. And after the UK joined the EEC (the European Economic Community, as it then was), the Common Fisheries Policy (CFP) of the EEC became the dominant factor regulating UK fisheries activities.

The Common Fisheries Policy

The CFP had its origin in an extension of the original *Treaty of Rome* in 1970, but only really became a separate and distinct policy in 1972 when the UK, Denmark and Ireland joined the EEC. It has since been reviewed and modified (sometimes substantially) roughly every 10 years, in 1983, 1992, 2002 and 2013. The original idea was that all EEC/EU fishermen would have equal access to Community waters outside the (mostly) 12-n.m. coastal zone. However, that was rapidly recognised as unworkable and/or undesirable, and restrictions were adopted, notably to prevent access to the North Sea by fishermen from Ireland (in 1972) and Spain (in 1986).

Since its inception the CFP has largely relied on setting international Total Allowable Catch (TAC) levels for each fish stock (a fish stock is a population of a particular species living in a specific sea area). The TACs are then split into national quota allocations, based on the concept of *relative stability*,† so that in essence each member state gets the same percentage of each TAC every year (although there are some variations on this theme). These TACs and the quotas derived from them are supported by various technical measures (closed areas and seasons, minimum mesh sizes and landing sizes, etc.). The success or otherwise of this system relies mainly on two things. Firstly, the ability to set TACs at appropriate levels, so that fish stocks are not over-exploited (which requires both good scientific advice and the political will to follow it), and secondly, the ability to ensure compliance with the regulations that are agreed. Enforcement is the Achilles heel of all fisheries management. Good intentions and international agreements are useless unless someone has the power to ensure that the regulations and quotas are respected.

The great merit of the regime of well defined EEZs and the CFP has been that together they have established a system of rights and obligations that are legally enforceable on and by the coastal states. The CFP is widely criticised and often regarded as a failure. It is certainly far from perfect, but Europe has not (yet) carried out the control experiment of doing without it. In our view it is almost certain that without the CFP, and its system of restrictions including TACs and quotas, the state of most fish stocks would be far worse than it is today. After all, it was the perceived over-exploitation of some fisheries way back when there were very few restrictions that led to the founding of the International Council for the Exploration of the Sea (ICES) in 1902, and many other regional fisheries bodies thereafter. It has certainly taken a long time, but in the past ten or fifteen years the restrictions imposed under the CFP have finally bitten, and led to a situation where many important stocks are no longer regarded as over-exploited.

In the North Sea and Channel, for example, the latest ICES advice shows that 25 out of 43 assessed stocks are now being fished below the maximum sustainable fishing rate. North Sea plaice is fished at just below maximum sustainable rate, and its mature biomass, at nearly one million tonnes is the highest for at least 50 years. The North Sea cod, which for 20 years has suffered poor recruitment (low numbers of young fish joining the stock), is still being fished above maximum sustainable rate, but the fishing rate has been cut by 60% compared with fishing in the 1980s and 1990s.

*https://ec.europa.eu/commission/publications/political-declaration-setting-out-framework-future-relationship-between-european-union-and-united-kingdom_en

†ICNAF was superseded by the Northwest Atlantic Fisheries Organization (NAFO), now largely concerned with US–Canadian issues.

*The now familiar 200-n.m. Exclusive Economic Zones (EEZs) – for which fisheries limits were in some cases in a sense precursors – were only formally agreed in 1982 with the adoption of the *UN Convention on the Law of the Sea (UNCLOS)*.

†Note that (confusingly) it is actually the relativity that is stable, not the stability that is relative !

National quotas and 'relative stability'

The establishment of the percentages which determine who gets what is, to say the least, a bit of a black art (not only in Europe but everywhere it has to be done) and has always been fraught, and any attempt to adjust the shares is guaranteed to lead to disputes. This has happened periodically, for example when additional fishing nations like Spain have joined the EU, and when there have been major shifts in the geographical distributions of some stocks (e.g. of the western mackerel in the late 70s and again recently). The complexity of the situation is compounded because some stocks are shared with non-EU member states like Iceland and Norway, so that bilateral (or multilateral) negotiations are needed, but in practice these are largely guided by the same general principle, i.e. largely fixed percentage shares. There is unfortunately no scientific way of determining these percentages. Many people suppose that one could and should just figure out what fraction of each stock lives in each member state's EEZ, and use that information. Sadly, however, that ignores several complicating factors, including:

- The biological reality that fish move around all the time, undertaking regular seasonal migrations between feeding, spawning and nursery grounds, as well as sometimes shifting their distributions in response to climate change or other environmental factors.

- The scientific reality that we do not know where the fish are with any accuracy most of the time. Trawl and acoustic surveys provide some information for some stocks for some seasons, but this is only approximate information, and such surveys are very expensive.

- The fundamental issue that anyway we have no obvious basis for deciding how to weight and combine whatever information we do have: should one use the annual average total stock biomass distribution, or the seasonal spawning stock distribution, or the exploitable stock distribution (which may change with the fishing gear), or what ?

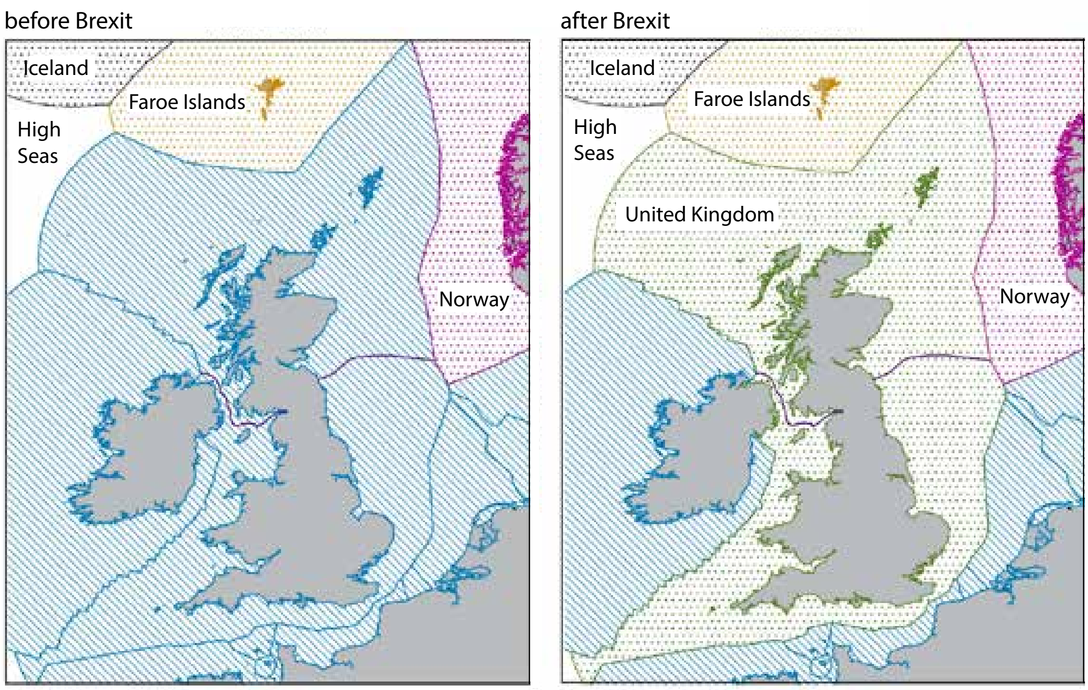
- The practical reality that most stocks have been exploited by fishermen of several nationalities for a long time, sometimes for several (or many) generations. Any 'objectively' determined percentages would inevitably fail to match these historic shares of the resource, and thus generate conflicts.

This last situation is exactly what caused the Cod Wars between Iceland and the UK, and a number of other conflicts since. The Icelanders understandably figured that they were entitled to 100% of cod stocks that never went anywhere near the UK, but UK fishermen (supported by their government) thought otherwise, since they had been catching fish there for centuries.

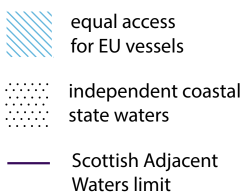
In practice, therefore, the required shares are hammered out by negotiation among the interested parties, a process that is certainly influenced by any relevant scientific information, but certainly not decided by it. In the early 1970s when the CFP was being implemented for the first time, scientists from all the fishing nations concerned were seconded to Brussels for months on end, trying to assemble a consensus on what scientific information was available and relevant to 'inform' the final horse-trading among fisheries ministers. Some enduring friendships and enmities were formed as a result … The historic shares (known as 'track records' in the trade) have usually been just as influential as the scientific information.

What about Brexit ?

Is it brave or foolhardy to predict life after Brexit? In fact, the position for fisheries may be a little clearer than it is for some of the Brexit issues, since most of the other difficulties lie in trade, borders and movement of people. We can perhaps anticipate the future of fisheries from the *Fisheries Bill 2017–2019* currently making its way through Parliament, its preceding White Paper, the Bill's *Explanatory Memorandum*, subsequent government statements and even (to a very small extent) the negotiated EU *Withdrawal Agreement* of November 2018. At the time of writing (early April 2019) it remains uncertain when the UK is to leave the EU. Whenever that occurs, for the purpose of fisheries management the UK will become an independent coastal state, under the *United Nations Convention on the Law of the Sea* (*UNCLOS*) and other international treaties. It will become free from the Common Fisheries Policy. It will control *inter alia* conditions on access to the waters of our EEZ, and will have to agree, with the EU and others, the level of exploitation on any shared fish stocks. At present, EU and UK vessels can in general fish in any of the Community EEZ waters outside of the 12-n.m. territorial limit subject to their national quotas, and the rules on the gears to be used etc. are common in EU waters (with some regional variations). In the future the UK will in principle be able to stipulate whatever measures it



Fishing limits of north-west Atlantic fisheries for the EU and independent coastal states before and after Brexit. The boundaries are of the states' exclusive economic zones, apart from the Scottish Adjacent Waters limit introduced on devolution of the Scottish Parliament.



pleases within its EEZ. The 1964 *London Fisheries Convention* consolidated the right of access of a limited number of non-UK vessels to fish in the UK's 6–12-n.m. zone; and the UK had similar rights elsewhere. On 3 July 2018, the UK gave its statutory two-year notice of withdrawal from this Convention, but what reciprocal rights of access may be decided for the future remains uncertain. Access is important, but so too is management of shared resources and their allocation, usually by means of TACs and quotas. As explained above, under the CFP, fish resources are mostly allocated to member states using the concept of relative stability. For many of the UK's important stocks this was agreed on the basis of landings over the period 1973–1978. As a result, the UK gets, for example, only 4% of the North Sea sole TAC, but 47% of the EU's share of the TAC for North Sea cod (some of the total having gone to Norway under bilateral agreements). Each year the TAC may be raised or lowered but the percentage allocation is normally broadly unchanged. The baseline dates are important but essentially arbitrary, being a historical accident.

In general, international fishery negotiations tend to allocate quotas to nation states through the degree of 'zonal attachment' of that stock to the EEZ(s) in question. This concept has no precise definition, but is essentially the degree to which a stock resides in, or is dependent on, a state's waters. The *UK Fisheries White Paper* provided some indications of what the UK government thinks the effect of applying zonal attachment might be, compared with using relative stability, for a range of stocks. For North Sea sole it asserts that this 'attachment' is over 30% in contrast to the 4% derived using relative stability. The UK has had a low proportion of most sole stocks because, during the 1970s reference period, its trawl fleet was mainly of side-trawlers mostly fishing for plaice, and taking sole only at night. The continental fleets had already changed to beam trawlers, catching sole over 24 hours and thus more effectively. Whether or not the EU, representing the other member states, will reach the same conclusions and agree to these UK 'attachment' estimates remains to be seen …

There have been many examples in western Atlantic waters where states have failed to agree zonal attachment figures. Often autonomous quotas have been set, so that (usually) the total TAC exceeds sustainable levels and puts the stocks and the fisheries that depend on them at risk. We can therefore expect that agreeing new allocation percentages will not be easy. With a transition period as currently envisaged the UK will negotiate as an independent state in late 2020, setting quotas for 2021. However, under the draft withdrawal agreement, the UK would apparently be bound by the current arrangements until any transition period ends.

In deciding future policy the UK will remain constrained by many of the high level drivers of the CFP, including an objective of achieving maximum sustainable yield derived from *UNCLOS* and the UN Sustainable Development goals. The White Paper sets this as an objective in a multispecies and ecosystem context, but the devil will be in the detail (and the dynamics of the negotiations). One assumes that ICES will remain the key source of advice on the state of the fish stocks and the marine environment, but how the bi- and multilateral negotiations on quotas will work out remains to be seen. It is inconceivable that they will not also consider access to the markets in other EU member states, which will remain vitally important to UK fishermen for the foreseeable future.

The UK has also stated that it will continue to pursue the ending of wasteful discarding of fish that have been caught. It is now widely recognised that the current EU Discards Regulation (which was, as we among others had warned, a triumph of principle over practice) is difficult to implement in highly mixed fisheries, resulting in the early closure of fisheries, and continued discarding 'over the horizon'. The UK and the Devolved Administrations will be able to introduce different approaches more suitable to their fisheries, but it is difficult to find easy solutions. However, wider application of fishing effort limitation (e.g. by kilowatt-days at sea), as opposed to catch limits, could be a way forward.

