SAMS
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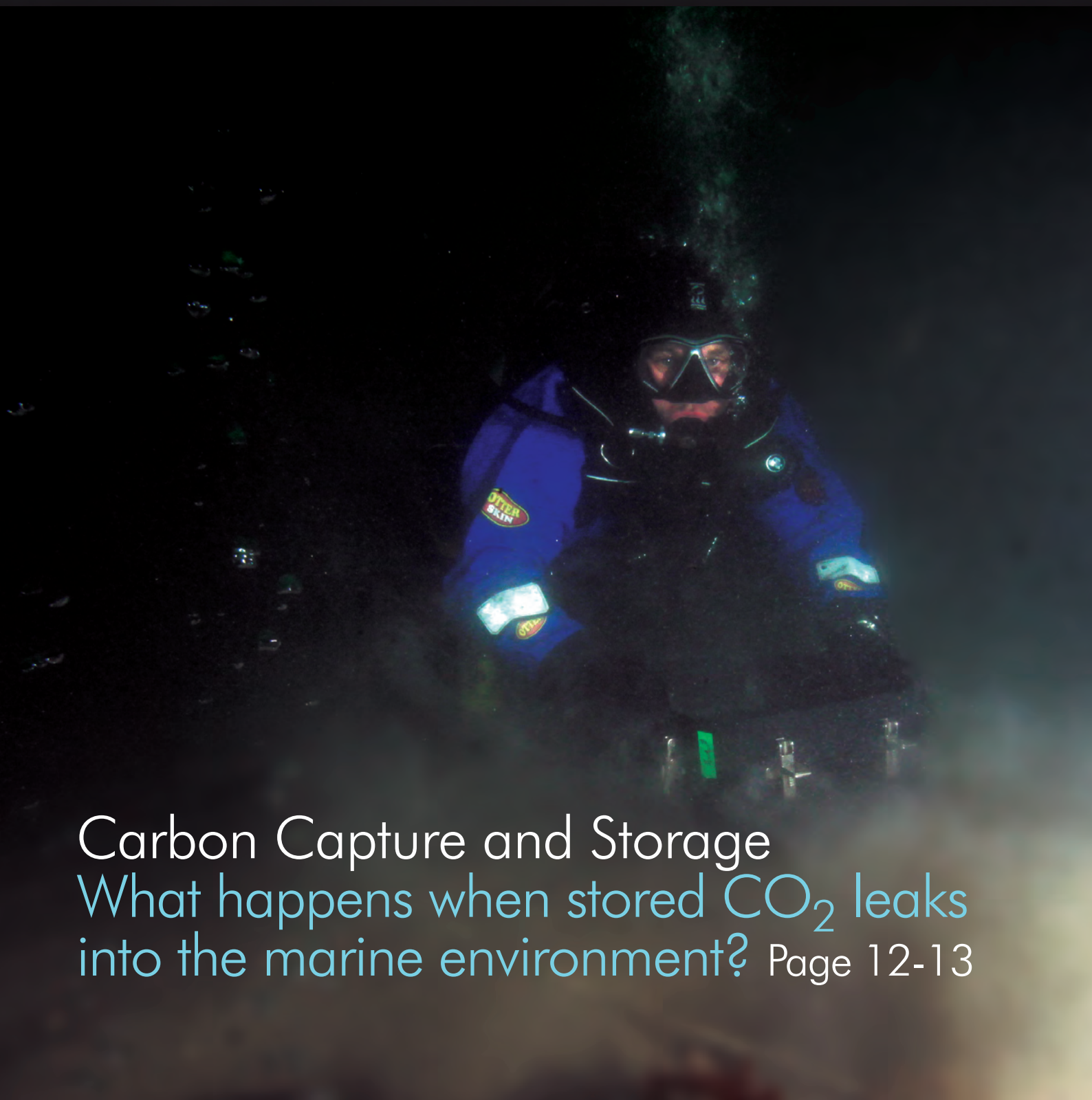
Ocean Explorer

Marine science magazine for SAMS members and friends

ISSUE 36 AUTUMN 2012



Carbon Capture and Storage
What happens when stored CO_2 leaks into the marine environment? Page 12-13

CUCKOO EFFECT Page 17
How did the practice to lay eggs in nests of other species evolve?

COD GALLORE Page 20
What the Sea Sami can teach us about sustainable fisheries...

CORRYVRECKAN Page 22
Mapping the seabed and water flow of a legendary whirlpool area

Front cover: A scientific diver from the SAMS hosted National Facility for Scientific Diving places monitoring equipment on the Ardmucknish Bay seabed near a carbon dioxide release site as part of the QICS project reported on page 12-13.

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Our main partners

ABOUT US

SAMS (The Scottish Association for Marine Science) activities aim to deliver world-class marine science that supports society with innovative solutions to developing a sustainable relationship with the marine environment. We deliver this mission through research, education, services to business, learned society activities and public engagement initiatives.

SAMS is a Company Limited by Guarantee registered in Scotland (SC009292) and a registered Scottish charity (009206). It is a learned society with 300 members and employs 150 staff at its laboratory at Dunstaffnage near Oban.

SAMS administers its commercial services through SRSL, a wholly owned commercial subsidiary company.

SAMS also hosts the European Centre for Marine Biotechnology. ECMB is a business incubator for new marine biotechnology companies and currently hosts two tenants: Aquapharm Biodiscovery Ltd and GlycoMar Ltd.

SAMS is a founding partner of the University of the Highlands and Islands www.uhi.ac.uk and a collaborative centre of the UK's Natural Environment Research Council www.nerc.ac.uk.

GOVERNANCE STRUCTURE

SAMS is ruled by its members, who elect office bearers at the Annual General Meeting. SAMS Council, chaired by the SAMS President, has responsibility for strategy, risk management and appointment and performance of executive management. Council is supported by a Board and four committees. Council members are the non-executive directors of the company.

The Director of SAMS is responsible for the effective management of the organisation and is supported by an executive group. Research and teaching staff are managed within five departments: Ecology; Microbial and Molecular Biology; Biogeochemistry and Earth Science; Physics, Sea Ice and Technology; and Education.

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Professor Laurence Mee Director

DYNAMIC OCEANS

Those of us who enjoy sailing, diving or kayaking in the sea soon become acutely aware of its dynamic environment. We also experience the importance of fronts for example as some of the best places to observe marine life or catch mackerel, and eddies as a way to get a ride home when the wind drops with a contrary tide. I moor my boat close to the Falls of Lora - a spectacular tidal phenomenon caused by the huge volume of water surging through the narrow entrance to Loch Etive and a popular spot for an unusual form of salty white water kayaking. The kayakers are well aware of the vast amount of energy reliably available for their own adrenaline high. Many of them are probably unaware that their kicks come from the energy dispensed during the very gradual slowing of the earth's rotation coupled with gravitational forces on Earth and its moon. They are probably more aware of the huge renewable energy resource that this represents and of plans to locate wind, tide and wave devices in Scottish coastal waters.

SAMS is thus ideally located for studying our dynamic oceans: The sea around us provides a remarkable natural laboratory for making observations and testing innovative ideas. We use this experience worldwide: from studies of upwelling in Papua New Guinea to the dynamics of sea ice in the Arctic. Moreover, we work on the much slower dynamics of geochemical processes on the sea floor; last year, one of our scientists deployed an instrumented 'lander' at the Challenger Deep, 10.9 km below the surface of the Pacific Ocean and its deepest point. We also use our decades of monitoring data to understand long term changes in North Atlantic circulation and changes in the biodiversity of the intricate sublittoral of the Highlands and Islands.

Understanding and communicating the dynamic oceans is enormously important if we are to use the sea sustainably. Traditional textbooks convey information through graphs, maps and transects and the long term averages or snapshots they present hide much of the variability and patchiness that characterises the real ocean. The eddies that I use to get back to my mooring after the tide has turned would not appear on a larger scale map with average currents. On the other hand, climate change sceptics know how to select and exploit short term trends to argue that the ocean is really cooling and that scientists are conspiring against global corporations.

At SAMS we are taking considerable care to ensure that we work at relevant scales and present our findings in the appropriate context. In the case of global change, this is only possible with long term data sets (including paleo-oceanography to develop even longer term reference points for change). We benefit from our status as a delivery partner to the NERC National Oceanography Centre to secure "National Capability" funding for our long term observations such as the Ellet Line (see Ocean Explorer 35) but also to use new smart technology such as gliders, autonomous underwater vehicles and landers to help understand the finer scale processes that are the vital link between the physics and biology of our seas. Communicating these relatively complex processes is also part of our duty as a learned society and educational institution.

We are dedicating the current magazine issue to our dynamic oceans and the cross cutting research on this theme in SAMS. It is an opportunity to demonstrate how SAMS scientists are working together across disciplines to understand these fundamentally important processes and apply them to the difficult decisions that our contemporary society must take. In a world where the word 'turbulence' is more often associated with market failure than ocean mixing, it is easy to lose sight of the need to understand the fundamental processes that lead to fertile seas, control our global climate and offer perspectives for long term human sustainability at local and planetary scales.

Follow Laurence's blog:
scotmarineinst.blogspot.com

MEMBERSHIP NEWS

Dr Anuschka Miller Editor

Voice your views in membership survey

SAMS is a very old learned society (going back to 1884) and SAMS members play the deciding role in what the Association does.

As the world around us is changing, we periodically examine what we should offer our members for their subscriptions. SAMS membership fees have never increased in the 11 years I have been working here, nor have the benefits changed. It is thus high time to re-examine what members want SAMS to do for them.

We are now instigating an online survey and I urge you to contribute your thoughts on the future direction of our learned society at:

https://www.surveymonkey.com/s/SAMSmembersurvey

If you don't have online access, please contact me for a printed survey (SAMS; Scottish Marine Institute; Oban PA37 1QA; UK).

The survey closes Friday 2nd November 2012.

Oban's Festival of the Sea celebrates, explores and educates

The 2nd Festival of the Sea for Oban, Lorn and the Isles took place from 18th to 28th May this year and attracted more than 10,000 visits to its 56 different events. The festival aimed to engender pride and stewardship towards the marine environment and to highlight marine and science related careers.

Events were delivered over a wide geographical area that for the first time included North Uist, Canna and Bute. Highlights included a new Ocean Challenge Badge for Girl-guiding Argyll that - if successful locally may be rolled out nationwide; the James Hutton Institute's Virtual Landscape Theatre facilitating debates about tomorrow's seascapes; and a local music CD celebrating the sea.

The festival was organised by SAMS with core funding from SAMS, the Scottish Government (managed through HIE), and Argyll and Bute Council with other organisations supporting individual events.

SAMS AGM and NEWTH LECTURE

Our 98th Annual General Meeting will take place on **Friday, 9th November 2012** at SAMS, starting at 15:15. Members will be sent all relevant papers three weeks before the meeting. The meeting will be followed by the 23rd Newth Lecture. This lecture, held in memory of former SAMS President David Newth, will be delivered by SAMS Council member Professor Lora Fleming, Director of the European Centre for Environment and Human Health at the Royal Cornwall Hospital. She will talk on oceans and human health: a new area of interdisciplinary science.

Scottish Ocean Explorer Centre going ahead

Next summer SAMS will open a small interactive visitor/science centre focussing on the marine environment and marine research.

The Scottish Ocean Explorer Centre will be part of the SAMS estate adjacent to Dunstaffage Castle, an existing Historic Scotland visitor attraction. Once fully functional the SOEC will also deliver workshops for schools and organise public events.

The SOEC will consist of an interactive display area, a cinema, a marine technology garden and a multi-purpose area that will be used as a cafe in the summer and as a workshop area outside the visitor season. There will also be a small shop for visitors.

The SOEC is becoming a reality thanks to fundraising support from the University of the Highlands and Islands Development Trust and financial donations by the Robertson Trust, the Stevenson Family Charitable Trust, the Steel Charitable Trust, the Gordon Fraser Charitable Trust, the Hugh Fraser Foundation, the Fishmonger's Company and Oban Common Good Fund.

We are, however, still fundraising to increase the functionality of the facility further:
E:Anuschka.Miller@sams.ac.uk

POLAR MEDAL FOR DAVID MELDRUM

David Meldrum has devoted much of the past 40 years of his career to the exploration of polar regions. The award in 2011 of the Polar Medal recognises his exceptional accomplishments in both new discoveries and particularly in new technologies. David is the leading designer of the modern, smart and low cost communication units for use in polar regions. His technologies are deployed in both polar oceans where they collect and transmit ice, ocean and meteorological data to worldwide data centres for research use and for incorporation into operational forecasting models.

During the 1970s David worked on the development and installation of radar sounders in Antarctica. These revealed the internal layering of ice sheets, the existence of Lake Vostok and the configuration of the land surface beneath the ice.

In 1978 David came to Oban to join the Association. Since then he has been busy developing scores of measuring, monitoring and communications technologies to study polar oceans for example to measure the dynamics and drift rates of sea ice, and the growth-melt cycles of ice.

