
SAMS
ANNUAL
REPORT
2012-13

FRONT COVER: Bathymetry of the Firth of Lorn generated by the SEUPB funded INIS Hydro project. Image: Philip Crump, SAMS

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Funders

Our main partners

ABOUT US

SAMS (The Scottish Association for Marine Science) is a learned society with around 300 members who share an interest in marine science. SAMS is a charity (009206) and a Company Limited by Guarantee (SC009292) registered in Scotland.

SAMS' mission is to deliver world-class marine science that supports society with innovative solutions to developing a sustainable relationship with the marine environment. SAMS delivers this mission through research, education and services to business, learned society activities and public engagement initiatives.

The organisation maintains four strategic partnerships: it is a founding partner of the University of the Highlands and Islands, a delivery partner of the Natural Environment Research Council, the only marine associated institution of the United Nations University and a member of the Marine Alliance for Science and Technology for Scotland.

SAMS operates the Scottish Marine Institute at Dunstaffnage near Oban where more than 160 employees conduct research and provide education and services in marine science.

Services to business are delivered through SRSL, a wholly owned commercial subsidiary company (SC224404). SAMS also operates a business incubator known as the European Centre for Marine Biotechnology (SC205318) that hosts tenant companies.

The Association is governed by an independent non-executive Council elected by SAMS' members at the Annual General Meeting. Council is supported by the Board of Council and a number of committees: research; education; finance; audit. Board and committees are made up from Council members and executive staff. The audit committee also includes independent members. SAMS business is conducted in accordance with the Articles and the Memorandum of Association.

SAMS Council members are the non-executive directors of the company and trustees of the charity.

SAMS Council members on 31 March 2013 were:

President Professor Geoffrey Boulton

Chairman of Board Michael Gibson

Council (Board of Directors)

Professor Mary Bownes
Professor Peter Burkill
Stuart Cannon
Professor Robert Ferrier
Professor Lora Fleming
Gordon McAllister
Professor David Paterson
Dr Carol Phillips
Professor Monty Priede
Commodore Angus Ross
Ken Rundle
Michael Wilkins

External members of Audit Committee
Dr Keith Duff
Marilyn Jeffcoat

Director Professor Laurence Mee

Company Secretary

Elaine Walton

Vice Presidents

Professor Sir John Arbuthnott
Professor Sir Frederick Holliday
Sir David Smith
Dr John H Steele
Professor Stephen A Thorpe

CONTENTS

OUR LOCATION

@ Dunstaffnage, Oban

WELCOME FROM THE CROW'S NEST:

THE BUZZ GETS LOUDER

I have always felt a buzz in the air at SAMS as new ideas emerge and my colleagues share their enthusiasm and excitement. Nowadays, this virtual buzz has been augmented by a real buzz as our newly acquired **remotely piloted aircraft** (RPAs) take off with their precision cameras that can accurately survey intertidal areas or the sea surface in a fraction of the time of traditional techniques (p. 56). SAMS has become a leader in smart technology for observations and holds the record for the longest operational deployment of an underwater glider in Europe (to Iceland and back). We have a versatile *Remus* autonomous underwater vehicle and are in the process of acquiring a new ROV (remotely operated vehicle). One of our benthic landers was deployed to the bottom of the Challenger Deep in the Marianas Trench, the deepest point in the oceans (p.46).

Deploying these devices is not just about breaking endurance records, it is the logical way forward for filling the huge gap we have in observations of the sea. Incredibly, we have only surveyed some 7% of the deep oceans and the main reason why climate models have high levels of uncertainty is our lack of knowledge of ocean processes and long term cycles. There just isn't enough money and time to fill these observational gaps 'the old way' using research vessels (we still use them by the way and will always have to; not everything can be automated).

This development gives you a little insight into the modern SAMS. We have a solid foundation as the oldest marine institute in Scotland (130 year birthday in 2014) but are constantly working at the frontier of knowledge, technology and applications… and also of public engagement. This is why we are working on the development of marine biofuels, on renewable energy, on marine spatial planning, on climate change in the sea and on deep-sea mining impacts, to name a few examples. Much of this work would have been unimaginable just a decade ago and yet we are building on the past and now reaping the rewards of well over 40 years on the Dunstaffnage site. This has given enough time to develop time series such as the Ellet Line (repeat surveys between Scotland and Iceland) and the West Coast shoreline and intertidal surveys.

SAMS work in education (p. 74-83) has taken a huge leap forward thanks to three main factors. The first is the full commissioning of our new Sheina Marshall building; one of the best marine science teaching facilities in the UK. Secondly, UHI's full university title has made it more attractive to students. Thirdly, and most importantly, we have established a strong reputation for experiential learning with a high level of engagement of research-active staff.

Another key development has been in our engagement with society: we organised a second successful marine science festival and prepared the new Ocean Explorer Centre, where our world will be open to visitors to explore and discover.

SAMS' research success has been mirrored by our commercial work, conducted through SRSL, a wholly owned company (p. 84). SRSL has a diverse portfolio with particular success in understanding the impacts of mine tailings disposal in the seas around Papua New Guinea and in the development and marketing of instruments to measure sea ice cover in both polar regions. We also conduct a wide programme of sanitary surveys for the Food Standards Agency. All of this underlines our 'end-to-end' approach to marine science: education and training - research - applications – societal impacts.

I hope you will enjoy learning about the progress in our work and our many new partnerships, including that with the United Nations University (p. 82). My own voyage of discovery as Director of SAMS has already lasted five years, not a roller coaster ride but a continuous process of engagement and teamwork as we face the challenges of operating in a period of relative austerity but with huge opportunities for hard-working scientific entrepreneurs. And we have plenty of them here! The big milestone in my own journey is that I am no longer called 'the new Director'…

Professor Laurence Mee
Director of SAMS

Follow Laurence's 'Musings from the Crow's Nest' blog at:
http://scotmarineinst.blogspot.co.uk/

OUR RESEARCH

DR ADAM HUGHES

The search for economic & environmental sustainability in the aquaculture industry

Aquaculture is expanding faster than any other food production sector and is crucial in helping to ensure global food security. In Europe, however, the aquaculture industry is experiencing low to zero growth.

The European industry is characterised by monoculture of fin and shellfish species. This model may be contributing to the lack of economic growth and the issues of environmental sustainability within the European industry. Moving away from this monoculture model into a more diversified and integrated industry may be one way of ensuring both economic and environmental sustainability, against the background of increased global competition.

Research at SAMS is helping the Scottish and European aquaculture industries through this transition.

Integrated Multi-Trophic Aquaculture

In 2012 the FP7 project IDREEM (Increasing Industrial Resource Efficiency in European Mariculture) began: This €5.7 million project is coordinated by SAMS and delivered in collaboration with fourteen industrial and research partners from across Europe.

In four years, the IDREEM consortium will develop tools and methods to help the European aquaculture industry adopt more environmentally and economically efficient practices using Integrated Multi-Trophic Aquaculture (IMTA) on a commercial scale.

The idea behind IMTA is simple: using the by-products from one species as the food for another species, so increasing productivity and reducing waste. The IDREEM project will demonstrate the benefits of IMTA through pilot commercial-scale testing, field research and modelling. Interdisciplinary research within IDREEM will examine the obstacles and risks to the use of IMTA systems and develop tools to overcome these constraints, whether they are economic, technical, environmental, social or regulatory.

Developing our seaweed industry

Another way for the aquaculture industry to diversify and develop is the use of the marine environment to produce non-food products; for example growing seaweed for a source of biofuels. To make this economically attractive there is a need for technological development of the growing techniques.

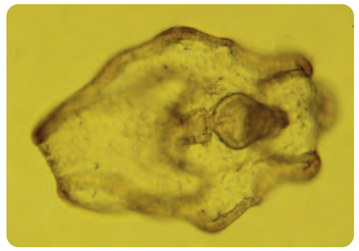
The FP7 project AT~SEA (Advanced Textiles for open SEA biomass cultivation) is working with the European textiles industry to provide cheap and effective technology for the production of marine biofuels. The first milestone in the project was the successful harvesting of large quantities of seaweed from the new SAMS seaweed farm. This seaweed had been grown on a range of especially designed advanced textiles and will be used to design the optimal textile based production system.

Turning seaweed into biofuel

Producing seaweed is only half the story; there is then a need to breakdown the seaweed into biofuels or other valuable chemicals. This process can be complicated and energy intensive.

There are a whole range of organisms who live in the sea which have already evolved the tools to breakdown and convert the seaweed to other chemicals. We can use these organisms to convert seaweed to biofuels. But first we have to find which organisms can do this.

In a pilot scale project with the Central Laser Facility at the STFC Rutherford Appleton Laboratory (an institution of the Science and Technology Facilities Council) Ramen microscopy and laser tweezers were used to identify and isolate marine bacteria who had been consuming and breaking down seaweeds. This research will hopefully lead to the development of techniques for the rapid screening of marine bacteria with the potential to convert seaweed to biofuels.



A Scottish Cotton Spinner Sea Cucumber larva

High value species

Another way to increase the economic sustainability is to develop the aquaculture of species with a known high market value, but a limited natural supply. One such example is the sea cucumber. These animals are highly prized in Asian cuisine and are linked to good health and traditional medicine. With the emergence of the Asian economies, demand can outstrip supply, leading to unsustainable fisheries.

One solution is to produce sea cucumbers through aquaculture. The project HoloPharmII is doing just that, and has developed hatchery methods for the Scottish Cotton Spinner sea cucumber resulting in the first controlled spawning for this species.

We plan to integrate the sea cucumber into the existing Scottish aquaculture system to feed on the by-products that accumulate under the cages of existing fish farms. This provides increased economic benefit to the farmer and reduces the impacts to the environment.

RESEARCH STUDENTS

Iona Campbell (PhD): Interaction between macroalgae aquaculture for biofuels and phytoplankton. Funded by the European Social Fund. University of the Highlands and Islands

Morgan Humphreys (Masters by Research): Aquacultural study of sea urchin *Paracentrotus lividus*: Diet trials and lipid metabolism. University of the Highlands and Islands (completed)

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DR BHAVANI NARAYANASWAMY

Deep-sea biology: Exploring seamounts

Seamounts are effectively underwater mountains that break up the vast expanse of relatively flat soft deep-sea sediment. They can look like mountains, hills or knolls and globally there are thought to be between 25,000 and 140,000 seamounts that rise more than 1,000 m above the background sediment.

Unlike their terrestrial counterparts, seamounts are not usually barren, species poor habitats but can appear as oases of life, hosting large sessile corals and sponges as well as smaller fauna living within the framework and sediment.

Seamounts are important features that can act as nursery grounds for a variety of fish species and are home to a number of fragile organisms that are protected by law in many countries.

The SAMS deep-sea group is investigating several seamounts in the Atlantic, Mediterranean and south-west Indian Ocean. Much of our research focuses on the smaller infauna: just because they are small does not mean they are not important.

Seamounts in the North Atlantic & Mediterranean Sea

The North-East Atlantic Ocean is home to an estimated 550 seamounts with a further 100 in the Mediterranean Sea. Through TOPODEEP (a NERC funded project) and HERMIONE (an EU FP7 programme) we investigated three seamounts: Ampere and Senghor in the Atlantic and Eratosthenes in the Mediterranean.

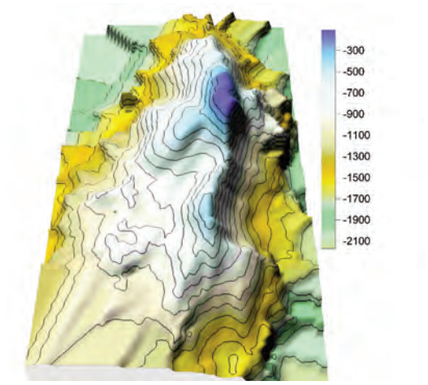
The overlying water column at Eratosthenes is so nutrient depleted that numbers of macrofaunal individuals collected from this seamount were very low, some cores contained just one individual.

At Senghor seamount however, numbers were much higher. Here we could investigate the macrofauna in greater detail and compare stations at the same depth but on and off the seamount. At family level there seemed to be no difference, but at more detailed level identification we found that the dominant species were different even though they belonged to the same genus.

Adam Chivers (a NERC and MASTS funded PhD student) is looking in greater detail at the diversity, composition and standing stock of macrofauna, particularly the polychaetes, collected from four transects on Senghor seamount. Results from the northern transect alone based on ca 950 polychaetes and 130 putative species indicated that although standing stock was low at the upper slopes there was a high species diversity and richness at depth (Chivers *et al.* 2013). What was interesting about this station was that it was found in an area of relatively low oxygen concentration.

Seamounts along the South-West Indian Ridge

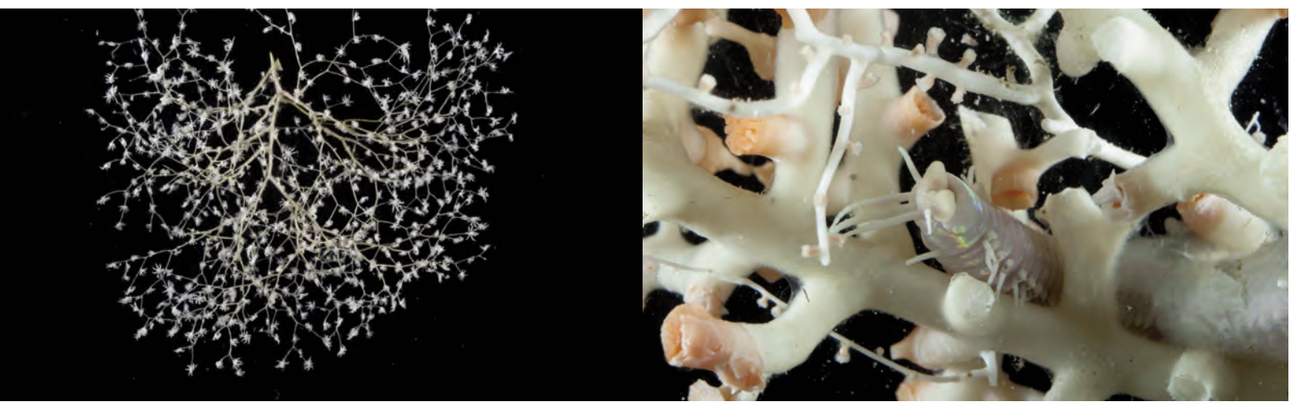
Very little is known about deep-sea life of the South-West Indian Ocean. A NERC funded project has enabled us to explore five seamouts lying South-East of Madagascar together with Professor Alex Rogers from the



Depth profile of Melville seamount.

Image courtesy of Natalia Serpetti

University of Oxford and Dr Gordon Paterson from the Natural History Museum, London. These seamounts harbour a high faunal diversity ranging from microscopic animals to large sponges, corals and fish. We thus involve a wide group of researchers to identify the species, some of which may be new to science. The project is not only investigating the richness of marine life but also the threats that this fauna faces.



A selection of fauna collected from the SW Indian Ocean seamounts: **left** an octocoral and **right** a eunicid polychaete hiding amongst the corals.

Both photographs courtesy of David Shale.

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RESEARCH STUDENTS

Adam Chivers (PhD):The Biodiversity and Ecology of Seamounts in the NE Atlantic. Funded by NERC & MASTS. University of the Highlands and Islands. 2010-2014

Stephen Watson (MRes): Seasonal and inter-annual trends in macrobenthic community structure in the Rockall Trough, NE Atlantic. St Andrews University. 2012 (completed)

Tom Rea (Undergraduate placement): Extraction of endo-crypolithic fauna through dissolution of coral carbonate samples in acetic acid. Funded by ERASMUS, Galway Mayo Institute of Technology. 2013 (completed)

DR NATALIA SERPETTI

In the last year I have been working in the deep water benthic ecology group as a benthic seamount ecologist. I have mainly been analysing the benthic macrofauna composition of five seamounts along the south-west Indian Ocean Ridge (SWIOR).

In addition we have also been collaborating with Professor Ursula Witte of Oceanlab, University of Aberdeen in the EU FP7 project, HERMIONE. The specific area of work was to investigate the macrofauna community in the Darwin Mounds Special Area of Conservation located in the Rockall Trough, NE Atlantic.

Both these projects are not only investigating the diversity and richness of marine deep-water fauna but also the threats due to human impact and climate change. Over the past two decades, concern has been growing regarding the effects of towed fishing gear, such as trawls and dredges, on deep-sea biodiversity and ecosystem functioning. Trawling disturbs the benthic communities both physically and biologically, and can eliminate the most vulnerable organisms and modify habitat structure. Chronically disturbed communities are often dominated by opportunistic species. However, we are still far from understanding the efficiency of these closures, particularly on an ecosystem level.

RESEARCH STUDENTS

Stephen Watson (MRes): Seasonal and inter-annual trends in macrobenthic community structure in the Rockall Trough, Northeast Atlantic. University of St Andrews. 2012 (completed)

Tom Rea (Undergraduate placement): Extraction of endo-crypolithic fauna through dissolution of coral carbonate samples in acetic acid. Funded by ERASMUS, Galway Mayo Institute of Technology. 2013 (completed)

PUBLICATION

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Darwin Mounds Special Area of Conservation

ABOVE: The abundance of the polychaete worm *Paramphinome jeffreysii* was higher outside the SAC area than within.

ABOVE: Also the amphipod *Haploops setosa* was more common outside the SAC. This may be because their preditors here are removed by fishing.

The European Union is under obligation to designate a network of offshore Special Areas of Conservation (SACs) and Marine Protected Areas (MPAs) based on the perceived expectation that regulating human activities in these areas will protect faunal biodiversity. Moreover, while there are several studies showing clear depth and large scale spatial distribution patterns of deep-sea faunal communities (Rex *et al.*, 2006, *MEPS* **317**: 1-8), much less attention has been given to the small scale horizontal patterns (Budaeva *et al.*, 2008, *Deep-Sea Res.I*, **55**: 1167-1178).

To investigate these aspects, two areas were studied outside and within the Darwin Mounds SAC. Deep-water trawling regularly takes place outside the Darwin Mounds SAC whilst the area inside the SAC has been closed to bottom trawling since 2004. Our attention was focused on the small sediment fauna (macrofauna) which are particularly important for the ecology and functioning of the ecosystem. We found no difference in terms of their diversity inside and outside the SAC. This maybe because there is still some violation of the fisheries closure. What was surprising was that abundance was higher outside the SAC compared to within. The difference was mostly driven by changes in the abundance of the small macrofauna such as polychaete worms, crustaceans and roundworms.

Because fishing has a greater impact on larger species that include seabed predators, this unexpected result could represent an ecological response to the reduced predation pressure on small animals.

Horizontal "small-scale" spatial distribution patterns of macrofauna, the impact of trawling on these communities and the role of marine protected areas for their preservation are concepts that to date are not well understood, particularly in deep sea sediments. These aspects are gaining ever more importance considering the overarching goal of the European integrated maritime policy to achieve a 'Good Environmental Status' by 2020 across Europe's offshore Special Areas of Conservation and Marine Protected Areas.

DR MAEVE KELLY

From sea urchins to biofuels...

From sea urchins to biofuels (taking in seaweed in between), the path of my research career at SAMS has certainly been varied and unpredictable.

It all started with a colleague's observation that there was a large natural population of sea urchins on the net cages of a neighbouring salmon farm. Ah-ah! Sea urchins are a valued food product AND they grow on salmon cages? A little further investigation showed that this was the case and that sea urchins are indeed adept and trapping and eating any salmon feed the fish have missed. This nutritious, high energy feed would otherwise be lost to the environment and so growing species together, polyculture or Integrated Multitrophic Aquaculture (IMTA) research at SAMS began.

Nursery research

I developed hatchery nursery techniques to grow native sea urchins at SAMS, and also explored the possibilities of farming other high-value shellfish such as the European abalone or ormer. Their favourite food is the red seaweed dulse. And it wasn't long before we asked the question, if we want to culture rather than destructively wild-harvest seaweed – then where would that seaweed grow the best?

Growing seaweed

Yes, back to sea, beside the salmon cages where there is a source of dissolved nitrogen, the perfect plant food. Here the seaweeds can utilise the energy which is otherwise lost from the system. Another layer of the IMTA system was born.

So, how do biofuels fit in? Well, in the course of our seaweed investigations we discovered we could culture a variety of seaweeds very well and that some species grew very rapidly, from a tiny plant a few millimeters long to huge fronds over 2 meters in length in a matter of months.

Seaweed methane

In this day and age we are mindful of the pitfalls of turning land and freshwater resources over to biofuel production at the cost of food production. So where better then to grow biofuel than at sea? Seaweeds are a perfect substrate for biodigestion to produce natural gas (methane) which can be used as a transport fuel and to generate electricity.

It's all go...

At SAMS today, as well as teaching Aquaculture to 3rd year students on our Marine Science BSc degree programme, my research into sea urchin aquaculture continues; perfecting diets for juvenile urchins.

We are also busy culturing a variety of healthful edible seaweeds in conjunction with our small business partners, keen to market health products.

SAMS has its own seaweed farm and we are developing a range of uses for seaweeds from human foods, to animal fodder and environmentally friendly renewable energy.

PUBLICATIONS 2012-13

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PROFESSOR KENNY BLACK

ECOLOGY

Modelling effects of fish farming on the seabed

Salmon farming is a major Scottish food production industry and jointly the Scottish Government and Salmon Industry have an ambition to increase production from around 160,000 to 220,000+ tonnes per year by 2020. To achieve this and ensure that environmental impacts are managed and minimised, regulators need modelling tools to match the scale of new farms to the ability of the local environment to assimilate the wastes without breaking quality standards.

For about a decade, the Scottish Environment Protection Agency has been using the SAMS computer model AutoDEPOMOD for this purpose. However, AutoDEPOMOD was originally developed for quiescent sea loch sites. New sites are now often planned in more dynamic, exposed locations and the model must thus be refreshed to improve its predictive power in such environments.

SARF funds us to look at incorporating sulphur biogeochemistry into the model – a task that we believe is important for several reasons, including to predict recover rates better. We have been working on this at a range of fish farms looking at the relationship between sediment sulphide concentration and other indicators of seabed status such as redox potential and biological indices, as well as using a variety of state-of-the-art measurement techniques to understand sulphur dynamics and incorporate this into AutoDEPOMOD.

The Scottish Government funds us to recode AutoDEPOMOD in a modern computer language (Java) and to improve the simulation of seabed erosion processes that are important in redistributing organic wastes from farms around dynamic sites with high current speeds. This project involves collaboration with Partrac Ltd, a company specialising in studying particle transport in the marine environment.

The fieldwork has been done from the SEPA vessel MV *Sir John Murray* at eight salmon farms on the west coast of Scotland where, for the first time, we have been deploying the seabed Voyager II flume (pictured on the right).

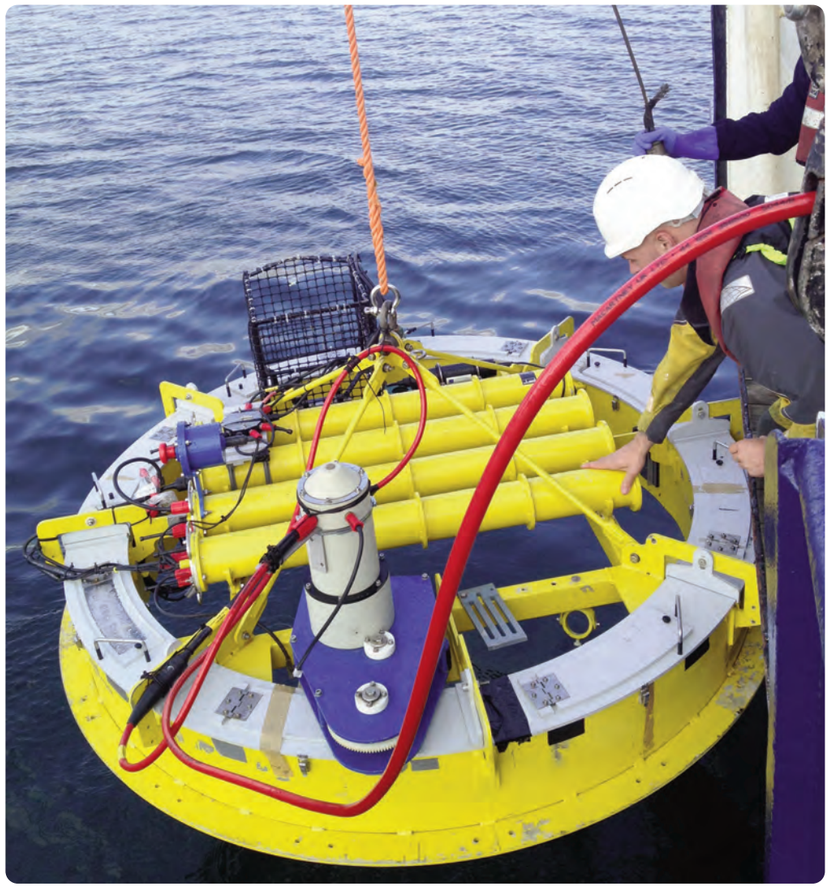
The seabed Voyager II flume is deployed on the seabed and programmed to create a controlled series of current speeds over the sediment and to monitor erosion using turbidity sensors. This allows us to quantify the relationship between current speed, the onset of erosion and the mass eroded.

When complete this will keep Scotland's regulators at the front edge of fish farm regulation and contribute to the national strategy for sustainable aquaculture growth.

RESEARCH STUDENTS

Suzi Billing (PhD): The role of change agents in the sustainable development of marine renewable energy in the Highland and Islands region of Scotland. Funded by the European Social Fund. University of the Highlands and Islands. 2012-2015

Joanna Gosling (PhD): The biogeochemistry of highly reducing sediments. Funded by MASTS and SAMS. University of the Highlands and Islands. 2012-2015



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DR ELIZABETH COOK

ECOLOGY

Invasives species research at a marine lab near YOU!

Biological invasions by species that are not native to our region are generally accepted to be one of the greatest threats to biodiversity world-wide.

A small number of these 'non-native' species can cause huge economic and social impacts, and are estimated to cause global damage amounting to hundreds of billions of dollars.

One major area of research, led by the invasive species team at SAMS, is trying to understand the role of artificial structures, such as vessels, pontoons, navigation buoys and offshore renewables structures, in providing refuges and assisting the spread of non-native species around our coasts. A major review on this subject was published in 2012, co-authored by me and my then PhD student Adrian Macleod. In his thesis Adrian showed that even navigation buoys in remote locations on the west and north coasts of Scotland, subjected to high tidal flow, can provide a suitable surface for non-native species to colonise. Implications for the offshore renewables industry, which is keen to develop sites in these environments, are currently being further studied through a joint PhD studentship with North Highland College UHI's Environmental Research Institute in Thurso.

