OCEAN Challenge

Challenger Expedition

150th Anniversary

Capturing carbon by removing invasive seaweed
The Winter Krill Project • Pacific islanders face interacting dangers • A pioneering 19th century female naturalist • HMS *Challenger* and SMS *Gazelle*

Vol.26, No.2

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
www.challenger-society.org.uk

MEMBERSHIP SUBSCRIPTIONS

The annual subscription is £50 (£25 for students in the UK only). If you would like to join the Society or obtain further information, see the website (given above).

COUNCIL FOR THE CHALLENGER SOCIETY

For information about Council members see the Challenger Society website

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 'Guidance for Authors') please contact the Editor:

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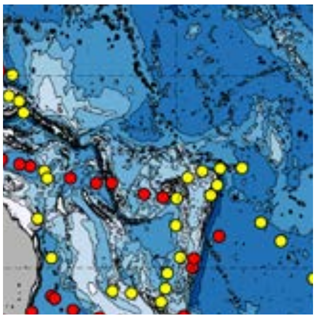

Most of the maps and diagrams were drawn by The ArtWorks.

The cover and heading graphics were designed by Ann Aldred.

Cover image: HMS Challenger off *the southern tip of the Kerguelen Islands*

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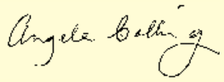
Message from the Editor

Apologies for the late arrival of this second '*Challenger* Expedition Anniversary Issue' of *Ocean Challenge*. We have continued to face a serious shortage of copy as would-be authors struggle to catch up after the disruption caused by Covid-19. Remember – we always welcome contributions from readers; we are particularly keen to hear about books that may have altered the course of your marine science career (see p.14).

The *Challenger* Expedition of course features in this issue, and will feature over future issues as well: the vessel departed in December 1872 and the pioneering oceanography continued for three-and-a-half years. As part of the *Challenger*-related content in this issue, and with thanks to Tony Rice, we are including a revised version of an article that appeared in the first ever volume of *Ocean Challenge*, in 1990!



Results of the Challenger 150th Anniversary Photographic Competition

By tradition, Challenger Society conferences involve a photographic competition. The theme this time was 'Ocean Challenges', chosen by Ros Rickaby, the outgoing President of the Society, and judge of the competition.

Winning photograph

Polar bear at sunset

Birthe Zaencker

This photo was taken during a research cruise to the Central Arctic Ocean. It illustrates the loss of sea ice and how this affects the hunting grounds and habitat of polar bears. With the Arctic warming at four times the average global rate, polar bears and other Arctic animals have to adapt to climate change much quicker than animals in other regions.

Runner-up

Winston explores the deck

Anna Belcher

It was all hands on deck when Winston the curlew arrived to join our RRS Discovery *cruise to the Porcupine Abyssal Plain (PAP). The challenge: keep Winston alive until our return to shore in three weeks! Rising to the challenge, the galley provided curlew-friendly titbits to keep up Winston's strength, and he soon became part of the deck team, keeping his watchful eye over the PAP mooring deployment.*

A Challenger Society Conference with a difference

The 2022 Challenger Society Conference was special and different in a number of ways. It marked the 150th anniversary of the year that HMS *Challenger* set sail on its global expedition, and to mark this, it was hosted by the Natural History Museum in London. Last but not least, it was the first time that many of us had managed to meet up in person since Covid ruined all our plans.

The main venue was the elegant Royal Geographical Society, with other sessions at Imperial College's Royal School of Mines and the Natural History Museum's Flett Theatre. For those of us who enjoy a multidisciplinary conference, it was disappointing that the shorter conference (three days as opposed to the four days of recent conferences) meant that there were a lot of parallel sessions, so some hard choices had to be made, and the venues were just too far away to do much 'session-hopping'.

The 'headline sponsor' of the conference was the International Seabed Authority, established under the 1982 United Nations Convention on the Law of the Sea (UNCLOS). For many delegates the associated 'Deep Sea Mining' sessions – with talks ranging from ore formation to conservation of biodiversity in mined areas – were particularly interesting, as this is an area that many of us are not very familiar with.

Challenger conferences are perhaps best known as a forum where early-career marine scientists can give presentations in a supportive atmosphere. The standard of talks was very high and the panel charged with attending all talks between them to identify the best, had a tough job. The award for the best talk (the Norman Heaps Prize) went to Eva Stewart (Natural History Museum), who spoke on 'Biodiversity, biogeography and connectivity of polychaetes in the world's largest marine minerals exploration frontier'. The runner up was Oliver Tooth (University of Oxford) for 'Seasonal overturning variability in the eastern subpolar North Atlantic Ocean: A Lagrangian perspective'.

There seemed to be many more posters than usual and it was a challenge to see them all. The largest group were in a marquee, where the sound of rain beating on the roof was at times even louder than the buzz of conversation. The Cath Allen Prize for the best poster went to Katie Sieradzan (Bangor University) for her 'Impact of tidal mixing on shelf sea flushing times in a global climate model', and the runner up was Philippa Birchenall (British Antarctic Survey) for 'Microplastic distribution and characteristics around the South Sandwich Islands, Southern Ocean'.

Challenger Fellowships were awarded to Antony Birchill (now at the University of Portsmouth), Emma Cavan (Imperial College) and Alice Marzocchi (National Oceanography Centre), and the Woodward Fellowship (for a researcher working in nutrients and nutrient cycling) went to Felipe Sales de Freitas (University of Bristol).

The Society's most prestigious award is the Challenger Medal, and because the previous conference had to be cancelled, there were two Challenger Medals to be awarded and hence two terrific 'Medal lectures', both addressing the need to understand more about the ocean's role in taking up atmospheric CO_2. Carol Robinson's wide-ranging talk covered the techniques needed to study marine microbial respiration, which is a key determinant of the balance between storage of carbon and production of CO_2 in the ocean. By contrast, Alberto Naveira Garabato's talk introduced a new theory about the physics regulating the deep ocean's ability to sequester heat and carbon.

Two of the most entertaining keynote presentations came in the last session of the conference. Erika Jones' talk – 'From warship to research vessel' – was well pitched for an audience which included some well versed in *Challenger* lore, and others who knew very little. It was a special treat because there were fewer talks relating to the history of marine science than might have been expected for a Challenger 150th Anniversary Conference – just one short session, including some talks by staff from the Natural History Museum.

The final talk, by Autun Purser included some amazing videos obtained by the Alfred Wegener Institute's OBIS system. These showed a large group of fish nests in the Weddell Sea, and some crawling sponges on an extinct hydrothermal vent system in the high Arctic (described in *Ocean Challenge*, Vol. 26 (1)).

The Conference marked the official handover of the Challenger Society Presidency from Ros Rickaby to Mike Meredith. Ros's last official duty was to judge the photograhy competiton, the results of which can be seen on p.2.

The conference dinner was held in the Natural History Museum's stunning Hintze Hall, with tables set out beneath the blue whale skeleton. Delegates were welcomed to the venue by the London Sea Shanty Collective, who performed again later, to enthusiastic applause. Great ingenuity had gone into making the table decorations, and the appearance of the dishes themselves, relate in some way to 19th century marine research!

The next Challenger Society Conference will be on 2–6 September 2024 in Oban, hosted by the Scottish Assocation for Marine Science. Put the dates in your diary now!

Ed.

The conference dinner beneath the blue whale in the Natural History Museum's magnificent Hintze Hall
(Photo: Natural History Museum)

Stepping Stones to a successful career

Reasons to apply for a Challenger Society Early Career Bursary

The Stepping Stones Bursary scheme is designed to support career development for members of the UK marine science research community currently without employment. Below, a recent beneficiary of the Award explains how he used his Bursary to enable him to collaborate more effectively with colleagues in Australia.

Using a Stepping Stones Bursary to make a brief but important visit to a university 'down under' Neill Mackay

I am a physical oceanographer working at the University of Exeter. My research focusses on the polar regions, and I have been using both models and observations to try to understand their role in the oceanic overturning circulation. In recent years, my work has expanded into the realm of biogeochemistry, studying the uptake of carbon in the Southern Ocean.

In early 2021, I was approaching the end of a post-doc contract, and funding for a proposal I had put together with my boss, Andy Watson, and others, was being considered by NERC. The project, entitled 'Understanding Interdecadal Changes in the Ocean Carbon Sink' (UNICORNS), aims to reconcile reconstructions of the carbon inventory in the ocean interior with those of air–sea CO_2 fluxes using a combination of observations, machine learning, and numerical and inverse modelling. The project hopes to determine whether recent decadal variability in the global carbon sink can be explained through changes in the physical ocean circulation.

For the project, I needed to work with a colleague at the University of New South Wales (UNSW), and getting started would be much easier with an in-person visit. I applied for the Stepping Stones Bursary with the idea that if we didn't get the NERC funding that round, with the help of the Bursary we could still scrape together the funds for me to go to Australia, while my boss figured out what to do next.

Making the most of a brief visit

In April 2022 I travelled to Sydney, Australia, for a two-week collaborative visit to the Climate Change Research Centre (CCRC) at UNSW. The trip had been long anticipated as an opportunity to meet face-to-face with Dr Jan Zika, a colleague who is based there, and was finally made possible by a combination of a relaxation of Covid-19 travel restrictions and my receiving the Challenger Society Stepping Stones Bursary.

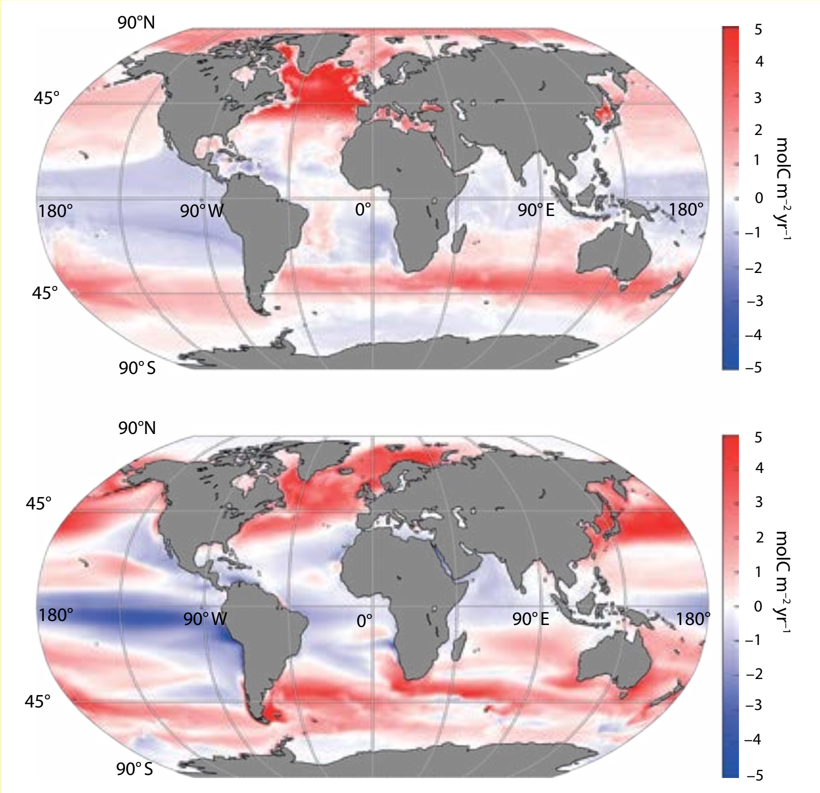
The primary purpose of the visit was to lay the groundwork for developing a new method of determining the uptake of CO_2 from the atmosphere by the ocean, and its redistribution within the ocean interior. Uptake of CO_2 from the atmosphere by the ocean is of significance to both the marine science community and the wider world, because the ocean's ability to absorb atmospheric CO_2 and sequester it deep down has a mitigating effect on climate change. The challenge for climate scientists is that over the last few decades CO_2 uptake has been showing significant variability, and the drivers of this variability are complex and yet to be fully understood. The task I had set myself for my visit to Sydney was going to be difficult to achieve in only two weeks, but I was determined to make the most of the opportunity!

I began my visit by delivering a seminar to some of the researchers at CCRC, which gave me the opportunity to introduce myself, and to explain the purpose of my being there. It also gave me the chance to talk through the work I had been doing in preparation for the trip: an attempt to extend a method I had developed for studying the ocean circulation and apply it to ocean CO_2 uptake. My expectation at this point, however, was to go back to the drawing board, since some months of effort had led me to the conclusion that this particular approach is not well suited to the problem we were trying to solve. After my talk, I sat down with Jan, and

Neill on a cruise in the Southern Ocean in 2018.

with Dr Taimoor Sohail (another member of the research group who has been working on similar methods) to figure out the best way forward. We quickly agreed on an alternative approach, based on the same principles but with a somewhat different implementation. Underlying these method is Water Mass Theory, a powerful framework originally proposed by a scientist named Gösta Walin, which allows the complex three-dimensional ocean circulation to be simplified with minimal loss of information.

Water masses are traditionally viewed in a geographical coordinate system as bodies of ocean water with certain temperature and salinity characteristics, but in a water mass framework, temperature and salinity replace the traditional spatial coordinates. We can then utilise a balance between the changes seen in each water mass over time, the surface forcing, and transports and mixing in the ocean interior, to infer aspects of the circulation from incomplete information. In our 'Minimum Transformation Method', we combine knowledge of changes in temperature and salinity in the ocean interior with information about air–sea fluxes of heat and fresh-



*Annual mean air–sea carbon fluxes between 2000 and 2010: (**top**) estimated from changes in distributions of temperature, salinity and carbon in the interior using our Minimum Transformation Method (MTM); and (**bottom**) as output from the ocean biogeochemical model ECCO-Darwin* (the model 'truth'). The similarity between the magnitudes and spatial distribution of the carbon fluxes estimated using MTM and those output by ECCO-Darwin shows that the method works when applied to model data.*

**Carroll et al. (2020) doi: 10.1029/2019MS001888*

water, and use the temperature–salinity water mass framework to infer transports and mixing between water masses and between basins.

Over the next two weeks, I worked closely with Taimoor and Jan developing the new approach. Making use of some model data that I had brought with me, we were able to extend their methodology (which had thus far been used to study the physical circulation) to incorporate the ocean's uptake of carbon. By the time I left Sydney, we had succeeded in a proof-of-concept of the new method (*see maps above*) – something we had not been able to achieve in several months of collaborating remotely. It was more than I had hoped I would be able to accomplish in such a short time, and I returned to the UK reassured that the long journey with its associated costs (not to mention CO_2 footprint) had been more than worthwhile.

In the event, we did get the funding for UNICORNS, on which I have now been employed since January 2022. Since returning from UNSW I have continued to make progress with developing and validating the method we devised, and kept in touch with my colleagues via Slack and video conferencing. I have also been reminded, post pandemic, of the benefits – and the joys – of working with people face-to-face!

Neill works in the Department of Geography at the University of Exeter. After completing validation of his method, he plans to apply it to observations, and in doing so construct a new and independent estimate of the ocean carbon sink.
N.Mackay@exeter.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 who are not employed. Applications are not accepted from researchers holding permanent positions, but those on fixed-term contracts may apply in the six months before the end of their contract.

Individuals may 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. Bursaries can be used for research-related activities which could enhance career prospects including, but not limited to, travel, collaborative visits, laboratory time, fieldwork and conference participation. It cannot be used to pay salary. The Society aims to fund four bursaries per year, and applications will be considered quarterly (deadlines: 15 January, 15 April, 15 July and 15 October).

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).

See the Challenger Society website for other awards and grants that are available, including Travel Awards, the Virtual Conference Award which aims to cover the costs of registration and administration involved in attending virtual conferences, and the Chris Daniels Early Career Grant intended to provide opportunities for motivated early-career researchers (ECR) to create or establish a forum to discuss specific challenges and resources relevant to ECRs in the field of marine science.

An interview with a passionate deep-sea ecologist

Bhavani Narayanaswamy is a benthic ecologist who researches deep-sea and Arctic ecosystems, focussing on the impacts of biotic, abiotic and anthropogenic inputs on the faunal community. Here, she is interviewed by Kim Last, a colleague at the Scottish Association for Marine Science.

Ed

Bhavani 'The Mud Queen'
(Photo: Callum Whyte, SAMS)

We first met 20 years ago, when we were both just finishing our Ph.Ds! We were in Ireland, on a bus on the way to a conference.

Yes, this was my first deep-sea conference and I was really looking forward to meeting the community as well as being able to present my research to this audience for the first time. I was looking at macrofauna in the Faroe–Shetland Channel and was hoping that this topic would pique the interests of one of the big names in deep-sea research at the time, Fred Grassle. In fact, I met him whilst I was pacing the floor before I was due to give my talk! He was very kind, providing words of encouragement before my talk and then discussing my research afterwards.

During the conference I met with my mentor, Brian Bett, and we talked through the structure of my thesis. Immediately after the conference I was on a mission to write up the different chapters and have the thesis submitted by Christmas that year. I then undertook various jobs working with a commercial company called SEAS Ltd, identifying sediment fauna from beneath fish farms – a long way from the deep sea – before securing a post-doc position with John Gage at SAMS to carry on what I had been doing for my Ph.D.

One of your first roles at SAMS was to become the Co-ordinator of the European Census of Marine Life. Was this a daunting task?

It was quite daunting to be honest but also exciting. The Chair of the European Census of Marine Life was Graham Shimmield, who was also the Director of SAMS. For a young researcher working directly with the Director was a bit nerve-racking, but Graham let me get on with the role, manage the budget and work with whoever I wanted. It meant trying to engage with researchers around Europe, in all disciplines, making them aware of the Census programme and encouraging them to hold workshops that would lead to large collaborative grants, reviewing papers on the current state of knowledge, as well as undertaking outreach events to raise the understanding of the marine environment. I met so many amazing, knowledgeable, supportive researchers in so many different fields of marine science – many of whom I would normally never have interacted with, as our disciplines were so different.

In your career you've had a number of opportunities to go on research cruises. What are the highs and lows of being at sea?

I have been really fortunate to go to sea and have been on cruises in Atlantic, Arctic and Antarctic waters. The highs have included seeing cold-water corals and sponges on the UK's seamounts and in waters north of Svalbard, as well as the more 'touristy' things like seeing humpback whales swimming around the ship whilst we were box-coring in the Weddell Sea. We stopped the coring just to watch these majestic animals watch what we were doing! There were also penguins on beautiful, coloured icebergs. Most importantly, I've loved working with colleagues and friends who are passionate about the science that they do. On the flip side, the lows include being away from family without email or phone connection for up to three months.

There was also the time that a long-term camera deployment failed to collect any data – you were there for that one Kim! We had been up for about 12 hours trying to retrieve the camera. The crew were determined to get it back and I have a picture of the ship's track which shows ever decreasing circles around the site of the camera deployment as we tried to dislodge it with rope to let it float to the surface. You were the person who had to tell me that I had no data – I just remember being really upset and demoralised, but the support from all on board was phenomenal as they tried to hatch alternative plans for what could be done instead.

After many years of deep-sea research, your work has extended into plastic pollution. How did this come about?