Discussion

In the past two years there has understandably been a lot of talk about how much fish the UK industry will be entitled to when we are finally freed from the shackles of Brussels. Some optimistic estimates have been made by the fishing industry and by the government, whose basis will doubtless be challenged enthusiastically when real and detailed negotiations on fisheries take place. These estimates purport to show that UK fishermen will be entitled to far more fish than they have actually caught in recent years. Whether or not such a claim can survive what will surely be a brutal negotiation remains to be seen. But even if it does, it ignores the commercial reality that there is no point in catching a lot of fish unless you can sell it at an acceptable price. And most fish caught under UK quotas are sold abroad, to other member states like France and Spain, where more consumers and chefs appreciate and know what to do with fish and are prepared to pay higher prices as a result. That means that there will be no point in negotiating for high fish quotas unless we can also negotiate for the right to export to those EU member states, as our fishermen do now. Some idea of the possible complications can be got from the government guidance on issues such as access, quota-swaps, imports and exports, work-visas, etc. (see bit.ly/2ERjW3Q). Fishing rights and trading opportunities are inextricably linked, and will remain so. It is therefore quite possible that when the dust settles, and all those negotiations have taken place, the final outcome will not be all that much different to what has gone before. Physical, biological, political and commercial realities will remain, and will inevitably constrain any gains to be expected from greater control of 'our' resources.

Further Reading

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Other information

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Fisheries Bill Explanatory Notes: https://publications.parliament.uk/pa/bills/cbill/2017-2019/0278/en/181278en.pdf

Sustainable fisheries for future generations (July 2018): https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/722074/fisheries-wp-consult-document.pdf

Relevant publications by the European Commission can be found at https://ec.europa.eu/commission/publications/

The United Nations Convention on the Law of the Sea (UNCLOS) (1982) http://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf

Acknowledgements

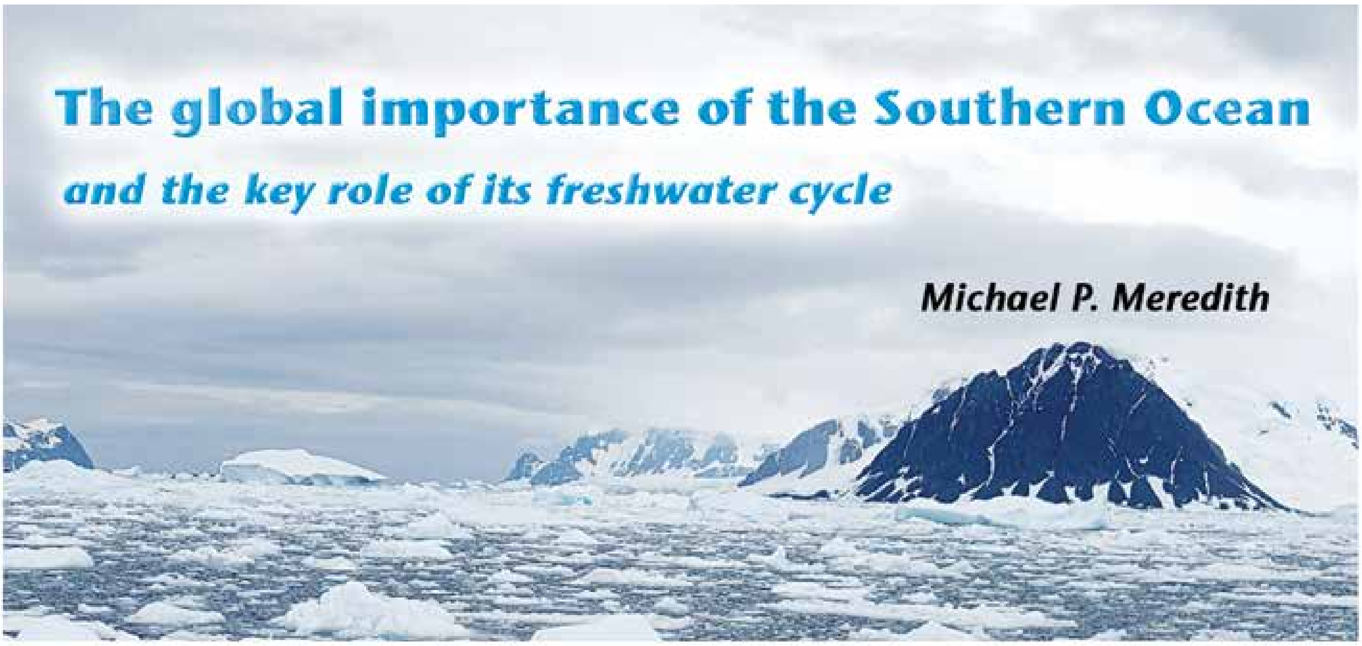
The map showing fishing limits is taken from https://digitalpublications.parliament.scot/ResearchBriefings/Report/2018/12/17/UK-Fisheries-Bill#Access-to-British-fisheries-and-fishing-licences

John Shepherd and **Joe Horwood** are both former Chief Fisheries Science Advisers to Defra, with extensive experience of UK and European fisheries management.

The global importance of the Southern Ocean

and the key role of its freshwater cycle

Michael P. Meredith



This article is based on the lecture given by the author on receipt of the Challenger Medal in September 2018

'How inappropriate to call this planet Earth when it is quite clearly Ocean.' This quote, beloved of oceanographers and others who care about the sea, comes from Arthur C. Clarke, famed writer of science fiction. To many, it encapsulates perfectly the pre-eminence of the ocean in everything to do with our planet – sustaining life, controlling our climate, feeding our populations. Clarke's use of 'Ocean' as a singular noun also foreshadows the first principle of Ocean Literacy (http://oceanliteracy.wp2.coexploration.org) which is that 'Our planet has one big ocean with many features'. The idea of a single interconnected ocean with many features becomes accessible visually when the world is viewed on a Spilhaus Projection (Figure 1), designed by Athelstan Spilhaus in 1942 as a side project whilst developing the early bathythermograph. The projection not only emphasises this interconnectedness, but also highlights the centrality of the Southern Ocean in the global ocean circulation. Flowing around Antarctica, the Antarctic Circumpolar Current – the world's largest current system – connects the Atlantic, Pacific and Indian Ocean basins, and moves huge quantities of heat and freshwater, along with carbon and other climatically and ecologically important substances, between them.

The global importance of the Southern Ocean transcends even this connecting role, however. The Southern Ocean is the site of much atmospheric and cryospheric forcing that drives the global circulation. It is the key site globally where old, deep waters rise to the surface, and are thus able to interact with the atmosphere and cryosphere. These deep waters were last in contact with the atmosphere hundreds of years ago, so this represents the main interaction globally of the industrial-era atmosphere with the pre-industrial ocean. Large amounts of heat and carbon are exchanged at the surface, before the water sinks back into the interior, both in a less dense form in intermediate layers, and in a denser form as bottom waters (Figure 2 overleaf).

The key role of the Southern Ocean in the global circulation becomes very clear when the Spilhaus projection is used

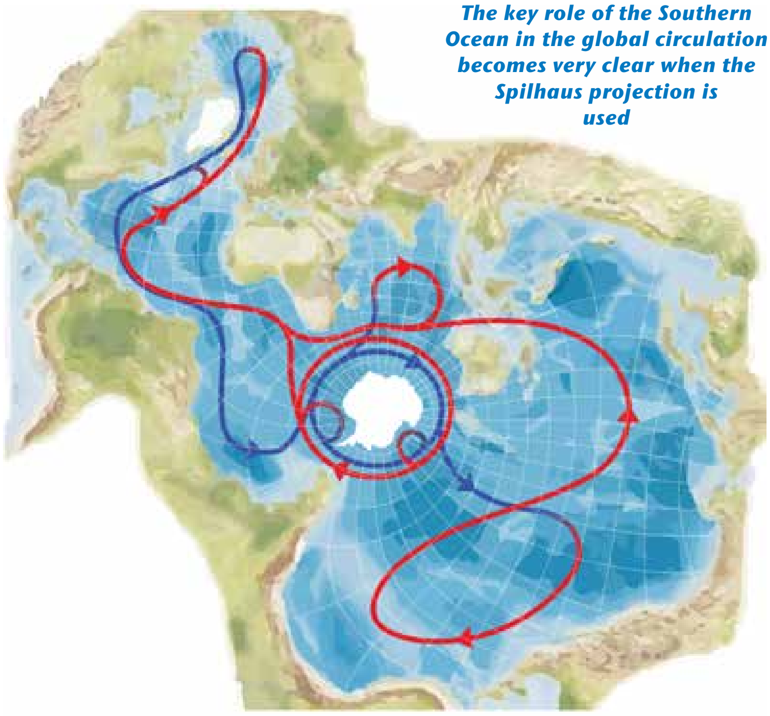
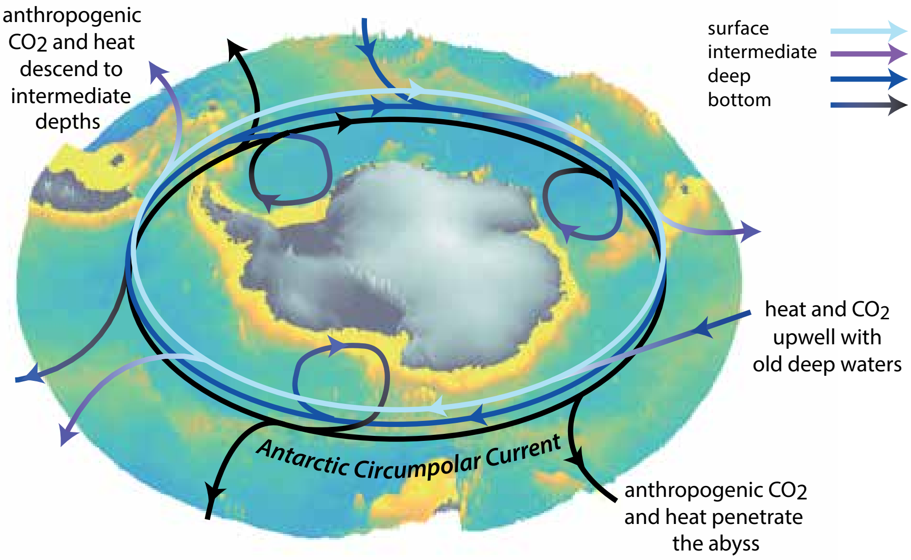


Figure 1 *The globe viewed on a Spilhaus projection; in contrast to conventional misleading projections, this portrays the ocean fringed by land. The global thermohaline circulation is shown in cartoon form, with upper-layer flow in red and lower-layer flow in blue.*

As well as being the key connecting region for the global ocean, the Southern Ocean is the most important region for the reprocessing of old, deep waters into newer water masses, both denser and less dense

Reprocessing of water masses around Antarctica has a profound effect on global climate by removing heat and carbon from the atmosphere and storing it in the deep ocean for centuries or longer



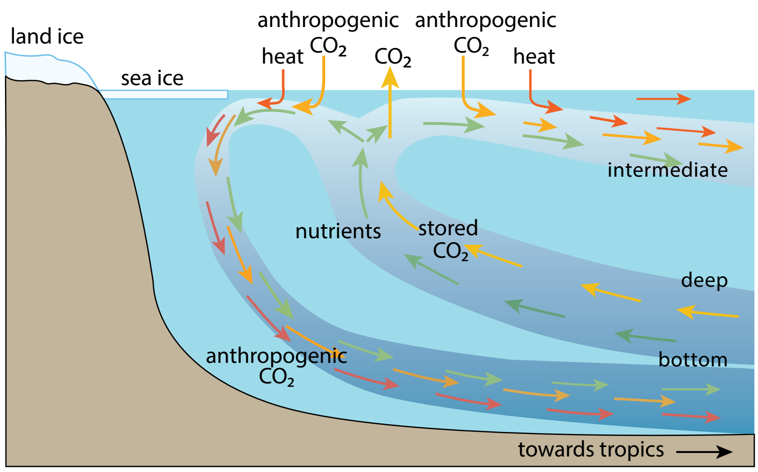


Figure 2** **Above *3D map of Antarctica and the Southern Ocean (yellow corresponds to continental shelf/tops of ridges), showing schematically deep water rising to the surface to be converted to intermediate and bottom water within the Antarctic Circumpolar Current. (Adapted from Meredith, 2016)*

Left *Cross-section of the Southern Ocean to show how the reprocessing of deep water to form intermediate and bottom waters results in heat and carbon (including that produced by human activity) being removed from the atmosphere. The carbon is removed both in dissolved form in sinking water and via high primary productivity largely supported by nutrients being brought to the surface around Antarctica.*

Figure 3 *The Southern Ocean data desert, as seen in the global distribution of temperature observations between 1955 and 2017. The dominance of the Northern Hemisphere in the data is clear; by contrast, the Southern Hemisphere south of 60°S is especially poorly covered. Whilst innovations such as the* Argo *programme are addressing this data desert, it remains as problematic as ever for parameters that cannot yet be measured autonomously.*

The bar charts show the distribution of observations by longitude (top panel) and by latitude (right-hand panel). The smooth curve in the right-hand panel is the expected distribution of those ocean observations if they were spread equally on a sphere; the irregular curve is the expected distribution of ocean observations also taking into account the shape and size of the Earth's land masses.

