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DIRECTOR'S INTRODUCTION

PROFESSOR GRAHAM SHIMMIELD

This Annual Report comes at the end of the first year in which the entire research, educational and financial activity of the Dunstaffnage Marine Laboratory has been under the ownership and management of SAMS. The Agreement between NERC and SAMS was finally ratified on 16th April 2002 by the SAMS President, Dr Ian Graham-Bryce. SAMS Council has guided us towards a new vision for the Association and for the Dunstaffnage site, with a new building under construction and associated changes in financial management that are described below. These will place SAMS in a better position to take advantage of the opportunities now available to us in our dual role as a research and education centre. It is with immense pride that I can look back at what we have achieved through the collective hard work of everyone involved in the new activities that we have engaged in this year.

A key component of the research activity has been the funding of the "Northern Seas Programme" reported below. This core strategic grant for five years funded by the NERC allows us to pursue and develop, in an interdisciplinary fashion, some major scientific objectives and issues facing the more northern latitudes of Europe. Through a rigorous peer-review process, we have convinced the NERC Science Innovation and Strategy Board that there are major natural and man-made pressures on the coastal and deep-water marine environment that are pertinent to the sea loch/fjord/continental margin north of 55°N to the polar ice. These include aquaculture, deep sea fishing, oil and gas activities and climate change. The Northern Seas Programme, which represents 45 % of our staff effort, forms the backbone of the research base and helps to develop and promote the culture of interdisciplinarity in the marine sciences to address and solve major environmental challenges. We are delighted to have received this support from NERC, and I am confident that the product resulting from the work will enhance the reputation of the UK's research in this region.

Whilst we were engaged in securing the core programme funding, SAMS staff involved in the UHI Millennium Institute (UHI) were also participating in the Research Assessment Exercise. For us, this happened at short notice following a decision by the Scottish Higher Education Funding Council to review the UHI. The outcome (Grade 4, Environmental Sciences) was a great fillip and a recognition of the reputation of the work of SAMS. Especially gratifying, was the grade achieved by a (generally!) young cohort of researchers and the contribution from a colleague at each of Perth and North Highland Colleges, pointing to the capacity for development and growth in the future. Our involvement with the UHI continues to advance with the highest number of undergraduates so far enrolling for the BSc Marine

Science this academic year. The recognition of UHI as a Higher Education Institute now sets it well on the way to achieving its Charter as a university over the next five years.

Behind the scenes, the academic development of SAMS has been matched by the innovation and dedication of the new build project team led by Dr Ken Jones. Over the reporting year, success in attracting substantial (£2.55 million) funding from the European Regional Development Fund for the new European Centre for Marine Biotechnology, and support from Argyll and Islands Enterprise, and Highlands and Islands Enterprise, has led to confirmation that the new £8 million laboratory would become a reality. Looking out of the window (and on the new SAMS webcam!), the reality is plain to see as the steel rises out of the ground. The NERC has supported us with £2 million, awarded under the changes in the lease associated with the new Agreement plus a contribution, leaving a mortgage of £3 million to repay over the next 15 years. To do this, and protect the charitable objects of the Association, SAMS has created a wholly owned subsidiary through a motion passed at its AGM on 6th November 2001. SAMS Research Services Ltd will conduct certain commercial projects for SAMS and, in turn, will own the new European Centre for Marine Biotechnology, and the new building. Such changes are reflected by sister organisations such as the Plymouth Marine Laboratory, and illustrate the new approach to funding and operating research institutions. For the staff at Dunstaffnage, this will introduce clarity into their activity, clearly defining when a product is deemed of commercial value to the organisation. Arising from these changes, we now see the emergence of the "SAMS Group" and the development of the Dunstaffnage campus.

New appointments continue to be made to the Association. Notable among these, although not taking up his post until January 2003, is Professor Peter Wadhams and his research team from the Scott Polar Research Institute in Cambridge University. Peter brings a wealth of knowledge and a substantial international reputation in the field of sea ice dynamics, complementing the Northern Seas Programme very well. We wish Peter and his colleagues every success in their new environment with us at Dunstaffnage. Traditionally in this section, I have highlighted the contribution of the SAMS Fellows and Honorary Fellows. Now, the laboratory encompasses significant achievements from a wide range of staff described below, and the importance of brevity precludes individual citations here. Nonetheless, I pay tribute to each individual staff member and their dedication and inspiration that make the laboratory such a joy to work in. Our close-knit community will go from strength to strength, moving forward on our tripartite strategy of fundamental research, education, and enterprise. This Annual Report reflects the new project structures in place at SAMS and represents an important milestone in the history of the Association. I commend it to you.

GRAHAM SHIMMIELD
DIRECTOR OF SAMS

THEME A

UNDERSTANDING FJORDIC SYSTEMS: INSIGHTS FOR COASTAL AND OCEANIC PROCESSES

DR KEN JONES

Fjords are the characteristic coastal typology for northern coastal seas. The presence of entrance sills and over-deepened basins can result in long water residence times and high retention of materials input from the land via rivers and glaciers, along with the potential for accumulation of nutrients and organic matter from natural and anthropogenic sources both distant and local. Restricted exchange predisposes fjordic systems to eutrophication and hypoxia; it also regulates colonisation and dispersal of organisms through its control on the import and export of planktonic larval stages. Fjordic systems are of considerable economic importance, providing sheltered, deep-water anchorages and productive fisheries, encouraging human habitation of their shorelines and their use for leisure purposes. Temperate fjords have become a major location for development of the aquaculture industry in Europe. Because of their geographical isolation, and despite increasing human exploitation, many fjordic regions are still considered pristine environments. Some contain unique species assemblages and habitats worthy of protection by European Law. For example in Scotland, parts of the Firth of Lorn and Loch Creran are amongst those regions of UK coastal waters designated as potential Special Areas of Conservation. The conflicting economic and conservation demands relating to these environments have made management of the sustainable development of these regions a high priority and set a major scientific challenge of developing a good understanding of the ways in which fjords and their contained marine ecosystems function. Within Theme A of the Core Strategic Research Programme, five projects, encompassing the disciplines of physical oceanography, microbial ecology, animal ecology and geochemistry, address specific scientific questions that have key significance for the functioning of ecosystems in northern coastal waters. Detailed reports on these projects are given below. In addition, some of these studies exploit the physical and hydrographic characteristics of fjordic systems as 'natural laboratories' in which hypotheses relating to whole ecosystem function may be tested.

Our fjordic studies have been strengthened through the development of international links with Scandinavian colleagues: (a) through the European network of high-latitude scientists, ENVINET (b) through successful bids to use the European Large Scale Facilities at Norwegian Polar Institute's base at Ny Alesund, Svalbard and the Kristineberg Marine Research Station in Sweden and (c) through collaboration with partners in European Framework V projects such as HOLSMEER and OAERRE, described in detail elsewhere in this report. These associations have enabled us to place the results of work in Scottish sea lochs in a wider geographical context and through the concept of studies along a 'latitudinal gradient' have added the extra dimension of comparing responses of fjordic processes to the variability in climatic and other forcing associated with latitudinal position.

K J JONES (SAMS)

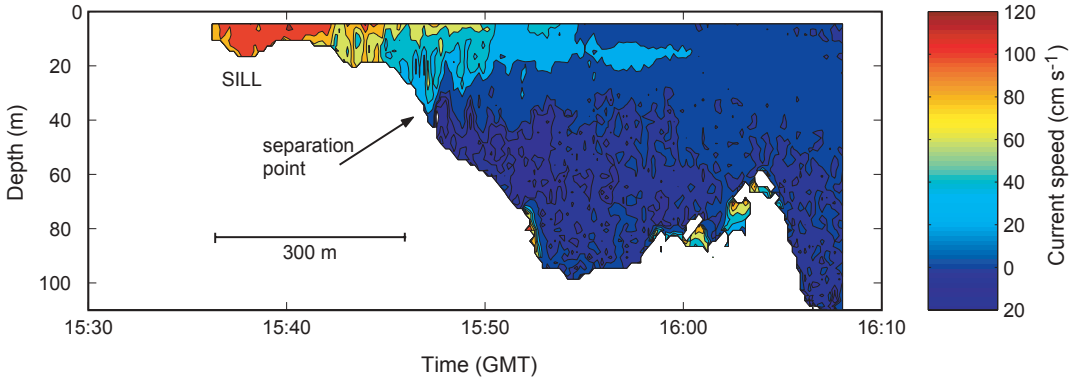


Fig. 1. Cross-sill flow at maximum flood tide from the sill (left), towards RE5 (right) from the vessel-mounted ADCP.

ENERGY DISSIPATION IN FJORDS

Sea lochs and fjords may be classified into two broad categories; wave-type and jet-type, depending on the properties of the tide as it passes over the sill and the degree of stratification in the fjord basin. If flow is greater than the speed of the mode 1 internal wave, a tidal jet forms (Fig. 1) on the lee side of the sill – a jet-type system; if the flow is less than the speed of the mode 1 internal wave, then an internal oscillation of the pycnocline at tidal frequency can be excited – a wave-type system. The physical pathways whereby tidal energy is transformed at the sill and propagated through the fjord have implications for the efficacy of vertical mixing in each system type which in turn has important consequences for nutrient, carbon and and oxygen fluxes. Our two primary study sites are the upper basin of Loch Etive, a jet-type fjord, and the Clyde Sea, a wave-type fjord.

Loch Etive

Our investigation into the energy transfer in this jet-type fjord involved a week-long, two-boat, four-mooring experiment in the upper basin of Loch Etive in July 2001. The hypothesis under investigation was that only a small proportion of the barotropic energy at the sill is lost through baroclinic wave drag to the internal tide, due to the supercritical nature of the tidal flow to the mode 1 internal tide at the sill (Fig. 2). We suggest that the rapidly dissipated tidal jet and weak internal tide are in part responsible for the long mean renewal period (1.3 years) of the deep basin waters.

Further observation of the Loch Etive system included evidence for aspiration, a process where the cross-sill flow draws water up from depth. Our data show that on both flood and ebb tides, basin water from nearly 40 m depth is drawn to the surface and onto the sill, at a depth of 10 m. This mechanism of vertical transport, and the subsequent compaction of isopycnals on the sill, is likely to be a significant contribution to mixing in the surface waters.

Clyde Sea

Work in the Clyde Sea has focused on three distinct aspects of the system. First, horizontal exchanges across the shallow sill extending from Kintyre to the Ayrshire coast have been investigated using data from ship surveys and an array of three moorings. There is demarcation of the well-mixed water of the North Channel and the stratified Clyde Sea water by a well-developed front. The position of the front and the subsequent exchange of water is forced by the barotropic tide and analysis of the hydrographic data has revealed heterogeneous flow across the sill. Further investigation using a combination of the observations and tidal models will allow the estimation of horizontal exchange rates, bringing a clearer understanding of the factors determining the flow characteristics.

The second aspect of our study of mixing in the Clyde Sea is the transfer of energy across the sill and its subsequent transformation and dissipation. The objective was to map the vertical turbulent mixing processes in this wave-type fjord based on basin-scale observations. Work on this has been completed, essentially comparing the flux divergence of the internal tide energy with the measured rate of turbulent kinetic energy dissipation. An agreement between the two was taken to indicate the significance of the former in modifying deep-water properties within the basin.

Fjordic and estuarine sites typically undergo seasonal changes in the vertical structure of the water column. In essence, these changes influence the stability of the water column through the variation in horizontal fluxes, thermal exchange at the surface and the efficacy of mixing processes. The third element of our work in the Clyde Sea has been to look at salinity, temperature and current data from a near-continuous 13-month mooring deployment in Inchmarnock Water, north of Arran. Using these data we have revisited the internal tide phenomenon and are developing our understanding of the seasonal changes in internal wave energy in relation to the changing stratification of the water column.

M INALL, CR GRIFFITHS, F COTTIER and P PROVOST (SAMS)

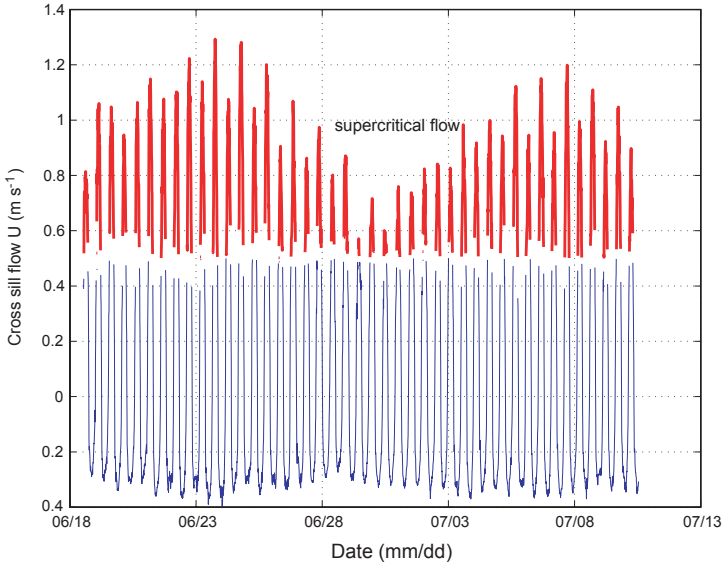


Fig. 2. Depth-averaged cross-sill flow from the sill-moored ADCP. Red line indicates flow rates supercritical to the mode 1 internal wave speed.

RESPONSES OF PELAGIC MICROBIAL COMMUNITIES TO CHANGES IN THE QUALITY AND QUANTITY OF NUTRIENT INPUTS

Fjordic systems receive high levels of natural and anthropogenic nutrients. Changes in climate and human activity may alter both the quality and quantity of these inputs leading to changes in ecosystem structure and function. The pelagic microbial community plays a key role in how these coastal systems respond to changes in nutrient inputs. However, our detailed understanding of how inorganic-organic nutrient interactions influence microbial community structure and function, and hence carbon flow in fjords, remains incomplete. To address this question effectively, we also need to investigate the importance of interactions between different microbes in structuring pelagic microbial communities. The results can then be synthesised into refined models of microbial community dynamics, which will provide insights into the effects of nutrient additions to fjords. These objectives have been addressed in year 1 via a range of field and laboratory projects funded by the Northern Seas core programme, a SAMS fellowship, a New Zealand Fellowship, an EU Framework V grant (OAERRE), two NERC thematic grants and one NERC small grant. Two of the projects are reported below.

Response of the pelagic bacterial community to nutrient inputs within sea lochs

Point sources of nutrients from fish farm cages offer an opportunity to examine the response of pelagic microbial communities to changes in nutrient inputs. Previous studies at SAMS have documented the biomass and activity of the total pelagic bacterial community near salmon farm cages. The effect of nutrient additions on bacterial community composition is less well understood, however. Samples were taken therefore at differing proximity to fish farm cages in a local sea loch, in order to examine possible changes in the diversity of free living and particle-attached pelagic bacteria, using molecular methods. Bacterial clone libraries have been generated and amplified, and now await DNA fingerprint analysis. Data from these studies will underpin further microcosm experiments examining the response of the pelagic bacterial community to changes in organic nutrients.

CJS BOLCH, M HART and R LEAKEY (SAMS) and D GREEN (NEW ZEALAND SCIENCE AND TECHNOLOGY FELLOW)

Modelling microbial communities: the influence of nutrient ratios

The small size of pelagic microbes and the complexity of the communities in which they exist make them particularly difficult to study routinely by experiment. Mathematical models provide a means to simulate the interactions between pelagic organisms in the sea. In particular, study of these models allows assessment of the behaviour of pelagic food webs in response to different nutrient conditions, amounts and ratios.

The phytoplankton component of different pelagic ecosystem models varies considerably in complexity. Simple methods relate growth to the concentration of certain nutrients (usually nitrogen) in the water. More complex models make growth a combined function of light, temperature and nutrients, while others attempt to describe growth as a function of multiple resources. In this project we used a closely controlled data set from large-scale enclosure experiments that received a range of N and Si concentrations, to investigate the predictive behaviour of models of different levels of sophistication.

Our results showed that to obtain accurate predictions of our experimental data, it was necessary to incorporate the utilisation of both N and Si by the diatoms in our model. We were then able to predict the timing and magnitude of the increase in diatom and other phytoplankton biomass. Furthermore, a single version of the model could predict the outcome of different experimental situations without changing its structure or parameterisation, provided that it included a representation of the concentration of both nitrogen and silicon inside as well as outside the phytoplankton cells.

Further extension of these models is envisaged to develop them as a tool to assess water quality changes that may result from variation in the rate of input of nitrogen and silicon from the land to coastal seas.

K DAVIDSON and J DEARMAN (SAMS) and A TAYLOR (PLYMOUTH MARINE LABORATORY)

Fig. 3. Measurement of a subsample of adult barnacles *(Semibalanus balanoides)* from a digital photograph. The coin is used as a scale object.