Before invasive species can be effectively managed it is critical to have a complete picture of what non-native species already occur in the UK and where they are distributed.

In early 2013, we published a major new paper listing all non-native species that had ever been recorded in British waters from before the turn of the last century. This paper was a culmination of over eight years of data collation and provides information regarding date of entry, origin, pathway of arrival and potential environment and economic threats.

The plan now is to co-ordinate these recording efforts across Europe, through a European programme entitled 'European Information System for Alien Species', which has over 27 participating countries (including the UK and SAMS), so that a more pan-European approach can be taken in preventing the introduction and spread of the really 'invasive' non-native species that are potentially going to cause the most harm to our way of life.

ABOVE: The Japanese Skeleton Shrimp *Caprella mutica* was the first marine invasive species studied at SAMS.

LEFT: Navigation buoys are floating refuges for a host of different species including a growing number of non-native species.

PUBLICATIONS 2012-13

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Mineur F, **Cook EJ**, Minchin D, Bohn K, MacLeod A, Maggs CA. 2012.. Changing coasts: marine aliens and artificial structures. *Oceanography and Marine Biology: An Annual Review*, **50**: 187-232.

Nimmo F, **Cook EJ**, Moxey AP, Hambrey J and Black K. 2012. Cost-benefit analysis of management options for *Didemnum vexillum* (carpet sea squirt) in Scotland. Report by Hambrey Consulting in association with the Scottish Association for Marine Science and Poseidon Aquatic Resource Management to the Scottish Government. Tender Ref: Cr/2011/16. pp. 69 http://www.scotland.gov.uk/Resource/0038/00388277.pdf

Cook EJ, Davidson K, Fox C and Black K. 2012. Monitoring and eradication of invasive and non-native species in aquaculture units. Report by Scottish Association for Marine Science to the Scottish Aquaculture Research Forum. Tender Ref: SARF087. 39pp. ISBN: 978-1-907266-52-2. http://www.sarf.org.uk/cms-assets/documents/91976-5284.sarf087.pdf

RESEARCH STUDENTS

Adrian MacLeod (PhD): Provision of refuges for invasive non-native species by marine renewable energy structures. Funded by SuperGen. University of the Highlands and Islands. 2009-2012 (completed)

Clare Davies (MRes): Potential for recruitment of non-indigenous species on damaged antifouling surfaces. University of St Andrews. 2012 (completed)

Co-supervising Morgan Humphreys (SAMS) and Chris Nall (Environmental Research Institute UHI)

DR KIM LAST

Unexpected findings from a small marine worm to seawater chlorination

As any boat owner who has had to scrape barnacles and seaweed off the bottom on their boat will know, put something in the sea and it will soon become fouled by marine plants and animals. To combat this we use anti-fouling paints but sometimes this is not practical especially in large industrial applications with miles of inaccessible pipework. Power stations for example use a lot of seawater to drive their turbines and for such industries an alternative anti-fouling agent is employed, one we are very familiar with from our drinking water: chlorine.

Chlorine, which is an oxidising agent, is routinely used worldwide as an effective anti-fouling additive to coolant water systems. Surprisingly, however, given its widespread use, little is known of its side effects when discharged into the marine environment, particularly in relation to increased temperature associated with the discharge thermal plume.

Over the last few years we have been investigating the effects of chlorine (in its aqueous form) and temperature on a small marine worm *Sabellaria alveolata* not uncommonly found on coasts and in estuaries favoured by power station companies. This worm builds intricate honeycomb structures out of sand and shell fragments that eventually form large reefs. The honeycomb worm thereby increases local biodiversity and is therefore protected by European law.

To assess the impact of temperature and chlorine on these worms required us to build specialist aquaria. Since the worms only live in very sediment loaded water we needed to design and build tanks that could keep sand particles continuously suspended whilst also producing a gentle water current as would be experienced by the worms on the shore. Temperature and chlorine were controlled and experiments lasted several months with many thousand worms assessed for survival and dwelling tube growth and strength.

The results showed that with increasing chlorine levels, there was increased mortality, but only at higher temperatures. However, at low chlorine doses, and irrespective of temperature, there was increased tube growth at the expense of tube strength. Whether such low dose "stimulation" of dwelling tube growth indicated a positive response we do not know, certainly if this is at the expense of weaker dwelling tubes one could argue perhaps not since the reef integrity of the whole worm colony may be compromised. The finding, that low dose stimulation of a physiological response to a toxic compound is not new, and is termed hormesis though its mechanism and function is still debated. In the case of Sabellaria we can only speculate that increased tube growth may be as a response to reduced competition from bacteria or algae, inhibited by the chlorine, for food or other nutrient resources, yet without further detailed investigation this will probably remain a mystery for a little while yet.

It is clear that our data is of some relevance to industry and hopefully may provide information for future environmentally conscious chlorination strategies.

This work was carried out in collaboration with Dr Vicki Hendrick, Christine Beveridge and Dr Tom Wilding.

ABOVE: A colony of the honeycomb worm *Sabellaria alveolata* at St Bees in Cumbria. Insert shows a composite image of an individual worm comprising a series of pictures amalgamated using Combine Z stack image processing software.

Photograph: Dr Vicki Hendrick

ABOVE: The VOrtex Resuspension Tank (VORT) array in the SAMS Alan Ansell research aquarium: All tanks are lagged to facilitate above ambient temperature; dosing pumps and carboys with chlorine stock below can be seen bottom right.

Photograph: Dr Vicki Hendrick

PUBLICATIONS 2012-13

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RESEARCH STUDENTS

Zoe Hutchison (PhD): Sensitivity of biogenic reef forming organisms and commercially important benthic invertebrates in an area of marine renewable development. Funded by MaREE. University of the Highlands and Islands. 2010-2014

Beatriz de Francisco (PhD): Effects of ocean acidification and warming on the cold-water coral *Lophelia pertusa*. Funded by the EU FP7 programme EPOCA. University of the Highlands and Islands. 2009-2013 (completed)

Co-supervising Laura Hobbs (SAMS) and Flora Kent (Heriot-Watt University)

DR STEVEN BENJAMINS

Studying marine mammals in high-energy environments

Areas such as tidal channels, where water regularly flows rapidly due to tidal forces, represent localised high-energy environments that are both complex and hard to study. Along exposed shores, large waves may create similarly forbidding conditions for research. These areas, however, are increasingly recognised as important for marine top predators such as whales, seals, seabirds and others, because they appear to offer lucrative feeding opportunities. Scotland is currently leading the way in developing new techniques to extract renewable energy from the sea, including both from tidal currents and from surface wave action, and there is an increasing interest in assessing potential risks of such developments to marine top predators.

As part of the Cetaceans & Renewables (CetRens) Team, a major element of my research has been focused on developing new methods of acoustically studying cetaceans (particularly harbour porpoise) in high-energy environments. Deploying passively drifting acoustic sensors has emerged as a promising new approach to establish distribution and relative density of harbour porpoise in tidal streams, while remaining logistically and financially competitive. Results of this approach, tested across several such environments across western Scotland under the MaREE project, suggest strongly that porpoises distribute themselves in close relationship to tidal currents. Exact responses appeared variable between sites, apparently depending on local bathymetry and topography, but porpoises did not appear to frequent narrow tidal channels with strong currents that are of interest to developers. These findings have implications for future developments of tidal energy resources in these areas, and will be published in 2013.

Some of my other research has focused on assessing the influence of mooring designs on the detection rates of moored passive acoustic porpoise detectors. Results of this work, undertaken under the Hebridean Energy Marine Futures project, suggest that deployments nearer the seabed are likely to be more successful in detecting harbour porpoise and other echolocating cetaceans.

There has also been an increased focus on advancing knowledge of appropriate survey design and disseminating this knowledge into high-level policy documents. To that end, I was heavily involved in producing a 2013 report on marine mammal ecology through the International Council for the Exploration of the Sea, focusing on survey and monitoring requirements of the marine renewables industry.

I furthermore finalised a long-term study of entanglements of large whales in fishing gears off eastern Canada, published in 2012. While not currently the main focus of research at SAMS, entanglement is a significant cause of injury and mortality among marine top predators worldwide and long-term datasets are crucial in documenting how entanglement rates and effects might change following changes to the fishing industry over decadal timescales.

ABOVE: Close-up of two drifting passive acoustic porpoise detectors in Kyle Rhea (Highlands).

PUBLICATIONS 2012-13

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DR SHEILA HEYMANS

What are the environmental impacts of fisheries and ecosystem change?

My work generally involves using foodweb models of marine ecosystems to examine the environmental impacts of fisheries and ecosystem change, looking at indicators of ecosystem status, reasons for species decline, and the impact of fisheries and fish subsidies on ecosystems.

I am working on a model of the west coast of Scotland and the Clyde Sea (for the Scottish Inshore Fisheries Trust) to address the impacts of fisheries in Scotland as well as working on indicators of change in ecosystems with Indiseas (www.indiseas.org).

We are looking at trophic level indicators of fishing effects and biodiversity and conservation based indicators used to evaluate the exploitation status of marine systems.

With collaborators, I have worked on the impact of the proposed discard ban on the new Common Fisheries Policy (Sarda *et al*), the indicators of ecosystem status and regime shifts in the Baltic Sea (Tomczak *et al*) and on the ecological traits of marine ecosystems.

With my PhD students I have worked on the attitudes of Scottish fishers toward marine renewable energy (Alexander *et al* 2013) and the importance of kelp detritus to sandy beach surf zone animals (Orr *et al*).

Under KnowSeas I have been involved with looking at good environmental status in the NE Atlantic (Kershaw *et al*) and at resilience of the European seas (Blenckner *et al*).

PUBLICATIONS 2012-13

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RESEARCH STUDENTS

Kyla Orr (PhD): Predicting the ecosystem effect of harvesting beach-cast kelp for biofuel. Funded by the SEUPB BioMara project. University of the Highlands and Islands. 2009-2013 (completed)

Karen Alexander (PhD): Offshore power production and marine stakeholders: from understanding conflict to impact mitigation. Funded by SuperGen. University of the Highlands and Islands. 2009-2012 (completed)

Sarah Marjoram (MRes): Using ecosystem modelling to investigate a phase shift between minke whales and basking sharks off the west coast of Scotland. University of St Andrews. 2012 (completed)

Marian Torres (PhD): Development and application of an Ecopath model in the Gulf of Cadiz ecosystem. Instituto Espanol de Oceanografia, Spain

Ismet Saygu (PhD): Ecosystem modelling to evaluate eastern-Mediterranean (Turkey coast) fisheries management plan. Dukurova Univerity, Turkey

DR TOM ADAMS

Connecting models & marine management

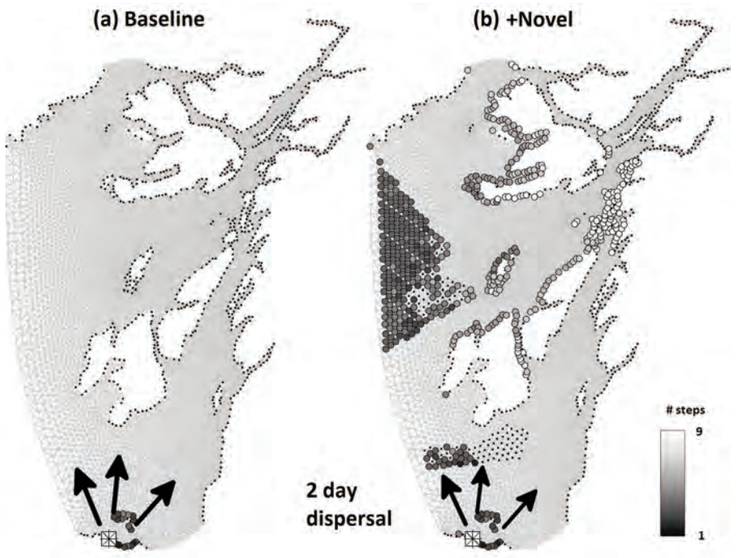
Humans interact with the marine environment in many ways. Accurate prediction of the potential impacts of these activities is a challenge for marine ecologists, as our understanding of marine ecosystems is far from complete. Increasingly, ecological surveys are complemented by computational models, which provide estimates for quantities which are difficult to measure in the field and assist in selecting survey sites.

New paths for dispersal

Objects installed in the marine environment may cause changes in current regime, or provide new habitat to a wide range of species (particularly those with pelagic larvae that move passively under the influence of currents).

We used a combined hydrodynamic-biological modelling approach to investigate the role of coastal topography on potential larval dispersal, and how this might be altered by novel offshore habitat provided by renewable energy devices in the Firth of Lorn and Kintyre sea. We know that coastal topography and dispersal potential are linked, which is likely to affect the development of dispersal strategies, particularly when habitat suitability is taken into account.

The study region contains a biogeographic barrier (a physical limit to dispersal provided by strong currents moving northwards into the area from the Irish sea), which ensures the isolation of biological populations on Irish and Scottish shorelines, regardless of dispersal duration. If suitable habitat becomes available offshore, organisms with a range of dispersal durations are likely to become able to make the jump northward to Scotland (see figure). This has implications for the distribution of native species, and the control of invasive organisms. Novel offshore sites will thus need to be closely monitored.



ABOVE: Multistep potential dispersal paths in the Firth of Lorn region. Path lengths (number of discrete dispersal events) required to access each habitat site from a site on the Northern Irish coastline (box/asterisk) in (a) the absence and (b) the presence of novel habitat, for a species with a 2 day larval duration. Black indicates a single step is required; white 9 steps. Sites marked with a small black dot are inaccessible from the source (box/asterisk) site.

Controlling parasites

As Scotland expands its aquaculture industry, care is required to limit environmental impacts while also maximising production efficiency. A particular issue affecting salmon (farmed and wild) are parasitic sea lice, which can injure and even kill fish when present in high enough numbers. As farms provide ideal conditions for these organisms, careful management is required. Typically this is achieved through synchronous chemical treatments and fallow periods within management areas. However, connections within and between these areas are not particularly well understood, and as a consequence neither are the dynamics of parasite spread.

Again using a combined biophysical modelling approach, we studied the spread of sea lice in Loch Fyne. This enabled insight into patterns of lice abundance at farm sites, and work is currently under way to integrate estimates of dispersal into spatio-temporal models of lice abundance.

PUBLICATIONS 2012-13

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Adams TP, Burrows MT and Aleynik D. In review. Larval dispersal of intertidal organisms and the influence of coastline geography.

Adams TP, Miller RG, Aleynik D and Burrows MT. In review. Offshore marine renewable energy devices as stepping stones across biogeographic boundaries.

RESEARCH STUDENTS

Roland Proud (MRes): Dynamics of parasitic sea lice populations on salmon farms. University of St Andrews. 2012 (completed)

RUTH BRENNAN

Exploring attitudes and conflicts about people's uses of the sea

Art-science projects

In the past year I continued to build a strong art-science collaboration with Glasgow-based visual artist Stephen Hurrel (www.hurrelvisualarts.com). As the Mapping the Sea Group (www.mappingthesea.net), we have undertaken several sea-based projects on the Hebridean island of Barra and on Arranmore island, off Donegal. These projects involved interviewing the local fishermen and developing a creative response to the material through video and sound, as well as in a full colour publication.

The **Connecting Coastal Communities** project explored the Gaelic speaking islands of Arranmore and Barra, where the fishermen believe that their livelihood and way of living are being threatened by powerful governmental forces who are not listening to them. The project outcomes were published in a short book - *Duthchas na Mara/Duchas na Mara/Belonging to the Sea* - which explores the cultural roots of maritime conflict on these two islands. This work was funded by Colmcille (www.colmcille.net).

Building on the Connecting Coastal Communities project, **Sgeulachdan na Mara/Sea Stories** is a collaborative art-science-community mapping project based on cultural and historical information related to the sea and coastline around Barra.

Together with community organisation Voluntary Action Barra and Vatersay, we gathered information in the form of stories, anecdotes and names of specific areas or features in the sea from people on Barra, who have, or have had, a close involvement with the sea. This information reveals aspects of the marine environment that are invisible to many people and is a way of preserving that knowledge for future generations as well as complementing the more static and one-dimensional maps often used by government agencies to represent the marine environment in community consultations. Alongside a design team, we have created a dynamic digital interactive map that contains images, sounds and stories of the sea around Barra and enables users to access different layers of information and knowledge related to specific marine locations. The intention of this project is to create a working prototype system that can become a resource within the community and be added to on a continuing basis. It will be launched on Barra on 16 November 2013. Sea Stories is funded by Creative Scotland's First in a Lifetime award.

Designation of SACs in waters surrounding Barra

In parallel to my art-science work, my PhD research has drawn on a visual participatory methodology to explore the social, cultural and historical roots of the conflict on Barra around the designation of two marine Special Areas of Conservation.

A short photo-text publication illustrating this research can be accessed at www.sams.ac.uk/ruth-brennan/what-lies-beneath-e-book../view and viewed as a slideshow at https://www.dropbox.com/sh/xdugks5gjx94ndh/q95Ii2FLpT

I presented my PhD research at the MASTS Annual Science Meeting in Edinburgh in September 2012 and at the Association of American Geographers Annual Meeting in Los Angeles in April 2013.

PUBLICATIONS

Smith G and **Brennan RE**. 2012. Losing our way with mapping: thinking critically about marine spatial planning in Scotland. *Ocean & Coastal Management*, **69**:210-216.

Brennan RE and Valcic B. 2012. Feature Article: Shifting perspectives - how the masks we wear can facilitate and inhibit channels of communication in the social-environmental policy context. *Ocean & Coastal Management*, **62**: 1-8.

MacKinnon I. and **Brennan R**. 2012. *Dùthchas na Mara/Dúchas na Mara/Belonging to the Sea*. Exploring the cultural roots of maritime conflict on Gaelic speaking islands in Scotland and Ireland. Photography: Stephen Hurrel. ISBN 978-0-9529089-8-2.

Ruth Brennan is a MASTS Research Associate in social ecology and a part-time PhD candidate.

DR TAVIS POTTS

ECOLOGY

The Centre for Sustainable Coasts

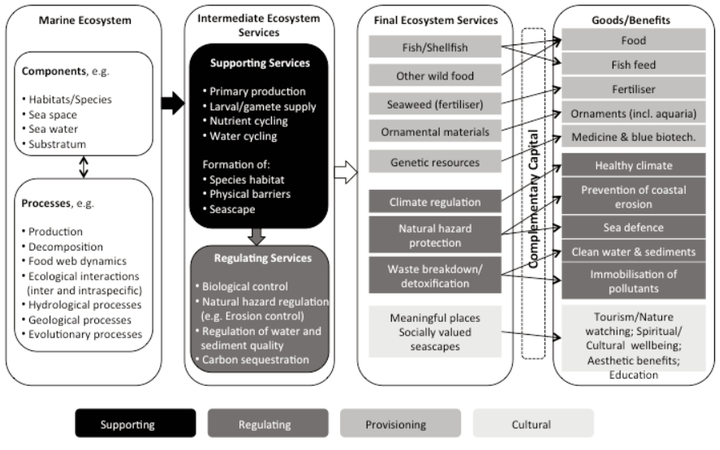
It has been a busy academic year for the Centre for Sustainable Coasts. As marine and coastal policy continues the trend of setting new reforms that underpin the sustainable use of our marine environments, we have seen action from Brussels to Oban on issues from new marine protected areas, establishing marine planning, the implementation of the EU Marine Strategy Directive, and the emergence of the Blue Economy across Europe. These policy reforms have real outcomes for maritime industries and coastal communities.

My research objective is to stay at the forefront of producing ideas and understanding societal relationships with the sea. Keeping social science research innovative and critical strengthens political debate.

SAMS social science research, delivered increasingly in partnership with the James Hutton Institute through our Centre for Sustainable Coasts, provides support, data and critique of marine policy initiatives and continually aims to push the boundaries and create ideas for future development.

The Valuing Nature Network

The NERC funded VNN project ran across 2012-13 and explores the concepts surrounding the valuation of natural ecosystem services – the goods and benefits that nature provides to society. Our specific project within VNN looked at the emergence of Marine Protected Areas across the UK and the broader benefits they can provide. Marine Protected Areas are an important means of protecting marine biodiversity. The dominant reason for MPA development is environmental protection where marine species and habitats are protected from 'damaging' activity'. Our research explored how the concept of ecosystem services can be linked to the development of MPAs and assessed a number of benefits from UK MPA sites including provisioning services *e.g.* fisheries, marine plants and natural resources; regulatory services including absorption of CO_2 and wastes; and cultural services such as recreation, sense of place, and education. While we are at an early stage in terms of understanding and capturing the concept of value from ecosystem services, acknowledging the contribution of MPAs in supporting human welfare is an integral step in building public support for their designation.



SCHEMATIC showing the intermediate and final ecosystem services and the goods and benefits provided by protected species and habitats of Marine Protected Areas.

Supporting Marine Spatial Planning with Local Socio-Economic Data (MSP-LED)

The demand for local scale social and economic data for coastal regions has never been greater. As the Scottish Government implements national and regional marine planning under the Marine (Scotland) Act 2010, the inclusion of local knowledge, data and values will be essential to delivering a successful process. Despite the growing amount of spatial data available, detailed information on local uses of the sea at smaller scales is rarely recorded. There is little information on how communities and users value the sea and how sectors interact spatially.

Mapping local socio-economic data ensures all voices are heard in the debate and decisions are made with appropriate information. This is particularly important for coastal stakeholders that operate at local scales (e.g. recreation and tourism).

This project, supported by the Scottish Government CREW program, is pioneering new engagement technology to respond to the challenge of gathering information on local uses and engaging with marine users in planning. It is pioneering a revolutionary data collection process via the deployment of an interactive GIS enabled 'touchtable' in a series of workshops around Scotland. The device allows stakeholders to 'draw' and evaluate zones onto a digital map in a highly interactive environment. Local knowledge is easily and intuitively drawn onto a map and the information is incorporated into a GIS database.

Two case study sites have been selected to test and demonstrate the approach. The first is currently being conducted in Argyll and Bute in partnership with the local authority and Martine Scotland to develop regional maps of coastal based tourism. The second case study will be conducted in the Moray Firth in collaboration with the Moray Firth Partnership to map interactions and conflicts between local marine sectors.

Follow Tavis' Sustainable Seas blog at http://sustainable-seas.blogspot.co.uk/

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Charlotte Hopkins (PhD): Climate Change and the Resillience of Scottish Marine Protected Areas. University of Glasgow. Scottish Government Centre of Expertise in Climate Exchange. 2011-2014

Karen Alexander (PhD): Offshore power production and marine stakeholders: from understanding conflict to impact mitigation. Funded by SuperGen. University of the Highland and Islands. 2009-2012 (completed)

DR TIM O'HIGGINS

"A poor man wants the oyster, a rich man wants the pearl..."

These words of Elvis Presley, though more famous 50 years ago, are no less resonant today. Values given to resources from the marine environment differ, and incorporating different types of values into management of the seas is vital to sustainability.

In Europe, as Member States struggle to maintain prosperity and re-establish their economies, the Integrated Maritime Policy sets out a vision of 'Blue Growth' to support economic improvement in maritime sectors. At the same time, the environmental component of the policy, the Marine Strategy Framework Directive, mandates that Good Environmental Status be achieved or maintained in Europe's Seas by 2020.

The stakes are high. From oil and gas, to the freight transport which underpins European international trade, maritime sectors are of huge importance. But not all of the value of the marine environment is measured by markets.

Natural capital

The seas generate other benefits, sometimes called ecosystem services or natural capital. For example, the aesthetic conditions which support recreation, such as clear water, beautiful natural scenery, and clean beaches, are valuable in terms of the enjoyment, but are not for sale; in addition the oceans perform the fundamental biogeochemical processes which provide the living conditions necessary for all human activities to take place.

The graphic on the right shows estimates of the economic worth of marine sectors and ecosystem services. Altering the marine environment can reduce these stocks of natural capital and lessen their capacity to generate ecosystem services. The degree to which we can exploit marine ecosystems without depleting natural capital defines the limits of sustainability.

Recognising the value of the environment and of the ecosystem services it provides when implementing the integrated policy is therefore hugely important. This is an enormous undertaking. European marine territory is vast and diverse both in terms of the ecology within it and the social and cultural norms of the people surrounding it. Around Europe marine managers face the same challenge, that of balancing use and conservation.

Understanding trade-offs

Aligning these twin goals requires an understanding of the trade-offs between exploitation and ecosystem service supply. European society places many pressures on the seas through fishing, agriculture and shipping amongst other activities. These pressures result in an alarming list of environmental problems: collapsing fish stocks, oxygen depletion and ocean acidification are just a few. The damage done to oceans diminishes their capacity to supply ecosystem services on which all human activities rely. For example, ocean acidification, caused by the uptake of carbon dioxide by seawater, may destroy cold water coral reefs, eliminating essential fish habitat - and production of commercially important species - as well as reducing biodiversity and the potential for the discovery of new genetic resources with pharmaceutical worth.

Know-Seas project

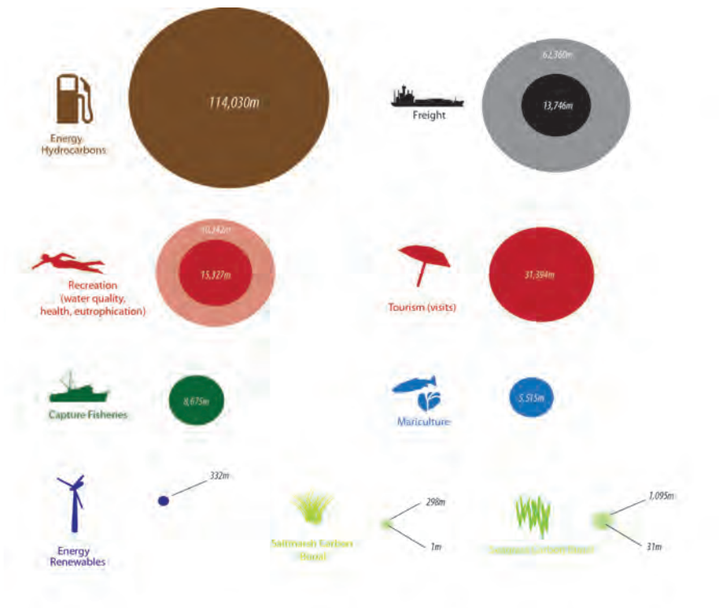
Understanding how best to manage the marine environment to maintain ecosystem services, as well as support economic development, has been the focus of the KnowSeas project led by SAMS.

The 33 partners from 16 countries have taken a systems approach to support implementation of the Marine Strategy Framework Directive.

The project output tools and reports are available at www.msfd.eu.

With jobs and economic growth currently top priority on most national agendas, there is a danger that the trade-offs between economic profit and ecological loss will be ignored. The harsh reality is that ecosystem services are unlikely to be fully considered in management and that our stocks of natural capital may continue to be depleted further in the coming years.