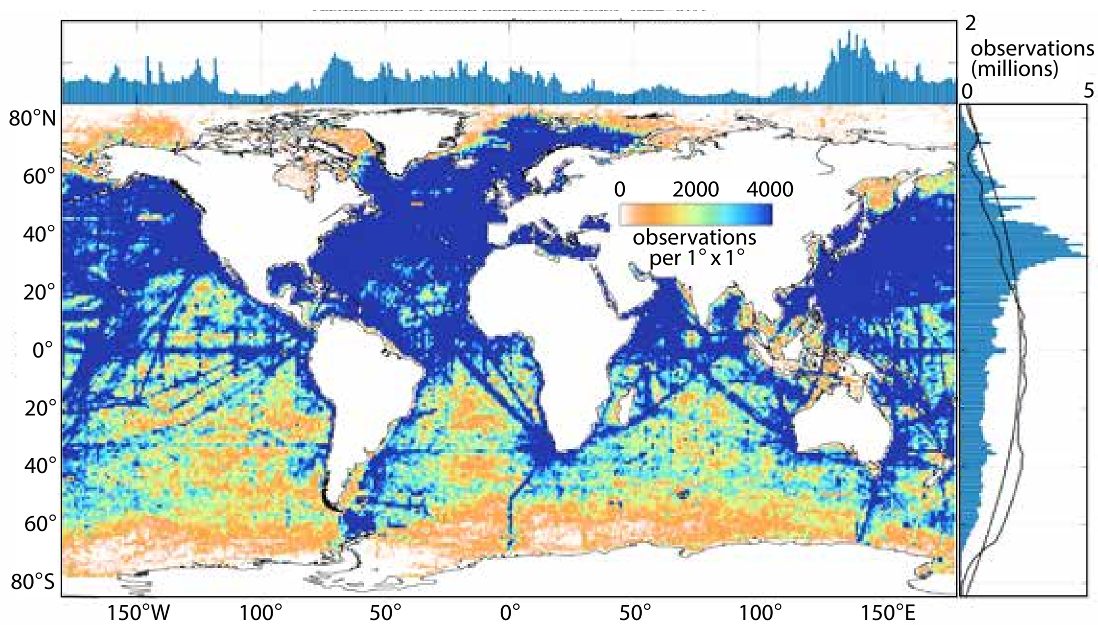


Figure 4 **Left** *View forward from RRS* James Clark Ross, *as she moves south into the Weddell Sea in April 2016 (cruise JR15006).* **Right** *A CTD being recovered in a blizzard. (Photos by the author)*

There are many challenges to collecting data in the Southern Ocean

The world's largest data desert

It is thus beyond question that the Southern Ocean deserves special attention, so that we can better understand it and better predict its changes and its future impacts on the rest of the world. However, the Southern Ocean is also arguably the biggest data desert on the planet. Global shipping tends to avoid the Southern Ocean, focussing instead on major trade routes that lie predominantly in the Northern Hemisphere. Indeed, there are large regions of the Southern Ocean that remain virtually unvisited each year, and from which very few direct ocean measurements are obtained (Figure 3).

The problem is especially severe in winter, when some of the strongest winds on the planet drive massive seas, and when the Antarctic continent effectively doubles in size due to the expansion of sea ice. This makes collecting data from the Southern Ocean using conventional ship-based methods extremely challenging (cf. Figure 4). Robotic and other innovative techniques are beginning to fill this data void, and the advent of floats capable of operating under ice and long-duration gliders offers great potential for the collection of the sustained, systematic ocean datasets that are required. Nonetheless, many of the measurements we need cannot yet be made using automated techniques, and still rely on collection of discrete water samples for processing and analysis; this makes such data as are collected from the Southern Ocean, especially in winter, of disproportionately high value.

A sustained, year-round ocean series in Antarctic waters: RaTS

One example of a sustained, coherent measurement programme in the Southern Ocean is the Rothera Time Series (RaTS), which is conducted by the British Antarctic Survey (BAS) and operates out of Rothera Research Station on the Antarctic Peninsula (Figure 5). This series has been providing quasi-weekly ocean data for more than two decades.

The Rothera Research Station alllows year-round sampling at the RaTS site

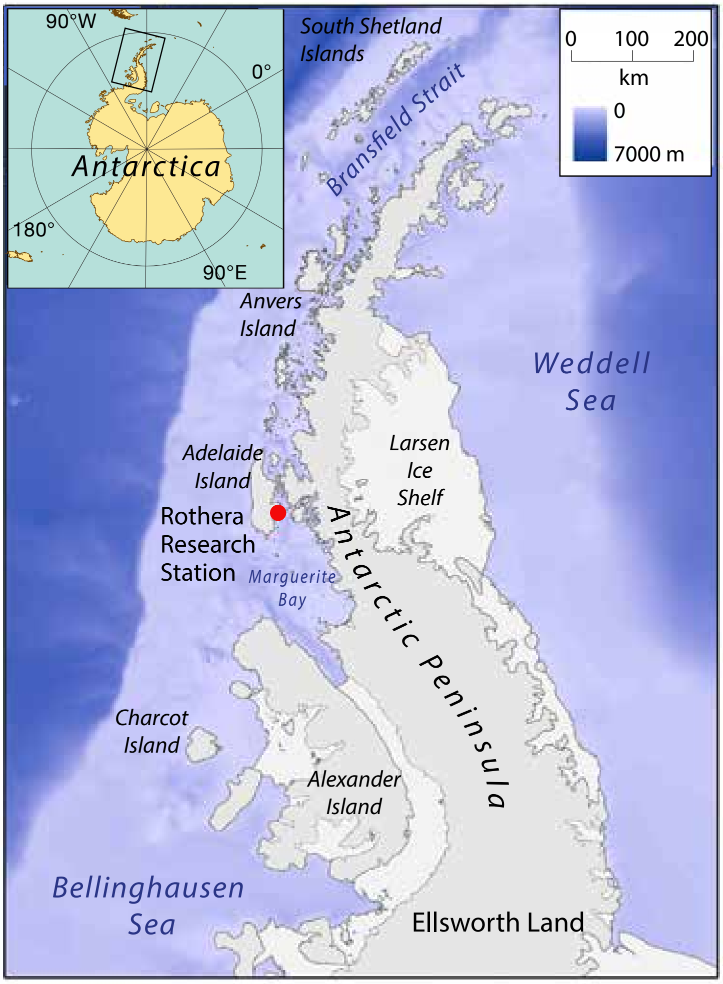


Figure 5 *Map of the Antarctic Peninsula, showing the location of Rothera Research Station on Adelaide Island, the home of RaTS. The RaTS sampling site is within Ryder Bay on the eastern side of the island. (Meredith* et al.*, 2017)*

Figure 6 Left *The author conducting a RaTS profiling operation by hand-winching a CTD upwards from 500 m depth in Ryder Bay, adjacent to Rothera Research Station (see Figure 5). Dr Hugh Venables (BAS) looks on in amusement.*
Right *BAS Marine Assistant Zoë Waring preparing to collect a seawater sample using a Niskin bottle. Behind her, two Ryder Bay residents are decidedly unfazed by the ground-breaking science happening nearby. (Photo by Rich Rowe, British Antarctic Survey)*

Measurements of temperature and salinity, and water samples, are regularly collected at the RaTS station

Rothera's coastal location allows scientists and support staff based there to access the ocean weekly and year-round, with sampling conducted from small boats in summer (Figure 6), or through holes cut in the ice when ice cover precludes boating operations The systematic collection of data and samples during wintertime is almost unique in the Southern Ocean, making them extremely valuable.

RaTS core variables include a range of physical and biogeochemical parameters, including temperature, salinity, phytoplankon fluorescence (to measure chlorophyll concentration), size-fractionated chlorophyll, macronutrients (nitrate, phosphate and silicate) and many others. RaTS also provides the scientific context and infrastructure for numerous collaborative investigations both nationally and internationally; these have supported collection of measurements to answer specific hypothesis-driven questions, including those relating to trace metals, viruses and climatically active gases.

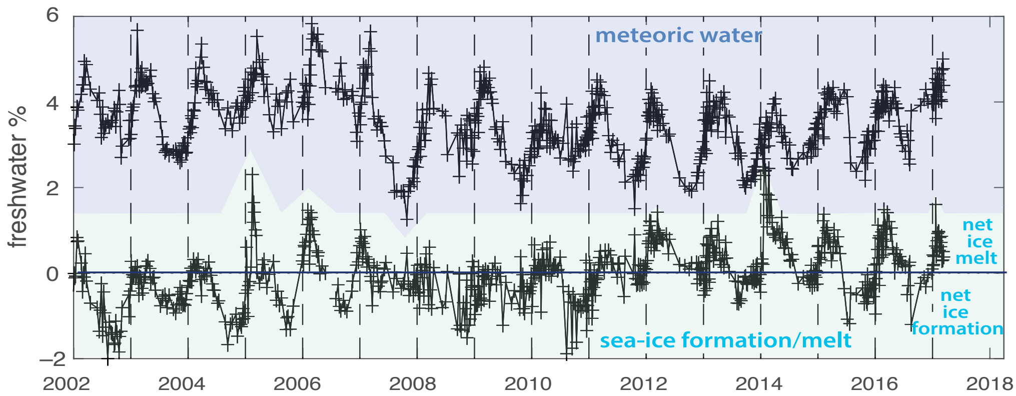
Tracing different freshwater inputs at RaTS

One of the core RaTS variables is $\delta^{18}O$, a measure of the ratio of stable oxygen isotopes in seawater (see Box). This is measured from water samples which are returned to the UK and analysed at the NERC Isotope Geosciences Laboratory (BGS Keyworth), and is a tracer which provides valuable insight into the sources of freshwater injected into Antarctic waters. When measured along with salinity, $\delta^{18}O$ provides information on whether the freshwater present in a seawater sample derives from sea-ice melt, or from other sources (namely glacial discharge and precipitation). This is critical information: freshwater from different sources can affect the ocean in different ways. For example, glaciers (which originate as compressed snow) can scour underlying rock and sediment, and thus they can contain significant concentrations of trace metals such as iron, which are released when the glaciers, ice sheets, and the icebergs that break off from them, melt. Accordingly, in regions such as the Southern Ocean, where primary production is limited over large areas by low

Distinguishing the origins of freshwater input to the Southern Ocean

Naturally occurring oxygen is composed of three stable isotopes, ^{16}O, ^{17}O and ^{18}O, with ^{16}O being the most abundant (99.76% of the total, compared with 0.04% ^{17}O and 0.20% ^{18}O). Water that evaporates from the ocean eventually condenses as cloud droplets and falls as rain or snow. When seawater evaporates, molecules with the lighter oxygen isotope ($H_2{}^{16}O$) evaporate more readily, so atmospheric water vapour is relatively enriched in ^{16}O. When water vapour condenses and is precipitated back into the ocean, water containing the heavier isotope ($H_2{}^{18}O$) condenses preferentially. Both processes therefore deplete water vapour over the ocean in $H_2{}^{18}O$ relative to $H_2{}^{16}O$. When ^{18}O-depleted water vapour is precipitated as snow, the snow will also be depleted in ^{18}O relative to the oceans – and the same will be true of ice sheets, glaciers and icebergs.

Conversely, when sea ice melts into the ocean, it provides freshwater that is isotopically much more similar to the seawater into which it melts. This is because, aside from a small fractionation factor, sea ice acquires the isotopic signature of the seawater from which it was formed. Thus, whilst sea ice, snow, glacial melt and iceberg melt all provide waters with similar salinities to the ocean (zero, or nearly zero), we can distinguish them from each other by also measuring the seawater's isotopic composition. The measurement made is of $\delta^{18}O$, being the ratio of $H_2{}^{18}O$ to $H_2{}^{16}O$ in seawater, relative to a known standard.



Time series of salinity and δ18O data collected at the RaTS station allow us to see seasonal, interannual and longer-term variations in the contribution of meteoric water and sea-ice formation/melt to near-surface seawater

Figure 7 *Time series showing the percentage of meteoric water (upper curve) and sea-ice meltwater (lower curve) in water samples collected from a depth of 15 m at the RaTS station, derived from salinity and δ^{18}O data. Note that the contribution of sea-ice meltwater can be both positive and negative, with the former reflecting net sea-ice melt to the water sampled, and the latter reflecting net sea-ice production from the water sampled. (Figure updated from Meredith* et al.*, 2017)*

concentrations of micronutrients, the spatial patterns and temporal changes in glacial discharge are very important biogeochemically, ecologically and even climatically. Other freshwater sources are important in other contexts; for example, sea-ice formation and melt impacts strongly on upper-ocean stratification and dense water production (cf. Figure 2), and provides a seasonally varying ecological habitat that is exploited by a range of species in manifold ways. On a global scale, changing glacial discharge from the Antarctic continent can have significant impacts on sea-level rise, whereas sea-ice melt exerts only a minimal effect. Accordingly, it is of great importance to discriminate between the sources of different freshwater inputs to the ocean, even when they result in comparable salinity changes.