Initially my interest in plastic pollution arose through a chance conversation with Brian Quinn who was working on microplastics. I wondered whether the historical deep-sea biological samples that SAMS had could be used to ascertain when microplastics were first seen in deep-sea animals. A Ph.D student, Winnie Courtene-Jones, worked on these historical samples, and what we found was that animals collected in the mid-1970s had ingested similar numbers of microplastic particles to those collected in 2015. Not what I was expecting. At around the same time we had also collected samples from seamounts in the south-west Indian Ocean and comparisons were made of the numbers of microplastics found in the sediment here with those from other deep-sea areas. Now I try and balance my passion for all things deep-sea with the impacts plastic and litter are having on the marine environment.

I've heard that even the deepest trenches in our oceans have plastic litter. What are the most surprising items you have come across?

That's right, plastic litter is found in the deepest parts of the planet. The oddest items I have come across are a lone welly boot caught on camera in the Barents Sea, and a laptop bag drifting upstream in the mangroves in Ghana.

I know that you are a keen advocate of science communication. Can you give me some examples of successes that have made you feel proud?

I have worked with an ex-student of ours, Jessica Gianotti, who has her own company (Crùbag) merging science with art to produce a variety of unique products, ranging from scarves through to textile-covered notebooks, all of which convey information about the project. For example, there is the Seamount Collection of scarves and the Plastic Oceans Notebook Collection.*

I enjoy going into my local school to talk about the science I do, or the recent expedition that I have been on. In fact, it was a joint collaboration between the local primary school, Crùbag and myself which resulted in the Plastic Oceans Notebook Collection.

How do you think we can best protect our oceans?

I feel that we as scientists have a duty to educate and inform others about our findings, especially when the general public and other stakeholders can do something tangible to help make a difference. We also need to ensure that we understand the challenges faced by other countries and that different potential solutions could be implemented in different areas – one size does not fit all.

What three things do you think are the most important in being a successful scientist?

Being passionate about what you are doing. Encouraging and supporting the next generation with their research and their ideas. And having the courage to take a gamble with new ideas and working with new colleagues.

*See https://crubag.co.uk Crùbag shares 10% of its profits to fund important science and support dissemination of knowledge about the ocean.

You are married (to another successful scientist) and have two young boys. How do you juggle the home/work life balance?

Juggle is the right word. My children know what I do and why I do it, and they find it really interesting and 'cool' that their mum gets to travel and go to different places. They also get to meet some of my students and the people I work with, and to hear what we do. I think this helps them accept why I am sometimes away for long periods of time. I am also really lucky that I have family, friends, colleagues and students who support me when things get really busy.

Finally – and this is for my kids – if you were a marine animal what would you be and why?

It would have to be a polychaete. Polychaetes are marine worms generally living on/in the mud. I have studied these beautiful worms, which come in all sorts of shapes, colours, sizes, from when I was a Ph.D student. Some of them have scales which look like armour plating, others glisten from the light of the microscope, whilst others have a feathery look about them. All this variety and the role polychaetes can play within the community in which they live, make them fascinating to study.

Bhavani in her lab at SAMS
(Photo: Dynamic Earth)

Bhavani Narayanaswamy is a professor at the Scottish Association of Marine Science (SAMS), Dunbeg, Oban, Argyll PA37 1QA
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The MBA says goodbye to Eve Southward

Eve Southward died in January 2023 at the age of 92. Eve was an expert on a range of marine invertebrate species, including sediment-dwelling tubeworms (Pogonophora). Her expertise on tubeworms led to her ground-breaking work on the symbiosis between chemosynthetic bacteria and the tubeworms that live on hydrothermal vents. This in turn led to her participating in a dive in the US submersible *Alvin*, which she found thrilling.

Eve began working at the Marine Biological Association's Laboratory in Plymouth in the 1950s, but was never paid a salary, as she joined in order to work with her husband, Alan Southward, at a time when the MBA did not permit husbands and wives to be employed together.

Eve and Alan's research on the impact of the 1967 *Torrey Canyon* oil spill and its clean-up showed that physical methods of containing and clearing up oil spills are much less damaging to intertidal organisms than chemical oil dispersants.

Together they initiated the intertidal surveys around the British Isles and Ireland that became the foundation for the pioneering MarClim project which for over 60 years has been using intertidal rocky shore biota to assess the influence of climatic change.

As the tribute to Eve on the MBA website notes: 'She did much ground-breaking research at a time when being a women in science was far from easy.' Eve published what was to be her last paper, on Pogonophora, in 2021, and she continued working to the end.

An interview with Eve, and an article by her about the *Torrey Canyon* work, can be found in *Ocean Challenge* Vol.22 (2), 8–12. *Ed.*

Memories of David Pugh

Philip Woodworth

David Pugh died on 1 August 2022 during a walking trip in Wales. He was well known as a tidal and sea-level scientist, and many people will have learned about tides from David's books. An obituary can be found on the National Oceanography Centre (NOC) website,* while anecdotes by former friends and colleagues are on the Bidston Observatory website.† I shall mention here just some of the highlights of David's long career in oceanography.

David did his first degree at University College London, and his second was at Cambridge where his thesis topic was 'The thermal environment of the deep-sea floor'. This work involved David in sea-going with scientists from the National Institute of Oceanography at Wormley, and it led to a *Nature* paper (1967) on hot brines in the Red Sea. He never lost interest in the topic of geothermal heat fluxes in the ocean and in lakes, and he returned to it in several later publications, the last being in 1998 in a study with Liverpool University of heat fluxes in Patagonian lakes.

However, in 1969 he moved to work at Bidston Observatory in the Wirral (which became the Proudman Oceanographic Laboratory and is now part of NOC), where he met his wife Carole, and where the focus of his work was on tides and sea levels. I'll give just two examples of advances that resulted from David's work at Bidston. The first is the equipment that records the tides around our coasts to this day (called a 'bubbler gauge'), which was invented by David. He used that equipment to measure the tides at many places, notably in the Indian Ocean. The second example concerns the mathematical methods of 'extreme level joint probabilities' that David developed with Ian Vassie to estimate the risk of flooding at any point on the coast; these mathermaticl methods are now used extensively by coastal engineers. David also worked on the topic of long-term changes in sea level due to climate change and was the head of the global databank for such information (the Permanent Service for Mean Sea Level). Later, he was a co-founder, and first Chairman, of the Global Sea Level Observing System (GLOSS) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

In 1984, David changed direction from science into science management. He was based at the Natural Environment Research Council (NERC) headquarters at Swindon, where he became Head of Oceanography, Hydrology and Meteorology. That post involved considerable liaison between the research council bosses and the various laboratories, universities and government agencies in the UK which had an interest in the ocean. At about the same time he became more involved in the work of the International Oceanographic Commission. David was Chairman (or President) of the IOC for five years in the 2000s – not an easy job, as being Chairman of such a body requires a mixture of diplomacy and firmness. For all this work, in 2003 he was awarded an OBE. In between times, David was an author, managing to write several books on tides and sea levels, something he found very fulfilling.

David on a visit to the coast of Victoria, Australia, with part of the Twelve Apostles rock formation in the background.

It is notable how much of David's scientific research was done after he retired. At a time when many people would decide to take it easy, David returned to doing research, mostly with former colleagues. For example, together we made measurements of the tide in Loch Ness (they are only 2 mm). Other research he took on with new sets of people – in particular, he recently worked on tides and sea levels in Ireland where, partly thanks to David, there is now an active tidal research community. In recent years David managed to publish on average about one major science paper a year.

Why did he do all this work in retirement? Partly I think because he liked to travel to all the new places to be discovered around the coast. Also, I think he continued to have a great love of getting good, reliable data from instruments that he had helped to develop and using that data to learn something useful. You might say that is what science is all about. In David's case, I think it was the simple satisfaction of doing something he enjoyed and was good at.

In between the science, David was an active member of Chester Golf Club, and a watcher of cricket (a member of Lancashire Cricket Club) and football (an Everton supporter). He was also a keen photographer and walker. He was very proud of his Welsh roots.

I'll miss my travels with David to measure sea levels at places as far apart as the Falklands and Shetland. I'll miss our visits to good restaurants which he had a knack of discovering. More generally, the UK marine community will miss one of its leading and most active members.

Philip Woodworth
Emeritus Fellow,
National Oceanography Centre

*https://noc.ac.uk/news/memoriam-david-thomas-pugh

†http://www.bidstonobservatory.org.uk/ and select Articles and you will find memories of both David Pugh and Keith Thompson. Keith was an Emeritus Professor of Oceanography at Dalhousie University in Canada. He also worked on sea levels at Bidston and died just a few weeks before David.

Special Interest Groups get together at Challenger 150

The Challenger 150th Anniversary Conference presented a much appreciated opportunity for Challenger Special Interest Groups (SIGs) to meet up. Here are reports from two of them. For information about other SIGs, see the Challenger Society website.

Advances in Marine Biogeochemistry (AMBIO)

Rhiannon Jones

For the marine biogeochemistry community, the (traditionally) biennial Challenger conference is a key event in the academic calendar. This year, the Challenger Special Interest Group in Advances in Marine Biogeochemistry (AMBIO) made the most of the event by holding its own meeting

The morning session was aimed at early-career researchers (ECRs), and was led by AMBIO Chairs Kate Hendry and Amber Annett, with support from myself. It was a great success. Around fourteen ECR AMBIO members from various institutes attended, enjoying talks, networking and sharing conference experiences over coffee. Amber and Kate provided a relaxed and informal atmosphere, and the session was a great way to ease pre-conference nerves. The group practised 30-second 'elevator pitches' – summaries of their research, aimed at a non-specialist audience. One attendee practised their exciting Challenger talk and got feedback from the group. Another, Sandy Avrutin (University of Southampton), said: 'I found [the session] useful because it helped me approach the entire Challenger conference more deliberately ... and get advice on how to reach my conference goals from experienced academics.'

The afternoon 'town hall meeting' was well attended and brought ECRs and seasoned researchers together to discuss recent and future activities in marine biogeochemistry. It allowed members to share information about past research and brainstorm about future directions in the field. Alessandro Tagliabue (University of Liverpool) presented on the international multidisciplinary BioGeoScapes programme, which is of particular interest to the AMBIO community. Its main objectives are to advance understanding of the interactions between biogeochemical cycles and ocean microbes through a coordinated global programme. Such programmes provide opportunities for collaboration, and channels for sharing progress, for ECRs and senior researchers alike. As the UK marine chemistry representative on the RRS *Sir David Attenborough*, Malcolm Woodward from Plymouth Marine Laboratory provided updates on the capabilities of the new state-of-the-art icebreaker commissioned by the British Antarctic Survey to perform polar science and logistics. The session was informal, with space for members to contribute questions and personal experiences. Oli Flanagan (University of Southampton), who attended both the ECR and town hall sessions, said that they 'were a great way for me to engage with the Challenger community as a fairly junior scientist … By talking with like-minded scientists and ECRs, the sessions made me feel more relaxed and supported in preparation for my first talk.'

Looking forward, it was agreed that there would be a dedicated AMBIO science meeting in the next year or two, and potential host institutions were discussed but not confirmed. Furthermore, members decided that full AMBIO SIG meetings would return, likely biennally. During the town hall closing remarks, Amber stepped down from her role as AMBIO Chair, and the group welcomed Sarah Reynolds (University of Portsmouth) as the new Chair.

Overall, the AMBIO pre-Challenger sessions brought together a diverse range of members, providing support and advice for newer members, and a springboard for brainstorming ideas and future activities for us all. To join the emailing list, please go to https://www.challenger-society.org.uk/Advances_in_Marine_Biogiochemistry

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Twitter @rhiofthesea.

Ocean Wind Waves

Lucy Bricheno

It was a treat to meet in-person again, and find out all the latest developments in UK waves research. The Ocean Wind Waves SIG has over 80 members, and this year our get-together attracted international visitors from the wider waves community, including academic institutions, consultancies and research agencies. The meeting covered the mathematics of wave shape and wave groups, and interactions between wind and waves. We discussed risks to infrastructure and offshore operations resulting from large waves, and the topic of wave energy resource assessment. New results from experimental flume tanks were presented as well as novel tools using machine leaning along with statistical techniques for wave forecasting. We also heard about the latest observations using satellites and even video cameras at the beach. Speakers ranged from Ph.D students to professors, and were able to share content with remote participants unable to attend in person.

Our SIG welcomes new members from all areas of wave science. We aim to promote research in ocean surface waves and their interactions with oceanographic, atmospheric and climatic processes, and to provide a forum for cross-disciplinary exchange of information. We also aim to encourage early-career researchers in this field by providing an informal forum for presentations and interactions.

Ocean surface waves are an important phenomenon in many fields of oceanography, crossing many disciplines, including meteorology, sediment transport, renewable energy, coastal morphology and coastal engineering. Waves have direct impact on the safety of navigation and on coastal erosion, while also mediating ocean–atmosphere interactions through transfers of momentum and heat, along with water, CO_2 etc. While ocean waves may not attract the same level of study as other ocean processes, their inclusion (or neglect) can impact the performance of global ocean and meteorological forecasts. They are often implicitly included in models, but this does not properly account for dynamic feedbacks, and can undermine momentum budgets, and reduce model skill.

The study of waves involves a wide range of techniques, from *in situ* observation to satellite remote sensing, from the statistics of extremes to long-term climatic trends, and from modelling of ocean waves on global scales down to details of wave–current interactions or the bottom boundary layer in shallow water.

For more, see: https://projects.noc.ac.uk/windwavesSIG/. To join the emailing list, please contact Lucy or go to https://challenger-society.org.uk/Ocean_Wind_Waves

Our next meeting will be hosted by Oxford University in Spring 2024. We hope to see many members and new faces then!

Lucy Bricheno leads the Coastal Ocean Modelling Team at the National Oceanography Centre, Liverpool.
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The complexities of climate-related 'Loss and Damage'

The establishment of a Loss and Damage Fund to provide financial assistance to nations most vulnerable to the effects of climate change was, for many, the highlight of the UN Climate Conference (COP 27). The term 'loss and damage' was first introduced at UN climate negotiations in 1991, by Vanuatu. Pacific small island developing states (SIDS) already face average annual losses from climate-related events totalling US$ 1.1 billion, and under moderate climate warming scenarios Vanuatu could lose 20% of its GDP annually. But why is Vanuatu particularly vulnerable to climate change? After all, it is mountainous (*see right*), not a low-lying coral island or atoll.

Port Vila, capital of Vanuatu, on the island of Efate in 2006. 60% of the population of Vanuatu live within a kilometre of the coast, where they are dealing with worsening floods and intrusion of saltwater into the soil.

(Photo: Phillip Capper/Flickr)

Growing, interacting threats

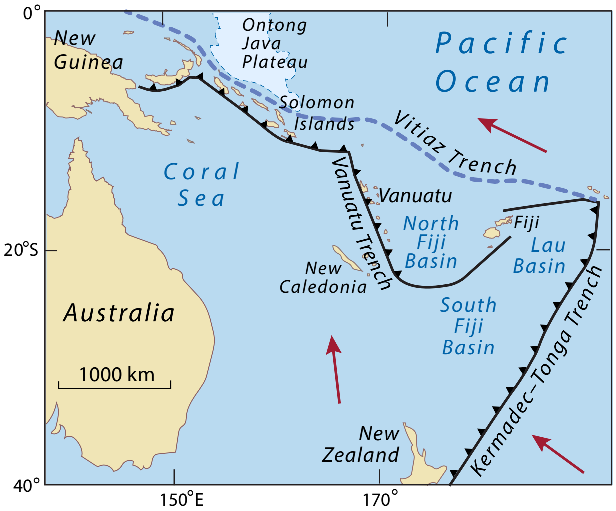
At the time of writing (early March 2023) Vanuatu has just been hit by two destructive Category 4 tropical cyclones, and an earthquake of 6.5 magnitude, all within 48 hours, impacting over 80% of its population. This was not a freak happening: Vanuatu lies lies in a tectonically active region (*see map below*) and its Geohazards Division regularly sends out warnings of geohazards – eruptions (Vanuatu has six active volcanoes), earthquakes and tsunamis – along with weather and shipping forecasts, warnings about increasingly unpredictable tropical cyclones, the likelihood of coral bleaching and other climate-related alerts, including the state of El Nino–Southern Oscillation.

Heavy rainfall is an increasing hazard, adding to the problem of sea-level rise by causing flash flooding and landslides, and flooding of low-lying areas. As a result, Vanuatu's government is dealing with the prospect of large-scale resettlement within the country, while building resilient infrastructure. It already has experience of relocating people; in 2005, it moved an entire community on the island of Tegua from a flood-prone coastal area to higher ground, and in 2017, a volcanic eruption on the island of Ambae meant that all of its 11 000 inhabitants had to be urgently ferried to other islands.

Of course, Vanuatu is just one of the many states facng multiple environmental challenges. There is growing awarenss that climate change as a risk factor cannot be considered on its own. For example, events triggered by earthquakes, such as landslides and rock falls, are becoming more destructive as a result of climate-related changes (e.g. a rise in the water table). Perhaps more worryingly, recent studies have proposed a causal link between rising sea-level and increased frequency of volcanic eruptions and earthquakes (*see end of article*).

Migrating to the Metaverse

While coastal residents of Vanuatu can move to higher ground, the same cannot be said for the ~12 000 inhabitants of Tuvalu, whose three tropical reef islands and six atolls even now have total area of only 26 km^2. Up to 40% of its capital district is under water at high tide, and the entire country could be submerged by the end of the century. Tuvalu therefore plans to build a digital version of itself, replicating islands and landmarks, and as far as possible preserving its history and culture. Tuvalu's Foreign Minister Simon Kofe told the COP 27 climate summit that 'Our land, our ocean, our culture are the most precious assets of our people, and to keep them safe from harm, no matter what happens in the physical world, we will move them to the Cloud.' The hope is that existence in the Metaverse would allow Tuvalu to continue to function as a state even if completely submerged.



Tectonic setting of Vanuatu (highly simplified). The islands lie along the plate boundary where the Australian plate is being subducted underneath the Pacific plate ('toothed' black lines = subduction zones; arrows show relative plate motions). As the map indicates, the Solomon Islands face problems similar to those of Vanuatu.

Does a submerged state have an EEZ?

So what happens to an island state's maritime boundaries, as the island shrinks until it no longer has a coastline? What happens to its territorial seas, its exclusive economic zones and fishing zones, and their associated resources? Unsurprisingly, this is something that vulnerable island states have already thought deeply about. In August 2021 the Pacific Islands Forum (whose members include Australia and New Zealand as well as numerous small island states), published its *Declaration on Preserving Maritime Zones in the Face of Climate Change-related Sea-Level Rise.* This states that: *'once having, in accordance with the Convention, established and notified our maritime zones ... , we intend to maintain these zones without reduction, notwithstanding climate change-related sea-level rise, ...'*

Putting this aspiration into practice will be challenging.

Ed.

Further sources of information

unescap.org/blog/vanuatu-twin-cyclones-underscore-pacifics-vulnerability-compounding-climate-disaster-risks; unescap.org/kp/2022/pathways-adaptation-and-resilience-pacific-sids-subregional-report

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Sinking seaweed to capture carbon while cleaning up Caribbean coasts

Kelvin Boot

Europeans discovered the Sargasso Sea more than half a millennium ago, when Christopher Columbus sailed into it back in 1492. At the mercy of winds and currents, 15th century sailors regarded it as a treacherous place shrouded in mist and mystery, a portent of shallow water and hence danger of being wrecked, or an entangling morass condemning sailing ships and their crews to circle throughout eternity with no hope of escape or rescue. Today we know better, and while the Sargasso Sea remains strange and fascinating, it has lost its dreadful reputation. Now this vast area of ocean is regarded as one of nature's treasures: a habitat, created by masses of *Sargassum* seaweed, home to a unique assemblage of marine organisms and an irreplaceable nursery ground for many creatures, including the American and European eels, which migrate across the ocean to spawn there. The Sargasso Sea is a place of wonder, worthy of conservation, but now the weed that names the sea is turning up in huge amounts elsewhere, posing threats to tourism and fisheries with potentially severe economic and health consequences.