If we chose to deplete natural capital now for the sake of economic growth we endanger the very ecosystems on which our societies depend for life.



Annual value (€2010) of selected benefits from Europe's regional seas. Dark colours show lower estimates pale colours show upper estimates. Highest confidence in estimates are for energy, fisheries and mariculture, lowest confidence is for freight transport.

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Suzanne Van Osch (MSc): Growing fish in troubled waters? Determining consumers' willingness to pay for reduced environmental pressures of aquaculture production processes. VU Amsterdam

Nicola Edwards (MRes): Quantifying social ecological scale mismatch in the Mediterranean. University of St Andrews

Arnaud Brival (MRes): A preliminary study for a systematic conservation approach using MARXAN along the Var coastline. "A spatio-temproal analysis of on-board recreational fishing: intensity, conflicts and impacts". University of St Andrews

John Bainbridge (PhD): An investigation into the opportunity to develop a future policy framework to deal with policy complexity in a coastal region. University of the Highlands and Islands

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DR TOM WILDING

ECOLOGY

The impacts of mussel farming on the seabed

Aquaculture, as a means of food production, is growing rapidly in response to an increasing demand for protein and the over-exploitation of wild fisheries.

Mussel culture is frequently perceived as having little environmental impact yet mussel biodeposits and shell debris accumulate around the production site and are linked to changes in animals associated with the seabed. Mussel production may also increase in the near future as they colonise new structures associated with offshore energy production.

To assess the extent and nature of changes in benthos associated with mussel farming sediments were sampled with corers and grabs and observed using a video. Sediment cores were analysed for 'redox' which is a measure of sedimentary oxygenation. Grab samples were analysed for macrofauna and shell-hash content whilst starfish were counted and the shell-hash cover estimated from video imaging. The goal was to comprehensively, and holistically, describe the relationship between distance from farm and impact metrics.

The data suggest that the benthic impacts of mussel farms are relatively localised and that a likely mechanism for this impact revolves around the loss of mussel-shell to the seabed. Once on the seabed mussel shells attract predators, such as starfish, and the resultant empty shells enhance the entrapment of mussel-derived organic detritus and the subsequent enhancement of the benthic community (in terms of abundance) and the concomitant consumption of sedimentary oxygen (see figure above).

Mussel farms change the nature of the sediment, and associated animals. Meaningful change extend approximately 10 m from the farm boundary (see figure).

These data suggest that mussel farming is a relatively benign way of producing food, compared with intensive fish-farming, in similar environments and that mussel colonisation of offshore structures is likely to enhance local benthic productivity.

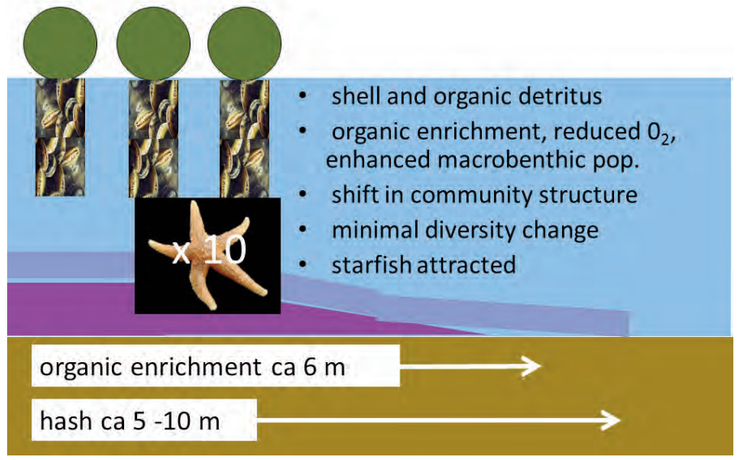

FIGURE: Summary of changes associated with mussel farms

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Sally Rouse (PhD): Understanding benthic productivity on artificial structures: maximising the benefits of marine renewable energy. Funded by SAMS, UHI, Heriot-Watt and Scottish Power Renewables. University of the Highlands and Islands. 2011-2014

Karen Alexander (PhD): Offshore power production and marine stakeholders: fromunderstanding conflict to impact mitigation. Funded by SuperGen. University of the Highlands and Islands (completed)

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Co-supervisor of Kyla Orr (PhD) (completed)

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DR CLAIRE GACHON

PICTURE: Collecting kelps at the Atlantic Bridge with visiting PhD student Marine Vallet (left), who was funded through the EU FP7 program ASSEMBLE. Marine is training as a chemist and investigates bioactive compounds produced by so-called 'endophytic' fungi that grow inside the seaweeds, without causing any apparent symptom.

Molecular Phycology

Our interest for little known diseases of algae took our group into many exciting directions to work with many overseas collaborators. In fact, last year was unprecedented in terms of the diversity of projects and contracts that we were involved in. On top of pursuing our existing activities, we have been developing an edge in exploiting novel DNA sequencing technologies for marine biology.

Investigating algal pathogens in the field and in the lab

During an intensive, but rather short sampling campaign in Greece, we discovered algal pathogens that had never been reported in the Eastern Mediterranean basin. Our findings suggest that algal pathogens are an abundant, though often disregarded, part of the marine ecosystem. Using lab-controlled cultures that can be infected at will, we have combined fluorescent probes with confocal microscopy to follow the progress of infection within the algal cells in detail.

Deciphering the genomes of seaweeds

Following our contribution to deciphering the first seaweed genome back in 2010 (the small filamentous brown alga *Ectocarpus siliculosus*), we have been busy tackling the genome of Irish moss. This red seaweed, called Cairgean in Gaelic, is best known for its jellifying properties. It is the source of high-value carrageen, which has many uses as an additive in the food industry.

After several years of joint work with an international consortium led by the Station Biologique de Roscoff in France, the Irish moss genome and its 9606 genes are now accessible to everyone! Of special interest for us was to identify genes potentially encoding pathogen receptors, since those are likely to play a key role in algal defence against infection.

We are currently pursuing our research on red algae through some very exciting collaborative work with South Korean colleagues. We are using novel high throughput DNA sequencing technologies to investigate the infection mechanisms of *Pythium porphyria*, a devastating pathogen that plagues laver, the seaweed used as sushi wrap in oriental cuisine.

New concepts on infection in land plants.

The potato late blight is best known for causing the Great Famine in Ireland in the 1840s. It remains a problem and causes the loss of a fifth or a quarter of potato crops worldwide. Potato late blight not only costs 5-7 bn dollars to the industry every year, but it also threatens food safety in many countries where potato is a staple crop. In a thought-provoking piece of work, we examined how pathogen proteins are imported into the potato cells, where they wreak havoc. Our study provides unexpected clues on how this protein transport might be blocked, which in turn might halt infection.

This piece of work is a prime example of how our expertise on little known marine pathogens and diseases enables us to tackle issues of wide societal relevance.

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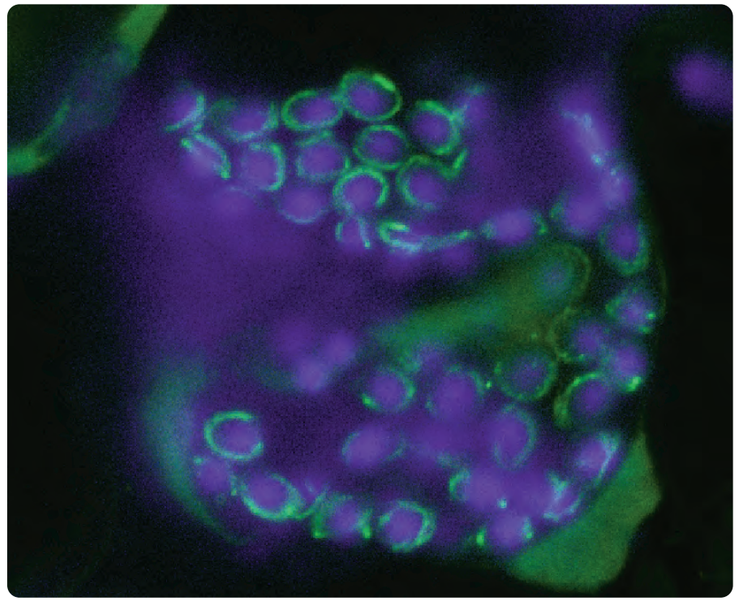

PICTURE: Confocal microscopy imaging of the seaweed pathogen *Eurychasma disckonii* (Tsirigoti *et al*, 2013). Each blue dot represents the nucleaus of a parasitic cell, surrounded by green cytoskeleton filaments. Scale: each blue dot is about 4 micrometres in diametre.

RESEARCH STUDENTS

Alexander Schober (BSc): In silico characterisation of recombining LRR-domains in ROCO-GTPases and associated loci as candidate pathogen receptors in brown algae. Funded by ERASMUS. University of Konstanz, Germany.

Amerssa Tsirigoti (PhD). University of Athens, Greece. 2011-

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DR MICHELE STANLEY

The end of BioMara

The Sustainable Fuels from Marine Biomass project, BioMara, entered its final year. This €6M project was funded by INTERREG IVA with match funding from Highlands and Islands Enterprise and The Crown Estate. BioMara has enabled six research institutes from Western Scotland, Northern Ireland and the border region of Ireland to investigate the feasibility and viability of using marine biomass as a source for biofuels over the last four years.

Four BioMara research themes

Under the leadership of SAMS, the project has addressed four research themes:

1. Identifying the most appropriate seaweeds for biofuel generation

2. Identifying high oil producing microalgae

3. Evaluating the environmental impacts of algal cultivation and extraction

4. Examining the technological and socio-economic practicalities of producing competitive and sustainable biofuels from marine biomass

Underpinning this has been the engagement with the wider community to explore ways of meeting long term energy needs and developing new business utilising algal biomass as a source of biofuels.

RESEARCH STUDENTS

Peter Schiener (PhD): Ethanol production from algal biomass. Funded by BioMara. University of the Highlands and Islands. 2009-2013.

Carole Shellcock (PhD): Molecular aspects of algal biofuels for the 21st century. Funded by BioMara. University of the Highlands and Islands. 2009-2013.

Iona Campbell (PhD): Interactions between macroalgae aquaculture for biofuels and phytoplankton. Funded by the European Social Fund. University of the Highlands and Islands. 2011-2014

Adrian MacLeod (PhD): The impacts of marine renewable energy structures on the invasion of biofouling non-native species. Funded by SuperGen. University of the Highlands and Islands. 2009-2013. Completed

The BioMara legacy

The legacy of this project will continue for years to come with the knowledge gained being applied and built upon within the community through interactions with local SMEs.

A learning resource created (poster on left) and distributed to schools by the BioMara project will continue to introduce the next generation to algae, their many properties and uses.

The BioMara project has supported the training of the next generation of researchers in the field of algal biofuels with a number of Ph.Ds funded through the project.

These include:

Brían Carpenter: Assessment of marine algae as a potential source of bioethanol. Centre for Renewable Energy at Dundalk IT (CREDIT)

Janet McKennedy: Anerobic digestion of marine macroalgae. Centre for Renewable Energy at Dundalk IT (CREDIT)

Kyla Orr: Effects of seaweed extraction for biofuel on marine ecosystems in Western Scotland. UHI

Carole Shellcock: Molecular aspects of algal biofuels for the 21st century. UHI

Peter Schiener: Bioethanol production from brown seaweeds. UHI

Carlos Venegas: Optimisation of biogas production from marine algae biomass. IT Sligo

Celebrating BioMara

A dinner, hosted by Sir John Arbuthnott, President of the Royal Society of Edinburgh, was held to share the findings of the project with politicians, policy makers, businesses, community representatives and academia. Approximately 60 people attended the event at the Royal Society of Edinburgh to celebrate the advances made by the BioMara project. Sir John Arbuthnott, President of the RSE, welcomed guests from the Scottish Government, the wider community, academia and business. The funders and the six project partners from Ireland (Dundalk Institute of Technology, Institute of Technology Sligo), Northern Ireland (University of Ulster, Queens University) and Scotland (SAMS, University of Strathclyde) were also present to share their findings.

Following my summary of the project, several short presentations highlighting the various benefits of the project were given by Mike Russell MSP (Cabinet Secretary for Education and Lifelong Learning in the Scottish Government), Bob Hannah (Department of Energy, Ireland), Paul Boylan (Special EU Programmes Body) and Professor Mike Cowling (The Crown Estate).

Further information, a summary of the main findings and the algal teaching material can be found at

www.biomara.org

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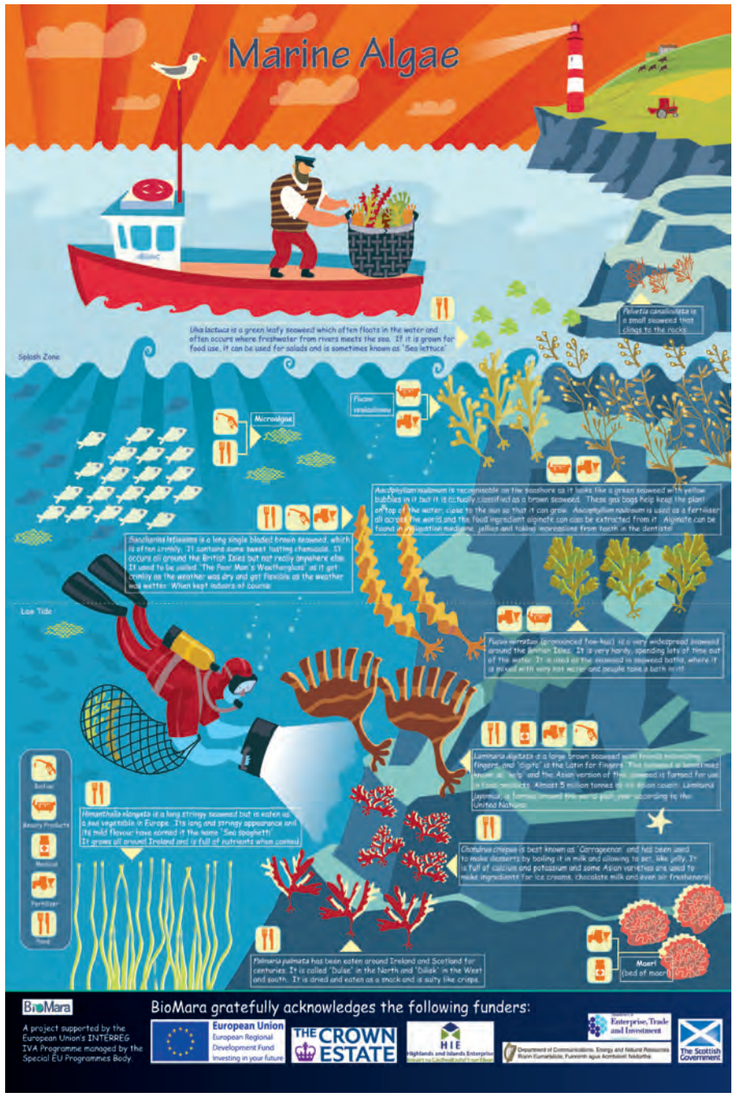


PICTURE: The BioMara project produced a school resource for upper primary levels with six lesson plans and a variety of additional resources including this child-friendly poster. The resource was distributed to schools throughout western Scotland, Northern Ireland and the Republic of Ireland.

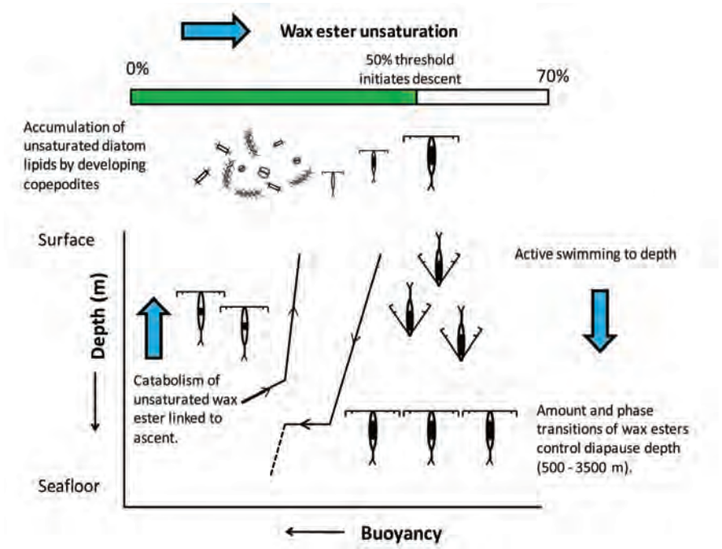
DR DAVID POND

The ups and downs of copepods: Fat floaters and sinkers

Calanoid copepods are a crucial link between the microscopic algal producers in the oceans and commercially important species of fish.

An intriguing yet little understood aspect of the life cycle of these copepods is their overwintering behaviour, when they descend into the deep ocean and become dormant. Dormancy enables the copepods to avoid predators and conserve energy. Despite decades of research, the key controls on dormancy have remained elusive. This information is required to develop predictive models of the distribution and abundance of these animals and the consequences for fisheries and biogeochemical cycles.

We found that large lipid reserves accumulated by the copepods prior to dormancy and their novel pressure sensitivities act as a key contol mechanism.



Schematic of the key roles that lipids play in the life cycle of calanoid copepods

Three main roles of lipids in the life cycle of calanoid copepods

Initiation of diapause: controlled by the level of polyunsaturated lipids derived from diatoms in the oil sac. Copepods initiate dorrmancy when the oil sac contains ~50% omega-3 polyunsaturated lipids.

Neutral buoyancy: Lipid-loaded, positively buoyant copepods swim actively to depths >500 m until their oil sac undergoes liquid-solid phase transitions, thereby reducing hydrostatic lift and facilitating neutral buoyancy.

Termination of diapause: Copepods "eat their own weight belts" and ascend to surface waters, *i.e.* the copepods selectively catabolise the more dense, solid phase omega-3 polyunsaturated lipids.

The physical properties of the lipids and their pressure-dependent phase transitions thus provide a unifying explanation of the key controls on dormancy in calanoid copepods.

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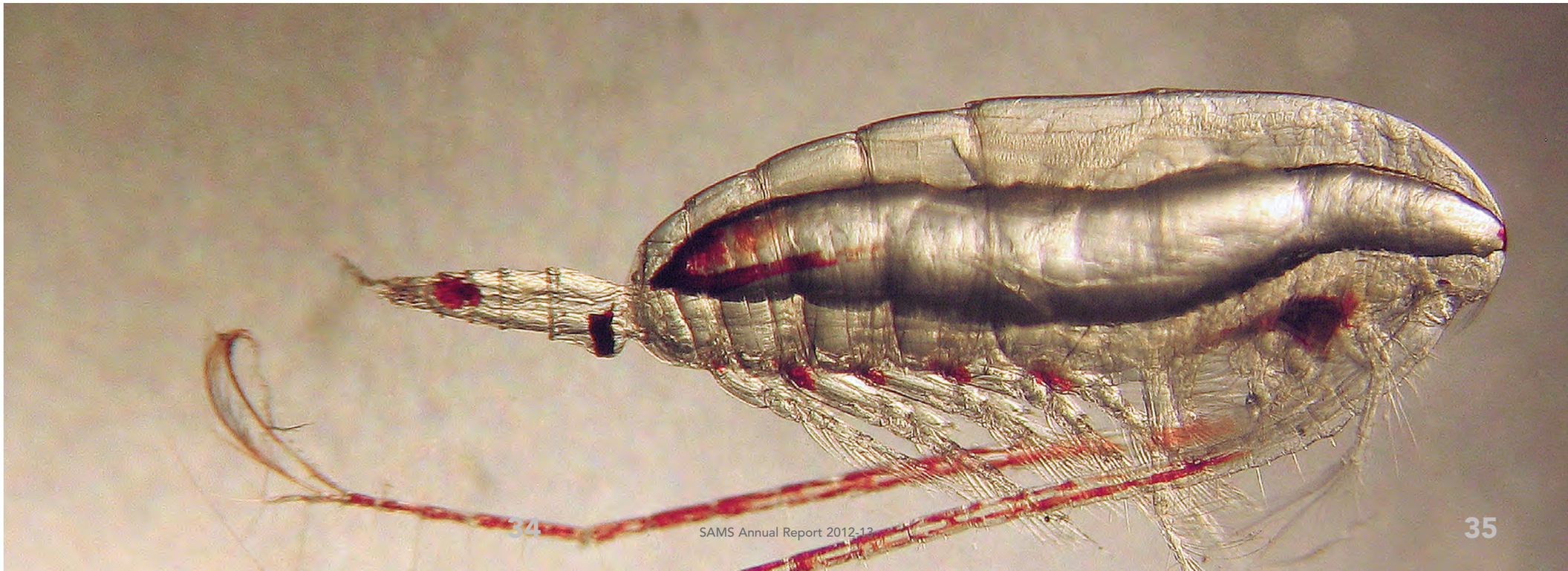

DR JOHN DAY

Successful cryopreservation of a transgenic alga

Algal biotechnology as a scientific discipline, and as an industrial sector, is developing at an exponential rate. Furthermore, there is increasing interest in the genetic manipulation of algae to generate transgenic algae, where genes are inserted, to enhance productivity, or suitability for a particular process.

SAMS is one of the leading European centres for algal biotechnology and the leadership, engagement and delivery of SAMS personnel are highlighted in various sections of this annual report. A key aspect of this delivery is the research associated with the Culture Collection of Algae and Protozoa (CCAP), where cryopreservation (the science of rendering biological materials into "suspended animation" without losing their functional or genetic capabilities) is a major focus of research.

Guaranteeing consistency in productivity of algal master-cultures is a key challenge for the development of future algal-derived biofuels and other sectors of biotechnology.

Uniquely in biotechnological exploitation of micro-organisms routine serial-transfer of algal cultures is accepted by many practitioners as the optimal method of long-term maintenance. Whilst there is limited evidence of long-term genotypic or functional stability for some algae, there are also examples of deleterious changes on prolonged maintenance including morphological changes and loss of metabolite production such as toxins by *Anabaena flos-aquae* and *Pseudo-nitzschia*. Stock-cultures, *i.e.* the master material used to initiate new cultures, of most micro-organisms are conserved by freeze-drying, or cryopreservation at ultra-low temperatures, both approaches work by removal of water making it unavailable for biological activity.

Whilst lyophilization has potential for the conservation of axenic cyanobacteria, it is not applicable to eukaryotic algae. However, cryopreservation, with storage <-135ºC, can guarantee stability for hundreds of years.

Over the past year, working with Rachel Hipkin and Dr Thomas Mock from the University of East Anglia, we have focussed on the conservation, and assessment of functional stability, of wild-type and transgenic algae. In this study the transgenic model strain *Thalassiosira pseudonana* CCAP 1085/23 (figure 1) was cryopreserved using a conventional, low-tech cryopreservation protocol. This employed dimethyl sulphoxide [5% (v/v)] as a cryoprotectant, using a two-step cooling approach; initial controlled-rate cooling, followed by plunging into liquid nitrogen, with storage at -196ºC. High levels of post-thaw viability (70-85%) were obtained and on recovery of cryopreserved material no reduction in expression of the inserted gene (BIG1-eGFP) was observed (figure 2).

This work provides the first conclusive evidence for the successful cryopreservation of a transgenic alga and as such provides a fundamental building-block for the development of algal biotechnological processes base on genetically manipulated algae.

In algal biotechnology, as in other industrial sectors investors will insist that their "assets" (i.e. the algal strains on which their product depends), whether wild-type, conventionally mutated, or transgenic are 'secure'. This work provides an initial evidence-base for transgenic algal conservation; however, there are significant challenges to the cryopreservation of algae and many algae, including some that are currently exploited, are problematic/ have not yet been successfully cryopreserved.

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Adrian MacLeod (PhD): The role of marine renewable energy structures and biofouling communities in promoting self-sustaining populations of non-native species. Funded by SuperGen. University of the Highlands and Islands. 2009-2013. Completed

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Letícia Tessarolli (PhD): Cryopreservation of Brazilian algal biodiversity. Funded by FAPESP. Federal University of São Carlos, Brazil. 2012-2016.

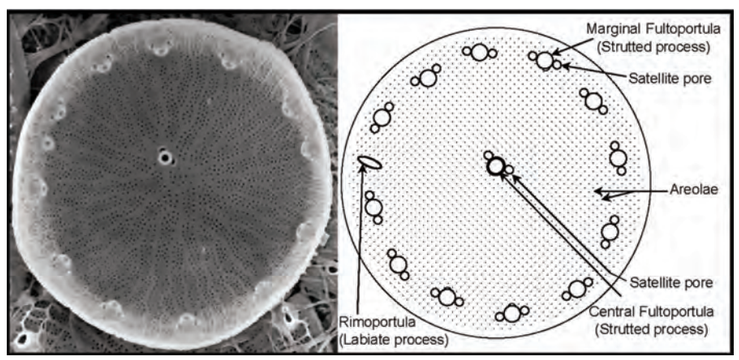

FIGURE 1: Left is an electron micrograph of *Thalassiosira pseudonana*; right a diagram showing morphological features.

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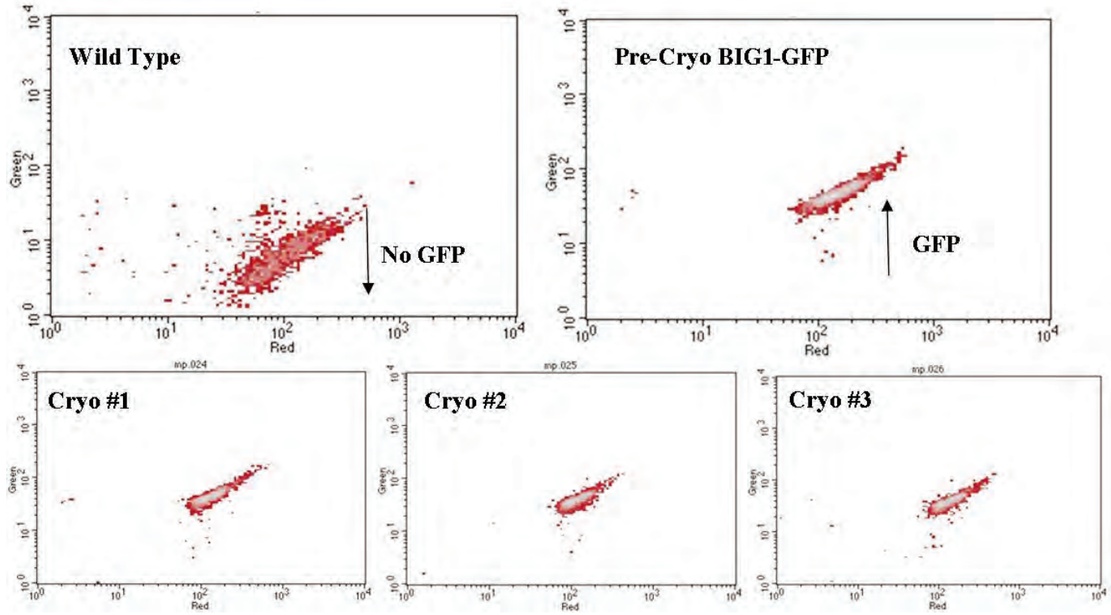

FIGURE 2: Flow-cytometer plot of *T. pseudonana* wild-type, a pre-cryopreserved (Pre-Cryo) cell line of *T. pseudonana* overexpressing BIG1 fused to GFP and three independent thawed viable cryopreserved cells (Cryo 1-3)

PROFESSOR KEITH DAVIDSON

Harmful algal bloom research

Marine phytoplankton through their photosynthetic growth form the base of the marine food chain. A small subset of the phytoplankton may be harmful to human health or to human use of the ecosystem. The species that cause harm are now widely referred to as 'Harmful Algae' with the term 'Harmful Algal Bloom' (HAB) commonly being used to describe their occurrence and effects.