Measuring salinity and δ^{18}O concurrently allows us to quantitatively separate freshwater into an amount that derives from sea-ice melt, and an amount that derives from meteoric water (i.e. water originating from the atmosphere, being the sum of glacial discharge plus precipitation). The RaTS series of these quantities are shown in Figure 7. Numerous features are apparent in these series, and have different significance depending on their time scales.

Marked seasonal variability in the amount of sea-ice melt in the upper ocean at the Antarctic Peninsula is clear; this is to be expected, given the profound seasonality in the area covered by sea ice. Arguably more surprising is that the seasonality in meteoric water is equally as strong as sea-ice melt, reflecting both seasonality in glacial discharge to the ocean, and melt of snow which has accumulated during winter either on land or on top of the sea ice. Thus, whilst the advance and retreat of sea ice around Antarctica is often referred to as the biggest seasonal signal on the planet, its impact on the water column at RaTS is matched by those caused by changes in fresh water from other sources.

On interannual time-scales, there are years of marked extremes in the concentration of both sea-ice melt and meteoric water in the ocean at RaTS. For example, sea-ice melt showed a strong peak (more than 2%) in early 2005 and an even stronger peak in 2014. Previous work has revealed the sensitivity of this part of the Southern Ocean to large-scale coupled modes of climate variability, including the El Niño/Southern Oscillation (ENSO) phenomenon, the Southern Annular Mode (SAM), and others, each of which can affect the different components of the freshwater budget, in addition to upper-ocean stratification and mixing. These modes operate over very large spatial scales; in the case of ENSO, the signature in the time series confirms the impact that it can have on even the remotest regions.

On decadal time scales, the series are not yet sufficiently long to draw unambiguous inferences concerning trends. However, the sea-ice melt tends to be higher in the latter part of the record compared with the earlier part, indicative of a shift from the region being one of net sea-ice production to one of net sea-ice melt. Further, the concentration of meteoric water tends to be lower in the latter part of the record compared with the earlier part; this has been traced to changes in ocean stratification, specifically wintertime mixed layer depth, which affects the vertical distribution of the freshwater in the water column and hence alters the freshwater concentration at the 15 m sampling depth. Such climatic signals have strong relevance for ecosystems by, for example, affecting the concentrations of glacier-supplied micronutrients in the photic zone, with long-term consequences for primary production.

There are numerous further aspects to the series shown here, and also the other RaTS and associated datasets, and the reader is cordially invited to follow up the references included below, or to visit https://www.bas.ac.uk/team/science-teams/oceans/.

Take-home messages

- Processes occurring in the Southern Ocean are of global importance, affecting climate, sea level and all parts of the marine ecosystem.
- Freshwater processes are key to this importance, and require more than just salinity measurements to be understood. The ratio of oxygen isotopes in seawater offers key extra insight into freshwater sources.
- Maintaining long-term, systematic time series is critical in order to detect, understand and predict the global impacts of changes in Antarctic waters.

Further Reading

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Personal thoughts and thanks

Being awarded the 2018 Challenger Medal is both delightful and humbling; I am extremely grateful to those who made and supported the nomination, and to the Challenger Society for bestowing the honour. The award reflects a team effort by a huge number of people over many years, including support staff, ships' officers and crews, Antarctic staff and countless others. It also reflects the efforts of an incredible group of scientific collaborators, with whom I have had the privilege of working. Space precludes listing them individually here – instead, please see below. They are all thanked profusely for their wisdom, energy and patience. Jamie Oliver, Peter Fretwell and Laura Gerrish are thanked for help with the graphics for this article.

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Word cloud of scientists with whom the author collaborates. Font size is proportional to number of articles published together, but all are thanked equally profusely.

Increasing confidence that captured CO_2 will stay put

Kelvin Boot

If we are going to store large volumes of carbon dioxide (CO_2) in depleted oil and gas reservoirs beneath the sea bed we need to be sure that in the unlikely event of a leak we can detect it. A world-first experiment, designed to develop methods for the detection and monitoring of leaks, has reached a successful conclusion.

Climate change, driven by increasing levels of CO_2 in the atmosphere, is now a well established phenomenon that is having profound effects on the Earth's natural systems. While efforts are being made to reduce sources of human-related CO_2 production, such as from industry and transport, there is a parallel need to prevent CO_2 emissions from entering the atmosphere. Putting the CO_2 back into some of the reservoirs whence it came as hydrocarbons seems a logical solution. Increasing societal confidence in this technique by being able to detect a leak, should it occur, and predict any effects it may have, is a priority.

The Strategies for Environmental Monitoring of Marine Carbon Capture and Storage (STEMM-CCS) project is an EU Horizon2020-funded project bringing together researchers from Germany, Norway, Austria and the UK, and industry partner Shell, to develop the techniques and technology to detect traces of any leaks if they occur, observe how the escaped CO_2 behaves in sediments and the water column, and predict how far it might spread and what impacts it might have. During May this year, a research cruise set sail from Southampton's National Oceanography Centre (NOC) aboard the Natural Environment Research Council's RRS *James Cook*. On station in the North Sea, close to Shell's Goldeneye platform in 120 m of water, a curved steel pipe was successfully positioned with its exit 3 m beneath the sea floor using a special drill rig developed and built by Cellula Robotics. The pipe was then connected to a CO_2 supply on the sea bed, allowing gas to flow through the pipe into the sediments. This is the first time such an experiment has been attempted in the open sea, in as near to real-life conditions as possible.

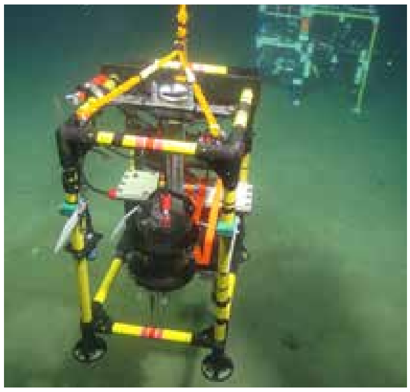
__Right__ The rigours of the saltwater environment required specially designed gas cylinders, housed in a special rig, here being lowered over the side.

__Below right__ The microprofiler developed by Dirk De Beer at MPI allowed measurement of sediment chemistry at micrometre resolution. Electrodes were slowly inserted into the sediments over a one-hour period, recording changes occurring in the sediments as the CO_2 dissolved.

A great success

Fortunately, conditions remained calm during this deployment and the science team on board breathed a sigh of relief as CO_2 bubbles began to emerge from beneath the sediment. The idea was then to test the performance of an array of sensors, developed and built for the experiment. Acoustic and visual instruments were deployed to listen for and spot streams of bubbles, while chemical sensors 'sniffed out' the CO_2, which was laced with minute amounts of chemical tracers that enable scientists to differentiate this signal from naturally occurring CO_2. ROVs and autonomous underwater vehicles carrying other sensors completed the arsenal of technology being employed. During the two-week controlled release of CO_2, samples were taken from around the simulated leak to establish how the CO_2 behaves when passing through sediment and how it affects the sediment and the life it contains.

It has taken many months of hard work and innovative thinking to get to this point in the STEMM-CCS project. The team, led by Prof. Douglas Connelly (NOC), successfully tested the sensors that have been developed to give peace of mind that, in the unlikely event of a CO_2 leak occurring, it can be detected quickly and



precisely. The team are satisfied that they completed all they set out to achieve: placing 3 tonnes of CO_2 on the sea bed and releasing it in a controlled manner 3 m below the sea bed, and then demonstrating the high sensitivity that the new generation of marine sensors have in detecting the dissolved and bubbling gas, was no mean feat. Professor Connelly said: '*This experiment gives us a step change in our confidence that in a real-world situation we have the capability to detect and monitor any escape of CO_2.*'

Further information, including a fascinating cruise blog, and a full list of research partners, can be found on the project website www.stemm-ccs.eu.

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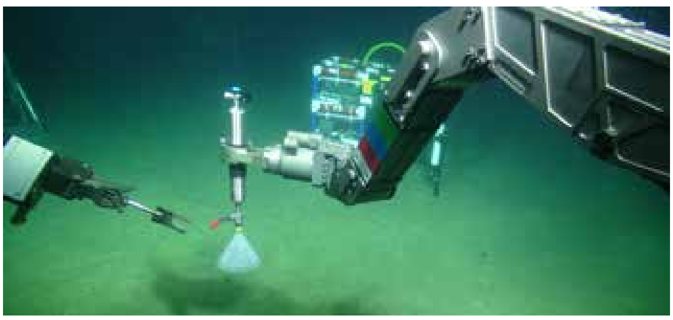
Escaping bubbles of CO_2 were collected, 120 m down at the sea bed, with the aid of some delicate ROV manoeuvring



A song for the Challenger*'s crew*

Philip Pearson

When news reached London early in 1873 that one of the *Challenger*'s dredges had been lost overboard little more than a month into the voyage, a shanty, 'A Song for the Challenger's Crew', was mailed to the ship. The chorus ran:

> *So never mind your Dredge, my boys,*
> *Which you have lost below;*
> *Our country now your power employs,*
> *That man may wiser grow.*

The song later exhorts the crew to carry on dredging, for *'England now expects each man / His duty to perform …'*

The setbacks bedevilling the expedition's sea trials, and the arrival of the song, are described by the young assistant steward, Joe Matkin, in his letters home. Joe wrote that when the London mail arrived in Madeira in February 1873, '*there was a Parcel containing Songs, for the "Challenger's" Crew & addressed to the best Singer on board*'. He transcribed all nine verses, but doesn't say if it was sung on board. (A version by the 'The Boarding Party' folk group is available on CD.)

Joe wrote not only of the loss of thousands of fathoms of line and dredging gear, but of a boy sailor's life three months later. One day in March, the tension on the dredge rope became so severe that it carried away an iron block screwed into the deck. Joe reported that *'The block as it flew up struck a sailor boy, named Stokes, on the head, & dashed him to the deck with such a terrible force, that his thigh was broken, and spine dreadfully injured*.' He died a few hours later. The next day, with all the ship's company attending, his body was lowered into the sea. The muster book shows that his effects were sold and, with the proceeds, his bible and few remaining things were remitted home.

Published in 1992 as *At Sea with the Scientifics*, Joe's 69 letters give the only 'below decks' account of *Challenger*'s voyage. The letters provide an extended narrative of the voyage on which to pin such traces of oral and documentary history as may come to light from the countless descendants of the crew, of whom one is my great-grandfather, able seaman* Charles Matthewman Collings.

In our family, Charlie is something of a mythical figure, 'sailing to the South Pole on the Nares–Thomson expedition'. Charlie was a leading stoker. Steam power was essential for dredging and sounding, the propeller providing a constant push into the wind to hold the ship's position steady while the sounding line ran out. A day's dredging began with furling the sails, while engineer William Spry and his crew of 'dustmen' down below in the engine room were firing up the boilers for the 1234-horsepower engine.

Charlie's entry in Challenger*'s muster book. The annotations tell us that his service number was 64774, that he was engaged on 18 August 1866, that he was a Boy 2nd Class (2B) then a seaman (SM).*

(By courtesy of the National Archives)

In the ship's muster book for November–December 1872, Charlie was one of four leading stokers, and was the highest paid among the complement of 14 stokers in the 'Steam Department', earning £65 10s a year and with two service badges to his name. He was earning roughly twice the annual wage of a standard able seaman at the time. A leading stoker was more highly valued than a standard

A group of bluejackets, and the two Germans they rescued, photographed on Inaccessible Island in February 1874 Charlie Collings (arrowed) can be seen at the back. The Germans are the man with the pale smock next to Charlie and the man with the pipe.

(By courtesy of the National Maritime Museum, Greenwich, London)

*The term able seaman referred to a seaman with more than two years' experience at sea and considered 'well acquainted with his duty'.

able seaman, having considerably more responsibility but working in even worse conditions.

Charlie enlisted on 1 January 1866 at the age of 14 as a Boy 2nd Class, enigmatically under his mother's maiden name, Collings. My mother's explanation is that his father's name, Charles Napoleon Matthewman, would work against him, while another grandchild says that 'grandad ran away from his family without their sanction'. His uncle, Henry Collings, signed 'parental' consent.

When he was posted to the *Challenger* in November 1872, the 'personal description' in his Certificate of Service records a 'blacksmith' from Brighton, five feet three and a half inches tall, with colour highlights including a sallow complexion, dark brown hair and hazel eyes. His 'marks' (tattoos) include a 'Ship on breast,' denoting that he had rounded Cape Horn.