BEHAVIOURAL AND PHYSIOLOGICAL COMPONENTS OF CONTROL OF SEA LOCH ECOSYSTEMS

Ecological processes that are important in structuring populations and communities are strongly reliant on the behaviour and physiology of individual organisms. If these individual characteristics are important at the scale of coastal ecosystems and not just for survival and growth, there must be demonstrable effects on key ecosystem processes. Examples are interactions with other species as prey, predators or competitors, delivery of ecosystem functions or as structuring of the physical environment by, for example, the building of biogenic reefs. Studies of ecological processes at small scales, at SAMS and elsewhere, have shown the importance of the link between behaviour, physiology and community structure. Yet this link has rarely been directly addressed at spatial scales encompassing whole coasts or wider latitudinal gradients. To remedy this, we use sealochs as replicate mesocosms for marine systems spread over large spatial scales. By comparisons over these scales, we aim to determine the relative importance of large-scale physical and biological forcing functions, such as temperature and pelagic primary production, versus small-scale processes like predation and competition, controlled by behaviour and physiological performance. Studies in 2001 were designed to reveal the degree to which coastal marine ecosystems are shaped by bottom-up factors: physical conditions and primary productivity.

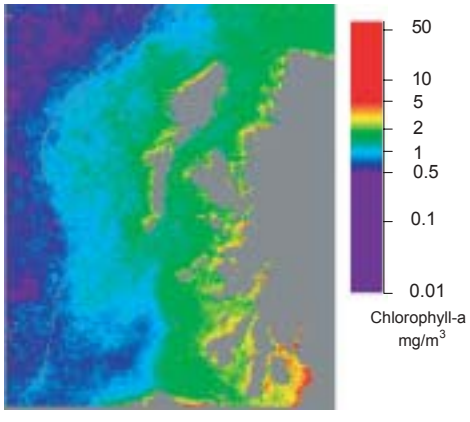
We chose two ubiquitous species to indicate production at two trophic levels; the barnacle *Semibalanus balanoides* and the plaice *Pleuronectes platessa*, as the initial focus for comparison of growth and population structure among sealochs. The key question was: Can spatial variation in growth-rate responses of key species predict spatial scales of variation in ecosystem function among sea lochs? To answer this we did rapid censuses of adult and juvenile barnacles at two sites within each of over 30 sea lochs from the Clyde Sea to the north coast. Barnacle populations were imaged with digital macro photography and individuals were measured using interactive software developed for the purpose (Fig. 3). Sizes of juvenile plaice were compared among sea lochs by sampling 22 sites in August 2001.

For barnacles, the emergent large-scale patterns suggested that local effects such as water flow, depth, aspect or wave exposure were relatively unimportant compared to whole-loch or regional scale forcing. Subsequent analysis of satellite data including SeaWIFS chlorophyll and AVHRR temperature showed that juvenile growth and adult size were very strongly correlated with average chlorophyll for adjacent sea areas (Fig. 4). In contrast, size distributions of juvenile plaice populations were highly variable on smaller scales. Analysis of variance over the range of spatial scales covered by the sample sites showed that the size of young fish in August was most variable at 150-300 km scales, and next most variable between adjacent sites.

RS BATTY, MT BURROWS, R HARVEY and L ROBB (SAMS)

BIOTURBATION: RESPONSES TO ENVIRONMENTAL FORCING AND CONSEQUENCES FOR REDISTRIBUTION OF CONTAMINANTS

The bioturbation project has three strands, the first of which, *TRANSFLUX*, is an interdisciplinary study of faunal community structure, bioturbation potential and effects on geochemical cycling and pollutant redistribution along an organic gradient imposed by a fish farm in a Scottish sea loch. The role of benthic fauna in the mediation of impacts from fish farming is known to be significant, with dramatic effects on carbon and nitrogen dynamics in sediments. Factors stimulating the responses of benthic animals to organic food supply are examined in the *CUES* sub-project. These factors are important in determining spatial and temporal variability in bioturbation rates and consequences. Chemotactic responses have been demonstrated by other workers in echiurans, holothurians and sipunculans and it is possible that methylated sulphur compounds such as DMSP and DMS produced by phytoplankton may act as a chemical trigger for the benthos. There is increasing evidence that large, deposit-feeding organisms dominate biogenic mixing and in this initial year we sought to examine the behavioural responses of megafaunal burrowers to organic carbon input. The third strand of our work, *WORMOD*, aims to improve particle deposition models through the incorporation of biological mixing rates, but is not described this year.



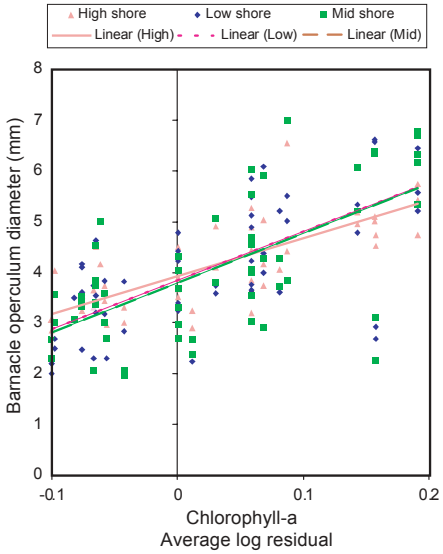


Fig. 4. Regional measures of primary productivity in coastal waters e.g. chlorophyll-a average from all SeaWIFS images in 2001 (left) are the best predictor of population size-distribution in barnacles (right). In contrast, variables such as average depth, sea loch surface area or freshwater runoff are poor predictors of barnacle size.

TRANSFLUX

This investigation sought to relate the benthic macro- and megafaunal community structure to fluxes of oxygen and vertical sediment micro-profiles across a transect of organic enrichment in the central muddy basin of Loch Creran; to further relate these to the supply of organic carbon, its sources and its quality, and to determine the consequences of bioturbation for metal pollutant dynamics. Four stations in Loch Creran, representing a gradient of organic input centred on a major fish farm, were sampled in August and November 2001. A wide range of techniques allowed *in situ* measurements (from profiling landers, benthic chambers, time-lapse video and diver observations) to be coupled with laboratory analyses of a range of geochemical parameters. These data were integrated with those from bottom-mounted current meters and macrofaunal community analysis. Results indicated profound effects on sediments from large scale mariculture, both in terms of biological and biogeochemical parameters, although in this case the effects were limited to a small area. Bioturbation depth and diffusive mixing rate, derived from chlorophyll-a profiles (Fig. 5), increased away from the farm but were greatest where organic carbon quality was intermediate. Epifaunal activity increased in the vicinity of the farm, where epifauna may contribute significantly to removal of labile carbon. Macrofaunal abundance and biomass generally followed patterns predicted from successional models. Indices incorporating structural and functional components of benthic communities show relationships with mixing intensity that could be useful in elucidating mechanistic responses of benthic communities to environmental change (Fig. 6). Megafauna may influence the burial of carbon profoundly, through their own bioturbatory activity and structuring influences on macrofauna and microbial communities, but further work using alternative sampling methods is necessary to clarify their role.

KD BLACK, T BRAND, E BREUER, C CROMEY, SM HARVEY, K JONES, J OVERNELL, TM SHIMMIELD and T SAWYER (SAMS)

CUES

In order to determine the behavioural response of large burrowing infauna to chemical cues, such as DMS, present in phytoplankton, the behaviour of burrowing thalassinidean crustaceans was recorded under infra-red light in laboratory mesocosms with the experimental addition of phytodetritus. Similar field experiments were carried out in upper Loch Creran where echiuran burrows were targeted using underwater video with infra-red lighting. Activity was also characterised by measurement of sediment ejecta pre- and post phytodetritus addition. To date, the mesocosm experiments have provided no evidence that input of phytoplankton stimulates increased foraging on the sediment surface by the crustaceans. However, preliminary analysis of videotapes indicates that there may be more subtle effects on sub-surface activity, with the animals altering the areas of the burrow within which they are active pre- and post addition. In the field, phytodetrital enrichment of sediment around burrow openings of the echiuran worm *Maxmuelleria lankesteri* did stimulate increased activity, as evidenced by burrow sediment ejecta collections. However, measurements of sediment turnover rate suggest that the monthly pattern of activity of *M. lankesteri* in Loch Creran may differ from that previously recorded in Loch Sween. Experiments are due to continue later this year and may clarify whether there are geographical and seasonal differences in the responses of these organisms.

LA NICKELL, DJ HUGHES, MT BURROWS, A HATTON and L ROBB (SAMS)

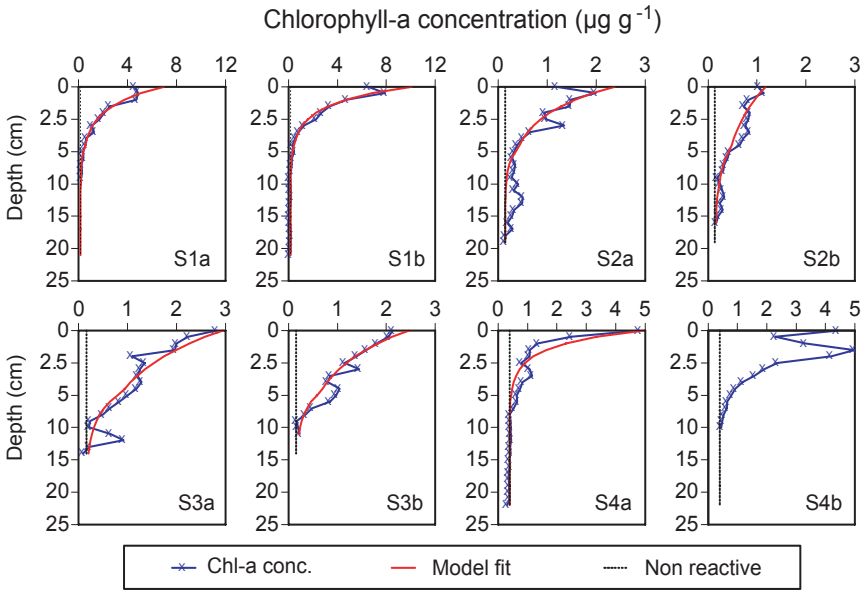


Fig. 5. Down-core profiles of chlorophyll-a (blue) in 2 cores taken at stations 1 to 4 along an organic gradient. Station 1 is beneath the fish farm. The red line shows the modelled fit from which the biodiffusion mixing co-efficient was derived. The dotted line indicates non-reactive chlorophyll-a. Evidence of non-local mixing in core S4b meant that it was inappropriate to model this profile diffusively.

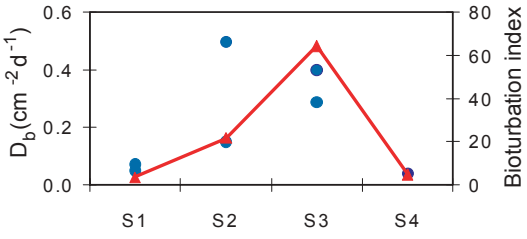


Fig. 6. Relationship between biodiffusive mixing coefficient Db, derived from chlorophyll-a profiles (circles), and Bioturbation Index (triangles) (modified from Swift 1993 to take account of structural and functional components of the benthic community) at stations along the Loch Creran transect. Station 1 is located at the fish farm.

PROXIES: HIGH RESOLUTION SEDIMENTARY RECORDS OF ENVIRONMENTAL AND CLIMATIC CHANGE IN FJORDIC ENVIRONMENTS.

In order to model predictions of environmental and climatic response to anthropogenic forcing, it is essential that we can identify the magnitude and timing of historical natural climatic variations, such as the Little Ice Age and the Medieval Warm Period, and interpret their influence on the ecosystem. To investigate the environmental status of such episodes during time periods before instrumental records were available, it is necessary to use proxy-indicators. These geochemical and biological palaeo proxies may be used to reconstruct such variations as fresh water inputs, sea surface temperature, salinity and the redox conditions of sediments and bottom waters.

Fjordic sea loch environments have sheltered water and high sedimentation rates. Such depositional environments are ideal for preserving high-resolution climate records in sediments, offering the potential to provide the annual to decadal resolution and environmental sensitivity necessary to reveal the extent and effects of environmental fluctuations. These include changes in terrestrial run-off, vegetation cover, denudation, and exchange with coastal waters. To this end, two gravity cores from the inner basin of Loch Etive, GC004 from a water depth of 110 m and GC005 from a depth of 143 m, were analysed and dated using ^{14}C (Fig. 7).

Sedimentation rates were calculated using ^{14}C for older sediment and a combination of ^{210}Pb, ^{137}Cs and stable Pb isotope (Fig. 8) for more recent sediments (core LE3). The sediment at the bottom of the gravity cores (approximately 200 cm deep) has an age of *c.*12000 years Before Present (BP).

Figure 8 indicates that the $^{206}Pb/^{207}Pb$ ratio and Pb (lead) concentrations vary with depth. Different sources of pollutant Pb have different $^{206}Pb/^{207}Pb$ ratios; natural Pb varies, depending on the source, but is typically around 1.20. Lead produced from heavy industry has a ratio of approximately 1.18, while alkyl lead which was added to petrol in the UK in 1922 has a ratio of 1.092. By measuring the ratio it is possible to calculate recent sedimentation rates and determine the quantity and source of pollutant lead.

Unfortunately, the gravity corer is not ideal for sampling very soft sediments in sea loch basins, as the top layers are frequently lost, along with data for the very recent past. We have solved this problem by building a new spear corer (Fig. 9) that can retrieve cores up to 2 m in length with the sediment-water interface intact.

TM SHIMMIELD, J HOWE and JM FOSTER
(SAMS)

Fig. 9. Sediment core recovered from Loch Etive using the new design spear corer. The intact sediment-water interface is indicated by the arrow.

Fig. 7. (left) Sediment core dates from Loch Etive show reasonable agreement for the two gravity cores, GC004 and GC005. The third core, from a short Sholkovitch corer that disturbs the top few cm much less, gives a very different date at around 60 cm. The x-axis scale represents the accumulation of sediment over time.

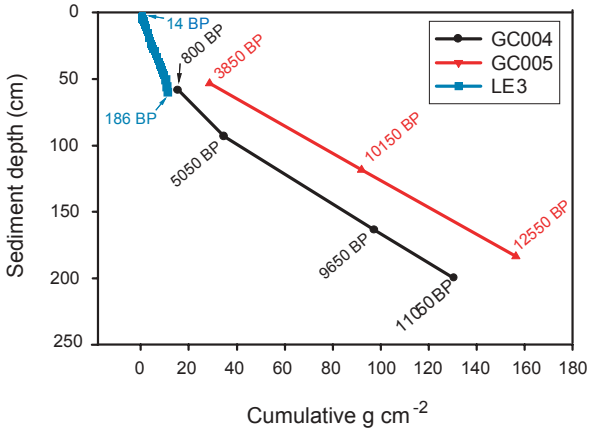
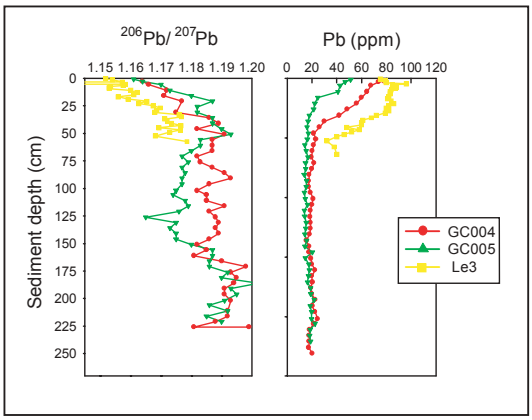


Fig. 8. (right) Pb concentration (ppm) and $^{206}Pb/^{207}Pb$ stable isotope ratio vs sediment depth in upper Loch Etive.



THEME B

OCEAN MARGINS: THE INTERFACE BETWEEN THE COASTAL ZONE AND OCEANIC REALM.

PROFESSOR GRAHAM SHIMMIELD

CARBON DYNAMICS AT OCEAN MARGINS

In this start-up year of the Programme, the Geochemistry and Deep-Sea Benthic Groups addressed the first of three sub-themes within Theme B, namely carbon dynamics at ocean margins. The boundary between the continental shelves and the deep ocean has been proposed as an important zone of carbon deposition and burial at the seabed. The benthic biota is believed to exert a major influence on the rates of mineralisation and burial of organic matter at the sediment-water interface, but there is great uncertainty over the extent to which these processes are affected by differences in benthic faunal composition.

For the first year's work, the Wyville - Thomson Ridge off NW Scotland was chosen as the study site. This is a submarine sill that has long been known to constitute a topographic barrier separating two distinct deep-water masses. To the south is the ~ 4° C water characteristic of this depth in the North Atlantic, while to the north there is sub-zero, Arctic water in the deep Faroe Bank Channel originating from the deep Norwegian Sea (Fig 10). Due to the relatively recent Quaternary recolonisation of the Arctic deep sea, these areas support quite distinct, yet here almost contiguous, benthic faunal provinces. This contrast provides a unique opportunity to test the extent to which benthic faunal composition and size structure determine rates of carbon cycling at the sea bed and hence serve to characterise 'biogeochemical provinces' at the benthic boundary. Discrimination of such provinces will help in more accurate budgeting of the role of the oceans in removing excess atmospheric carbon generated by man, which is generally accepted to be already causing global warming.

