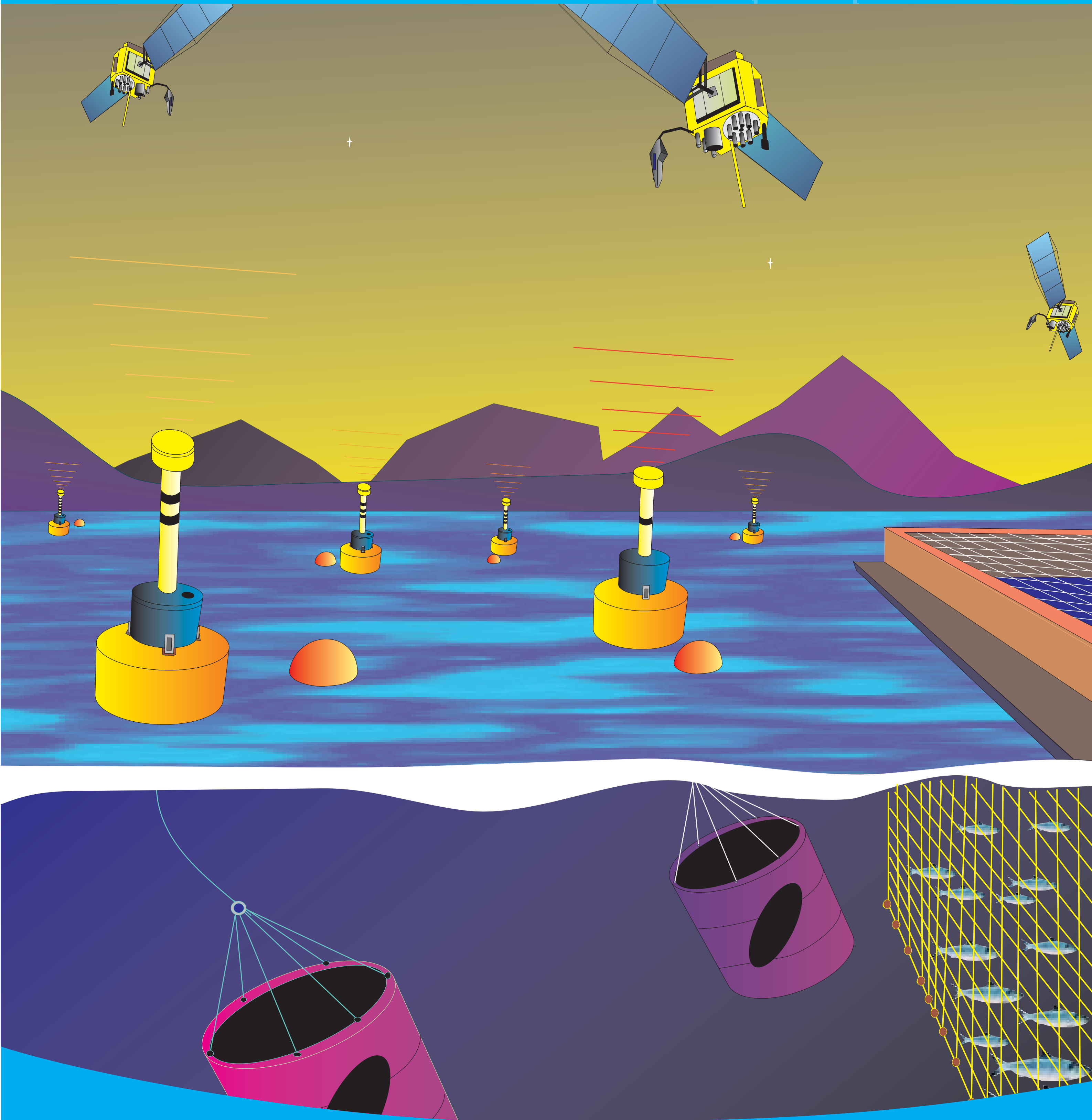
The Scottish Association for Marine Science NEWSLETTER 25

SAMS

ISSN 1475-7214



THE LAST FRONTIER –

DEVELOPMENTS IN MARINE TECHNOLOGY SEE PAGE 6-7

March 2002

Oceanology International 2002

5-8 March 2002
ExCel, London

For more information contact:
Cheri Arvonio
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SAMS Open Evening

Wed 13 March 2002
18.30 to 20.30
Dunstaffnage Marine Laboratory, Oban

For more information contact the editor

Benthic dynamics: *in-situ* surveillance of the sediment-water interface

25-29 March 2002
University of Aberdeen, Zoology Department

For more information see www.sams.ac.uk

The Greenwich Forum

Maritime World 2025: Future Challenges & Opportunities

Conference 3-5 April 2002
Old Royal Naval College Greenwich, London

For registration email: enquiries@conferencebusiness.co.uk
Tel: 01444 416678

Aquaculture International 2002

18-20 April 2002
SECC, Glasgow

For more information contact:
Sue Hill
Tel/Fax: 020 7505 3608
Email: sue.hill@informa.com

www.heighwayevents.com/aq2002/

Developmental Ecology of Marine Animals: Industry, Science & Society

2 - 3 July 2002
Newcastle, UK

Tel: 01224 273272
Email: dema@abdn.ac.uk
www.abdn.ac.uk/dema

8th International Conference on Copepoda

21-26 July 2002

National Taiwan Ocean University, Keelung, Taiwan

http://8thicoc.ntou.edu.tw

Underwater Optics Division Conference

Underwater Optics

2-5 September 2002
Cardiff

For information contact:
Derek Pilgrim
01752 232457
or Michael Wall
020 7470 4800

Freshwater Biological Association

Annual Scientific Meeting

Fresh Water in the Landscape

4 – 6 September 2002
University of Durham, UK

Contact: Sarah Gee
Tel: 015394 42468
Fax: 015394 88541
Email: sage@fba.org.uk
Website: www.fba.org.uk

Abstract deadline: 13 May 02
Registration deadline: 9 Aug 02

Scottish Marine Group

Autumn Meeting

Thurs 31 October 2002
Stirling University

For information contact:
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Front cover graphics by Kevin Langan, Gray's School of Art, Aberdeen

About SAMS

The Scottish Association for Marine Science (SAMS) is a charity committed to promoting research and education in marine science. It is based at the Dunstaffnage Marine Laboratory near Oban, and is a full academic partner in the UHI Millennium Institute.

SAMS is funded by an agreement with the Natural Environment Research Council for its Northern Seas Programme, by commissioned research for other public and private organisations, and by donations and subscriptions from its 500+ members from all over the world.

SAMS Membership

Ordinary: anyone interested in marine science Subscription - £12.

Student: any person under 18, or registered students at Higher Education Institutes Subscription - £5.

Corporate: organisations interested in supporting marine science Subscription - £60.

Unwaged: anyone without a regular wage. Subscription - £5.

For further information and application forms please contact the editor.

Editor

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To keep up-to-date on events at SAMS, visit our website:

www.sams.ac.uk

SAMS Board

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Dear **SAMS** member

Dr Anuschka Miller, EDITOR

Welcome to the spring 2002 edition of the SAMS Newsletter, which marks the launch of a new layout for the publication. A new SAMS logo required the rethinking of some aspects of the design and was a welcome opportunity to update the look of the Newsletter. I hope the results will be to your liking.

While looks have their place, content is what matters. This Newsletter is a testament to the breadth of research and activity undertaken by the Association.