Arguably David's single greatest innovation is the development of drifting buoy technologies. In the 1990s he introduced GPS satellite navigation systems into polar oceanography, combining a GPS receiver and Argos transmitter to enable researchers to know exactly where buoys are. By exploiting emerging satellite telemetry systems like Iridium and Orbcomm, David went on to develop a system that delivered remote data on tilt, strain, acceleration and conductivity alongside the GPS position. He then worked on developing two-way communication with buoy sensors and introduced intelligent systems that can adapt sampling regimes based on prevailing conditions, thereby reducing buoy power consumption and increasing their lifespan.

Professor David Dewry, a colleague during various Antarctic fieldwork trips, described David as 'an outstanding companion in the field: focused, energetic, adaptable, hardworking and great fun.'

David's humility was testified in his response to the announcement of the polar medal award last December: "Who deserves a medal for having a great time, when most people have to endure being shot at..."

SCIENCE NEWS

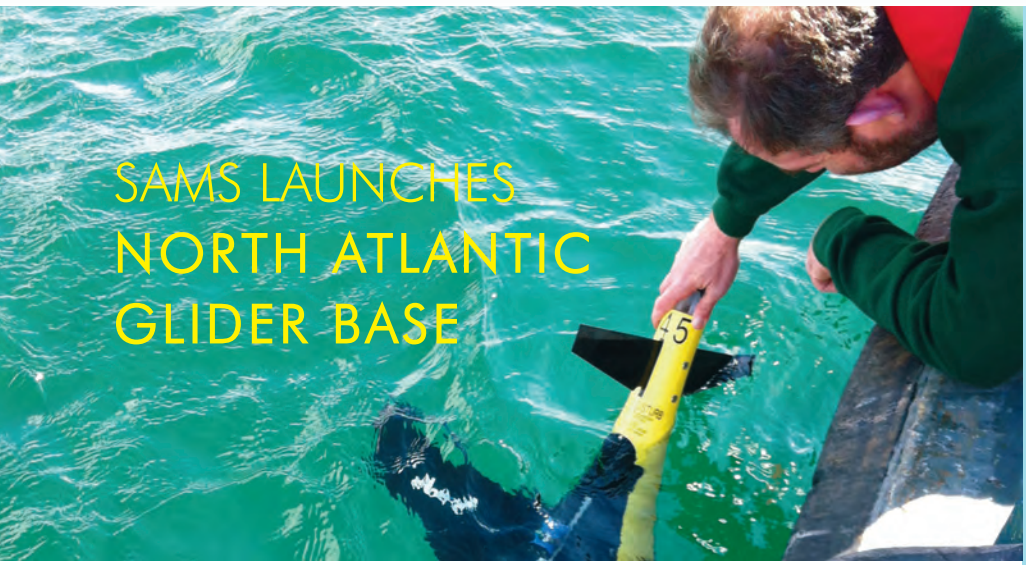
EUROPEAN MARINE SCIENCE PARK TAKES SHAPE

Highlands and Islands Enterprise is currently developing the first phase of an ambitious 'European Marine Science Park' adjacent to SAMS. The facility will provide high quality laboratory and office space in a sustainably designed building for new, expanding and inward-investing companies with a focus on marine science, marine energy and related support.

The first building is scheduled for completion later in 2012 and the building project is delivered by Robertson as the main contractor.

Two further buildings may be added in the coming decade depending on demand and sector development (see artists impression with all buildings).

The EMSP is a major iniative aiming to grow the marine science cluster in Oban into an international centre of excellence. Building on SAMS strenghts and the economic success of our European Centre for Marine Biotechnology, the EMSP will play an important role in the economic development of northern Argyll.



SAMS LAUNCHES NORTH ATLANTIC GLIDER BASE

In April 2012 the SAMS Marine Physics Group launched the North Atlantic Glider Base. Scientists from all over the world are invited to bring gliders to the NAGB for deep water testing, launch and recovery for North Atlantic missions, and for instruction on operations and on real-time data delivery. The NAGB can also provides access to two Seagliders and a Remus 600 AUV for development and trial of sensors.

The NAGB offers access to:
1. lab space for glider preparation
2. coastal research vessels for sheltered deep water testing (200m)
3. fast vessels for deployment and recovery of N Atlantic glider missions

The NAGB team offers advice on scientific and operational aspects of North Atlantic glider missions and on real-time glider data delivery to GTS or to data centres.

The NAGB is a delivery partner of the Marine Autonomous Robotic Systems at the UK's National Oceanography Centre and is supported by NERC National Capability funding.

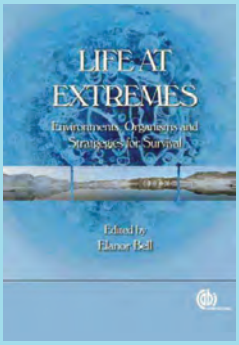
Further information

www.sams.ac.uk/smart-observations

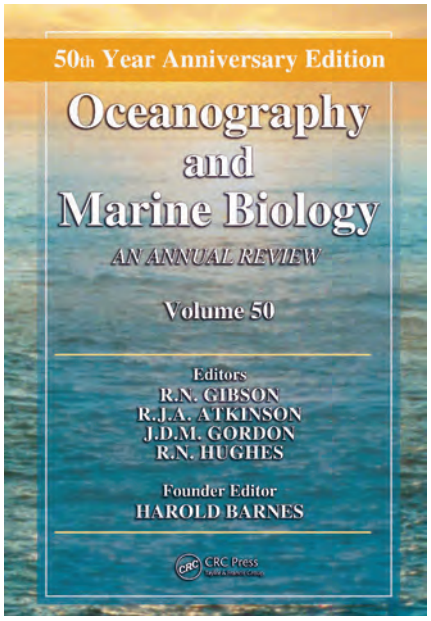
LIFE AT EXTREMES

A new book edited by microbial ecologist and polar expert Dr Elanor Bell details 'Life at Extremes: Environments, Organisms and Strategies for Survival'.

From icy poles to arid deserts, boiling pools to the depths of the sea, this exciting new work studies the remarkable life forms that have made these inhospitable environments their home. The ecological, biological and biogeochemical challenges that higher-level plants and animals, microorganisms and viruses face are detailed, and the unifying themes found between environments discussed. A fascinating and comprehensive resource for researchers and students, this book is packed with colour figures and photos showcasing the most extreme environments and the organisms that have adapted to live in them.



The book has 576 pages, costs £95 and is published by CABI.



GOLDEN JUBILEE EDITION OF *OCEANOGRAPHY & MARINE BIOLOGY: AN ANNUAL REVIEW*

Congratulations to the editors and authors of *Oceanography and Marine Biology: An Annual Review* (OMBAR), which published its 50th volume this summer. The first volume appeared in 1963 and was founded in Millport by Harold Barnes, a senior researcher at the Association. He spotted that there was a place for a review series that has appeared annually ever since and continues to be widely read and cited. Consequently, its impact factor is consistently at the top in its field.

The secrets of the publication's success include selecting excellent authors who dedicate time to writing long and detailed review articles, allowing these authors freedom regarding article length, reference lists and figures, as well as covering a diversity of topics in each issue that attract a wide readership.

In the 50 years since the first volume was published the marine environment has changed: Seas are now warmer, more polluted and over-exploited, mainly as a result of the continued expansion of the human population and its increasing pressure on marine resources. The publication also reflects the fact that marine science has changed over the years, with marine technology producing constantly new tools for studying marine life, and studies that are now not only curiosity driven but may also have relevance to anthropogenic influences on the oceans.

Throughout its first 50 years OMBAR has continued to be intimately associated with the Association: Following Harold Barnes' untimely death in 1978, his wife and co-worker Margaret, a SAMS Honorary Fellow, took over the editorship and ensured the series' smooth continuation. In 1988 two other SAMS scientists, Alan Ansell and Robin Gibson, joined Margaret on the editorial team. Alan Ansell was Managing Editor from 1994 until his death in 1999 when the post passed to Robin Gibson. Following Alan's death, Jim Atkinson from the University Marine Biological Station Millport was recruited and on Margaret Barnes' final retirement in 2002 after 40 years as editor her place was filled by another SAMS Honorary Fellow, John Gordon. After a cumulative 47 years in post, Drs Gibson, Atkinson and Gordon all retire this year as editors but the SAMS and UMBSM connection will be retained through David Hughes (SAMS) and Philip Smith (UMBS). The new Managing Editor will be Professor R.N. Hughes, who recently retired from the University of Bangor, Wales.

SAMS is well known as the home of OMBAR and on its behalf the editors have been able to attend numerous conferences to keep up-to-date with current trends. Over the years SAMS staff have published many papers in the series and it is very fitting that two articles authored by SAMS researchers appear in the golden jubilee volume.

HOW THE PUBLIC SEES THE SEA

Europe's regional seas have suffered severe environmental degradation due to human pressure. As the likelihood of recovery is largely dependent on societal choices, the EC-funded consortium project *KnowSeas* investigated how, why and for what people value the oceans based on a 7000 people strong survey conducted in seven European countries. The resulting policy brief '*Public Perceptions of Europe's Seas*' details that people most value the sea for its influence on weather and climate, food provision and scenery. But in general the oceans were given low priority compared to cost of living, health and education. While scientists and environmental groups were perceived as the most competent to manage the ocean environment, the research also identified a schism between scientific and public perceptions of ocean problems, suggesting ineffectual communication between scientists and public.

The report recommends that successful management initiatives need to incorporate public opinion into the decision making process, however difficult. To drive social and political acceptability towards a sustainable marine system will thus require major public engagement.

WHAT DRIVES OCEANIC WATERS ONTO OUR SHELF SEAS?

Fluxes Across Sloping Topography of the North East Atlantic - FASTNEt for short - is a four-year NERC-funded consortium project aiming to construct a new paradigm of ocean-shelf exchange. Using a range of novel observation and model techniques FASTNEt will investigate seasonal, interannual and regional mixing processes we currently do not understand.

FASTNEt combines data gathered by standard oceanographic moorings with data from 60 satellite tracked drifters and eight state-of-the-art robotic sea gliders. This amazing fleet of smart observation technology will patrol the shelf break from west of the Scilly Isles to the north of Scotland, relaying measurements in real time.

Professor Mark Inall from SAMS led the project on the first of two project expeditions into the Celtic Sea in June aboard RRS *Discovery*.

Monitoring 20 drifters released into the southern region on the Celtic Sea and drouged at 50m, the FASTNEt team were in for a surpise finding. While the movement of water in this area was unmapped, the scientists had expected a current to run along the shelf edge towards the north. Instead, they saw their drifters move south into deep water.

The physical oceanography team also deployed four gliders, which allow for a more detailed study of seawater properties and will operate in the area for three months, continuously providing information.

The next cruise is planned for summer 2013 and will be heading for the Malin shelf edge.

Further information

www.sams.ac.uk/fastnet

CELEBRATING BIOMARA

The €6 million and SAMS led algal biofuels project 'BioMara' has had unparalleled interest from the media and public since its launch in 2009. Especially the potential use of kelp for the generation of biogas has found interest, in particular in rural coastal and island communities.

On the evening of 29th November there will be a final meeting to showcase and celebrate the main outcomes of this project in the Scottish Parliament hosted by Murdo Fraser MSP as convenor of the Economy, Energy and Tourism Committee. The project has been delivered by a working partnership of six research organisations with complementary skills from Ireland, Northern Ireland and Scotland, and funded by the European Union's INTERREG IVA Programme managed by the Special EU Programmes Body.

European Union
European Regional Development Fund
Investing in your future

Further information

Please email **biomara@sams.ac.uk** if you are interested in attending this meeting. Limited places available.

A MARINE LITTER STRATEGY FOR SCOTLAND

In 2010, more than 53,000 pieces of litter were collected from a sample of 22 km of Scottish beaches. Marine litter negatively impacts our environment, society and economy, and new research suggests that changes in public behaviour, awareness and attitude are key to the solution.

The 2011 Scottish Government commissioned study by the James Hutton Institute (JHI) and SAMS found that marine litter costs Scotland a minimum of £16.8 million per annum. Worse still, this figure is thought to be a gross underestimate because there is no data on the economic impact of litter on many sectors, like tourism or recreation.

During the study, our scientists looked at the extent of the marine litter problem, the impacts and the existing activities and regulation to deal with it. They identified several policy responses at local, regional and national scales, but first and foremost saw the need for coordination via a single marine litter strategy for Scotland. In recent months this initiative is now being taken forward by the Scottish Government in an effort to steer society towards an ethic of 'waste as resource'. Tavis Potts (SAMS) and Emily Hastings (JHI) are both active in this Scottish Government Committee and are involved in drafting a Scottish Marine Litter Strategy.

Further information

www.knowledgescotland.org/briefings.php?id=261

HOMELESS
DUE TO CLIMATE SHIFT?

Rising temperatures are likely to force more and more species of animals and plants to emigrate to find new places to live where the climatic conditions are better for their survival. This may leave some marine species with nowhere to go, according to research led by SAMS Professor Mike Burrows published in the journal *Science*.

The international research team compared changing temperatures for both land and sea and from place to place over a 50 year period, from 1960 to 2009. They used large existing databases to calculate how quickly populations of terrestrial and marine species would have had to relocate to keep up with changing temperatures.