In late September 2001, RRS *Discovery* Cruise 257 established stations just to the north and south of the Ridge, hence avoiding potentially confounding effects of latitude on the flux of organic particles from plankton-based production at the surface that fuel the benthic system. The participants' expertise in hydrography, benthic biology and biogeochemistry was combined to address the strongly interdisciplinary cruise objectives. The benthic lander facility at SAMS provided state-of-the-art technology for *in situ* measurements of seabed processes, this being an important contribution to the work. The two study sites; north (WTN) and south (WTS) of the Ridge were in approx. 1,100 m depth.

Current meter moorings were deployed at each site, while water column parameters were sampled by CTD to obtain data on hydrographic profiles. Downwards particle flux and particle residence times were estimated using ^{210}Po and ^{210}Pb tracers.
The SAMS *Profilur* benthic lander was deployed to record sediment redox profiles *in situ*, while sediment-water oxygen and nutrient fluxes were measured by means of on-board incubation of undisturbed sediment cores from the sea bed. The sediment type found at the northern station, WTN, was sandy with gravel lenses at a depth of approximately 10 cm. The sediment type at WTS was a muddy sand with no gravel lenses. A number of cores were obtained at WTN allowing a full suite of analyses to be carried out, but

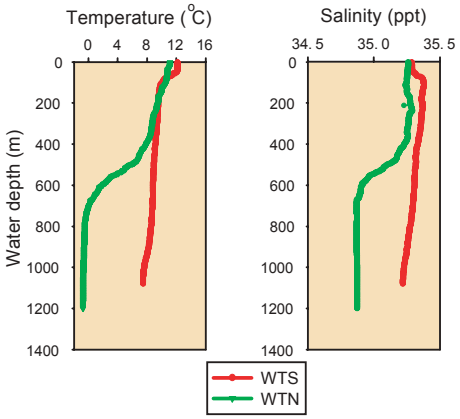


Fig. 10. Temperature and salinity *versus* depth for stations WTS (south) and WTN (north) of the Wyville-Thomson Ridge.

Fig. 11. *In situ* profiles of dissolved oxygen measured using the SAMS *Profilur* benthic lander. The green crosses are measurements made using inserted oxygen micro electrodes (units: mmole l^{-1}; the blue profile represents depth integrated oxygen consumption rates (mmole $m^{-2}d^{-1}$).

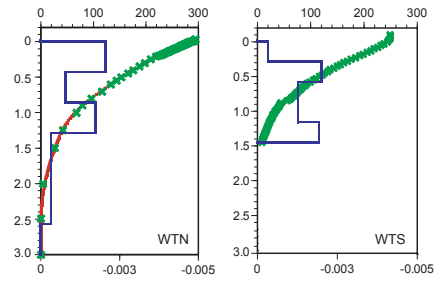
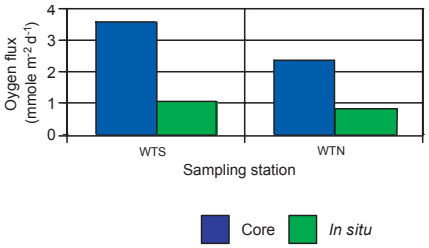


Fig. 12. Comparison between *in situ* and shipboard determinations of oxygen consumption at Wyville-Thomson South (WTS) and North (WTN)



worsening weather severely limited the number of cores at WTS resulting in no pore water extraction at this site. Cores were also sectioned for analysis of profiles of radionuclides (^{234}Th, ^{210}Pb), chlorophyll, lipids to characterise biogenic sediment mixing rates, and total organic carbon, along with solid phase and pore water trace metals. Others were sectioned for analysis of total abundance, biomass and vertical distribution of the benthic metazoan fauna, body size spectra and trophic group composition. Seabed photographs were taken for quantification of benthic megafauna and animal traces. These photographs, along with X-rays of sediment slices and careful hand dissection of burrow structure in box cores, provided data on the amount and styles of bioturbation by the larger burrowing organisms.

Dissolved oxygen profiles (Fig. 11) show a depth penetration of 2 cm (WTN) and 1-1.5 cm (WTS). Converting these profiles into diffusive fluxes (Fig. 12) gives derived fluxes of 1.02 mmole $m^{-2}d^{-1}$ (WTS) and 0.80 mmole $m^{-2}d^{-1}$ (WTN). When compared to the shipboard determined fluxes of 3.56 (WTS) and 2.34 (WTN) mmole m^{-2} d^{-1} the calculated ratios of *in situ*/core are 0.29 and 0.34 respectively. Calculated oxygen respiration rates and depth integrated O_2 consumptions were not significantly different from the diffusive oxygen uptake calculated from the profiles (Fig. 11). These data demonstrate the expected large difference in oxygen flux observed between the methods. As reported by previous workers, the difference between values given by the two methods provides an estimate of the community respiration. The preliminary results presented here give an indication that a quantitative relationship may exist between core and *in situ* derived fluxes.

Some pore water results from WTN are presented in Figure 13 for dissolved redox sensitive elements (U, Mo, Fe and Mn). The point above the origin indicates the content of the element in the water overlying the sediment. Uranium is soluble in oxidising conditions but insoluble (i.e. will be removed from the pore water) in reducing conditions. In contrast, manganese is soluble in reducing conditions and insoluble under oxidising conditions. The Mn profile from WTN indicates that oxygen is present to a depth of 4.5 cm; thereafter the concentration of Mn in the pore water increases suggesting there is a more reducing sediment at depth. The U profile also indicates that the sediments are oxidising to a depth of approximately 8 cm with the concentration of U in the pore water being similar to that of seawater (4 ppb). However at a depth of 8 cm (cf Mn profile) the U concentration increases reaching a maximum concentration of 9 ppb at a depth of 11.5 cm, thereafter the concentration falls to 2 ppb at a depth of 15 cm. The enhanced U concentration would suggest that the sediments are becoming more reducing, or that there is a different supply of U to the pore waters at this depth. This correlates with the depth of the gravel lenses.

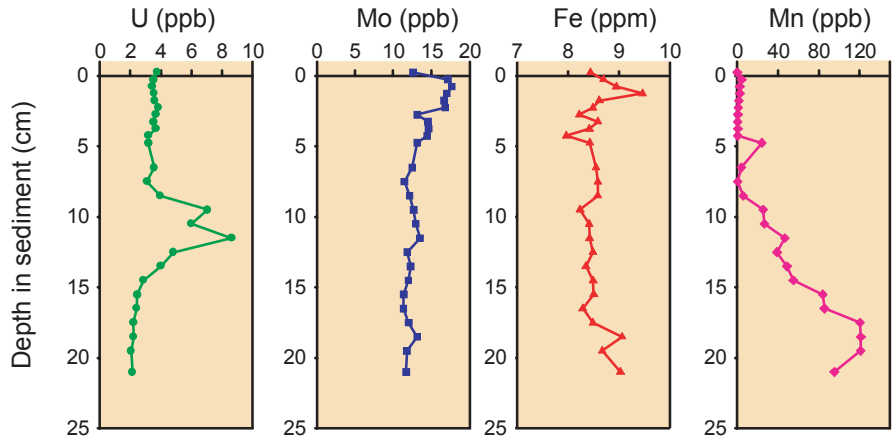


Fig. 13. Profiles for redox sensitive metals in a core from the Wyville-Thomson North station.

Unfortunately, bad weather restricted sampling time at the two stations, but although the number of samples was lower than hoped for, they were sufficient to address most of the cruise objectives. Analyses of hydrographic data, geochemistry core slices, faunal samples and seabed photographs are all still in progress. However, differences in benthic faunal composition and activity at the two sites were very obvious, both in seabed photographs (Fig. 14) and X-rays of sediment slabs from box cores. At WTN, the community is concentrated at the muddy sandy/gravely sediment interface as both suspension and deposit feeders, with little evidence of deep burrowing, while at WTS the sandy ooze showed fewer epifaunal animals, but much greater evidence of burrowing deposit feeders. The sediment incubations showed clear differences in sediment community oxygen consumption. Paradoxically, significantly higher rates were recorded at WTS than WTN despite the apparently lower epifaunal benthic biomass at the former. However, definitive estimates of benthic biomass are not available until sample processing is completed and temperature-related corrections to these rates have been applied.

Further analysis of results from the cruise will involve close links between geochemistry and biology staff in order to develop an integrated view of benthic processes at the study sites. A useful bonus from the cruise was the collection (by trawl) of living cold-water coral (*Lophelia pertusa*) at a coastal site east of Mingulay, Outer Hebrides, from which old records of coral were known.

The second sub-theme relates to the Ellett Line of hydrographic stations that extends from the Sound of Mull to west of Rockall. This work will be reported on at a later date.

JD GAGE, TM SHIMMIELD, KD BLACK, CR GRIFFITHS, SM HARVEY, ER BREUER, DJ HUGHES, LA NICKELL, JM FOSTER, OC PEPPE, PA LAMONT and T BRAND (SAMS)

THE ECOLOGY OF DEEP-WATER FISHERIES IN THE NORTHERN ROCKALL TROUGH

SAMS began its major programme on the deep-water demersal (bottom-living) fishes of the Rockall Trough in 1975. Initially, the emphasis was on seasonal studies on the biology of individual species and community studies linked to trophic ecology. The rapid development of the deep-water fisheries in the northern Rockall Trough since 1989 is a concern for the sustainability of the stocks. The landings per unit of fishing effort for all exploited species, including those shown in Figure 15, have decreased by more than 50%. If these deep-water fisheries are to be exploited in a sustainable manner, knowledge of the biology and life history of the fishes and of the impact of these fisheries on the ecosystem is essential. To this end, sub-theme 3 of the Programme has the following objectives. (1) To provide information on age estimates and life history characteristics of target and non-target fish species to underpin ecosystem-based management strategies for deep-water fisheries and (2) to construct simple food web models to better understand the effect of fishing on the deep-water ecosystem. Linked to Objective 1 is the recognition that a knowledge of stock identification is crucial to any management strategy. The results from work on the first of these tasks is reported this year.

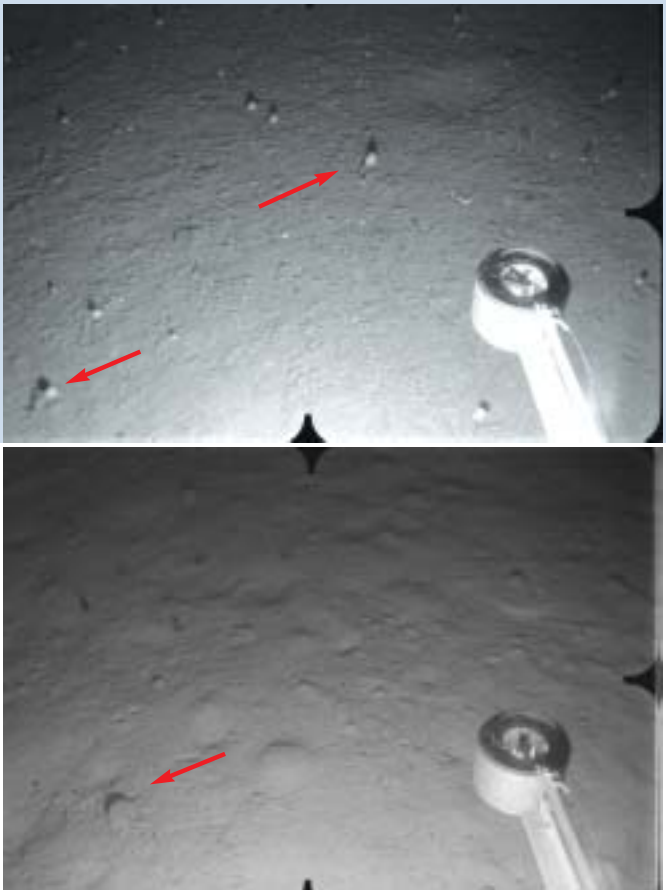


Fig. 14. Seabed images from north of the Wyville-Thomson Ridge (upper) and south of the ridge (lower). There is considerably more epifauna e.g. glass sponges (arrows) and brittle stars at the northern site. In contrast, the southern site shows signs of bioturbation in the form of numerous small mounds and pits. A xenophyophore is visible at lower left (arrow). The field of view in each is image is *c.* 1 m at the lower edge.

Fig. 15. Orange roughy, roundose grenadier and black scabbardfish, three of the fish species being exploited in deep water to the west of the British Isles. The current ICES advice on the status of these species is that they are outside safe biological limits.

We have addressed this problem through an EC shared-cost FAIR project entitled *Otolith microchemistry as a means of identifying stocks of deep-water demersal fish* (OTOMIC). This project aims to use Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to quantify the levels of trace elements present in some deep-water fish otoliths (ear bones) and assess their usefulness for stock discrimination. The concentrations of some of these elements can be measured using laser-ablation ICP-MS. The laser has excellent spatial resolution and, unlike other probe methods, minimum sample preparation is required. It can be used to examine discrete parts of the otolith, which is particularly advantageous for a fish species whose depth range may extend over several thousand metres throughout its life. Elemental signatures from several distinct water masses may be incorporated into the otolith during the life of the fish.

Laser-ablation ICP-MS has been used to analyse the otoliths of European hake (*Merluccius merluccius*), a commercially important species that is widely distributed throughout the Atlantic and Mediterranean, spanning a depth range of about 50 m to 900 m. Otolith samples were prepared by mounting in resin blocks and sectioning through the dorsal-ventral axis using a low-speed diamond-blade saw. The laser was used to ablate a series of spots, starting from the edge of the otolith and ending in the nucleus (the area within the first annual translucent zone) (Fig. 16). The nuclear area represents the first year of life and probably in hake this includes a larval, pelagic and early demersal settlement stage. Nursery areas for young hake tend to be on the shelf between depths of 50 - 200 m and older fish are found in deeper waters. Otoliths from large hake caught at about 300 m in Romsdal Fjord, Norway were found to have the highest concentrations of barium within the core and also slightly elevated levels towards the otolith edge (Fig. 17). Although barium is generally found in greater concentration at ocean depths, high concentrations in shallow waters have been associated with river run-off. In fjords, freshwater input tends to form a surface layer and therefore young, pelagic hake could be subjected to higher levels of barium in the surrounding waters. It is interesting to speculate whether this might indicate that hake either spawn in the fjord or are advected as larvae from outside the fjord.

JDM GORDON, SC SWAN and GB SHIMMIELD (SAMS)

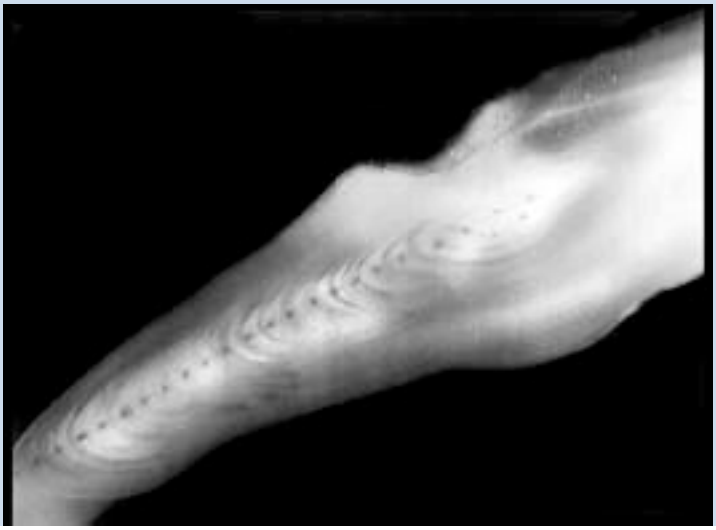


Fig. 16. Sectioned otolith of hake. Craters (indicated by the dark spots) are made by the laser during the ablation process. The vapourised material is then analysed by the ICP mass spectrometer.

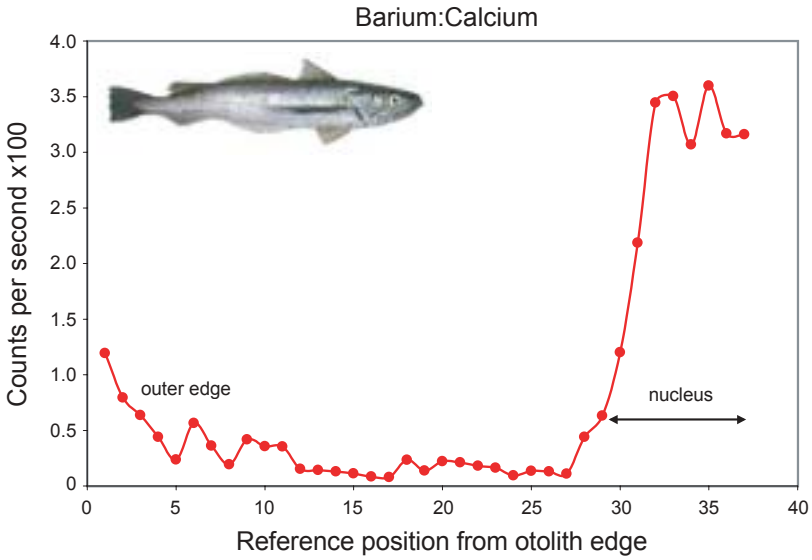


Fig. 17. The concentration of barium relative to calcium is highest in the otolith nucleus for this sample from Romsdal Fjord, Norway.