On pages 6 and 7 David Meldrum shares some personal thoughts on the latest developments in marine technology, which provide the tools every marine scientist needs to explore the *Terra Incognita* below the surface layer of the oceans.

A meeting of the Scottish Marine Group in November 2001 focused on the advances - or otherwise - of sustainability in the marine environment since the Rio Summit ten years ago. Three of the presentations are summarised on pages 10 to 12, exploring the meaning of a Marine Act for Scotland, the state of the deep seabed, and new European legislation designed to improve the condition of European waters.

A third theme of the Newsletter is the varied engagement of SAMS with aquaculture (pages 14-16). We use aquaculture to study processes in the marine environment, and investigate environmental impacts. We also explore new avenues towards improved sustainability. Kenny Black appeared as an independent scientist at the Aquaculture Inquiry in the Scottish Parliament and shares his impressions of this experience with us on page 16.

In this issue we also introduce a new page: In 'My PhD Project' a SAMS PhD student describes his/her research project. In this issue Clara Morri talks about her Marine Geology project on the effects of past climate changes on sediments.

These are just some of the subjects covered in this issue, and I wish you pleasurable reading.

SAMSnews

Professor Graham B. Shimmield, DIRECTOR

QUALITY OF SAMS RESEARCH RECOGNISED

At the end of last year SAMS received the exciting news that our research was awarded a Grade 4 in the Environmental Sciences category of the Research Assessment Exercise (RAE) which grades all research in Higher Education Institutions in the UK on a scale from 1 to 5. Grade 4 indicates that our science is of national excellence in virtually all of the research activity submitted, with some evidence of international excellence. Although only the research from 13 UHI staff members was submitted to the exercise – 11 from SAMS as well as Dr Stuart Gibb of The North Highland College and Dr Martin Price of Perth College - the result reflects most creditably on the performance of SAMS over the past 5 years. The overall contribution of the laboratory's research activities towards the UHI Millennium Institute is marked by the substantive contribution by the NERC staff submitted under category C (research conducted by staff contributing to the research programme but not salaried by SAMS/UHI). The preparation for such an assessment requires considerable effort. As the Scottish Higher Education Funding Council (SHEFC) had notified UHI only six weeks before the submission date about our new eligibility to participate, I would like to record my thanks to Dr Axel Miller and Ms Jane Foster for working extremely hard to prepare our submission. Our forward strategy derives considerably from the Northern Seas Core Science Programme and thus sets the framework on which to build the natural systems science strategy for the UHI. At a recent postgraduate conference UHI has further defined and reinforced a future research strategy.

SAMS SUBSIDIARY FORMED

Following a decision of the SAMS Annual General Meeting on the 6th November a wholly owned subsidiary of SAMS has been formed. SAMS Research Services Limited (SRSL) will deliver the commercial activities of the Association such as the operation of the hyperbaric chamber and sales from the Culture Collection of Algae and Protozoa. In addition, SRSL will act as the primary vehicle for the procurement and financing of the new building development.

NEW LOOK FOR SAMS

Some of you with a keen eye for detail will have noticed the new look to both this Newsletter and the corporate logo for the Association. In keeping with modern times it was felt that a change in logo emphasising the interdisciplinarity of marine science represented by the Association would be an important benchmark for SAMS. I am delighted at the finished product, which contains a very strong message of the SAMS name. The logo of SRSL utilises the same graphic features, albeit in a different colour scheme.

I had hoped that the new logo would also mark the completion and signing of the agreement with NERC, but although this is in its final stages, it has not yet been completed. Nevertheless a full and satisfactory outcome of the agreement is but a few weeks away, and we look forward to the President of SAMS and the Chief Executive of NERC confirming the partnership between NERC and SAMS in the future.

NEW SAMS COUNCIL MEMBERS

The AGM also saw the appointment of three new council members. Dr Sandy Tudhope and Dr Paul Thompson strengthen the academic base of Council whilst Mr Bill Balfour contributes his wealth of experience as a retired lawyer from the city of Edinburgh. I believe we have one of the most dynamic and informed learned society councils that I have had the pleasure to be involved with. The current membership exemplifies well the varied but important aspects of SAMS business. I believe the new members will be a powerful asset for the development of the Association over the coming years.

PROGRESS ON NEW BUILDING DEVELOPMENTS

Finally, I would like to update you on the new building project. At the time of writing, the survey work of the ground conditions have been completed. We are now putting the final touches to a submission to Argyll and Bute Council Planning Department for amendments to the original planning consent. Assuming that this goes according to plan, we expect the diggers to arrive on site in early April. It takes, of course, a considerable amount of detailed planning to put the legal framework for the relationship between SAMS and Dunstaffnage Developments Ltd - a wholly owned subsidiary of ERDC in Partnership – into place. Our relationship has been working well, and we are confident that we will have superb new marine science research facilities for the next decades here on the west coast of Scotland. Although much work remains until all the detailed matters associated with the new building are completed, I would like to record my thanks to Dr Ken Jones and to Elaine Walton for their help in getting us this far.

To fully develop the European Centre for Marine Biotechnology, we are currently advertising for the post of Project Executive. He or she, when appointed, will strengthen the directorate team and will be tasked with delivering this exciting new project between SAMS and Heriot-Watt University.

2002 has started well with recognition for our international scientific capability. Now our infrastructure is about to be developed in a significant manner. We are looking forward to delivering a wide range of core strategic science and research projects. It promises to be a good year.

Obituary: Sir Cyril Edward Lucas

Born Hull, 30 July 1909; Died Aberdeen, 14 January 2002.

Sir Cyril Edward Lucas, former Director of Fisheries Research for Scotland and Vice President of SAMS, died peacefully in Aberdeen on Monday 14 January 2002 at the age of 92.

Born and educated in Hull, Cyril Lucas studied and later worked under Sir Alister Hardy investigating the relationship between plankton and fisheries, and was involved in the development of the Continuous Plankton Recorder. After a few years heading a new branch of the Hull Oceanographic Laboratory in Leith, Cyril Lucas was appointed director of the Marine Laboratory Aberdeen in 1948. Under his leadership the laboratory expanded considerably both in size and reputation. He was a driving force behind the development of the UK fisheries laboratories, and was also heavily involved in international fisheries issues. He retired from his position in 1970 but remained actively involved with the scientific community, serving for example as member of Council of the Natural Environment Research Council from 1970 to 1978.

For his outstanding contribution to international fisheries Cyril Lucas was appointed a Knight Commander of the Order of St Michael and St George in 1976. He was also a Fellow of the Royal Society and of the Royal Society of Edinburgh, whose Neill Prize he had received in 1959.

A friendly, humble and quietly spoken man, Sir Cyril Lucas was married and had three children.

Obituary: David James Ellett

Born Great Yarmouth, 22 July 1934; Died Oban, 5 October 2001.

David Meldrum and Colin Griffiths, SAMS

David was born and raised in Norfolk, completing his formal education at Great Yarmouth Grammar School in 1952 with A-levels in physics and geography. It is a testament to his intelligence, dedication and scientific insight that despite these slender qualifications he rose to become a physical oceanographer of considerable international standing, whose meticulous work and deep insight commanded the highest respect amongst his peers, and whose name lives on with the Ellett Line, a major hydrographic section running from Scotland to Rockall and beyond.


© M.Harvey, SAMS

David joined the UK Met Office in October 1952, but transferred to MAFF's Fisheries Laboratory in Lowestoft in January 1954 because he had "always wanted to do something connected with the sea". Over the next decade, he absorbed and mastered the science (and art) of hydrography by participation in wide-ranging cruises, including, notably, the International Council for the Exploration of the Seas (ICES) Faroe-Iceland Overflow Experiment of 1958, marking the beginning of a long interest in these dense northern overflows.