In terms of human health, the most important consequence is the production, by some species, of biotoxins. Typically, biotoxin-producing phytoplankton species exist at relatively low densities of a few hundred or thousands of cells per litre. The toxins become concentrated in the flesh of organisms such as bivalve molluscs that filter feed on phytoplankton. In most cases, there are no adverse effects to these primary consumers, but this concentrating mechanism creates a risk to health if the shellfish are consumed by humans.

Human health is protected by monitoring HABs and shellfish toxins. However, better understanding of the factors that govern HAB appearance is still required to allow regulators and industry better manage the coastal aquaculture that is affected by these events.

A range of research projects related to HABs and how the marine environment influences their timing, location, magnitude and toxicity are on-going at SAMS. Two recent projects are described below:

Identifying the Paralytic Shellfish toxin producing dinoflagellate *Alexandrium tamarense*

This species is the most important HAB organism in UK waters due to the high toxicity of some of its strains. Recent research at SAMS has demonstrated that morphologically indistinguishable toxic and non-toxic strains can co-occur making it difficult to use *Alexandrium* abundance as a predictor of future shellfish toxicity.

Though a NERC funded PhD studentship (to Lisa Eckford Soper) and a Food Standards Agency Scotland research grant we have developed a method that allows rapid identification of toxic and non-toxic *A. tamarense* using a combination of molecular fluorescence *in situ* hybridization (FISH) based probes and flow cytometry (FC).

The FISH-FC method allowed effective discrimination between laboratory cultures of Group I and Group III ribotypes, with toxic and non-toxic cells creating distinct, easily identifiable, clusters of each. Comparison of estimates of cell abundance obtained by the FISH-FC technique with those obtained by microscopy were good (figure 1). Subsequently, the methodology was successfully applied on natural seawater samples, spiked with known concentrations of toxic and non-toxic *A. tamarense* cells at environmentally relevant concentrations (figure 2).

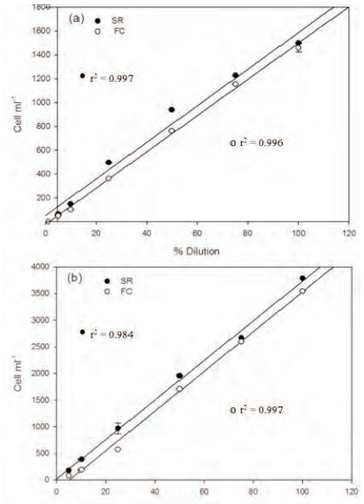

FIGURE 1: The relationship between FISH-FC (□FC) derived *A. tamarense* abundance for (a) toxic and (b) non-toxic cells and those obtained using a Sedgwick rafter (SR) counting chamber. All results are means of triplicate samples. Error bars represent SE.

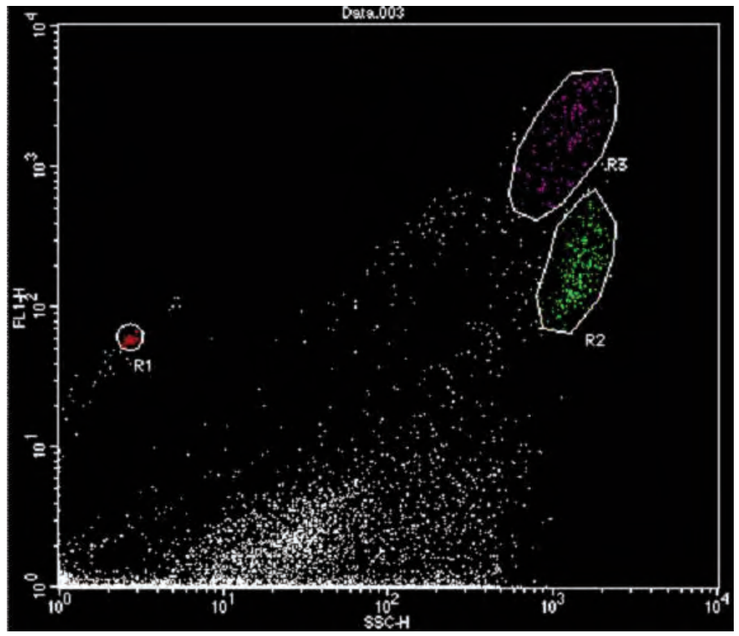

FIGURE 2: FC dot-plot of a natural seawater samples spiked with cultured *A. tamarense* cells. This demonstrates the discrimination that could be achieved between toxic (R2) and non-toxic (R3) cells even in the presence of a natural assemblage of non-target organisms. R1 is a gated region for the fluorescent latex beads of known concentration that are used to calibrate the instrument.

The role of anthropogenic nutrients and their ratios in promoting HABs

Anthropogenic nutrient enrichment of coastal waters is frequently assumed to be a reason for the putative worldwide increase in the occurrence of HABs.

Scientists from SAMS participated in a DEFRA funded working group to evaluate this issue.

Results have recently been published (Gowen *et al.* 2012, Davidson *et al.* 2012).

The analysis in these papers demonstrates that evidence for an anthropogenic nutrient – HAB link is limited. For large-biomass HABs, the hypothesis that nutrient enrichment can cause HABs is supported in some water bodies but not in others. Evidence that enrichment brings about an increase in low-biomass HABs of toxin-producing species is more equivocal. While change in nutrient ratios (for example nitrogen: phosphorous or nitrogen: silicon) can influence toxin production, evidence that changes in such ratios influence HAB abundance or magnitude is weak.

RESEARCH STUDENTS

Lisa Eckford-Soper (PhD): The competitive dynamics of toxic and non-toxic ribotypes of the harmful dinoflagellate Alexandrium tamarense. Funded by NERC (CASE - MSS). Univeristy of the Highlands and Islands. 2009-2013. Completed

Grigorios Moschonas (PhD): Dissolved organic nitrogen dynamics and its influence on phyoplankton communities in coastal waters around the UK, with a focus on HAB species. Funded by NERC. University of the Highlands and Islands. 2011-2015.

Co-supervising:

Iona Campbell (PhD): Interactions between macroalgae aquaculture for biofuels and phytoplankton. University of the Highlands and Islands. 2011-2015.

Silje-Kristin Jenssen (PhD): Is biotoxin exposure from harmful algae the reason for the decline in harbour seal populations in Scotland? A view through a food chain study. MASTS prize studentship. University of St Andrews. 2011-2015.

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DR PAUL TETT

State space: A new framework for understanding marine ecosystem health

As of November 2012 my job title is Reader in Coastal Systems, which refers to the approach, based on General Systems Theory, that I am aiming to bring to coastal zone social-ecological systems.

During the reporting period the highlight has been the finalizing of a long, multi-authored paper that provides a framework for understanding marine ecosystem health. This paper is the outcome of a long term collaboration with the Centre for Environment, Fisheries and Aquaculture Science (Cefas) in Lowestoft, and the Agri-Food and Biosciences Institute (AFBI) in Belfast, that initially concerned phytoplankton and the 'undesirable disturbance of the balance of organisms' associated with eutrophication, but which came to recognize the need to view ecosystems holistically.

Hitherto, institutions concerned with the protection of the sea have tended to focus on parts of ecosystems: regulating fishing to ensure maximum sustainable yield, reducing anthropogenic loads of nitrogen and phosphorus to prevent eutrophication, conserving sea-birds or special habitats, and so on.

However, there is increasing concern, recognized in the 'Ecosystem Approach' proposed at the Earth Summit in Rio de Janeiro in 1992 that this is not enough: that ecosystem components interact. In some cases these interactions help preserve ecosystem integrity in the face of pressures such as climate change or overfishing. In other cases, disturbances multiply, leading to major changes - called regime shifts - in food webs, with consequences for marine ecosystem services and their uses by humans.

The paper, now in press in *Marine Ecology Progress Series*, includes a proposal to monitor changes in the state of marine ecosystems using the 'state space' approach illustrated on the left. In this diagram, changes in the pelagic ecosystem of the north-western North Sea are tracked in a 3-dimensional space in which the axes are the breeding success of kittiwakes, the abundance of copepods of the genus *Calanus*, and primary production estimated by a simulation model. Taken together, these three measures give a picture of the overall state of the ecosystem, which has clearly changed substantially since the start of the time-series in 1958.

Research into this approach continues, with the aim of identifying parts of this state space that correspond to good ecosystem health, and to what the Marine Strategy Framework Directive calls 'Good Environmental Status'. The former is defined by the MEPS paper as the condition of a system that is self-maintaining, vigorous, resilient to externally imposed pressures, and able to sustain services to humans. The latter is defined by the Directive as the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable. The big questions, of course, concerns resilience (resistance to change) and sustainable use.

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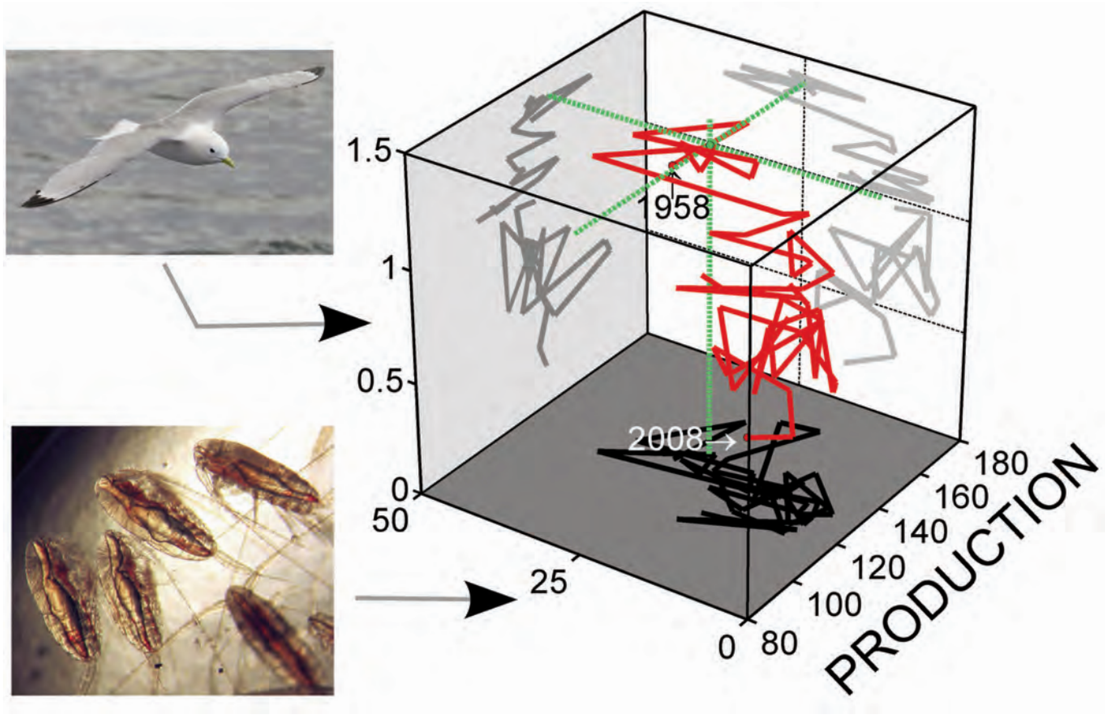


FIGURE: Changes in the Northern North Sea, 1958 - 2008, plotted in a state space defined by the breeding success of kittiwakes (photograph: R. Gowen), abundance of copepods *Calanus spp.* (photograph: D. Pond), and simulated annual primary production

MICROBIAL

PHOTO: RRS *James Clark Ross* in Isfjorden, Svalbard. Photograph: Laila Sadler

The effects of ocean acidification on Arctic Ocean biology

The global ocean currently absorbs approximately half of the CO_2 produced by burning fossil fuel. When CO_2 dissolves in seawater it forms carbonic acid so the oceans are becoming more acidic as human activities release more CO_2 from fossil fuels. This process is known as ocean acidification and can have potentially damaging impacts on marine organisms and ecosystems.

Polar seas, such as the Arctic Ocean, are expected to be especially sensitive to the effects of ocean acidification, since more CO_2 dissolves in cold water, making Arctic waters a valuable natural example of how the marine environment will respond to a high CO_2 world. Also, the sensitivity of surface seawater in the Arctic will mean that they become corrosive to calcium carbonate before anywhere else in the world, which could pose a problem for marine plankton and other organisms that use calcium carbonate for their shells or skeletons.

To determine the impact of ocean acidification on the biology of the Arctic Ocean, scientists at SAMS are currently undertaking research as part of the Sea Surface Research Consortium of the UK Ocean Acidification Research Programme. The overall aim of the consortium research is to obtain a quantitative understanding of how changes in the carbonate chemistry of the Arctic Ocean may impact on bacteria, phytoplankton and zooplankton species that together form the lower levels of the marine food web.

Specific objectives are to:

1. Ascertain the impact of ocean acidification on planktonic organisms (in terms of physiological impacts, morphology, population abundances and community composition).

2.Quantify the impacts of ocean acidification on biogeochemical processes affecting the ocean carbon cycle (both directly and indirectly, such as via availability of biolimiting nutrients).

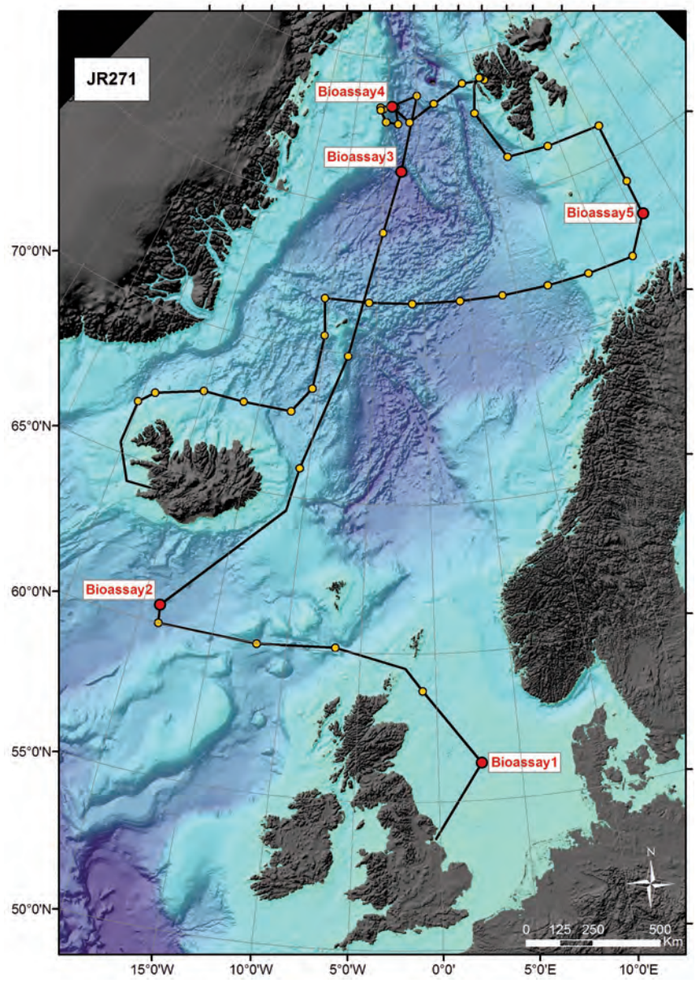
3. Quantify the impacts of ocean acidification on the air-sea flux of climate active gases (DMS and N_2O in particular).

These objectives were addressed by the research consortium during an expedition, led by SAMS, to the Atlantic sector of Arctic during June 2012 on the RRS *James Clark Ross*.

During the expedition *in situ* observations were made across natural carbonate chemistry gradients and five on-deck CO_2 perturbation incubations ("bioassays") were undertaken in contrasting surface-water environments. Data from these observations and experiments will be analysed in 2013.

To our knowledge the cruise was the first attempt to link Arctic pelagic ocean carbonate system variations with sea-surface biology, biogeochemical rates and climate processes in such a comprehensive manner.

The project is funded by the Natural Environment Research Council, the Department of Environment, Food and Rural Affairs (Defra) and the Department of Energy and Climate Change (DECC).



MAP: Cruise track of the RRS *James Clark Ross*, showing in location of *in situ* observations and bioassay experiments undertaken during the SAMS-led UK Ocean Acidification Research Programme expedition to the Arctic in June 2012. (Map by Estelle Dumont)

DR STEPHEN SLOCOMBE

Maximising the productivity of microalgae

Cultivation of micro-algae is a rapidly developing area that could play an important role in next-generation biofuels production, fish-farming, animal feeds, synthesis of nutraceuticals and other value-products of commercial interest. Micro-algae are already being cultivated at large-scale for producing useful compounds; for instance the bulk of the world's supply of beta-carotene is produced in this way at Hutt lagoon in South-west Australia.

Micro-algae are a highly diverse group comprising at least 30,000 species globally. Many are held in collections, of which the CCAP collection at SAMS is one of the largest.

Productivities can vary a great deal within strains of the same species. It is therefore worth screening all the algae in these collections for biotechnological potential. Screening of the micro-algal culture collection at SAMS has identified a selection of top marine micro-algal strains that show high biomass productivities and/or are able to produce high levels of oil for biofuels. Specific strains were also found that produced high levels of omega-3 fatty acids of dietary value such as EPA and DHA.

In an MSc project, one strain was identified that produced high levels of alkenones that have potential for biofuel. These molecules can be readily 'cracked' to the correct size to mimic petrochemicals. Currently some of these strains are undergoing next-generation sequencing to decipher their DNA in order to carry out further research. The aim of this work is to identify which genes are responsible for high productivities and also for synthesizing biofuels.

The strains are also undergoing genetic-engineering to develop higher quality biofuels and to understand better the function of genes. These approaches involve either knocking out the gene or increasing its activity to reveal gene function. Methods have been developed to transform these strains and I have been collaborating with a biotech company that will be developing a kit for genetic transformation of algae. The initial work was carried out as part of an Erasmus student project where *Nannochloropsis oculata* was first transformed here at SAMS.

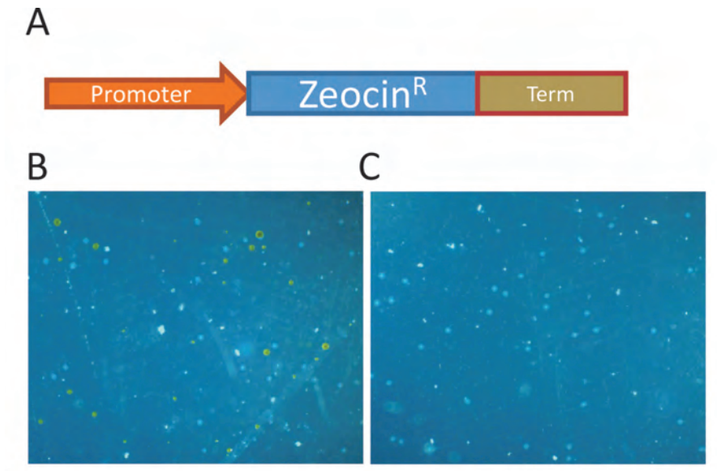


FIGURE: Transformation of *Nannochloropsis* with DNA construct (A) showing growth on Zeocin (5 mg/L) plates (B) compare with minus DNA control (C). The presence of green colonies was indicative of Zeocin resistance conferred by genetic transformation. The DNA construct (A) consisted of a Promoter obtained by PCR from the *Nannochloropsis* genome joined to a Zeocin resistance gene and a transcriptional terminator from *Phaeodactylum tricornutum*.

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*Joint first authorship.

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DR JOHN HOWE

The INIS Hydro project: submarine mapping of the Firth of Lorn

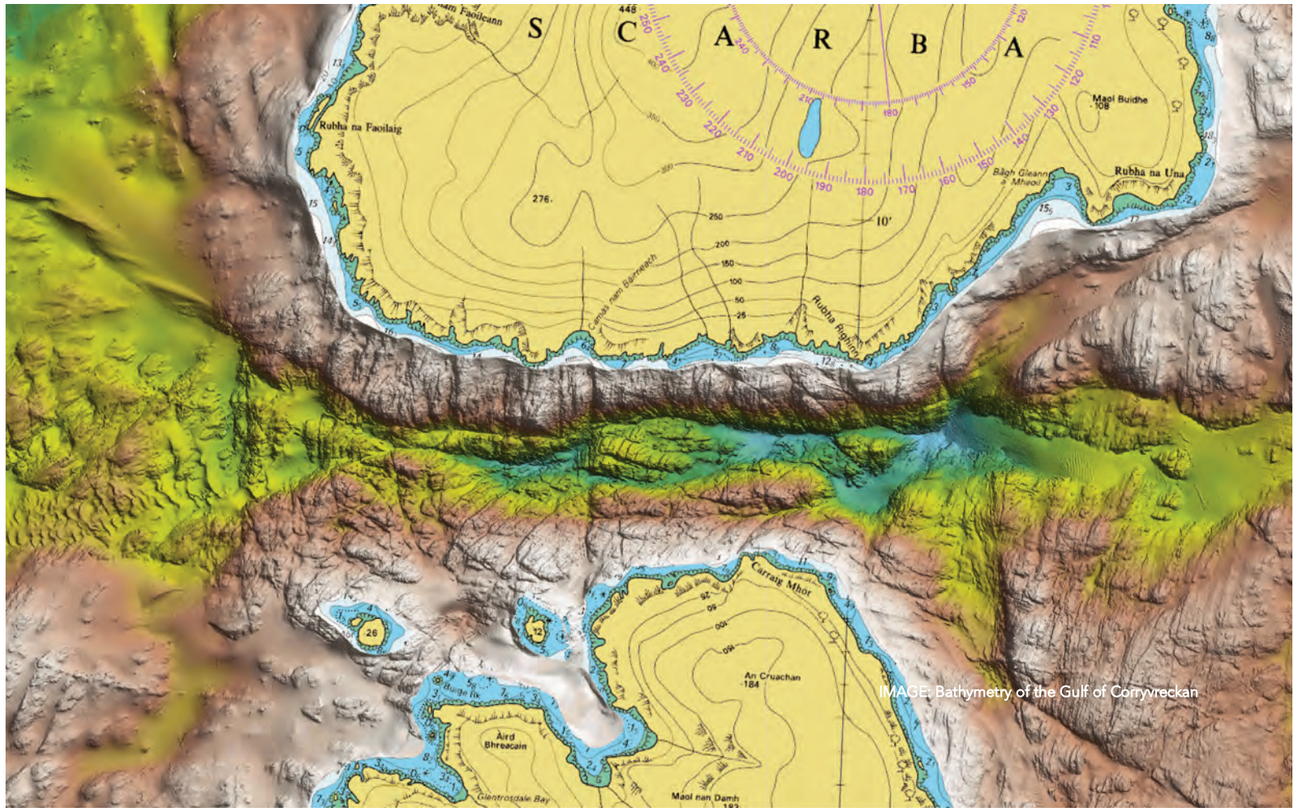

IMAGE: Bathymetry of the Gulf of Corryvreckan

During 2012-2013 the INIS Hydro project (Ireland, Northern Ireland and Scotland Hydrographic Survey) mapped 553km^2 of sea floor from Oban to the Isle of Jura using a multibeam sonar onboard SAMS vessel R.V. *Calanus* and with additional shallow water surveys conducted from the British Geological Survey vessel, R.V. *White Ribbon*. The inshore waters covered by this survey represent a priority area for the renewables industry, for shipping, tourism and encompass a number of Special Areas of Conservation (SAC) especially for rocky reef habitats. Surprisingly, given this interest, this project is the first comprehensive bathymetric survey in the area.

This region of near shore continental shelf is revealed as predominantly bedrock-dominated seabed, characterised by a series of narrow, strongly fault-controlled troughs, part of the Great Glen Fault Zone complex. The region includes the Corryvreckan Whirlpool (see picture) and Great Race tidal flows beneath which occur active sand waves and submarine dunes. Evidence for past glaciation is widespread and well preserved in the Firth of Lorn with preserved moraines and overdeepened basins common across the area. Initial geomorphological mapping shows that our understanding of the configuration and style of deglaciation in these sectors of the former British-Irish Ice Sheet can be greatly improved by the collection of these new high-resolution bathymetric datasets.

ACKNOWLEDGEMENTS

The INIS Hydro survey is part-financed by the European Union's INTERREG Iva Cross-border programme managed by the Special EU Projects body. The authors would like to thank project partners the Maritime and Coastguard Agency, the Geological Survey of Ireland, the Marine Institute, Galway, the Northern Lighthouse Board and the UK Hydrographic Office. Reson Offshore Ltd and the British Geological Survey are thanked for technical support.

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PROFESSOR RONNIE GLUD

First study of the biogeochemistry of the Mariana Trench

My research focus on understanding how oceanic cycling of nitrogen and carbon interrelate with climatic changes. The work spans from investigating microbial processing in sea ice to degradation and deposition of organic material in the deep sea.

To perform measurements at relevant scales and in challenging environments considerable effort is put into the development and optimisation of sophisticated instrumentation. This includes developing different electrochemical and optical sensors and the use of autonomous vehicles for exploring different parts of the ocean.

The Challenger Deep expedition

The research highlight of the past year was the investigation of The Challenger Deep in the Mariana Trench which at 11,000m depth represents the deepest site on Earth. The extent by which organic material that reaches the seabed is either degraded or buried in the sediment record is the most important process for regulating the availability of oxygen and carbon dioxide in the oceans and the atmosphere. The microbial degradation efficiency of organic material in the seabed ultimately determines the conditions for live on planet Earth through geological time scales.

We wanted to explore if anything was going on at the most extreme and remote place on Earth, and if so how efficiently organic material was being degraded and by which process and organisms.