The researchers found that the rates with which marine and terrestrial animals and plants move is surprisingly similar although the land is warming about three times faster than the ocean.

When land temperatures become too hot for some species, they can move to higher ground where temperatures are generally cooler. But that is not an option for many marine species which live at, or near, the surface of the ocean.

When temperatures rise, species such as fish may be able to move into deeper water to find the cooler environments they prefer. Other species, however, especially if they depend on light or other depth-dependent properties, cannot move over a short distance to deeper, cooler waters but have to move longer distances to colder latitudes to find suitable habitats. Especially slow moving organisms could thus become trapped and it may become harder and harder for them to keep up with climate change.

"Being stuck in a warming environment can cause reductions in growth, reproduction and survival of ecologically and economically important ocean life such as fish, corals and sea birds," explains co-author Dr John Bruno from the University of North Carolina.

The study also highlights how much ocean surface temperatures can sometimes change over quite minor distances. Spring-time water temperatures on the east coast of Scotland, for example, have arrived around five days per decade earlier, whereas there has been almost no shift in spring temperature on the west coast.

It is somewhat worrying that some of the areas where where species may have to relocate the fastest if they are to stay ahead of climate changes, are particularly important hotspots of biodiversity, such as the coral triangle in Southeast Asia.

"Understanding this may help conservationists to prepare for change and protect future coral habitats," suggests Professor Burrows.

SAMS EDUCATION NEWS

UHI STUDENT TEACHING AWARDS FOR SAMS LECTURERS

Inspirational, innovative and engaging are compliments given by students to their lecturers at the University of the Highlands and Islands in the 3rd annual teaching awards scheme.

Organised by the UHI Students' Association, the awards recognise excellence in seven categories of which two of the most prestigious were awarded to SAMS lecturers: Dr John Howe was voted most inspiring lecturer while Professor Toby Sherwin won best research supervisor.

Some of the stiffest competition for these awards came from other SAMS nominees, demonstrating that SAMS students appreciate the dedicated commitment from their lecturers.

Most inspiring lecturer, Dr John Howe (above), a marine geologist and Head of the Biogeochemistry and Earth Science Department at SAMS, was commended for his positivity and passion for geology.

"John is the most incredible lecturer I have ever had." said one student. "With love for his subject, he has the ability to bring across knowledge in a short time and raise the interest of the whole class."

Best research supervisor Toby Sherwin (below), a UHI Professor of Oceanography at SAMS, was selected for his commitment and support. His former PhD student Clare Johnson explained: "Toby is a dedicated and diligent supervisor and has supported me over several years, including during a period of ill-health. He has an open door policy and was really supportive during the year I was unable to study. He collected samples at sea for me and drove me home when I was too ill to use public transport."

RENEWABLE ENERGY ENGINEERS STUDY MARINE LIFE @ SAMS

Six of the UK's very best engineering research students - aiming to lead the development of offshore renewable energy technologies in the future - spent a fortnight at SAMS between 2nd and 13th of July for an Ecology Summer School. The training provided the students with a deeper knowledge of the biology of the UK's marine environment so that they will be able to consider the interactions marine organisms are likely to have with any renewable energy installations that will be placed into the sea. This new understanding should inform their engineering practice in the future so they can consider environmental interactions from the outset of designing new devices.

The students, who are conducting their engineering research based at a range of sponsoring companies, greatly enjoyed their marine science module, with their spokesperson saying "I don't think I am overstating to say that this module has been one of the most fun and engaging we have had."

SAMS module leader Dr Ben Wilson said: "Likewise we have really enjoyed this teaching experience. We particularly valued the chance to broaden the perspectives of engineering students who are ultimately destined for the heart of the marine renewables industry. The education wasn't unidirectional either. In discussion they taught us a thing or two about the engineering constraints facing these embryonic technologies."

SAMS is a partner in IDCORE, the Industrial Doctoral Centre for Offshore Renewable Energy, which offers a four-year full-time engineering doctorate in Offshore Renewable Energy aimed at the very best EngD students.

IDCORE aims to train their students to deliver world-class industrially focussed research that will accelerate the deployment of offshore wind, wave and tidal-current technologies so that the UK can meet its 2020 and 2050 targets for renewable energy generating capacity.

IDCORE is a consortium of the Universities of Edinburgh, Exeter and Strathclyde, HR Wallingford and SAMS and is funded by the Engineering and Physical Sciences Research Council and the Energy Technologies Institute to train 50 research engineers over an eight year period.

DEVELOP YOUR SKILLS THROUGH SHORT COURSES OFFERED AT SAMS

SAMS offers a comprehensive training programme of short courses delivered by our scientists that enable participants to keep up to date with latest advances in research and methodologies and develop the training portfolios of their CV.

This autumn's courses include:

- Algaculture (25-26 Sep)
- Algal molecular methods (27/8 Sep)
- Marine Invasive Species (4-5 Oct)
- Data & Google maps (23-24 Oct)
- Mapping and GIS (25-26 Oct)

Science and technology changes on a daily basis. As professional scientists, learned society members, or others with a vested interest in marine science, it is ever more important to keep abreast of new findings to inform the direction of your work and increase your options for employment and application in the work place.

The inter-disciplinary nature of SAMS enables members to appreciate the bigger picture and the fine balances that exist between the sciences. SAMS believes it is critical to create a culture of lifelong learning for members, staff and students. As such, we have renewed our emphasis on educational programmes, especially short courses, and would urge you to involve yourself in continuing professional development.

This sharing of knowledge and investment in our futures will accelerate scientific thought, improve employability options especially for students and early career scientists, enable us to extend our reach and influence and, crucially, assist in resolving some of the greatest challenges ever to face our global marine environment.

Use the following to find out more about SAMS' education programmes or to run a seminar and share your own findings:

W: www.sams.ac.uk/education
E: education@sams.ac.uk
T: 01631 559 335

ST ANDREWS AND SAMS COLLABORATE ON MASTERS IN MARINE MANAGMENT

February 2012 saw the first cohort of 13 St Andrews postgraduate students arrive at SAMS for their second term of studying for a new MRes in Ecosystem-Based Management of Marine Systems.

This programme provides students with the expertise in the ecological and physical sciences and the essential quantitative skills needed to manage marine ecosystems sustainably. Students learn to deliver integrated coastal zone managment from the tropics to the polar regions. The module in Tropical Marine Systems includes a 2-week fieldtrip to Australia's Great Barrier Reef. For 2012/3 we expect 17 students. More information at **www.sams.ac.uk/education**

UNDER DEVELOPMENT: NEW MASTERS IN ALGAL BIOTECHNOLOGY

Algae are an amazingly diverse group with enormous potential for use in the biotechnology sector. SAMS, which hosts Europe's largest collection of algae, has significant experience in the development of algal biofuel and other aspects of biotechnology involving algae.

SAMS UHI is therefore developing a new Masters programme for 2013/14 that will provide students with specialist knowledge, expertise and transferable skills relevant to the biotech sector and with the opportunity to undertake substantial research as part of the course.

RUTH PATERSON: OUR STUDENT OF THE YEAR

SAMS has named Ruth Paterson (20) as its UHI student of the year 2012. Ruth, a third year student studying for a BSc (Hons) Marine Science, was selected by her lecturers because of her motivation and exemplary academic performance.

Ruth is an exceptionally proactive student: On her own initiative she secured a grant from the British Phycological Society (BPS) for research to investigate why only some strains of the dinoflagellate alga *Alexandrium tamarense* make the shellfish that ingest them poisonous to humans. Results from her ongoing research have already been presented at international conferences and featured in the BPS newsletter.

SAMS director Professor Laurence Mee commented: "*Alexandrium* is becoming a massive problem for the shellfish industry. Ruth showed huge confidence and dedication by undertaking this work and it is a great success story for research-based teaching."

Ruth, who hails from Colintraive on the Kyles of Bute, said: "I am overjoyed with the award. I continue to love my time here and look forward to a stellar fourth year completing my honours degree. My project showed me what it's really like to work in a research environment - it's completely different from the student experience. I'm so lucky to have SAMS UHI on my doorstep! I would like to thank Dr Keith Davidson for his help and Mrs Christine Campbell for providing the algal cultures for this project."

PEOPLE NEWS

UHI AWARDS PROFESSORSHIPS TO MARK INALL & MIKE BURROWS

UHI has honoured two SAMS research scientists for their achievements. Michael Burrows (top left) and Mark Inall (bottom left) have been awarded personal chairs for their research. Personal chairs are one of the highest professional accolades in academia.

With over 28 years' experience in coastal ecology, **Professor Michael Burrows** has been described as one of Europe's leading marine ecologists. His interest in using research about individual organisms to inform our understanding of global ecosystems has led him to contribute to over 80 academic publications and give keynote speeches at several international conferences. As Head of the SAMS Ecology Department, Professor Burrows also teaches under- and postgraduate students and has supervised twelve PhD students.

Since joining the organisation in 1998, **Professor Mark Inall** has built up an internationally recognised research group and made a significant contribution to teaching at SAMS UHI. He was instrumental in developing the BSc (Hons) Marine Science and has taught on many undergraduate modules.

Combining knowledge of physics and oceanography, Professor Inall's research specialises in the movement of internal waves. He has produced internationally renowned research on fjords and coastal processes and has written and contributed to many publications and conferences. Since 2010 Professor Inall is Associate Director for Research at SAMS.

DR STUART CUNNINGHAM JOINS SAMS AND TAKES ON LEADERSHIP OF THE MASTS MARINE SYSTEMS AND DYNAMICS THEME

In August SAMS welcomed Dr Stuart Cunningham onto the staff as MASTS Physical Oceanographer. Stuart is an observational physcial oceanographer with extensive seagoing experience and a publication list including three papers in *Nature* or *Science*.

From 2004-12, while based at the National Oceanography Centre, Southampton, he was Principal Investigator for the NERC/NSF funded RAPID-WATCH programme for sustained observations of the Atlantic Meridional Overturning Circulation. Besides continued involvement with RAPID-WATCH through the programme advisory group, Stuart currently also works on projects including Thermohaline Overturning at Risk? (THOR) and North Atlantic Climate Variability (NACLIM). Over several years Stuart has been advocating basin-wide observations in the subpolar gyre because of the relevance to the UK.

For the MASTS Marine Systems and Dynamics theme Stuart will develop a prospectus of critical scientific research questions and develop a vision for strategic marine research over the next 20 years. His strategy is likely to espouse sustained observing, analysis and interpretation as well as modelling of the ocean at all time and space scales. Stuart is a strong supporter of national and international coorperation.

E: Stuart.Cunningham@sams.ac.uk

DR BEN WILSON IS ELECTED AS MASTS MARINE ENERGY FORUM CONVENOR

Marine ecologist Dr Ben Wilson has been elected by his peers to serve as the Convener of the MASTS Marine Energy Forum. Ben, who has led the SAMS Blue Energy Research Group since its inception, conducts research investigating the environmental interactions between marine renewable energy devices and marine fauna, with a particular focus on the physical and acoustic interactions between marine vertebrates and tidal-stream devices.

Ben will be supported by a steering group and plans to concentrate on information flow and opportunities for building scientifically valid collaborations.

E: Ben.Wilson@sams.ac.uk

Former Director **CLIFFORD MORTIMER** dies aged 99

Born Whitechurch 27 Feb 1911; Died USA 11 May 2010

ABOVE: Clifford Mortimer received his final greetings from SAMS on his 99th birthday...

Born into a Quaker family in the village of Whitechurch, Somerset Clifford H. Mortimer entered the University of Manchester in 1929 to study Zoology. Following graduation he attended a short course at the Freshwater Biological Association led by W.H. Pearsall. This initiated his interest in freshwater biology. He received a DPhil from the University of Berlin following his work on the biology and genetics of the genus *Daphnia*. He took up his first research post at the FBA in October 1935 and soon developed a deep, lifelong passion for limnology.

In 1956 Mortimer became Director of our then Scottish Marine Biological Association in Millport. He was eager to pursue better integration between freshwater and marine research but was torn by his desire to pursue his research interests into internal waves at the continental shelf edge and his directorial duties.

His nine year directorship is noted for one of the most historic events in the Association's history: the move from Millport to the site SAMS now occupies near Oban. It was a traumatic period, with many staff opposed to a relocation that is now seen as key to SAMS' continued growth and success.

Clifford Mortimer did not make the move to Oban, instead taking up a position as Distinguished Professor of Zoology at the University of Wisconsin-Milwaukee in 1966. The post included Directorship of the Centre for Great Lakes Studies. As part of the duties Mortimer acquired and refitted a government ship, *Neeskay*, ready for research trips on the Great Lakes.

Mortimer retired from administrative duties in 1978 and from academic duties in 1981. However, he continued his interest in limnology and in 2004, at the age of 93, published 'Lake Michigan in motion: responses of an inland sea to weather, earth spin and human activities'. His last paper came out in 2006 and assessed inertial oscillations in Lakes Michigan and Ontario.

On 11th May 2010 Clifford Mortimer died peacefully. His ashes were scattered on Lake Michigan from his research vessel *Neeskay*.