The 50s and 60s saw the emergence of ocean variability as a major research theme. David brought his key qualities of meticulous observation and interpretation to this area of study, and with Arthur Lee published in the mid 60s important, lucid and pioneering works on the role of the various overflows in the formation of the Atlantic's deep watermasses. These seminal works are still in use today.

The Rockall Trough was to be David's main working area and interest to the end of his career. Right up until his retirement in 1994, he explored these waters. He deployed the first long term current meter moorings in the Trough in 1975, planned and participated in the JASIN Air-Sea Interaction Experiment in 1978, recovered the first unequivocal evidence of a Slope Current west of Scotland in 1979, and made the first direct measurements of overflow crossing the Wyville-Thomson Ridge in 1987-88.

His many campaigns led to more than 80 publications. Nor did this work stop at retirement. As a SAMS Honorary Fellow, David continued his patient elucidation of the long-term trends that awaited discovery in the data from his many cruises, until intractable ill health made further study impossible.

David's collaboration with Dunstaffnage began when he sailed with the then Scottish Marine Biological Association for the second ICES Overflow Survey in 1973. This led to his secondment in 1975, and ultimately to his transfer to Oban. Here, with Roy Bowers, he built up a respected Marine Physics Group that combined intellectual acumen with formidable success in winning lucrative contracts. His attentive mentoring of younger members of staff, coupled with his quiet manner and donnish appearance, earned him the affectionate nickname of "Professor". But there was steel behind the gentle exterior, and he was swift, sure and deadly in his many actions to deal with unfairness and intransigence in officialdom.

Despite the honours bestowed on him both by ICES and the Society for Underwater Technology, one suspects that David derived greatest satisfaction from being designated a Data Quality Evaluator for the World Ocean Circulation Experiment (WOCE), from the adoption of the 'Ellett Line' by the community, and from the use of its time-series to record the arrival-time of particular vintages of Labrador Sea Water, thus establishing for the first time their trans-ocean spreading rates. As he would happily confess, he was first and foremost a `watermass man'.

David married Sally in Beccles, Suffolk in 1963, and they had one son, Tom, in 1969. His wish to have his ashes scattered at sea was fulfilled on 4 November 2001, when the ship's company of *RRS Discovery* gathered on the after deck for a ceremony led by two of David's oldest colleagues, Captain Robin Plumley and Dr Raymond Pollard. To the sound of a long blast on the ship's whistle, David, that gentlest of gentlemen, set forth on his longest voyage, across the Ellett Line.

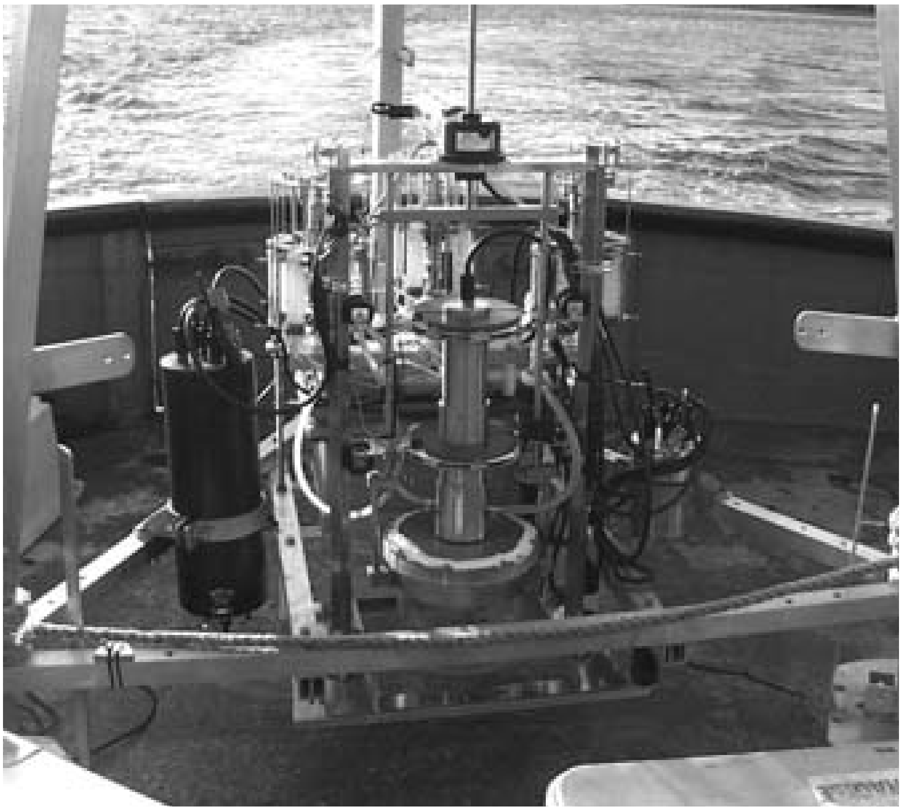
The Last Frontier:

DEVELOPMENTS IN MARINE TECHNOLOGY

David Meldrum, SAMS

I grew up in cold war Scotland, where regular reports of missile and bomb tests imbued our daily lives with a distinct sense of unease. Then, in parallel to the Arms Race, came the Space Race. Kennedy's commitment to put a man on the moon within 10 years assured NASA of limitless funds for space exploration. But it was the *Voyager* missions, the exploration of the outer reaches of the solar system by small smart probes, that really caught my imagination.


© D.J.L. Mercer, SAMS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ABOVE: Deep-sea lander on the afterdeck of the SAMS research vessel *Seol Mara*

BELOW: Duncan Mercer (left) and Oli Peppe of the SAMS marine technology development group


© D.Meldrum, SAMS

In a way, though, the explorers of space had it easy. The missile programme had solved the launcher problems, so escaping the Earth's gravity was eminently feasible, if expensive. Once in space the rest was straightforward – limitless supplies of energy from solar panels, or your personal chunk of plutonium as in the *Voyager* craft; no motion resistance, no corrosion, and so on. But the greatest boon of space was its transparency to the electromagnetic spectrum, allowing unfettered optical and radar imaging of planetary surfaces and, more significantly, ease of radio-communication with the spacecraft.

However, my university education in physics, coupled with several summers exploring in Greenland, led not to space science but to the Scott Polar Research Institute. There I joined a team using airborne radars to map the Antarctic continent, hidden under several kilometres of ice. Unfortunately ice is not as transparent as space: powers that could bounce signals off the moon are needed to generate detectable echoes through 5 km of polar ice. But at least radio waves do penetrate ice. And we did find the unexpected – Lake Vostok, deep in the heart of the continent, under more than 4 km of ice.

When this programme wound down I moved back to Dunstaffnage in Scotland to study a natural medium that is, for all practical purposes, totally opaque to radio waves – the sea. Because of this simple fact the bottom of the oceans is much less well mapped than, say, the far side of the moon, or the surface of Mars. Satellite-borne instruments, which have done so much to advance our knowledge of the Earth's surface and atmosphere, ▸▸

are powerless to see beneath the surface of the ocean. Seabed mappers have to rely on acoustic instruments to build up images of the ocean floor, and these instruments have to be within the water. Unlike space, water resists the motion of objects through it: building the oceanographic equivalent of a satellite — an autonomous underwater vehicle (AUV) – faces the immediate problem of supplying the vehicle with enough energy to navigate. And, unlike the days of *Voyager*, small nuclear reactors are no longer popular.