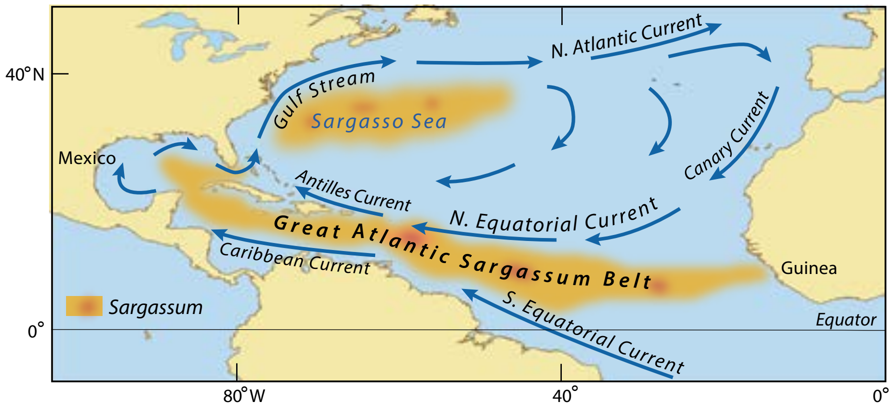


Figure 1 *The Great Atlantic* Sargassum *Belt stretches from West Africa to Central America and into the Caribbean.*

Rogue Sargassum

The Sargasso Sea often appears on maps as a discrete, delineated area in mid-ocean, but the boundaries of the *Sargassum* are always in a state of flux. It may be that *Sargassum* has escaped the clutches of the gyre to drift free, but the source of the now invasive infestation seems to be closer to home, arising from existing yet small coastal colonies that have been given a boost by 'the usual suspects' responsible for ecological turmoil: climate change, agricultural run-off and sewage spillage, introduced from polluted rivers, and enriching iron, blown from deforested landscapes. This perilous anthropogenic cocktail once again appears to have upset the natural balance, encouraging what were once small, isolated pockets of *Sargassum* to bloom and spread into new territory. Now an arc of *Sargassum*, some 8800 km in length, extending between West Africa and the Caribbean, threatens coastal waters on both sides of the Atlantic. A huge band of weed, the 'Great Atlantic *Sargassum* Belt', was reported in 2019 by University of South Florida optical oceanographers as containing some 24 million tonnes of the alga.

But shouldn't we be celebrating the spread of an organism that, in mid Atlantic, has major ecological benefits? It's all a question of it being in the wrong place, the result of unnatural impacts of humans that allow the weed to thrive in new locations, having consequences for native fauna and flora. In mid ocean, *Sargassum* has evolved into a discrete, and very valuable ecosystem of its own, but the *Sargassum* that finds its way into coastal areas does not support a community of organisms and is totally out of its ecological context, causing significant damage – the hero of the mid ocean becomes the villain of the coast! The rogue *Sargassum* smothers shallow-water habitats, shading corals and seagrasses from sunlight and killing a multitude of organisms below, while trapping larger creatures such as turtles at the surface. This misplaced *Sargassum*

Figure 2 ***Left*** Sargassum *rafts are swept into bays and coves by wind and currents.* ***Right*** Sargassum *rafts rapidly build into large heaps along the shoreline, posing a threat to coastal wildlife, human health and local economies. (Photos: © Seaweed Generation)*

is having disastrous impacts on coastal fish nursery grounds and, in turn, on populations of various species of fish and spiny lobster, essential contributors to local livelihoods and economies.

Inevitably the floating weed is cast ashore, presenting a literal raft of new problems. Along the strandline vast quantities may accumulate and be metres thick (Figure 2). Here it dies and rots away producing the characteristic 'bad egg' smell of decay as hydrogen sulphide is released. The once pristine beaches and clear waters are stained dark brown. Littoral organisms become buried under the suppurating mass and suffocate; turtle eggs either fail to hatch or the hatchlings face an impossible struggle to emerge from their nests and find the sanctuary of the sea.

But it isn't just the wildlife that suffers, there are human health issues too, as noxious gases invade the air, and heavy metals are released. Caribbean resorts, famous for their crystal seas and immaculate beaches, are no longer as attractive to tourists, so local economies can be hard hit. As I began writing this in January 2023 a news alert concerning *Sargassum*, one of many that appear daily, popped onto my screen. The online *Cancun Sun* newspaper has an article (12/01/2023) explaining why February is the perfect time to visit this popular Mexican destination. Listing cheap flights, great weather and plenty of hotel rooms, it also says: 'February is the perfect time to visit Cancun as it's likely to be the last month that beaches are free from the invasion of *Sargassum*. The stinky seaweed was out in force last year, ruining the trip for many travelers – and early signs are suggesting that it will be back with a vengeance from March.' Just a few days later the *Cancun Sun* announced the 'first significant wave of *Sargassum* ... and it's come earlier than predicted'. The *Sargassum* invasion can now be regarded as an annual event; there is now a recognised 'golden tide' season, although its duration appears to be expanding by the year, and it seems like it might be here to stay and cannot be ignored.

A growing threat

It is only in the last decade that this *Sargassum* threat has grown to be of real concern, with rafts of the weed, some 40 km long, regularly approaching shallow water, and efforts to combat the ecological and economic destruction it wreaks have relied heavily on existing technologies. Local administrations within the realm of impact of the Great Atlantic *Sargassum* Belt are already spending millions of dollars in simply removing the dangerous flotsam using manual labour, bulldozers, and booms just offshore. The collected seaweed is dumped in landfill where it continues to decay and emit noxious and greenhouse gases (including CO_2 and methane), while attempts to recycle it as agricultural fertilisers are thwarted by the toxic cocktail it contains. Recent research has shown that crops grown with *Sargassum* fertiliser sourced from the Great Atlantic *Sargassum* Belt have higher levels of heavy metals, particularly arsenic and cadmium, than those grown without the fertiliser.

By the time the *Sargassum* is heaped on beaches or cloaking shallow waters the ecological damage is already done. Now a UK-based start-up company, centred on the University of Exeter – Seaweed Generation – is developing a technology that will capture the floating *Sargassum* before it reaches shallow coastal waters and beaches, and safely dispose of it, with the bonus that it can also contribute to the removal of greenhouse gases from the atmosphere.

AlgaRay – the solution

The Seaweed Generation team has a track record of using a range of algal species to extract useful products ranging from cosmetics, food ingredients and nutraceuticals, to biostimulants and biofuels. Seaweed Generation is already developing technologies to grow and harvest seaweeds for such products, and at scale as a mechanism for carbon removal, so it's a natural extension to turn its attention to the rogue *Sargassum* problem. The company, led by CEO Patricia (Paddy) Estridge and Chief Science Officer Professor Mike Allen, has come up with an ingenious idea for removing the threatening weed before its gets to shore. It is elegantly simple and cost-effective and so applicable to even the smallest island nations and coastal communities – those most at risk of disrupted fisheries and loss of tourism income, and those that often have the most valuable shallow-water environments.

Paddy Estridge explains how the AlgaRay device has been designed to remove rogue *Sargassum* before it gets to shore, and to dispose of it and the carbon it contains:

> 'This device has been through many design iterations to the point where we now have a very efficient working prototype; it resembles a bright yellow Manta ray. Like its namesake it cruises the surface waters scooping up its prey – plankton for Mantas, *Sargassum* for AlgaRay. I think of it as Pacman meets Roomba. We aim for shoals of 10 m-wide AlgaRays scouring the *Sargassum* rafts, 'swallowing' the weed before it gets close to land. Once each AlgaRay has 'devoured' around 16 tonnes of the pernicious weed, it will dive into deeper water where it deposits the *Sargassum* out of harm's way. While everything we know indicates that impact on deep seafloor biota is likely to be insignificant we shall be monitoring all of our activities to ensure we don't create a new problem by solving an existing one. Further careful observation during operation will also determine whether we are catching other marine life while we harvest the weed. We are certain that the design of AlgaRay will prevent this, but we'll be monitoring just in case.'

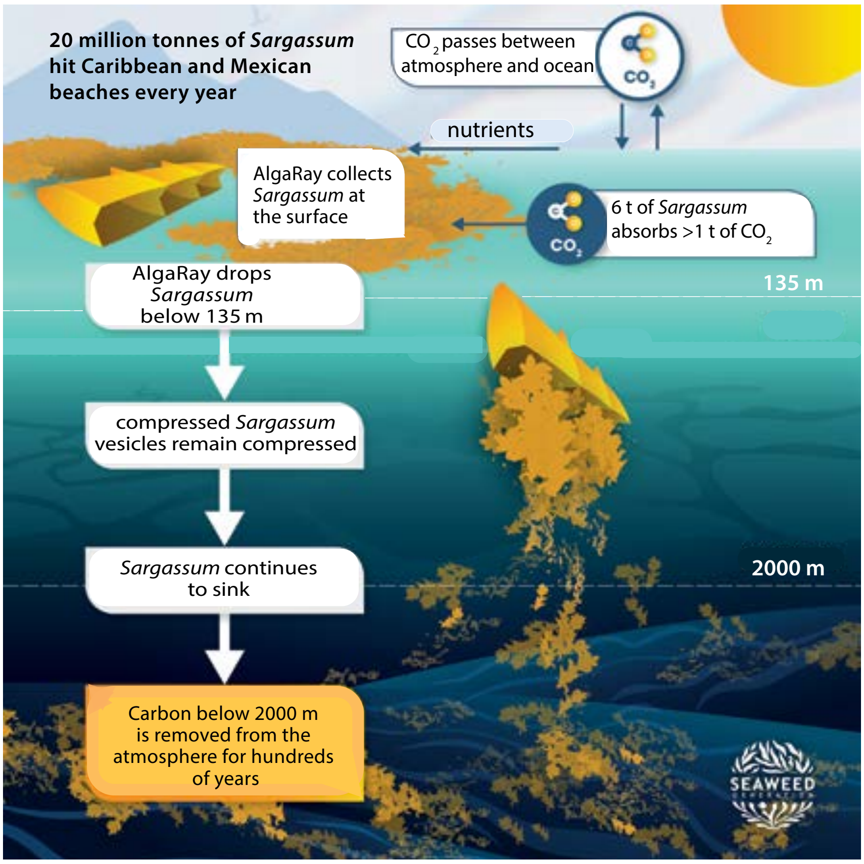
Negative asset

Essential to the success of this operation is a property of *Sargassum* that can render it negatively buoyant so that it sinks down to deeper water. Mike Allen explains the science:

> '*Sargassum* is an unusual seaweed in that it floats in open water without the requirement to be anchored to a substrate, which is why it can survive out in the mid-Atlantic. It does this thanks to the grape-like pneumatocysts, or air

Figure 3 *Manta rays cruise for plankton, AlgaRays will scour the surface for* Sargassum *weed. A prototype AlgaRay is towed behind a boat to tests its performance, but AlgaRay will eventually become fully autonomous.* ***Inset*** Sargassum *being scooped into the AlgaRay.*

Figure 4 ***Above*** *Air-filled vesicles keep the* Sargassum *afloat, but at depth the air in them is compressed and the negatively buoyant weed sinks to the deep sea bed.* ***Right*** *AlgaRay will collect* Sargassum *floating at the surface and deposit it out of harm's way at depth.* *(© Seaweed Generation)*



bladders, that keep it suspended in the water, at the surface where it can photosynthesise. Experiments have shown that for *Sargassum* to attain negative buoyancy, so that it sinks, almost 100% of the air-containing vesicles have to be squashed. Mechanical squeezing to flatten the pneumatocysts is energetically costly and can be difficult, and may only result in 90% success, not enough to achieve the negative buoyancy required. However, at depths of between 150 and 200 m below the sea surface the pressure is such that all air is compressed, and the weed can sink down to 2000 m or more. At this depth the *Sargassum* will likely remain for centuries if not millennia, eventually becoming recycled through deep sea bed food chains or being sequestered into sediments, no longer a threat and safely locked away. Once AlgaRay has released its payload, it will ascend to gather its next consignment.'

CO_2 removal

While this is aimed at being a very accessible and efficient solution to *Sargassum* on beaches and in shallow waters, it may also play a significant role in CO_2 removal. *Sargassum* is very efficient at sequestering CO_2 into its tissues as it grows, so removing the weed from surface waters also removes CO_2. Estimates show that each AlgaRay trip will take the equivalent of two tonnes of CO_2 down with it, locking it away from the surface waters and the atmosphere. The device is capable of up to four trips per hour, and taking into consideration the seasonality of *Sargassum* inundations, inclement weather conditions, such as caused by hurricanes, and other negative factors that may affect efficiency, a single operational unit will be able to collect and sink around 8000 tonnes of CO_2 each year.

As AlgaRay is further developed and refined, its capturing capacity will greatly increase, limited only by the sunlight available to power the solar cells that drive it through the weed and down to the depths. The concept has already been tested successfully in sea trials, and the next step is to put the prototype to work *in situ*, off the coasts of Antigua and Barbuda, with the blessing of the islands' government. Once AlgaRay is proven, as is fully expected, schools of AlgaRays will be deployed, using the power of the sun to propel them, and artificial intelligence fed by remotely sensed satellite data to steer them to their 'prey'. Previously, individual AlgaRays were towed behind vessels into the path of encroaching *Sargassum*; the latest iteration is remotely operated from a support vessel. The aim is for fleets of them to be totally autonomous, going about their task of keeping Caribbean beaches clear of *Sargassum*, protecting coastal wildlife, and making a significant contribution to reducing climate change by removing CO_2 and sequestering it from the atmosphere, out of harm's way.

For more information about AlgaRay and other projects being developed by Seaweed Generation please visit: www.seaweed-generation.com

We would like to thank Chuanmin Hu for information about the present-day distribution of *Sargassum* in the Sargasso Sea, as represented in Figure 1.

Further reading

Gouvêa, L.P. and 12 others (2020) Golden carbon of *Sargassum* forests revealed as an opportunity for climate change mitigation. *Science of The Total Environment* **729**, 10 August 2020, 138745. doi: 10.1016/j.scitotenv.2020.138745

Gray, L.A. (2020) *Sequestering Floating Biomass in the Deep Ocean: "Sargassum Ocean Sequestration of Carbon" (SOS Carbon)*. https://dspace.mit.edu/handle/1721.1/127483

Johnson, J. and S. Engel (2022) *Sargassum* fertilizer transfers heavy metals to vegetables. *BioNews-54 Dutch Caribbean Newsletter. Dutch Caribbean Biodiversity Database*. https://www.dcbd.nl/document/sargassum-fertilizer-transfers-heavy-metals-vegetables

Resiere, D. (2018) *Sargassum* seaweed on Caribbean islands: an international public health concern. *The Lancet* **392**, 10165. doi: 10.1016/S0140-6736(18)32777-6

Wang, M., C. Hu, B.B. Barnes, G. Mitchum, B. Lapointe, and J. P. Montoya (2019) The great Atlantic *Sargassum* Belt. *Science*, **365**, 83–7. doi: 10.1126/science.aaw7912

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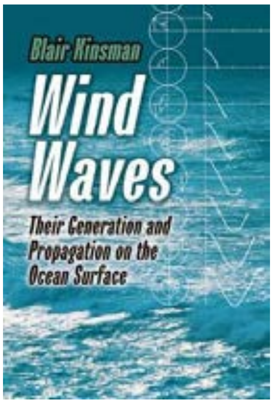
Books that have inspired us

Here is the second in a series about books that have influenced our lives as marine scientists. Do you have such a book? If so, please let us know. If you would like to write about two books, as one of our contributors has this time, you would be most welcome. *Ed.*

Wind Waves: Their Generation and Propagation on the Ocean Surface
by Blair Kinsman

Dover Publications, Inc., New York, 2012, originally published by Prentice-Hall, Englewood Cliffs, N.J. in 1965; a 2nd edition by Dover Publications Inc., including a new Preface by the author, came out in 1984.



Chosen by Judith Wolf, numerical modeller of hydrodynamics, waves and their interactions

Blair Kinsman (1914–1989) – a dedicated and gifted teacher and a physical oceanographer who specialised in wind waves – was a Professor in the Department of Oceanography at the John Hopkins University when he wrote this book. He was later a member of the faculty of the Marine Sciences Research Center at Stony Brook University (1977 to 1980) and played a major role in the design and development of the Center's doctoral programme in Coastal Oceanography.

I first read *Wind Waves* – then fairly recently published – while I was studying maths and physical oceanography at the University College of North Wales, Bangor (as it was known in the early 1970s). I read it again, many years later, when I found I was working a lot on wave modelling, and realised how much I had been influenced by it. As a mathematician with an interest in physical geography, I initially had no real clue where my career would take me, but waves had always fascinated me. The fact that you can observe many of the phenomena related to surface wind waves with your naked eye, plus the power of wave theory to explain oceanographic processes, make this area of study both broad and deep.

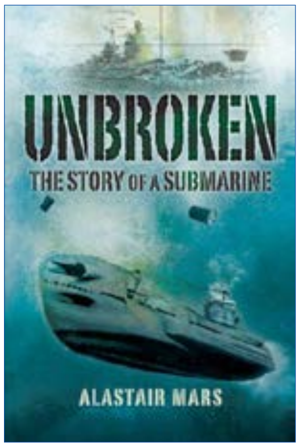
Blair Kinsman's beautiful writing enthralled me: 'If you look out over the sea, you get the impression that there is an endlessly moving succession of irregular humps and hollows reaching from horizon to horizon. If the winds are light, the irregularities are small. If the winds are heavy, you may be awed by gigantic storm seas ... Even when drifting in a glassy calm, you will usually find the ocean heaving itself in a low smooth swell whose source is a storm which may have occurred days before and hundreds of miles away.' At the first time of reading I had never been at sea, but since then I have sailed thousands of miles and never ceased to wonder at the beauty and power of the ocean surface.

I was struck by how quickly the book goes from lyrical descriptions of the ocean to practical seamanship (describing the power of waves when they arrive in shallow water: 'Never attempt to land through surf in a small boat unless you have already abandoned all hope for life'), and on to mathematics and its power to simplify and explain wave phenomena.

Blair Kinsman's classic book introduces the nature of waves and wave processes, along with methods of measurement and analysis. The data requirements and details of the power spectral analysis method are discussed. This analysis was pretty revolutionary in 1965, since computing power was still in its early stages of development. Further topics include perturbations of irrotational motion, energy considerations, the mystery of wave generation by wind, and much more. The way the chapters are introduced still thrills me. Chapter 2, for example, is on Hydrodynamics 'in which we reaffirm our faith in the efficacy of Newtonian mechanics and the fluid continuum'. This almost Biblical language let me know that a feeling of beauty and truth is amongst the rewards of studying science, although we must also use detailed and careful measurements and analysis to reach it.