Autonomous instrumentation was sent to the bottom of the trench. Measurements taken directly on the seabed documented an intensified microbial activity at these extreme conditions. The activity was fueled by elevated deposition of materia. The trench sediments hosted much greater densities of bacteria than we found in the sediments of the surrounding 6,000 m deep abyssal plains.

Trenches thus act as traps for sedimenting organic material. They also host bacterial communities that degrade such material very efficiently at the low temperatures and extreme hydrostatic pressures of these depths.

PHOTO: The autonomous lander returning to the ship after a dive to the bottom of the Mariana Trench at almost 11,000m depth to investigate its microbial activity.

We are currently characterising the microbial communities of the Challenger Deep using modern molecular techniques. Upcoming expeditions will compare the bacterial activities and characterise the microbial communities of other trenches around the globe, trenches that are underlying water columns of very different productivity and thereby sedimentation regimes.

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Gavin Turner (PhD): Benthic carbon turnover as assessed from the aquatic Eddy Correlation approach. Funded by NERC. University of the Highlands and Islands. 2010-2013.

Dorthe Soegaard (PhD): Sea-ice biogeochemisty and microbiology. University of Southern Denmark. 2010-2013.

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Zeljko Jovanovic (PhD): Small-scale spatial and temporal oxygen variability in coastal marine sediments. University of Southern Denmark. 2010-2013.

Adam J Kessler (PhD): Nitrogen cycling in permeable sandy sediments. Monarch University. 2011-2014.

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DR HENRIK STAHL

Quantifying & monitoring potential ecosystem impacts of Geological Carbon Storage

Carbon Capture and Storage (CCS) is seen as a possible mitigation strategy for combating climate change and involves capturing CO_2 from anthropogenic point sources (*e.g.* coal or oil fired power plants) and pumping it down into depleted oil reservoirs or saline aquifers deep below the seabed. Although the CCS technology and suitable storage sites (mainly in North Sea) are available already, little is known about the potential impacts of a potential CO_2 leak from CCS on marine ecosystems.

The QICS project

With that in mind, SAMS last year hosted a large scale controlled sub-seabed CO_2 release experiment as part of the UK based QICS project (Quantifying and monitoring potential ecosystem Impacts of geological Carbon Storage), which is a NERC/DECC funded consortium project with 13 UK partners and four Japanese collaborative institutes.

The primary aim of QICS is to develop knowledge of use to government, industry, regulators, environmental guardians and the public, on methodologies of detecting and quantifying a leak of CO_2 from a sub-seabed Carbon Capture and Storage reservoir and an understanding of any potential environmental consequences of such a leak.

Whilst QICS is multidisciplinary, using a range of modelling and synthesis techniques, at its heart lays a novel controlled experimental release of CO_2 into marine sediments (figure 1), simulating a leak from a CCS reservoir. This experiment was conducted in northern Ardmucknish Bay close to SAMS. A bore-hole was drilled thorough the bedrock (using directional drilling) from Tralee Beach into the sediment, ~350m off-shore, at 12m below the seabed. Gas was injected into the seabed from an on-shore CO_2 gas release facility, through a stainless steel pipeline (inserted through the bore hole) with a 5m long gas diffusor at the end.

The CO_2 was released into the sediments over 37days, incrementally increasing from 20kg CO_2 d^{-1} to 220kg CO_2 d^{-1}, followed by a 90 day recovery period.

During this period, a total of 4.2 tonnes of

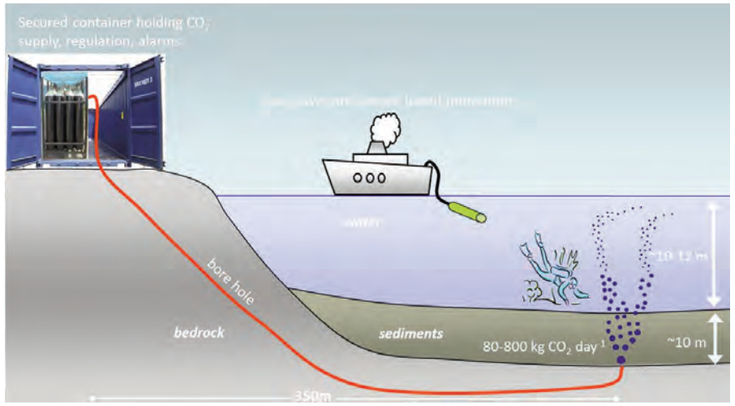

FIGURE 1: Conceptual design of the QICS *in situ* controlled CO_2 release experiment.

CO_2 was injected into the sediments at the site and extensive diver- and ship-based surveys (figure 2) where carried out along a 450m long transect, from the release site to a control site.

A whole host of state-of-the-art technologies were deployed during the experiment, including Autonomous Underwater Vehicles, online pCO_2 and pH sensors, passive acoustic techniques for monitoring bubble flow *etc* (figure 3).

Although the QICS project will run until 2014, the experiment has already delivered several fundamentally new insights: that the majority of CO_2 stays within the sediments (on the timescale investigated here) and that only a relatively small percentage (<10%) escapes in the form of gas bubbles into the overlying water; that physical flow routes in through the overburden are complex and that sediments seem to have a buffering capacity on the released CO_2.

Biological impacts are detectable but seem limited in both time and space and recovery (biologically as well as biogeochemically) was rapid for the relatively small CO_2 dosage used (Stahl, 2012; Blackford *et al* in prep).

FIGURE 2: Diver sampling the seabed for CO_2 at the release site in Ardmucknish Bay.

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Ashleigh Currie (PhD): Quantifying the impacts of ocean acidification on benthic biogeochemistry: Effects on total carbon and nitrogen turnover rates in marine sediments. University of the Highlands and Islands. 2011-current.

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FIGURE 3: Sensor monitoring CO_2 concentrations in the bottom water at the release site.

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DR NATALIE HICKS

EARTH SCIENCE

Environmental change: ocean acidification & rising temperatures

For the past two years, SAMS scientists have engaged within a network of UK scientists brought together under the UK Ocean Acidification Research Programme (UKOA) in an integrated multidisciplinary approach to tackle the issue of Ocean Acidification - the other CO_2 problem.

It is generally accepted that climate change from carbon emissions is known to increase global temperatures, but the corresponding effect of elevated carbon on the oceans is less widely known.

About a third of the atmospheric CO_2 is absorbed by the oceans and this directly affects the seawater chemistry, making the oceans less alkaline and more acidic. In the last 200 years, global ocean pH has decline by 0.1 (from ~8.2 to ~ 8.1), which means a 30% increase in acidity. Current predictions suggest this could fall by an additional 0.4 by 2100 – a 150% increase in acidity. This is the lowest ocean pH level recorded in the last 25 years.

Marine ecosystems are struggling to deal with such rapid changes in the environment, and the predominant effects of this ocean acidification appear to be negative. In more acidic waters organisms that build shells or exoskeletons such as plankton, mussels, crabs, lobsters and corals struggle to obtain the calcium carbonate ions that are the essential building blocks for hard structures. The increasing acidity reduces the availability of these building blocks and in extreme cases shells can become thinner and dissolve.

The oceans are not only important as a food source or recreational environment, they also contribute a significant proportion of global nutrient recycling. Much of this occurs in the marine sediments, both sandy and muddy habitats, and coastal sediments are particularly important in oxygen production due to the high productivity of these systems. Coastal sediments, such as estuaries, mudflats and shallow lochs, contain many single celled algae (figure 1) that actively photosynthesise, soaking up CO_2 and light and producing oxygen.

Very little OA research has been carried out to determine the effects of elevated CO_2 and temperature on nutrient and oxygen dynamics within these sediments.

Together with Dr Henrik Stahl I have spent the last two years running a series of experiments to fill this critical gap in knowledge.

A new facility to investigate benthic acidification and warming

To achieve this, a custom built facility of six recirculating seawater tanks with manipulated CO_2 and temperature were filled with sandy and muddy sediments to allow precise monitoring of oxygen dynamics, primary production, nutrient (ammonia, nitrate) flux and bacterial activity.

Initial results suggest that whilst ocean acidification is likely to have a small negative effect, elevated temperature has a much stronger negative effect on all processes. However, when CO_2 and temperature were both elevated in the same tanks, the strong effect of temperature was less noticeable.

This suggests that whilst some changes in these processes are likely to take place under inevitable future environmental conditions, the effects may not be as negative as initially feared.

Experimental research like this is vital for bridging the knowledge gaps in how our oceans are likely to respond to human-driven environmental changes in the future. For now, SAMS scientists continue to work on understanding the complex dynamics of coastal systems under such scenarios, and this will contribute to UK and international research efforts on fully comprehending the ability of the oceans to adapt to small and large scale environmental changes.

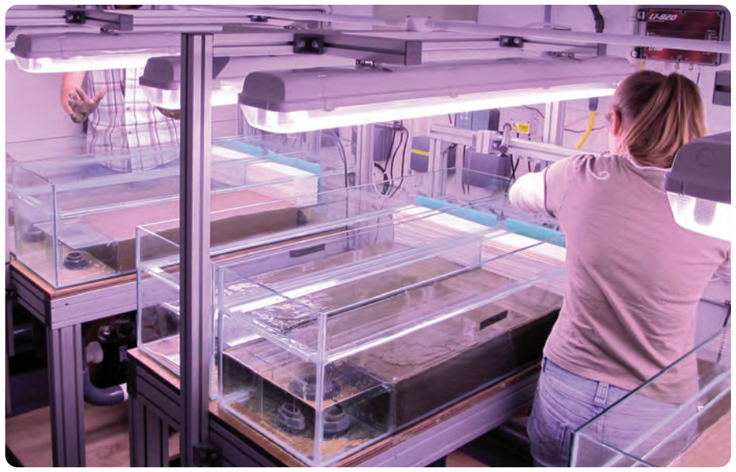

FIGURE 2: Custom built facility with recirculating seawater tanks containing sediments.

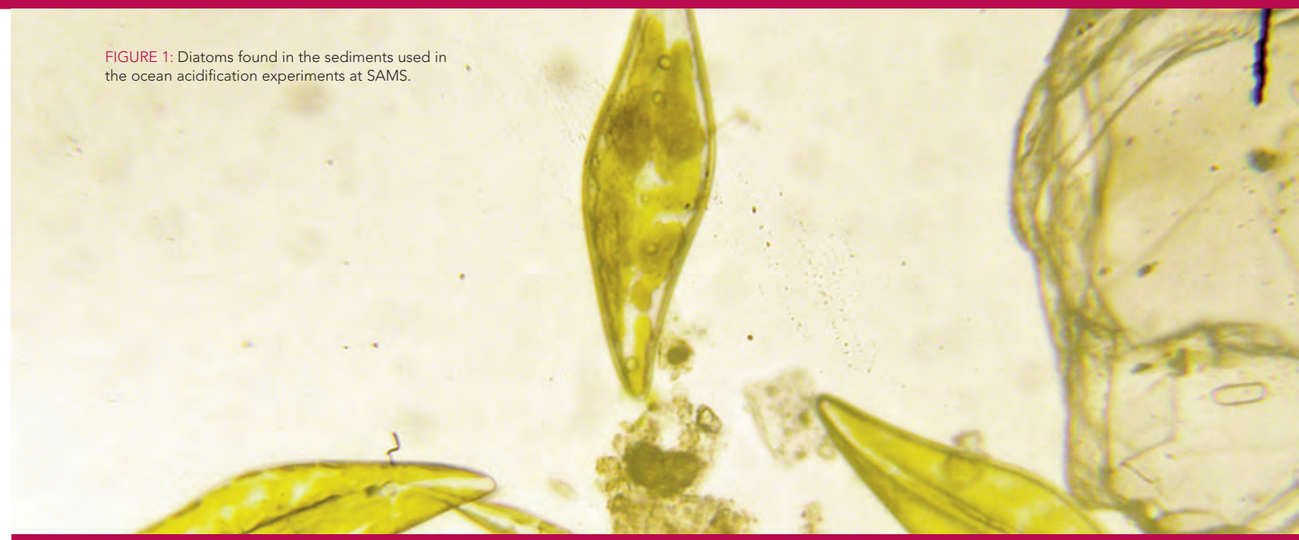

FIGURE 1: Diatoms found in the sediments used in the ocean acidification experiments at SAMS.

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Hicks, N., Bulling, M.T., Solan, M., Raffaelli, D.G., White, P.C.L. and Paterson, D.M. Submitted. Interactive effects of multiple stressors and temporal variability on benthic ecosystem function in a model system. *Proceedings of the Royal Society: B*

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Middelburg, J.J., Paterson, D.M., Mayor, D. J., Blackford, J., Bothwell, J., Defew, E.C., **Hicks, N.**, Hubas, C., Stephens, N., Polimene, L., Kitidis, V. and Tait, K. (in prep) Towards an improved representation of benthic microbial processes in Shelf Seas

FIGURE 3: Collecting sediment at the study site of the Eden Estuary, St Andrews.

DR ROBERT TURNEWITSCH

Deep-sea landscapes and sediments: from seamounts to hadal trenches

Deep-sea sediments play a central role in a wide range of subject areas such as global biogeochemistry, biodiversity, and reconstructions of past environmental changes in Earth's history. A number of important controls on the formation of sedimentary deposits in the deep sea have been studied.

However, to date, the impact of submarine landscape geometry as a possible control has received little attention. This seems to be particularly true for 'intermediate-scale' topographic features such as abyssal hills, seamounts and different types of valleys (canyons, fracture zones, hadal trenches) and is despite estimates suggesting that in the deep open oceans, away from continental margins, there could be as many as ~25 million abyssal hills, knolls and seamounts. Several initiatives are pursued to fill this knowledge gap in our understanding of how deep-sea landscapes control the formation of sedimentary deposits and the wider implications.

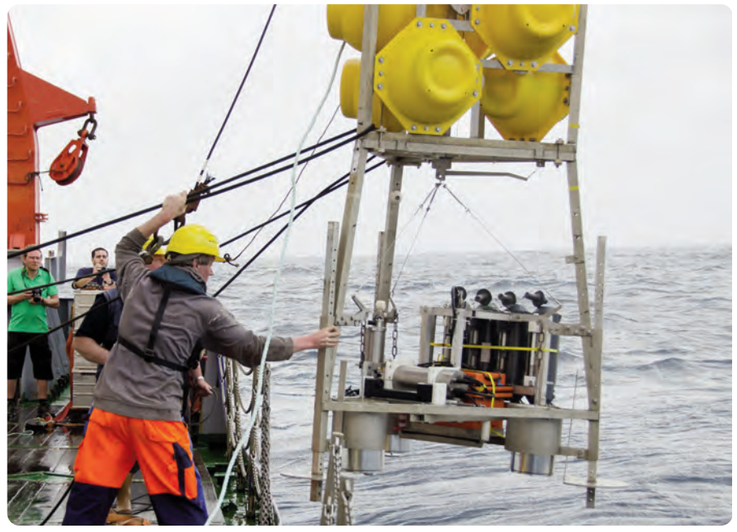

FIGURE 1: Deployment of a SAMS benthic-lander system from RV Poseidon north of Senghor Seamount, February 2013. The lander is equipped with a transmissometer, acoustic current meters and bottles to collect water samples near the seafloor.

Photo copyright: Benjamin Stefanowitsch.

Investigating Senghor Seamount

In February 2013 one of SAMS' benthic lander systems (figure 1) and a megacorer were deployed from RV *Poseidon* to investigate the far-field influence on sediments of a tall seamount within an important part of the physical-oceanographic parameter space that governs the interactions of ocean flow with hill- and seamount-type seafloor elevations. The seamount is named Senghor Seamount, located near the Cape Verde archipelago and an important fishing ground.

The results from this cruise are currently interpreted within the context of information on the near-field of the seamount that was obtained during two previous cruises on RV *Meteor* and RV *Poseidon*.

Pelagic sedimentation in trenches

Another line of work looks into the dynamics of pelagic sedimentation in the deepest places of the Earth's oceans, the hadal trenches.

This year saw the publication of the first direct information on microbial activity in the surface sediments of the deepest location of the Earth's oceans in the Challenger Deep of the Mariana Trench. It was shown that this deep-sea trench acts as a microbial 'hot spot' with surprisingly high rates of microbial activity (see Ronnie Glud's report).

It is unclear how food of sufficient quality and quantity is transported to these great depths to sustain this microbial community and its high activity. We currently strive to better understand the mechanisms behind the food supply to these extreme environments.

In this context sediment transport is traced by a naturally occurring substance called lead-210: measurements of lead-210 help determine how much sediment is transported down the trench slopes in addition to the material that settles straight from the overlying waters (figure 2).

These data in combination with information from numerical modelling of fluid dynamics provide preliminary evidence suggesting that not only surface ocean productivity but also regional internal-tide dynamics play a crucial role. This would lead to a step change in our mechanistic understanding of the relative importance of different factors controlling food supply to the deep sea.

This work has been partly funded through the NERC project 'Impact of the Geometry of Submarine Landscapes on Deep-Sea Biogeochemistry' and is the result of collaboration with colleagues from the University of Southern Denmark, JAMSTEC, University of Rostock, University of Hamburg and Princeton University.

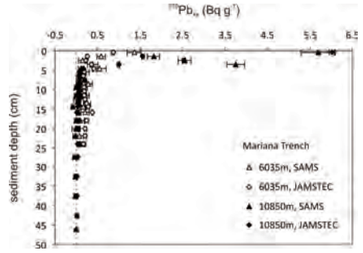

FIGURE 2: Vertical profiles of the sediment-particle tracer lead 210 (^{210}Pb) in surface sediments from the axis (water depth at seafloor: 10850m) and southern rim (water depth at seafloor: 6035m) of the Challenger Deep in the Mariana Trench.

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RESEARCH STUDENTS

Jirina Stehlikova (PhD): Sediment deposition in the deep sea - from seamounts to the hadal trenches. Funded by NERC. University of the Highlands and Islands. 2012-2016

I am also co-supervising:

Adam Chivers (PhD): The biodiversity and ecology of seamounts in the NE Atlantic. Funded by NERC. University of the Highlands and Islands. 2010-2014

PROFESSOR MARK INALL

Fluxes Across Sloping Topography of the North East Atlantic (FASTNEt) and declining nutrient concentrations in the NE Atlantic

FASTNEt is a NERC funded consortium led by Professor Mark Inall at SAMS in collaboration with physical oceanographers from across the UK and the US (NOC, U. Bangor, U. Liverpool, U. Plymouth and PML, UKMO, Marine Scotland Science, AFBI, Marine Institute Ireland and Scripps Institution of Oceanography).

The FASTNEt consortium is a four year physical ocean shelf edge exchange research programme running until October 2015. FASTNEt's main aim is:

"to construct a new paradigm of Ocean/Shelf exchange using novel observations and model techniques to resolve the key seasonal, interannual and regional variation absent from existing knowledge."

FASTNEt recognises that shelf seas are a critical interface, linking the terrestrial, atmospheric and oceanic carbon pools and acting as a physical gateway to key biogeochemical fluxes. As a predominantly physical oceanography project FASTNEt works closely with new and existing biogeochemical projects and modelling programmes to combine our physical science advances with linked advances in biogeochemical processes and exchanges in shelf seas and at ocean margins.

Four objectives underpin our aim of constructing a new paradigm of Ocean/Shelf exchange:

1. To determine the seasonality of physical gradients and exchange across the shelf edge by deploying new observational technologies (Gliders, Autosub Long Range) and established techniques (long term moorings, drifters).

2. To quantify key exchange mechanisms and to collect new data targeted at testing and improving high resolution models of the shelf edge, by carrying out detailed process studies in contrasting regions of the shelf edge of the NE Atlantic margin

3. To develop a new parameterisation of shelf edge exchange processes suitable for regional-scale models, using improved resolution numerical, and new empirical models constrained by the observations.

4. To test the new parameterisations in a regional model in the context of making an assessment of inter-annual variability of ocean-shelf exchange.

Science highlights 2013

In July 2013 on the second FASTNEt research cruise we took the RSS *James Cook* on a 24-day science mission to the Malin Shelf. Deploying five autonomous ocean Gliders, thirty two satellite tracked drifters and 5km long streak of fluorescent dye, we successfully tracked the incursion of Atlantic waters onto the UK continental shelf over a sub-marine canyon feature in the shelf break west of Ireland. This unique data set unambiguously demonstrates the effect of changes in shelf edge topography on the exchange of waters between ocean and shelf. The drifter programme, led by Dr Marie Porter, gives the most visual and dynamic view of oceanic waters flowing onto the shelf (figure 2).

In a related piece of ground breaking research Dr Clare Johnson and co-workers at SAMS and in the US have demonstrated definitively that, between 1996 and the mid-2000s, the upper waters (200-700 m) of the North East Atlantic became warmer (+0.72 °C), saltier (+0.088) and reduced in nitrate and phosphate (-2.00 M and -0.14 M respectively) (Johnson *et al*, 2013, Deep Sea Research in press). These changes, out-with calculated errors, can be explained by the varying influence of southern versus subpolar water masses in the basin as the Subpolar Gyre weakened and contracted. Since the early-2000s the Subpolar Gyre has been weaker than observed since 1992, or modelled since 1960-1970. Hence upper waters within the Rockall Trough may be warmer, saltier and more depleted in nitrate and phosphate than at any time in the last half century. How this significant depletion in oceanic nutrients affects the shelf and coastal waters, which rely on the ocean for the greatest proportion of their nutrients, is a subject of great importance to the changing biochemistry of our shelf seas.

FIGURE 1: Regional map showing shelf sectors and intensive study regions.

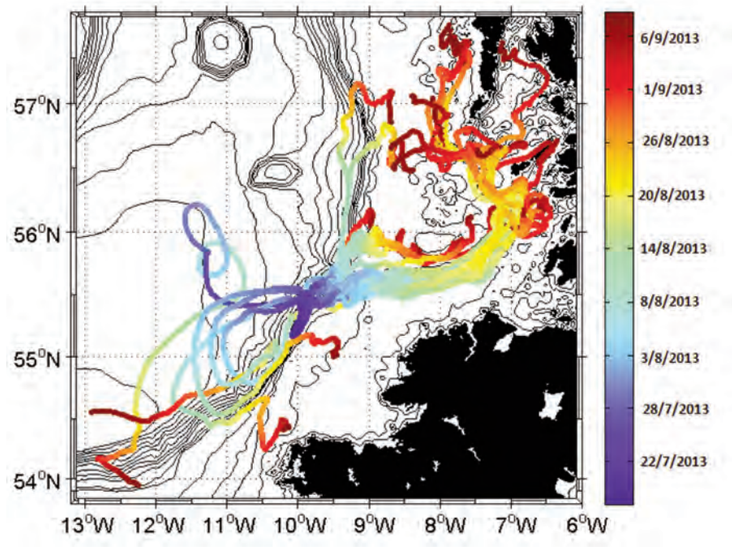


FIGURE 2: The paths of 30 drifters released at 10.25°W, 55.5°N. These drifters have clearly tracked water that has crossed on to the shelf, showing flow through the Tiree Passage, the Sea of the Hebrides and around the Outer Hebrides.

PROFESSOR TOBY SHERWIN

This has been a year of consolidation as I move into retirement with a handing over of responsibilities to younger colleagues and completion of the writing of outstanding papers and with keeping involved with FASTNEt.

In [Berx *et al.*, 2013] we show that altimeter observations of the NE transport of warm water through the Faroe-Shetland Channel can be used to supplement the existing array of moored current meters. The evaluation is not yet finalised but the work shows potential for enabling a more economical monitoring an important ocean current.

In addition I have seen to a successful conclusion the PhD studies of Clare Johnson and Marie Porter, both of whom performed extremely well in their vivas and are now employed by SAMS.

I also attended an EU glider workshop where I gave a talk on SAMS glider activities through the North Atlantic Glider Base.

RESEARCH STUDENTS

Clare Johnson (PhD): Tracing Wyville Thomson Ridge Overflow Water in the Rockall Trough. University of the Highlands and Islands. Completed.

Marie Porter (PhD): Linking of the Surface North Atlantic Ocean to adjacent terrestrial ice masses. University of the Highlands and Islands. Completed.

PUBLICATIONS 2012-13

Berx, B., B. Hansen, S. Østerhus, K. Larsen, **T. Sherwin,** and K. Jochumsen. 2013. Combining *in-situ* measurements and altimetry to estimate volume, heat and salt transport variability through the Faroe Shetland Channel. *Ocean Science Discussions*, **10**: 153-195.

SHANE RODWELL

NEW at SAMS: Remotely piloted aircraft

Shane Rodwell with one of the SAMS RPA at Oban Airport.

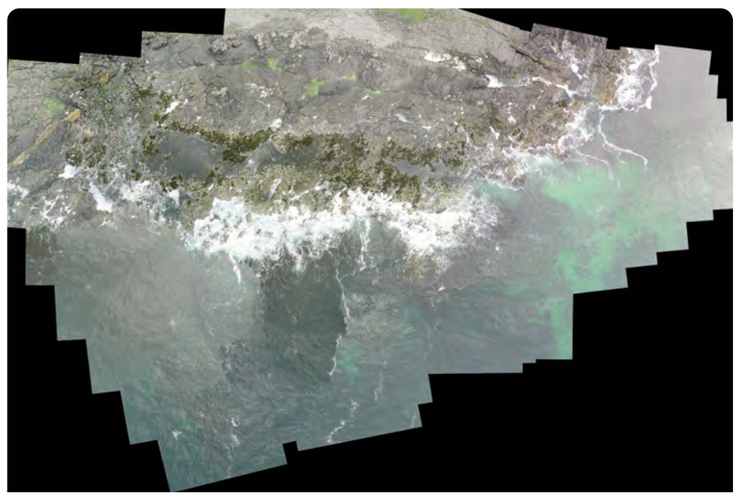
The oceans remain grossly under-sampled in space and time. There is a drive for routine, systematic observing programmes to be delivered wherever possible by autonomous platforms. One of the main functions of the Marine Technology group is to identify, develop and adapt new technologies for collecting environmental data.

Remotely piloted aircraft (RPA) are an emerging technology and the Marine Technology group at SAMS are committed to providing the capability to operate RPA in the coastal regions of Scotland. These mobile platforms can make measurements in locations that are otherwise inaccessible, and at a resolution and coverage that is impossible to achieve by alternative means.

At SAMS we have been working on researching and developing available RPA technologies to produce a suitable platform for marine scientific observation, whilst also looking at the development and integration of particular sensors. A unique marine-capable aircraft has been developed and tested, allowing operations from the water. We have trialled and formalised our operating procedures, to meet the challenges of the local environment whilst also adhering to the legal framework set out by the Civil Aviation Authority.

Current applications have included high-resolution shoreline photogrammetry for renewable energy environmental impact assessment. The development of our marine aircraft operation will enable RPA-based multi-spectral imagery for assessing and monitoring harmful algal blooms.

Setting up RPA command station on Eilean Mor location.