THEME C

TECHNOLOGY DEVELOPMENT

MR DAVID MELDRUM

Technology development at SAMS is driven by the need to develop new tools and technologies in order to retain a competitive edge in marine science. In particular, we need to move away from ship-based unrepresentative snapshot measurements towards a new generation of smart, autonomous platforms in direct communication with the laboratory. To achieve this, we are building on our existing track record in the use of miniaturised satellite technology for position finding and data telemetry, and the application of microprocessors as the kernel of smart instruments, to develop new packages such as landers and profilers.

Our objectives for 2001-2 may be classified under the generic headings of platforms, sensors and data handling. Much of the work has capitalised on previous NERC investment in enabling technologies (e.g. through LOIS) and on joint work with outside agencies (e.g. the DEFRA Deep Water Observing System programme), but we also maintain a critical overview of emerging technologies in other disciplines that might be turned to advantage in marine science.

PLATFORMS

The principal objective for this year has been to develop and build geochemical and camera landers capable of being deployed on the seabed for periods of several months. This work has been greatly assisted by the establishment at Dunstaffnage of a purpose-built lander development centre, funded as part of the JIF-supported Autonomous Marine Environment Research Stations (AutoMERS) programme. We have also welcomed Mr. Bruce Barr to the group, who is working as an engineer in support of lander operations.

Our fleet of landers consists of three fully autonomous vehicles (Fig. 18), two of which are designed to carry a number of different instrumentation modules in support of geochemical and biogeochemical research. These two landers have been used both offshore, as part of the Northern Seas research cruise on RRS *Discovery*, and inshore, as part of the OAERRE and Transflux projects. During each of these cruises, the landers have been deployed in their micro-profiling mode *Profilur*, whereby oxygen micro-electrodes are driven into the sediment in steps of as little as 50 µm in order to obtain very high resolution oxygen profiles across the sediment-water interface. Additionally, during the *Transflux* project, a biogeochemical study of bioturbation at a fish farm site, we used a newly developed benthic chamber (Fig. 19) for measuring the critical erosion threshold of the sediments. Based on a laboratory

Fig. 18. The SAMS lander fleet ready for deployment. In the foreground is the photo lander, which has returned new observations of cold water coral reefs. Behind are the two 'KC-landers', used in pioneering biogeochemical studies of the sediment-water interface.

design by Professor Gust from TUHH, Germany, we initially developed this novel *in situ* system as part of a project for Shell to aid the characterisation of drill cuttings piles in the North Sea. Unfortunately, despite extensive trials near Dunstaffnage on RVs *Calanus* and *Seòl Mara*, the system was not used in the North Sea this year because of logistical constraints.

Development work has now also started on an 'oxystat' system for the lander, as part of the new Arabian Sea programme. An existing benthic chamber design is being adapted so that oxygen levels in the chamber are maintained close to ambient levels, enabling longer term tracer studies to be carried out.

SENSORS

The main objective has been to work closely with collaborators in the creation of new fouling-resistant and high selectivity chemical sensors, and to further develop novel applications for GPS. Our close alliance with the Optoelectronics group at the Robert Gordon University has been a major step forward in the realisation of a new generation of chemical sensors for marine use, and we have just been granted a major award by Scottish Enterprise to take forward this work. We have also worked closely with a number of GPS receiver manufacturers, particularly uBlox in Switzerland, to harness the additional processing power available in the latest miniature receivers to construct highly integrated sensor and communications packages.

DATA HANDLING

Our aim here has been to implement the latest technologies in low power microprocessors, advanced data compression, and acoustic and satellite telemetry to maximise the return of useful data from remote, energy limited platforms (Fig. 20). A large element of this involves critically assessing new technologies that are emerging in other disciplines, such as personal mobile satellite communications. In this context we are amongst the very first groups worldwide to evaluate the Iridium satellite constellation for global two-way communication with remote sensor platforms.

We have also piloted the use of miniature mass-storage devices to record images from our Benthos high-quality digital stills camera. In its original guise, this camera was configured for use in real time, at the end of an umbilical cable. For use on our autonomous photo lander, it was necessary to re-engineer the camera and its software to store images on a 1 gigabyte hard drive. Currently this drive provides space for around 500 pictures, although this will increase dramatically when we upgrade the camera software to implement image compression.

DT MELDRUM, OC PEPPE, DJ MERCER, W THOMSON, RB BARR and J WATSON (SAMS)

Fig. 19 (left). The deep-sea microcosm on board RV *Seòl Mara*. This novel chamber has been deployed in Loch Creran to measure critical erosion thresholds of sediment under fish farm cages.

Fig. 20 (right). New technology in use at SAMS. In the background are two satellite transceivers; an Orbcomm unit (left) as used in our ice buoy deployments, and a new Iridium modem (right) complete with its antenna. The latter unit will permit two-way communications with sensor packages wherever they might be in the world. In the foreground (from l to r) are an IBM 1 gigabyte hard drive, a powerful Persistor CF1 processor, and a uBlox miniature GPS receiver.

GEOCHEMISTRY

DR TRACY SHIMMIELD

The group's involvement with the new Core Strategic Programme is wide ranging, with activity in three key research areas: bioturbation, proxy-indicators of environmental and climatic change, and carbon dynamics at ocean margins. Planning and execution of fieldwork have made heavy demands on the group, with staff being involved in both coastal (Loch Etive, Loch Sunart and Loch Creran) and deep sea (Wyville-Thomson Ridge, North Atlantic) cruises. However, the hard work has been rewarded by the collection of unique samples that are providing interesting results and are posing further scientific questions.

Along with the core strategic research, the group has been involved in a number of externally funded projects. These include HOLSMEER (Late Holocene and Shallow Marine Environments of EuRope), a European funded project investigating environmental and climatic change across Europe over the last 2000 years. Benthic processes in the Arabian Sea, funded by NERC, is investigating the interrelationships between the benthos, sediment biogeochemistry, and organic matter cycling. Finally, research into deep sea sedimentary environments of the north-western Weddell Sea, Antarctica was undertaken.

The analytical capabilities of the group have expanded with the purchase of new equipment for both trace element and radionuclide analysis. The Inductively Coupled Plasma Mass Spectrometry (ICP-MS) facility, the first UK laboratory dedicated to the microanalysis of marine skeletal material, has expanded to include an ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometer). This will be used in conjunction with the existing laser ablation technology to help answer a wide variety of questions in different marine disciplines e.g. climate change (corals), stock discrimination (fish otoliths) and pollutants in birds (shell composition). Furthermore, the addition to the gamma and alpha spectrometry facility of three new gamma spectrometers, one of which has sea-going capabilities, will allow the investigation of short term mixing within different sedimentary environments.

TM SHIMMIELD (SAMS)

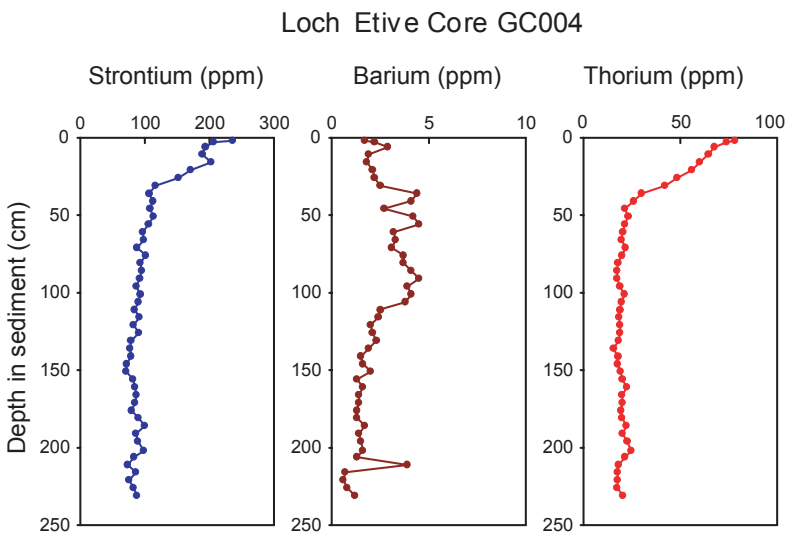


Fig. 21. Concentration vs depth profile of strontium (Sr), barium (Ba) and thorium (Th) in a sediment core from Loch Etive.

HOLSMEER: LATE HOLOCENE AND SHALLOW MARINE ENVIRONMENTS OF EUROPE

This research is focused on investigating the natural variation in climate change within north-west Europe over the last 2000 years. One of the main objectives of the project is to identify suitable palaeo proxy-indicators and calibrate them against recent instrumental data (e.g. sea surface temperature), which has been obtained over the last 50 years. When suitable calibrations are obtained it will then be possible to extrapolate back to times before instrumental data was available.

SAMS' main contribution to the project is to assess sediment accumulation within Scottish sea lochs over the last century, and to determine which geochemical indicators (Fig. 21) are suitable proxy-indicators to investigate high-resolution sedimentary archives of environmental change. The first sea loch to be investigated within HOLSMEER was Loch Etive, but the ^{14}C dating of a 2 m sediment core has shown that these sediments are 10,000 years old at the bottom of the core and therefore do not provide a high enough resolution to look at climatic change in detail over the last 2000 years. The research focus is now on Loch Sunart (Fig. 22), and in conjunction with colleagues at St Andrews we have obtained 3 m-long sediment cores from Loch Sunart which give a ^{14}C date of 2025 yr BP at a depth of 286 cm. It is hoped that these cores will hold the environmental archive required to allow us to determine the natural variation of climatic change in this region. This project is funded by the European Commission under the Framework 5 programme *Energy, environment and sustainable development*.

TM SHIMMIELD and GB SHIMMIELD (SAMS)

BENTHIC PROCESSES IN THE ARABIAN SEA: INTERRELATIONSHIPS BETWEEN THE BENTHOS, SEDIMENT BIOGEOCHEMISTRY, AND ORGANIC MATTER CYCLING

This research grant was awarded by NERC in October 2001 and involves four main partners: SAMS, University of Edinburgh, University of Liverpool and Southampton Oceanography Centre. The project is an interdisciplinary benthic process study investigating surficial sediments across the oxygen minimum zone on the Pakistan margin. The main objectives of the research are to assess biological community structure and function and how it controls the redox status and fluxes of dissolved organic carbon, nutrients and trace metals (Fig. 23) along with the alteration and burial of organic matter. The research will combine a quantitative study of benthic communities with comprehensive geochemical analyses of sediments and pore waters, tracer incubation studies and measurements of benthic fluxes and bacterial processes. These data should provide the foundation for improved models of diagenetic processes.

The research is focused on carrying out the majority of the measurements *in situ* using lander technology such as the *Profilur* (see p. 16) and *Elinor* benthic chambers. Four research cruises will take place in 2003 on the research vessel RRS *Charles Darwin*.

DEEP-WATER SEDIMENTARY ENVIRONMENTS OFF ANTARCTICA

Two transects were sampled during the ANDEEP cruise (see. also p. 20) using short cores (multi & box), seabed photography, video sequences and sediment profile images across the north-western Weddell Sea and South Sandwich Trench, Antarctica. The most southerly (Weddell) transect extends from the northwestern Weddell continental slope and across the abyssal plain to the fracture zone 1100 m – 4500 m deep, (66°S 50° W – 60°S 27°W). The second extends across the western slope of the South Sandwich Trench, east of Montague Island from 2200 m – 6300 m, (60°S 25°W – 58°S 20°W). This study aims to identify the modern and short-term palaeo-depositional environments occurring in the extreme deep-water areas within the region. Sites of active bottom currents, down-slope turbidity currents or low energy pelagic/hemipelagic settling will be identified and related to the rapid environmental change that has characterised these regions over the last 10,000 years. The fieldwork was aided by a grant from the Trans-Antarctic Association.

JA HOWE (SAMS / UHIMI)

Fig. 22. Gravity coring, Loch Sunart. © Tracy Shimmield

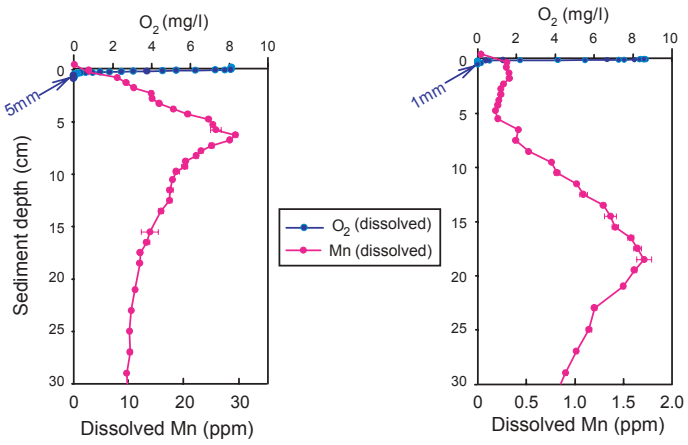


Fig. 23. Contrasting manganese and oxygen profiles obtained in two different cores with the *Profilur* lander.

DEEP SEA BENTHOS

PROFESSOR JOHN GAGE

Involvement in the SAMS Core Strategic Programme, and in particular the cruise in September/October to the Wyville-Thomson Ridge on RRS *Discovery* (see pp. 12-14), has renewed our interdisciplinary approach to benthic biology as part of a wider landscape in benthic processes, particularly those relating to the fate of organic carbon at the deep seabed. Our previous NERC-funded work in the Shelf Edge Study and in BENBO, has underscored the importance of benthic organisms, not only in processing organic particles as consumers, but also, by their burrowing activity, modifying biogeochemical reactions and rapidly transporting organic carbon deep into the sediment. However, as detailed below, the work also includes more traditional studies on variability in benthic populations, both spatial and temporal.

ANTARCTIC BENTHIC DEEP-SEA BIODIVERSITY: COLONISATION HISTORY AND RECENT COMMUNITY PATTERNS (ANDEEP)

SAMS is one of many institutions world-wide taking part in ANDEEP, a project that is investigating the deep-water benthic biology of the Scotia and Weddell Seas. Dr Bhavani Narayanaswamy took part in the 2nd leg of the ANDEEP cruise on board the German icebreaker *Polarstern* in spring 2002. Our objectives were to look at polychaete species diversity and composition on the east side of the Antarctic Peninsula, along the Abyssal Plain and in the South Sandwich Trench. The results should significantly augment knowledge in an area where the deep-sea benthic biology is very poorly known. The data will contribute to biogeographic studies to clarify taxonomic relationships and evolutionary origins of the evidently very rich benthic biodiversity in the Southern Ocean.

Samples were collected with a divided boxcorer (Fig. 24) yielding 25 sub-cores per box. The samples are being sorted in Germany before being sent out to different experts to identify the fauna. This work is being undertaken in collaboration with Dr Brigitte Hilbig – Zoologisches Institüt und Zoologisches Museum, Hamburg. Additional sub-cores were also collected and macrofaunal polychaetes will be removed and identified. The results will be combined with those of James Blake – ENSR Marine and Coastal Center, USA.

BE NARAYANASWAMY (SAMS)

Fig. 24. Box corer with sample on board RV *Polarstern* among icebergs in the Weddell Sea.

DECADAL CHANGES IN DEEP-SEA INVERTEBRATE POPULATIONS

As part of a joint NERC/industry funded CONNECT B award to Professor John Gage and Dr Brian Bett (Southampton Oceanography Centre), Dr Narayanaswamy has started work on analysis of a benthic sample time-series that was started in 1996. The samples were taken down a depth transect on the eastern flank of the Faroe-Shetland Channel, as part of the broad-area survey of the Atlantic Margin undertaken for the oil/gas industry and the Department of Trade and Industry. The transect has been sampled every two years since then, and the first two data sets formed the basis for her PhD, awarded last year. With this unique time-series it is hoped to establish the basis of natural variability in benthic populations in this area, particularly polychaete worms, so that such changes can be separated from any that might be caused by industry operations in deep water.

Peter Lamont is working on polychaete worms in boxcore samples taken by SAMS in a small area of the continental margin off Scotland in water depths of between 800 and 2000 metres. These samples date back to June 1976, with data from 20 cores at present spanning the seven years up to 1982. Samples from 1995, taking the span of the time-series to 19 years, are now being examined. This painstaking work has shown that many of the polychaete species are new to science and remain to be described. Nevertheless, the work has shown that a change in species composition has occurred (Fig. 25 a, b). In these plots it should be noted that the declining number of species numbers per core with depth (the Y axis) simply reflects decreasing numbers of animals present in any small area of seabed with increasing depth. In actual fact there seem to be greater numbers of species present with increasing depth over much larger areas of seabed.

The time-series pre-dates the development of a deep-water fishery that has expanded greatly in the last 10-15 years along this section of the continental margin. It is not yet clear, however, whether this trawling, which is known to physically disturb the seabed, along with the discarding of unwanted fish species (about half the total catch, which sink as dead carcasses to the seabed) can be related to these changes.