My family has none of Charlie's letters home. But Charlie can be seen in a photograph of a group of *Challenger*'s sailors, taken on Inaccessible Island in the South Atlantic, now held at the National Maritime Museum, Greenwich. The photograph must have been taken in October 1873, when Joe Matkin reported the rescue of two stranded German sailors, the Stoltenhoff brothers, by a crew dispatched from the mother ship, Charlie among them. (The scientific reason for visiting the island was to investigate the flora and fauna.)

On the *Challenger*'s return to Sheerness in May 1876 Charlie was paid off after serving 13 years at sea. He trimmed his name to Collins, and with his wife of six years, Mary Frances (née Patching), moved to Brighton, managing first a pub then a shop. He was variously employed as a smith, bell-hanger and gas fitter. Mary had nine children, three of whom died in infancy. She would work as a laundress, especially it seems during his frequent, unexplained and impoverishing 'disappearances,' and supported her children's education. A line drawing of the *Challenger* hung in the living room of 'The Anchorage', his home in Brighton, and he was also said to have sailed on the *Cutty Sark*.

In his widowed years, Charlie was a regular at the Springfield Hotel just up the hill from where he lived with his son and their children. If my mother and her brother George were playing outside, they'd put their heads round the pub door: 'Grandad, can we have some lemonade please?' they'd ask. In front of his hard-drinking cronies, the devoted grandfather would reply 'Hello my pretties, hello my pretties.' He'd buy them a lemonade, and meet them at the door, saying 'Here's your lemonade. Now bugger off!' My mother would always smile at this memory.

Photograph from the Sussex Daily News *for 5 October 1932. The original caption read 'Covered with the Union Jack, the coffin bearing the remains of Mr Charles Collins, last member of the ship's company of The Nares–Thompson* [sic] *Scientific Expedition in H.M.S. "Challenger" (1872–6), whose burial took place yesterday in Brighton Borough Cemetery.'*

Charlie passed away on 29 September 1932, aged 85. My mother recalled that, '*There was a grand funeral through the town, with the Union Jack draped on the coffin, for he was one of the last surviving members of that Challenger crew*.'
The funeral was organised by the Navy, and his his grandchildren remembered not only the Union Jack draped over the coffin but also that the funeral carriage was pulled by four black-plumed horses, while they rode in a carriage behind. A local paper reported that Charlie was the 'last surviving member' of the ship's company', and published a photograph of the funeral (see above).

Charlie's grandchildren always remembered his kindness – and the whisky in the wardrobe

Acknowledgements

I am grateful to my mother, Stella Pearson (née Collins), and my cousin Tony Collins and his wife, Diana, for sharing their memories; and to Emma Collins whose blog allowed me to put a face to my great-great grandfather. I would also like to thank John Phillips and Tony Rice for useful extra information relating to the *Challenger* Expedition.

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'A song for the *Challenger*'s crew' is track 5 on The Boarding Party's Folk Legacy CD *Too Far from the Shore*; you can also find it on https://www.youtube.com/watch?v=K2MIsPRqmx8 The words of the song are given on pp.46–7 of *At Sea with the Scientifics.*

Admiralty (ADM) documents held at the National Archives.

Challenger's Muster book ADM 117/196 Muster books are a great source of information. https://discovery.nationalarchives.gov.uk/details/r/C1745.

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Philip (and *Ocean Challenge*) would be interested to learn about oral and documentary histories of other descendants of the crew.

Albert I of Monaco: ‘Prince of the Seas’

Albert I of Monaco (great-great-grandfather of His Serene Highness, Prince Albert II) was born in Paris in 1848. On the death of his father in 1889, he became sovereign of a country undergoing considerable political, economic and social change. Despite this heavy responsibility, he devoted much of his life to the study of the oceans – then a relatively new science – and was nicknamed ‘Prince of the seas’. His scientific work, which was not confined to marine science, was recognised by a number of international honours, including the US National Academy of Sciences’ Alexander Agassiz Medal in 1918.

Albert was fascinated by the sea from an early age, and in 1866 his father entered him into the Spanish Navy where he gained the rank of Sub-Lieuteneant and learned how to command a ship. Four years later, he joined the French Navy and fought in the war against Prussia. Perhaps because of this experience he later became a pacifist, establishing in Monaco the International Institute of Peace, whose aim was to promote peaceful settlement of conflict through arbitration.

Albert acquired his first vessel – a 200-ton pleasure-craft, *L’Hirondelle I* – in 1873. In 1875, he transformed the yacht into a research vessel. Increasingly impressive steam schooners, La *Princesse Alice I, La Princesse Alice II* and *Hirondelle II,* followed, in 1891, 1898 and 1911.

Between 1885 and 1915, Prince Albert led 28 scientific expeditions, often accompaned by leading marine scientists. For example, John Young Buchanan (who had been chemist on the *Challenger* Expedition) was a guest on many cruises.

Albert sailed throughout the Mediterranean making oceanographic studies, and collecting data for maps and charts. From the larger vessels, he could study conditions in the open ocean and the fauna of the deep sea. In the Atlantic, he mapped surface currents by releasing floats, and off the Azores he discovered the Princess Alice Bank, got involved in a whale hunt and became fascinated by the giant squid. To the south of Madeira he undertook dredging to a depth of 5580 m. There were also expeditions to the Cape Verde islands, and along the coasts of Brazil and North America.

Between 1898 and 1907 he made four cruises to Svalbard on *La Princesse Alice*. The 1898 cruise was intended to add to the collections of the Oceanographic Museum (see below), for which construction had just started. On the second expedition, in 1899, the focus was on the hydrography and topography of Raudfjorden, in Spitsbergen.

Prince Albert lent his support, either financially, or through gifts or loans of oceanographic instruments, to numerous Arctic and Antarctic explorers. He supported expeditions to Spitsbergen by William Bruce and Gunnar Isachsen, and his funding of the latter led to regular Norwegian scientific expeditions to Svalbard, and in 1928 to the foundation of the Norwegian Polar Institute.

In his introduction to the last edition of Albert’s book, *The Career of a Navigator,* published in 1966, Jacques-Yves Cousteau, then Director of the Oceanographic Museum in Monaco, wrote:

‘The Prince himself directed 3,698 operations at sea, sending lobster pots and giant nets down to 6,000 metres, providing proof of the endless vertical migrations of pelagic animals, studying the penetration of light, using photography and cinematography, discovering anaphylaxia, ... denouncing the damage caused by trawling, publishing the first bathymetric chart of the oceans, encouraging depth-measurement by ultrasonic means ...’.

The Prince on the bridge of Princesse Alice II in 1904. *(This image and the inset below are © Collections du Musée océanographique)*

Albert founded not only the Oceanographic Museum of Monaco, but the Oceanographic Institute in Paris, now known as La Maison des Océans. Together, they represent their founder’s aim of ‘knowing, loving and protecting the oceans’ by acting as a link between the scientific community, political and economic decision-makers and the general public to promote the protection and sustainable management of the oceans – a role that remains important to HSH Albert II today. *Ed.*

The Oceanographic Museum of Monaco. *© M. Dagnino.*

Further reading

Prince Albert I of Monaco (1898) Some results of my researches on oceanography. *Nature* **58**, 200–204. doi: 10.1038/058200e0

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For information about the Museum see https://www.oceano.mc/en/presentation/the-oceanographic-museum/the-temple-of-the-sea A new exhibition ‘Monaco and the Ocean, from exploration to protection’ opens in July.

With grateful thanks to the Oceanographic Museum of Monaco and the Consulate General of Monaco in New York.

A 'cranky little vessel': The story of HM steam vessel *Lightning*

Part 5: Lightning*, George Evans and a brush with naval bureaucracy*

Tony Rice

Oceanography – a suitable interest for European royals

The successively grander pioneering scientific cruises of HMS *Lightning, Porcupine* and *Challenger* in the 1860s and 1870s inspired two European 'royals' to take up the oceanographic baton, so to speak, by allowing their personal yachts to be used for research cruises. The most important, of course, was Albert I, Prince of Monaco, who hosted oceanographic cruises more or less every year between 1885 and the First World War and established the Institut Océanographique in Monaco, still in existence today (cf. p.36). The other was Albert's royal friend Dom Carlos de Bragança, King of Portugal from 1889 to 1908. Fifteen years younger than Albert, Carlos was only nine years old when the *Challenger* called into Lisbon in January 1873 at the beginning of her seminal world cruise. Though there is no evidence that Carlos accompanied his father on his official visit to the ship (Figure 1), he would certainly have been fascinated by it because he had a lifelong interest in maritime matters generally and was a talented marine artist. And like Albert, Carlos used his successively larger yachts, all named *Amelia* after his queen, for oceanographic cruises from 1896 to 1905, though whereas Albert's cruises ranged through the Mediterranean and Atlantic as far north as Spitsbergen, and covered all aspects of marine science, the *Amelia* cruises were mainly restricted to Portuguese waters and concentrated on topics like fishing that Carlos thought might be of economic value to his subjects.

By 19th century standards, Carlos was a forward-looking and fairly enlightened ruler. But he had inherited a troubled kingdom, socially, economically and industrially under-developed and a political tinderbox with fanatical pro and anti monarchical factions. In the face of these problems, Carlos' oceanographic endeavours were part of a much broader plan in which he tried to modernise Portugal and defuse the increasingly difficult political situation. As he told his friend Albert in a letter in February 1907, he was desperately trying to reform the governance of his country

Figure 1 *King Luís I on board* Challenger *in January 1873. The King is flanked on his left by Captain George Nares (blurred because he moved during the exposure) and his second-in-command, Commander John Maclear. On the King's right is Staff Surgeon Alexander Crosbie while behind him are Professor Charles Wyville Thomson (with buttonhole), Henry Moseley and John Buchanan and (with bow tie) the British Ambassador in Lisbon, Sir Charles Murray. (Reproduced by courtesy of the Natural History Museum)*

Figure 2 *During his 1897 oceanographic cruise, Carlos embellished his daily journal with watercolour sketches. This one shows Carlos working on deck, possibly on this very painting, while the sailors look on.*

(By courtesy of Dom Carlos I Oceanographic Museum Collection, Aquário Vasco da Gama, Lisbon)

with a revolution originating from the top, that is, himself, in the hope of avoiding a threatened revolution from the bottom which, Carlos feared, would destroy his country. Sadly, his fears were only too well justified; his efforts were too little and too late, and just a year later both Carlos and his eldest son were assassinated by republican sympathisers as they travelled by coach through the streets of Lisbon. He was succeeded by his second son, Manuel, who ruled as the last King of Portugal from 1908 to 1910, but was forced to abdicate to make way for the Portuguese republic that we know today.

But republicanism and political turmoil had a long history in Portugal and, almost 40 years before Carlos was born, our little paddle steamer became tangentially involved with Portuguese affairs involving Carlos' grandmother Maria and her uncle Miguel as we will see in a future episode.

HMS Lightning *and her first commissioned officer*

In the last episode we left *Lightning* in December 1827 with the Navy Board writing to the Board of Admiralty with the Duke of Clarence's instructions that the proper establishment of steam vessels was to be '*one Lieutenant, one mate, two engineers, twelve men (including stokers) ...*'. The *Navy List* of January 1828 accordingly confirms that on 4 December 1827, the *Lightning's* commander was 36 year-old Lieutenant George Evans who had already been in this rank for almost seven years. Evans' rise through the naval ranks had hardly been meteoric, probably because he lacked 'interest', the support of powerful naval or political figures so crucial for advancement in the Georgian navy. So although his command of the *Lightning* was to last only five months, it was an extremely interesting period both in the history of naval steam and late Georgian power politics, and was crucial in Evans' career.

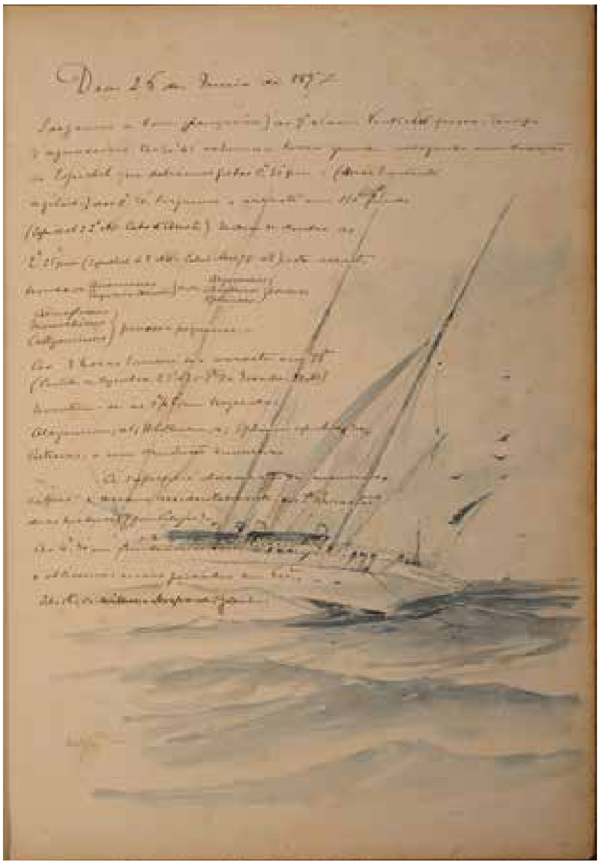

Figure 3
On the journal page for 26 May 1897, Carlos described the weather and ship's position and listed some of the specimens collected. He then embellished the page with a watercolour sketch of his new yacht, Amelia II.