High resolution imaging of ~10 ha site on Isle of Lewis.

DR FINLO COTTIER

Arctic time series

The SAMS time series of hydrographic and biological data from the archipelago of Svalbard has been in operation for a decade.

Originally data was acquired from only Kongsfjorden (influenced by Atlantic Waters) in the NW of Spitsbergen and that is now supplemented by similar data series from Rijpfjorden (influenced by Arctic Waters) in the far north east and in Billefjorden (seasonally ice covered).

These three observatories are now integral to two Norwegian funded research projects: "Circadian rhythms of Arctic zooplankton from polar twilight to polar night - patterns, processes, and ecosystem implications (CircA)" and "Marine Night".

Both of these projects are directed at unravelling the previously unknown details of ecosystem function in the Arctic during the polar night. Despite the fact that there is apparent continuous darkness, there is still considerable activity in the pelagic zone in mid-winter.

Field data is incredibly difficult to acquire during the polar winter and the University of Tromsø has teamed up with SAMS to access the mooring expertise of the Physics and Technology Department. We are using acoustics to track the vertical position of zooplankton as the light transitions from 24 hours daylight, to 24 hours darkness and back again. We then try and relate the patterns in zooplankton migration to the light, ice and hydrographic conditions. The three contrasting sites give us analogues for ice-covered and ice-free arctic conditions.

Ultimately the project aims to understand the impact of reduced ice cover on the efficiency by which zooplankton contribute to the carbon cycle.

PUBLICATIONS 2012-13

Wallace M, **Cottier F**, Brierley A, Tarling G. 2013. Modelling the influence of copepod behaviour on fecal pellet export at high latitudes. *Polar Biology*, **36**: 579–592.

Kwasniewski S, Walkusz W, **Cottier F**, Leu E. 2012. Mesozooplankton dynamics in relation to food availability during spring and early summer in a high latitude glaciated fjord (Kongsfjorden), with focus on *Calanus*. *Journal of Marine Systems*.

Ambrose WG, Renaud PE, Locke W, **Cottier FR**, Berge J, Carroll ML, Levin B, Ryan S. 2012. Growth line deposition and variability in growth of two circumpolar bivalves (*Serripes groenlandicus* and *Clinocardium ciliatum*). *Polar Biology*, **35**: 345-354.

RESEARCH STUDENTS

Laura Hobbs (PhD) Pan Arctic Diel Vertical Migration. Funded by the Norwegian Research Council. University of the Highlands and Islands. 2012-2015.

Sam Jones (PhD): Shelf edge exchange and the influence on coastal oceanography. Funded by NERC. University of the Highlands and Islands. 2012-2015.

J Grenvald (PhD): Diel vertical migration of marine zooplankton in the polar night: who, how and why? Funded by Norwegian Research Council. University of Tromsø. 2012-2015.

A Goldsack (PhD): Oceanographic variability around South East Greenland. Swansea University. 2011-

DR STUART CUNNINGHAM

Atlantic Circulation and Climate

The Atlantic - because of its extensive, high-latitude deep-water basins of the Labrador and Nordic Seas - plays a special role in Earth's climate that is not equalled by either the Pacific or Indian Oceans. In the Labrador and Nordic Seas warmer surface waters are drawn north all the way from the South Atlantic to the North Atlantic high latitudes: there it cools and sinks to depths between 1 and 5 km down. The warm waters flowing north and the deep cold waters flowing south are called the Atlantic meridional overturning circulation and lead to a northward transport of heat in the Atlantic ($1.3x10^{15}$ watts). This heat is transferred from the ocean to the atmosphere and gives us our mild UK and western European climate, that is some 5-10°C warmer than other countries at similar latitudes (*e.g.* Siberia). The absence of high latitude seas in the Pacific and Indian Oceans means they do not transport energy as effectively as the Atlantic.

The late Dave Ellett in 1993 memorably described the Atlantic overturning circulation as a *fan assisted storage heater for European climate*. Over the past decades we have gained a deep appreciation of its role in climate and a growing apprehension of how the overturning will change when forced by global warming. Climate models suggest that global warming will slow down the overturning circulation and alter the ocean's role in climate. This concern is driving new, sustained and world-leading observation programmes to monitor the health of the Atlantic overturning.

Figure 1 is a schematic of the RAPID-Watch/MOCHA purposefully designed monitoring array in the subtropical North Atlantic and Figure 2 is an eight year long timeseries of transports measured by the array. Notable is the 30% decline in overturning beginning in 2009 (McCarthy *et al*. 2012. Geophys Res Lett doi:10.1029/2012GL052933.) shown by the red line in Figure 2.

In a recently submitted paper (Cunningham *et al*. 2013. *Geophys Res Lett*) we show that this decline causes a reduction in the northward warm water transport and a subsequent cooling of the North Atlantic Ocean which Taws and co-workers (2011. *Geophys Res Lett* **38**: L20601) link to the extreme UK winters of 2009/10 and particular to the subsequent extremely cold, snowy weather in the following December 2010 (Figure 3). This slowing has also been accompanied by a weaker, long-term slowing over the eight year timeseries (Smeed *et al*. 2013. *Ocean Sci*) larger than that forecast by climate models and is probably linked to multi-decadal variability in climate throughout the North Atlantic.

SAMS is at the forefront of Atlantic overturning research and is a leading partner in the development of a second purposefully designed transatlantic monitoring array – this time, however, for the far more challenging environment of the subpolar North Atlantic (Figure 4). This project aims to generate new knowledge and understanding of the North Atlantic Subpolar Gyre and its wider impacts on climate. Funding for the array was announced this year and planning and preparation are well under way for the first deployment of the whole array in summer 2014.

PUBLICATIONS 2012-13

Atkinson, C., H. L. Bryden, **S. A. Cunningham**, and B. A. King. 2012. Atlantic Transport Variability at 25°N in Six Hydrographic Sections. *Ocean Science*, **8**: 497-523.

Baringer, M. O., *et al*. 2013. Meridional overturning circulation and heat transport observations in the Atlantic Ocean. *Bulletin of the American Meteorological Society*, **94**: S65-S68.

Holliday, N. P., and **S. A. Cunningham**. 2013. The Extended Ellett Line: Discoveries from 65 years of marine observations west of the UK. *Oceanography*, doi.org/10.5670/oceanog.2013.5617.

McCarthy, G., E. Frajka-Williams, W. Johns, M. O. Baringer, C. S. Meinen, H. L. Bryden, D. Rayner, A. Duchez, C. Roberts, and **S. A. Cunningham**. 2012. Observed interannual variability of the Atlantic meridional overturning circulation at 26.5°N. *Geophysical Research Letters*, **39** (19): doi:10.1029/2012GL052933.

Srokoz, M. A., M. Baringer, H. Bryden, **S. A. Cunningham**, T. Delworth, S. Lozier, J. Marotzke, and R. Suttion. 2012. Past, present and future change in the Atlantic meridional overturning circulation. *Bulletin of the American Meteorological Society*, 10.1175/BAMS-D-1111-00151.00151.

Cunningham, S. A., T. Kanzow, and M. O. Baringer. 2013. The Atlantic Meridional Overturning Circulation (AMOC). *IPCC WGI Fifth Assessment Report*, in press.

Duchez, A., J. J.-M. Hirshchi, A. Blaker, H. Bryden, G. McCarthy, E. Frajka-Williams, D. Rayner, D. A. Smeed, **S. A. Cunningham** and C. Atkinson .2013. A new index for the Atlantic Meridional Overturning Circulation at 26°N. *Journal of Climate*, accepted (subject to revision).

Marzocchi, A., J. J.-M. Hirschi, N. P. Holliday, **S. A. Cunningham**, A. T. Blaker, S. Masina, and A. C. Coward. 2013. Establishment of the North Atlantic subpolar circulation in an eddy-resolving ocean model. *Journal of Marine Systems*, accepted (subject to revision).

Clément, L., E. Frajka-Williams, Z. Szuts and **S. A. Cunningham.** 2013. On the vertical structure of eddies and Rossby waves and their effect on the meridional overturning circulation. *Journal of Geophysical Research Oceans*, in revision.

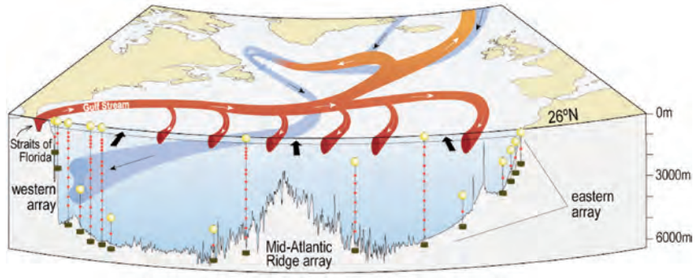


FIGURE 1: Schematic of the RAPID monitoring system in the subtropical Atlantic. Warm waters (red) in the Gulf Stream move north to the Labrador and Nordic Seas where they cool, sink and return south at depth (blue). The purposefully designed monitoring array consists of submarine cable measurements of Gulf Stream transport in the Florida Straits, moorings with current meters measuring the deep southward flows in the western array, a transatlantic array of moorings measuring temperature and salinity (west, mid-Atlantic and eastern arrays) and satellite measurements of the near-surface wind driven circulation ([Cunningham *et al*., 2007]).

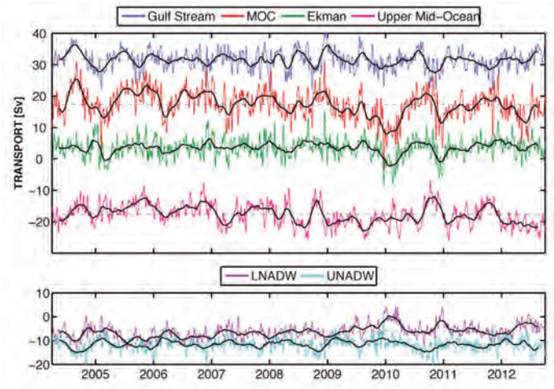


FIGURE 2: Ten-day (colors) and three month low-pass (black) time series of, from top to bottom, Gulf Stream transport (blue), overturning transport (red), Ekman transport (green), upper mid-ocean transport [0 to ~1100m] (magenta), lower [3000-5000m] (purple) and upper [1100-3000m] (green) North Atlantic Deep Water transport for the period 1 April 2004 to 1 October 2012.

Positive transports correspond to northward flow. Dashed lines indicate mean values of 31.5 Sv, 17.5 Sv, 3.5 Sv, -17.5 Sv, -6.5 Sv and -11.6 Sv respectively [1 Sv = 1 million cubic meters of water per second which is approximately 1 million tons of water per second].

Data are freely available from www.rapid.ac.uk/rapidmoc/.

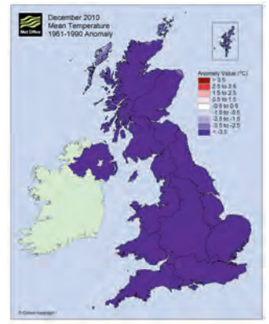


FIGURE 3: Met Office: UK climate: Winter December 2010 mean temperature anomalies relative to the 1961-1990 mean.

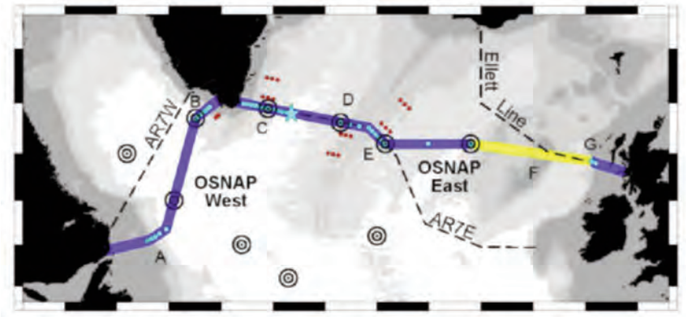


FIGURE 4: Observing the Subpolar North Atlantic Programme (OSNAP) elements: (A) German 53°N western boundary array and Canadian shelf-break array; (B) US West Greenland boundary array; (C) US/UK East Greenland boundary array; (D) Netherlands western Mid-Atlantic Ridge array; (E) US eastern Mid-Atlantic Ridge array; (F) UK (SAMS) glider survey over the Hatton-Rockall Bank and Rockall Trough; (G) UK (SAMS) Scottish Slope current array. Red dots: US float launch sites. Blue star: US OOI Irminger Sea global node. Black concentric circles: US sound sources.

DR DMITRY ALEYNIK

Developing of the high resolution unstructured 3D hydrodynamic models of the South West and the West Scotland coastal seas for EU FP7 'Applied Simulations and Integrated Modeling for the Understanding of Toxic and Harmful algal blooms (ASIMUTH)' project and for the Marine Scotland and European Fishery Fund (EFF-MSS) 'Sea Lice in MINCH' projects and the supplementary Weather Research Forecasting Model WRF- Scotland with 2 km horizontal resolution received the most of attention during the reporting period. All the model runs have been performed at HECToR - the largest in UK CRAY Supercomputer.

Sea going expeditions included the JC88 FASTNeT cruise in the area which has the greatest impact on the Scottish Coastal waters dynamics.

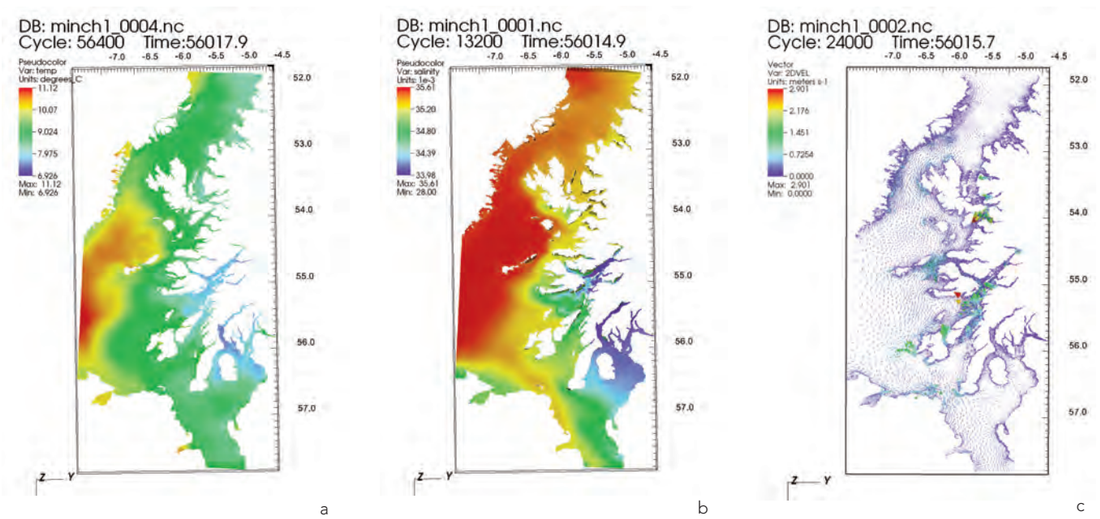
PUBLICATIONS 2012-13

Inall, M.E., **Aleynik, D**., Neil, C. 2013. Horizontal advection and dispersion in a stratified shelf sea: The role of inertial oscillations. *Progress in Oceanography* http://dx.doi.org/10.1016/j.pocean.2013.06.008.

Hsieh, YT, Geibert, W, van-Beek, P, Stahl, H, **Aleynik, D**, and M. Henderson, GM. 2013. Using the radium quartet (^{228}Ra, ^{226}Ra, ^{224}Ra and ^{223}Ra) to estimate water mixing and radium inputs in Loch Etive, Scotland, *Limnology and Oceanography*, **58** (3): 1089-1102.

Friedrich, J., Janssen, F., **Aleynik, D**. *et al*. 2013. Investigating hypoxia in aquatic environments: diverse approaches to addressing a complex phenomenon, *Biogeosciences* Discuss., 10, 12655-12772.

Adams, T. P., **Aleynik, D.L.**, Burrows, M. T. Larval dispersal of intertidal organisms and the influence of coastline geography. *Ecography*, under review. arXiv:1304.6319.



a b c

ABOVE: West Scotland FVCOM hydrodynamic model snapshot of the Sea Surface Temperature (a), Salinity (b) and Velocity (c) distribution on 4th April 2012.

SAMS HONORARY FELLOWS

Dr J C A Craik

SOUTH SHIAN TERN RAFTS 1996 - 2012

	Nests with eggs	Young fledged
1996	1	1
1997	1	3
1998	3	5
1999	12	0
2000	14	19
2001	12	0
2002	5	1
2003	27	55
2004	80	109
2005	40	0
2006	0	0
2007	1	0
2008	36	10
2009	104	140
2010	177	110
2011	300	400
2012	600	500

Introduced American mink, now widespread in west Scotland, are good swimmers and often reach small islands up to a kilometre from the mainland. Seabirds breed at high density on such islands to avoid mammalian predators.

Mink are members of the polecat-weasel-stoat family and predation by mink of eggs and chicks of island-breeding birds is having serious effects. The Mink-Seabird Project studies this problem, undertakes mink control at selected seabird colonies and evaluates the effectiveness of such measures. In summer 2012 the project was continued for its eighteenth successive year. Visits were made to seabird colonies on 94 small islands along the mainland coast between Mallaig and West Loch Tarbert and in the Sound of Mull, Loch Fyne and the Kyles of Bute. Mink control of varying intensity was undertaken at 26 sites and seabirds bred successfully at 16 of these. Six of the ten failures were definitely or probably caused by mink and four were caused by other predator species. Thus the project achieved its aim (to prevent breeding failures caused by mink) at 20 of the 26 sites.

The four other predators were a fox on Eilean Mor (Dunstaffnage), an individual Herring Gull specialising on eggs at Eilean an Ruisg (Loch Feochan), large gulls, and a raptor. While the last two are widespread and mundane, a fox on a small island with many hundreds of pairs of ground-nesting seabirds is unusual, while individual gulls that specialise on a particular prey are equally intriguing. Not a single chick was reared on either of these islands. Taking a positive view, the devastating but contrasting effects of these two predators provided interesting insights!

Some small-island communities of breeding seabirds still exist in this area because of continuing mink control, but many others have disappeared after annual whole-island breeding failures caused by mink. Conventional live-trapping of mink, the main method used in this work, is labour-intensive, expensive and, as shown above, not always successful, so other methods are being sought. The most successful of these, particularly for terns, is provision of breeding rafts that are inaccessible to mink. In 1996 a single pair of Common Terns first bred on an adapted mussel raft at South Shian in Loch Creran. This project has grown, particularly since 2009, and in 2012 about 600 pairs fledged about 500 young there, making this one of the largest tern colonies in the British Isles and by far the largest in the study area (see table). In spring 2013 more raft space was provided at South Shian in the hope of further increase, and measures were refined to exclude both mink and otter (a serious native predator of tern chicks in west Scotland). Elsewhere in the study area, nestboxes were provided for Black Guillemots at five sites and these were occupied at three. All results from this project are sent to the JNCC Seabird Monitoring Programme and to other organisations and individuals who request them.

Hitherto, the South Shian site has been regarded by the licensing bodies (the Crown Estate and Marine Scotland) as a mussel farm on which terns happened to be nesting. In 2012 the four adapted mussel rafts were licensed as tern rafts and the site officially ceased to be a mussel farm. At the same time I took over ownership of the rafts.

Members of the public often approach this laboratory with requests that we identify items they have found on the shore. Usually these are things such as bones of marine birds or mammals, but early in 2013 there was a spate of local findings of suspected ambergris. Some were easily identified as burnt rubber or degraded plastic. However, although I claim no expertise in this subject, two unusual items brought in by one person were less straightforward and might have been the real thing. They were sent for a more expert opinion and the verdict is still awaited.

Publications this year

Results of the Mink-Seabird Project in 2012. Unpublished Report (23 pp.)

Professor J Murray Roberts

- Professor of Marine Biology, Heriot-Watt University
- Adjunct Faculty, University of North Carolina Wilmington

This year saw the end of two European research projects focussed on ocean acidification (EPOCA) and human impacts on deep-sea ecosystems (HERMIONE) that both included research on cold-water coral ecosystems led by Murray Roberts.

Research themes from these two projects were developed and expanded at Heriot-Watt University through the UK Ocean Acidification programme's work on calcifying biogenic habitats. In 2012 the Heriot-Watt team co-ordinated the month-long Changing Oceans Expedition on board the RRS *James Cook* (cruise 073, http://changingoceans2012.blogspot.co.uk). Additional NERC funding allowed the cruise to include international participants from Denmark, Germany, Spain and the USA. The expedition's science plan was developed around a work-class remotely operated vehicle (*Holland-1* ROV, Irish Marine Institute) to survey, sample and experiment throughout the day with a series of ecological, hydrographic, mapping, carbonate chemistry and biogeochemical studies using other equipment overnight.

The expedition visited contrasting cold-water coral habitats beginning at the shallow Mingulay Reef Complex before moving offshore to the deeper Rockall Bank to work on the giant Logachev coral carbonate mounds. The ship then relocated to the NW Rockall Bank to revisit the site dived by the *Pisces III* manned submersible in 1973 and a site surveyed over recent years by both Marine Science Scotland and NOC. At the end of the cruise the ROV was used to carry out the first visual surveys of the Hebrides Terrace Seamount on behalf of the UK Joint Nature Conservation Committee. These revealed a series of distinct benthic communities, including the deepest coral ecosystems discovered by the expedition that will underpin the seamount's selection in Scotland's developing marine protected area network.

The last year also saw the start of a new NERC-funded project in collaboration with Dr Gavin Foster (University of Southampton) to see whether the deep-sea coral *Desmophyllum dianthus* from the Southern Ocean can provide the long-term, high resolution archive of seawater pH needed to follow the history of CO_2 storage in deep water masses. This work has meant expanding Heriot-Watt's cold-water coral aquaria to work with this new species supplied through collaboration with the Monaco Marine Laboratory.

A highlight of the last year was the chance to take a group of schoolchildren and their teachers from Benbecula out to the RRS *James Cook* to meet the scientists at see the Mingulay cold-water coral reefs with their own eyes. After a year of planning and preparation with NERC and the ship's managers the visit went without a hitch – despite a delayed departure and some gusty winds on the day of the boat transfer at sea.

Heriot-Watt University and Our Dynamic Earth subsequently organised a series of workshops at the Sgoil Lionacleit School on the Island of Benbecula to follow-up on the visit at sea and discuss the issues around marine protected areas from the perspectives of local residents, fishermen and conservationists.

Publications this year

Wicks L, **Roberts JM**. 2012. Benthic invertebrates in a high CO_2 world. *Oceanography and Marine Biology: An Annual Review*, **50**: 127 -188.

Scottish Minister for Transport, Infrastructure and Climate Change (2011-2012) Stewart Stephenson and Heriot-Watt University Principal Steve Chapman with Murray Roberts on the bridge of the RRS *James Cook* during a tour of the ship before the Changing Oceans Expedition.

A pupil from Sgoil Lionacleit gets the chance to control the ROV during a dive to the Mingulay cold-water coral reef.

A greater forkbeard (*Phycis blennoides*) swimming above the cold-water coral reef frameworks on the Logachev carbonate mounds.

NATIONAL CAPABILITIES

Our National Capabilities include:

Culture Collection of Algae and Protozoa
National Facility for Scientific Diving
Centre for Smart Observations
North Atlantic Glider Base

Following the reorganisation of National Capabilities at the conclusion of Oceans 2025, SAMS has focused its £1.38M funding for National Capability on enabling a cost effective observational and technical backbone to support NERC long-term research, knowledge transfer and research projects that require access to specialist skills, biological resources and innovative technology.

SAMS provides key facilities, services and data that are used throughout the NERC community, areas of 'National Good' to enable the benefits to be transferred more widely, long-term marine science to support larger scale science and decision making and elements that will contribute to a programme of integrated science.

SAMS is well placed to meet the challenges set by the Government for smarter observations, the increased use of robotics and the development of new biotechnology.

Professor Mark Inall
Associate Director, Research

Culture Collection of Algae and Protozoa

visit us at www.ccap.ac.uk

The Culture Collection of Algae and Protozoa (CCAP), located at SAMS, is funded by NERC as a component of its National Capability provision. National Capability enables the UK to deliver world-leading science and to support national strategic needs. Furthermore, it includes the research and development activities which keeps this capability at the cutting-edge. The CCAP, a UK service collection, or Biological Resource Centre (BRC) provides cultures (cyanobacterial, protistan, and macroalgal), bioinformatic data, services and advice to the scientific community.

In 2012/13 there was a further increase in culture/service provision with 36,800 visits to the CCAP KnowledgeBase at www.ccap.ac.uk (10% increase on 2011/12), 634 orders being serviced, with the provision of >1500 cultures to non-SAMS users. These live cultures are employed by both public and private sector users for applications as diverse as: aquaculture, teaching, applied & blue sky's research, as well as being used as biological standards in ecotoxicological, product efficacy, or biomedical tests.

Applied research (algal biotechnology) has continued to be a major growth sector over the past year, with the CCAP contributing through the provision of defined materials (cultures), bioinformatic data, advice, training, patent services and consultancy for users in the UK and elsewhere.

The development of future biofuels has been the most active area in the sector and CCAP has participated in the INTERREG funded Biomara project, completed in 2012.

SeaBioTech

Additionally CCAP is involved in the recently launched EU-FP7 project SeaBioTech. This project has been designed and driven by SMEs to create innovative marine biodiscovery pipelines as a means to convert the potential of marine biotechnology into novel industrial products for the pharmaceutical (human and aquaculture), cosmetic, functional food and industrial chemistry sectors. To achieve its goals, SeaBioTech brings together complementary and world-leading experts, including SAMS/CCAP, integrating biology, genomics, natural product chemistry, bioactivity testing, industrial bioprocessing, legal aspects, market analysis and knowledge exchange.