Unbroken: The Story of a Submarine
by Alastair Mars

Frederick Muller, 1953
reprinted by Pen & Sword Books Ltd, 2009



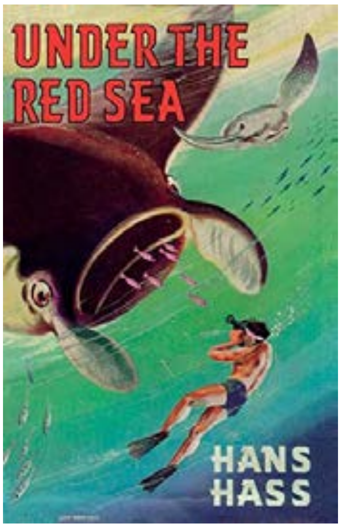
Chosen by Tony Rice, marine biologist

I have no idea why a council estate kid brought up in post-war land-locked Northamptonshire, and with absolutely no maritime antecedents, should develop a passion for the ocean, but I did. So much so that by the time I was about 12 or 13 in the early 1950s I knew that, one way or another, the seas would play a big part in my life, but exactly how was up for grabs. Two particular books pulled me in quite different directions.

The first, pulling me towards a naval career, was Alistair Mars', *Unbroken, the story of a submarine*, first published in 1953. Television being still very much in its infancy at that time, like most lads of roughly my age I had already devoured a heady mix of books, films and radio programmes based on various aspects of the recent war. Inevitably, it was the naval ones that particularly attracted me, and especially Nicholas Monsarrat's *The Cruel Sea*, published in 1951 and made into a popular film in 1953. Based on Monsarrat's own experiences, the book tells the dramatic stories of a number of crew members of a small naval corvette assigned to convoy protection against German U-boats in the North Atlantic. Inevitably, U-boats get a very bad press in the book but, somewhat perversely, this simply fuelled my existing fascination with submarines and submariners. Isolated in their cramped and highly vulnerable craft, and roaming the oceans in search of targets while hunted themselves by much larger and faster surface vessels, submariners seemed to my naive mind to epitomise a modern version of the independent derring-do attitude of the old time buccaneers intercepting Spanish bullion ships. So when *Unbroken* appeared when I was just 15 I was ready for it. It is Mars' vivid and personal account of his experiences as a 26-year-old commander of a tiny, 58 m-long submarine with a crew of 30, and particularly of its service as the only allied sub operating in the western Mediterranean in the dreadful months of 1942 when Malta was being besieged and battered by the Axis forces. *Unbroken*'s task was to try to protect convoys supplying the island and to attack enemy vessels; it was a hectic and perilous time. In little over a year she sank more than 30 000 tons of Axis, mostly Italian, shipping, and survived more than 400 depth charges, any one of which could have destroyed her.

I was besotted, and decided that the only way to avoid the dreaded National Service in the army when I reached 18 was to join the navy a.s.a.p. and get into submarines! Fortunately for me, and possibly even more so for the navy, my mother talked her sole chick out of such precipitate action (as mums did in those days) and persuaded me to stay on at school and 'get some qualifications'. So I did, and the influence of the second, and thankfully more successful, inspirational book, Hans Haas's *Under the Red Sea* had already started to kick in when it appeared in English in 1952.

Under the Red Sea
by Hans Hass
Jarrolds, 1952



Like his more egotistical near contemporary Jacques Cousteau, Haas was a pioneer scuba diver and underwater film-maker. But also like many early divers, his initial attitude to the undersea world was less than politically correct by modern standards, given that he was mainly interested in killing more or less anything he encountered, and the bigger the better. For instance, he was accused, admittedly unfairly, of being personally responsible for the local extinction of the Atlantic goliath grouper in the Caribbean, and the title of his *Red Sea* book originally included the words 'with spear and camera'. But this phrase was removed from the TV film based on the book which appeared a few months later. For by that time, Haas had realised that live marine animals, from corals to sharks, have much more public appeal than dead ones, so that from then on his many books and films had a much stronger conservationist theme. And he also had the foresight to marry his young blonde diving assistant, Charlotte or Lotte, who was at least as good a diver and film-maker, and much more attractive than him to at least half of the potential audience. I was hooked by the translated text and the grainy black and white still and movie images of the then alien underwater world. Ten years later, as a Ph.D student at Port Erin, I became one of the founder members of the Isle of Man branch of the British Sub-Aqua Club and began my own much less exciting diving career. And the rest, as they often say rather irritatingly, is history.

Oh, except that I never did do National Service either in or out of submarines. In a last ditch effort to improve my chances of getting into the navy when the dreaded call eventually came, as an undergraduate in Liverpool I tried to join the Royal Naval Volunteer Reserve – but was firmly rejected! In no uncertain terms, the recruiting officer pointed out to me that, while they were anxious to attract recruits with all manner of skills, marine biology was definitely not one of them, so I should prepare myself for the army! But I needn't have worried. Having had my National Service deferred to do a first degree and then a Ph.D, in my second year in Port Erin the government abandoned National Service completely. Good on yer Mum!

If there is a book that has changed the course of your career, or inspired you in some way, please write in and tell others about it.

Send your recommendations (300–400 words) to AngelaMColling@gmail.com

Collins Pocket Guide to the Sea Shore
by John Barrett and C.M. Yonge
Collins, 1958 (frequently reprinted)

Chosen by Nick Owens
marine biogeochemist
(his own treasured copy is shown above)

It was not an entirely straightforward decision to choose Barrett and Yonge (B&Y) as my 'inspirational book'. Hardy's classic *The Open Sea* (featured in the first of this series) immediately came to mind. Another was Rachel Carson's trilogy, usually collected in one volume – *The Sea*. Both these masterpieces influenced me hugely. But on reflection I came to them because of B&Y, my constant companion and guide as I roamed the shores of the Solway Firth, during a solitary period of recovery from illness. Aged around 13, I contracted jaundice; although the initial stages were horrid, I quickly recovered, but was barred from returning to boarding school, for fear of infecting my school mates. No home schooling for me; rather, three months of wandering (together with my dog), discovering and studying the shoreline inhabitants with this inspirational and necessary guide to an unfamiliar world.

No lofty prose as in Carson or Hardy but instead wonderfully succinct descriptions of all the animals and 'plants' (their term) one is likely to find between the extremes of the tides of the North Atlantic. There is a splendid essay about the intertidal environment by way of introduction, and over 750 beautiful drawings and black-and-white and colour plates: a veritable feast. While Hardy and Carson *cemented* the foundations of my career, it was Barrett and Yonge that *laid* them. My original 1960s copy is sadly mislaid but the one I still treasure (1972) has a bookmark of a blessed palm from a Palm Sunday church service, a poignant reminder of Easter field-courses as an undergraduate on the splendid shores of the Isle of Man. Happy days!

The Winter Krill Project

Cecilia Liszka and Martin Collins

Antarctic krill (*Euphausia superba*) (Figure 1) is a vitally important species of crustacean, considered the 'keystone' species of the Southern Ocean food web. The largest of the euphausiid species at up to 10 cm long, krill play a critical role in transferring energy and nutrients between primary producers and higher trophic levels and supporting vast populations of the most iconic Southern Ocean animals, including numerous species of penguins, seals, seabirds and whales.

Krill are found in their greatest numbers in the South Atlantic sector of the Southern Ocean, where vast swarms commonly occupy areas up to 100 km^2, and the sea-ice and currents that encircle Antarctica play an important role in their life cycle. Krill larvae are heavily reliant upon the sea-ice habitat around the Antarctic Peninsula, and the young krill are carried north-east on the Antarctic Circumpolar Current (ACC) towards the island of South Georgia (Figure 2, inset) where, as adults, they become key prey for many of South Georgia's abundant marine predators.

Management and conservation

The sub-Antarctic island of South Georgia forms part of the UK Overseas Territory of South Georgia and the South Sandwich Islands (SGSSI). It is surrounded by a Marine Protected Area (MPA) which was established in 2012 to conserve the important biodiversity of these waters, and which is reviewed at five-yearly intervals. The abundance and biomass of Antarctic krill around South Georgia also make them the focus of a valuable commercial fishery.

To balance the interests of the krill fishery with the requirements of the predators that rely on krill, this fishery is carefully managed, firstly by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) which sets maximum catch limits for zones within the Southern Ocean, and secondly by the SGSSI Government which imposes further restrictions specific to the South Georgia region (CCAMLR sub-area 48.3) (Figure 2). Together, these management structures regulate the activity of the South Georgia fishery, for example by: imposing a maximum annual catch limit of 279 000 tonnes; only allowing it to operate during the winter months (outside of breeding seasons of key predators); and prohibiting fishing inside 30 km No-Take Zones (NTZs) surrounding South Georgia and the South Sandwich Islands.

Monitoring over recent decades

To monitor the impact of the fishery on wildlife, and inform conservation policies for South Georgia, scientists at the research stations at King Edward Point (near Maiviken) and Bird Island regularly collect samples of plankton including krill, analyse the dietary composition of Antarctic fur seals, and measure the breeding success of these and other key predators. In addition, krill biomass has been routinely monitored for the last 20+ years with the British Antarctic Survey's Western Core Box (WCB)* survey work, which includes a series of pre-defined acoustic transects to monitor krill abundance and biomass (Figure 2). These BAS monitoring programmes have resulted in unparalleled insights into the ecology of krill around South Georgia, and their spatial and temporal variability, albeit focussed predominantly on spring and summer. In contrast, there is very little information on the winter period, and as the fishery around South

Figure 1 *Antarctic krill (*Euphausia superba*) may be small but they are a vital part of Southern Ocean ecosystems, sustaining important Antarctic wildlife and vital biogeochemical cycling. (Photo: Martin Collins)*

*The BAS Western and Eastern Core Boxes (WCB and ECB) are 80 km x 100 km survey boxes, located on the north-western and north-eastern shelves of South Georgia respectively. The WCB has been monitored annually since 1996 to provide a unique time series of mesoscale distribution and abundance of macrozooplankton and micronekton, and an understanding of their physical environment at South Georgia. The ECB has also been periodically surveyed, with more regular monitoring in recent years.

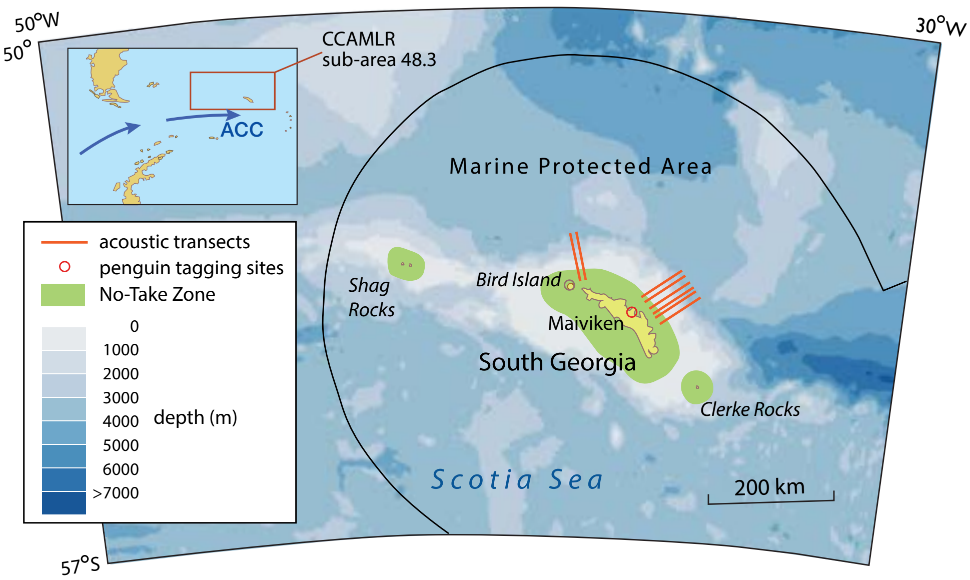


Figure 2 *Map of CCAMLR sub-area 48.3 encompassing South Georgia showing the Winter Krill Project acoustic transects (red lines), penguin tagging sites, the MPA boundary (solid black line) and the 30 km No-Take Zones (green) imposed by the SGSSI Government. The acoustic transects surveyed in the Winter Krill Project include two Western Core Box transects and six Eastern Core Box transects. Large aggregations of krill are frequently found around the shelf or shelf-break (~200 m), in relatively shallow water.*
Inset *CCAMLR sub-area 48.3 (red box) in relation to the tip of South America, the Antarctic Peninsula, and the path of the Antarctic Circumpolar Current (ACC).*
(Cecilia Liszka)

Georgia operates exclusively during the winter, there is a temporal mismatch between management of the fishery and the data required to inform it.

It is becoming increasingly apparent that there is an information gap that needs to be filled: whilst a 279 000 tonne annual catch limit for krill in the South Georgia region applies to a large area, the fishery tends to concentrate in an area of shelf *north-east* of South Georgia. This area coincides with important foraging grounds of South Georgia's Antarctic fur seals and gentoo penguins (cf. Figure 5) which do not fully disperse during the winter, and recent work suggests that these predators may extend their foraging ranges beyond the NTZ, increasing the risk of direct competition with the fishery, particularly in poor krill years. We are also now seeing the welcome return of baleen whales which also rely on krill for their food, but we do not know how many of these whales remain in the vicinity of South Georgia over the winter. To compound the problem, fishery catches have been increasing over the last two decades, potentially intensifying the effect of other pressures on krill populations, for example the southward contraction of krill distributions due to regional warming. A clearer understanding of the abundance and distribution of krill during winter is therefore critical.

The Winter Krill Project

Obtaining that understanding is the focus of an exciting project that started in December 2021, led by the British Antarctic Survey in partnership with the SGSSI Government and the Antarctic Research Trust, and funded by Defra's Darwin Plus scheme. The objective of the project is to obtain information on (1) the distribution and abundance of Antarctic krill during the winter; and (2) overlap between the distribution of krill-dependent predators and krill in the fishery area.

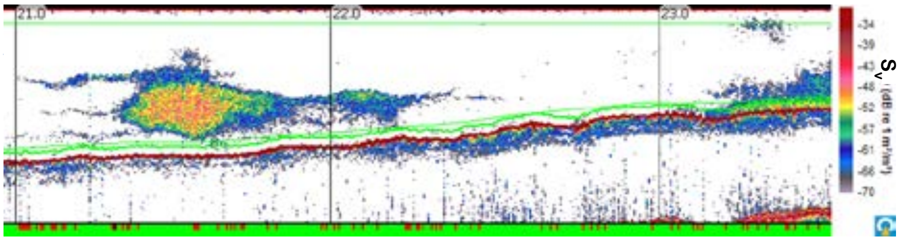


Figure 3 *An example of an echogram image showing a large aggregation of krill close to the sea floor. The backscatter strength, S_v, can be converted into a measure of krill biomass (g m^{-3}) using information from plankton trawls undertaken alongside the acoustic surveys.*

To achieve this, we are carrying out comprehensive surveys of krill and their predators over two consecutive austral winters (2022 and 2023), with three periods of fieldwork each year that are timed to correspond with the start (May), middle (July) and end (September) of the krill fishing season. Central to the project is acoustic monitoring focussed on the areas of greatest overlap with the krill fishery, which will generate data on krill abundance and distribution both within and outside the NTZ. This monitoring covers not only six transects in the Eastern Core Box (ECB), but also two transects from the routinely monitored WCB (Figure 2), with all surveyed during both day and night whenever possible. As the WCB is usually surveyed during austral summer, this will enable us to make both spatial and temporal comparisons. To determine krill biomass from the acoustic data (Figure 3), plankton trawls are conducted in association with each acoustic transect. These provide the krill length–frequency data which are used in the conversion of acoustic backscatter strength to biomass.

The survey work is being facilitated by the SGSSI Government fisheries patrol vessel, MV *Pharos SG,* which in March 2022 was fitted with a scientific echosounder (Simrad EK80) with 38 and 120 kHz transducers specifically for the project. This new technical capacity will also enable the SGSSI Government to continue monitoring krill acoustically throughout the year beyond the duration of the project.

To understand how krill-dependent predators interact with their prey during winter, and to determine potential overlap between predators and the krill fishery, cetacean and seabird observations are being carried out alongside the daytime acoustic transects. In 2022, a specialist seabird observer obtained bird counts using standard JNCC* Seabirds at Sea methodology from the bridge of the MV *Pharos SG* during each survey, and in July 2022 – i.e. during the time of year we currently know least about – a team of three specialist cetacean researchers joined the vessel to collect more detailed sightings data for whales. Where possible, cetacean

*UK Joint Nature Conservation Committee.

Figure 4 ***Below*** *Southern Ocean blue whales depend on krill, and may ingest up to 4 tonnes of krill a day. (Photo: Martin Collins)* ***Right*** *Krill are an important food source for many seabirds, including* ***(above)*** *wandering albatross and* ***(below)*** *snow petrels, here with the mountains of South Georgia in the background. (Photos: Martin Collins and Ryan Irvine)*

photo identification is also being gathered to provide information on residency, movement patterns, and which groups individual whales belong to, and photographs of humpback whales are being uploaded to https://happywhale.com/home for comparison with other Southern Hemisphere images. To gather wider data on cetacean distribution from beyond the range of visual sightings, passive acoustic DIFAR sonobuoys (Ultra Electronics HIDAR units) are deployed to acoustically locate whales in real time, and record their vocalisations. This is made possible through funding provided by Friends of South Georgia Island and South Georgia Heritage Trust.

We are also working in collaboration with the Antarctic Research Trust, who are providing the project with 12 Wildlife Computers satellite tags each year. In the first year of the project, we deployed six satellite tracking tags on gentoo penguins at both Bird Island and the study site at Maiviken (Figure 2). Four tags were deployed at each site in advance of the May survey, and a further two were deployed at each site in July. These tags send locations by satellite for as long as the batteries last, and do not require the birds to be recaptured to obtain data. We also deployed GPS tags which provided position data on seven further birds at Bird Island. These provide more detailed locations but require the birds to return within 1 km of a base station to relay the data. Combined, the two groups of tags are providing us with some fascinating insights into the foraging behaviour of the gentoos throughout winter and into spring.

So far, we have completed the first full year of surveys, and we are about to embark on the second year. We are already delving into the rich suite of data to explore the ecology of krill and its predators during winter, so we can put this information into the context of fishery operations, and use what this reveals to inform future management of the fishery. We look forward to sharing the results of this work as they emerge.

The project's progress can be followed on our website: https://www.bas.ac.uk/project/winter-krill-at-south-georgia/. To get in touch or to join our stakeholder mailing list, please email ceclis56@bas.ac.uk or macol@bas.ac.uk.

Further reading

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Figure 5 *Maiviken Bay in South Georgia with some of the tagged gentoo penguins in the foreground and fur seals on the left. The fisheries vessel, MV* Pharos SG *can be seen at anchor offshore. The photo was taken during the austral winter (July). (Photo: Kate Owen)*

Preparations for the *Challenger* voyage – and for a parallel German venture

John Gould

In February 1876, two naval vessels anchored in the River Plate off Montevideo, Uruguay. Each was near the end of a pioneering multiyear, scientific circumnavigation. The voyage of HMS *Challenger* is well known and documented in numerous reports and publications. Its data, biological and sea bed samples continue to be analysed today. The other, by the German vessel SMS* *Gazelle*, had similar goals and yet is much less well known. How were those expeditions planned and what were their similarities and differences?