(By courtesy of Dom Carlos I Oceanographic Museum Collection, Aquário Vasco da Gama, Lisbon)

Because *Lightning* was by this time an official RN vessel we have much better records of her day-to-day proceedings in the form of her official log books preserved in the Public Record Office, the first of these, ADM 51/3257, covering the period of Evans' command from 10 December 1827 to 21 June 1828. But ships' logs are notoriously dry and dispassionate documents and can be difficult to decipher; fortunately, in this case, we also have Evans' personal recollections, later published (see Guest, 1876, in Further Reading), to flesh out a fascinating episode in the life of the *Lightning* and of Evans himself.

According to the log, the first couple of weeks of Evans' command were spent at Woolwich and Deptford loading coal and other supplies including lots of rum and a six-inch hawser 'laid up for towing'. The hawser was clearly in preparation for a towing job the following day because, despite their newly elevated status, and despite Evans claiming in his memoirs that *Lightning* was '... employed as His Royal Highness's Yacht', it is clear that she and her fellow early naval steam vessels were still employed largely as glorified tugs. After all, it was her ability to tow sailing vessels in and out of harbour that had attracted the Duke of Clarence's attention to the *Lightning* in the first place. Reading between the lines it seems that Clarence employed *Lightning*, not so much as transport for himself, for which she was probably not grand enough, but rather as a piece of modern technology able to tow his sailing yacht when tides and winds made this desirable. Accordingly, the log records that on Friday 21 December she towed the Admiralty yacht (presumably the *Royal Sovereign)* down the Thames to the Downs anchorage off the Kent coast and then, on Christmas Day afternoon, she crossed the channel to Calais, apparently accompanying the yacht but not towing it. It seems that the wind was not favourable for the return journey so on the morning of 29 December she *'took the yacht in tow and proceeded out of Calais harbour ...'* bound for the Thames.

Enter the Infante Dom Miguel

All this seems pretty mundane stuff, and indeed it is. But the entry for 29 December continues with *'Came on board a servant of the Infant Dom Miguel for a passage',* seemingly similarly mundane, but in the event of considerable significance for the *Lightning,* and particularly for Evans, as we are about to see. The anonymous 'servant' disappears from history at this point, but the 'Infant Dom Miguel' is a different matter. The note should have read 'Infante' rather than infant, for Dom Miguel was no child, the title Infante simply being that given to all the sons and daughters of Portuguese kings. This particular Infante, Dom Miguel Maria do Patrocinio de Bragança e Bourbon to give him his full name, had been born in 1802 and was therefore 25 years old when he moved his servant to the *Lightning* while he presumably crossed the Channel in the more comfortable accommodation of the yacht. He was Dom Carlos' great, great, uncle and we will see why he was so significant in the next episode, but now let's stay with *Lightning* and her next major job.

Having arrived back in Deptford, the *Lightning* spent the following four weeks in the Thames, mostly at Woolwich, with nothing much happening other than having her funnel swept, her boilers repaired by a team of engineers from Maudslay's, who had built her engines, and fixing of damage to her bulwark caused when a smack ran into her on 8 January 1828. But at the end of January she was off again, first, on 27 January, moving down to the Nore anchorage off Sheerness and then on to the Downs where, on 28 January, she picked up 80 supernumeraries from HMS *Ramillies,* a 3rd rate 74-gun ship, along with a load of stores, presumably to feed them as they were transported down the Channel to be discharged into the flagship at Hamoaze, Devonport. With 80 passengers in addition to her own crew, the *Lightning* must have been crowded, to say the least. The terse wording of the logbook, of course, makes no reference to any possible discomfort, and the entries for the following few days simply document some seemingly mundane tasks of towing various ships out of Plymouth harbour and then the return trip up the Channel to Portsmouth in pretty inclement weather, stopping off near the Needles to have the armourer mend the 'feeding pipe of the engine' which had 'started from the violence of the sea'. But from Evans' personal account we know that this was far from a routine trip. Instead, it exemplifies a classic dilemma in which a junior officer with confusing and contradictory orders had to deal with awkward and opinionated seniors and decide which way to jump; fortunately for Evans, he seems to have backed the right horse on this occasion.

'On 27th of January, 1828, [wrote Evans] *when commanding HM steam-vessel the Lightning, then employed as His Royal Highness's Yacht, I was sent for by His Royal Highness, and told that important despatches had arrived from Lisbon, and that I was to proceed in the Lightning as quickly as possible to Plymouth, where I should receive my orders; and that I was to obtain as many men as I could take from the Ramillies*, *the Coast Blockade-ship in the Downs, delivering them to the Flagship at Plymouth, to man the Squadron under orders for Lisbon*.'

Evans then describes how, having delivered the *Ramillies* men he reported to Lord Northesk, the Commander-in-Chief at Plymouth, who told him that the Lisbon squadron was stuck in the Hamoaze (the section of the River Tamar as it passes Devonport) because of contrary winds. Evans' offer to tow the squadron past Drake's Island was turned down because, said Northesk, Evans' written orders from the Lord High Admiral were to return directly to Portsmouth. Evans protested and was allowed to tow the squadron out the following morning, but only after he had produced a written statement saying that, notwithstanding the written orders, the Admiral was extremely anxious that the squadron should leave a.s.a.p. and that he (Evans) '*felt certain that he would dismiss me from my command if I returned without towing the vessels out'.*

But having completed the towing job, Evans had insufficient coal to get back to Portsmouth, and was told that the dockyard stores were closed for the day and he would have to wait until the morning. Despite the support of Lord Northesk, the Dockyard Commissioner, the relatively lowly Captain William Shield, unbelievably refused to open the stores, so Evans had to wait yet another night in Plymouth before replenishing his bunkers, finally arriving back in Portsmouth late at night on 1 February.

Clarence was hosting one of his large dinners when Evans appeared, and was initially furious with him that the *Lightning's* trip had taken so long. But his anger soon changed direction when Evans explained what had happened in Plymouth and why he had insisted on towing the squadron out, despite the consequences. *'You did quite right, sir,'* said the Lord High Admiral according to Evans, '*and I would not give a "damn" for any Officer who did not know when the good of the Service required his disobeying Written orders. Your good health, Captain Evans: I beg your pardon, sir, but you shall be promoted; mind, Spencer, take a note of that.' This was the signal,* wrote Evans, *'for the Death Warrant of our old "affectionate friends", who soon afterwards disappeared from the scene, and the control over the dockyards was placed, and has remained ever since, under the Admiralty.'*

Sure enough, only four months later, at the end of May 1828, William Shield, who had been the Commissioner of Plymouth Dockyard since 1815, was sacked, while Lord Northesk, who had been appointed C-in-C Plymouth only in April 1827, was himself replaced by Admiral Sir Manley Dixon in April 1830. In contrast, just as the Lord High Admiral had ordered, on 2 June 1828 Evans was promoted from Lieutenant to Commander, a seemingly fitting reward for doing exactly what his boss wanted in the face of bureaucratic opposition. Sadly, however, it was not quite the accolade it was intended to be because, under the Navy's strict rules, Evans was now too highly qualified to continue to command the *Lightning.* Accordingly, on 4 June 1828, only two days after Evans' promotion, command of *Lightning* passed to Lieutenant George B. Hutchings while Evans was cast ashore to twiddle his thumbs on half pay, the scourge of 19th century naval officers, until he was eventually given command of HMS *Rhadamanthus*, a rather larger paddle steamer than *Lightning,* in October 1832.

But why was Evans so confident that he could safely ignore his written orders to return to Portsmouth on 30 January and, instead, help the Lisbon-bound squadron to sail despite the contrary winds? Clearly because, as he wrote himself, whatever his written instructions said, his verbal ones direct from the Duke of Clarence had '*expressed the utmost anxiety that the Squadron should reach Lisbon as soon as possible'.* So what was the big hurry? For an answer, in the next episode we will have to digress into earthquakes, turbidites, British interests in early 19th century Portuguese politics – and the background to the mysterious 'Infante Dom Miguel'.

Further reading

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Carpine-Lancre, J. and L.V.C. Saldanha, (1992) *Souverains océanographes.* Fondation Calouste Gulbenkian, Lisbon, 178pp.

Clowes, W.L. (1901) *Royal Navy. A history from the earliest times to the present.* Volume VI, 592pp. Republished 1997 by Chatham Publishing.

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Book Reviews

An interdiciplinary encounter with the Arctic

North Pole: Nature and culture by Michael Bravo (2019) Reaktion Books, London, 224pp. £14.95, paperback (ISBN: 978-1-78914-008-8).

North Pole is one of a series of some 25 volumes published since 2012 under the general title 'Earth', and with titles ranging alphabetically from Air to Waterfall. The brief for each of them is to trace the 'historical significance and cultural history of natural phenomena'.

This one is written by a polar historian and naturally therefore includes a chapter dealing with attempts to reach the Pole from the 16th to the 19th centuries; but it is emphatically not a history of Arctic exploration. Similarly, although the long-standing but erroneous belief that the polar ocean would be ice-free is a recurring theme, oceanography is otherwise hardly mentioned. So why on Earth would the book be of any interest to the average *Ocean Challenge* reader? Well, to many it won't be. But for anyone with an interest in the Arctic regions it is a fascinating read. It covers a huge range of topics from astronomy and cartography, through exploration and navigation, to art, culture, mythology and literature – and a fair amount of international polar politics. And along the way it introduced this amateur Arctic enthusiast to a plethora of North Pole concepts and facts that I had previously given little or no thought to. It's difficult to choose highlights from such a range of goodies, but here are a couple of examples that particularly appealed to me.

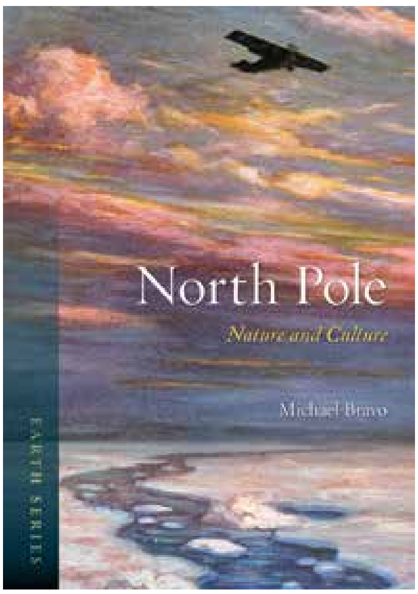
First, a chapter comparing the significance of the North Pole to the ancient Greeks on the one hand and, on the other, to the Inuit, who have lived cheek by jowl with the Pole for thousands of years, reveals some fascinating differences. To both groups it is not the North Pole *per se* that is so interesting, but rather the celestial pole, the imaginary extension of the Earth's axis into the heavens and its nearest star, the almost, but not quite, stationary Polaris. But whereas to the Greeks and their mid-latitude successors the Pole Star was crucially important in cartography and navigation, to the high-latitude Inuit it was far too high in the sky for day-to-day navigation, so their established migration routes were followed using moving stars and constellations. Obvious when you think about it, but somewhat counterintuitive.

And what of the North Pole and the redoubtable Baron von Munchausen? Yes, the very man who gave his name to the strange syndromes. The original Munchausen was an 18th century minor German aristocrat who told tall stories about his adventures during the Russo-Turkish wars and was fictionalised in the 1780s by Erich Raspe. Raspe made his Munchausen's adventures even more ridiculous, including riding a cannon ball and visiting the Moon. But his works became so popular that he inspired many imitators, one of whom had Munchausen visit the Arctic in 1819 and, amongst many other fantastic adventures, climb the North Pole itself and, half way up, find a huge volume labelled *Science* in which every page was blank.

Michael Bravo lucidly explains that this was part of much bigger satirical movement of the time, lampooning government Arctic policies for wasting effort and resources. *Munchausen at the Pole* appeared in response to two failed 1818 Arctic expeditions, one under John Ross in search of the North-West Passage and the other under Alexander Buchan to the polar seas north of Spitsbergen. The Ross expedition prompted several satirical cartoons, including a famous one by George Cruikshank, '*Landing the Treasures, or Results of the Polar Expedition!!!',* reproduced in the book in full glorious colour. More than 40 years ago I used this same cartoon, though sadly only in black and white, to accompany a little paper I wrote about the oceanography of the Ross expedition. I wish I had known as much about its significance then as I do now after reading Michael Bravo's book, which is one of the many reasons I thoroughly recommend it.

And on the subject of colour, the publishers are to be commended for reproducing in colour most of the copious illustrations in this volume and, according to their blurb, all the other volumes in the series. It is important to point this out because, in a review of another of their books of much the same size and appeal in this issue of *Ocean Challenge,* I have castigated them for reproducing black-and-white illustrations, and some of them very badly. The economics of publishing baffle me.