P LAMONT, B NARAYANASWAMY and JD GAGE (SAMS)

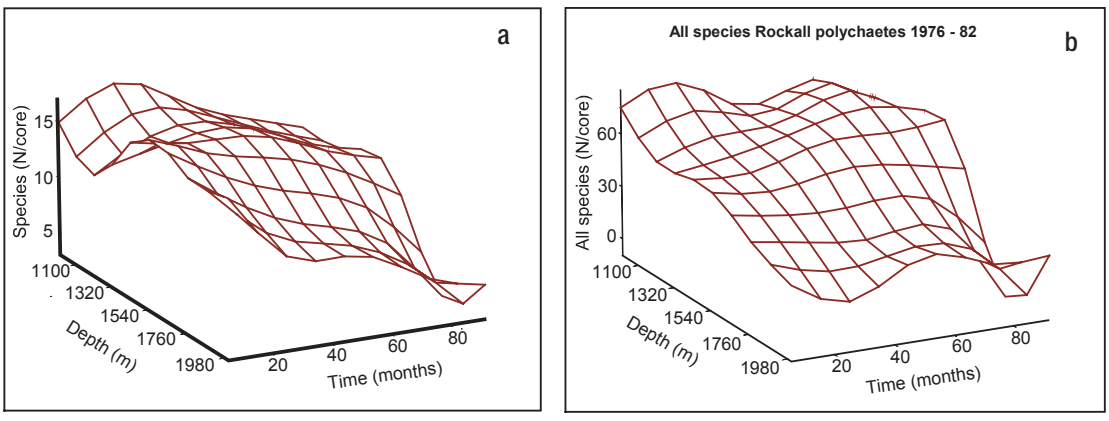


Fig. 25. (a) When the presence or absence of polychaete species are plotted with time and depth in a three-dimensional grid, a general trend towards a decrease with time is suggested leading to the tentative hypothesis of a community composition change over this seven-year time scale. (b) This trend is not evident when the total number of species is plotted in the same way, suggesting that there is a steady species turnover, but that the total number of species remains the same.

ATLANTIC CORAL ECOSYSTEM STUDY (ACES)

SAMS is a partner in this 5th Framework EU project, now in its second year, and Professor Gage leads Workpackage 3 on the associated biodiversity in the cold-water coral ecosystem. Our new Photo Lander (Fig. 26) was successfully deployed and recovered from the seabed adjacent to the 14-km long Sula Ridge cold-water coral reef complex off Norway; the first lander deployment in this area. The images from the seabed are rich in bonelliid echiuran worms whose feeding activity using a long extensible proboscis could be recorded, while near seabed optical instrument records could be related to the tidal cycle in flow over the reef, recorded by the lander's current meter.

Bad weather down-time during the first Northern Seas cruise on RRS *Discovery* provided an opportunity to investigate a 1960s record of coral off the island of Mingulay in the Minch. Living coral was recovered confirming the persistence of this inshore Scottish coral site. A sample was taken showing very high benthic biodiversity associated with sediments containing large amounts of coral rubble. A similar analysis was undertaken by Leanne Hepburn of boxcore samples from the deep-water coral site on the Darwin Mounds during an Aberdeen University MSc research project at SAMS. In another MSc project at SAMS, Emma Walker from Heriot-Watt University recorded the response of coral polyps to increased levels of sand deposition in the laboratory. In other aquarium studies, coral calcification has been studied by buoyant weighing over a three-month period and initial measurements of respiration rate have been completed.

JM ROBERTS and JD GAGE (SAMS)

Fig. 26. Deep-sea benthic group's Photo Lander. At the end of its mission, which may last from days to weeks, the lander is commanded to release the ballast suspended from each of its three legs and a buoyant sphere (not shown) returns it to the surface where it is retrieved by the research ship. On-board time-lapse cameras record activity on the seabed while a current meter and optical instruments record the near seabed water flow and the particles suspended in it.

DEEP-WATER FISH

DR JOHN GORDON

SAMS continues to have a high international profile within organisations such as ICES and the European Commission, as the future management strategies for deep-water fish stocks in the north-east Atlantic are debated. Dr Gordon represented both of these organisations as co-convenor of the Northwest Atlantic Fisheries Organisation's (NAFO) Scientific Symposium on deep-sea fisheries in September 2001. His keynote paper entitled *The Rockall Trough, North East Atlantic: the cradle of deep-sea biological oceanography that is now being subjected to unsustainable fishing activity*, attempted to document all the research from the 1860s to the present and summarised our current state of knowledge of the fish and the fisheries.

The Special Issue of *Fisheries Research* containing 27 selected papers from the ICES Deep-water Fish and Fisheries Symposium was published. In addition to being guest editor, Dr Gordon wrote the introduction, incorporating a summary of the results of the EC FAIR Deep-water Fisheries project. The volume also included a review of age estimation of macrourid fishes with new results on age validation by Ms Swan and Dr Gordon. At the NAFO deep-sea fisheries symposium, in addition to his keynote lecture, Dr Gordon was also a joint author of two papers on the fisheries of the ICES area. Ms Swan, together with Dr Gordon and Dr T Shimmield, gave a paper on stock identification of the black scabbardfish using otolith microchemistry, based on the results of the completed EC supported BASBLACK project. Two posters were prepared; one described the EC OTOMIC project described on p. 15 while the other detailed Mr Crozier's deep-water elasmobranch PhD project.

In the BASBLACK project, SAMS was also involved in the sub-task on age validation led by CSIC Spain and this work is now in press, with Dr Gordon and Ms Swan as co-authors.

JDM GORDON, SC SWAN, P CROZIER and J BARRINGTON (SAMS)

FOOD WEB MODELLING

This relies on the comprehensive data on stomach content analysis carried out by Dr J Mauchline during the 1980s. These are in handwritten format and a summer student (Ms McFadden) entered much of the data into a Microsoft Access ™ Database.

JDM GORDON and M MCFADDEN (SAMS)

DEEP-WATER ELASMOBRANCHS

Mr Crozier's UHMI PhD reached the end of its third and final year in March and he is now writing his thesis. Data on the distribution and reproductive biology of over 10 squalid sharks, four chimaerid fishes and two deep-water ray species have been collected from four research cruises. The low fecundity of these species makes them particularly vulnerable to over-fishing. Information has been obtained on the landings of the deep-water commercial fishery over a three-year period, beginning in 1999, from monthly market sampling at the Scottish port of Lochinver. An essential part of this work is the correct identification of the species being landed, as they are relatively unfamiliar to the industry. Data on discarding practices and material for biological studies were collected from six observer trips on commercial trawlers. The availability of such basic data is essential for the future management of the fishery and assessing the impact of the fishery on these vulnerable species.

P CROZIER (UHIMI) and JDM GORDON (SAMS)

ANGLERFISH AND MEGRIM

The anglerfish (*Lophius* spp Fig. 27), which until the 1980s was a bycatch species, has become one of Scotland's most important fisheries. Adult fish are now scarce on the continental shelf and the fishery has been moving into deep water. Ms Woodroffe completed her contract on the EC-funded project *Distribution and biology of anglerfish and megrim in waters to the west of Scotland* (co-ordinated by SAMS). The final report was accepted by the Commission and three papers, all in collaboration with Fisheries Research Services, have been submitted for publication.

JDM GORDON and D WOODROFFE (SAMS) and PJ WRIGHT (FISHERIES RESEARCH SERVICES, ABERDEEN)

FISHERIES IMPACTS

The report of the study of the effects of deep-water fishing carried out jointly by CEFAS, SAMS and IFREMER and funded by JNCC was accepted and is now in press. The study relied, to a considerable extent, on the long SAMS time-series of trawl catch data. Part of the series comprised an experiment to determine whether artificial lights attached to the trawl influenced the catch composition or rates. A multivariate analysis of the fish catches showed that there was no significant difference in catch composition, but for a small number of species there were significant differences in abundance. A paper on this study is now in press. Dr Mauchline had previously identified the crustaceans in these catches. Miss Aina Carbonell, of the IEO, Palma, Majorca, while on a study visit to SAMS, identified the 1999 samples. A preliminary comparison of the pre-fishery (1985) and the post-fishery (1999) has revealed differences that may be related to fishing impacts.

JDM GORDON (SAMS) and A CARBONELL (IEO, SPAIN)

Fig. 27. The angler fish occurs on the continental shelf and also on the slope down to *c.* 1000 m depth.

ECOLOGY AND BEHAVIOUR OF COASTAL ORGANISMS

DR MIKE BURROWS

The research of the group focuses on the behaviour and physiology of shallow water and intertidal species. There are two recurring themes among the diverse projects we are involved in: (1) understanding behaviour and physiology of animals as evolutionary adaptations that enhance growth and survival of the species, and (2) using this understanding to better predict the workings of coastal ecosystems and their response to change, whether man-made or natural. We choose species for study because they are either commercially important, in aquaculture and fisheries for example, or because they are of key importance for coastal ecosystems. Working in shallow water and between the tidemarks allows for much more intensive and extensive study of behaviour and population interactions than can be achieved in deeper water from expensive ships. Rocky and sandy shores can be seen as are our experimental workbench where easily accessible species can be used to test ecological theory.

EFFECTS OF TEMPERATURE AND GROWTH IN JUVENILE PLAICE: RNA:DNA RATIOS AS AN INSTANTANEOUS INDICATOR

Growth was measured for different levels of natural food diets in fishes from different nursery areas (Port Erin, Isle of Man; Tralee Beach, west Scotland; West Sands St Andrews, east Scotland). The effects of temperature and diet on growth in juvenile plaice were not consistent across populations, suggesting some degree of compensatory growth in more northern populations (Fig. 28). Extraction and analysis of the ratio of the nucleic acids RNA and DNA will allow us to evaluate this method as a measure of instantaneous growth for the early life stages of this particular species.

RS BATTY, R HARVEY, L ROBB, C MOLINA and MT BURROWS (SAMS) and T TARGETT (UNIVERSITY OF DELAWARE)

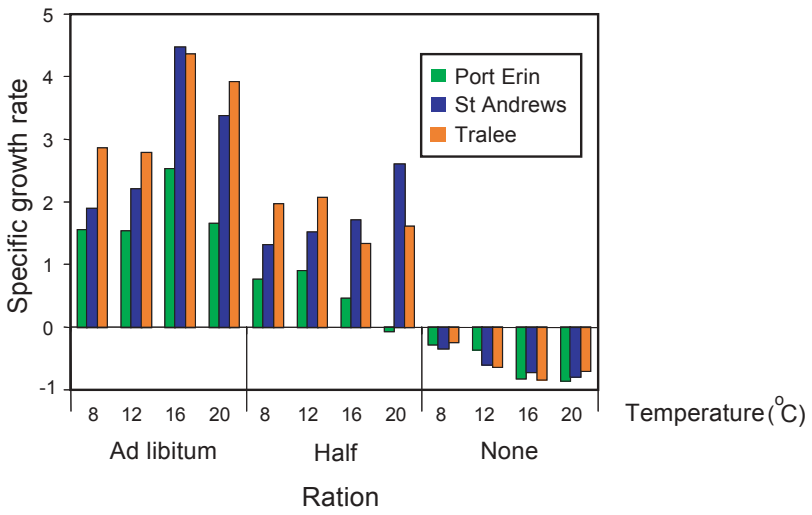


Fig. 28. Growth rates of juvenile plaice (% change in body weight per day) fed on different ration levels for 10 d periods. Each population responded differently to temperature and ration; therefore a single growth response to food and temperature cannot be assumed for this species.

COMMUNICATION IN HERRING SCHOOLS

Fish emit sounds both actively (e.g. during mating) or passively (e.g. during escape responses). Recent experiments have shown that herring produce high frequency sounds at night. Infra red illumination, video and hydrophone recording revealed that fish in leading positions in a school produce these sounds by releasing swim bladder gas through their anal duct. Herring are physostomatous fish; they have an open swimbladder that must be filled by gulping air at the water surface. Our study has revealed an additional probable function for the swimbladder in communication for maintaining school structure and directing movement at night. This behaviour also has implications for interactions with cetacean predators that possess high frequency hearing.

RS BATTY (SAMS), B WILSON (SEA MAMMAL RESEARCH UNIT) and LM DILL (SIMON FRAZER UNIVERSITY)

MODELS OF ZOOPLANKTON DIEL VERTICAL MIGRATION AND ITS EFFECTS ON ADVECTION

The diel vertical migration behaviour (DVM) of zooplankton may play an important role in determining distribution patterns. As animals move through the water column they pass through strata often moving in different directions and the residence time of the animal in each stratum has a significant effect on the animal's distributional fate. The greatest level of retention was seen in model organisms with DVM strategies similar to *Calanus* (Fig. 29), yet *Calanus* only inhabits the Irish Sea during intermittent invasions. It is unclear why the species does not persist for long periods post invasion, as these results suggest that, once invasion has occurred, the combination of its DVM strategy and the advective regime in the Irish Sea would act to enhance retention within the system. The rapid depletion of the invading population is therefore likely to be the result of high predation levels or poor trophic conditions.

S EMSLEY, G TARLING and MT BURROWS (SAMS)

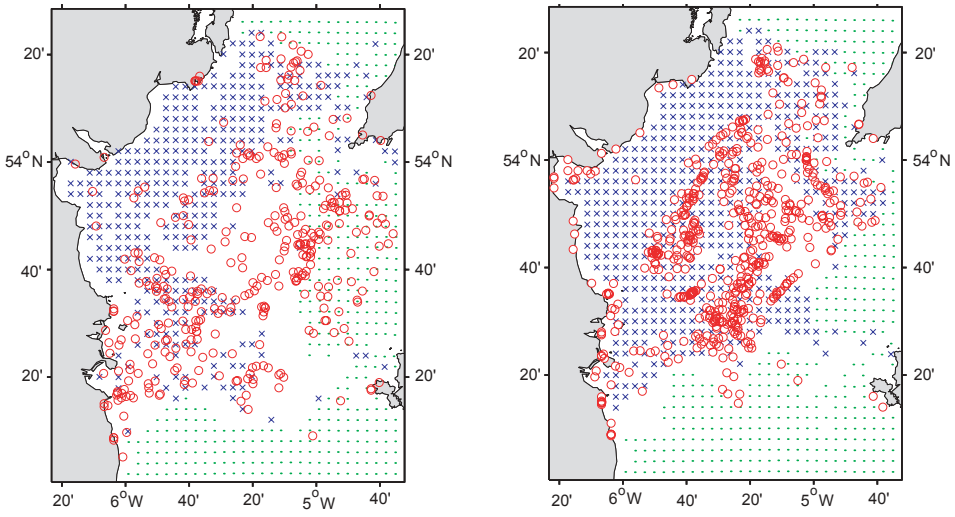


Fig. 29. Plot of positions of model zooplankton (X = *Calanus* spp.; O = krill, *Meganyctiphanes norvegica*) remaining in the model box after 90 days (April-May). (left) Non-migrating zooplankton, initial depth 5 m. (right) Zooplankton migrating at 0.01 m s^{-1} in phase with solar cycle.

OPTIMAL FORAGING ON A RENEWABLE RESOURCE

Advanced data tagging technology has allowed researchers at the University of Florence to record long time-series of information on rasping behaviour and heart rate, and thus metabolism, of intertidal grazers. Homing limpets, *Patella caerulea* and *Patella rustica* in the Mediterranean, are excellent subjects, as *in vivo* sensors can be directly wired to data recorders on the shore. These data sets are ideal for testing new predictive models of behaviour.

One of us (MTB) was invited to Florence for a month, extending an earlier collaboration to produce models of interaction of grazers with renewable resources. These models were designed to predict patterns of resource exploitation from the principle of optimisation of evolutionary fitness. The models showed that central-place foragers such as limpets can maximise their long-term rate of energy intake and resource replenishment by following simple area selection rules. By avoiding recently exploited areas, the animals can effectively maintain a maximal rate of food intake.

MT BURROWS (SAMS) and G SANTINI (UNIVERSITY OF FLORENCE)

NUCLEOTIDE ENHANCEMENT OF HALIBUT BROODSTOCK DIET

Energy reserves of fish eggs are finite and constitute the source of metabolic energy needed throughout embryonic development. Yolk composition in fish eggs and yolk-sac larvae depends upon maternal supply, and the impact that broodstock diet has on some aspects of egg quality has been well established with particular reference to fatty acid content. Recent studies have reported the improvement of a number of physiological processes including osmoregulation, growth and disease resistance by increasing the availability of nucleotides in fish diets. During oocyte development within the female, there is a high requirement for RNA and DNA. Initial results from this UHI postgraduate studentship have demonstrated that increasing the availability of nucleotides in broodstock diets has beneficial effects on oogenesis resulting in a significant increase in fecundity mean egg density, hatching rate and larval performance of Atlantic halibut *Hippoglossus hippoglossus*. Further work will include broadening the study to include comparative work on haddock *Melanogrammus aeglefinus*.