The scientific and technological context

The 1860s and 1870s were decades of invention, expansion and change. At sea, steam and sail co-existed, with many ships now powered with both sails and steam-driven screw propulsion using coal-fired boilers. Sails freed them from total dependence on widely spaced coaling stations on long voyages, while steam gave them greater manoeuvrability in light winds and in confined waters.

In June 1870, a new era dawned as the final connection was made in a telegraph cable linking Britain to India. Laying and maintaining submarine cables brought about a growth in what we now call marine technology. Ships with suitable steam-powered winches were needed to deploy the submarine cables and to recover them if they failed. Critically, knowledge was needed of ocean depths and of the nature of the sea bed, not just close to land but along the entire cable routes.

Before the 1870s, there had been very few global scale expeditions, and certainly a very small number had a significant scientific component. Most had been aboard British vessels: HMS *Endeavour*, 1776–1781 (commanded by James Cook); HMS *Discovery* and HMS *Chatham,* 1792–1795 (George Vancouver); HMS *Investigator,* 1801–1803 (Matthew Flinders); and HMS *Beagle,* 1831–1836 (Robert Fitzroy). Some of these vessels carried civilian scientists, notably Joseph Banks with Cook and Charles Darwin with Fitzroy.

Less well known are the two voyages led by Jules Dumont d'Urville aboard the French ship *l'Astrolabe* (1826–29 and 1837–40). Both had a Pacific and Australasian focus, but the second sought to reach the south magnetic pole. The 1857–1859 circumnavigation by SMS *Novara* on behalf of the Austro-Hungarian Navy involved scientists, and its investigations were guided by Alexander von Humboldt, who exhorted them *inter alia* to measure sea temperatures and ocean currents (using drift bottles), and to create benchmarks against which sea level change could be measured. However, it is also little known.

Many years of seafaring had resulted in the accumulation of a great deal of knowledge about waves and currents. These were systematically analysed and summarised in Matthew Maury's *Physical Geography of the Sea*, an initiative perhaps in part stimulated by Benjamin Franklin's study of the Gulf Stream and Timothy Folger's map published in 1778, and by James Rennell's posthumously published study of ocean currents.

Safe access to ports depended on knowledge of the state of the tides, and during the 19th century many more places, mostly in Europe and North America, started to collect systematic tidal observations. The understanding of tidal theory increased to the point where a tidal prediction machine could be built by Sir William Thomson in 1872. However, below the surface, the oceans remained unexplored and unknown save for the discoveries made on a small number of pioneering voyages, notably the research of William Carpenter, Gwyn Jeffreys, and Charles Wyville Thomson on HMS *Lightning* and HMS *Porcupine* in 1869.

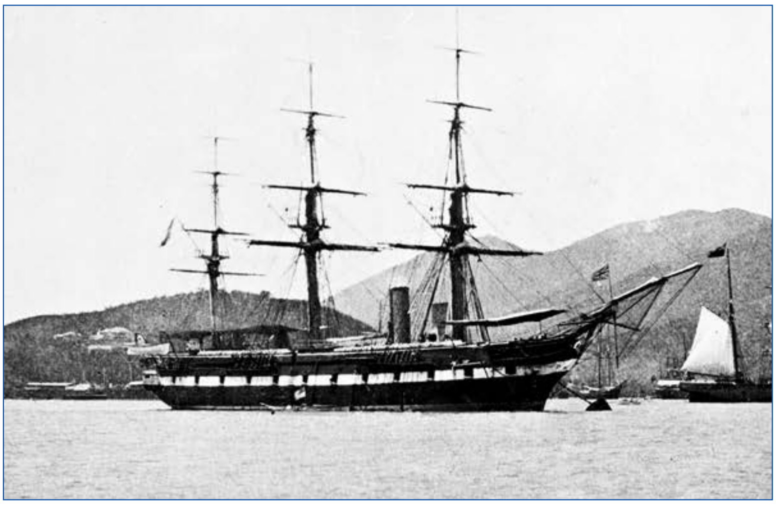
This article is an abridged version of a paper first published in **History of Geo- and Space. Sciences** *(see p.25 for more details)*

*SMS = Seiner Majestät Schiff (His Majesty's Ship).

The large-scale understanding of terrestrial geological features was at that time encapsulated in the various works of Charles Lyell between 1830 and 1868, notably his *Principles of Geology*. The development of the understanding of the terrestrial and coastal flora and fauna had been published in Darwin's *Origin of Species*.

Naval involvement in the two expeditions

Present-day expeditions with global scope require detailed and extensive planning and the commitment of substantial resources. The same was true in the 1870s, and the fact that both of these voyages were carried out using naval vessels indicated national levels of commitment. However, the *Challenger* and *Gazelle* belonged to very different navies, although both were in the midst of a transition from sail to steam.



Although smaller than* Gazelle, Challenger *must have been less crowded

Figure 1 Above *HMS* Challenger *at St Thomas, West Indies, in March 1873. Her length/beam/draught (in m) were 68.7/12.3/5.7 and her displacement was 2137 tonnes. She had a 1450 HP two-cylinder trunk engine, and a two-blade screw. She sailed with a complement of 233 (175 naval naval personnel, 50 boys, 6 scientists, 1 lab assistant, 1 domestic servant).*

Below *SMS* Gazelle. *Her length/beam/draught (in m) were 72.0/13.0/6.5 and her displacement was 2391 tonnes. She had a 1320 HP single expansion steam engine, and a two-blade screw. She sailed with a complement of 338 (officers, crew and 1 scientist).*

(Photos: Trustees of the Natural History Museum, London; Archives of Marineschule Mürwik, Germany)

Both ships required modification to prepare them for their multi-year voyages and for the changes from their normal naval duties. Their standard pre-expedition armaments were reduced, less so in the case of *Gazelle*, perhaps reflecting the exhortation in her first sailing orders that she 'must retain the character of a warship'.

The Challenger *Expedition and the Royal Navy*

The Royal Navy was long-established and in the 1870s was arguably the sole global sea power, a position encapsulated in the phrase 'Britannia rules the waves' originating in the 1760s. As already mentioned, the Royal Navy also had a long history of its ships carrying out global scale voyages of exploration. The Navy's role in, and support for, the *Challenger* voyage is unsurprising.

The rationale behind the *Challenger* expedition is summarised in the introduction to Wyville Thomson's 1878 report on the Atlantic, largely written while *Challenger* was still at sea. The report is dedicated to the Right Honourable George Goschen MP (Figure 2), 'the First Lord of the Admiralty under whose administration the *Challenger* expedition was organised', a clear recognition of the scientists' indebtedness to the Admiralty.

Wyville Thomson states the following:

> '... and finally Dr. Carpenter addressed a letter to the First Lord of the Admiralty, urging the dispatch of a circumnavigating expedition thoroughly equipped, and with a competent scientific staff, to traverse the great ocean basins and prepare sections showing their physical and biological conditions, along certain lines. Dr Carpenter's letter was referred in due course to the Hydrographer to the Navy, who at once threw himself cordially into the project and prepared a report, which resulted in the Lords of the Admiralty agreeing to the dispatch of such an expedition if the Royal Society recommended it, and provided them with a feasible scheme. A committee was appointed by the Royal Society, and the comprehensive scheme was set up.'

This was to be an unusual arrangement with a fully equipped naval survey vessel carrying out her normal duties as detailed in the sailing instructions issued to her commanding officer and yet carrying a team of distinguished, civilian scientists each with their own interests and more loosely defined objectives and with a recognised scientific leader. These potential tensions are alluded to by Wyville Thomson in the preface to the report on the Atlantic, but, clearly, they did not pose a problem:

> 'The somewhat critical experiment of associating a party of civilians, holding to a certain extent an independent position, with the naval staff of a man-of-war, has for once been successful.

Captain Nares and Captain Thomson both fully recognized that the expedition was intended for scientific purposes, and I do not think that in one single case the operations of the combined scientific staff were hampered in the least by avoidable service routine. All the naval officers, without exception, assisted the civilian staff in every way in their power, and in the most friendly spirit. If I wished anything done I had only to consider who was the man, naval or civilian, who was likely to do it best; and the consequence has been that, with the entire sanction of Captain Nares and Captain Thomson, the parties sent to camp out or detailed for any special service have always been mixed, to the great advantage, I believe, of all concerned.'

The Gazelle *voyage and the new German navy*

The Imperial German Navy (Kaiserliche Marine) had only come into existence after the foundation of the German Reich in 1871. It grew out of the Prussian Navy and was headed by General Albrecht von Stosch (1818–1896) (Figure 2). The personal memoirs of Admiral Alfred von Tirpitz provide some context in terms of von Stosch's leadership, of the new navy's primary objectives, and of the wider political climate.

> '[von] Stosch started from the idea of developing Germany's maritime interests, of strengthening and protecting "Germandom" and German labour in the world.
>
> Stosch's increasing endeavour to further Germany's maritime interests in all directions was pursued under great difficulties from the beginning of his period of office. Foreign service at this time almost overstrained the resources of the navy. Every commander, however, could reckon upon Stosch's consistent support in his activities abroad, even in the often independent and difficult decisions which foreign service required as a result of the scarcity of cable connections. But this was not done without some friction with the Imperial Chancellor.'

Von Tirpitz remarks that the continuing Prussian influences in Germany's government favoured the army over the new navy, which was seen as being tainted with links to commerce and trade:

> 'As far back as the seventies Stosch was convinced that we must acquire colonies and that we could not continue in existence without some means of expansion. He considered that the prosperity of the young empire would only be ephemeral if we did not counterbalance the decided disadvantage of our position and history overseas before it was too late.
>
> He attached great value to the posting of cruisers to foreign stations, and rightly too in his time.'

There is however a clear hint that von Stosch supported the new navy being technologically and scientifically advanced. He founded a naval academy at Kiel at which:

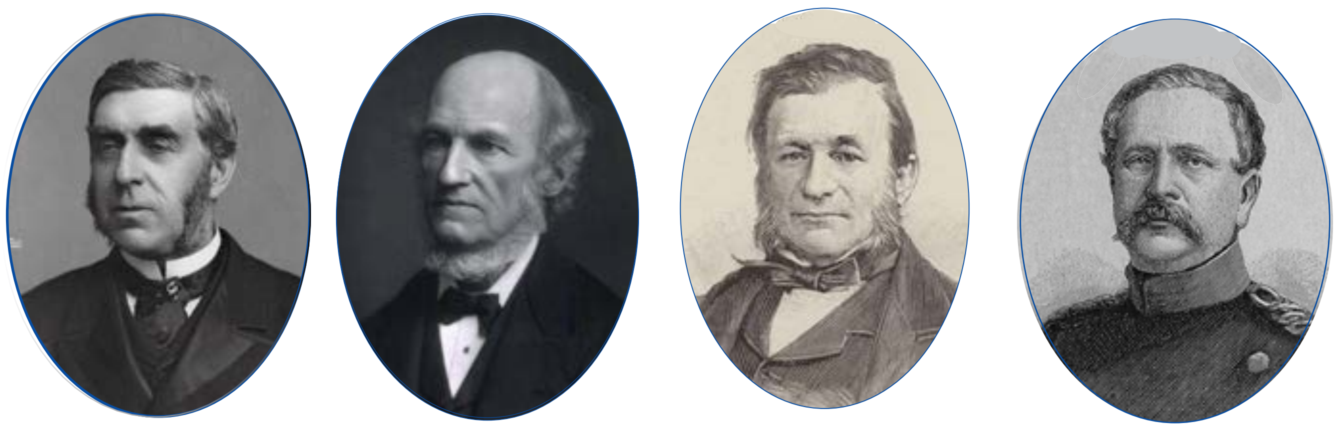
> 'A great deal of mathematics was taught, besides philosophy, natural and nautical science (regarding which we sent many observations to the museums during our voyages), and astronomy, which in any case can be reckoned among the special sciences.'

Von Tirpitz also remarks on the high esteem in which the British (English) Royal Navy was held, both in terms of military experience and technical prowess, as the following quotation makes clear:

> 'We grew up on the British Navy like a creeping plant. We preferred to get our supplies from England. If an engine ran smoothly and without a hitch, if a rope or a chain did not break, then it was certain not to be a homemade article but a product of English workshops – a rope with the famous red strand of the British Navy. In those ships which we had built ourselves things broke with uncomfortable readiness.'

Figure 2 *The principle eminent supporters of the two expeditions.* ***Far Left*** *The First Lord of the Admiralty, the Right Honourable George Goschen (1831–1907).* ***Centre left*** *William Carpenter (1813–1885), a physiologist with wide-ranging interests who sailed on the pioneering voyage of HMS* Porcupine *in 1869, and played a key role in convincing both the Admiralty and the British government to undertake a large-scale oceanographic expedition.* ***Centre right*** *Admiral George Richards (1820–1896). For 20 years Richards was chairman of Telcon, a telegraph construction company responsible for laying 76 000 miles of submarine cables.* ***Far Right*** *General Albrecht von Stosch (1818–1896) who headed the Imperial German Navy from its foundation in 1871, but who did not become an admiral until 1875. (Third image: The Bridgeman Art Library Ltd. The other three are in the public domain, reproduced via Wikimedia Commons.)*

Both expeditions benefitted from support in high places



Scientific guidance and operational orders

The plan for Challenger

The *Challenger* voyage can be seen as a continuation and expansion of the pioneering work aboard HMS *Lightning* and HMS *Porcupine.* It was given strong scientific guidance delivered primarily through the Royal Society and to a lesser extent by deliberations within the British Association for the Advancement of Science. These coalesced into a report by the Royal Society's Circumnavigation Committee. The Committee was made up of officers and council members of the Royal Society and included Carpenter, Wyville Thomson, Gwyn Jeffreys (an expert on molluscs who had collected samples on HMS *Porcupine*), Captain (later Admiral) Richards (the Admiralty's Hydrographer), the biologist Thomas Huxley (who came to be known as Darwin's bulldog for his advocacy of the theory of evolution), Sir William Thomson (renowned for his work on tides and his innovative work on submarine telegraphy and who had been involved in discussions about the voyage within the British Association), and the botanist Joseph Dalton Hooker.

The Committee's report, finalised in August 1872, recommended where *Challenger* should go and provided details of the observations that should be made and the manner in which they should be carried out. Interestingly, the report was published by the US Navy in 1872 and so became widely available. The report was also published in *Nature* in the following January.

Here it is perhaps appropriate to mention just a few striking features of the guidance – first, balance; a single page is devoted to defining the route to be taken and four pages to physical observations under the headings of 'Temperature (subsurface and surface)', 'Movements of the ocean', 'Tidal observations', 'Bench-marks', 'Specific gravity', and 'Transparency of the water'. Only half a page relates to chemical observations, five and a half pages to botany, and half a page to zoology. The concluding remarks also encourage the collection of ethnological information in remote communities.

The positioning of the depth sounding and sampling stations is prescribed only generally:

> 'In crossing the great ocean basins observations should be made at stations, the positions of which are carefully determined, chosen so far as possible at equal distances, the length of the intervals being of course dependent on circumstances.
>
> The simple determination of the depths of the ocean at tolerably regular distances throughout the entire voyage is an object of such primary importance that it should be carried out whenever possible, even when circumstances may not admit of dredging or of anything beyond sounding.'

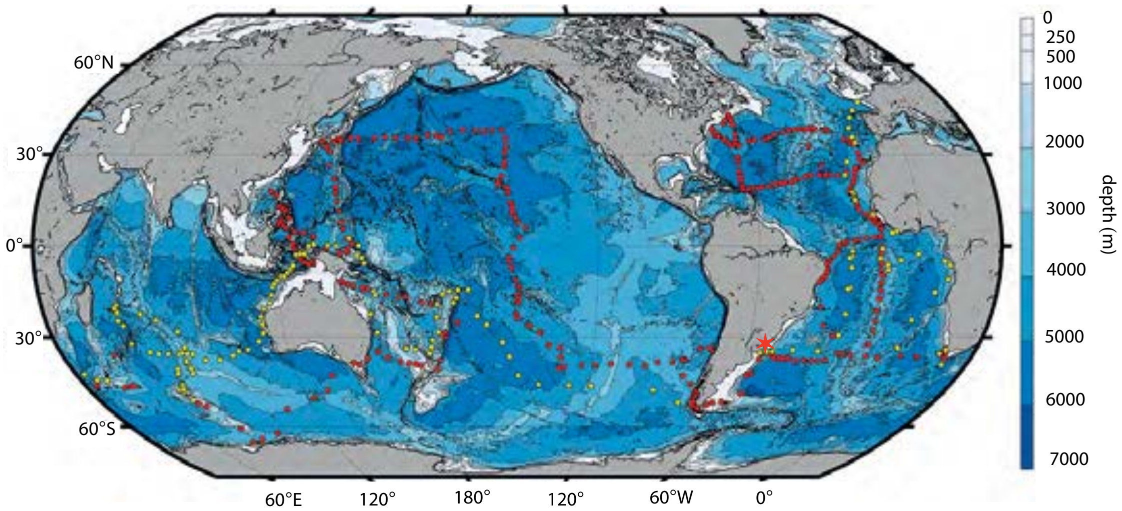
The following is also advised:

> 'Each station should have a special number associated with it in the regular journal of the day's proceedings, and that number should be noted prominently on everything connected with that station.'

Interestingly, while it is recommended that the collection of subsurface temperatures should be carried out with thermometers and with 'Mr Siemen's instrument', it is implied that the collection of serial information using thermometers would be time-consuming and that compromises in sampling strategy might have to be made.

The guidance of the Circumnavigation Committee was primarily directed towards the scientific party, but, as with all naval voyages, the *Challenger*'s commanding officer was issued with sailing orders indicating where the vessel was to go and what tasks it should undertake and setting the rules under which the vessel should operate. *Challenger*'s sailing orders, issued to the captain and to Professor Wyville Thomson both by the Navy Hydrographer, George Henry Richards, and by Robert Hall, Naval Secretary of the Admiralty, contain the following instructions to Nares.

> 'The main object of the voyage is to investigate the physical conditions of the deep sea throughout the three great ocean basins, that is, to ascertain the depth, temperature, circulation &c., to examine the physical and chemical characteristics of their deposits and to determine the distribution of organic life, throughout the areas traversed, at the surface, at intermediate depths, and especially at the deep ocean bottoms.
>
> As secondary but by no means unimportant objects are the hydrographical examination of all the unknown or partially explored regions which you may visit, a diligent search for all dangers which may be in or near your track, with a view to expunging them from the charts or definitely determining their positions, a careful series of magnetical and meteorological data, and the observation and record generally of all those oceanic and atmospheric or phenomena, which, when faithfully recorded, afford the means of compiling practical information of the greatest importance to seamen.
>
> Your own experience as the commander of a surveying ship, and the general rules which have been issued from time to time by the hydrographical department for the guidance of Admiralty Surveyors – copies of which are supplied to you – obviate the necessity of entering into any detailed instructions on this head, and I will only observe that on all the coasts along which you may pass, and at all the ports which you may visit, I shall hope to receive from you such surveys and such complete hydrographical information as circumstances and the time at your disposal may enable you to accomplish.
>
> If any one of the various objects of the expedition is more important than another, it may be said to be the accurate determination of the depth of the ocean, for on this must depend many other problems of deep scientific interest.'