PERSONAL CHAIR FOR SAMS DIRECTOR **PROFESSOR LAURENCE MEE**

SAMS Director Professor Laurence Mee has been honoured for his career achievements by the University of the Highlands and Islands.

He has been awarded a personal chair in recognition of his work and widespread renown in marine science. Personal chairs – as opposed to those which are established by universities for academic leadership in a specific discipline – represent one of the highest professional accolades.

James Fraser, UHI Principal and Vice-Chancellor, said: "Although Laurence already carried the title of professor before he came to the university, the personal chair is a much deserved recognition of his reputation and distinction as a scientist and academic. Professor Mee combines a high level of achievement in research, teaching, and academic leadership, with a national and international reputation for knowledge, policy and service in marine science and the marine environment."

Professor Mee joined SAMS in 2008 after an international career at the forefront of marine science and oceanography. He was previously the director of the University of Plymouth's Marine Institute where he was also the UK's first Professor of Marine and Coastal Policy.

Prior to this he spent eleven years working at the United Nations, including six years heading the Marine Environmental Studies Laboratory in Monaco. Professor Mee facilitated negotiations for the first post-Soviet

inter-ministerial declaration on the Black Sea in 1992 and subsequently led the $110m Black Sea Environmental Programme which was designed to help the system recover from severe eutrophication.

Currently Professor Mee conducts multi-disciplinary research on coupled marine social-ecological systems and leads the European research project KnowSeas.

CARBON CAPTURE AND STORAGE
WHAT HAPPENS WHEN CO_2 LEAKS FROM A SUB-SEABED STORAGE SITE?

Dr Henrik Stahl, SAMS

As the world searches for viable climate change mitigation strategies one proposal is to capture carbon dioxide generated by large-scale industrial processes at source before it can reach the atmosphere, and to store it in underground reservoirs.

This so-called Carbon Capture and Storage (CCS) is already happening: At least one prominent energy company already stores annually one million tonnes of carbon dioxide in the North Sea's Sleipner site. Many other potential storage sites are also in the marine environment.

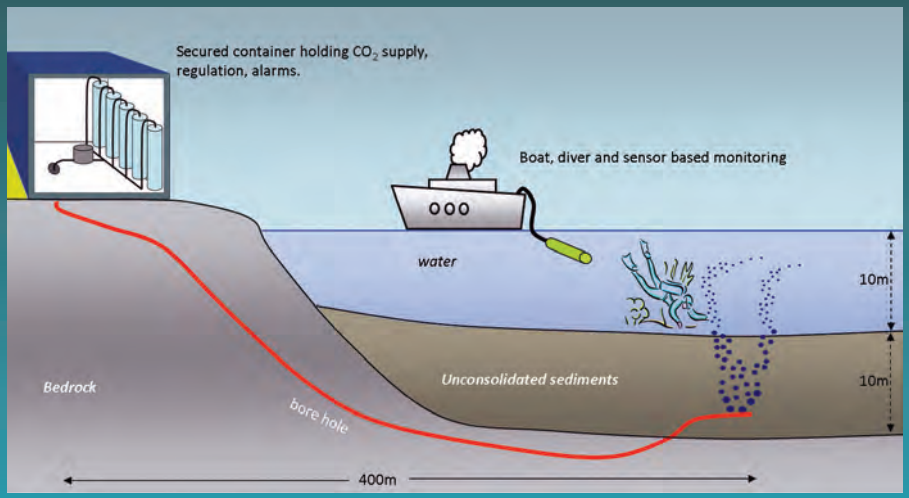
As society has to decide between many options of generating energy and dealing with a changing climate, the role of science is to provide the factual understanding needed to make informed decisions. To judge the role CCS should play requires much currently outstanding information, including what happens to the marine environment should carbon dioxide accidentally leak either from pipes or from the storage sites directly.

World first release study

During the spring and summer of 2012, a team of scientists carried out an *in situ* CO_2 release experiment in Ardmucknish Bay near Oban as part of a project aiming to investigate and quantify the potential impacts of CO_2 leakage from a CCS site on the marine ecosystem.

First we carefully studied the biology and chemistry of the local sediment and water so that we understood the baseline state of the environment.

Then, in the early spring, a bore hole was drilled 450m from Tralee Bay Caravan Park into Ardmucknish Bay. The bore hole was lined with a stainless steel pipe with a perforated screen at the end from where we could release CO_2 12 m below the surface of the seabed.



ABOVE: The Ardmucknish Bay carbon dioxide release study pumped daily 80-180 kg CO_2 into the sediment over 36 days and studied the environmental impacts of this input and the recovery of the marine environment over the following three months.

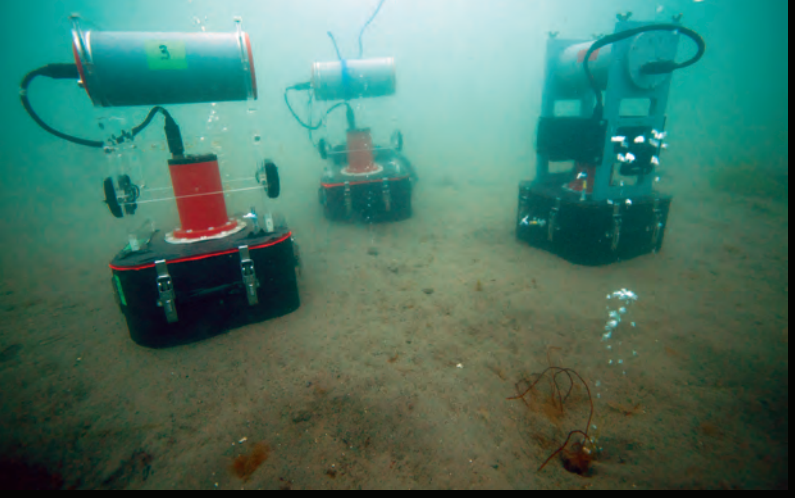
On May 17th the CO_2 gas release started and was left on continuously for 36 days. The gas was initially released at a rate of 80kg/day which was gradually increased to 180 kg/day over the duration of the experiment. This amount of CO_2 equates to the exhalations of just a few hundred people per day and thus represents a small leak rather than a mayor accident.

First results

Only a few days after the release start, concentrated bubble streams began to emerge from the sediment into the water column ca 10 - 15 m NW of the tip of the screen. This observation was complemented by sub-bottom profiling data which found that the CO_2 did not migrate only vertically from the release point but also horizontally along sediment layers with decreased permeability. These results combined with direct flow measurements of the bubble streams indicated that only around 20% of the released CO_2 gas left the sediment in the form of gas bubbles while the remaining 80% either dissolved or remained within the sediment.

The CO_2 bubbles had an almost immediate local effect on the overlying water column chemistry: amongst the bubble streams we recorded pH values as low as 7.6 and pCO_2 as high as 2000 µatm.

The change in sediment chemistry, however, was much slower.



We could pick up signficant changes in the alkalinity and pH of the surface layers of the sediment only towards the end of the 36 days of CO_2 release. This delayed response could be due to the buffering capacity of the sediments and/or to the slower transport of CO_2 within sediments compared to water.

Unexpectedly, we also measured elevated CO_2 concentrations above the seawater interface immediately above the release site.

When we eventually stopped the gas release on 22nd July to monitor longer term impacts and recovery, we observed the reverse reaction: signals in the water column deteriorated very rapidly while the signal in the sediment remains for the time being (stand: early September).

In terms of effect on the fauna, it is still early days as sample enumeration and identification is still underway. Visual observations by divers during the release, however, suggest that certain types of infauna, such as the burrowing sea urchin *Echinocardium cordatum*, could have been adversely affected by the perturbation, whereas other epifauna (e.g. crabs and hermit crabs) seemed attracted by the perturbation.

I must, however, emphasise that the results summarised above are preliminary and possibly subject to change as additional data accumulates and is analysed and then peer reviewed. But our preliminary data certainly suggest that the effect of CO_2 was localised as we detected no elevated concentrations in the water column >100 m away from the epicenter of the release.

Currently, the team is studying the recovery at the release site over the first three months after the release came to an end.

Project details

QICS (Quantifying and Monitoring Potential Ecosystem Impacts on Geological Carbon Storage) is a collaboration between ten UK partners with several Japanese associates that is coordinated by Plymouth Marine Laboratory and funded by the UK's Natural Environment Research Council.

Further information

www.bgs.ac.uk/qics
www.sams.ac.uk/henrik-stahl/qics

ABOVE: A tense moment when after years of preparation the gas is finally switched on and the world's first in situ release experiment investigating the impacts of CO_2 leaking into the marine environment gets under way.

THE EVIL TWIN OF CLIMATE CHANGE:

Ocean Acidification in sediments

Dr Natalie Hicks (Natalie.Hicks@sams.ac.uk) and **Dr Henrik Stahl** (Henrik.Stahl@sams.ac.uk), SAMS

It is widely accepted that recent increases in global atmospheric temperatures are a result of climate change caused by anthropogenic release of CO_2. However, the rising atmospheric CO_2 levels will also directly impact our marine ecosystems as our oceans absorb up to 50% of the atmospheric CO_2 produced by burning fossil fuels, deforestation and cement production. This causes the ocean pH to decrease, since the CO_2 gas reacts with water to form a weak acid, thus making the oceans more 'acidic'.

Ocean acidification is also known as "the evil twin of climate change" or the "other CO_2 problem", and is likely to have wide implications for our marine ecosystems. Ocean pH has dropped by 0.1 pH units since the start of the industrial revolution (from 8.2 to 8.1, see Figure 1), which actually equates to a 30% increase in acidity as the pH scale is logarithmic.

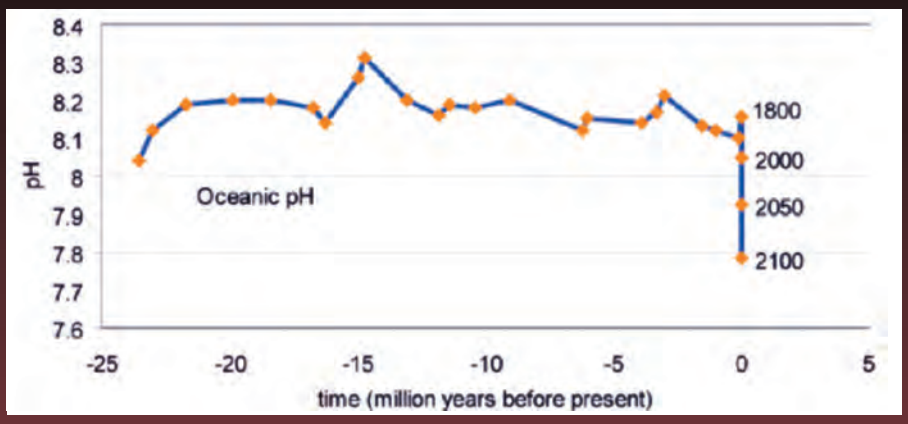


Figure 1: Past and present variability of marine pH. The model prediction is based on IPCC mean scenarios (from Perason and Palmer, adapted by Turley et al for EurOceans Fact Sheet 7).

These changes in pH are predicted to affect marine ecosystems, from the level of individual species to whole populations and communities, and the ecosystem services they provide us with.

More than 40% of the world's population live within 100km of the coast and coastal habitats provide humans with a variety of services including food, recreation and jobs. Many of these ecosystems harbour high levels of biodiversity, and this will be affected by environmental changes such as ocean acidification and rising sea-surface temperatures.

Over the last decade, ocean acidification research has demonstrated how changing pH affects organisms that calcify such as corals, molluscs, crustaceans, echinoderms and some algae. Increasing acidity lowers the availability of carbonate ions (CO_3^{2-}), which are vital for animals to form skeletons and shells from calcium carbonate ($CaCO_3$). However, little is known about the combined effects of ocean acidification and rising temperature on the coastal sediments where a large proportion of primary production and global nutrient cycling occurs.

How will ocean acidification and elevated temperature affect the biogeochemistry of benthic habitats?

As part of a UK-wide NERC funded consortium, this is a question that researchers at SAMS are determined to answer. We have just completed a series of experiments to identify the effects of ocean acidification and elevated temperature on benthic biogeochemistry on two important coastal sediment types: cohesive mud and carbonate sand. These sediments dominate many of our UK coastal habitats, ranging from broad sandy beaches to tidal estuarine mudflats which are important feeding sites for a variety of wading bird species. The sediment used in our project was collected from the Eden Estuary in St Andrews.

Using custom-built flume tanks and a new purpose-built CO_2 manipulation system (Figure 2), sediments were exposed to different CO_2 and temperature treatments, based on future ocean acidification scenarios under current CO_2 emissions, under natural flow and light conditions.

State-of-the-art sensing techniques (oxygen microelectrodes) and broad-scale measurements (water nutrient concentration, primary productivity on the sediment surface) were applied to find out how the different types of coastal sediment respond to future environmental changes.

The results from these experiments will ascertain the changes in pH, nutrients, oxygen concentration, primary production in mud and sand and the microbial content of each substrate.