JL GONZALEZ VECINO and RS BATTY (UHIMI/SAMS) and C CUTTS and C MAZORRA (SEA FISH INDUSTRY AUTHORITY, ARDTOE)

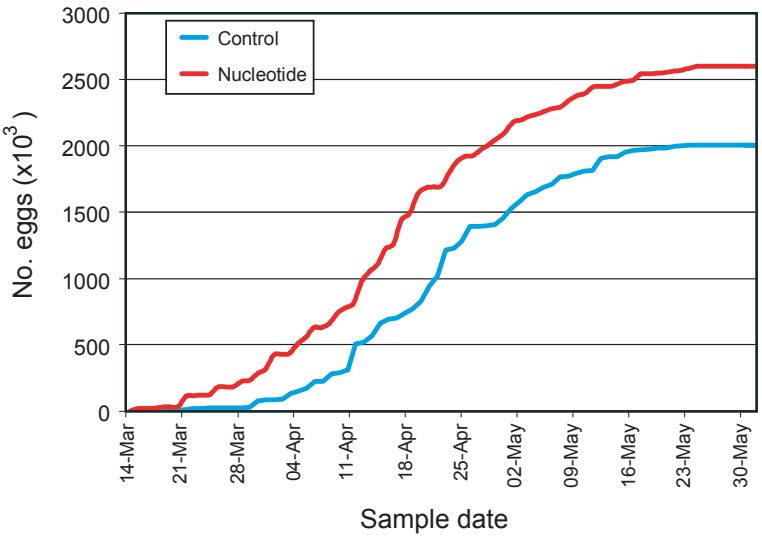


Fig. 30. Cumulative egg production by groups of 15 female halibut fed either an adenine nucleotide enhanced diet or a control diet.

ANIMAL ENVIRONMENT INTERACTION

DR MARTIN SAYER

The ability of marine animals to grow, reproduce and survive is continually influenced by the environment they are in and the condition of that environment. This is true both for animals in the wild and for animals cultured in the marine habitat. The degree of variation recorded in the natural environment and associated anthropogenic influences are concentrated in inshore coastal waters. These support fisheries and mariculture industries, as well as providing a valued habitat for the early life stages of fish species of commercial relevance. The projects described below all examine the inshore marine environment in relation to the health and condition of the animals that live and grow there.

INSHORE FISHERIES AND ENVIRONMENTAL VARIATION

Shallow inshore habitats provide essential nursery habitats for the juvenile stages of many marine fish, including commercial species such as Atlantic cod (*Gadus morhua*). Environmental factors are thought to play a major role in determining abundance and distribution of larval and juvenile cod, in turn regulating the future recruitment levels of fish populations. Understanding how changes in environmental factors, such as temperature, affect marine fish populations may help determine the response of such populations to climate change. Long-term monitoring data, from a diver-based survey programme, is allowing assessment of abundance and distribution patterns of aged 0+ cod at two inshore rocky subtidal sites on the west coast of Scotland. Observed abundance patterns indicate both significant spatial variation between sites as well as substantial interannual variation in the years 1995-2001 (Fig. 31). Daily average seawater temperature has also been monitored at the two survey sites since 1995. Substantial variation in temperature was observed, particularly over the winter period, and observed patterns in yearly abundance are currently being examined in the light of recorded winter temperature anomalies. Results indicate that winter seawater temperature could be used to aid prediction of subsequent abundance of juvenile cod in inshore habitats.

Physiological studies indicate that the osmoregulatory capacity of juvenile cod is extremely tolerant of rapid (six hour) and medium term (48 hours) exposure to fluctuations of temperature and salinity. Seasonal alteration in response to experimental conditions indicates that environmental factors may play a key role in determining seasonal distribution patterns of juvenile cod.

SH MAGILL and MDJ SAYER (SAMS)

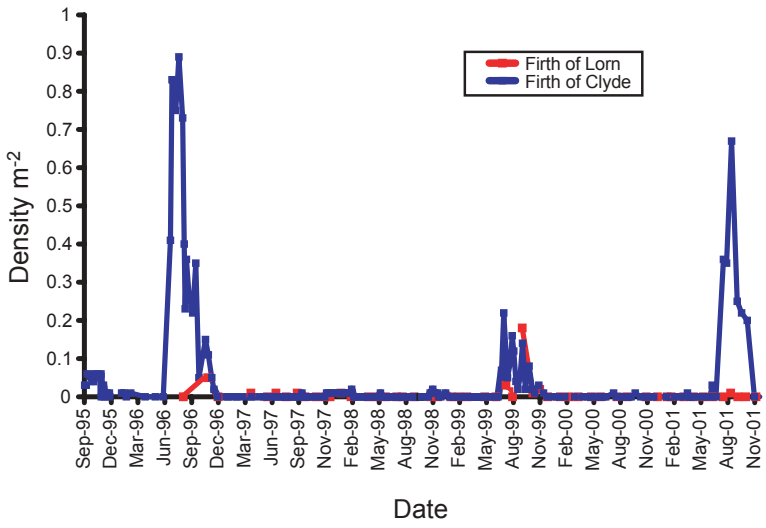


Fig. 31. Density of juvenile cod observed on two inshore rocky subtidal sites on the west coast of Scotland.

ANIMAL INTERACTIONS WITH MODIFIED ENVIRONMENTS: ARTIFICIAL REEFS

The Loch Linnhe experimental artificial reef complex, the largest such reef in Europe, was licensed for deployment in 2001. Yeoman (Morvern) Ltd, the industrial partners in the project, are currently producing the two types of concrete blocks for use in the experimental reef modules, and deployment of these blocks commenced in late 2001 at the reef site on the west coast of Scotland near Oban. Construction is ongoing, but the monitoring programme and associated research into the environmental impacts of the reef are already underway.

In spring 2002, a high resolution sidescan sonar survey was carried out to ascertain the spatial distribution of habitats at the reef site and surrounding seabed. This survey was conducted shortly after three of the reef modules were deployed, and the distribution of the blocks on the seabed is clearly visible from the sidescan data (Fig. 32). A comprehensive benthic grab survey has been conducted, based upon the output from the sidescan, to identify characterising benthic assemblages within the region. These data will form part of a temporal monitoring programme to assess near and far-field effects of the reef on soft sediment benthic communities.

Work has also commenced to monitor the development of epifaunal communities on the surface of the reef blocks. Assemblage structure will be assessed over time to determine the rate of development, and this will give an indication as to the impact of the reef on benthic productivity at the site. In addition, trials are also underway to compare epifaunal community development on other potential artificial reef building materials.

Much of the work assumes a modification of the receiving environment and the consequent effects on animals inhabiting or recruiting to the area. This assumption is being examined using the brittlestar genus *Amphiura* as test organisms. The reef deployment area is very dynamic and the physical presence of the reef structures results in the accumulation and subsequent breakdown of seaweed detritus around the reef edge and enhances colonisation. This increases localised food sources adjacent to the reefs but can also induce sediment hypoxia. How these localised environmental effects influence *Amphiura* populations is being examined through the assessment of *Amphiura filiformis* and *Amphiura chiajei*.

CJ BROWN, TA WILDING and MDJ SAYER (SAMS)

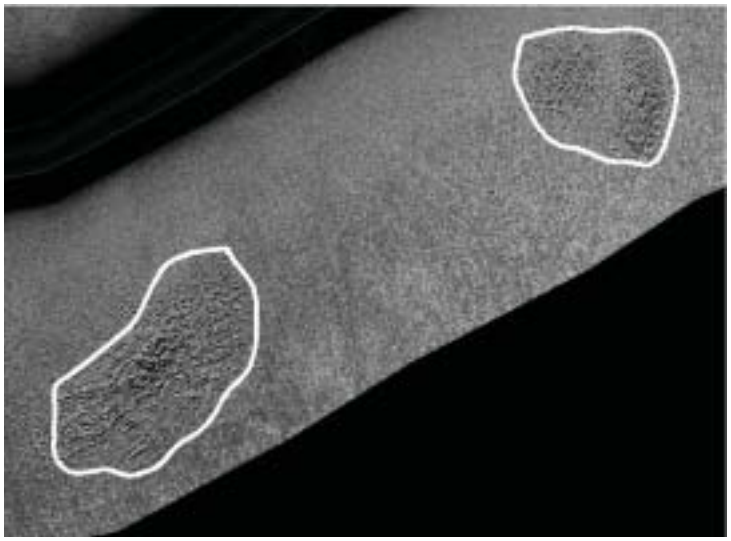


Fig 32. Sidescan Sonar image showing two of the reef modules (outlined in white). Each module comprises 200 tonnes of blocks.

BIOLOGICAL METHODS OF ENVIRONMENTAL MITIGATION: BIOFILTRATION AND AQUACULTURE (BIOFAQS)

Finfish farming is dominated in North European waters by intensive open cage culture of Atlantic salmon and in southern Europe by sea bass and sea bream. Dissolved and particulate wastes are dispersed from the cage farms and may enrich the surrounding ecosystem, possibly leading to increased primary and secondary production, eutrophication and benthic impacts. BIOFAQs, a pan-European research project aims to explore the effectiveness of biofilter deployments in reducing the environmental impacts of effluents from intensive mariculture. The project is now in its second year and the developments/results are discussed below.

The initial biofilter design has been tested in mesocosms *in situ* (Crete and Piran) and in the SAMS aquaria. The influence of the biofilters (uptake dynamics) on suspended particulate matter, nutrients, bacteria and algal abundance has been measured.

Biofilters were deployed in June 2001 near fish farms off the west coast of Scotland, in the Adriatic Sea, the Mediterranean and the Gulf of Aqaba (Red Sea). In the Gulf of Aqaba and Scotland, a greater biomass was recorded at the fish farm site compared with the reference site (Fig. 33). The opposite trend was observed at the Adriatic Sea site. In the Mediterranean, Adriatic and Red Sea sites, the biofilters were initially colonised by macroalgae (Fig. 34, left) whereas in Scotland, ascidians dominated (Fig. 34, right). Stable isotope fingerprints of particulate organic material and fouling organisms at the fish farm and control sites have also been used to assess the effectiveness of the biofilters.

For more information, see the BIOFAQs website at www.sams.ac.uk/biofaqs

EJ COOK, KD BLACK and MDJ SAYER (SAMS)

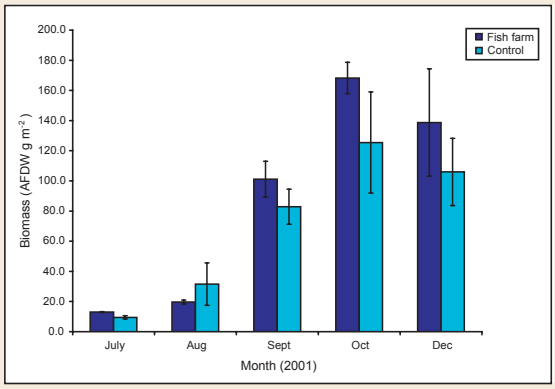


Fig. 33. In Scotland, biomass on the biofilters at the fish farm site soon overtook that at the control site.

Fig. 34. Biofilters in the Mediterranean and Red Sea (left) were initially colonised by algae, while those in Scotland were colonised by ascidians (right). The filter in the left image is 25 cm in diameter and 80 cm high.

MARINE ALGAE

DR CHRIS BOLCH

The marine algal research group (MARG) incorporates research projects in the areas of marine algal biology, genetics and microbiology, the staff and activities of the Culture Collection of Algae and Protozoa-Marine (CCAP-M) and the Molecular Genetics Facility. Research through the past year has focussed on population genetics, biogeography, phylogeny and the role of bacteria in the life-cycle of toxic marine algae. Staff from MARG and CCAP-M are contributing to the NERC funded Northern Seas Programme, MAFF Link Aquaculture halibut larval rearing project and are underpinning SAMS research which requires the supply of micro-algae.

CULTURE COLLECTION OF ALGAE AND PROTOZOA – MARINE (CCAP-M)

The Culture Collection of Algae and Protozoa-Marine is a living collection of marine algae and protozoan cultures. CCAP-M holds more than 550 algal strains from more than 420 species across 116 genera and 16 algal classes.

In 2001, five year funding from the NERC was confirmed and work was begun on a programme of development to expand the services and facilities of the Collection. A total of 583 individual starter cultures were supplied to over 30 countries on all continents through 2001. This represented an income of over £20k. As in 2000, sales were split between academic (51%) and commercial (49%) sectors.

The CCAP web-site, maintained by staff of the freshwater section of CCAP (CCAP-F) at the Windermere Laboratory, has been completely updated and improved to reflect changes in the management of the whole Collection. The new web-site address is http://windermere.ceh.ac.uk/ccap/

CN CAMPBELL, P PROUDLOCK, C SMALLEY and T COMSTOCK (SAMS) and CJS BOLCH (SAMS/UNIVERSITY OF TASMANIA)

A NEW SPECIES OF SAND DINOFLAGELLATE?

An unusual dinoflagellate was isolated and grown from a single motile cell collected from Loch Ewe, Wester Ross. Light microscopy revealed heavily thecate, ovoid cells with a dense golden-brown pigmentation and mean cell dimensions of 45 µm (height) x 32 µm (depth) x 28 µm (width). Scanning electron microscopy (Fig. 35) showed that the cells possess smooth thecal plates with numerous pores evenly distributed on the plate surfaces and densely distributed along the cingular margins. The cell morphology is similar to species in the genus *Thecadinium* but the girdle position is not consistent with any previously described species. The cell morphology, thecal plate arrangement and large subunit rDNA sequence analysis strongly support this as a new species of the genus *Thecadinium*.

CN CAMPBELL and R HARVEY (SAMS) and CJS BOLCH (SAMS/UNIVERSITY OF TASMANIA)

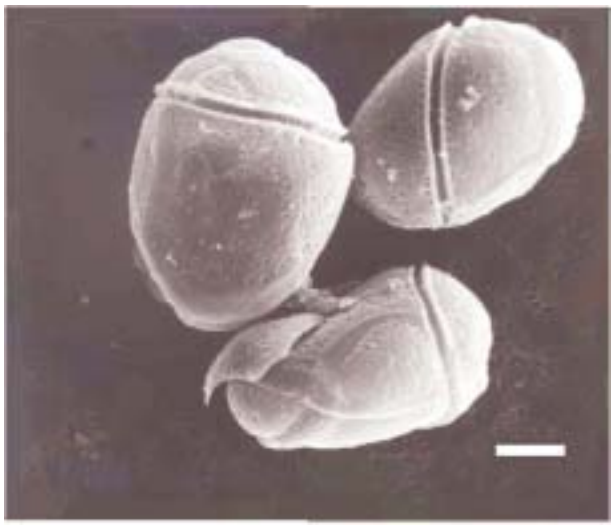


Fig. 35. SEM image of the putative new species of *Thecadinium* from Loch Ewe. Scale bar = 10 µm.

TOXIC *PSEUDO-NITZSCHIA* SPECIES IN SCOTTISH WATERS

Diatoms of the genus *Pseudo-nitzschia* are capable of producing the neurotoxin domoic acid (DA), responsible for amnesic shellfish poisoning (ASP). From 1999, the majority of the Scottish scallop-harvesting areas have been periodically closed because DA concentrations exceeded internationally accepted limits.

A phytoplankton monitoring programme in the Firth of Lorn was commenced in November 2000. The aim is to track changes in the abundance of toxic and non-toxic *Pseudo-nitzschia*, the species composition of the phytoplankton community and abiotic parameters such as temperature, salinity and nutrients at this site. During monitoring, the dominant toxic species *P. australis* was isolated into laboratory culture and DA production confirmed. Other species isolated, such as *P. fraudulenta* and *P. pungens* were shown to be non-toxic in laboratory culture. Results have shown that the spring bloom was formed by the *Pseudo-nitzschia delicatissima* group and *Skeletonema costatum* in 2001 and 2002, while the potentially toxic *Pseudo-nitzschia seriata* group reached highest cell numbers in July 2001. Morphological characterisation of *Pseudo-nitzschia* species collected using light and electron microscopy is being augmented by use of molecular genetic methods. Here the aim is to understand the evolutionary relationships within Scottish and global representatives of the genus and to establish if toxicity is co-incident with a specific genetic population.