Water friction can, however, be turned to advantage: the oceans move, and it is possible to hitch a free, if largely unpredictable, ride on the back of ocean currents. At Dunstaffnage I have become closely involved in exploiting this free ride, and in recycling new technologies such as GPS for the detailed study of ocean currents. We have deployed drifting instruments in many areas, including the polar ice packs, where they have yielded new data for the climate change debate. Elsewhere, the profiling floats of the international Argo programme drift for days on deep currents, surfacing periodically to download thermal data that will help us understand the interplay between the oceanic heat reservoir and climate change.

This still leaves the ocean floor largely unmapped: speculative reconnaissance – exploration in the true sense – is largely ruled out. However, change is afoot, spurred by events such as the chance discovery of the biological communities thriving around hydrothermal vents. Plans are well advanced in many countries for the establishment of ocean observatories linked by sea-floor cables - an Internet of the deep ocean, open to primary schools as well as universities. Instrument pods, connected to the network *via* sea-floor junction boxes, will both deliver data and receive commands and energy. AUVs will now be able to dock routinely to report their findings and recharge their batteries. The spirit of exploration which has led to such amazing discoveries as the volcanic activity on Jupiter's moon Io, and Lake Vostok in the Antarctic, is about to be fostered once more in the oceans. And, connected to the Internet, what new wonders will our last frontier reveal – and to whom?

First published as THES 'Cutting Edge' feature, 7 Sept 2001. Reproduced by permission of the Times Higher Education Supplement, www.thesis.co.uk

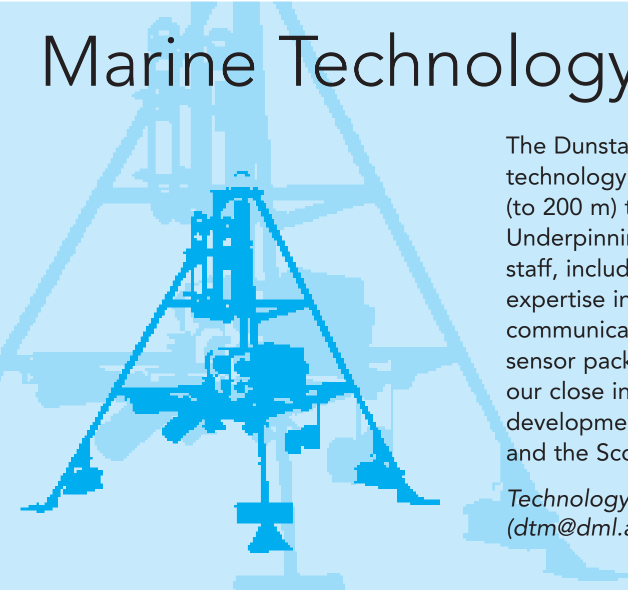
David Meldrum heads the Marine Technology section at SAMS and is a member of the Executive Group.

© O.Peppe, SAMS

ABOVE: Novel drifting buoys increased our understanding of the interaction between climate and Antartic sea ice

© O.Peppe, SAMS

ABOVE: Autosub trials in the Firth of Lorne



Marine Technology Development at **SAMS**

The Dunstaffnage site is, in UK terms, uniquely well equipped for marine technology development, offering a wide range of sheltered deep-water (to 200 m) trials sites, backed up by vessel, diving and aquarium support. Underpinning this are the multi-disciplinary strengths of the laboratory and its staff, including a technology development group which offers cutting edge expertise in instrumentation design, platform development and satellite communications. Currently the main activities of this group are in free-drifting sensor packages, landers, smart instruments, GPS and telemetry. In addition to our close involvement with the SAMS science mission, we also undertake outside development work, recent customers being DSTL, QinetiQ, DEFRA, Shell and the Scottish aquaculture industry.

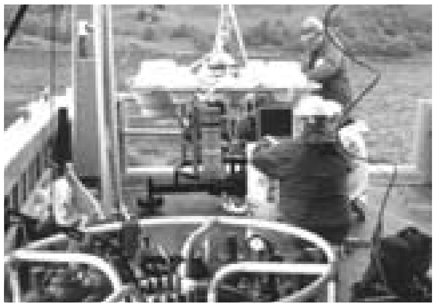
Technology development at SAMS is led by David Meldrum (dtm@dml.ac.uk, tel +44 1631 559273)

Energetics in **Loch Etive**

Dr Finlo Cottier, SAMS

© H. Powell

ABOVE: The Falls of Lora at the entrance to Loch Etive



© C. Griffiths

ABOVE: Instrument deployments off the *Calanus* working deck in Loch Etive, June 2001

The Falls of Lora at the entrance to Loch Etive are one of Scotland's most dramatic natural sights. Twice a day, during mid-ebb, loch water cascades into the Lynn of Lorne generating the famous seawater falls.

It doesn't take specialist knowledge to appreciate that during both ebb and flood tides The Falls are the physical manifestation of a massive transfer of energy between the coastal waters and Loch Etive. Eight miles inland at the narrows at Bonawe there is also considerable turbulence as the flood tide races over the shallow sill into the deep upper basin. But where does the energy go? And how does tidal activity modify the basin water?

Lochs are sinks for substantial volumes of freshwater from their catchment areas. Surface water thus tends to be buoyant, capping underlying more dense basin water. Surface capping restricts mixing in the basin, causing the deep water to stagnate.

In the 1970s, Dunstaffnage physicists made observations of the hydrography of Loch Etive from which they determined basic principles governing periodic flushing of the upper basin. Stratification caused by the freshwater input from the Rivers Etive and Awe means stagnation periods can be greater than two years. Renewal depends upon seasonal variations in freshwater input and tends to occur during times of low run-off.

While seasonal changes may trigger renewal, the susceptibility of a fjord to this is controlled by density differences between the water outside the sill and the deep water within. Gradual modification of deep water relies on diffusion and more complex exchange mechanisms to effect vertical mixing.

The tides and the wind provide the forces for mixing. In Loch Etive the tidal range is relatively small, and despite the powerful tidal stream at Connel Bridge and Bonawe, water below sill depth in the upper basin can be surprisingly quiescent.

Tidal energy may be of two forms: barotropic, derived from the semi-diurnal tides, and baroclinic, a consequence of variations in water density. Where the barotropic tide interacts with a rapid change in topography, *e.g.* the sill, its energy may be converted to the baroclinic form.

Baroclinic energy tends to propagate away from the sill to the basin interior, carried by density gradients. This form of internal energy is referred to as the internal tide and has the potential for enhancing vertical mixing in deep water.

OAERRE (Oceanographic Application of Eutrophication in Regions of Restricted Exchange) is a three-year EU-funded project to study the processes that lead to eutrophication in fjord-like environments. The physics component of OAERRE focuses on exchange processes. In June 2001 scientists from SAMS and the School of Ocean Sciences at Bangor conducted a hydrographic survey of upper Loch Etive to investigate mechanisms of energy exchange and dispersion at the sill, and the subsequent propagation and dissipation of the internal tide.

SAMS research vessels were used to investigate the density structure throughout the upper layers of the basin, and to conduct a detailed 3D survey of the flow structure over the sill at Bonawe. Instrumented moorings were deployed throughout the basin, making continuous recordings of water temperature, salinity and current velocity.