***Challenger's* 68 590 n.m journey took 1250 days, (21 December 1872 to 24 May 1876); *Gazelle's* 36 000 n.m. journey took 678 days (21 June 1874 to 28 May 1876)**

Figure 3 Challenger *(red) and* Gazelle *(yellow) station positions overlaid on the now known ocean bathymetry. When both expeditions were in port at Montevideo (✶) in February 1876 they agreed that the two vessels would follow different tracks towards Europe – * Gazelle *eastwards on 35° S and then northwards on 25° W, and* Challenger *eastwards on 38° S and then northwards on 15° W.*

The part of the sailing orders describing the route (Figure 3) was prefaced with the following:

> 'The general route which it is proposed the ship should follow is shown on a chart of the world which you are provided with, and although it is possible that it may be found necessary to deviate in some degree from the course there laid down and that you may not be able to adhere strictly to the dates assigned in these instructions, yet they are to be observed as far as circumstances will admit, and there must be no departure from the general programme without the special sanction of their Lordships.'

The *Challenger* voyage was a major event in the history of the Royal Navy's Hydrographic Service and in the career of Richards (knighted in 1877 and promoted to the rank of Admiral in 1885), as is remarked in Commander Llewellyn Dawson's *Memoirs of Hydrography*, published in 1885:

> 'At the close of 1872, the chief event of Sir George Richards' official career as hydrographer took place, in the sailing of the *Challenger* on a scientific voyage of three years' duration. There is no doubt but that he was the prime mover in that undertaking from start to finish, not only in a scientific sense, owing to his position as one of the Council of the Royal Society, but especially as regards the more practical and less pleasant portion of his official duty, in successfully overcoming any monetary objection raised against its advancement. In a few remarks made in public, prior to the Challenger's departure, the hydrographer remarked that an expedition such as this, which had been the hope and dream of his life, was now on the eve of realization.'

The plan for Gazelle

The only source of information on the *Gazelle* expedition that describes the voyage's overall purpose can be found in the first volume of the published report, and it is clear that *Gazelle*'s sailing orders were drawn up with due consideration of the orders give to *Challenger*. However, the opening lines of the preface to the report* state the following:

> 'In 1874, SMS *Gazelle* was sent on a two-year voyage, firstly to carry the German expedition destined for the observation of the transit of Venus in December 1874 to the Kerguelen Islands and to take part in these observations and secondly to promote oceanography and to conduct physical and oceanographic research in the maritime sciences.'

The importance of the Transit of Venus in defining the early part of the *Gazelle* expedition is a major difference between the two voyages. *Gazelle* was tasked with transporting a team of six astronomers, led by Carl Börgen, and their equipment, to the observation site at Betsy Cove on the Island of Kerguelen in the South Indian Ocean (approx. 49° S, 69° E) (Figure 4). Following the completion of the observations, the astronomers and their equipment were to be taken to Mauritius from

*Translations of the *Gazelle* reports are by the author.

Figure 4 Gazelle *anchored in Betsy Cove, Kerguelen, during the second 1974 German Transit of Venus Expedition. (Federal Archives of Germany)*

whence they would return to Europe on a commercial vessel, and *Gazelle* would continue her circumnavigation.

The overall scientific rationale for the *Gazelle*'s oceanographic and geophysical observations is similar to that given for the *Challenger* voyage and indeed refers to her voyage which had set off 18 months before *Gazelle*. The rationale for the *Gazelle*'s work is also set in the context of Maury's promotion of the collection of systematic observations as follows:

> 'Only at the beginning of the fifties did a new area of systematic exploration of the seas begin on a strictly scientific basis. MAURY, the director of the National Observatory in Washington, deserves the credit for giving the first impetus to this and for having applied a systematic approach. After collecting oceanic and meteorological observations made by American seafarers between 1840 and 1850, he designed schemes to achieve a uniform observation system, which was given to the American ships to record their observations which were then returned to the central office after the voyage and analysed. Furthermore, following his suggestion, the government of the United States requested other seafaring nations to develop and participate in oceanic and maritime-meteorological research. They were invited to a conference in Brussels in August 1853, at which the first agreements on this were made.
>
> MAURY's efforts were particularly encouraged by the need for cable-laying overseas, which arises from the trade and transport conditions of the new era and which in turn requires precise knowledge of the depths of the sea, the nature of the seabed and other physical properties of the ocean.'

Further sailing orders (dated 3 June and 13 November 1874 and 23 June 1875) were issued by von Stosch, who by now was an Admiral. It is clear from these orders that the German Admiralty was monitoring *Challenger*'s progress as there are references to it in the first sailing orders:

> 'After leaving Kiel, after the coal has been replenished in Plymouth if necessary, you should choose the course so that it starts from the latitude of the Azores almost halfway between the course of the English ship "*Challenger*" and the European–African coast then to pass Madeira and the Canary Islands in the west and, if necessary, to call at the Cape Verde Islands to refill coal.
>
> The most recent work by HMS "*Challenger*" in the North and South Atlantic Ocean gives clues for deciding the importance of the positions with regard to these observations. There is a copy of the report on this work up to the Cape of Good Hope on board SMS "*Gazelle*", from which the main sounding positions can be taken, and since comparison observations relating to the earlier American work are also included in this report, it offers the clues for the decision of the expediency of the observation for certain stretches.'

It should be noted that *Gazelle* had virtually identical oceanographic equipment to that carried by *Challenger*. As *Gazelle*'s report noted:

> 'The sounding equipment as well as the deep thermometers were all obtained from England, as there was no experience with this in Germany. With the kind co-operation of the Hydrographic Office in London, all the sounding devices were provided by the Royal Shipyard Chatham and delivered to the "Gazelle" when she was in Plymouth.'

The G*azelle* took account of what Challenger had observed and her sailing instructions state the following:

> 'Consideration should also be given to the soundings along the line on which HMS "Challenger" has recently been active in the western part of the Pacific Ocean and will continue to do so in the northern and western parts in the near future, as well as on the routes and areas already worked by the "Gazelle".'

There follow detailed instructions relating to *Gazelle* making observations to complement those made by *Challenger* in the Pacific around the Kermadec Islands, Tonga, and Fiji.

The sailing instructions give indications of a political agenda for *Gazelle*'s voyage and the constraints within which she operated:

> 'By the highest cabinet order of March 10th this year, S.M.S. Gazelle is commissioned for scientific purposes, and the corvette has been given special equipment for this purpose. In order to gain space, the guns have been reduced to eight and the crew has been reduced. Nevertheless, S.M.S. Gazelle must retain the character of a warship, and I expect that, Your Excellency, the conventions of managing the ship will always be maintained, even under the given circumstances.'

Shortly thereafter there is a reference to a visit by *Gazelle* to the River Congo and to Loanda (Luanda, Angola).

> 'You will find the German expedition to explore Central Africa on the Loanda coast. The appearance of the "*Gazelle*" there will increase the reputation of the expedition among the population and can be of advantage for their work. A further purpose should by no means be connected with the visit to this coast, and your Excellency must avoid any demonstration which could give the inhabitants the impression that you are pursuing political aims.'

This must refer to the Loango expedition (1873–1876). The report of that expedition refers to observations by SMS *Gazelle* being used to confirm the expedition's magnetic observations. The wording of the sailing instructions hints, perhaps, that the voyage may also have had an underlying 'show the flag' purpose on behalf of the newly founded German state and its navy but that they were trying not to give that impression.

Outcome and legacy

Both expeditions returned to their home ports and the ships' companies were paid off. They had accomplished their planned objectives, but not without enduring considerable hardships and loss of life. The health problems faced by the *Gazelle,* and which ultimately led to the voyage's obscurity, are detailed in the paper from which this material is drawn. Both vessels had almost reached the end of their sea-going lives and were destined be hulks and be broken up.

In a review of Wyville Thomson and Carpenter's book *The Depths of the Sea* in *The Times* of 11 June 1873 there was a prophetic comment about the *Challenger voyage*:

> 'If the first fruits be such, what will be the whole crop when reaped? But it will be long-centuries perhaps – before the crop is reaped or a quarter reaped.'

The lasting scientific legacy of both voyages is the information contained in their published reports and in unpublished logbooks, notes and diaries, together with the preserved samples that were collected. The reports are readily available in print and online, but other material is widely scattered and, in the case of *Gazelle*, little seems to have survived the intervening 150 years.

Because the voyages took place early in the industrial age, the recorded observations made from both ships provide an important baseline against which the modern ocean, affected by anthropogenic climate change, may be compared. We are now celebrating the 150th anniversaries of these voyages and, while there will be many retrospective assessments, a fitting tribute to all those involved in the two expeditions would be the further use of their measurements and samples to better understand the oceans' role in Earth's climate.

There is no doubt that the 'crop' is yet to be fully reaped.

This article is an highly abridged version of: HMS **Challenger** *and SMS* **Gazelle** *– their 19th century voyages compared, by W.J. Gould (2022)* **Hist. Geo Space Sci**, ***13***, *171–204, in which can be found a more extensive reference list.*
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John Gould began his career in ocean physics at the National Institute of Oceanography in 1967. He was particularly interested in ocean circulation and later directed the WOCE and CLIVAR components of the World Climate Research Programme and the International *Argo* profiling float programme. His recent work has focussed on the use of 19th century data to document changes in the ocean and their climatic significance. He also maintains a website devoted to developments in UK marine science since the 1940s (https://oceanswormley.org). wjg@noc.ac.uk

Jeanne Villepreux-Power – pioneering investigator of marine and terrestrial life

Forty years before *Challenger* set sail – at a time when animals were studied only when dead and either pickled or stuffed – a resourceful and intelligent young Frenchwoman was studying living marine animals in their own environment.

Jeanne Villepreux was born in 1794 in the country town of Juillac, 400 km from Paris. Although from a modest background she could read and write, and in her late teens she decided to walk to Paris to find work. After some traumatic experiences she found employment as a seamstress, and such was her skill that by 1816 she was working on the wedding dress for a princess from Sicily. This commission changed the course of her life because through it she met James Power, a wealthy Irish merchant who was based in Messina, Sicily. Their marriage two years later gave her the wealth and security she would need to satisfy her curiosity about the natural world.

At her new home in Sicily, Madame Villepreux-Power began improving her education, studying geology, archaeology and natural history. She decided to make an inventory of the island's flora and fauna, so explored it extensively, recording, describing and collecting minerals, fossils, shells and animals. The life cycles and food sources of butterflies were a particular interest. Her 1842 *Guida per la Sicilia* was republished in 2012 by the Historical Society of Messina.

She began her systematic observation of animals in her large house with a tortoise (which she had intended to dissect) and then acquired some pine martens, for which she installed a tree, and fed with birds caught for her by the local children. She had a reliable supply of live marine animals through her close relationship with the local fishermen. To keep her marine animals alive and living in seawater, she designed, and had made, large glass containers that she called 'cages' ('aquaria' being unknown).

The mysterious Argonauta argo

Jeanne Villepreux-Power became most famous for her pioneering research on the octopus *Argo argonauta*, often referred to as the paper nautilus (or 'argonaut'). Between 1832 and 1843, she carried out a detailed and time-consuming series of observations and experiments, through which she discovered that much of what was believed about *A. argonata* was, in fact, completely wrong.

She believed it was important to study animals in their natural environment and kept her 'argonauts' in large slatted cages anchored off the coast. Every day, she rowed out to bring them food, and would then observe them for hours. To study the development of young, she acquired three pregnant females (she had discovered that all specimens previously described were females), studied the embryos under the microscope, watched the baby octopuses hatch and develop, and saw that they started building their own shells at about two days old. Her peers believed that argonauts were like hermit crabs, taking over the shells of other animals. Importantly, she also discovered that if she damaged a shell, the animal could mend it. Her discoveries were presented in the face of considerable opposition.

Making a name in science

At the time, women were excluded from the scientific establishment, unable to attend universities. Jeanne's work on *A. argonauta* was presented to the Geoinia Academy in Sicily by a supportive male scientist, and she became its first female member. Wishing to present her findings more widely she sent details of her research to a scientist in Paris, but he presented the research as his own, adding various incorrect details.

Jeanne Villepreux-Power photographed by the fashionable photographer André-Adolphe-Eugène Disdéri in 1861.

She had better luck with the eminent but famously difficult naturalist Sir Richard Owen, who presented her findings before the London Zoological Society, and supported her claim to be the inventor of aquaria. Soon, her work was being circulated widely across Europe, and by the end of her long life, Jeanne Villepreux-Power belonged to more than a dozen scientific societies.

There is no doubt that her social position, and lack of children, made Jeanne's scientific researches easier, but her life was not without setbacks, and not just because of the scientific establishment. In 1838, 16 cases of her possessions, including specimens that she had collected and preserved while in Messina, along with her records and exquisite drawings, were lost at sea. She continued to publish, but undertook no further research. She died the year before *Challenger* set sail.

Ed.

A coloured drawing of Argonauta argo *by Jeanne Villepreux-Power; completed in 1839, this is her only surviving scientific illustration. The way the animal is shown with other organisms illustrates how important she thought it was to study animals in their natural environment.*

(Muséum national d'Histoire naturelle, Paris)

For more information, see:

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Oceanographic fame and fortune

The pay of scientists and sailors on the *Challenger*

Tony Rice

This is a slightly modified version of an article that appeared in **Ocean Challenge** *in 1990, in its first ever Volume.*

It is well known that research scientists, including oceanographers, are motivated by a deep interest in their work rather than by money. Not for us the undignified scramble for the high salaries, company cars and other fringe benefits of our friends and neighbours who opted for the sordid world of commerce or for soul-destroying professions such as law, accountancy or even medicine. It is just as well that we are unimpressed by such mundane factors, for academic oceanography is certainly not well paid. But was this always so? In 1987 I came across a rather obscure paper published in 1940 by James Ritchie, then Professor of Natural History at the University of Edinburgh, which prompted me to compare the pay of the scientists and sailors on board HMS *Challenger* from 1872 to 1876 with that of their modern (1986)* counterparts. The results were quite interesting.

Ritchie had found in the university archives some documents dealing with the arrangements made by the authorities to cope with the absence of his illlustrious predecessor, Charles Wyville Thomson, while Director of the scientific staff (what we would now call the Principal Scientist) on the *Challenger* Expedition (Figure 1). Then as now, Edinburgh was one of the nation's principal locations for medical education but, unike now, the study of natural history was considered a crucial element in the training of a future doctor. Since the teaching of natural history was entirely in the hands of the Professor, his uncompensated absence for more than three years could have been disastrous. Accordingly, the university invited first Julius Victor Carus, Professor of Comparative Anatomy and Director of the Zoological Institute at Leipzig, and later Thomas Henry Huxley, to stand in for Thomson and teach the natural history classes.

Figure 1 *Charles Wyville Thomson (1830–1882), whose successful cruises in HMS* Lightning *and HMS* Porcupine *stimulated the Royal Society and the Admiralty to mount the* Challenger *Expedition. Following the ship's return home, Thomson was able to enjoy his new-found fame and enhanced earning capacity for only a short time. His health soon began to fail and he became seriously ill in 1879, suffering an attack of paralysis possibly brought on by the financial and administrative tussles with the Treasury over the publication of the Expedition* Reports. *He resigned his directorship of the* Challenger *Commission and his professorship in 1881, and died the following March.*

(World History Archive / Alamy Stock Photo)

In the meantime, Thomson was wandering around the world accompanied by an artist-cum-secretary, a chemist, three naturalists and, of course, the ship's naval complement of officers and men. To pay for the scientific staff, the Admiralty had originally allowed £2000 a year, of which Thomson was to receive £1000 and J.J. Wild, the artist, £400, while the chemist and naturalists were each to receive £200. The annual scientific salary bill was ultimately increased to £2282 to cover also the army pay of a non-commissioned officer from the Royal Engineers who was to act as the Expedition's official photographer. In defending this increased expenditure and claiming that the Admiralty allow-

Charles Wyville Thomson, the Challenger's 'Principal Scientist'

*For approximate present-day values, multiply 1986 figures by 3.5.

ances were by no means over-generous, the contemporary Hydrographer, G.H. Richards, reasoned that Thomson would be giving up a shore-based salary of £2000 per annum, a figure that seemed to me to be inordinately large for the time.

To convert the salaries of the 1870s into 1986 terms I used Wilsher's (1970) *The Pound in Your Pocket 1870–1970*, which indicates that the pound in 1870 was equivalent to £5 10s (= £5.50) in 1970. For the period of high inflation in the 70s and 80s I used the *Department of Employment Retail Price Indices 1914–1986* which gives indices for January 1970 and December 1986 as 159.2 and 869.7 respectively. Thus the pound in 1870 is deemed to be equivalent to 5.5 x 869.7 / 159.2 = £30.045 in December 1986. Using this conversion, Thomson's supposed professorial salary would be worth more than £60 000 in 1986, at a time when his equivalent was earning just £22 241 ! This seemed to confirm my view that Richards must have grossly overestimated Thomson's earnings, but Ritchie's researches demonstrated that I was quite wrong.

Ritchie pointed out that it was the practice of the time for a university lecturer to collect, and pocket, the student fees himself. Accordingly, at four guineas per student, the twelve-week classes which Carus gave to 252 students in 1873, and 266 in 1874, brought him a total income of well over £2000. The first of these classes, incidentally, included Robert Louis Stevenson – but apparently for only three weeks! More than satisfied with his earnings, Carus retired to Leipzig and declined the invitation to return in the summer of 1875, his place being taken by Huxley. Then in his fiftieth year and at the height of his fame, Huxley gave a course of 54 lectures which attracted no less than 352 students – a record for the university at that time but one destined shortly to be broken. The following year the student numbers fell slightly to 319, but the two courses together would have earned him over £2800, equivalent to almost £85 000 in 1986!

John (later Sir John) Murray, in the long run the most important of the* Challenger *scientists

As Huxley began the 1874 natural history course, Thomson was returning triumphantly from the *Challenger* voyage, a venture which had captured the public imagination as much as the space shots were destined to do in the 1960s. Shortly after the ship arrived at Spithead on 24 May 1876, Thomson received a knighthood from the the Queen. By early July he was back in Edinburgh, ready to begin the task of sorting and distributing the vast *Challenger* collections and supervising the publication of the official reports.

The following year, having resumed his position as Professor, Thomson also returned to teaching. His enhanced reputation following the great Expedition resulted in an unprecedented 411 students paying a total of £1726 4s 0d in fees to join the course. The additional fees from the practical classes which Thomson had instigated in 1872 and which had continued in his absence, together with his earnings from other courses which he would have undoubtedly have offered, must have given him an annual income well in excess of £2000; Richard's figure was clearly not an overestimate after all.

But if a Professor of Natural History in the 1870s, at least in the University of Edinburgh, did considerably better financially than his modern counterpart, how did the other scientists fare while on the *Challenger*?

Scientists' pay while on Challenger

As noted above, the 42-year-old Thomson took a very considerable drop in salary to become 'Principal Scientist' on the *Challenger*, receiving £1000 per annum, equivalent to about £30 000 in 1986. Most UK government-employed scientists of his age acting as principal scientists in modern British oceanographic vessels would be in Principal Scientific Officer grade with a salary maximum in December 1986 of £18 049, and more than £100 000 in 2022. A small number of the most able scientists by their early 40s reach the next higher grade (Senior Principal Scientific Officer) with a salary maximum in December 1986 of £24 302. (These two grades currently (2022) have annual salaries with means of about £50 000 per year and £60 000 per year, respectively.) Thus, even on his reduced salary, Thomson appears to have been treated fairly generously compared with modern principal scientists.