After an intensive year of running these 28 day experiments, the practical work has just been completed, and now the laboratory work and data analysis commences.

This research includes close collaboration with colleagues from St Andrews and Hull universities under the UK Ocean Acidification program (UKOA), and aims to contribute to understanding how ocean acidification is likely to affect global nutrient cycles under future scenarios. Research within UKOA will provide evidence for the IPCC 5th Assessment Report on climate change, and help feed into the Climate Change Adaptation Program.

Ocean acidification is already happening. If CO_2 levels continue to rise, by the end of this century ocean pH could have dropped by another 0.4 units according to current models. Research such as this is thus timely and essential in determining the impacts future environmental change may have on our oceans, and may provide information on how to deal with, and mitigate, ocean acidification.

Further information

http://oceanacidification.org.uk

http://www.benthic-acidification.org

Figure 2: The custom-built flume facility at SAMS is used to study the combined impacts from ocean acidification and temperature increases on benthic biogeochemistry in cohesive mud and in carbonate sand.

SAMS BURSARY RESEARCH
WILL OCEAN ACIDIFICATION CHANGE MICROBIAL RELATIONSHIPS?

Virginia Echavarri, Heriot-Watt University student and SAMS member and **Dr David Green**, SAMS

The discovery of a new bacterium – whose relatives normally thrive under highly acidic conditions – in association with a coccolithophore (a microalga surrounded by calcium carbonate scales known as coccoliths) prompted questions about what such an acidophilic microbe might be doing in the ocean, how it can live in the mild alkalinity of seawater and whether it could weaken or even dissolve the $CaCO_3$ of coccoliths.

A SAMS scientist discovered a new bacterial strain closely related to the acidophilic phylum Acidobacteria in an *Emiliania huxleyi* culture held at SAMS. The name, Acidobacteria, derives from the acid-loving way of life of these bacteria. To find Acidobacteria in seawater and in association with an alga, therefore appeared to be highly unusual. Curiously, though, other marine relatives of this Acidobacteria have been found by other researchers looking at corals and other calcarious marine animals. This suggests there might be an ecological pattern related to $CaCO_3$?

The project's main objective was to investigate the relationship between Acidobacteria and coccolithophores to find out whether the bacteria could negatively affect the algal coccoliths.

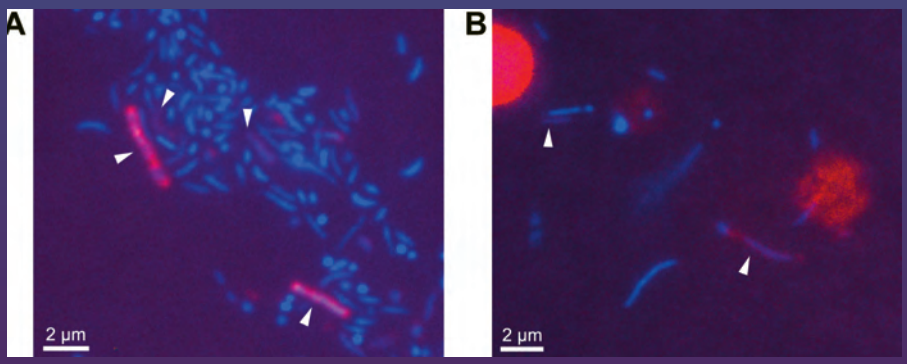
To do this, we first studied the physiology of the new acidobacterial strain, then investigated the association with *Emiliania huxleyi* and latterly, screened other coccolithophore cultures from different regions for presence of Acidobacteria.

Methods used

A series of experiments were devised to study bacterial growth, assess salinity tolerance, the optimum pH for growth, carbon and nitrogen utilisation, Ca^{2+} tolerance and the relationship between $CaCO_3$ and bacterial growth. To visualize Acidobacteria in algal cultures, and whether they were only found close to *E. huxleyi* cells, fluorescent *in situ* hybridization (FISH) was used.

What we found

Like many epipelagic bacteria in the ocean, our bacterium was motile and heterophototrophic, with a preference for organic carbon sources such as those found on the cell wall of coccolithophores (e.g. acidic sugars). The bacterium was small (ca 2 µm x 0.6 µm) and it produced carotenoid pigments giving the cells a yellow appearance. But it was not an acidophile. Instead, the organism grew best in slightly alkaline conditions of pH 7.7 - 8.5, with salt concentrations of 2 - 3% and calcium concentrations in the region of 7.75 - 15 mM. Curiously, the bacteria also grew faster in the light than in the dark, suggesting it may harvest photons as an energy source to help it grow – it is photosynthetic, but does not produce oxygen.



ABOVE: FISH detection of Acidobacteria in E. huxleyi cultures. (A) E. huxleyi RCC1214 and (B) E. huxleyi isolated from a Bergen mesocosm (2008). Arrowheads denote "pink-purple" stained acidobacterial cells detected using Cy3 fluorescently labeled probes. Cells stained blue (DAPI) are other types of bacteria. Scale bar, 2 µm.

The FISH technique revealed that the association of these bacteria with coccolithophores is probably not coincidental. We found Acidobacteria to be widely distributed in cultures originating from Norway, Scotland, Ireland, Italy and New Zealand. They could thus be as widespread in the marine environment as on land.

Conclusions

The growth requirements of the new strain of Acidobacteria suggest that it is adapted to the environmental conditions of the ocean with a preference for surface waters where it can take advantage of sunlight for growth. We propose that the reasons for its association with coccolithophores include access to light and its ability to use the acidic sugars associated with coccoliths.

The results of this study also confirm the distribution of the Acidobacteria phylum in association with calcifying marine algae.

Further work should include in-depth analysis of the relationship between members of the Acidobacteria phylum and calcium carbonate as the main component of the coccoliths, and whether cells actively cause carbonate dissolution. Further characterisation of the carotenoid pigments may reveal novel compounds for use in biotechnology.

Acknowledgements

Virginia would like to thank all colleagues at SAMS for their help and cheerfulness and the good times spent in and out of the lab. A particular thank you goes to Dr David H Green for his patience, support and inspiration. We are both indebted to SAMS for supporting this research financially through award of a SAMS bursary.

This research formed part of the final dissertation for the MSc Marine Biodiversity and Biotechnology at Heriot-Watt University.

EVOLUTION OF THE CUCKOO EFFECT

Dr Clive Craik SAMS Fellow

Everyone knows the story of the cuckoo, one of the most amazing and intriguing in the whole of nature. The female cuckoo lays her egg in the nest of another bird species and the unsuspecting victim incubates it, along with its own eggs. The first thing the young cuckoo does after hatching is to heave the other young out of the nest to their deaths. The foster parents then rear the strange young bird until it can fend for itself.

The habit of laying in other birds' nests occurs in many bird groups, and recent work at SAMS on seabirds breeding in sealochs, firths and sounds of west Scotland has cast a little more light on the story ["Mixed clutches at seabird colonies in west Scotland 1996-2009" in *Seabird* 23 (2010) 41-52]. For the first time, the percentage of birds that do this has been measured.

Over the years 1996-2009, 123 mixed clutches (containing the eggs of two species) were recorded in 69,775 seabird nests, or 0.18%. This percentage is higher than we might have expected and, if it is representative of birds in general, it suggests that the habit is widespread enough to have evolved into the more specialised nest parasitism of the cuckoo. But why should birds lay in other birds' nests in the first place?

Work in recent years by others has shown that surprisingly large numbers of some seabirds lay in the nests of other birds of their own species. For example, 34% of Black-headed Gull nests, 31-42% of Eider nests and 36% of Barnacle Goose nests were found to hold eggs of more than one female! This kind of egg parasitism within a species can be understood as individual birds trying to increase their output of young at no cost to themselves. Mixed clutches involving two species almost certainly arise when such birds lay in the nest of another species rather than their own.

Some probably do this simply by mistake, but others may do it to cast their parasitic net even further. In some of the closely-related mixed clutches found in the Scottish work, such as Common Gull-Black-headed Gull, or Herring Gull-Great Black-backed Gull, the way the parents feed and tend the young are so alike that the guest young might well have been raised to flying by the foster parent. Indeed, the same issue of *Seabird* reports an amazing case from France of a Sandwich Tern laying its egg in the nest of a Roseate Tern pair, which then hatched and raised the young Sandwich Tern successfully!

Others species in the Scottish study were less compatible, including the two pairs found most often: Common Gull-Oystercatcher (a wader) (see image below), and Herring Gull-Eider duck. Even here, the author suggests, there are small possibilities that the guest young might survive. The nesting colonies are dense, mixed and close to the sea. Before it could be noticed and eaten by its foster parent, a newly-hatched Eider duckling in a Herring Gull nest might be able to run through undergrowth to join a crèche of Eider ducklings nearby on the sea, drawn by the constant contact calls of their guardian adult ducks. Similarly, a newly-hatched Herring Gull chick in an Eider nest might be adopted by a nearby adult Herring Gull, since this has been recorded for orphaned Herring Gull chicks. The parasitic parent gull or duck would then have succeeded. However, more work is needed to find if such things really happen.

Some of the least compatible mixed clutches that were recorded in west Scotland, such as a Herring Gull chick in a Shag nest, and a Shag egg in a Herring Gull nest, must surely have ended with the death of the guest chick or egg, since the way these adults feed their young are so different. Such bizarre layings are almost certainly mistakes. Putting it another way, they are imperfections in evolution. But they illuminate the twists, turns and blind alleys that must have accompanied the evolution of the extraordinary life history of the cuckoo.

Three eggs of Oystercatcher and two of Common Gull in an Oystercatcher nest.

Six eggs of of Merganser and two eggs of Eider in a Merganser nest.

Dynamic Oceans Research

ON THE CHANGING DISTRIBUTION OF SPECIES

by **Dr Tom Adams** and **Professor Michael Burrows** SAMS

Life in our oceans is dazzlingly diverse, varying both geographically and over time, but our hunger for natural marine resources is putting marine life systems under increasing pressure.

If we want to manage our biological marine resources sustainably, we need to improve our understanding of this system, including the factors that drive variation in species distribution and abundance as well as how different populations are connected.

Larvae - moving around

Many marine species go through mobile larval stages that drift in ocean currents. Their ultimate success in replenishing existing adult populations depends on their reaching a suitable habitat by the time they are ready to settle.

How organisms respond to variation in local environmental conditions largely determines where they can live. For instance, water temperature influences the production of larvae as well as the ability of these larvae to survive and develop. Food availability is especially important for immobile organisms such as barnacles. These animals cannot actively forage. Instead they filter tiny food particles from the surrounding water. The amount of food that they can extract is limited by its concentration in the water, and by the amount of water movement.

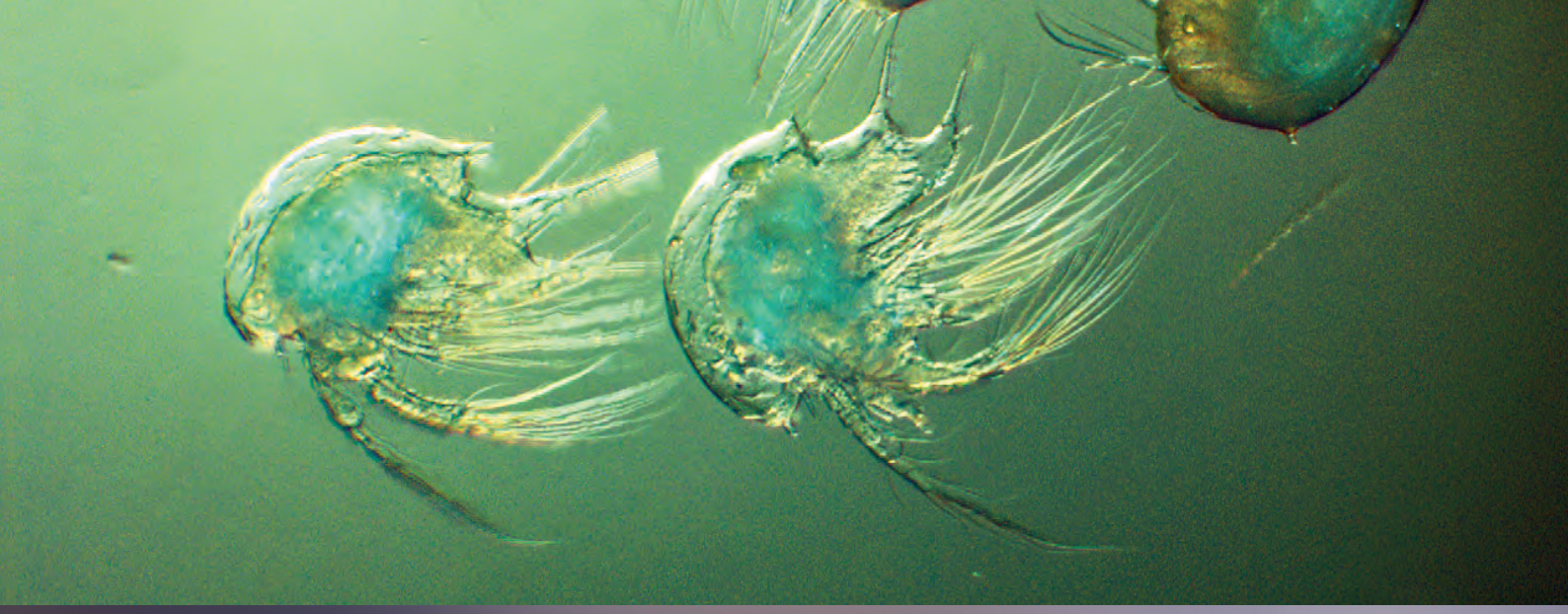
The distribution of larvae, which are capable of only limited (if any) active movement, is largely a product of water currents. Coastal eddies and topography such as bays and inlets, serve to retain larvae close to the shore, while larger scale currents have the potential to distribute larvae far from their parents. In order to improve our understanding of dispersal patterns of marine organisms, ecologists are increasingly applying coupled biological and hydrodynamic models.