ASSEMBLE

In the past year CCAP has made major contributions to SAMS deliverables to the ASSEMBLE project. This is an EU FP7 research infrastructure initiative comprising a network of marine research stations across Europe and South America. CCAP has focussed on refining and contributing methodological toolkits to facilitate strain selection, strain enhancement and the improvement of productivity. CCAP personnel have authored 13 of the published protocols and hosted, collaborated in, or underpinned five ASSEMBLE funded projects based at SAMS. These projects, lasting between 2-12 weeks, have covered a wide spectrum of scientific areas including:

- somatic variation in *Ectocarpus* candidate pathogen receptors
- detection of a suitable cryopreservation method usable for the polar prymnesiophyte *Phaeocystis antarctica*
- cryopreservation of diatoms
- molecular and cellular biology of different strains of brown algae infected by the Oomycete *Eurychasma dicksonii*
- and a project exploring the feeding ecology and metabolic response of the cold-water coral *Lophelia pertusa*

New strains

Finally, in 2012/13 the diversity of strains held was increased with the targeted expansion of the collection resulting in the accession of 37 new strains, with 9 being ex-type cultures (newly described taxa to science): these include both algae and protozoa (details of all holdings and accessions are listed on the CCAP knowledgebase: www.ccap.ac.uk

Dr John Day
Head of CCAP

NATIONAL FACILITY FOR SCIENTIFIC DIVING

Introduction

The NERC Facility for Scientific Diving (NFSD) at SAMS provides divers, equipment, training and scientific/technical support that underpins a wide range of interdisciplinary research in the underwater environment. The service delivers practical support for diving-related underwater scientific projects through providing additional manpower for groups with limited diving experience, total project management for scientists with no diving experience and/or specialist equipment loans for groups with diving experience but limited resources. In addition, the Facility undertakes to ensure proper adherence to Health and Safety legislation as applied to diving at work activities. This can be through targeted training programmes, communicating advice and guidance for senior management with legal responsibilities for diving at work, undertaking safety audits on behalf of the NERC Health and Safety management structure and facilitating a wider interactive dialogue with others in the higher education field and the Health and Safety Executive. The NFSD is the main service provider and the major supporter of research within the UK that involves scientific diving through: support and maintenance of an extensive underwater research programme; support for the UK Scientific Diving Supervisory Committee (SDSC); interactions with other diving industry bodies; ongoing diving research and evaluation programmes; and a focussed training programme for scientists and technicians involved with working underwater. In addition to diving services per se, the NFSD also provides support and training in associated small boat operations and in emergency diving medicine.

Overview

A total of 841 diving operations were completed in 2012 in support of 15 projects. The on-going projects in 2012/13 continue to demonstrate the highly interdisciplinary nature of the science being supported through diving. These projects include contributing to studies investigating sea-level measurement, water-quality assessment, underwater light measurement, functional ecology, cell biology, animal genomics, paleoclimatology, ocean acidification, biogeochemistry, eco-physiology, habitat mapping and maritime science-based archaeology. Support in 2012/13 was provided to researchers from the following universities/institutes: BAS, CEH, NOC, BGS, PML, SAMS, MBA, Aberdeen, Bangor, Cambridge, Edinburgh, Leeds, Liverpool, Liverpool John Moores, Natural History Museum London, St. Andrews (x2), Southampton and Ulster (x2).

Major projects

Considerable support this year was provided to NERC consortium grant NE/H013962/1: "Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage (QICS)". The purpose of the study is to improve understanding of the sensitivities of the UK marine environment to a potential leak from a carbon capture and storage (CCS) system. Because of the limited nature of the controlled release, diving was an essential research tool to ensure accurate deployment and retrieval of a large array of varied monitoring equipment. During the course of the *in-situ* experiment divers collected >650 sediment cores, accurately laid >1600m of underwater cable, manually collected >300 water samples, took >500 UW images and deployed/ recovered/moved various instruments and sensors (including benthic chambers, moorings and time-lapse camera systems). For further information see page 48-49 of this report.

"Urban Research on Biodiversity on Artificial and Natural coastal Environments (URBANE)", which aims to better understand the ecology of artificial urban coastal habitats so as to promote biodiversity and minimise impacts, was another main user of the Facility in 2012. The project was again highly dependent on diving to facilitate access into very restricted environments that included dock walls and the underside of floating structures. Two, one week-long research campaigns were supported by the NFSD in 2012; planning was complicated by the research having to be undertaken in a working waterway.

Training and Guidance

The NFSD has continued to provide advice and guidance to the NERC Health and Safety Management Team on matters related to diving and the use of small boats. It continues to support the diving activities of the CEH and NOC Liverpool through equipment loans and advanced training schemes. The British Antarctic Survey once again employed the NFSD to provide the staff and facilities to support a range of familiarisation exercises prior to the BAS divers' deployment to the Antarctic. Additional training courses were delivered to researchers and PhD students in small boat handling (to RYA level 2), professional diving (to HSE SCUBA level) and recompression familiarisation. The NFSD has continued to support the UK Scientific Diving Supervisory Committee and represents UK and NERC scientific diving at the national and international levels.

Conferences and Workshops

The NFSD was the lead partner in an ASSEMBLE workshop focusing on Scientific Diving that was held in Oban 8-11 October 2012. Through currently holding the chair of the European Scientific Diving Panel (ESDP) of the European Marine Board, the NFSD were co-conveners of the 2013 International Scientific Diving Symposium jointly with the American Academy of Underwater Sciences. The NFSD was also on the Scientific Organising Committee for the 2013 Tri-Continental Scientific Meeting on Diving and Hyperbaric Medicine.

Value-added research

The NFSD continues to contribute to the areas of diving safety, physiology and hyperbaric medicine. Particular focus in 2012 has been on developing a greater understanding of how dive computers work in relation to decompression management.

Capital spending

Over £180k was secured from NERC in 2012/13 to replace the diving support vessel, upgrade some underwater camera systems, to replace the topside support vehicle and to refurbish the portable recompression system.

Outputs

Acknowledged on, or co-authored twenty-three ISI-rated papers and 22 conference proceedings/non ISI publications in 2012-13. Two PhD students, who had received NFSD support, graduated.

PICTURE 1: NFSD studies have been integrating GPS with dive computers to improve georeferencing underwater.

PICTURE 2: The NFSD team has been assessing dive computer performance as measurement tools and in their prediction of decompression stress.

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Dr Martin Sayer
Head of the National Facility for Scientific Diving

PICTURE 3: An NFSD diver takes *in situ* bottom water samples at or close to the area of experimental CO_2 release.

Centre for Smart Observations

The SAMS Centre for Smart Technology (CST) houses the expertise and knowledge-base for autonomous platforms and sensors for the acquisition and streaming of environmental data.

The Centre delivers National Capability to NERC in the areas of polar technologies, Autonomous Underwater Vehicles (AUV) development, acoustic drifters and Remotely Piloted Aircraft (RPA) for airborne remote sensing and sampling. It is essential that the UK retains an ability to build this skill and knowledge base in engineering, test feasibility of novel sensors and fund proof-of-concept technologies in anticipation of scientific need. NC funding also enables the skills existing within a physics-based Technology group, rich in micro-controller and robotics expertise, to be extended across such inter-disciplinary boundaries as marine biology, habitat mapping, sea and air chemistry and atmospheric science. CST is an enabling umbrella for the North Atlantic Glider Base.

Professor Mark Inall

North Atlantic Glider Base

To formalise SAMS longstanding capacity and activity in support of the development and use of autonomous (smart) marine systems, and with the forward vision of the North Atlantic as an exemplar hub for networks of Gliders, the North Atlantic Glider Base (NAGB) was established at SAMS. NAGB marginally predates MARS (Marine Autonomous Robotics Systems at NOC), and now a close collaboration between the two exists.

NAGB offers:

- Access to laboratory space for pre-mission, post-service Glider preparation (including buoyancy correction)
- Access to SAMS two coastal research vessels for sheltered deep water testing (to 200m).
- Arrangement of fast vessel hire for deployment and recovery for North Atlantic missions.
- Advice on scientific and operational aspects of Gliders mission planning and execution.
- Advice and software for real-time Glider data delivery to GTS or to data centres.

Since inception, NAGB has:

- Hosted a total of eleven visits, from all UK Glider operators, including three MARS visits.
- Developed the model now being adopted across the UK for a Seaglider real time piloting interface and the real time Glider data delivery to data centres and the GTS.
- Played an enabling role for the Glider operations of large NERC, EU and international programmes: OSMOSIS, FASTNEt, GROOM and OSNAP.
- Hosted trials of new sensors for Gliders: biogeochemical (from NOC) and acoustic marine mammal detectors (St Andrews).
- Become a founding component of the European Glider infrastructure proposed under the FP7 project GROOM (Gliders for Research Ocean Observation and Management).
- Been a key contributor to the NERC Roadmap on Marine Robotic Systems.

Going forwards, NAGB will:

- Host phase 2 trials of the NERC/SBRI/dstl funded Long Endurance Marine Unmanned Surface Vehicles (LEMUS V).
- Work with commercial and government partners (BP and Marine Scotland) to bring Gliders into operation in the oil fields west of Shetland.
- Host trials of Liquid Robotic's Wave Glider winch prototype.

Continue to enable Glider and AUV development: platforms (e.g. deep Gliders), data (delivery for model assimilation and network design), and sensors (physical, biochemical and bioacoustics).

Professor Mark Inall

EDUCATION

Education @ SAMS

Summary by Dr Lois Calder
Head of Education

Education activities at SAMS continue to go from strength to strength with increasing numbers of students across all degree levels. The total population of undergraduate and postgraduate students grew to 140 in 2012-13, filling the new Sheina Marshall Building, the SAMS-UHI dedicated teaching facility, and bringing a great 'university' feel to the campus.

Significant events during the year included the re-approval in autumn 2012 of our BSc degrees, Marine Science and Marine Science with Arctic Studies, for another five years. Included in the outcome report, SAMS was commended for the rich research environment to which students are exposed and the high quality and relevance of the course content.

Then in February, 2013, SAMS became formally recognised as an Associated Institution of the United Nations University (UNU), the only member institution specialising in marine science. This is an exciting new direction for SAMS and is the culmination of work with the UNU Institute for Water Environment and Health (INWEH) with which SAMS has been collaborating. However, the voyage is just beginning and great opportunities lie ahead.

During the year, SAMS also strengthened its relationship with the University of Edinburgh and was successful in achieving Associated Institution status with this university also. This collaborative partnership will promote new research initiatives and the development of a collaborative PhD programme. With changes to the ways in which doctoral funding comes to institutions, we hope that this initiatives will strengthen SAMS' position for the future.

One of SAMS' great strengths remains its staff and their contribution to research across a multitude of disciplines. They are, of course, essential to the educational delivery at SAMS and their dedication, passion and commitment remains at the core of all we do, nurturing students within a richly creative research culture.

A year of loss and mourning

The successes this report docments have been tainted by the devastating loss of one of our postgraduate researchers, Chris Bell, who died in an avalanche in Glen Coe earlier this year along with three of his friends. As the horrific news began to sink in, a second event rocked SAMS and Chris's supervisor, Tim Boyd, a respected polar scientist and vibrant figure at SAMS, died in a lightning storm.

The incredible double tragedy had a tremendous impact on all at SAMS. Chris and Tim are sorely missed and family, friends and colleagues mourn their loss. The SAMS 'family' has also lost two wonderful people but it has been richer for their presence and each is immortalised in the memories of them that we shall cherish.

SAMS physical oceanography PhD student **Christopher William Bell** died as a result of an avalanche accident in Glencoe on Saturday 18 January 2013.

Dr Tim Boyd, SAMS' popular Senior Lecturer in Polar Oceanography, was tragically killed by lightening strike on Sunday 27 January 2013 near his home in Appin.

Degree delivery: Undergraduate teaching

As a founding member of the University of the Highlands and Islands, SAMS continues to support the growth of the university through many of its activities, including delivery of our two Bachelor degrees: Marine Science and Marine Science with Arctic Studies. Twenty two new undergraduate students started in 2012-13, bringing the undergraduate student population to 76.

As always, induction was swiftly followed by our graduation ceremony. Seven undergraduate degrees were awarded: Bachelor of Science to Helen Ranson and Andrew Reynolds (awarded *in absentia*), Bachelor of Science with distinction to Owen Kilbride, a Bachelor of Science with Honours to Chris McCaig (lower second class) and Bachelor of Science with Honours to Sarah Cresswell, Kirsty Hill and Jirina Stehlikova (all first class).

Three postgraduates celebrated their successes: Clare Johnson and Andrew Mogg received Doctor of Philosophy awards and Undine Achilles-Day achieved a Masters by Research. Two further successful PhD research students, Kate MacIntyre and Morten Larsen unable to attend the graduation.

Prizes were awarded to Ruth Paterson (SAMS-UHI Student of the Year 2012), Jirina Stehlikova (SAMS Council Award for Academic Excellence), Susan Evans (Best Masters Project) and Karen Alexander (Johanna Fehling Memorial Prize for Best PhD Student Paper).

Professor Nick Owens, Director of the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) gave the key note address with Mr James Fraser, Principal of UHI, presiding over the degree awards. The SAMS Director, Professor Laurence Mee, and Head of Education and Academic Development, Professor Axel Miller, also spoke at the event which culminated in a celebration ceilidh for both graduates and our newest students, who are just at the start of their degrees.

The excitement of the graduates and their families was heartening to see and a testament to the journey that education at SAMS has travelled.

In a little over 10 years, we have built a highly regarded degree that is regularly facilitating the transition of graduates into high quality employment, with many students going on to pursue postgraduate study at both Masters and Doctoral level. Our highly skilled graduates are competing successfully in a global employment market and there is an ever increasing presence of SAMS-UHI alumni at diverse locations around the world.

With degree re-approval secured and another five years ahead, SAMS looks forward to welcoming many more undergraduates through the doors and to continuing the excellent work in training future generations.

Degree delivery: Masters degrees

MRes in Ecosystem-Based Management of Marine Systems

Now in its second year, the MRes in Ecosystem-Based Management of Marine Systems continues to be a success with 17 students enrolling in 2012-13. This is a University of St Andrews degree delivered collaboratively with SAMS. Students spend a semester at each institution before choosing one at which to continue with the research semester of the programme. Sixteen students elected to remain at SAMS this year with diverse dissertation topics ranging from species conservation and biosecurity to aquaculture impacts and predictive modelling of marine species. Student performance this year has been excellent and we hope that students will emerge well-equipped for further study, and for academic or other employment.

Of the 13 MRes students who graduated in the autumn of 2012 from the first intake of this course, six have since gone on to PhD study whilst three more are working in conservation or as research assistants.

Masters in Algal Biotechnology

Building on the success of our first Masters provision, SAMS is now working on delivery of a second degree programme, a research Masters in Algal Biotechnology.

The area of marine biotechnology is rapidly expanding and marine environments have the potential to provide new pharmaceuticals, neutracuetucals and foods and fuels on an industrial scale. The global drivers to develop new products to address human health and welfare issues are pressing but development of research capacity is critical if we are to reap the benefits in a environmentally sustainable manner. Responding to considerable growth of the biotechnology sector and the call for a skilled workforce to meet the needs of research, industries and businesses, the new Masters in Algal Biotechnology is due for delivery in the 2014-15 academic year.

With a strong focus on practical skills in laboratory techniques, algal identification, culture, physiology and biodiversity, as well as development of an in-depth knowledge of the applications for biofuels and other biotechnology products this degree programme will promote professional development of students, including entrepreneurial and communication skills, to equip them for employment in the sector.

Additionally, SAMS is forging strong links with industries and businesses to allow students to work in a business environment and to deliver research dissertations that address key questions for the sector, building capacity in this expanding field for Scotland and beyond.

Postgraduate research degree delivery

The community of postgraduate research students at SAMS continues to grow, bringing vibrancy and creativity to the institution. At the peak this year there were **34 postgraduates with 8 new students starting in 2012-13.** Seven, including a Masters by Research student, completed during the year and this autumn will see the largest graduation of postgraduates to date.

In the meantime, postgraduate research at SAMS continues to growe with studentships in diverse areas such as marine renewable energy and the hydrodynamic and ecological impacts of energy generation structures, marine spatial planning, biofuels, harmful algal blooms, deep-sea and seamounts ecology, sediment biogeochemistry, ocean acidification, climate impacts, ocean circulation and glaciology, and carbon capture.

Nine new studentships will start in the coming academic year 2013-14. These studenyships are set to bring yet more diversity to the postgraduate research portfolio, building research capacity and reputation for SAMS and supporting the students who will become future innovators and leaders in business, industry and academia.

In addition to lab and fieldwork all around Scotland, many of our postgraduate researchers and their supervisors have taken part in deep sea cruises and collaborated with colleagues at universities and institutions in the UK and internationally. In many cases, postgraduate researchers have been successful at securing additional funding for attending conference workshops and training at venues across the world. Even at the earliest career stages, SAMS' researchers have global visibility and impact working across all latitudes from Svalbard to Bermuda and Hawaii, Australia and Antarctica.

New Associate Institution status

SAMS has entered in a new Associate Institution status with the University of Edinburgh. This will deliver a collaborative programme of doctoral studentships with the Schools of Geosciences and Engineering in the coming year. Recruitment is already in progress to attract four new postgraduate researchers to spend time working in both institutions.

In the longer term it is envisaged that this agreement will forge new relationships between researchers and stimulate the growth of exciting, novel research between SAMS and the University of Edinburgh.

The Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE)

In April 2012, SAMS welcomed its first cohort from the Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE) with a second group arriving in April 2013. IDCORE is an initiative of the Energy Technologies Institute and the Research Councils UK (RCUK) Energy Programme. It is a partnership of the Universities of Edinburgh, Exeter, and Strathclyde, HR Wallingford and SAMS.

This five-year collaboration incorporates two SAMS course modules per year: Marine Renewables and the Environment, led by Dr Ben Wilson, and Marine Renewables and Society, led by Dr Tavis Potts. These two modules effectively give the engineering students a crash course in marine environmental science and broaden their perspectives on the environmental, social and policy related implications of off-shore energy production that will be needed to meet ambitious UK renewable energy targets. Feedback on the two SAMS modules has been exemplary, from both the students and external examiners.

In addition, **the course and SAMS' parts have been awarded CPD status from the Institute of Marine Engineering, Science and Technology (IMarEST).**

For SAMS' teaching staff, it has been a pleasure to teach such talented engineering students and to see them embark on their three year industrial placements with a better understanding of the issues beyond the engineering challenges.

Continuing Professional Development

SAMS' portfolio of Continuing Professional Development (CPD) courses and field courses has expanded through the year, largely due to the efforts of the new Educational Marketing Manager, Joanne Allday.

SAMS organised eight Continuing Professional Development (CPD) Courses in 2012-13 and doubled average delegate numbers from last year to twelve per course.

Over the year, we welcomed delegates from around the world and September's Molecular Methods in Algae Research course was wholly booked by international students, a first for SAMS and a clear message of our international visibility.

Other specialist areas for course delivery included Algaculture for Biotechnology, Marine Invasive Species Identification, Geo-referencing, Mapping and GIS, Marine Ecosystem Modelling and a Training Workshop on Unmanned Aerial Vehicles (UAV) and their application for research.

SAMS is playing an active role in training and developing individuals from the public, private and third sectors who return to their host organisations with new skills and techniques. Course delegates get a great interactive experience and benefit from the contributions made by research-active scientists willing to share the latest findings and technologies. Many course attendees have kept in touch with their course tutors and requested further information on future courses and research collaboration, including the development of PhD studentships.

These courses are broadening SAMS international network and are extending the impact of our science.

SAMS is now looking at the development of its own staff and students and January saw the launch of a new stream of professional development courses open to SAMS students and employees. These employability courses encompass life skills such as time management, presentation skills, IT shortcuts and interview skills.

Together with other UHI partners, we are planning the launch of the UHI Skills Awards later in the year. Working alongside UHI's Careers Service, we hope to provide on-going development opportunities internally and create an even greater culture of lifelong learning within SAMS.

"A fantastic and interesting course!"

Marine Invasives Species delegate from Scottish Power Renwables

SAMS as an Associated Institution of the United Nations University (UNU)

SAMS became the first marine research institute to become an associated institution of the United Nations University (UNU) in early 2013.

We recently appointed Dr Liz Cook (see p 16-17) to lead the SAMS UNU associated institute. With her previous experience in leading international scientific programmes, Liz is excited by the prospect of working to develop a new network of scientists across the world to promote the sustainable use of the marine environment.

The United Nations University was founded some 40 years ago as the academic arm of the United Nations. Its mandate is to support the United Nations and its Member States through research, postgraduate education and capacity building and to serve as a think tank for the United Nations system. UNU is a global university, with its headquarters in Tokyo, Japan and 15 institutes and programmes located throughout the world. Around 200 students are currently enrolled in its seven master and PhD programs.

The UNU's objectives are to promote training and research into issues of pressing global concern and to transfer knowledge to communities and countries to aid resolution and management of these challenges.

The UNU relationship provides a strong synergy with SAMS' mission of delivering research to promote stewardship of the marine environment and sustainable development.

Over the coming years, it is envisaged that we will build on previous SAMS-UNU collaborations to promote research, postgraduate training and the sharing of knowledge on coastal and marine resource management, safe water provisioning and water health, focusing especially on the challenges faced by developing nations. We look forward to exciting new research and educational activity in the years to come.

Student life beyond academia...

As the student body grows, more and more is happening socially for our students. Whilst SAMS provides a great academic culture into which students are immersed from the very outset of their studies, the broader student experience at SAMS is helped by a strong sense of community and shared social activities from coffee mornings and barbeques to the annual graduation and welcome ceilidh.

The newly formed local Student Association is providing activities for undergraduate and postgraduate students, including new clubs and societies, and organisation of events and social gatherings. These have included the formation of a new UHI diving club based at SAMS.

There is also a wealth of local groups and clubs offering activities from cycling to Octopush. Student involvement in these helps their integration into the wider Oban society.

This is a crucial part of student life, providing peer support and helping integration across year groups, and imparting as sense of belonging to the wider community, to give our students the best academic and life experience whilst there are studying at SAMS.

The Student Association can also be a vehicle for the student voice, in addition to the committee representations offered to student representatives. Strong links exist with the UHI Student Association (UHISA) and in the coming year, a SAMS undergraduate student, Rachel Parker, will take a sabbatical to fulfil the role as new UHISA president, representing students across the whole of UHI. SAMS is delighted to host Rachel and we look forward to supporting the development of both the local and UHI Student Associations.

ABOVE: SAMS undergraduate student Rachel Parker has been elected as the new President of the UHI Student Association for 2013-14 and will represent all UHI students at UHI governance and management level.

SAMS Research Services Ltd

www.samsrsl.co.uk

SRSL Annual Report 2012-13

SRSL is the commercial arm of the SAMS Group and is based at the Scottish Marine Institute. Since beginning trading in 2002, we have delivered independent and high-quality marine environmental survey and consultancy services, underpinned by cutting-edge research.

Our mission is to enable clients to understand and mitigate the risks involved in industry interaction with the marine environment. We have a number of key markets both internationally and in the UK.

RENEWABLES

Baseline Surveys and Environmental Impact Assessment (EIA) services to the renewables industry are core business for SRSL. With our powerful combination in-house environmental consultants, marine scientists and technical specialists (ranging from underwater noise to marine ecology), we are uniquely placed to ensure offshore renewable projects move smoothly from consent award to construction and beyond, in-line with consent conditions.

- Marine mammal & underwater noise surveys
- Benthic & intertidal surveys
- Natural & commercial fish surveys
- Sediment & water quality sampling
- Seafloor mapping
- Metocean surveys
- Consenting support services
- Post-consent monitoring
- Vessel & equipment hire

SRSL specialises in assessing environmental impacts on marine mammals, including underwater noise at potential tidal energy development sites. This year SRSL has delivered marine mammal and fish EIA and Environmental Statement chapters for the West Islay Tidal Farm (DP Energy), which has now been submitted to Marine Scotland.

At SRSL, an experienced Renewables Services Manager oversees all renewables projects to ensure our clients have the best possible understanding of regulatory requirements and expectations. Meanwhile our professional project managers ensure that contracts are delivered to both time and budget. This year SRSL has recruited another environmental consultant with expertise in renewables and also marine biofouling.

SRSL has supplied Environmental Impact Assessment services to developers and regulators across four of the main wind and tidal developments off the west coast of Scotland. Our valued clients include Scottish Power Renewables, Scottish and Southern Energy, OpenHydro, Voith Hydro, Pelamis, Marine Scotland, SNH, SEPA, JNCC and many more.

SRSL is currently working towards ISO9001:2008 and extensions of scope to ISO17025:2005, as well as participation in various NMBACQ scheme components.

MINING

SRSL is a world-renowned thought leader in environmental best practice and impact assessment of Deep Sea Mine Tailings Placement (DSTP). We have assessed three DSTP-permitted mines worldwide and now seek to apply our relevant and unique expertise to the emerging field of Deep Sea Mining. We have over a decade of experience working with industry, landowners and regulators internationally.

MARINE TECHNOLOGIES

SRSL design and manufacture novel autonomous sea-ice mass balance buoys (SIMBA) for monitoring sea-ice cover in the Arctic/Antarctic. For five years, these devices have been built at the Scottish Marine Institute, Oban, in shared laboratories. This year however, SRSL have moved production to a dedicated manufacturing facility on the same site, which has been custom-designed to maximise production-efficiency and facilitate quality assurance of these devices. To date, we have delivered in excess of 150 SIMBA units, which have been deployed in both the Arctic and Antarctic regions. SRSL continue the R&D process, improving design and adding new capabilities to the current model.

AQUACULTURE

SRSL offers a range of environmental monitoring programmes of interest to a variety of market sectors, from the aquaculture industry to food and public health including:

- Toxic phytoplankton monitoring of designated shellfish growing areas
- Sanitary Surveys (including field surveys to assess E.coli contamination in shellfish farms)

Dr Tracy Shimmield
Managing Director of SRSL

- Toxicity studies on shellfish (e.g. aqueous chlorine tolerance in edible bivalves)
- Assessment of the Impacts on Cetaceans and Basking Sharks (at a proposed fish farm)

BIOFOULING

Biofouling services from SRSL build on a strong and supporting research background in marine bacteria, biofilms, invasive species and seawater quality. This in-depth understanding allows us to offer consultancy services, bespoke monitoring, contract-research and scientific assessments of marine growth. SRSL aims to reduce the impacts of marine biofouling and facilitate development of antifouling approaches and technologies.

All marine services from SRSL benefit from access to the full range of national capabilities, facilities and equipment at the Scottish Marine Institute, including the National Facility for Scientific Diving, Culture Collection of Algae and Protozoa, European Marine Test Facility, analytical suites, research vessels, aquarium, conference rooms and new-business incubator unit.

Dr Keri Wallace
SRSL Marketing Manager

SAMS PUBLIC ENGAGEMENT

CELEBRATING THE FESTIVAL OF THE SEA

Oban's second Festival of the Sea ran from Friday 18 to Monday 28 May 2012. The Festival was organized by Dr Anuschka Miller and Helen McNeill from SAMS and core funded by SAMS, the Scottish Government (managed through Highlands and Islands Enterprise), and Argyll & Bute Council with other organisations supporting individual events.

A steering committee representing public, commercial, educational, charitable organisations with marine related interests and local Councillors advised and supported the festival organisation team.

The festival was conceptualised as a community event aiming to involve hard-to-reach rural audiences.