J FEHLING (UHIMI), K DAVIDSON (SAMS/UHIMI), CJS BOLCH (SAMS/UNIVERSITY OF TASMANIA), P TETT (NAPIER UNIVERSITY) and S BATES (FISHERIES & OCEANS, CANADA)

GENOTYPING *DINOPHYSIS* SPP. AND ITS LINK WITH DIARRHETIC SHELLFISH POISONING

During the past year research by SAMS and FRS Aberdeen scientists, funded by the Food Standards Agency, has been undertaken to examine the link between diarrhetic shellfish poisoning (DSP) events and the dinoflagellate genus *Dinophysis* (Fig. 36). At SAMS, genetic analysis of different *Dinophysis* species found at two sites along the Scottish coast with histories of DSP outbreaks; Loch Ewe, Wester Ross and Scapa Flow, Orkney, has been carried out. The aim of this study is to investigate genetic relationships between species and the link with toxicity, and to compare genetic make-up of *Dinophysis* species off the Scottish coast with species isolated at other sites around the world. This research was performed alongside a monitoring programme carried out by FRS Aberdeen at Loch Ewe and Scapa Flow, in which the co-occurrence of *Dinophysis*

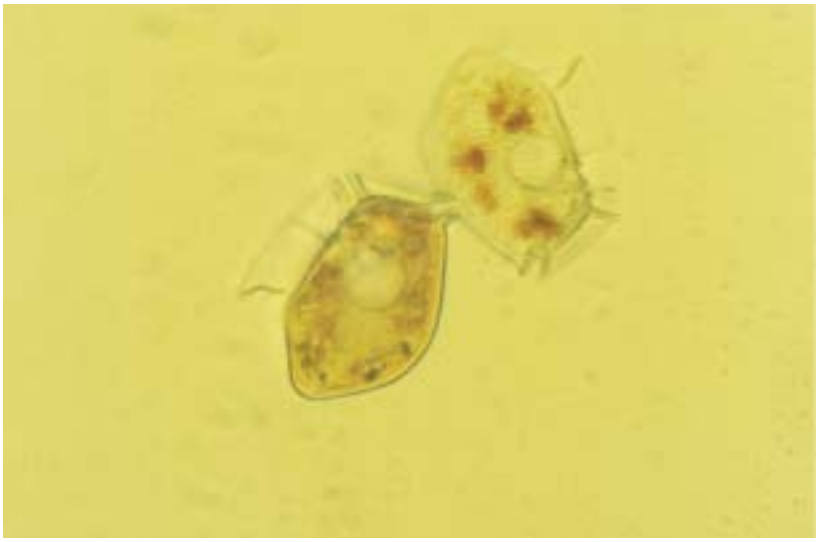


Fig. 36. Cells of *Dinophysis* spp. that may be linked to diarrhetic shellfish poisoning outbreaks. Length of cells is *c.*70 µm.

blooms and the detection of DSP toxins was being investigated.

This work has enabled the development of DNA isolation techniques and improved methods of Polymerase Chain Reaction (PCR) amplification of DNA from dinoflagellate cells. As a result we are able to consistently recover high quality genetic information from a single algal cell, either freshly isolated or, more significantly, from Lugol's Iodine-fixed samples. A total of approximately 400 *Dinophysis* cells, mostly of the species *D. acuta* and *D. acuminata,* have been examined in this study. When compared to species isolated from other sites in the UK and the world, the genetic differences within the regions of interest are small, but significant. This genetic analysis has enabled us to develop molecular tools to distinguish between different *Dinophysis* species.

MC HART (SAMS), CJS BOLCH (SAMS/UNIVERSITY OF TASMANIA), and E BRESNAN (FRS ABERDEEN)

INVOLVEMENT OF BACTERIA IN THE LIFE-CYCLE AND IN THE INDUCTION OF PARALYTIC SHELLFISH TOXIN PRODUCTION BY *GYMNODINIUM CATENATUM*

Research by SAMS and collaborating scientists has identified that the neurotoxins produced by the dinoflagellate *Gymnodinium catenatum* are significantly influenced by both its sexual life-cycle and the bacteria surrounding the dinoflagellate cell. Current research aims to understand how this interaction affects toxin production and how specific molecular or physiological interactions between the host algal cell and its bacterial flora may regulate algal cell toxicity, directly or indirectly. Longer-term aims are to understand how and why these toxins are produced, and by which entity. Through this understanding, we may be able to develop means to alleviate the impact of harmful algal blooms. Research has identified several common bacterial groups associated with different *G. catenatum* populations and has identified key bacterial groups important in the life-cycle of *G. catenatum*. This data will be corroborated by collection and examination of fresh material from *G. catenatum* blooms in Australia. Future research will hopefully elucidate the 'switch' that turns toxicity on or off, and establish how specific bacterial types are beneficial to G. *catenatum*.

DH GREEN (SAMS-HOSTED NEW ZEALAND SCIENCE AND TECHNOLOGY FELLOW), CJS BOLCH (SAMS/UNIVERSITY OF TASMANIA), R LEAKEY(SAMS), A NEGRI and L LLEWELLYN (AIMS, AUSTRALIA) and SI BLACKBURN (CSIRO, AUSTRALIA)

PELAGIC PLANKTON

DR RAY LEAKEY

The pelagic environment is home to a range of unicellular and multicellular planktonic organisms. The phytoplankton (cyanobacteria and microalgae) are the main primary producers in both coastal and oceanic waters and form the base of the pelagic food web. The bacterioplankton (bacteria), protozooplankton (e.g. ciliates and flagellates) and metazoan zooplankton (e.g. copepods and euphausiids) consume dissolved and particulate material and other planktonic organisms within the water column. This material may either be recycled within the water column or channelled to larger organisms within the pelagic and benthic realms, including commercially important species. Planktonic communities therefore play key roles in marine ecosystems and biogeochemical processes.

The research activities of the pelagic plankton research group focus on understanding the ecological role of planktonic organisms in marine systems. Three projects, addressing both fundamental and applied questions, are reported below. Our research investigating how planktonic microbial communities respond to nutrient inputs is reported elsewhere as part of the SAMS Northern Seas programme.

PROTOZOOPLANKTON MODELLING

It is increasingly becoming recognised that the ingestion of phytoplankton as well as bacteria is a potentially important trophic link in marine food webs. However, few mathematical models include a detailed representation of protozooplankton grazers. To address this problem we are attempting to develop a physiology-based model of protozooplankton activity. The first step of this is a sub model representing the dynamics of predation and assimilation of ingested material.

In the model, predation rate was made a rectangular hyperbolic function of prey carbon (C) concentration, modified to simulate the prey selectivity that these organisms have been observed to exhibit experimentally in response to prey nutritional quality. We chose prey nitrogen:carbon (N:C) ratio as an index of selectivity and related both the maximum predation rate (PM) and the assimilation efficiency (AE) to changes in prey N:C. Changes in PM simulated the phenomena of ‘surge feeding’ and ‘prey rejection’. Changes in AE simulated sub-optimal assimilation of material from ingested prey, which in turn served to decrease the ingestion rate on this material. The model was parameterised using laboratory data sets that followed ingestion of non-growing phytoplankton prey of different N:C ratio by a

micro-flagellate predator. Investigative simulations in transient conditions, incorporating growing prey and hence with changing N:C ratio, indicated both PM and AE influenced the quantitative and temporal dynamics of C transfer to the higher trophic level. In particular, we noted that although various model formulations predicted similar trophic transfer of C, this was achieved on very different time scales. The next step will be the inclusion of this sub-model within a whole organism physiological model.

K DAVIDSON and A MITRA (SAMS) and KJ FLYNN (UNIVERSITY OF WALES, SWANSEA)

THE ROLE OF MICROALGAE IN ENHANCING ATLANTIC HALIBUT LARVAL SURVIVAL

The hatchery process for Atlantic halibut is now relatively well established, but is still constrained by low cumulative survival over the yolk sac incubation and first feeding period. The economics of hatchery production are currently being hampered by the losses at this stage. The presence of microalgae within the larval environment appears to enhance the initiation of first feeding and subsequent survival. The reasons for this effect have to be resolved, however, as previous research suggests that the larvae obtain minimal nutritional benefit from the algae. Experiments at SAMS have investigated the effect of microalgal type and concentration on larval foraging behaviour and survival. We have established that high concentrations of the alga *Nannochloris atomus* are most effective at promoting growth and survival of larvae (Fig. 37). The underlying mechanism by which the algae influence survival remains unknown but will be investigated in further experiments to be undertaken during 2002. The research forms part of a MAFF LINK Aquaculture research programme *Rearing protocols for Atlantic halibut larvae during transition from endogenous to exogenous nutrition* which is being undertaken in collaboration with scientists from the British Marine Finfish Association, Glasgow University and the Sea Fish Industry Authority (SFIA) at Ardtoe.

R LEAKEY, RS BATTY, Y CORRIPIO, and C MOLINA (SAMS) and C CUTTS, C MAZZORA and E COCHRANE (SEA FISH INDUSTRY AUTHORITY)

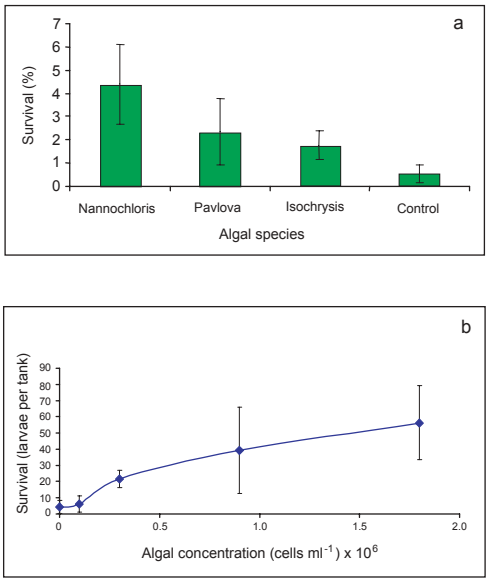


Fig. 37.
Survival of larval halibut in water containing three species of microalgae (a) and different concentrations of *Nannochloris atomus* (b).

THE ROLE OF ZOOPLANKTON IN BIOGEOCHEMICAL CYCLES

Zooplankton such as copepods and euphausiids are often seen to migrate up and down through the water column on a daily basis as an adaptation to their pelagic environment. On a global scale, these diel vertical migrations (DVM) result in a phenomenal translocation of biomass between the surface and the deeper layers of the water column. Given that feeding occurs mostly at the surface, this translocation represents a significant potential for the sequestration of biogeochemically important elements such as carbon and nitrogen in the ocean's interior. Using a previously suggested, but as yet relatively untested, statistically-based technique for quantifying this potential 'active flux' of material, field sampling was undertaken at three widely separated study sites: the Clyde Sea in Scotland, the Sargasso Sea off Bermuda and Doubtful Sound in New Zealand. The results showed that the nature of DVM, especially in the Clyde Sea, was variable and often difficult to interpret with the conventional sampling methods employed here. This resulted in an inability to quantify the active flux satisfactorily using the statistical technique. The wealth of biological and physical information gathered, however, in conjunction with simple modelling considerations, provided new insights into the nature and biogeochemical significance of DVM in a variety of marine environments. Furthermore, the use of acoustic techniques in the Clyde Sea (Fig. 38) revealed exciting new information regarding the behaviour of copepods and euphausiids at this site, and highlighted the usefulness of acoustic instruments in the study of zooplankton in their natural environment. This research forms the basis for a PhD project, funded by the newly established University of the Highlands and Islands Millennium Institute (UHIMI), and hosted at SAMS.

T JARVIS (UHIMI), GA TARLING (BRITISH ANTARCTIC SURVEY), JBL MATTHEWS (SAMS) and GC HAYS (UNIVERSITY OF WALES, SWANSEA)

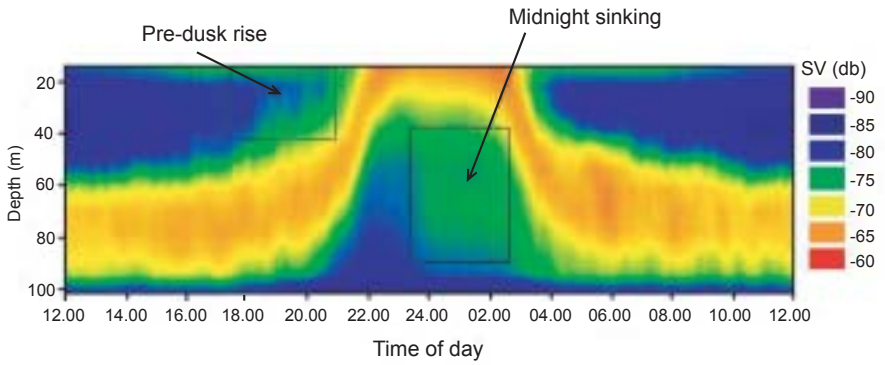


Fig. 38. Acoustic backscatter at 300 kHz, showing a 'normal' pattern of DVM (up at dusk, down at dawn) by krill (red-yellow areas). Also detectable is an 'abnormal' pattern of DVM by the copepod Calanus (yellow-green areas), which appears to be undertaking a pre-dusk rise followed by midnight sinking (both phases highlighted). This behaviour is thought to be the result of a trade-off between successful feeding in the food-rich surface layers, and avoidance of predatory krill. Times of sunrise and sunset were 04:40 h and 22:09 h respectively, in June 1999.

COASTAL IMPACTS

DR KENNY BLACK

In 2001, the group expanded by the incorporation of the Invertebrate Biology and Mariculture group, thus amalgamating experience of vertebrate and invertebrate culture systems and their interactions with the environment. Much of the group's work addresses environmental concerns surrounding the commercial culture of fish and shellfish and we continue to be involved in a range of major externally funded (especially EU) projects. Smaller projects include DEPOMOD V3, designed to incorporate an iterative decision-based support for regulators assessing discharge consents for medicines.

As part of an ongoing National reassessment of aquaculture strategy for Scotland, the group has been involved in assessing the scientific basis of discharge consent regulation for SEPA and provided a review for the Scottish Parliament and Executive on the major impacts of aquaculture in Scotland.

TUBEWORM FOULING ON SCOTTISH ROPE GROWN MUSSELS

Fouling by a tubeworm (*Pomatoceros*) threatens the Scottish mussel industry, which maintains its competitive edge by trading in premium quality mussels only (Fig. 39). This project monitored variation in tubeworm settlement between lochs and over depth, and assessed the importance of mussel size, density, culture depth and presence of conspecifics, for management strategies to alleviate tubeworm fouling.

In both Loch Beag and Loch Striven, *Pomatoceros triqueter* (L.) was the prevalent fouling species, and exhibited discrete periods of intense settlement (Fig. 40). On collector plates, the timing of peak settlement differed between lochs, but was synchronous within each loch and over depth, occurring after the highest water temperatures were recorded. Settlement intensity differed between and within lochs, and over depth, indicating the scale on which intra-loch variations influence settlement abundance. Local hydrography should therefore be considered when selecting farm sites.

The field trials showed large mussels to be more susceptible to fouling than small mussels, and the presence of conspecifics to further induce tubeworm settlement. Low culture densities intensified fouling in large mussels, and this was made worse by the routine size grading undertaken by the industry which disrupts mussel feeding formation and growth rates. In small mussels, initial stocking density had no effect on tubeworm settlement. In areas of persistent tubeworm

Fig. 39. Rope-grown mussels showing tubeworm fouled shells (left) and clean shells as required for sale (right).

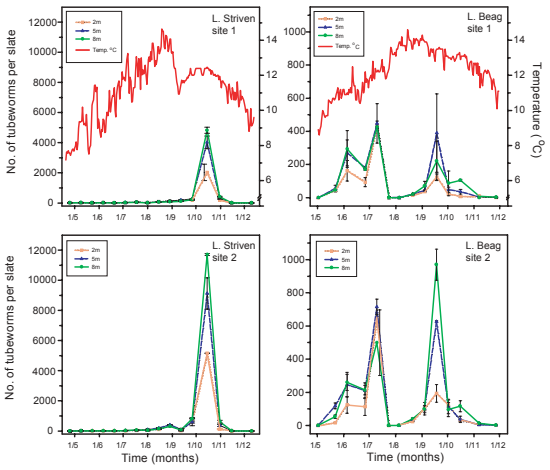


Fig. 40. A comparison of the density and timing of tubeworm fouling at two sites within each of two sea lochs. Note the multiple periods of settlement in Loch Beag (right hand plots) and the order of magnitude difference in density between the two lochs.

infestation, consistent annual monitoring of tubeworm settlement, specific to each loch, and the avoidance of grading during periods of intense tubeworm settlement, is recommended as part of a management strategy to avoid heavy fouling of mussel stock.

DA CAMPBELL and MS KELLY (SAMS)

THE ECOLOGICAL EFFECTS OF SEA LICE TREATMENT AGENTS

The use of chemical therapeutants to treat sea lice infestations of farmed salmon stocks has been an issue of public interest since the late 1980s. Fish farmers have traditionally had few medicines available to them and those that have been available have relatively poor efficacy. This has resulted in the development of tolerance by sea lice to those medicines.

The introduction of new treatments in recent years has been accompanied by efforts to ensure that these meet regulatory standards for the environment. Ecotoxicity testing is generally performed on indicator species, which might not reflect the impact on all parts of the marine ecosystems exposed. This project has been designed specifically to study ecosystem responses, over several years, and to detect changes in the natural species assemblages in Scottish sea lochs resulting from the use of sea lice treatments.

The plankton, meiofauna and macrofauna of a range of habitats in the vicinity of the farms selected for study have been monitored. Without a long dataset, it is difficult to distinguish effects from the use of sea lice medicines from the natural highly variable pattern of species succession in sea lochs. The effects of these natural seasonal and inter-annual patterns has been minimised by choosing sampling times for long-term studies at the same season in each year. The long-term, wide-scale ecosystem approach means that most of the significant conclusions will emerge nearer the conclusion of the project in 2004, but some early findings can be reported here:

- Initial studies of the effects of cypermethrin on zooplankton assemblages has not revealed treatment-related effects. Further studies at a different site should determine whether this result is reproducible. This aspect is important as crustacean zooplankton are likely to be highly susceptible to sea lice medicines.
- The settlement and succession of invertebrates from the zooplankton on to plates held in the water column show no effects that can be attributed to cypermethrin treatments.
- Grab samples taken from sediments on a transect away from the farm show low meiofaunal abundances, but this may be attributable to the

sampling technique employed. Subsequently, divers have collected undisturbed cores from which meiofauna can be extracted, to help determine whether these effects are related to the medicines or indeed to the organic waste generated by the farm. The analyses of these samples are not yet complete.