A first assessment of current data shows an intense jet of water entering the upper basin over virtually stationary deeper water. The sheer that develops between these regions is undoubtedly a source of turbulence and mixing energy. A great advantage of using Loch Etive for such a survey is that the relatively short period of intense observations can be set against the long record of observations in the SAMS archive. ●

Dr Finlo Cottier is a research scientist in the expanding marine physics group at SAMS.

Convective Chimneys in the Greenland Sea

Professor Peter Wadhams, SCOTT POLAR RESEARCH INSTITUTE

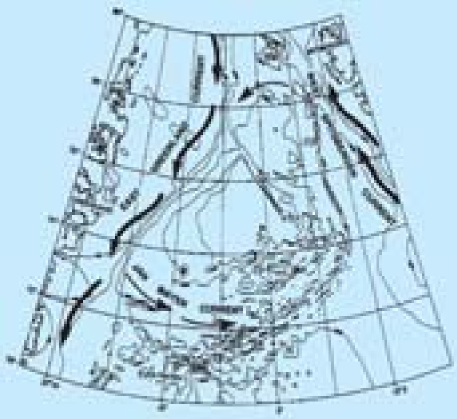
Open-ocean deep convection, which feeds the global thermohaline circulation, occurs at only three known northern hemisphere sites – in the Greenland, Labrador and Mediterranean Seas. These sites, small in size, are of great importance for ocean climate. In the Greenland Sea convection occurs at the centre of a cyclonic gyre which is bounded to the west by the cold East Greenland Current, advecting polar ice and water from the Arctic Basin, to the east by the warm northward-flowing West Spitsbergen Current, and to the south by the cold Jan Mayen Current, which diverts to the east from the East Greenland Current at about 72-73°N (Figure 1).

Deep winter convection in the Greenland Sea was thought to have ceased around 1970. Evidence from the structure of Greenland Sea Deep Water, and from tracers, suggested that significant ventilation last occurred in 1971 and that the typical depth reached by convection is now only 1,000-1,200 m. To predispose a region for convection there must be strong atmospheric forcing (to increase surface density through cooling or sea ice production), and existing weak stratification beneath the surface mixed layer (*e.g.* in the centre of a cyclonic gyre with domed isopycnals). One cause of decline in convection is assumed to be global warming. When air temperatures increase both thermal convection and the occurrence of frazil-pancake ice in the Odden ice tongue within the Jan Mayen Current zone are reduced. Odden could produce a positive salt flux through ice formation followed by advection of the young ice out of the region by northwesterly winds – a salt refinement process. These changes were enhanced since the 1990s by a positive North Atlantic Oscillation Index, giving a warm easterly wind anomaly which hinders the growth of Odden (none in 2000 and only minor growth in 2001).

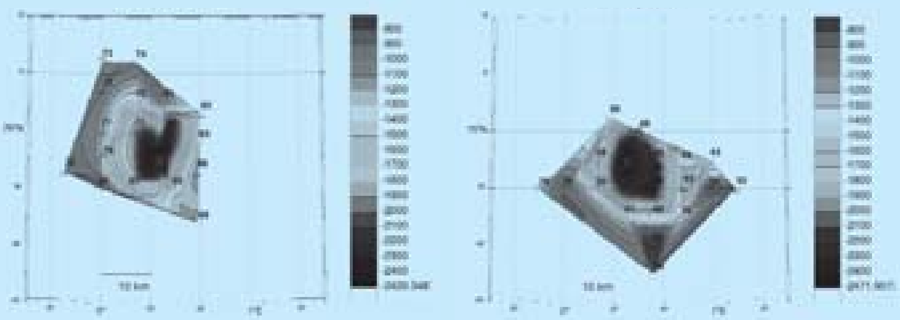
Surprisingly, during two winter cruises in 2001, we discovered a narrow (10 km diameter) convective chimney in the gyre centre at 75°N 0°W, extending to below 2,400 m. It was stable in shape for a month during which its centre moved only 700 m. Figure 2 is a contour map of the depth of convection. The feature was still in position in October although capped by fresh water.

The contour plots show that not only is this the deepest convection recorded in decades, but the chimney itself is extraordinary because of its small size, long-term stability and stationarity (Figure 3). For the chimney to attain geostrophic equilibrium it has to be in anticyclonic rotation, and it is relevant that Gascard detected long-lived anticyclonic eddies of diameter 10-20 km in the region using floats at 240-530 m. Most of these eddies migrated slowly, but one situated at 75°N 0°E remained stationary for two months.

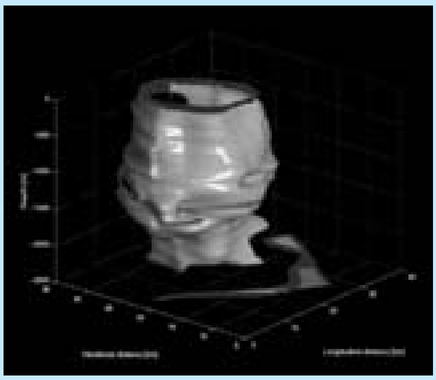
Since sea ice did not reach this location in 2001 or 2000 the origin of the overturning must be surface cooling rather than salinity enhancement. Yet the corresponding winters were not unusually cold, so the origin of this feature is at the moment an enigma. Questions such as whether other such features exist in the central gyre region, its lifetime, and the mechanism of its decay and impact on water structure at depth, can be answered only by further survey work. We ourselves will be back at the site in February 2002.●



ABOVE FIGURE 1: The bathymetry and surface current pattern in the Greenland Sea.



ABOVE FIGURE 2: The 2001 convective chimney: contour maps of depth of convection from surveys by "*Jan Mayen*" 22-23 March (left) and "*Lance*", 20-22 April 2001 (right).



ABOVE FIGURE 3: The shape of the chimney: a 3-dimensional view of the –1.0°C potential temperature surface as it displaces the warmer (-0.9°C) subsurface water in the region surrounding the chimney.

AUTUMN MEETING, THURSDAY, 1 NOVEMBER 2001, STIRLING UNIVERSITY

Marine Progress on Rio +10

Dr Hamish Mair of Heriot-Watt University invited six authoritative speakers to talk about the various changes in sustainable development in the marine environment since the UN Conference on Environment and Development - commonly referred to as the "Earth Summit" - in Rio de Janeiro in 1992. The over 100 guests attending the one-day meeting at Stirling University witnessed interesting presentations and participated in diverse and lively discussions inside and outside the lecture theatre. Three of the six presentations are summarised in the following pages. Professor Alasdair McIntyre furthermore presented a very enlightening talk about 'The Census of Marine Life: an emerging global programme', and Dr Rupert Ormond gave a beautifully illustrated presentation about the state of the world's coral reefs. Micheal Ó'Cinnéide, director of the Marine Institute, Ireland, reviewed and evaluated developments and experiences in the Irish Sea.

SAMS would like to thank Dr Hamish Mair for organising and chairing a very topical meeting. Thanks also to Stirling University for providing the meeting facilities, and to Dr Donald McLusky for local organisation.

A MARINE ACT FOR SCOTLAND

Alistair Davison, WWF SCOTLAND

The UK has a rich marine heritage. Its 20,000 kilometers of coastline border one ocean, three seas and arguably the busiest body of water in the world, the English Channel. Our marine habitats are diverse, including recently discovered deep water coral reefs at the edge of the continental shelf, the Shetland Isles with their sub-arctic influenced marine life and the lush seagrass meadows in the warmer waters off the Scilly Islands to the far south west. Human pressures and demands upon the marine environment also vary around the UK as the majority of the UK's population is concentrated in the south east of the country.