But to finish on a slightly more philosophical note, at the end of a book dealing mainly with times when few, if any, had set foot anywhere near the North Pole, Bravo devotes a final chapter to the situation in the later 20th and early 21st centuries with the Arctic increasingly impacted by industrial, military and political pressures. With planes now flying regularly over the pole, submarines reaching it beneath its ice cover, surface ships sailing ever closer through its diminishing ice and, now,



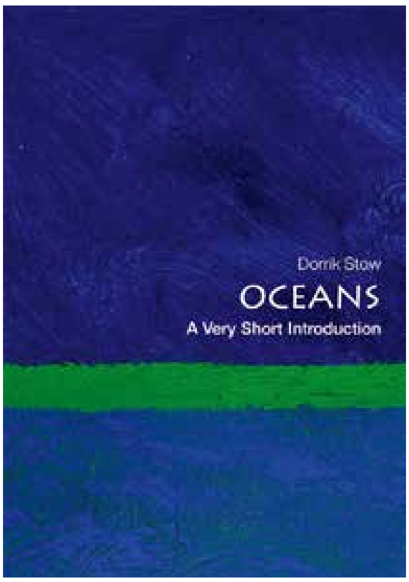
even regular North Pole marathons, this new familiarity might well breed a degree of contempt. But Bravo warns against hubris, pointing out that, quite apart from the melting ice, rising sea levels, suffering polar bears and the rest, following Cold War weapons testing the Barents Sea is one of the most radioactive in the world, and is also accumulating plastic litter like the Pacific Garbage Patch; a sobering and thought-provoking end to an excellent and entertaining book. I look forward to reading *South Pole* in the same series.

Tony Rice
Alton, Hants

A pocket-sized primer in oceanography

Oceans: A very short introduction by Dorrik Stow (2017) Oxford University Press, 184pp. £7.99, paperback (ISBN: 978-0-19-965507-6).

This little book (it will literally fit inside a large pocket!) is a good introduction to the science of the oceans for use in courses in Geography or the Earth sciences, where the oceans are not a primary focus. It covers the field comprehensively, in a readable, attractive and well illustrated form, although the writer is a marine geologist and the book therefore has a strong geological focus. This might put off some readers, although those with an interest in palaeoenvironmental change and marine sediments will find these aspects of the book to be excellent. This marine geology focus does also mean that there is very good coverage of marine biological processes, which will be of interest to those taking the carbon cycle chapters of the new A-level syllabus. I particularly liked that the book had folding front and back covers that could be used as bookmarks or reference holds.



In such a short introduction to a vast field there are always areas where the coverage is weaker. I felt the material on physical oceanography was less comprehensive and sometimes too simple – the description of the Ekman spiral and its consequences missed the opportunity to link to ocean gyre physics, and the explanation of the difference between the meteorological term 'easterly' and the oceanographic term 'eastward' did not work. Nevertheless, for those with little previous knowledge of the oceans, and the vital role they play in a range of climate processes, this neat little volume will prove an excellent introduction. *Oceans: A very short introduction* will be an asset as an environmental library resource.

Grant Bigg
University of Sheffield

(A version of this review first appeared in Geography*)*

Everyman's oceans

Vast expanses: A history of the oceans by Helen Rozwadowski (2018) Reaktion Books, London, 272pp. £16.00, hard cover (ISBN: 978-1-78023-997-2).

Helen Rozwadowski is a respected American maritime historian with a particular interest in oceanography. In an earlier excellent book, *Fathoming the ocean* published in 2005, she provided an extremely readable account of pre-*Challenger* marine science. In it, she pointed out that oceanography did not suddenly appear as if by magic with the *Challenger* Expedition but, instead, was the culmination of a long history of painstaking multinational efforts to uncover the mysteries of the deep oceans. In the process, by emphasising the enormous US contribution to mid 19th century ocean science, particularly in the study of winds and currents and deep sea sounding encouraged by Matthew Fontaine Maury, she did a good deal to redress the common Eurocentric imbalance of many accounts of this period.

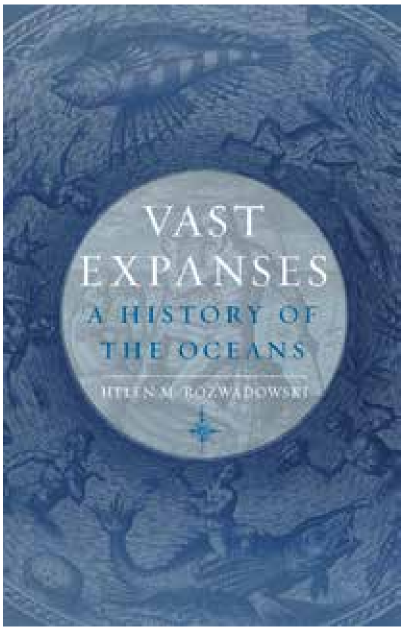
In this new book she has moved the goal posts a touch, attempting to tell the story of the oceans, and humanity's relationship with them, from four billion years ago to the present day. The first three chapters (about half of the book) cover the huge period from the oceans' first appearance on a cooling planet to the late 18th century. They are interesting and informative but, for me, the second half is much more thought-provoking.

Chapter 4, 'Fathoming all the oceans', describes the mid 19th century beginnings of what later became oceanography, stimulated by jingoism, commerce in the form of submarine telegraphy, and old fashioned curiosity. Unsurprisingly, it is based largely on the author's earlier book and is a very fair summary of early marine science and a fitting lead into the last three chapters dealing with humanity and the oceans in the 20th century.

Chapter 5, 'Industrial ocean', is a salutary tale, briefly describing the huge, and largely disastrous, increase in human exploitation of the oceans since the late 19th century, never more graphically illustrated than by the appalling error of T.H. Huxley's oft-reported statement in 1883 that sea fisheries were inexhaustible! A Huxley alive today would surely acknowledge his error and welcome a Common Fisheries Policy, but controlled and driven by fisheries scientists rather than politicians and fishermen! At the same time he would no doubt be flabbergasted at the huge increase in world fish catch in the last one hundred years, despite the ravages of overfishing, made possible by vast improvements in maritime technology stimulated at least partly by the pressures of two world wars – leading us neatly into Chapter 6, 'Ocean frontier'.

This covers the remarkable period between the 1950s and 1970s when, armed with the new technology, it seemed that engineers, industrialists, scientists and politicians were besotted with the conviction that the oceans would provide all the needs of a rapidly increasing human population, from oil and gas, through rich deposits of valuable minerals in manganese nodules, to abundant food from farmed algae, fish and even whales. The enthusiasm and resulting financial backing led to important developments such as saturation diving and both manned and unmanned submersibles, still used extensively today. However, many of the ideas were, and remain, totally off-the-wall, and the only remnant of the grandiose schemes for farming the oceans that seems to have survived is the culture of salmonids in various parts of the world and with varying degrees of success and acceptance.

But an increased fascination with the marine environment also filtered down to the proverbial man (and woman) in the street. Spear fishing had already been popular amongst a certain somewhat privileged class before the Second World War. But it was the availability of Cous-



teau and Gagnan's aqualung after the war that really opened up the undersea world to everyone, resulting in proliferating diving clubs, initially in the US but quickly spreading to Europe. Chapter 7, 'Accessible ocean', tells this story, along with the appearance of the subsurface ocean on our 1950s and '60s TV screens, with films showing the antics of a series of seemingly intrepid adventurers invading the alien undersea world and, all too often in the early days, slaughtering any reasonably large fish having the misfortune to wander into the ambit of the filmmaker. But fortunately, and fairly quickly, the ethos of amateur divers changed away from rampant destruction towards simply enjoying the marine environment, learning more about it and – eventually – conserving it.

And fast forwarding to the present, the final section of the book reminds us that even the most armchair-bound of us now has instant access via the internet to more or less unlimited ocean data and superb images from the deepest trenches. But it also points out that the new knowledge brings a less less welcome 'awareness'; of the collapse of major fisheries and their failure to recover; of environmental disasters like the Deepwater Horizon oil spill in the Gulf of Mexico in 2010; of sea-level rise resulting from global warming; of ocean acidification and the loss of coral reefs following increases in atmospheric CO_2; and, most recently, the shocking realisation that we have managed to spread our pollutants, including plastics, throughout the largest environment on Earth. All join a growing list of indications that the welfare of the oceans is inextricably linked to human activities, more so now than ever before.

So what did I think of the book? I enjoyed it; it is well written, well researched, covers a huge range of topics and is full of interesting stuff. Moreover, at £16.00 for a hardback it represents pretty good value these days, despite the very poor quality of many of its illustrations; in my copy, several of them are indecipherable.

So I'm left with a single, totally unreasonable, criticism. In the section on those early TV films of under-sea pioneers in the '50s, how could Helen ignore, as she does, those European icons, Hans and Lotte Haas, whose Mediterranean and Red Sea adventures inspired a spotty post-war teenage me to devote my future to marine biology?

Tony Rice
Alton, Hants

Stories of iconic ships

***Erebus*: the story of a ship** by Michael Palin (2018) Arrow, Penguin, 334pp., £8.99 (paperback, ISBN: 978-178475857-8), £20 (hard cover, ISBN: 978-184794812-0).

While this book is ostensibly about the ship *Erebus* it is really about much more. In his fascinating account Michael Palin brings together extensive research on the two ships *Erebus* and *Terror*, the men who sailed them and the historical context in which they operated. Although only one of the vessels is mentioned in the title, both the *Erebus* and the smaller barque *Terror* were an important part of British naval history, making enormous contributions to polar exploration and discovery, and charting of previously unexplored waters; their voyages did much to advance research into the Earth's magnetism and botany.

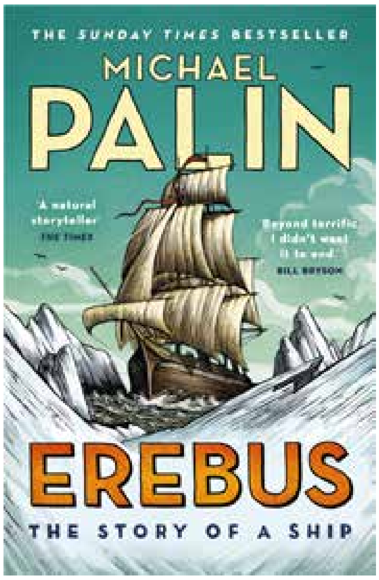
These expeditions took place after the Napoleonic wars when many Royal Navy ships lay idle. Polar exploration was a good opportunity for the Navy to justify its existence. This book reminds the reader that naval exploration played a vital role in the evolution of British national and imperial identity and Britain's perception of global superiority.

Erebus and *Terror* were not built for great sailing ability or speed, but had been originally constructed to be bomb ships (i.e. platforms for gunnery) before being adapted and refitted for Arctic exploration. Essentially they were platforms for ordnance afloat and built for stability, strength, and load-carrying. To absorb the shocks from the firing of their heavy weapons, the hulls were massively built and were broad and bulbous, making them stong enough to withstand the forces imposed by sea and pack ice, but slow and cumbersome. It must have added to the frustration on board to be crossing oceans at speeds of less than six knots for weeks at a time. The collision that occurred between the two ships, causing considerable damage, will have been partially the result of the poor manoeuvrability inherent in their design.

Palin admits in his introduction that 'I am not a naval historian, but have a sense of history. I am not a seafarer, but I'm drawn to the sea. With only the light of my own enthusiasm to guide me, I wondered where on Earth I should start such an adventure.'

The author's enthusiasm for the subject is clearly evident, as is his skill as a storyteller. Occasional inaccuracies in nautical terminology are compensated for by his evocative writing style. Palin not only delved into countless documents, letters and plans but also travelled to places the *Erebus* and *Terror* visited during their expeditions, including Cape Horn, Tasmania and the Arctic. He succeeds in conveying a real feeling of being present on these ships with these captains and crews. One can almost taste the salt and feel the dread they must have experienced. Most poignant is the account of the final expedition under the command of Sir John Franklin, which ended in protracted disaster in the frozen Arctic with all 129 of the ships' companies perishing from exposure, starvation and poisoning.

The dangerous conditions and the self-reliance required of these men (and possibly incognito women) in order to deal with harsh weather, ice and uncharted waters is something the modern mariner is very unlikely ever to have to face. Modern ships are of course fitted with engines and electronics, which the seafarers in the days of sail entirely lacked.

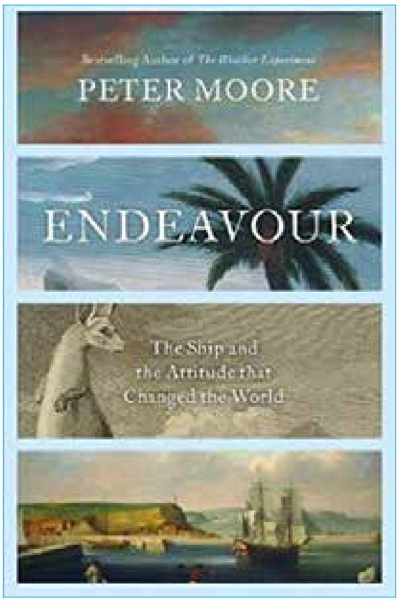


Arguably the account is more about the men than their ships. The stark contrast in the character of society then and now comes through very clearly. The author gives a surprising insight into social conditions at the time of these great naval expeditions and portrays the very different characters of the captains and crews of *Erebus* and *Terror* at different stages in their existence in some detail. It is clear that the skills possessed by contemporary captains had to be scientific, nautical, artistic and managerial at a very high level. The autonomy these captains exercised would be unthinkable in today's large government organisations. In the 1800s captains had to to act without the close scrutiny that modern communications afford today. Captains James Clarke Ross and Francis Crozier are the indisputable heroes of the piece.