Sea lice as model organisms

Many species of fish are farmed at sites on the coast around Scotland. At these sites parasitic sea lice may turn up and cause various problems. Careful management is required to avoid an infestation.

Sea lice have a passive larval stage, and an adult stage which lives inside a host fish. They occur naturally in wild populations, but salmon farms have relatively high fish densities, creating ideal conditions for parasitic sea life to thrive. While outbreaks can be managed using sea lice medicines, it may be desirable to limit the release of chemicals into open water.

Furthermore, there is a risk that sea lice may become more resistant to available treatments over time.



By modelling currents in the region of fish farms, we can begin to understand how lice larvae are transported within the water column. This enables us to determine connectivity between neighbouring farms, and also between the farms and migration routes of wild fish, allowing improved site selection and reduced medicine use.

The MaREE project

The Marine Renewable Energy and the Environment project (MaREE) is a broad project assessing the potential impact of renewable energy devices on ecological populations. Our work in the project considers devices' possible impacts on population connectivity.

When renewable energy devices are installed, they change the local environment in many ways: rocks are often placed around the base of structures in order to reduce the amount of seabed scouring that takes place. This, and other new hard surfaces such as metal towers and the turbines themselves, provide an ideal habitat for a wide range of plants and animals in previously inhospitable locations. It also may provide 'stepping-stones' or new migration pathways for incoming species.

Connectivity studies, combining an understanding of local and regional currents with species response to environmental conditions, allow us to predict the changes that may occur. Computer modelling is central to connectivity analyses, and recent advances have made the simulation of water movements around complex coastlines more feasible.

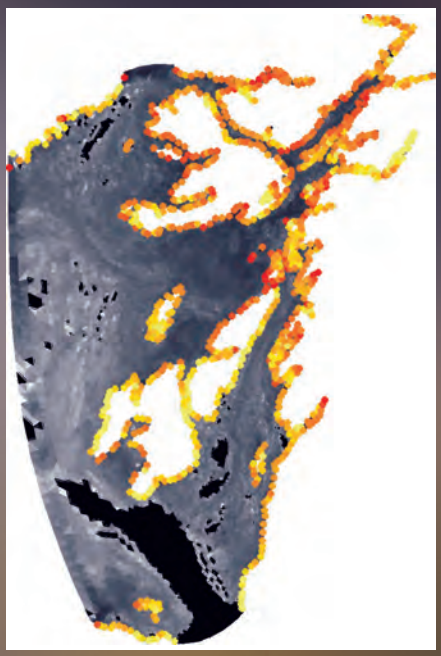
SAMS' physicists have specific expertise in hydrodynamic models for the west coast of Scotland, and we have been working increasingly closely with them. Coupling their hydrodynamic models with our biological models allows us to predict the abundance of species over time and space, while model outputs can aid our understanding of the relative importance of habitat sites to overall population survival.

Coupled hydrodynamic and biological models are powerful tools to assist in understanding the main drivers in the observed dynamics of marine populations.

An on-going challenge is the acquisition of data for model parameterisation and validation. SAMS has spent many years systematically collecting ecological and physical data but previous collection methods are not always appropriate to specific applications.

A further challenge is the development of multi-species models as interactions complicate patterns of response to external factors. Previous studies at SAMS have been successful in distinguishing between these effects, but as models become more complicated, a general understanding of inter-species interactions and their impact upon model predictions becomes increasingly important.

ABOVE: Configuration of habitat sites in the Firth of Lorn used to test hypotheses relating to the impact of offshore renewables on coastal habitats.



ABOVE: Simulation output without new renewable device habitat shows the relative number of larvae predicted to arrive at each site (yellow=low; red=high). The grey shading represents the relative amount of time larvae spent in each model element.

COD GALORE

SAMS member Eric McVicar goes fishing with the Sea Sami to discover why cod is so prolific in the Lofoten Islands

It was only at the third attempt that we managed to land at Svolvær on the Lofoten Islands. Our previous attempts in February, when I was guest lecturer on the cruise liner *Boudicca*, and in March, while aboard the *Marco Polo* were thwarted by the heavy swell which made it impossible to land by tenders.

Our third attempt was on the Norwegian Hurtigruten ship MV *Finnmarken*. Hurtigruten vessels are purpose built as lifeline ferries to remote areas of Norway, from Bergen to Norway's border with Russia. Going into Svolvær on Finnmarken, even in the teeth of a biting April blast, appeared easy on this highly manoeuvrable ship. So, at 6.30 on 7 April, I was finally on the pier of what must be regarded as the Cod Capital of the planet.

On entering this Arctic haven, the first thing that catches your eye are the drying racks of cod, thousands of cod drying in the chilling wind. From a distance they look like rows of buildings along the sea front, such is their size. Closer inspection reveals not only the vast numbers of cod but also the enormous sizes to which they grow.

Record breaking cod

The 2012 winter cod fishery in Norway has been spectacular, not just in the Lofoten but all the way from Ålesund to the Russian border. Wherever I went, I was told that this winter was the biggest and best in living memory, not just for sheer numbers but also for the average size of the individual fish. The largest cod landed at Svolvær was a specimen of over 55 kg, that is nearly 9 stone! The otoliths of this giant revealed that it was nineteen years old and had no doubt made a considerable contribution to the stock reproduction in previous spawning runs.

Further north, on the island of Sørøya, an angler caught a 42 kg cod, thereby breaking the rod caught record. So the giant cod are not confined to the Lofoten area.

For the fishermen this is excellent: The 2 man crew of an 11m gill-netter working out of Ålesund proudly told me that their best day's fishing this season saw them land 9 tonnes of quality cod. For British inshore fishermen such a catch is a distant dream.

My own experience from April/May 2011, when I lived with a Sea Sami family in North Troms, was that cod of over 20 kg were considered good but not exceptional. So, why are these fish so abundant and large when around our own coast the rare cod weighs mostly less than 5 kg?

Historically Lofoten had massive catches of cod that arrived around January from the Barents Sea to spawn in the area of Vestfjorden. Traditionally this was a longline and handline fishery. Boats came from hundreds of miles away, many of them open boats of under 9 m length.

Not much has changed: Like in the past, boats still come from hundreds of miles away, even if they are fewer in number now. And just like in the days of the Vikings and the Hanseatic League, the fish are air dried and exported south to Spain, Portugal, Italy and the Balkans.

Sustainable changes

What has changed is the design of the boats. Modern gill-netters are made from fibreglass and are equipped with automatic haulers and jigging machines. They may also sport an 11 m autoliner that can

ABOVE: Huge racks full of large cod drying in the Arctic wind look like large buildings for first time visitors to Svolvær on the Lofoten Islands.

ABOVE: Kjollefjord's 'juksa' fleet is part of the infrastructure generating a sustainable cod fishery.

set up to 15,000 hooks per day. And they only requires two men to crew it! So, although the number of vessels has declined, the actual catching capability has remained roughly the same.

And the fishers have also acquired a new customer: When the cods' tongues have been removed and sold as a local delicacy, the cod heads are dried and exported to Africa, mainly Nigeria.

Collapse of the Barents Sea cod world in the 1980s...

In the late 1980s the cod stocks in the Barents Sea collapsed dramatically. This was due to the over-fishing of capelin, a small fish which is a vital part of the Arctic food chain and was at that time used to produce food for Norway's iniquitous number of salmon farms. When the capelin had gone, the hungry adult cod began predating heavily on their own juvenile stock, almost wiping out entire year classes. This led eventually to a moratorium on cod fishing in the Barents Sea and all coastal fjords.

Compensation payments were made to keep the fishing industry alive. But only the indigenous Sami fishermen were allowed to continue their traditional fisheries.

The Sami fishermen had warned for over 30 years that trawling and seine netting would eventually lead to a stock collapse of monumental proportions. The collapse had been delayed by the exclusion of foreign vessels, but could not overcome the impact of industrial fishing down the food-chain.

Sami control fishing grounds

The newly formed Sami Parliament in Karasjok soon arranged for much of the inshore waters in the three areas of Nordland, Troms and Finnmark to become designated traditional Sami fishing grounds. The Sea Sami have fished sustainably in these waters for around 10,000 years, so were the perfect custodians to take care of this endangered fishery.

Today's Sami have modern boats and use a power operated Juksa, or hand line, allowing one man to work multiple lines at the same time. Many Sami fishermen and others of Sami descent consider juksa and long line caught fish to be of a superior size and quality and run highly successful fishing businesses using this technology.

No trawling or discarding

The absence of trawling may be a major factor for the cod stock recovery, but other factors also contribute: Where gillnetting is practiced, in ports such as Ålesund and Molde, the mesh size of the nets I measured varied between 200 mm and 300 mm across the stretched diamond. This ensures that smaller fish are not caught and that those fish which are enmeshed have probably spawned at least once. It also means that a policy of *No Discards* is easily adhered to.

Climate change also appears to have influenced the recovery. The slight warming of coastal waters has noticeably increased spring blooms of phytoplankton that fuel the entire food web. Especially herring have boomed so much as a consequence that their breathing can sometimes reduce oxygen concentrations in the water so much that suffocating fish are washed up on the shore or can be scooped out of the water. Also wolffish are plentiful here while their stocks have declined over 90% in the North Atlantic due to over fishing and trawling related habitat destruction.

Lessons for Scotland?

Witnessing such plenty makes me consider whether we could design a similar recovery for our own fisheries: Would an outright ban on trawling within a 25 mile limit of the coast resurrect our once prolific west coast cod and herring fisheries? Could we return to traditional line and gillnet fisheries and allow seabed life to return and stabilize? And would the leaders of fisheries organisations ever admit that they may have been dreadfully wrong back in the 1970s? And finally, could our politicians muster the foresight to protect sustainable food resources for future generations?

It would certainly take determination and short-term sacrifices, but I believe such a recovery is possible for Scotland's cod and other fisheries.

THE GREAT RACE OF THE GULF OF CORRYVRECKAN
Unravelling the eddies of a tidal race

Dr Andrew Dale SAMS

The Gulf of Corryvreckan

On the westward-flowing flood tide, currents in the Gulf of Corryvreckan can exceed 4 m/s (8 knots). The Great Race is the westward extension of this flow into the open water of the Firth of Lorn, a relatively narrow, turbulent plume of water that extends for up to 10 km into the area to the south of the Garvellachs as a patchwork of smooth boils, rippled convergences and breaking white-caps. With the Gulf being 1 km wide and up to 200 m deep, its peak throughput is comparable to the discharge of the Amazon (in the rainy season!) at an astonishing 300 000 cubic metres of water per second. This injection of momentum into the Firth of Lorn spins off a series of energetic eddies from its head and flanks.

The GREAT RACE project

Although the Great Race is a fascinating feature of our west coast environment, it has not previously been subject to detailed scientific study. The NERC-funded Great Race project is working to plug this gap.

Beyond a simple curiosity-led investigation of the structure and behaviour of the Great Race, we are using the system as a test bed to improve the representation of eddies and turbulence in numerical models. Our particular interest is in the 'cascade' of energy between eddies of differing scales and the model representation of this process. Improved models of the wider Scottish shelf will be available within the next few years and this project will help to ensure that such models accurately represent small yet important features, such as narrow tidal straits, in their wider shelf context. These models will ultimately help coastal managers to make better-informed decisions regarding marine renewables, fisheries, and protected areas.

These newly developed drifting buoys 'phone' their positions through to SAMS in real time.

Novel technology

Fieldwork in the Great Race is ongoing, using drifting buoys, moored current meters, boat-based surveys and the SAMS Autonomous Underwater Vehicle (AUV) to further refine our understanding. The drifters, developed by SAMS Technology Development Group, have been a great success, using mobile phone communications to relay their position in real time to servers at SAMS. This means that they are easily tracked in real time and collected by a fast RIB at the end of a deployment.

Surprising asymmetry

Drifter clusters released into the Gulf of Corryvreckan show complex eddying tracks as they are ejected into the Firth of Lorn. This fascinating dataset has revealed much about the

structure of the Great Race and also a few surprises, perhaps the greatest being a strong asymmetry between the northern and southern flanks of the Race. The northern flank sheds considerably more energetic eddies than the southern flank. We are using model simulations to investigate this asymmetry, untangling the relative influence of the Earth's rotation, topographic differences, and asymmetry of the flow within the Gulf of Corryvreckan itself.

