QUALITY OF SAMS RESEARCH RECOGNISED

At the end of last year SAMS received the 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

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.

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

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

© O.Peppe, SAMS

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, 8

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 wer
phr
rdecrd-ngs wf tater dtemer aure , sainicyInd tur .

Marine Progress on Rio +10

The EC Water Framework Directive

The preamble to the Rio 1992
Agenda 21 stated optimistically:

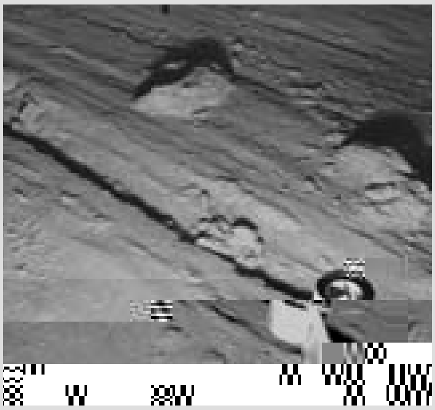
"Humanity stands at a defining moment

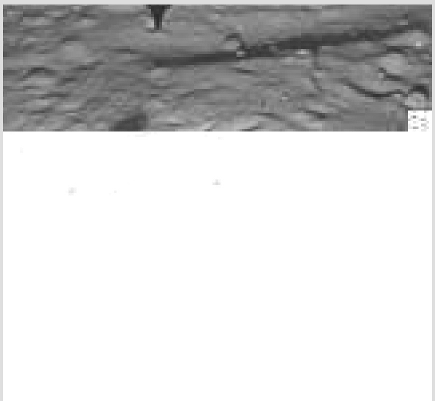
Marine Progress on Rio +10

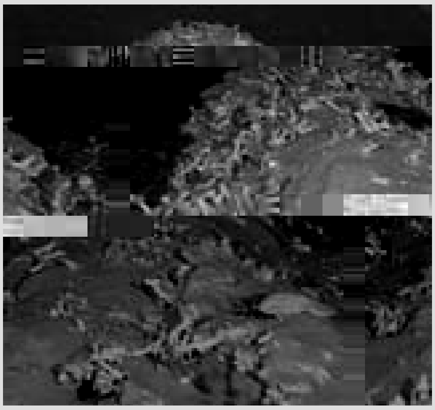
Seabed Scars from Deep-Sea Trawling

Professor John D Gage, SAMS

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*







My PhD Project

Getting into Deep Water!

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.

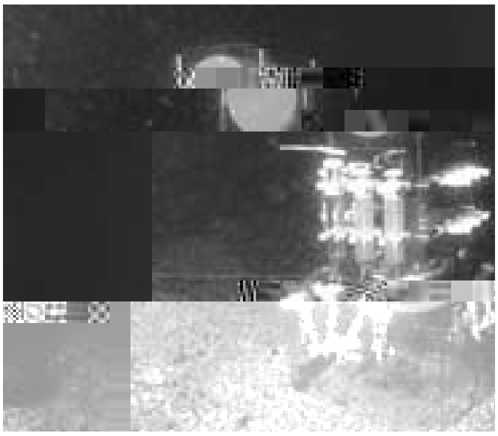
Recent studies undertaken by SAMS scientists have recorded enhanced planktonic bacterial activity in the vicinity of fish farm cages in a local sea loch. Such a response is to be expected in any natural water body subjected to enhanced inputs of organic material and offers the opportunity to investigate 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
.

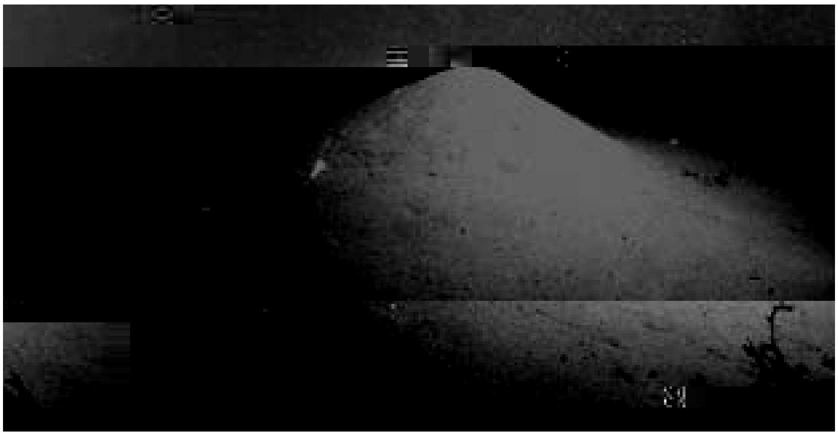
Dr Kenny Black heads the Coastal Impact Research Group at SAMS and is a member of the Executive Group. He recently spoke as an independent scientist at the Aquaculture Inquiry in the Scottish Parliament (see page 16).

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



© D. Hughes, SAMS

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

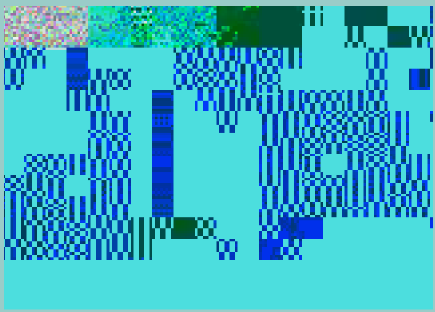


© D. Hughes, SAMS

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

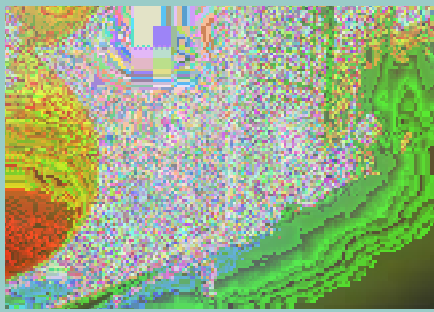
Sustainable Aquaculture @ SAMS

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.

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