The management of the UK's marine environment has historically been based upon a presumption of free access to common resources. In contrast to the terrestrial situation, marine management has developed by managing different human activities separately - a sectoral approach. Integration of these sectors and wider ecosystem considerations within management of the seas is currently poor and generally restricted to coastal marine protected areas.

The management of the UK's seas continues to be beset by three institutional problems: -

- For the most part, the UK's marine resources are not owned and therefore only limited restrictions are placed upon the types and scale of utilisation;
- Governance of different aspects of the marine environment falls to a large number of authorities, each of whom pursue their own priorities;
- Generally there is a lack of strategic co-operation in management of the marine environment between authorities (Berry, in prep).

Few now argue that the current approach to marine management is sustainable or can continue to operate in a sectoral manner. At last it appears that the tide is turning, across the UK and Europe. Beyond Europe's boundaries, in the international community over the last decade, there has been an evident shift towards formally defined, legislated Integrated Marine Policy - be it a Marine Act, Ocean Act or Ocean Policy (MacGarvin, 2000).

There are now increasing opportunities for greater co-ordination of effort and stakeholder involvement within new policy and legislative initiatives from the EC and international bodies such as the Oslo Paris Commission. To ensure that the benefits of these opportunities can be enjoyed throughout the UK, WWF are convinced that new devolved legislation, a Marine Act, would be required to ensure the future of our seas.

The Marine Act would draw together the disparate strands of marine management throughout the devolved UK administrations and require a consistent duty of care, policy integration and the adoption of an ecosystem approach to the management of our seas. In our busy seas it is only by taking such a bold approach to marine management that a vision of healthy seas supporting sustainable livelihoods and thriving coastal communities can be achieved and maintained.

REFERENCE:

Berry, C. (in prep) *Marine Stewardship.* A draft report to WWF Scotland. Edinburgh.

MacGarvin, M. (2000). *A Marine Act for the United Kingdom?* www.wwf-uk.org/orca/info.asp

Marine Progress on Rio +10

The EC Water Framework Directive

Anton Edwards, SCOTTISH ENVIRONMENTAL PROTECTION AGENCY

The preamble to the Rio 1992 Agenda 21 stated optimistically:

"Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being. However, integration of environment and development concerns and greater attention to them will lead to the fulfilment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. No nation can achieve this on its own; but together we can - in a global partnership for sustainable development."

Agenda 21 itself aimed to improve the position of the poor and the ill of the world: it sought to give more influence to many societal groups *via* money, science, education and internationalism. Underpinning these human objectives was a strong emphasis on the sustainablity of human activities and on conservation of the natural environment - air, land, freshwater and sea. In Europe, the most influential development since has been the passing of the EC Water Framework Directive (WFD). With an emphasis on sustainability, and in a combined approach with the directive on Integrated Pollution Prevention and Control (IPPC), the WFD will bring all Europe's waters, even those physically heavily modified for legitimate human use, up to good ecological condition.

The WFD draws together much community water legislation from the last thirty years. The means of improvement are clear and a continuation of some previous national approaches: monitoring of the condition of surface waters; comparison of results with standards; classification; and consequent pressure to improve conditions so as to meet conservation objectives by the application of the best available technology. Public participation in the process has to be explicit and will proceed *via* transparent River Basin District Management Plans.

Technically, in surface water bodies such as coastal or estuarine (so-called transitional) waters, the WFD will require the characterising of various types of water and the definition of reference conditions for the types. Classification will then proceed by comparison of the measured state of each body with the reference conditions for the type, leading to one of five classes (High, Good, Moderate, Poor and Bad). Any bodies failing to reach Good status will be improved. The cycle of characterising, monitoring, classification and improvement will turn every six years from 2009.

Within this process, with its emphasis on the biological condition of surface waters, there will be for many years to come a need for the expert opinion of a large cadre of marine biologists and ecologists.

Marine Progress on Rio +10

Seabed Scars from Deep-Sea Trawling

Professor John D Gage, SAMS

The deadly efficiency of modern trawlers, although regulated by fishing quotas and total allowable catches, is well known to threaten both fish stocks and the fishermen's livelihoods. Due to overfishing of traditional grounds the fishing industry - with the help of a grant-aid for building powerful new boats - has been forced to target new deep-water species whose most probably very slow growth rates make the likelihood of a sustainable fishery look doubtful. But what is less appreciated is that the aggressive trawling methods used in depths of thousands of metres may be inflicting severe long-term damage to a previously pristine, but little known, deep seabed whose biodiversity was so stunningly brought into our living rooms by the BBC's Blue Planet series.

What little we know of this impact has been obtained incidentally from other research programmes. In an oil industry funded survey on the upper continental slope off the island of Lewis, SAMS scientists found that 12% of the seabed photographs showed significant scouring marks made by trawls (Figure 1, Roberts *et al*., 2000). The physical impact on delicate organisms such as glass sponges will be obvious (Figure 2). We can only guess about the wider effects of clouds of disturbed sediment settling and thereby smothering seabed organisms.

We have already seen an unregulated 'boom-and-bust' fishery for the Orange Roughy in the deep waters off Australia and New Zealand, where these extremely slow-growing fish were very quickly depleted. When scientists found that trawling was furthermore causing massive damage to delicate organisms on the seabed, conservation measures were introduced to protect seamounts where the fish aggregated. Off northern Europe, deep-water fishing now threatens the massive but fragile reefs of the cold-water coral *Lophelia pertusa*, which forms a diverse habitat for hosts of different species. The largest of these coral-built mounds - thought to be thousands of years old - were discovered only recently off Norway and southern Ireland. After pictures of smashed coral (Figure 3) were shown on Norwegian television, the largest of these biodiversity hotspots, the Sula Ridge, was closed to fishing.

Off NW Scotland, the Darwin Mounds - discovered in 1998 - support fragile growths of *Lophelia* as well as fields of xenophyophores, relatives of the humble *Amoeba,* who grow to a 'giant' size of up to 5 cm across. But almost immediately evidence was seen of damage caused by trawlers dragging huge "rock-hopper" trawl rigs over them. The government has indicated its intention to introduce legislation for protection of the Darwin Mounds as the first marine protected area in deep water. But until such legislation is introduced, trawling damage will continue here and elsewhere. There is a growing suspicion that significant areas of coral - which Edouard Le Danois mapped in his classic book "Les Profundeurs de la Mer" as occurring over vast swaths of deep-seabed to the west of the British Isles - may already have been damaged.

Why has science taken so long to obtain an understanding of the wider environmental effects of trawling on seabed communities? The reason is partly political, with the unfortunate dichotomy of responsibilities between Fisheries and Environment in Brussels. Concern by fisheries biologists over ecosystem impacts of trawling seems generally not to extend beyond other fish species. And last but not least it is because environment bodies such as the UK Natural Environment Research Council have simply not funded any research investigating the deep seabed impacts by trawling. It is ludicrous that relevant science, which should be essential to underpinning the UK government's promised Marine Stewardship Report, is hamstrung in such a way.

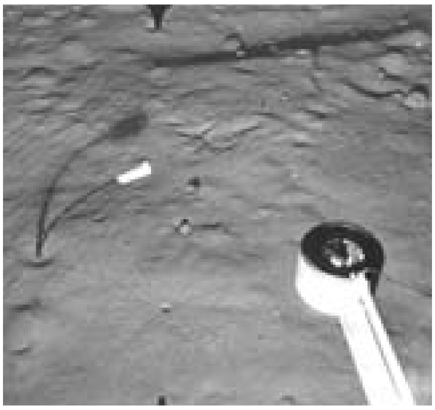
REFERENCE:

Roberts, J.M, Harvey, S.M, Lamont, P.A, Gage, J.D, Humphery, J.D (2000) Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides. *Hydrobiologia* **441:** 173-183.