Of vortices and vertebrates

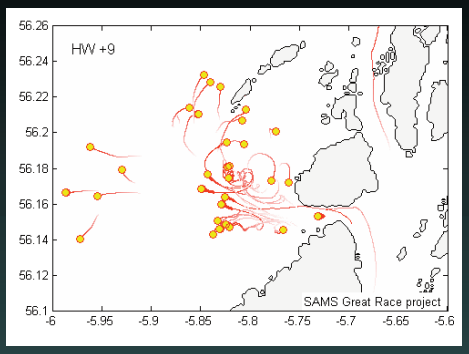
The Great Race is a feeding hotspot for both birds and marine mammals, and we aim to understand how these animals exploit tidal dynamics. Initial results are looking promising.

Acoustic porpoise detectors piggybacked on the drifters and moorings suggest that porpoises follow the energy pulse of the Great Race as it spreads westward into the Firth of Lorn. Razorbills, tracked from their Colonsay nest sites by the RSPB, also show a preference for strongest tidal flow when the Great Race extends into the area to the southwest of the Garvellachs. By understanding how animals use energetic tidal environments it will be easier to predict the impact on them of tidal power installations.

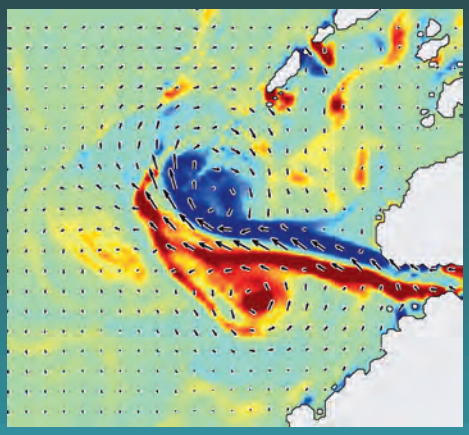
Further information

This project is funded by the Natural Environment Research Council between February 2010 and February 2013. Marine Scotland is a project partner.

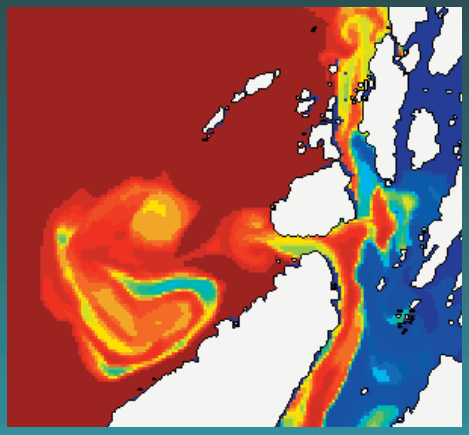
www.sams.ac.uk/andrew-dale/great-race



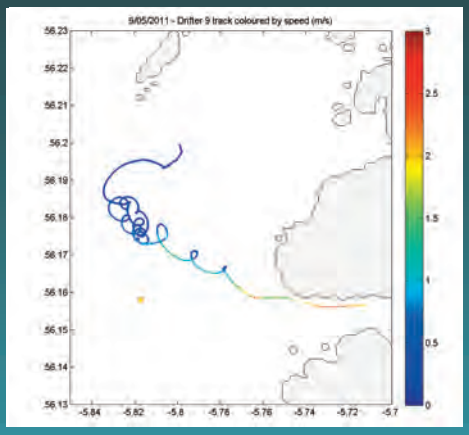
A composite of drifter tracks in the Great Race.



A model simulation of the vorticity of the Great Race showing an eddy pair towards the end of westward flow. Blue shows clockwise rotation and red shows anticlockwise.



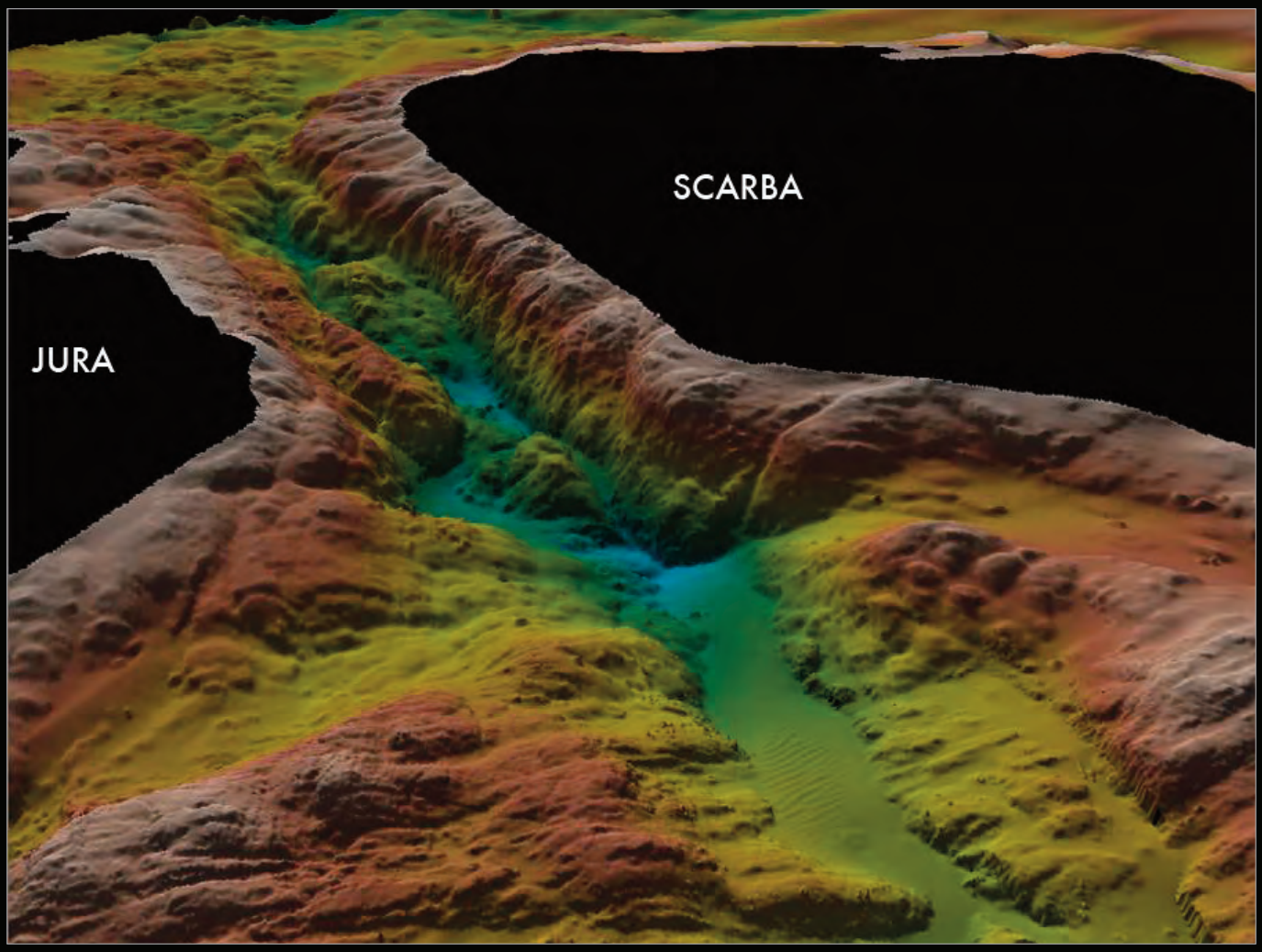
A model simulation of mixing between the Firth of Lorn (initially red) and the sound of Jura (initially blue).



The eddying track of a drifter on the northern flank of the Great Race.

REVEALING THE SEABED BELOW THE CORRYVRECKAN WHIRLPOOL

by Dr John Howe, Philip Crump, and Dr Anuschka Miller, SAMS with Andrew Lessnoff, UKHO



The Gulf of Corryvreckan that produces the 'Great Race' whirlpool lies between the islands of Jura and Scarba on Scotland's west coast. SAMS recently surveyed the seabed in this area to gather information on its depth, shape and predominant sediment types.

The whirlpool was believed to be caused by a pinnacle that pushes water up from deeper waters of over 200 m at the eastern side of the channel against the shallower western side that is less than 100m deep. The team was, however, surprised not to find such a pinnacle. Instead the scientists found a steep-sided buttress sticking out from the Scarba shore that appears to disrupt the flow and may generate the whirlpool.

The survey data further showed the seabed to consist of bare rock, which was not a surprise given the very strong currents characterising this narrow channel. All sand and mud is swept towards the west beyond the Great Race, where underwater dunes of very coarse sand are moving with the currents.

To collect this data the SAMS research vessel *Calanus* was fitted with high-resolution multibeam echosounder technology. This works by emitting hundreds of sound beams beneath the vessel while onboard computers listen for and record the return echoes that are reflected back from the seabed.

The INIS Hydro project

The work was carried out as part of the INIS Hydro project, which receives £3.2 million from the EU's INTERREG IVA Programme. INIS Hydro brings together seven partner organisations from the Republic of Ireland and the UK to generate high-resolution bathymetric datasets for over 1400 km^2 of key coastal seabed areas off the coasts of Ireland, Northern Ireland and Scotland to the most rigorous of international standards. The UK Hydrographic Office assures the quality of the acquired datasets. SAMS is currenttly surveying the entire Firth of Lorn as part of INIS Hydro.

For more information on the project, please visit www.inis-hydro.eu

THE JOURNEY TOWARDS UNIVERSITY TITLE

Former SAMS Director remembers the early days of SAMS engagement with the UHI

It's been a long time coming, but now the Highlands and Islands of Scotland have their very own University, whose area of operation extends over the whole north and west of Scotland from Shetland to the Western Isles and south to Argyll.

For centuries there had been talk of a university in the Highlands and Islands, but serious debate only started in 1967 when formation of Scotland's fifth university (after St Andrew's, Edinburgh, Glasgow and Aberdeen) became a choice between Stirling and Inverness. At that time Stirling won and Inverness lost.

After that, there followed a change of attitude: henceforth new universities would develop from existing FE institutions. New universities were indeed created in Scotland, but all of them in urban areas and the idea of a University in Inverness faded. Nevertheless there remained a need for higher education in and for the rural, more remote areas of Scotland.

In 1990 Highland Regional Council expressed its aim that a University of the Highlands and Islands should be created, and in 1992 HRC and the Highlands and Islands Development Board (now Highlands and Islands Enterprise) published a report they had commissioned from Professor Sir Graham Hills, former Principal of Strathclyde University, that envisaged a collegiate university that would embrace the whole Highlands and Islands region, developing as a partnership of existing institutions. Of all the areas within the region, only Argyll did not yet have such a college.

But Argyll did have an important research institute: SAMS with its established reputation in marine science and in postgraduate training that neatly complemented the strengths of the FE colleges. Together they would be essential components of the university as envisaged by Professor Hills. SAMS duly joined the University of the Highlands and Islands project partnership with full representation on the Board and Academic Council.

There was work to be done convincing people, locally and in the universities, that this was an appropriate role for SAMS, but the major problem was political: the Scottish Office was opposed to the whole idea. Then, quite suddenly that changed. The Secretary of State for Scotland had arranged that the Scottish Grand Committee should meet, not just in Westminster, but also in Scotland. On these occasions he was inclined to make an announcement of local importance. When the Committee came to Inverness, Michael Forsyth announced that he had heard of the proposal for a University of the Highlands and Islands and thought it sounded like a good idea!

SAMS started to develop a proposal for an Honours Degree in Marine Science with a full spread of disciplines that would make the course unique in the UK. Financial resources and additional staffing were minimal, so collaboration with existing institutions was essential. A complete programme for the course was submitted to the UHIp in 1997 and approved in principle by the Academic Council for further development as resources became available.

Those resources have since been found, and the course in its fully approved form has been running successfully for 12 years. It is now much less dependent on resources from outwith the UHI and improved in many ways, but the original aims and objectives remain unchanged: the provision of a first-class, full-scale university education in marine science.

I would thank all who have made UHI and its marine science degree happen, and all who provided the encouragement and support to see it through to its Charter, including Sir Graham Hills for his vision; Robin Lingard at Highlands and Islands Development Board for running the scheme in its early days; Sir David Smith, President of SAMS at the time, and his Council for their faith; SAMS staff who took on the extra responsibilities of nurturing the infant UHI Marine Science degree programme; staff at the North Highland College in Thurso, the Open University and elsewhere who were generous in their support of the course, and many others in the community and academia for their active support and encouragement.

The Highlanders and Islanders of Scotland have good cause to celebrate the creation of their University. My colleagues and I who were in it at the start send our best wishes to all who now shoulder the responsibilities that we once had.

Professor Jack Matthews

Dr JOHANNA FEHLING *in memoriam*

Born 25 October 1974; died 17 February 2011

Johanna Fehling died after a long fight against recurrent brain tumours on the 17th February 2011 at home with her family in Germany at the tragically young age of 36. At her request, Johanna's parents released her ashes into the North Sea on 8th March 2011. She was known to many in the harmful algal community and at SAMS.