Figure 2 *John Murray (1841–1914), aged around 40. Murray was assistant naturalist during the Expedition, and assumed responsibility for overseeing the publication of the* Reports *after Thomson's death. Paid only £200 per year during the voyage, Murray had amassed a fortune by the time of his death in a car accident in Edinburgh in 1914. (It is said that Murray's rivalry with the famous zoologist E. Ray Lankester prevented the Challenger Society from having a President when it was founded in 1903 – neither man could be given the position without offence being given to the other!)*

(From the Ernst Mayr Library and Archives of the Museum of Comparative Zoology, Harvard University)

The more junior *Challenger* scientists, on the other hand, did rather less well than their modern equivalents, for their £200 per annum would represent only about £6000 in 1986, and about £20 000 in 2022. At the time the vessel sailed from England, the most senior of these, John Murray (Figure 2), was 31 years old, while Henry Nottidge Moseley and John Young Buchanan, the Expedition chemist (Figure 3), were both 28. Present-day NERC scientists with university degrees and in their late twenties or very early thirties (more or less equivalent to the *Challenger* junior scientists) might expect to be either Higher Scientific Officers or Senior Scientific Officers, for whom the pay range in 1986 was from ~ £7000 to ~ £12 000 per annum (~ £34 000 and ~ £41 000 respectively in 2022). Moreover, such scientists involved in oceanography might expect to spend between 30 and 60 days at sea each year; during this period they would receive, in addition to their basic salaries, an average of about £75 per day in the form of various allowances and overtime payments, bringing their total annual earnings to between about £9000 and £16 500. Of course, once the *Challenger* scientists left England they stayed with the vessel for the full three-and-a-half years with no home leave, though they spent more than half of this time (567 days) ashore. A cruise of this length would be quite unheard of these days, but in the unlikely event that a Higher Scientific Officer or Senior Scientific Officer remained attached to an oceanographic vessel for a complete year, he or she might spend about 250 days at sea. The resulting allowances would bring their total salary in 1986 to between about £26 000 and £31 000, and probably would have earned them a place in a scurrilous article about overpaid civil servants in one of the tabloids! (I have no knowledge of current allowance rates but I suspect the same would be true today.)

Pay for sailors on Challenger

The relative pay situation for the *Challenger* sailors was rather different. The ship's Captain, George Strong Nares (Figure 4), was a year younger than Thomson. Having entered the Navy in 1845, he had reached the rank of Captain on 10 December 1869 and, when the *Challenger* sailed at the beginning of 1873, he was 170th in the seniority list of serving Captains. The standard annual rate of pay for Captains at the time depended on seniority, being £602 5s 0d for the first 50 on the list, £502 17s 6d for the second 50, and £410 12s 6d for the remainder, which included Nares.

In addition, Captains at sea received command money, amounting to to £328 10s 0d for 'sea-going rated ships and frigates with complements of not

John Young Buchanan, who outlived all of the other* Challenger *scientists

Figure 3 *John Young Buchanan (1844–25), chemist on the Expedition and, like Murray, paid £200 per year. Since he came from a wealthy Scottish family, this relatively low pay was probably of little significance to him. His photograph supports the opinion of his* Challenger *colleagues that he was aloof and difficult to get to know. Following the Expedition, Buchanan pursued his oceanographic interests with his own finances, and carried them out from his own specially built steam yacht in the late 1870s and 1880s. He also participated in numerous other cruises, including several with Prince Albert I of Monaco around the turn of the century. During 1885–86, on a cruise off the west African coast in the cable vessel* Buccaneer, *Buchanan discovered the easterly flowing Equatorial Undercurrent, but his results were largely disregarded until the Pacific version was discovered in 1952 and that in the Atlantic 'rediscovered' in 1959.*

(Trustees of the Natural History Museum, London).

George Strong Nares, the* Challenger*'s Captain – an authority on seamanship under sail

Figure 4 *George Strong Nares (1831–1915), the* Challenger*'s Captain until he took command of the Arctic Expedition and was replaced by Frank Tourle Thomson. Nares wrote a standard text on seamanship under sail, which was first published in 1860 and went through many editions. He was elected a Fellow of the Royal Society in 1875 and was knighted on the return of the Arctic Expedition. He was promoted to Rear Admiral in 1887 and Vice Admiral in 1872, and retired from the Navy in 1896. From 1896 to 1910, Nares was Acting Conservator of the River Mersey, a post normally reserved for retired Hydrographers, though he had never reached this position.*

(Welcome Images / Creative Commons Attribution 4 International)

less than 400 men ...'. The *Challenger* had a complement of only 174 men, so that Nares would not have been entitled to this payment. However, since he was technically engaged in surveying duties, presumably he would have received the special supplementary allowance for such work of £1 0s 0d per day, thus giving him a total annual pay of £775 12s 6d, equivalent to about £23 300 at the end of 1986. In 1986, the annual pay of a Royal Naval Captain with between two and four years seniority – the situation of Nares at the beginning of the *Challenger* voyage – was £25 068, with command pay supplement of £1.00 per day and specialist pay supplement of of £3.94 per day, giving a total annual pay of £26 871. Nares left the *Challenger* when she reached Hong Kong at the end of 1874 to take command of the British Arctic Expedition in HMS *Alert*. Under modern naval pay arrangements, when Nares' seniority increased to six years at the end of 1875, his basic pay would have risen to £29 401 and his total annual pay would have risen to £31 204. Thus the *Challenger*'s Captain was paid rather less well than his modern naval equivalent, but at a very similar level to merchant Masters, for in 1986 the average earning of the civilian Masters of the NERC research vessel fleet was £23 591, being made up of a basic salary of £21 822 plus an average of £1769 in overtime and other supplementary payments. The average salary for a Royal Navy Captain in 2022 was just under £100 000 per annum; I suspect that NERC Captains still earn rather less.

Curiously, the next most highly paid of the *Challenger* officers was not Nares' second-in-command, Commander John F.L.P. Maclear (Figure 5), who would have received £365 per annum, but Thomas Henry Tizard, the Navigating Lieutenant with general responsibility for the ship's surveying work (Figure 6). The navigating branch of the Navy, to which Tizard belonged, was fast approaching the end of its existence, for no new appointments to it were made after 1883. The branch traced its origins to the medieval navy where the senior officers on a naval vessel, including the captain,*

Nares' second-in-command, John F.L.P. Maclear

Figure 5 *John F.L.P. Maclear (1838–1907). Second-in-command throughout the* Challenger *Expedition with the rank of Commander, Maclear was afterwards promoted to Captain. Himself the son of the Astronomer Royal in Cape Town, in 1878 he married a grand-daughter of the even more celebrated Sir William Herschel. He remained in the Hydrographic Service until his retirement, with the rank of Rear Admiral, in 1891; he was advanced to Vice Admiral in 1897. In 1887, while Captain of HMS* Flying Fish, *Maclear collected rock samples for John Murray from Christmas Island; it was the analysis of these samples which revealed the presence of phosphates and ultimately led to the island's annexation and the exploitation of the deposits.*

(Trustees of the Natural History Museum, London)

*The terms 'captain', 'master' and 'commander' can cause considerable confusion. In the Royal Navy, Captain with a capital 'C' is a rank given to a senior officer able to take command of one of its larger vessels. Commander with a capital 'C' is also a naval rank, one below Captain, for those qualified to command rather smaller vessels. The rank Master no longer exists in the Royal Navy, but in the Merchant Service, including most oceanographic vessels, the terms master and captain, with or without an initial capital 'c', are used more or less indiscriminately to refer to the person in overall command.

The Challenger's Navigating Lieutenant, Thomas Henry Tizard

Figure 6 *Thomas Henry Tizard (1839–1924). Prior to the* Challenger *Expedition, Tizard had already served with Nares for four years, surveying in the Mediterranean and Red Sea. He was the Navigating Lieutenant throughout the* Challenger *voyage, and worked on the charts and the* Narrative *of the Expedition at the Hydrographic Office from 1876 to 1879. He was promoted to Staff Commander in 1874, during the Expedition; Nares recommended his further promotion to Staff Captain the following year but such promotions were difficult to come by at the time and Tizard had to wait a further fourteen years before he reached that rank. In command of the hired vessel* Knight Errant *in 1880, and of HMS* Triton *in 1882, Tizard surveyed the Faroe–Shetland Channel and demonstrated the existence of the bathymetric feature that was to be named the Wyville Thomson Ridge. He was Assistant Hydrographer from 1891 to 1907, though he officially retired from the Navy with the rank of Captain in 1896.*

(Trustees of the Natural History Museum, London)

were not sailors at all, but were soldiers who were aboard solely to fight. They left the actual sailing of the ship to professional seamen, the chief of which was the Master. The post of Master did not finally leave the warrant officer ranks to join the commissioned officers until 1843. Even after this time, navigating officers were treated as somewhat inferior to their executive officer colleagues; indeed, young men like Tizard entered the navigating branch of the Navy as 'Second Class Volunteers', whereas future executive officers were 'First Class Volunteers'. Having entered in this way in 1854 at the age of 15, Tizard became a Second Master in 1860 and Master in 1864; when the rank was abolished in 1867, it was replaced by that of Navigating Lieutenant, with Lieutenant's pay. In 1873, with a seniority date (i.e. date when he was promoted Master) of 23 January 1864, Tizard would have received a standard pay of £235 5s 0d per annum. But for his surveying duties he would have received a further 15s a day, giving him a total annual pay of £511, equivalent to about £15 330 in 1986, and considerably more than the Commander.

The *Challenger*'s more junior lieutenants received only £182 10s 0d per annum and, like their naturalist ship-mates, were therefore paid rather poorly compared with their modern equivalents. This pay would represent only about £5500 in 1986, at a time when Royal Naval Lieutenants received £12 217 per annum on promotion, rising to £14 189 after six years. (In 2022 Naval Lieutenants earned about £42 000 per annum.)

But if the junior officers and scientists on the *Challenger* Expedition were rather hard done by compared with their modern equivalents, consider the plight of the lower deck. In comparison with his father's or grandfather's generation, the ordinary *Challenger* sailor (Figure 7) was a good deal better off. Life on the lower deck of a naval vessel was still pretty harsh, crowded and uncomfortable, but since the manning reforms of the 1850s naval ratings had been able to look forward to more or less continual employment – a career, no less, and even with a small pension at the end of it. Previously, a naval career for a seaman was unheard of; he would have been taken on to a ship's books by her officers for the duration of her commission, usually three years, and unceremoniously dumped at the end of it. Moreover, although the Victorian era was a period of relatively stable economics compared with recent decades, the naval seaman's pay had been improved gradually over the years in an attempt to make it more attractive – and had been improved by a larger percentage than that of most senior officers.

In the 1820s, an Admiral of the Fleet received £168 a month (£2016 per annum), no less than 99 times the monthly pay of a contemporary Able Seaman (i.e. an experienced seaman) of £1 14s 0d (neither of them paid income tax as it had been abolished in 1815). By the 1870s, the differential had been reduced, but the Admiral of the Fleet still earned more than 70 times the pay of an Able Seaman. The Admiral's annual salary had increased to £2190, but he now paid income tax; in 1874 this amounted to the princely sum of £17 8s 5d, rising to £25 18s 7d in 1876 and no less than £43 7s 0d in 1878. The Able Seaman's pay was now 1s 8d a day, giving a yearly rate of £30 5s 11d, well below the £100 a year necessary to qualify for income tax. Fortunately, the erosion of the pay differentials has continued. By 1986, an Able Seaman received beween £6153 and £7545 per annum depending on seniority and length of service contract, an immense improvement on the pay of his 1870s

Figure 7 *The* Challenger*'s gig crew in the 'whites' version of the standard rating's uniform introduced in 1857. Bare feet on deck were normal as they gave a better grip on rigging; safely regulations would not permit this today!*

Some of the ordinary sailors, on whom fell the drudgery of dredging

(Trustees of the Natural History Museum, London)

predecessor, which would have been worth only £900 at 1986 values. The Admiral of the Fleet's salary, on the other hand, had increased by only about 14% in real terms, giving him an annual pay of £75 000, that is, between 10 and 12 times that of the Able Rating. Both of them, as we well know, were paying a good deal more in income tax! Making the same calculation for 2022 is a little more difficult. Most ratings in the current Navy earn between ~ £25 000 and ~ £30 000 a year. The modern equivalent of Admiral of the Fleet, i.e. a full Admiral, earns about £200 000 a year, so the differential has fallen to between 6.5 and 8.

Clearly the naval rating of the 1980s was much better off financially, and in most other ways, than his predecessor of the 1870s, while the pay of senior officers had not changed significantly over the same period. For the scientists, the comparison is less clear-cut. As a Victorian scientist at the top of his profession, Wyville Thomson was paid somewhat more generously than his modern counterpart while at sea, and he was used to a much higher shore-based salary than a modern university professor. The more junior *Challenger* scientists, however, received rather poor pay compared with oceanographers of the 1980s, and were no doubt even more disadvantaged relative to their contemporaries in other professions. On the other hand they probably counted themselves extremely fortunate to receive any pay at all to participate in the great scientific venture. In the 1870s there were no government-funded marine laboratories and, apart from the small number of posts in the universities and museums, it was impossible to earn a living from research at that time.

Life after the great adventure

As we have seen, Wyville Thomson returned to his post at the University of Edinburgh. but resigned in 1881 and died the following year. Of the four junior scientists on the *Challenger*, only one, Moseley, ultimately followed a university career. Moseley had graduated in natural sciences at Oxford in 1868. After the return of the *Challenger* he accepted a fellowship at Exeter College, Oxford, moving to London in 1879 as Assistant Registrar to the University. Two years later he returned to Oxford as Linacre Professor of Zoology, but in 1887 deteriorating health forced him to take premature retirement and he died in November 1891 at the age of only 47.

A second junior scientist, Buchanan, had no need to earn his living from science as he had a considerable private income which he used to finance his personal oceanographic studies. A third, Rudolf von Willemöes-Suhm, who had already completed his doctorate in the University of Munchen before the Expedition, was a late replacement for William Stirling who had resigned his place on the *Challenger* shortly before the ship sailed. Like Moseley, Willemöes-Suhm probably would have taken up a university post in his native Germany had he not died tragically of the bacterial infection erysipelas while the *Challenger* was in the Pacific.

Finally, John Murray – in the long term by far the most influential of the *Challenger* scientists – amassed a very considerable personal fortune from the exploitation of the Christmas Island phosphate deposits and ploughed large sums back into oceanography both during and after his lifetime. Since Murray's interest in coral islands, developed during the *Challenger* Expedition, led directly to the establishment of the Christmas Island Phosphate Company, his participation in the voyage certainly paid off handsomely.

But apart from their salaries, all the *Challenger* scientists earned a place in the annals of oceanography, on which it is impossible to put a value. Presumably Willemöes-Suhn would willingly have traded his fame for an obscure longevity, but the others clearly revelled in the experience. The nearest equivalent today would probably be a virtually unpaid place on a space shot – for which there would presumably be many takers. Personally, I would rather do a relatively low-profile job for a decent salary, but I'm not looking for immortality!

Acknowledgements

The results of the author's investigation into rates of pay were published in *Archives of Natural History* (1989) **16** (2), 213–20. We are grateful to the editors and publishers of this journal for allowing us to reproduce parts of the article.

The photographs reproduced by courtesy of the Trustees of the Natural History Museum, London, are taken from a facsimile of the volume of *Challenger* portraits presented to John Murray on completion of the official *Reports* in 1895. The original and the facsimile are held in the Library of the Museum.

The naval rates of pay at the time of the *Challenger* Expedition are taken from the *Navy List* for 1873, p.343. These rates had been set by an Order in Council dated 22 February 1870 and remained in force throughout the decade.

The naval rates of pay for 1986 are taken from *Whitaker's Almanack*, 118th edition, with additional information kindly supplied by Captain C.B. Wilson. Current naval pay rates are from glassdoor.co.uk and armedforces.co.uk websites.

Information about rates of pay in the NERC research vessel fleet was kindly supplied by Captain M. Perry of the NERC Research Vessel Services (now part of the National Oceanographic Centre, Southampton).

The information about professorial rates of pay was kindly provided by Professor J.M. Mitchison.

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The official report of the *Challenger* Expedition consists of 50 quarto volumes containing some 30 000 pages, published between 1879 and 1895. All of them are now available online.

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Book reviews

Fresh perspectives on the Challenger Expedition

The *Challenger* Expedition: Exploring the ocean's depths by Erika Jones (2022) Royal Museums Greenwich, 255pp. £25 (paperback, ISBN: 978-1-9063679-7-8).

This lavishly illustrated book provides a history of the *Challenger* expedition in six objects: the ship herself, the 'Baillie' sounding device, a clam, a starfish, an officer's photograph album, and the expedition's *Report on Deep Sea Deposits* that, along with the other expedition reports, helped define the emerging science of oceanography.

Erika Jones is Curator of Navigation and Oceanography at Royal Museums Greenwich. Her curator's eye for detail brings many delights, not just for the seasoned marine scientist but for the general reader new to the *Challenger* expedition. Uniquely, the book brings together the experiences of the labouring stokers, the inventive and hardy seamen, the scientists, and the many 'native peoples' whose images are scattered throughout the expedition's photographic albums.

Oceanography emerged during a period of technological development that revolutionised the movement of people, ideas and commerce around the globe. The drive to explore the deep sea arose not only from a scientific appetite for understanding its 'conditions' and life-forms, but also from the British government's geopolitical ambition to develop an undersea telegraph network connecting London to cities around the British Empire. The expedition's impressive results, the book argues, owe much to the vast infrastructure and influence of the British Empire, the manpower and reserves of the Royal Navy, and the speed of its ships.

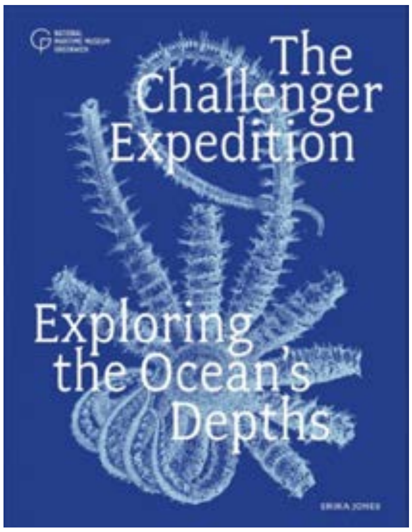
We are introduced to the *Challenger*'s crew and the ship herself, from the laboratories and workshops on the upper decks replacing the ship's gun emplacements, to the hold where stokers and coal-cutters laboured in 'smoky, dark and scalding hot' conditions. Steam power was vital both to *Challenger's* dredging routines and to combatting ocean storms, and the need to resupply the ship with coal and other necessities at British naval bases influenced the route for oceanographic study. And we learn of the role of enslaved people, observed by the ship's steward, Joe Matkin, in Bahia Bay, shouldering tons of coal onto the ship: for 'coal had a human cost'.