BELOW FIGURE 1: Seabed at 885 m depth off St Kilda gouged by trawl boards.

© J.D. Humphery, POL

BELOW FIGURE 2: Pristine seabed at 1,295 m off Lewis with a stalked glass sponge bent over in the current.



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BELOW FIGURE 3: *Lophelia* coral at 250-300m depth severely damaged by trawling on the Iverrygen in the Norwegian Sea.

© J.H Fosså, Institute of Marine Research, Bergen

My PhD Project

Getting into Deep Water!

Glaciation and Oceanic Circulation

Clara Morri, SAMS/UHI

© J. Howe, SAMS

ABOVE: *RRS James Clark Ross* in heavy seas

This PhD research aims to investigate the role of climate change on deep-water sedimentary environments in the North Atlantic. Extensive seismic surveys and core sampling were conducted over a period of two years by the British Geological Survey in collaboration with a consortium of oil exploration companies. A detailed analysis is being applied to sediment cores collected from the Northern Rockall Trough in water depths from 500 to 2,500m. The research concentrates on the time period from the Last Glacial Maximum (20,000 years ago) to the Holocene (10,000 years ago to the present day).

Five cores - collected from an east-west transect from the top of the Anton Dohn Seamount to the slopes of Rockall Bank - have been analysed with techniques such as magnetic susceptibility, grainsize and microfossils. In addition, the cores have been subject to carbon and oxygen isotope analysis.

The deep-water sediments of the northern Rockall Trough are influenced by both the northward surface flow of warm Atlantic waters and the southerly deep transport of cold nutrient-rich water from Arctic regions. Consequently, the Rockall Trough is an ideal area to study changes in climate and its influence on ocean circulation.

Climate in the North Atlantic is highly variable. The Last Glacial Maximum was the complete antithesis of our present climate. The transition from the extreme cold to the modern climate was not simple. At least three stages of deglaciation have been established. Onset of warm climates such as that prevailing today were punctuated by a series of cold events that returned large areas of Northern Europe to near glacial conditions as recently as 9,000 years ago. The timing and duration of such events still remain unresolved today.

The combined effects of alterations in ocean circulation and climate change influence sedimentation in the Rockall Trough. During a period of cold climate, sediments in the central regions of the Rockall Trough had a strong glacial input, represented by the occurrence of coarse-grained material from icebergs, either as they melted or overturned. Some of these areas, notably around banks and seamounts, provide clear evidence that levels of deposition are closely linked to strong flows of deep ocean currents.

A drilling cruise last summer on board the *RRS James Clark Ross* provided valuable first hand experience in seagoing surveying and data collection. In October 2001, the award of a Marie Curie Fellowship allowed pre-doctoral training hosted by the University of Svalbard and also at Bergen University. The three-month fellowship enabled a study of the effects of paleoclimate and sedimentology at these outstanding institutes with a number of international scientists.

Clara Morri is a second year UHI PhD student working under the supervision of Dr John Howe and Professor Graham Shimmield at SAMS and Dr Martyn Stoker of the British Geological Survey.

Aquaculture and Environmental Research

Dr Kenny Black & Dr Ray Leakey, SAMS

Researching the environmental effects of aquaculture has traditionally been seen as a highly applied science area, somewhat shunned by purists. Over recent years, however, researchers have realised that marine fish farming represents a unique research opportunity to develop process understanding and test hypotheses along steep environmental gradients in sediments and the water column. In general, salmonid farming takes place in relatively pristine areas. It is thus possible to study in isolation the effects of this activity on key ecosystem processes against the background of natural variability.

At SAMS we use fish farms as sites for experimentation in bioturbation and pelagic ecology studies.

BIOTURBATION

Tom Pearson's classic paradigm of the response of soft sediment infauna to organic enrichment (Pearson and Rosenberg, 1978) has become perhaps SAMS' most widely cited paper. We are interested in taking this qualitative model and developing quantitative relationships in terms of carbon supply, mixing rates, community structure and consequences for oxygen flux and the redistribution of contaminants.

Our first field campaign in 2001 focussed on Loch Creran. To assess bioturbation and its consequences we observed and measured a variety of biological and chemical features at four selected stations along a transect away from a fish farm. Station 1 was beneath the farm and station 2 at the edge, with 3 and 4 essentially outside the influence of the farm but station 4 had much greater evidence of megafaunal surface activity.

We hypothesise *inter alia* that bioturbation depth will increase between stations 1 and 4 mediated by large animals. However, bioturbation intensity in the surface sediments may decrease between stations 1 and 4 due to reduced macrofaunal biomass. Bioturbation depths were assessed using tracers such as chlorophyll a and ^{238}Th. These are supplied to the sediment surface and have half-lives of about 20 days. Tracers found deep in the sediment must therefore have been transported there recently. Tracer distribution down the core can thus indicate both intensity of diffusive mixing in the upper part of the core and any non-local transport to depth by larger animals.

The results of this and complementary studies are being assimilated into models. Much of this work will be transferred to Svalbard (Spitzbergen) in April 2002 as part of a Large Sale Facility project and later in June 2002 followed by a cruise of *James Clark Ross*. Our Arctic experience will doubtlessly be reported in a future SAMS Newsletter.

PELAGIC ECOLOGY

It is well established that phytoplankton populations in coastal waters can be influenced and controlled by the availability and relative proportions of dissolved inorganic nutrients. Likewise, planktonic bacteria are influenced and controlled by the quality and quantity of dissolved organic nutrients, such as dissolved carbon and nitrogen. Fish farms release a range of dissolved nutrient compounds into coastal waters. However, their impact on the structure and function of pelagic microbial communities has received little attention.

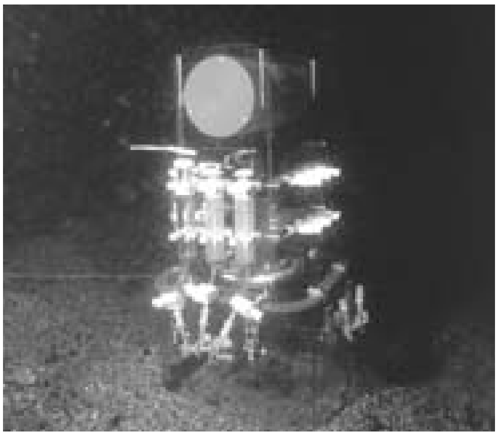
Recent studies undertaken by SAMS scientists have recorded enhanced planktonic bacterial activity in the vicinity of fish farm cages in a local sea loch. Such a response is to be expected in any natural water body subjected to enhanced inputs of organic material and offers the opportunity to investigate the effect of changes in the quality and quantity of nutrients on pelagic microbial communities. Future research, as part of the SAMS Northern Seas programme, will examine this microbial response to nutrient inputs in more detail *via* both laboratory and field studies. ●

REFERENCE:

Pearson, T. H. and Rosenberg, R. (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Reviews*, **16**: 229-311

Dr Kenny Black heads the Coastal Impact Research Group at SAMS and is a member of the Executive Group. He recently spoke as an independent scientist at the Aquaculture Inquiry in the Scottish Parliament (see page 16).

Dr Ray Leakey is a SAMS Research Fellow and leads the Pelagic Plankton Group at Dunstaffnage.