"Johanna came to SAMS in 2000 as a PhD student. Her work concentrated on *Pseudo-nitzschia* in Scottish waters. Her work has proven to be significant, particularly her two linked *Journal of Phycology* publications on growth and toxin production of *Pseudo-nitzschia seriata*.

At the time of her death we were in the final stages of formatting a manuscript based on her work relating *Pseudo-nitzschia* populations to physical and chemical characteristics in the NW Atlantic. It was a pity that we were unable to complete the manuscript a little sooner. It was published in March 2012 in PLoS ONE and keeps her name alive in the scientific literature.

Johanna was my first PhD student and as such we learned a lot together and I have many fond memories of her and her dedication to her work. Johanna was a natural networker who always interacted so well with her colleagues, many of whom became good friends.

Her illness began in 2006, and between then and 2010, she had six major operations and rounds of chemotherapy. Throughout her long illness, Johanna maintained a great zest for life. The last time we met face to face was during her final visit to Oban in 2009. Notwithstanding her illness, she was still grasping life with both hands, and had just completed a long hike on the island of Lismore.

During her illness, her telephone calls always began with "I am so lucky". Considering the cruel fortune that she had suffered, her positive attitude was nothing short of inspirational."

Keith Davidson, SAMS

"Johanna joined my lab in 2005, to work on a project to root the eukaryote tree of life. Johanna impressed me immediately with her enthusiasm and her very direct approach to everything. She worked on the project, although it was extremely difficult and I know she found it trying and discouraging at times. She continued to work on the project even after her diagnosis. Since she left, we have completed the project, which I think would have pleased her, and we are submitting a paper that we think will be a major contribution to the field. Johanna will be an author, and – if the journal allows it – the paper will also be dedicated to her.

As was her way, Johanna made many friends here in Sweden and especially within the systematics group. Her absence will be deeply felt by many."

Sandra Baldauf
Evolutionary Biology Centre Uppsala

"Johanna had such an optimistic outlook towards whatever she did. When she moved to Sweden, she was a bit dismayed the first night there, because her flat was surrounded by so many houses. However, the next morning she discovered that she was near a forest, like the country home where she grew up in Germany. She found it "amazing" to cycle to work for 20 minutes through the city forest."

Stephen S Bates
Fisheries & Oceans Canada

"Johanna came to the Institute for Polar Ecology in Kiel when I did my Diploma thesis in the group of Rolf Gradinger. I think it was back in 1997. I wanted to learn more about parasitic fungi that feed on *Pseudo-nitzschia seriata* that we had found in Arctic sea ice samples. Johanna was very excited and keen to work on this relationship. She took on this little project that later led to her Diploma thesis on sympagic protist communities in Arctic pack ice from the Fram Strait region.

Johanna was a very dedicated scientist, always pursuing her aims. I remember her as a very positive and kind person and it is a great sadness that she is no longer here."

Thomas Mock, UEA

"Johanna came to Oban as a PhD student not long after my own arrival and became an integral part of the microalgal research group. Her research papers on *Pseudo-nitzschia* continue to attract a high number of citations, and she was also a dedicated, gifted and enthusiastic teacher who delighted in helping students and researchers develop skills she had mastered in her own research.

As a PhD student Johanna was supremely organized, efficient and enthusiastic, with a tremendous capacity to work under the most difficult of conditions at sea, with never even a hint of complaint. I recall many supervisory meetings where I was *instructed* by Johanna as to the next phase of her studies, all delivered with a directness that compelled me to agree! Yet under this efficient ordered exterior was kindness, generosity, and a love of life that made firm friends of colleagues with whom she worked.

Johanna's positive spirit shone through in all she did. Johanna was dearly loved by all those who knew her and I remember her always with fondness and respect."

Christopher Bolch
University of Tasmania, Australia

Dr DUNCAN JAMES LESLIE MERCER

Born Wakefield 20 Jan 1971; died of cancer Sydney, Australia, 26 Sep 2010

After a bad start, 1997 ended up being a very happy year in the Marine Technology Department at SAMS: following many years of down-sizing in the lab, and the loss, sometimes in tragic circumstances, of valued staff members and friends, I was allowed to recruit two new colleagues. The first of these was Oli Peppe, who had ticked all our boxes before and at interview, and had presented himself elegantly in a neat grey suit. The second was Duncan, who ticked far less of our boxes, and sat before us in a state of some dishevelment, accentuated by very recent razor cuts to his face which suggested shaving in the lab toilets just before his interview. Nonetheless we were completely won over by his enthusiasm and honesty and offered him the second job alongside Oli. It turned out to be a three-way marriage made in heaven, and we all three not only complemented each other's experience, skills and aspirations in the workplace, but also found that we had common interests in the outdoors, in music, and in what might be best described as conviviality. Overall, we very quickly became a strong team, not frightened to challenge each other bluntly, nor to confront our scientific 'customers' with a sort of well-meaning arrogance (though they did not always see it that way), and gradually we earned respect in the wider community through a number of ground-breaking achievements, particularly in the field of autonomous instruments for the observation of polar sea ice and of the deep oceans.

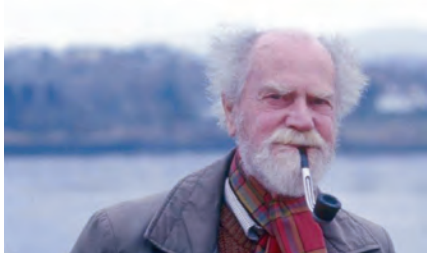
Duncan was the glue that held the team together for ten years before his departure to Australia: not only were his technical skills and attention to detail exceptional, he also possessed an amazing command of the wider subject and, out of hours (though his 'hours' were never possible to quantify) actively followed advances in general science and in his own speciality of microprocessor controlled instruments, so-called embedded systems. He also managed the Electronics Lab with a particular ferocity that earned him the nickname of Dr Strop, a somewhat draconian side of his personality that was totally at odds with his true self.

What was his true self? Duncan held incredibly low opinions about himself, in all areas, and it was a constant effort to reassure him about his exceptional capabilities. Not least about his abilities to form and sustain relationships. Yet, above all he loved people. Not in a shallow way: he really did love and care about people, and all who experienced that will never forget it. He became a caring member of so many people's families, and his loss for many of us is that of a close family member. He was a gifted and patient teacher in many areas, not least in electronics, programming, diving and climbing, but he also taught us all how to love as you would wish to be loved: openly and without hidden baggage. That is probably his greatest achievement.

I was privileged to be able to speak to him by phone not long before he died, and recounted much of the above on behalf of his many friends. Duncan was scarcely able to speak, but did manage to brush it all off in his best unprintable Yorkshire way!

Lovely man, special friend, you changed things for the better for lots of people, what more could one ask of a life?

David Meldrum



Dr MICHAEL DROOP DSc FRSE

Algal physiologist 1918 - 2011

by
Dr Paul Tett, SAMS and
Dr John Leftley, GlycoMar Ltd and SAMS member

Michael Richmond Droop died on 20 March 2011, and is buried in the kirkyard at Taynuilt, the village in Scotland where he lived for more than 40 years. His working life was spent with the Scottish Marine Biological Association (now SAMS), where he built up the stockpile of cultivated micro-organisms that is now part of the UK national Culture Collection of Algae and Protozoa, and developed what the world now calls the 'Droop Cell Quota' model of algal nutrient-limited growth.

Michael was born on 3 November 1918 in London. His father, J.P. Droop, was soon to occupy the chair of Classical Archaeology in the University of Liverpool, and Michael was sent to preparatory school and then to Marlborough College (1932-37). At Marlborough he developed an interest in aquatic life, and from here he visited the Marine Station at Millport on the Isle of Cumbrae. In 1952 he returned to the Marine Station to take up a post with the Scottish Marine Biological Association. In the years between he tried Medicine with Botany and then English Literature at Cambridge; was sent down from the University in 1939 (because he preferred to attend an opera rather than sit an exam); served in the Royal Engineers during the Second World War (including a spell working in bomb disposal); turned down the offer of a place at the Slade School of Fine Arts; took a first class honours degree in Botany at Liverpool University (1946-50); and in 1950 commenced research for a PhD at Cambridge under the supervision of Professor E.G. Pringsheim.

From Pringsheim, Michael learnt methods for isolating micro-organisms and growing them in synthetic media. These techniques he applied at Millport, cultivating algae and protozoa found in rock pools in Finland and on the shores of the Isle of Cumbrae, including the flagellate that he had discovered and named as *Monochrysis* (now *Pavlova*) *lutheri*.

The first step was to suck a single algal cell into a fine glass tube whilst keeping the cell in view under the lens of a microscope. Like dealing with unexploded bombs, this needed a steady hand. What followed was chemistry tinged with magic, for, as he experimented with cultivation media, Droop found that populations of *Monochrysis lutheri* would increase in artificial sea water only if the medium was enriched with extracts of animal liver or garden soil. It turned out that a key component of such 'magic ingredients' was cobalamin, vitamin B_{12}. It was required in minute amounts that were too low for direct chemical detection, but the central cobalt atom of the synthetic vitamin could be substituted by the radioactive ^{57}Co, allowing the very sensitive measurements that made possible his subsequent work. According to what came to be called Monod kinetics, the growth rate of algal cells should depend on the concentration of the limiting nutrient in the surrounding medium. Michael found evidence that this was not the case for *M. lutheri* and vitamin B_{12}.

To investigate further, he adapted the method of continuous culture that he and his colleague Martin Scott were using to grow micro-algae in bulk as food for oyster larvae. In this method, fresh medium is continuously pumped into a reactor vessel where the algae grow, displacing an equal volume of used medium and the algae it contains. Such a chemostat keeps the cultivated population in a nutrient-limited state and growing at a relative rate equal to the rate at which the reactor contents are diluted. This allowed him to show that the growth rate of the algal population depended not on the medium concentration but on the intracellular concentration (or Cell Quota) of vitamin B_{12}, and led to a much cited paper (Droop, 1968). Work with other nutrients and other algae led to the fleshing out of the Cell Quota model, as described in a series of papers during the 1970s, and summarized by Droop (1983).

By this time Michael's workplace had moved (in 1969) from the old buildings of the Marine Station at Millport to the newly built Dunstaffnage Marine Laboratory near Oban. As Barry Leadbeater (2006)

ABOVE: The way he saw himself; a self-portrait of Michael Droop that he donated to the Culture Collection of Algae and Protozoa.

describes in a detailed scientific biography, Michael's research was curiosity-driven. He was fortunate to live in an age when the supporters of science saw the key as securing the best minds and letting them get on with what they wanted to do. That age began to come to an end in the 1970s, and Michael, having achieved merit promotion to Senior Principal Scientific Officer, was happy to retire in 1982, to devote himself to painting and fly-fishing.

What he left behind for SAMS was his culture collection, maintained by his colleague Michael Turner until the latter's own retiral, expanded with material from other laboratories, and now, under John Day, a vital national resource, the Culture Collection of Algae and Protozoa (CCAP), with several thousand strains supporting research and commercial use. Michael's self-portrait now hangs outside the CCAP, next to an earlier portrait of his teacher Ernst Pringsheim (Leftley, 2009).

Michael's main intellectual legacy is the Cell Quota model, usually called by his name, and according to Flynn (2008) "the most cited model of phytoplankton growth." The seminal paper of 1968 was published before the start of the data-base searched by Web of Science, but his succeeding papers, mainly those from the early 1970s, were averaging more than 50 citations per year in the late 2000s. He didn't teach, and worked directly only with a few - who were deeply influenced by his ideas (e.g. Maestrini, Bonin & Droop, 1984; Tett, Heaney & Droop, 1985). What one of us (Paul Tett) took from our association was the idea of modelling as an epistemological tool and the constraint that models should be no more complicated than required by the experimental data. This tradition of experimental cultivation and modelling of micro-organisms, continues at SAMS (e.g. Davidson *et al.*, 2005).

As Leadbeater reports, Michael's first shot at university foundered on his inability to decide between the

ABOVE: Michael Droop in 1975 in his laboratory. Photo by Dr Serge Maestrini.

sciences and the arts. His wartime experience matured him, and he committed himself to marine science for nearly 40 years, although not until he had agonized between botany and art. When he retired he said that he was done with science. But this proved not to be the case, for he kept a link with SAMS and, 20 years later, returned with two more papers, one defending the superiority of the Cell Quota model (Droop, 2003) and the other concerning misconceptions about the requirements of marine pelagic algae for vitamin B_{12} (Droop, 2007). This brought the wheel almost full circle. For as he had earlier remarked (Droop, 1985), the Cell Quota model had originated in work to settle a 1950s controversy about the likely ecological importance of the vitamin to phytoplankton. In the 2007 paper Michael argued again that there is sufficient vitamin in the sea to support the growth of algae.

His wife Margarete, whom he married in 1951, died in 1996. He is survived by three sons and their families: Giles (a geologist at Manchester University) and Stephen (until recently at the Royal Botanic Gardens, Edinburgh) continue the academic clan.

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