Part of oceanography's 'hidden history', described in the book, is how scientists at this time used emerging global trade routes to ferry specimens at speed to their laboratory destinations. The author traces the journey of specimens of the bivalve mollusc *Cardita astartoides* – a small clam – collected near Kerguelen Island in January 1874, then preserved and bottled. *Challenger* reached Sydney in April and the bottles were crated and despatched by Royal Mail to San Francisco, from where they were sent by rail freight to New York and then by steamer to Britain. In July, the Kerguelen samples reached Edinburgh 'intact and well preserved'.

At the time, those marine molluscs that had been studied were mainly from the Northern Hemisphere; little was known about molluscs from tropical waters or from the remote and hostile Southern Ocean. The travels of a 'humble bivalve' from Kerguelen thus contributed to the knowledge that many species from southern high-latitude waters resembled those related species from similar conditions in the Northern Hemishere. This led to an appreciation that the deep oceans were not unchanging but evolved as conditions on the Earth changed over time.

Challenger was the first truly global scientific expedition to embrace photography. Many of the 800 photographs taken during the expedition feature in the personal albums of Assistant Paymaster John Hynes, including images of icebergs, and of the 'native races' encountered. As the book argues, the individuals are anonymous, clearly lacking agency, 'viewed as racial types rather than recognised as distinct individuals … A more comprehensive history of the expedition should include the lives and experiences of the communities the expedition visited.'

Photographs helped convey *Challenger's* progress to the British public. For instance, the ship's artist created a drawing of the ship moored at St Paul's Rocks in the Atlantic. His drawing was then photographed and a copy mailed to London at the next port, and subsequently published in the *Illustrated London News*. Indeed, hundreds of *Challenger* images were reproduced for newspapers and



scientific journals. Copies were sold for a shilling each to the crew, which explains how my family has a photo of my stoker great-grandfather, Charlie Collins, on Inaccessible Island.

The bulk of the *Scientific Results of the Voyage* describe new organisms, but the *Report on Deep Sea Deposits* (1891) also helped to define the emerging field of oceanography. John Murray and Belgian geologist Alphonse-Francois Renard's collaborative work includes the first mapped distribution of various kinds of deep-sea deposits, and state-of-the-art colour images showing crystalline structures of rocks. The volume also combined *Challenger's* 492 ocean soundings with data from many subsequent voyages. On *Challenger*, the 'Baillie' sounder was vital to meet the Admiralty's demand for accurate information about the depth and 'conditions' of the ocean floor. Navigating Lieutenant Baillie's design improved on the original developed by a blacksmith and two sailors aboard a navy vessel sounding the Arabian Gulf in preparation for laying the telegraph cable to India.

A sea urchin, *Salenocidaris varispina*, played its part in fostering the development of international cooperation in the study of deep sea things. The Harvard naturalist (and skilled networker) Alexander Agassiz, believed that echinoids, a small but ubiquitous taxonomic group, could provide empirical evidence of the theory of evolution. In 1869, Agassiz met Wyville Thomson and other leading naturalists in Europe, and he met the expedition's six scientists at their stopover in Halifax, Nova Scotia, in 1873. In 1876, Thomson and Agassiz collaborated in sorting through the 600 cases containing more than 100 000 individual specimens assembled at the *Challenger* Office in Edinburgh, in order to distribute them – controversially – to an international network of specialists. Agassiz chose to study *S. varispina*, dredged off the coast of Brazil. It was eventually gifted to the Smithsonian where it now rests, available for examination by scientists and curious historians alike.

Published under the aegis of the National Maritime Museum, the book has an elegant design and is well produced, justifying a steepish price. The high quality of reproduction of the charts, photographs and drawings, and the clarity of the author's writing, make this a fine tribute to the *Challenger* expedition's 150th anniversary.

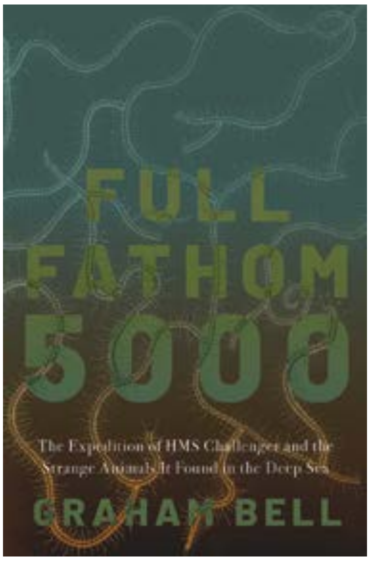
Philip Pearson
Author of *A Challenger's Song*
https://a-challengers-song.co.uk/

Full Fathom 5000: The expedition of HMS *Challenger* and the strange animals it found in the deep sea by Graham Bell (2022) Oxford University Press, 368pp. £25.99 (hard cover, ISBN 978-0-19-754157-9).

The 150th anniversary of the beginning of the *Challenger* expedition in 1872 was almost bound to be marked by new additions to the existing literature about this famous venture. Indeed, I toyed briefly, very briefly, with the idea of writing something myself. But I became convinced very quickly that anything I produced would simply be an up-to-date, but rather inferior, version of one or other of the accounts that have already appeared; after all, after 150 years what more is there to say? So when I was invited to review Graham Bell's new book I was a touch apprehensive. Thankfully, I need not have worried.

Not unexpectedly, *Full Fathom 5000* follows fairly closely the format of most earlier treatments, particularly Eric Linklater's *The Voyage of the Challenger,* published to coincide with the centenary in 1972. Like Linklater's, Graham Bell's book is dominated by a central chronological account of the voyage, preceded by a short introduction about the origins of the expedition and some of the more important participants, and followed by a tailpiece, very short in Linklater's case, summarising what happened to the collections and the participants, and attempting to assess the achievements of the voyage. And equally expectedly, many of the facts and figures referred to are the same in both; after all, they used mostly the same sources.

But here the resemblance ends – for two main reasons. First, of course, the world has moved on in the last fifty years, with knowledge of the deep ocean improving much more rapidly than in the previous century, and allowing the significance of the *Challenger* results, particularly the physical data, to be reassessed. Furthermore, biological sampling and data-gathering techniques have also improved hugely in the intervening period, turning our view of the structure of deep-sea communities in the 1950s, largely inherited from the *Challenger*, more or less on its head. Finally, previously inaccessible contemporary *Challenger* documents have also been published, particularly steward Joseph Matkin's letters giving a fascinating lower deck view of the undertaking. But the second reason for the differences is at least as important. Unlike Linklater, the author of this volume is a renowned evolutionary biologist, able to write authoritatively about the strange beasts collected by the *Challenger*, and to put them into the context of our improving knowledge.



The result is a lively text covering the voyage in a dozen or so sections, each accompanied by the relevant chart reproduced from the official narrative published by the expedition leader, Charles Wyville Thomson, and showing the positions of the 360 or so official stations from which samples or data were obtained. About 60 of these are highlighted and specifically mentioned in the text because of the capture of some particularly interesting creature or some other notable event such as the discovery of manganese nodules or cosmic dust. The choice is inevitably a little idiosyncratic and, being strictly chronological, there is no logical order to the way the animal groups are dealt with. So while most marine phyla are mentioned, they are not necessarily in the right order! But this gives the text a certain charming surprise quality, not unlike the surprises the *Challenger* scientists must have had as each new discovery appeared on deck. Bell introduces the reader to the weird and wonderful world of deep ocean life, skipping easily through most of the invertebrate phyla from foraminiferans and sponges all the way up to molluscs and echinoderms, and, finally, via the cephalochordates to sharks and bony fishes. In each case, he provides the reader with a brief but fascinating snippet about the beast's biology, often, of course, much more than was known at the time of the expedition. And he also introduces topics like hydrothermal vents and sea-floor spreading that the *Challenger* scientists had absolutely no knowledge of.

But the text is not just about the science, important and fascinating though this is. Bell also leads the reader through the trials and tribulations of a very mixed ship's company ranging from largely illiterate seamen to highly educated and sometimes aristocratic and status conscious officers and scientists, all confined for long periods in an overcrowded and often uncomfortable and dangerous vessel. No wonder the atmosphere aboard was far from the harmonious one tacitly implied by some treatments, including my own. Bell skillfully takes us into the murky world of somewhat questionable behaviour of all strata of this all-male world both at sea and ashore, but in no way detracting from the overall noble nature of the undertaking that continues to fascinate 150 years later.

So all in all I found it an excellent read and, even after more than fifty years of dipping into the *Challenger* story, I learned stuff about it that I had either forgotten or never known in the first place. Consequently, I enjoyed it thoroughly, though I can't decide exactly what audience it is written for. To get the maximum out of it, you would need at least a reasonable knowledge of oceanography, though I would think that most of it could be read with pleasure by anyone with a general interest in maritime exploration or ocean science.

But do I have any criticisms? Well, yes, but they are pretty minor and might be considered nitpicking. First, a technical point, little or nothing to do with the author. I have rarely seen a book with a less attractive dust jacket: muddy green lettering against a muddy green background decorated with muddy green worms does nothing for me. If I wasn't aware of the *Challenger* story I would probably not give it a second chance. But on a more serious level, a light editing of the text by someone familiar with the *Challenger* story and with modern oceanography could easily have removed some of the minor errors that suggest the author has not spent a great deal of time at sea on research vessels. It might at the same time have removed the rather patronising, and, in my view, unjustified, statement (p.312) that *'the expedition itself was amateurish, using untried, homemade equipment that had been installed into a halfheartedly converted survey ship'.*

And at a more personal level, such editing might have avoided my disappointment at Bell's well intentioned attempt to address the vexed question of where the deep ocean, so remote from the powerhouse of photosynthesis, gets its fuel from. He rightly emphasises the potential importance of fast-sinking large lumps of organic matter in the form of the carcasses of sharks, whales – and even sailors – compared with the old idea that food arrives in the deeper layers mainly as a constant thin drizzle of slowly sinking small particles. But he makes no mention of the seasonal phenomenon of rapidly sinking clumps of phytodetrital material (or 'fluff', as we called it when it was first discovered in the North Atlantic in the 1980s). In many parts of the ocean with highly seasonal surface conditions, this phenomenon seems to supply a significant pulse of energy to an otherwise extremely constant environment. I'm probably a touch over sensitive to this omission because the fluff story was the most exciting discovery that I was personally involved in. But personal sensibilities aside, I do think it is an important error in an otherwise excellent addition to the *Challenger* literature.

Tony Rice
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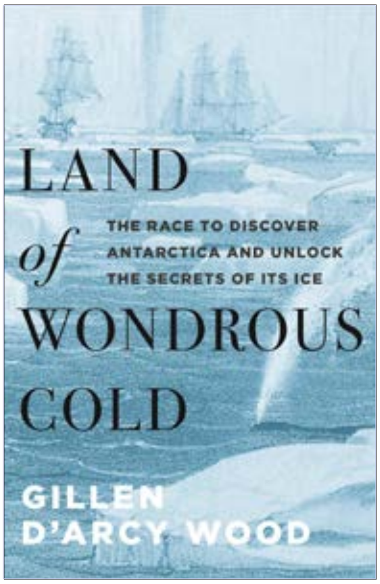
In search of Terra Australis

Land of Wondrous Cold: The race to discover Antarctica and unlock the secrets of its ice by Gillen D'Arcy Wood (2020 and 2022) Princeton University Press, 312pp. £14.99 (ISBN 13: 978-0-691-22904-1). Paperback edition published in 2022. Also available as an e-book.

The expeditions of Scott and Shackleton have made the Heroic Age of Antarctic Exploration familiar to many of us, but they were not the first to seek the most enigmatic of continents. In *Land of Wondrous Cold*, Gillen D'Arcy Wood presents an interesting and evocative account of the 19th century race to explore high southern latitudes, by expeditions from France, the United States and Great Britain. Led by captains of wildly different temperaments, these brave expeditions fought bone-chilling cold, and some quite feisty penguins, in an attempt to beat each other to Antarctica. The race played out over years, with the slow communication of the time meaning no-one knew quite where their competitors were, or even whether they themselves had already been beaten.



Without modern equipment and ships, the race to cross the stormy and ice-laden Southern Ocean, to reach record-breaking southings and eventually not just sight, but land on, fabled Terra Australis was perilous. Even for experienced and relatively well equipped crews, the unforgiving waters and short summer season were almost insurmountable obstacles. Yet the possibility of confirming the existence of a seventh continent, or of the madly speculated about 'hole at the pole' leading into the interior of a hollow Earth – a concept which now belongs to science fiction or planetary romance – remained alluring. Reputation, glory and wealth would be the reward of the ship's captain that led their crew to success. Financial and social ruin, or a freezing death in the pitiless Southern Ocean, might await those less determined, prepared or obsessed.

The stories of the three captains, Jules Dumont D'Urville (France), Charles Wilkes (USA) and James Clark Ross (Britain), dominate this book, as perhaps they should. Equal weight is given to each nation's would-be hero, although the details of their crews are a little sparse. The ordinary seamen who died to achieve another's fame seem sadly to have been forgotten by history. The experience of Dumont D'Urville and Ross as mariners and explorers contrasts with that of Wilkes. The American captain comes over as ill-equipped for the job at hand and almost frantic in his need for recognition and success. Ross's expedition was clearly the best equipped, with the wonderfully named HMS *Erebus* (who wouldn't want to head to near-certain death on the deck of a ship named for a Greek personification of darkness and the route to Hades?) and HMS *Terror*. However, Dumont D'Urville was the first to set sail and a famed explorer of the Pacific. Clearly, nothing was certain and the prize was up for grabs.

Every chapter features black and white reproductions of portraits, landscapes and maps. The portraits of the three captains help put a human face to each would-be hero. At the time, windswept snowscapes and storm-tossed ships became popular subjects with artists, and the public clamoured for such paintings as their interest in the expeditions grew. The maps are kept quite simple and give a sense of the actual distances that the expeditions traversed. I recommend contrasting Fig. 1.4, a contemporary 19th century map, with any modern map of the Southern Ocean.

Between chapters telling the story of the expeditions are a number of 'interludes'. The subjects of the interludes are diverse and range from an account of how the indigenous peoples of Tierra del Fuego and Patagonia came to live in such a hard-to-reach part of the world to a description of how historic and modern magnetic measurements have helped develop our understanding of the Earth's long history. I particularly enjoyed the interludes, as they are used to show how the legacies of all three expeditions helped build entirely new fields of science, and enabled me to appreciate their significance for modern Earth Sciences. Without them, I would have been left wondering about the lasting impact of the expeditions, which had a great personal cost for the crews.

It is easy to forget that the expeditions were not just a race for glory and wealth. There were also scientific aims, with Ross's ships dispatched to make magnetic measurements and locate the magnetic South Pole. Zoological and geological specimens were collected by James Hooker, Ross's assistant ship's surgeon, who would go on to become director of the Royal Botanical Gardens. These scientific achievements made valuable contributions to science during the 19th century and helped pave the way for future advancements. Discussion about them is skilfully woven into the wider story without distracting from it, and ties in well with some of the interludes.

This is a well written book that remains clear even whilst juggling three different expeditions. It could easily have been three times the length, but this would rather have spoilt the whole package, which is digestible and easy to read. The cost of the brevity is the loss of some of the details of events and interactions between crew members.

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British Antarctic Survey

A worthy celebration

Challenges in Estuarine and Coastal Science: Estuarine and Coastal Sciences Association 50th Anniversary Volume edited by John Humphreys and Sally Little (2022) Pelagic Publishing, 272pp. £45.00 (paperback, ISBN 978-178-427285-2). Also available as an e-book.

It was a pleasure to be asked to review this 50th anniversary volume compiled by the Estuarine and Coastal Sciences Association. Of course, 50th anniversary editions don't come around that often, but they are a great opportunity to consider the scope of the relevant science and how it has developed over the years. Therefore, I enjoyed the fact that the volume started with the origins and history of the Association, and it was very entertaining to look back over the numerous events, remembering which ones had been particularly significant to me on a personal level, but also recognising the scope of work and effort that has gone into the success of the Association over the years. The list of contributors to the volume is almost a 'who's who' of estuarine and coastal sciences and reaches far beyond the UK. The work is well written and the various contributions benefit from some excellent diagrams and figures, which are very helpful to newcomers to estuarine and coastal science.

After the quite detailed and historically oriented preface, the first chapters are generally concerned with the physical dynamics of different coastal systems, including morphodynamics and coastal erosion, and the effects of sea-level rise on tidal dynamics, plus the thorny issue of residence times and how they can be properly used. These are concise contributions, generally addressing the challenges that we are likely to face in the future and the understanding we need to develop to progress in this area of work. This is then followed by a more reflective piece (Mitchell and Uncles) placing these physical studies in context, again using the opportunity of the 50th anniversary edition to examine the past work and point toward the future. It is interesting to note that while our ability to measure and model a system has vastly increased, due to improved technology and methodology, many questions remain unanswered. This is not due to lack of effort but to the recognition of the complexity and variability of a system where physical dynamics and ecological factors so closely interact. This clearly presents a challenge to the community in terms of future prediction and modelling.

The emphasis of the volume then changes from physical challenges to global threats, recognising emerging pollutants such as marine plastics, invasive species, and sea-level rise. These are all useful contributions but I was particularly happy to find a chapter on the emerging threats of sea-level rise and coastal developments to freshwater tidal habitats. While it might be considered that estuaries themselves are often understudied in terms of their importance to coastal ecological systems, freshwater tidal habitats are even less well understood and rarely prioritised. This may be a mistake given the danger they face.

There are also two chapters considering carbon storage in coastal ecosystems. I think that science, like many other aspects of human endeavour, goes through phases (fashions?) in response to emerging threats or societal concerns (such as plastic pollution). Many governments across the globe, after COP 26 and COP 27, are now seriously concerning themselves with carbon storage in coastal systems, often referred to as 'blue carbon'. The difficulty seems to be that the recognition of a store of carbon, by itself, has no great effect on global CO_2 levels. However, it is true that the enhancement or loss of blue carbon systems may lead to significant change, either beneficial or harmful, and this is important. These two chapters helped to consider some of these issues, and the reader should note that I had a minor role in one of the contributions.

The final two chapters of the volume are more critical and political, and I have to admit a slight cynicism, hearing some assertions about actions to be taken by governments to protect the future of global ecosystems. It seems I may share this cynicism with John Humphreys (one of the editors of the volume) who in Chapter 15 highlights *'certain aspects of marine conservation policy that provide governments with opportunities to use a rhetoric of achievement that is inconsistent with reality'.* Smoke and mirrors, indeed, and I may well use this quote in future lectures. I would add that many recent initiatives are placing interactions with Government and related agencies at the centre of their work in support of marine planning (e.g. UKRI Sustainable Management of UK Marine Resources programme) and this is a positive development.

The volume ends with a short conclusion written by the editors, John Humphreys and Sally Little. This is a useful reflective piece, pointing out some of the developments in science but also how the challenges have changed. It is certainly true that concerns over the future of the environment have changed radically in the last 50 years and while not exactly a 'call to arms' the contributions and summaries provided in this volume should make us all think carefully about the future. The editors have done a great job in pulling this volume together and I will certainly be recommending it to others.

In summary, I enjoyed this volume and learned a great deal from it. The contributions are concise and generally thought-provoking, and a useful aid for teaching across many levels; the volume will also bring new researchers or interdisciplinary colleagues in allied fields up-to-date.

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