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ABOVE FIGURE 1: Benthic flux chamber used for *in situ* measurements of oxygen and nutrient fluxes in sediments in Loch Creran

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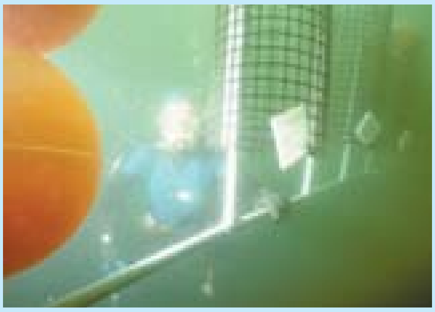
ABOVE FIGURE 2: Sediment mound of the echiuran worm *Maxmuelleria lankesteri* observed at sites outside the influence of fish farms

Sustainable Aquaculture @ SAMS

Dr Maeve Kelly & Dr Elizabeth J. Cook, SAMS

© T. Wilding, SAMS

ABOVE: Biofilters are deployed by divers at fish farms and control sites



© T. Wilding, SAMS

ABOVE: Filter feeding organisms settle on biofilters, potentially reducing the particle flux to the sea bed

© J.M. Roberts, SAMS

With an annual growth rate of 10%, aquaculture has been the world's fastest growing food production system for the past decade. As the yields from capture fisheries are stagnating globally, the development of aquaculture is such that its produce will soon outstrip that from wild capture fisheries. In Europe this corresponds to an annual production of some 1.46 million tonnes of finfish, crustaceans, molluscs and aquatic plants. In the UK, the aquaculture industry equates to over 1,000 fish and shellfish farming businesses, operating 1,400 sites and employing more than 3,000 people. In 1998 the total value at first sale of aquaculture products was £289 million.

At SAMS research into promoting the sustainability of aquaculture systems continues. Sustainable aquaculture is exploitation at a level which does not diminish environmental quality. Acceptable exploitation should, however, also consider the socio-economic needs of a region.

Our work on sustainable systems includes developing new aquaculture species, new cultivation systems and integrated aquaculture systems.

NEW SPECIES, INTEGRATION AND NUTRIENT BALANCE

Fin-fish can be thought of as nutrient enriching species. They are fed high-energy feeds resulting in a net input to coastal waters of an estimated 46 kg nitrogen and 4.9 kg of phosphate per tonne of fish produced. Our aim is to cultivate such nutrient enriching species alongside nutrient extracting species, such as filter feeding shellfish, grazing animals such as sea urchins, or seaweed which absorbs dissolved nutrients and acts as a bioremediator.

Research at SAMS has shown that sea urchins thrive in the salmon-cage environment. As well as the environmental benefits, sea urchins also provide the salmon grower with a second saleable crop. Protocols for growing large numbers of sea urchin juveniles have been developed in the SAMS sea urchin hatchery. The developing sea urchin cultivation industry can thus be independent of the vulnerable wild sea urchin populations.

BIOFAQS: BIOFILTRATION & AQUACULTURE

BIOFAQs - a new EU-funded project at SAMS - investigates how effective biological filters (bio-filters) are in reducing the environmental impacts of organic inputs from intensive mariculture. Accumulations of organic material on the seabed can lead to sediment anoxia and the release of hydrogen sulphide, which effects the benthos and potentially also the cultured fin-fish. Field studies are monitoring the effectiveness of filter feeders on the bio-filters in removing fine particulate material from the water column before it reaches the seabed. Environmental impact models are being used to predict the benefits of bio-filter deployments. These models are being validated by studies at fish farms on the west coast of Scotland, in the Mediterranean, the Adriatic and in the Red Sea.

HARMFUL ALGAL BLOOMS

Excessive nutrient input from anthropogenic sources can cause the prolific growth of marine organisms such as algae. More research is required before we can judge if the perceived increase in harmful algal bloom frequency is linked to changes in nutrient ratios due to anthropogenic sources. In 1999, however, the UK experienced its first major closure of shellfish fishing and cultivation areas due to the occurrence of domoic acid - which can cause Amnesic Shellfish Poisoning (ASP) - in shellfish. At SAMS researchers studied the occurrence of the ASP toxin in king scallop populations. The data show that the toxin is largely (to more than 99%) confined to the scallop's hepatopancreas, which is discarded during shucking. The controversy continues over what level of restriction should be applied to the shellfish harvesters when the ASP toxin is prevalent, while protecting the public and allowing economic survival of the industry. Future research at SAMS will ascertain if domoic acid impacts shellfish fecundity, and examine means of speeding up its depuration from the scallop tissue. ●

Dr Maeve Kelly is a project leader in Invertebrate Biology & Mariculture at SAMS. Dr Liz Cook is a research scientist on the BIOFAQs project and is based at Dunstaffnage.

The Aquaculture Inquiry in the Scottish Parliament

Dr Kenny Black, SAMS

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In response to a petition, and having been denied a public inquiry by the Scottish Executive, the Transport and Environment Committee of the Scottish Parliament last year set up its own "rolling inquiry" into the Scottish aquaculture industry. Written and oral evidence has been taken from a wide range of interested parties: from the industry to the regulators; private individuals to government agencies. On the 12th of December 2001, I joined Dr Dick Shelton, formerly Director of the Fisheries Research Services, Pitlochry Laboratory, and Professor Randolph Richards, Director of the Institute of Aquaculture at Stirling University, to be interviewed as independent scientists.

The full transcript of the meeting can be found on the parliamentary web site (http://www.scottish.parliament.uk/official_report/cttee/trans-01/tr01-3102.htm) but I summarise here the main themes of the meeting:

- Carrying capacity and the SE Locational Guidelines
- Moratorium on new sites and scientific uncertainty regarding carrying capacity
- Integrated Coastal Zone Management
- Polyculture, integrated aquaculture and new species
- Reporting of fish escapes and creation of exclusion zones around salmon rivers
- Strategy and regulations for sea lice control including fallowing
- Environmental consents by SEPA including promoting Best Available Environmental Practice
- Monitoring, audit and enforcement

The discussion was wide ranging but the highlights related to carrying capacity and to the issue of sea lice and the decline in wild salmonids on the west coast. The panel was in general agreement that regulations in Scotland were balanced more in favour of protecting the environment from the effects of sea lice medicines than from the lice themselves. In my opinion, sea lice numbers should be monitored by statute, and farms that cannot adequately control sea lice numbers, within the limits of medicine use imposed by SEPA, should have their biomass consents reduced. New ways to facilitate the relocation of fish farms from sheltered sea lochs to more exposed coastal areas are urgently required both to reduce transmission of sea lice and to aid dispersion of nutrients and medicines.

There was a call for more openness of information, including putting husbandry data into the public domain (*e.g.* lice counts) and for the criteria underlying the implementation of the Locational Guidelines to be made more transparent.

I thoroughly enjoyed the experience of giving evidence to the Committee. I am hopeful that the current debate will increase awareness of the complex environmental issues surrounding this industry allowing politicians and the public to make more informed decisions on its future. The Scottish Executive has promised a revised Strategy for Aquaculture Development in Scotland and it is to be hoped that at least some of the good ideas generated during the Parliamentary Inquiry are explored.

SAMS is in a good position to provide independent, high-quality science and expertise to underpin the industry (and its regulation) as it develops and takes on new technologies with increasing recognition of the complexity of the environment on which it depends.

Dr Kenny Black heads the Coastal Impact Research Group at SAMS.