The Festival of the Sea 2012 at a glance

- The second Festival of the Sea increased its geographical spread and was renamed 'Festival of the Sea - Oban, Lorn and the Isles'. Events stretches as far as Rothesay (Bute), Lochmaddy (North Uist) and the Isle of Canna
- The festival programme was made up of 56 events (several with multiple sessions) including 12 talks, competitions, six exhibitions, debates, three conferences, workshops and excursions, beach cleans, 12 open days, marine sports taster sessions, a molecule hunt, and seafood cookery sessions
- 10,490 event visits were recorded
- The educational programme involved 603 school-age children
- A CD by local musicians celebrating the marine environment was produced
- Over 200 people contributed their time and expertise to organising and running events.

The festival had seven objectives:

1. To increase awareness of the sea
2. To engender pride and responsibility
3. To excite young people about marine and science related careers
4. To discuss marine management
5. To facilitate understanding of marine science
6. To highlight Oban as a marine place
7. To promote healthy living

SCHOOLS ENGAGEMENT

It has been a busy year working with schools delivering a very wide variety of topics to over 900 pupils.

Topics presented include Renewable Energy, Algae and Seaweeds, Seabed Mapping, Waves and Currents, Marine Technology, Carbon Capture & Storage, the Deep Sea, Ocean Acidification, Touch-tank Animals and Plants, Microbiology, Plankton Investigation, The Biomara Project, the INIS Hydro Project, Sea Stories, Life on an Arctic Cruise, Marine Aggregate Dredging Impacts, Marine Mammals, Cold Water Corals, Marine Pollution, Arctic Animals, Food Chains, Marine Aliens, Beach Exploration, the Girl Guiding 'Ocean Challenge' Marine Science Badge, and the Food of the Sea Animation Project.

A snapshot of this year's outreach includes school environment days on Skye and Islay, nursery visits with an exciting sea trawl, the hosting of 20 work experience pupils, a visit by SAMS research vessel RV *Calanus* to Tobermory for pupils to find out first-hand about the INIS Hydro seabed mapping project, a visit by 50 S4 pupils to SAMS as part of the UHI Bridge to Engagement project to enthuse secondary pupils about science, the Sgeulachan Na Mara Sea Stories project on Barra , 12 student winter lectures, and a visit to North Uist for an INIS Hydro school workshop and delivery of the Comann Na Mara Annual Lecture.

Helen McNeill
Outreach Officer

SAMS IN THE NEWS...

During the year 2012-13, SAMS communications team decided to branch out beyond traditional media and began to use social media to better effect.

Our three social media target outlets are Twitter, FaceBook and LinkedIn. Of the three, we focussed on Twitter the most, which we use to follow relevant science news and issues and to let our followers know more about all aspects of SAMS whether science papers, research events, field work or social topics. The aim of this is to present the human face of SAMS and to interact with other like-minded institutions and individuals by sharing titbits of information (tweets cannot exceed 140 characters) that lead the reader to a longer news item, report, science paper or whatever, if they fancy. And, it has been paying off: our follower-base doubled within the year and now we have followers all over the world who are interested in us and our research. As for FaceBook and LinkedIn, a former student has been championing our Facebook page on our behalf and we're slowly building the professional networking webpage LinkedIn. In the forthcoming year we hope to develop each of those further.

As for more traditional forms of media, the year had some good highs and two very sad lows. It was at our lowest point SAMS had more media mentions in a month than in the whole of the rest of the year. Two of our scientists, Chris Bell (24) and Tim Boyd (54), were killed a week apart in tragic accidents. Chris was killed by an avalanche in Glen Coe and Tim was struck by lightning. It perhaps goes without saying that that coverage was mainly in the tabloid press.

On a happier note, but without producing an entire list of all the media coverage SAMS has generated, here's a roundup starting with a selection of trade magazines titles, perhaps more for the specialist reader, including TheFishSite, offshoreWIND.biz, the Algae Industry Magazine, Safety4Sea, Phys.org, Inshore Ireland, Maritime Journal, ComputeScotland.org and Bioenergy Consult…

An a local level, throughout the year SAMS has been mentioned on average at least every other week in the weekly newspaper, The Oban Times, with a similar record for a local online news website, ForArgyll. Across Scotland we've featured in the Buteman, Enterprising Scotland Magazine, Scottish Development International, the Ross-shire Journal and on STV as one offs. We've appeared a little more often in the Scotsman, the Press and Journal, (Scottish) Daily Mail/Mail on Sunday, and the Herald. In national newspapers, we've had two reports in The Guardian on Carbon Capture & Storage related research, the Sunday Times covered our seaweed cultivation work and the development/use of equipment for research in the Arctic, and the Economist wrote about energy technology for oil spills – reprinted subsequently in Business Insider and the Chicago Tribune.

As for the BBC, whether you like it or loathe it, it is a powerful tool and perhaps the most credible news provider the world-over. By early March 2013 there had been 13 BBC items ranging from news, to features (Seaweed: Should people eat more?) to podcasts (Costing the Earth) about SAMS science that were on national, regional or Gaelic services whether that be TV, radio or online. Then in mid-March we released a story about collaborative research in Marianas Trench: how life, plentiful microbial life, had been found in the world's deepest trench almost 11000m below sea level. This story with live and pre-recorded interviews by Dr Robert Turnewitsch featured 14 times on BBC outlets including Radio 4, Radio 5Live, Radio Scotland, Radio Wales, the World Service and from Radio Cornwall through the alphabet to Radio Surrey. This sort of BBC coverage has an unbeatable reach and in the next 24hours it was reprinted in newspapers from the Argentina Star to the North Korea Times, from the Toronto Telegraph to the Australia News via Kenya, Kyrgyzstan and Turkmenistan, appearing in more than 60 online publications outside of UK.

So, we ended the year 2012-13 on a communications lift, due to one of the numerous, deeply interesting and ground-breaking science projects in to which SAMS scientists pour their efforts, experience and expertise.

We continue to wave the SAMS flag.

Cathy Winterton
Communications Officer

VARIETY IS THE NAME OF THE GAME FOR SAMS' FILMMAKER-IN-RESIDENCE

'In residence' at first reading seems to imply staying in one location, but nothing could be further from the truth for SAMS' filmmaker in residence, Andy Crabb, and his project entitled *Songs of the Scottish Sea*.

Since arriving in Spring 2012 as part of Creative Scotland's 'Creative Futures' residency programme, Andy has worked on site with undergraduate and postgraduate students and staff and scientists at SAMS as well as locally with pupils from Oban High School and Lochnell Primary. The project at Lochnell, focusing on the 'Food of the Sea' involved a number of scientists from SAMS spending time at the school, and included the construction of a giant copepod and collaboration with a BAFTA winning animator, JessicaAshman.

Looking to more distant horizons, the project has also taken temporary residence on the water aboard a variety of vessels including the RV *Calanus* for the INIS Hydro project, RSS *James Cook* for the FASTNEt cruise to the Malin Shelf and the *Swan* (a Shetland Fifie herring sail boat) for Cape Farewell's 'Sea Change' expedition around the Orkneys.

Earlier in the year Andy initiated a time-lapse project at SAMS which has seen time-lapse filmmaking emerging into various aspects of life inside and outside of SAMS.

There remains some filming to be completed before winter sets in, which should then see editing taking over as the main activity, together with recording with the project musicians, Chris Stout & Catriona McKay to produce the film scores, before some finished films begin to emerge in the spring of next year.

OUR RESOURCES

2012/13 was most memorable for the announcement of retirements of Dr Ken Jones (Deputy Director and Head of Infrastructure) and Ivan Ezzi (Health & Safety Advisor and Ships' Operations Manager).

As a result, the progress reported here represents their respective final years of long service and dedicated contribution to SAMS.

LEFT: Retiring Deputy Director Dr Ken Jones (right) hands over the keys to SAMS to his successor, Professor Axel Miller, previously Associate Diretor for Education at SAMS.

RESEARCH VESSELS

The SAMS fleet was increased, with the addition of RV *Spirit of Jeanie* in September 2012.

Commissioned in 2009, she is an MCA Coded (Category 3), 6.65m, forward-cabin work boat (Pirate 21 class) and is powered by two 90hp outboard engines. Her carrying capacity is two crew plus four scientists. With a cruising speed of 15 knots, she is capable of over 30 knots, providing for fast transits between sites, hand deployments/ recoveries and observational work. To date, our scientists have used her for:

- Visiting aquaculture sites
- Deploying light instruments
- Observing and recovering remotely piloted aircraft (RPA)
- Filming work on other vessels
- Recovering oceanographic gliders

RV *Spirit of Jeanie* was gifted to SAMS by the National Oceanography Centre (NOC)

John Beaton
Ships Operations Manager

IT AND INFORMATION SERVICES

SAMS IT and Information Services had a busy year supporting the breadth of our science, education and commercial activities.

Our storage system was upgraded, with the primary storage getting a 1TB upgrade and new archive system offering 42TB of storage. This was the first full year using MS Exchange, and the major development challenge over the reporting period was the introduction of a new Virtual Private Network (VPN) service. This now allows remote and secure access, for all SAMS staff and students, to internal computing resources such as network drives, Ciphrnet and the intranet. In both cases the transitions caused minimal disruption to SAMS business.

In October 2012, SAMS were awarded a Scottish Government Contract to redevelop the AutoDepomod product for aquaculture, in which the IT department plays a central role.

The library service continues to be under-utilised and the first stages of a library use review were implemented. The outcomes will inform a wide-ranging review during the subsequent reporting period.

The major change project during the year was the implementation of the UHI PURE research management system, thus retiring the 12 year old SAMS OPMS database

Steve Gontarek
Head of ICT

FACILITIES

During the year, SAMS Facilities Team responded to 680 helpdesk requests. Some of the larger projects undertaken include:

1. The aquarium plant room controls sea water distribution. It has been fully automated and is now of the same standard as all other SAMS plant rooms.
2. Following a reported theft and some incident of vandalism, our CCTV coverage was enhanced in and around the Sheina Marshall Building.
3. The kitchen of the SAMS hostel was fully upgraded to meet the requirements of House in Multiple Occupation requirements. Also, a 'hospitality kitchen' was created within the Sir John Murray Building by amalgamating the old projection room and tea room to create a storage and preparation area.
4. Following direction from Strathclyde fire and rescue, the timber lined staircase in the old laboratory wing was refurbished.
5. Our main computer room FM 200 gas storage bottle area was refurbished.
6. Four sets of external doors were replaced

David Mathias
Head of Facilities

HEALTH & SAFETY

The Head of H&S continued his role on the NERC Safety Management Group. The Deputy Director continued to represent SAMS on the NERC Safety Management Team and attended meetings of the NERC Health and Safety Committee. He also attended meetings of the UHI Health & Safety Committee, with the Head of H&S. The UHI annual safety conference and committee meetings were hosted by SAMS in September.

A display screen equipment survey for all staff was undertaken and the internal inspection program continued. SAMS radiation facilities were inspected by an external agency and were graded excellent. Occupational health continued to provide pre-employment screening, medicals, travel advice, GP referrals and a "drop-in" service. Training was provided in the following areas:

- General safety induction
- Undergraduate inductions
- Manual handling train the trainer
- First aid at work
- Personal survival training (Glasgow College of Nautical Studies)
- Defibrillator and advanced first aid
- Fire extinguisher
- Fire marshal

There were two reported accidents and two incidents, none of which were notifiable to an enforcing authority.

Christopher Clay
Head of Health and Safety

OUR PEOPLE

Our people at SAMS

We hear repeatedly that SAMS is a special place to be, and we know that this is down to those who choose to work for us or to study with us. Our people bring the intellect, skills, professionalism, talent, energy and commitment that we rely on to succeed.

Our success enabled us to grow from 155 staff on 1st April 2012 to 165 staff on 31st March 2013, thereby increasing local employment opportunities. We hired 34 people during the year, while 24 left us. This amounts to 15% turnover, of which just over half was voluntary, the remainder being due mainly to the expiry of fixed-term contracts.

We were delighted to be able to strengthen our senior team with the arrival of Mike Meredith (Professor of Physical Oceanography), Stuart Cunningham (Senior Lecturer in Physical Oceanography), David Pond (Senior Lecturer in Biological Oceanography), Phil Anderson (Senior Lecturer and Head of Marine Technology Development), and Paula Lister (Director of Finance).

At the other end of the career ladder, and helping us to secure SAMS future through staff development and succession, we welcomed three new apprentices and four Post-Doctoral Research Associates who have chosen to launch their careers with SAMS.

Regrettably it was also a year of great sadness for SAMS as we lost both Dr Tim Boyd (Senior Lecturer in Physical Oceanography) and PhD student Chris Bell who both died in tragic personal accidents just a week apart. Both colleagues were close members of our SAMS family and have been sorely missed by staff and students alike. During the graduation later in 2013 we inaugurated the Tim Boyd Prize for Oceanography in Tim's memory and in recognition of his enthusiasm and dedication to education.

SAMS encourages 'on the job' learning and development, and was pleased to facilitate three internal transfers during the year from science departments to Education and to Business Development, where it is vital to our success to maintain a deep understanding of SAMS science.

As a not-for profit organisation, SAMS operates a responsible pay policy which broadly follows the UCEA pay arrangements. Pension provision is the main staff benefit and to date has been provided principally through USS.

In addition to pay and benefits, SAMS takes care of its staff through local occupational health arrangements, the provision of childcare vouchers, and by offering a range of flexible working arrangements to both men and women that are greatly appreciated by both SAMS and its staff.

SAMS recognises three unions under an informal arrangement, and operates a quarterly consultation process between staff representatives of the unions and management.

Our people at UHI

We are delighted that Angela Hatton, Keith Davidson and Kenny Black were awarded personal chairs by UHI during the reporting period, while Cambridge and British Antarctic Survey based oceanographer, Mike Meredith, who now spends a significant amount of his time working with SAMS, was awarded an honorary professorship. These awards recognise the advancement of scientific knowledge through research. SAMS is proud of its world class scientists and of their role in making UHI a distinctive university that contributes to the economic and social development in the region.

Our people in the community

SAMS encourages all staff to contribute to the wider community, and is proud to acknowledge the range of activities to which staff have voluntarily given their time and support. These include in particular public engagement events such as the Festival of the Sea and Girlguiding Argyll Ocean Challenge Badge, as well as the support of various charities, voluntary rescue organisations and community groups.

'Tour de UHI'

In March SAMS staff competed with other UHI partners to cycle around the partnership for Comic Relief (on exercise bikes placed in Reception!). We raised hundreds of pounds for charity and SAMS cycled the greatest distance – of course!

Linda Smith
Head of Human Resources

SAMS employees during 2012-13

Richard Abell
Colin Abernethy
Undine Achilles-Day
Tom Adams
Karen Alexander
Dmitry Aleynik
Joanne Allday
Angela Anderson
Phil Anderson
Elaine Azzopardi
John Bainbridge
John Beaton
Steven Benjamins
Peter Bentley
Christine Beveridge
Alasdair Black
Derek Black
Kenny Black
Tim Boyd
Tim Brand
Debra Brennan
Ruth Brennan
Hugh Brown
Lars Brunner
Mike Burrows
Lois Calder
Christine Campbell
Elizabeth Campbell
Karen Campbell
Stefano Carboni
Trevor Carpenter
Brian Clark
Alison Clarke
Eilidh Cole
Elizabeth Cottier
Finlo Cottier
Ian Crawford
Polly Crooks
Philip Crump
Jacqueline Cullen
Rachel Culver
Stuart Cunningham
Andrew Dale
Richard Dale
Fiona Darling
Keith Davidson
John Day
Arlene Ditchfield
Estelle Dumont
Janet Duncan
Jim Elliott
Ivan Ezzi
Sharyn Farmer
Joanne Field
Clive Fox
Neil Fraser
Claire Gachon
Ronnie Glud
Steven Gontarek
Rebecca Gore
David Green
Lucy Greenhill
Sue Greenwood
Colin Griffiths
Bernard Hagan
Fiona Hart
Mark Hart
Angela Hatton
John Hausrath
Shelia Heymans
Natalie Hicks
John Hill
Kirsty Hill
John Howe
Adam Hughes
David Hughes
Morgan Humphreys
Zoe Hutchison
Phil Hwang
Mark Inall
Chris Ireland
Vladimir Ivanov
Chris Jackson
Keith Jackson
Alistair James
Clare Johnson
Ken Jones
John Keeney
Maeve Kelly
Sarah Kennedy
Philip Kerrison
John Kershaw
Shirley Kersley
Olga Kimmins
Lindy Lamb
Peter Lamont
Kim Last
Vicki Last
Ray Leakey
Paula Lister
Nicola Longman
Sian Lordsmith
John MacDonald
Fraser MacDougall
Lorna MacKinnon
Rory MacKinnon
Kenneth MacLean
Adrian MacLeod
Nigel MacLucas
Shona MacVicar
Daniel Madej
Shona Magill
Eleanor Martin
David Mathias
Fran McCloskey
Gillian McLuckie
Helen McNeill
Sharon McNeill
Laurence Mee
David Meldrum
Mike Meredith
Anuschka Miller
Axel Miller
Raeanne Miller
Elaine Mitchell
Andrew Mogg
John Montgomery
Leah Morrison
Sine Murray
Bhavani Narayanaswamy
Thom Nickell
Elspeth Norris
Linda O'Higgins
Timothy O'Higgins
Christopher Old
Heather Orr
Ettore Pedretti
Dr Joanne Pitt
Judith Pollock
David Pond
Marie Porter
Tavis Potts
Cecilia Rad Menendez
Ian Rae
Andrew Reynolds
Linda Robb
Shane Rodwell
Lorenzo Rovelli
Rachel Saxon
Martin Sayer
Peter Schiener
Natalia Serpetti
Carole Shellcock
Toby Sherwin
Tracy Shimmield
Margaret Sime
Stephen Slocombe
Claire Smalley
Linda Smith
Norman Smith
Henrik Stahl
Michele Stanley
Marieke Steuben
Alan Stewart
Sarah Swan
Eugene Tening
Paul Tett
Naomi Thomas
Phillip Thompson
Simon Thurston
Robert Turnewitsch
Gail Twigg
Gangi Reddy Ubbara
Branka Valcic
Lovro Valcic
Andrea Veszelovszki
Fiona Wallace
Keri Wallace
Elaine Walton
Lorna Watt
Callum Whyte
Tom Wilding
Jeremy Wilkinson
Averil Wilson
Ben Wilson
Karen Wilson
Cathy Winterton
Kelly Wood
Antonios Zambounis

OUR FINANCES

The Association's financial results for the year show that whilst income has increased year on year our operating surplus has reduced from 2.7% of total income in 2011/12 to 0.1% in this year.

At an income level we continue to see increases across all categories of research, education and commercial work. The reduction in operating surplus is largely as a result of increased staff costs which reflect planned investment completed during the year.

Charity accounting for capital grants dictates that the full amount of any such funding should be recognised in the year in which it is received rather than deferred to fund the depreciation over the life of the asset. Thus creating a situation where net incoming resources are inflated in the year of receipt but future year's depreciation expense is unmatched. As a result, SAMS considers net operating surplus in managing the business. The table below shows the reconciliation from the operating surplus to the deficit of £400k (2011/12 – deficit of £331k) transferred to reserves.

As we continue to operate in economically challenging times and with much greater competition in the sector it is encouraging that SAMS continues to generate even small surpluses from its operations during the financial year.

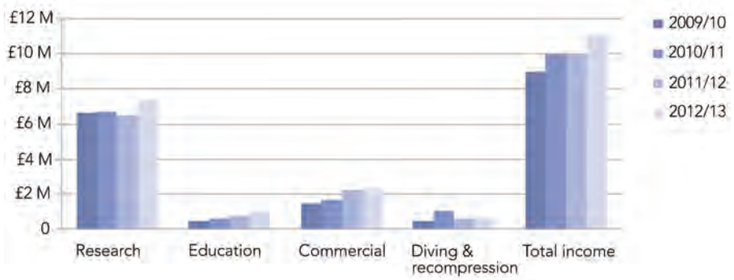

FIGURE above: Our total income over the past four years has been increasing.

Financial summary	2012/13 £000	2011/12 £000	Change %
Summary			
Operating Income excluding capital grants	11,150	10,052	11%
Operating Expenditure excluding grant funded depreciation	(11,136)	(9,778)	14%
Operating Surplus	14	274	(95%)
Capital Grants received in 2012/13	483	346	40%
Depreciation funded by grants received in previous years	(897)	(951)	(6%)
Deficit transferred to reserves	(400)	(331)	(21%)

Effective management of resources

Staff costs represent the highest proportion of expenditure at 58% of operating costs. These rose by 9% in the year largely as a result of planned investment.

A review of accounting policies in the financial year has resulted in a prior year adjustment to recognise a provision for unused annual leave carried forward between financial years which had not previously been recognised in the accounts. This resulted in a provision for £19k being included in staff costs for 2012/13.

Other operating costs rose by 25%. Whilst an element of this was to be expected given the increase in income, it also reflects the impact of growing inflationary cost pressures being faced. We will need to continue to exercise strict prioritisation of expenditure in order to contain and to offset these in future years.

A small decrease in depreciation reflects the difficulty in securing capital funds for investment. This is set to become increasingly challenging with further reductions in availability of capital funds from research and funding councils expected.

Alternative sources of capital funds continue to be sought with an overarching strategy for our facilities currently under development.

RESEARCH GRANTS & CONTRACTS

Income from research grants and contracts increased this year by 11% to £7.2m. Whilst we saw a small decrease in our level of funding from the Natural Environment Research Council (NERC) we achieved significant success in growth of funding from the EU (27%) and other sources (38%).

INIS Hydro, an ERDF survey project, was the main reason for the growth in income in 2012/13 in comparison to the EU income in the previous year. There were also 3 new EU FP7 projects started within the year, IDREEM (SAMS as lead partner), AT SEA and Groom.

The majority of the increase in other income is due to MASTS (Marine Alliance for Science and Technology, for Scotland) activity. There were also additional contracts through the Scottish Government, Crown Estate, SARF and the FSA.

Financial summary	2012/13 £000	2011/12 £000	Change %
Research income			
NERC (including National Capability)	2,975	3,070	-3%
EU	1,626	1,285	27%
Other	1,626	1,176	38%
RAE	954	959	-1%
Total research income	7,181	6,490	11%

However, grant income from Research Councils and the EU does not provide full cost recovery for overheads and therefore there is a gap in funding our research infrastructure costs which has to be bridged by other income sources, including the Research Excellence Grant received through UHI.

Our preparations for the 2014 Research Excellence Framework (REF) have continued in 2012/13, with several rounds of review and revision taking place. This will provide a solid base to ensure the highest quality submission to the 2014 REF.

Given the current funding climate for research in the UK, this will continue to be a difficult environment going forward.

EDUCATION

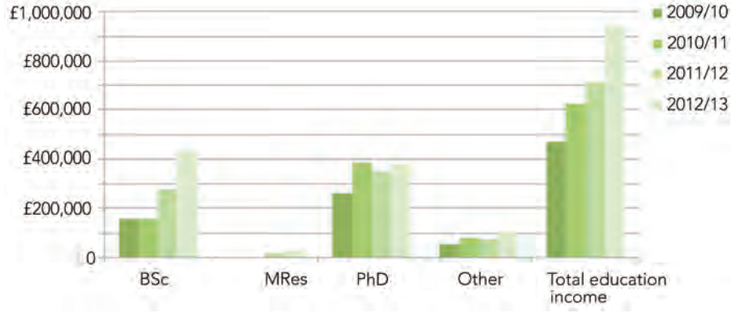

FIGURE above: Income from education activities has increased by over 100% in the past four years. It accounts for 8% of SAMS total income.

We continue to be an Academic Partner of the University of the Highlands and Islands, delivering both undergraduate and postgraduate education. At £943k, and a 101% increase since 2009/10, income from education activities now accounts for 8% of total income.

Income from undergraduate courses has seen a growth of 55% this year (74% growth in 2011/12) and represents almost half of the total education income in 2012/13.

In terms of postgraduate education, the Masters course, started in 2011/12, continued to gain momentum with income from this source doubling in 2012/13 whilst the PhD studentships have seen a modest increase.

Other education income includes activities such as field courses and CPD courses. A growing reputation for the quality of our CPD education is the driver behind the increase in income.

COMMERCIAL ACTIVITIES

	2012/13	2011/12	2010/11
Attributable to markets in the UK	60%	64%	80%
Attributable to markets outside the UK	40%	36%	20%

At 22% of total income, it is now recognised that income from commercial activities is an important part of the portfolio of work undertaken by staff at SAMS.

In a difficult global economy it is pleasing to report income levels of £2.4m in the year have shown an increase over 2011/12.

SAMS Research Services Ltd (SRSL), our trading subsidiary, is enhancing SAMS international reputation for science excellence.

Paula Lister
Associate Director, Finance

THE LEARNED SOCIETY

THE STATE OF THE MEMBERSHIP

During the reporting period members received a copy of the annual report inside a flagship brochure about SAMS, were invited to a number of events including the AGM, had the right to apply for a SAMS bursary, could stand for Council, and could consult the SAMS library.

SAMS currently has 302 members, a moderate increase compared to the 280 members the previous years: There are 248 ordinary members, 31 corporate members and 24 student members.

Membership subscriptions remained unchanged: £12 ordinary, £5 concession, £60 corporate.

Council and SAMS staff held a meeting to discuss options for the future of the learned society and these discussions are ongoing. To this end a new sub-committee to Council has been set up that deals with Communications and the Learned Society. It is chaired by Ken Rundle and also includes the President, Professor Geoffrey Boulton, and the SAMS Director.

MEMBERSHIP MEETINGS

Annual General Meeting

SAMS held it 98th Annual General Meeting on 9 November 2012. At this meeting Professor Geoffrey Boulton was voted to become our next President, taking over from Professor Andrew Hamnett.

Newth Lecture

The AGM was followed by the Annual Newth Lecture, presented this year by Professor Lora Fleming, Chair and Director of the European Centre for Environment and Human Health. She spoke on 'Oceans and human health: a new area of interdisciplinary science'.

Scottish Marine Group

As Dean of the MASTS Graduate School Professor Axel Miller of SAMS organised a Scottish Marine Group meeting for postgraduate students on 28 May 2012 during the Festival of the Sea. However, no autumn meeting was convened.

As numbers of participants and interest has been steadily falling over the years as other meetings have been increasing in frequency, it has been proposed to disband the Scottish Marine Group. This is currently under review.

Members with strong views on the future of the Scottish Marine Group should voice these for the attention of the new Communications and Learned Society Committee.

SAMS RESEARCH BURSARIES

TABLE: Research bursary awards to SAMS members during the reporting period

NAME	INSTITUTION	PROJECT TITLE	AWARD
Mark Hopwood	University of Southampton	Dissolved iron speciation in a Scottish Loch System	£ 930
Dr Sven Thatje	University of Southampton	The effects of sustained high hydrostatic pressure on the lipid composition and homeoviscous adaptation of shallow-water benthic marine invertebrates	£1,000
		TOTAL	**£ 1,930**

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