Palin's bibliography is extensive, and testament to the high level of interest these ships and their voyages generated at the time and today. The text is densely packed with information evidently obtained from disparate sources, and one can get the sense that the author has put into the book anything he could find on or around the subject of the *Erebus* and *Terror*. This is understandable but means that parts of the book can be a little hard to follow. In addition, from time to time Palin's transitions from his own experiences of places and those of the crews are a little unclear, making the reading experience a little confusing.

Packed with history and adventure this is a very engaging tale. It is well illustrated with a number of charts, drawings and photographs. The resulting book is impressive in its quality and presentation: for those interested in Arctic and Antarctic exploration Palin's work should be regarded as essential reading.

Martin Holland
Inveterate seafarer
Dittisham



***Endeavour*: The ship and the attitude that changed the world** by Peter Moore (2018) Chatto and Windus, 420pp. £9.99 (paperback, ISBN: 978-1-784-70392-9), £20.00 (hard cover, ISBN: 978-1-784-74090-0). Also available as an ebook.

The core of this book is the fascinating story of the selection of the *Endeavour* for James Cook's first voyage of exploration, and the at times exciting re-telling of the story of his voyage, the observation of the Transit of Venus in Tahiti, the 'discovery' of Australia and the rise of Joseph Banks towards eminence in late 18th century botanical science. This central element is very well written, constructed from a new viewpoint focussing on the ship herself as much as the crew sailing her, and compelling reading. The tension associated with *Endeavour*'s grounding on the Great Barrier Reef, and her eventual escape and repair, was well conveyed. Despite knowing the outcome already, I was gripped by the fears of imminent disaster expressed by much of the crew of sailors and scientists in their journals. The grounding and repair of the ship in Queensland, on the muddy banks of the river later to be named Endeavour River, was presented from an original perspective, with the views of both the English crew and the native aboriginals, for whom the site was a religious sanctuary of safe haven, being given equal coverage.

Around this core third of the book we are given a history of the ship herself, both its building and use as a Whitby collier before the great voyage and her use as a supply vessel thereafter. The evidence for the ship's history is more tenuous during these phases, particularly once she left the ownership of the Royal Navy in 1775. This gives the author, Peter Moore, more space to pursue the sub-text of 'the attitude that changed the world' in his title. My take on this is that it is a reference to the scientific and political ferment that was brewing in the second half of the 18th century, eventually boiling over into the American Revolution. There is an interesting and unusual discussion of this idea, driven by the roles and beliefs of the individuals involved, whether they be Benjamin Franklin, Joseph Banks, Thomas Paine or others of the military and scientific community around the onset of the Revolution. A keen student of the history of scientific and political thought will find this well worth reading. However, while the author tries to tie the *Endeavour*'s history into these events and associated developments in thinking, he has varying success. Sometimes the discussion loses itself in digression. The start of the book, with its extrapolation of the origin of the *Endeavour* to an acorn seed whose location we cannot know does not succeed. However, the reader should perservere! Also, the later parts of the book are really a discussion of the opening years of the American Revolution with, at best, tenuous links to the *Endeavour*. These links also don't work particularly well, although the military/political digression is an interesting read for a student of this period of history.

If the reader strips away these digressions what is left is a fascinating story of the multi-faceted life of an 18th century vessel. The *Endeavour* began life as the *Earl of Pembroke*, built in the Whitby shipyards for the colliery trade, taking coal from Newcastle to London. Her original Master was Thomas Milner; she left on her maiden voyage in July 1764. With her principal use being to transport large amounts of coal to the nation's capital, the collier had a large hold, with little need for decks beyond the minimum required by the small crew. She also needed to be able to sail well when fully loaded, whatever the weather. Seaworthiness and carrying capacity were therefore her key design factors, not speed or grace. These characteristics were what attracted her to the Navy Board in 1768, when a robust vessel with lots of room was being sought for Cook's voyage to observe the Transit of Venus. The *Earl of Pembroke* now became HM Bark *Endeavour*, and spent several months at the Deptford shipyard being re-fitted for her great voyage. She already had a capacious hold for supplies and the storage of scientific collections, but an additional deck was added to house the increased crew and their needs. By autumn 1768 she was sailing south on a global circumnavigation that would secure her place in history, and in the mythology of Australia, a country whose existence was as yet only suspected.

By the time of her return, three years later in July 1771, the *Endeavour* and her crew had been through a lot. This is not the place for re-telling the story of the voyage – readers are encouraged to read the book to find this riveting tale – but the bark had returned to England at an opportune time, as a vessel with a large cargo capacity was needed to re-supply the newly installed garrison at Port Egmont, in the Falkland Islands. After a swift overhaul, the *Endeavour*, commanded by James Gordon, sailed in October 1771 with a crew a third the size of that which had accompanied Cook, returning in August 1772. This meant she missed the chance to take Cook on his second voyage, to the Antarctic – the *Resolution* had set off in May 1772. The *Endeavour* now spent two years as the supply ship for the Falklands garrison. The base was eventually evacuated in May 1774, with the *Endeavour* carrying the force back to England. The *Endeavour* had now spent the best part of six years at sea. After a few months at dock she was in a poor state and the Navy Board sold her to George Brodrick in March 1775, with her fate at that time most likely being scrapped. This is where *Endeavour*'s trail becomes unclear. It seems she soon after set off on another voyage, either to Newfoundland or northern Russia, returning in late 1775 to be refitted as a merchant vessel, and renamed the *Lord Sandwich*. The vessel now entered her last phase, becoming involved in the struggle against the American revolutionaries. She transported Hessian troops across the Atlantic in 1776, became a prison ship off Newport, Rhode Island, and seems to have been eventually scuttled offshore in 1778 to prevent a French invasion fleet from landing in Newport.

Endeavour had a short life of only 14 years, but during a key period in the history of science and philosophy. She made a mark that has endured for two hundred and fifty years; this book is a fitting account to place her firmly in her time.

Grant Bigg
University of Sheffield

Lessons in fragility

A Sea of Glass: Searching for the Blaschkas' fragile legacy in an ocean at risk by Drew Harvell (2016) University of California Press, 215pp. £20 (paperback, ISBN: 978-0520-30357-7), £24 (hard cover. ISBN: 978-0520-28568-2).

This book describes something unusual: a synthesis of science and applied art that has remained fruitful across time. Its subtitle neatly combines the book's twin themes with the key-word 'fragile', referring to a property shared by glass and by the marine biosphere. Their conjunction in this case takes the form of glass models of sea creatures.

These beautiful artefacts were created by Leopold and Rudolf Blaschka, father and son glassworkers living in Dresden. Between 1863 and 1890 they produced accurate and detailed models of marine invertebrates, particularly the soft-bodied groups that don't preserve well, in coloured glass. These were sold to museums and universities all over the world for educational use as a substitute for live specimens. It has been estimated that the Blaschkas made at least 10 000 models including more than 800 species.

Their first models were of sea anemones, based on the watercolours of Philip Gosse reproduced in his *Actinologia Britannica* of 1860. The Blaschkas corresponded with Ernst Haeckel* and borrowed books from his library to copy zoological illustrations. Haeckel's well known drawings and watercolours of jellyfish (*Das System der Medusen*, 1879) influenced their work; the reproduction in translucent glass of the delicate floats borne by some of these animals is further evidence of amazing craftsmanship. In at least one other case the source of their design was a plate from the *Challenger* report. The Blaschkas were both skilled draughtsmen; some of their models were the three-dimensional embodiment of their own sketches and watercolours. In 1877 they bought preserved specimens from the Stazione Zoologica in Naples, recently established (1874) by Anton Dohrn. In later years, live specimens, packed in wet seaweed, were obtained from several sources, including Weymouth in Dorset. These were kept in tanks of seawater and contributed to the life-like appearance of the models.

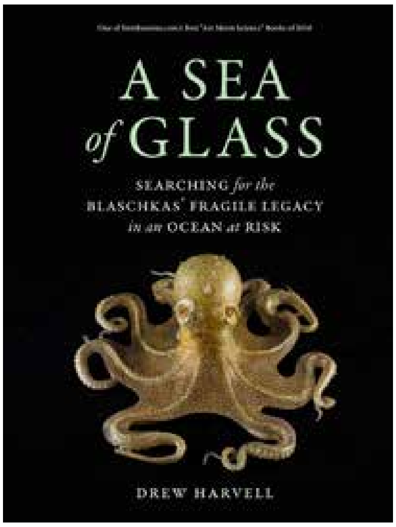
The author is Professor of Ecology and Evolutionary Biology at Cornell University, which houses the largest collection of Blaschka invertebrates in the USA (www.library.cornell.edu/blaschka-gallery). She tells an engrossing story: the rediscovery of Cornell's treasury of Blaschka models, the restoration of its damaged contents, her recognition of their potential as a 'baseline' for diversity and her years searching for their living counterparts in today's oceans. The opening chapter provides the historical background and introduces the idea of inferring changes in marine biodiversity since the Blaschkas' time from the present degree of difficulty in finding the species they modelled. The main text concludes with a chapter that attempts to summarise a mixed picture. Naturally many of the species chosen by the Blaschkas were abundant in their time, but now, while some are still thriving, others are rare or cannot be found at all. The direction of travel is clear enough. The six intervening chapters are arranged taxonomically: anemones and corals, jellyfish, worms, sea slugs, octopus and squid, and sea stars (starfish). Each of these is a blend of ecology, fieldwork – mostly underwater, often adventurous – and examples of the human impact on particular species and their wider consequences for marine ecosystems.

* See *Ocean Challenge* **21**(2), 28–37.

In the Appendix the major taxa concerned are located within the evolutionary scheme and some of their features described in greater detail. There is an extensive list of references and a good index. The book is illustrated throughout with many beautiful photographs of the models and the watercolours that preceded them. A surprising feature is the absence of any sense of scale; with the exception of one of the larger models illustrated (that of the siphonophore *Apolemia*), described as being 'over a foot' tall, no dimensions are given. We assume that most of the models are life-size, but how do they relate to the illustrations, some of which are clearly enlargements? Photographs are no substitute for the models themselves: within the British Isles, large collections of Blaschka invertebrates can be seen at the National Museum of Ireland (Dublin), National Museums Scotland (Edinburgh), National Museum Cardiff, Imperial College London and the Natural History Museum.

The Blaschka models are the unique products of a unique skill, originally created as teaching aids in the *Challenger* years and now, a century and a half later, taking on a new role as a yardstick by which to assess the widespread decline in marine biodiversity.

John Phillips
Milton Keynes



Postscript Dale Chihuly, the greatest glass artist of our time, has expressed admiration for the Blaschka models. He works at the other extreme in terms of scale – read feet for inches – but his abstract series 'Seaforms' resembles them in spirit. Sylvia Earle wrote 'the beauty and spirit reflected in each glowing rendition inspire those who see them to value and care for the living sea'. Chihuly's work, including some 'Seaforms', is currently displayed in Kew Gardens until the 27 October.

OCEAN Challenge

The Challenger Society for Marine Science

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The views expressed in *Ocean Challenge* are those of the authors and do not necessarily reflect those of the Challenger Society or the Editor.

SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and the rest of Europe. By covering the whole range of marine-related sciences in an accessible style it should be valuable both to specialist oceanographers who wish to broaden their knowledge of marine sciences, and to informed lay persons who are concerned about the oceanic environment.

NB *Ocean Challenge* can be downloaded from the Challenger Society website free of charge, but members can opt to receive printed copies.

For more information about the Society, or for queries concerning individual or library subscriptions to *Ocean Challenge*, please see the Challenger Society website (**www.challenger-society.org.uk**)

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

To advance the study of marine science through research and education

To encourage two-way collaboration between the marine science research base and industry/ commerce

To disseminate knowledge of marine science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management

To contribute to public debate and government policy on the development of marine science

The Society aims to achieve these objectives through a range of activities:

Holding regular scientific meetings covering all aspects of marine science

Setting up specialist groups in different disciplines to provide a forum for discussion

Publishing news of the activities of the Society and of the world of marine science

Membership provides the following benefits:

An opportunity to attend, at reduced rates, the biennial UK Marine Science Conference and a range of other scientific meetings supported by the Society. Funding support may be available

Receipt of our electronic newsletter *Challenger Wave* which carries topical marine science news, and information about jobs, conferences, meetings, courses and seminars

The Challenger Society website is
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ADVICE TO AUTHORS

Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references.

For further information (including our 'Information for Authors') please contact the Editor:

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