- No effect on sea loch ecosystems has been observed arising from cypermethrin treatment to date, but data continue to be gathered and assessed.

TD NICKELL, K WILLIS, P PROVOST, C CROMEY and K BLACK (SAMS)

MERAMED - ENVIRONMENTAL EFFECTS OF MEDITERRANEAN AQUACULTURE

The objectives of the MERAMED project are:

- to undertake a review of procedures used in the regulation and monitoring of marine cage fish farms in Norway, Scotland and elsewhere, to be used as the basis for creating an appropriate set of protocols, monitoring systems and techniques for the control of such farms in Mediterranean conditions.

- to carry out a field research programme to provide appropriate data on the environmental impact of marine cage fish farms in a range of conditions in the eastern Mediterranean.

- to develop a predictive model to simulate the environmental response at Mediterranean sea cage farms to differing cage stocking levels and feeding regimes. This will be designed as a management tool for both the industry and regulatory authorities.

At SAMS we are primarily addressing objectives 2 and 3. Under the former, we participated in two multidisciplinary cruises aboard the research vessel *Phylia* operated by the Institute of Marine Biology, Crete. The first cruise concentrated on the collection of physical data (currents and meteorological information) at each of seven sites, chosen to cover differing physical environments. On the second cruise we focused our attention on quantifying the rate of fluxes of particulate materials using sediment traps in combination with further physical measurements of water movement. Our colleagues from IfM Kiel in Germany collected data relating to the consumption of particulates by the wild fish that accumulate around farms, while our partners from Crete, Scotland (SEAS) and Norway (Akvaplan) collected information on the effects each farm had on sediment biology and biogeochemistry. These data will be used to adapt and calibrate our existing model *DEPOMOD* for use in predicting impacts at Mediterranean sites.

C CROMEY, P PROVOST and KD BLACK (SAMS)

BIOGEOCHEMICAL FLUXES

DR KEN JONES

The group is concerned with the characterisation and quantification of elemental fluxes between the atmosphere, water column and sediments that are mediated by biological processes. Our work focuses on three main science areas a) the relationships between nutrient, carbon and oxygen budgets with particular reference to development of eutrophication and hypoxia; b) the role of sediments in elemental cycling and carbon burial and c) the production and fate of biogenic gases in marine systems. The group has been involved in two major externally funded projects in 2001-2. The OAERRE Project (Oceanic Applications to Eutrophication in Regions of Restricted Exchange), funded through European Framework V, has focused on the biogeochemical controls on eutrophication in a range of European regions of restricted exchange, whilst a NERC funded Fellowship to Angela Hatton has supported work on the production and fate of the biogenic gas dimethyl sulphide in aerobic and anaerobic environments. Collaboration with Dr Alex Cunningham's underwater optics group at Strathclyde University, during some of the OAERRE fieldwork in the Clyde Sea, has contributed to a joint NERC funded project on relationships between photon budgets and primary production in shelf seas, but this work is not reported here.

MICROPLANKTON PRODUCTION UNDER VARYING IRRADIANCE

The OAERRE programme aims to understand the physical, biogeochemical and biological processes and their interactions involved in eutrophication in coastal regions of restricted exchange throughout Europe. Examples include the Scandinavian fjords, Scottish sea lochs and Portuguese lagoons, which have restricted water exchange with the open sea because of the presence of a topographic barrier such as a sill, or because of weak circulation, as in the case of the bays of the French Mediterranean coast and the Baltic Sea. The project will deliver closed budgets and coupled physical-biological research models for nitrogen and organic carbon in these locations. These will allow tests of hypotheses about biogeochemistry, water quality and the balance of microbial organisms in addition to screening models for the definition, assessment and prediction of eutrophication.

Most of our work this year has focused on the Firth of Clyde. The core objective of our component of the OAERRE study is to obtain seasonally relevant measurements of the pelagic microbial community structure and to make a suite of measurements to describe pelagic photosynthesis in relation to irradiance, chlorophyll yield from

dissolved nitrogen and pelagic respiration rates at a community level. Benthic regeneration processes have been measured using core incubations and *in situ* lander studies to estimate sediment oxygen and nutrient fluxes. These measurements have been made from the RV *Calanus* and RRS *Discovery*, at sites representative of the Estuary/Inner Firth, the Arran Deep and the Great Plateau of the Clyde Sea. They will be used to parameterise the research and screening models under development by other partners in the project. In addition to these measurements we have conducted nutrient enrichment experiments, in order to determine the hierarchical factors contributing to the increase of primary production during the autumnal bloom in the Clyde Sea. An experiment using fluctuating light and nutrient enrichments was undertaken in August 2001. Microplankton communities from the depth of maximum chlorophyll were submitted to four different treatments of fluctuating irradiance and nutrient enrichment under conditions of high and low natural incident irradiance.

Increased primary production by the phytoplankton community was observed under an alternating 1h light:1h dark regime, with or without nutrient additions, when the natural incident irradiance was low (Fig. 41). The data suggest that fluctuating light conditions, resulting from the wind-induced mixing of the water column, may be an important factor triggering the increase of primary production at low natural incident light levels and thus may explain the onset of the autumnal phytoplankton bloom in the Clyde Sea. Results also suggest that the alternating light regime may have a negative impact on the bacterial community production.

KJ JONES, R LEAKEY, SM HARVEY, E FOUILLAND, T BRAND and I EZZI (SAMS) and J SLATER (UNIVERSITY OF STRATHCLYDE)

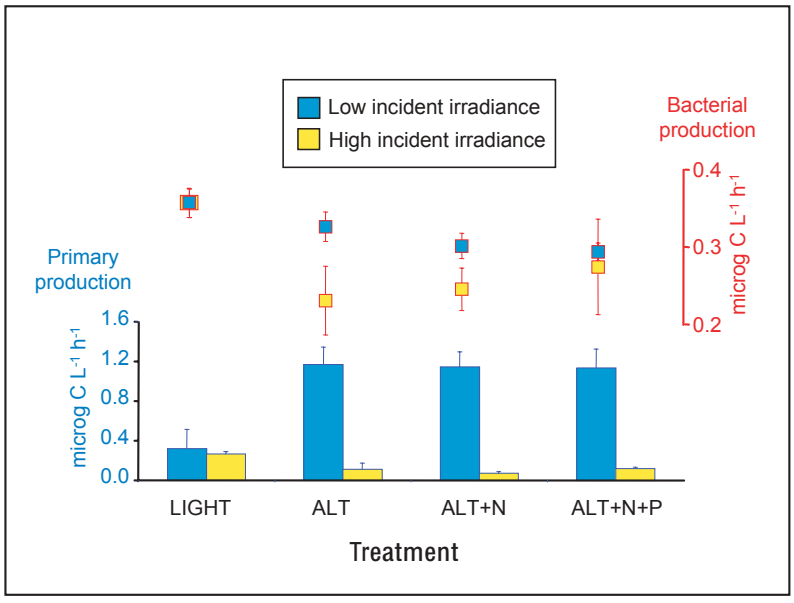


Fig. 41. Responses of phytoplankton and bacterial production in Clyde Sea microplankton communities to 4 different treatments of irradiance and nutrient enrichment. 1) Simulated *in situ* light at the depth of the chlorophyll maximum (LIGHT). 2) One hour simulated surface light (80% light attenuation), alternating with one hour complete darkness: 1:1 regime, to reproduce conditions equivalent to a 2 hour vertical mixing rate (ALT). 3) 1:1 regime with initial nitrate enrichment (ALT+N). 4) 1:1 regime with initial nitrate and phosphate enrichments (ALT+N+P).

MARINE PHYSICS

DR MARK INALL

Non-core science activities undertaken this past year have complemented our core activities reported earlier. The EU funded OAERRE project (Oceanographic Applications to Eutrophication in Regions of Restricted Exchange) entered its second year. For Marine Physics this involved a detailed two-boat process study in Loch Etive, and continuing analysis of the Clyde Sea circulation. Finally, current meters moored in the Faroe-Shetland Channel as part of a UHIMI PhD studentship, link our process studies of stratified flow over topography, until now confined to sea-lochs, to the ocean margin interests of the SAMS Northern Seas programme.

TIDAL ENERGY PROPAGATION IN LOCH ETIVE

A basin-wide survey of Loch Etive was undertaken in June 2001 in an attempt to follow the pathways by which tidal energy propagates into, and dissipates within, the loch. Both mechanisms, in part, determine vertical mixing within the upper basin, and horizontal exchange with coastal waters. Moorings were deployed along the axis of the basin, and instrumented with acoustic doppler current profilers (ADCPs), and temperature and salinity sensors. Bottom pressure recorders were levelled-in on either side of the sill at Bonawe. Simultaneous tidal cycle surveys were undertaken over the sill using a vessel-mounted ADCP and a hand-held CTD (conductivity-temperature-depth recorder) from RV *Seòl Mara*, and along the axis of the basin using a towed undulating CTD from RV *Calanus*. Standard CTD profiles where made at the reference stations RE1 to RE7.

Bottom pressure recorders revealed both a frictional mean sea level set-up of 0.11 m in the upper basin, and marked asymmetry in the barotropic forcing of the upper basin, both a result of tidal constrictions seaward of the sill. A simple hydrodynamic tidal model has been used to investigate the frictional values necessary to reproduce the free surface elevation measurements. The asymmetry is reflected in the tidal flows over the sill, with a fast flood tide and a slower, prolonged ebb.

A detailed ADCP survey across the sill has allowed us to examine some of the sill processes, particularly those occurring on the lee side as the tidal jet separates from the sea bed ('flow separation') creating strong vertical recirculation at that point.

Throughout the spring/neap cycle the inflow always becomes supercritical (internal Froude number >1) at some point during the flood

tide. Flow separation occurred throughout the spring flood tide of 19th June and flow over the sill was intense enough to draw water up from twice the sill depth (a process termed 'aspiration').

ME INALL, F COTTIER and
CR GRIFFITHS (SAMS)

CLYDE SEA TIDAL STUDIES

To a good approximation, the vertical structure of the water column in the deep basin of the Clyde Sea is locally forced. At the surface, buoyancy is added in the form of freshwater run-off and solar heating. In the deep water, its properties vary slowly by vertical mixing or rapidly by a transient influx of dense water. Under appropriate conditions the water column will become unstable and a complete overturn of the water column will result. Although many of these observations are well documented within short-term measurements, we have revisited these phenomena with a near-continuous 13-month record of the vertical structure of currents and temperature collected in the deep basin of the Clyde Sea.

Our first line of enquiry concerns the energy propagated by the mode-one baroclinic tide. In stratified waters, interaction between the tide and changes in topography will tend to generate linear internal oscillations in the density field when the internal Froude number is not small, but less than one. The Clyde Sea experiences such an interaction between the tide and a broad, relatively shallow sill, and has a maximum mode 1 internal Froude number of 0.4. By applying spectral techniques to the ADCP data, it is possible to show that a 48 hour phase lag between the barotropic and baroclinic signals explicitly points to the sill as the generation region for the baroclinic tide (Fig. 42). Furthermore, the energy contained in the baroclinic tide varies seasonally and with depth, a consequence of changes in the degree of vertical stratification. We have already measured and inferred vertical eddy diffusivity values for the deep waters of the Clyde Sea during summer stratification conditions. Analysis of the 13 month record is now essential to put these 'spot' diffusivity measurements into a seasonal context.

The second aspect of ADCP analysis is directed towards looking at the instrument response to a complete convective overturn event, which occurred in late November. Using CT chain data, the period of overturn has been pinpointed and we are currently analysing the ADCP record for characteristic signatures of this convective event.

ME INALL, F COTTIER and
CR GRIFFITHS (SAMS)

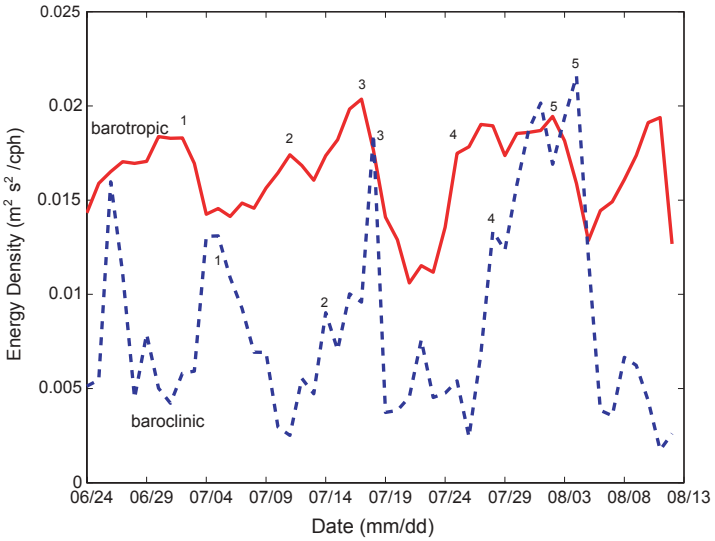


Fig. 42. Power of the M2 frequency in the barotropic and baroclinic components of the tide at station C1. The baroclinic response lags the barotropic by approximately two days, corresponding to the difference in propagation speeds between the sill and the mooring site.

MARINE ENVIRONMENTAL CHANGE NETWORK

The UK Marine Environmental Change Network (MECN) is a collaboration between organisations in England, Scotland, Wales and Northern Ireland, collecting and synthesising long-term time-series information for UK and Irish waters. The goal of the network is to use long-term marine environmental data to separate natural fluctuations from global, regional and local anthropogenic impacts. SAMS participation in MECN will enable the continuation of our current meter mooring in the Tiree Passage that has generated data since 1986, and ensure our involvement in the maintenance of the Ellett Line of CTD stations between Scotland and Rockall, initiated by SAMS in 1975.

CR GRIFFITHS and ME INALL (SAMS)

HYDROGRAPHIC SERVICES

The Marine Physics Group continues to collaborate with, and offer services to, other groups, both within and outwith SAMS. This year we have provided instruments and expertise for eight commissioned research projects within SAMS, for two proposed fish farm Environmental Impact Assessments, and for a variety of research and teaching groups from visiting UK universities.

P PROVOST (SAMS)

MARINE TECHNOLOGY

MR DAVID MELDRUM

The technology development activities described earlier under Theme C of the Northern Seas Programme overlap rather closely with a number of externally funded research contracts: indeed it is entirely appropriate to regard the NSP as the largest of a number of interlinked technology contracts undertaken by the group. Typically the thrust of the work is to integrate a number of technologies (sensors, processors, communications, energy sources, packaging) to deliver a tool that will advance marine science in a particular area. In order to achieve this we maintain a close watch on emerging technologies in other disciplines, as well as interacting closely with scientists at Dunstaffnage and elsewhere.

UK DEEP-WATER OBSERVING SYSTEM (DWOS)

This work has arisen from the Department for Environment, Food and Rural Affairs (DEFRA) requirement to implement an offshore water quality monitoring programme. The programme has been initiated to address the UK's commitments under the Oslo-Paris Convention (OSPAR) on the protection of the marine environment, and has involved a number of other UK agencies, notably the Met Office, CEFAS, DARDNI and FRS in Aberdeen.

The ultimate aims of DWOS are to make measurements of water properties throughout the water column at a number of sites in the deep-water approaches to the UK, report these data to a central processing and archiving centre in near real time, and publish data products in a number of formats via the Internet. SAMS, POL and the Queen's University, Belfast have been involved in exploring a number of concepts for the implementation of DWOS, and reported to DEFRA in late 2001. More recently, SAMS has been appointed as prime contractor to develop the concept into a workable design in a progressive way, involving the deployment of technology demonstrator systems at a number of sites over the next three years.

Fundamental to the operation of DWOS are the development of a tethered profiling vehicle to carry a sensor payload through the water column at predetermined intervals, and the development of a telemetry and control system to communicate data and commands between the sensor package and the land-based processing centre. The profiling vehicle will be based on the *Homer* system conceived at POL. In essence, a seabed docking

station pays out and then retrieves a buoyant sensor package. Data and energy are transferred between sensor package and docking station, and the profile is repeated as often as required. As the whole system is normally bottom resident, the risk of sensor fouling and trawl damage is minimised. A prototype of this system has undergone trials at Dunstaffnage (Fig. 43), and negotiations are well advanced to allow key personnel from POL to contribute to further development and commercialisation of the concept at SAMS.

The communications strategy involves using the large pre-existing moored buoys of the Met Office deep-water network as relay stations. Data and commands will be transferred between the seabed and surface using acoustic modems, whereas the link between surface and shore will use satellite communications technology. Both systems are undergoing evaluation and detailed trials at SAMS; the latter study including a practical assessment of the Iridium satellite system under a collaborative arrangement with the US National Oceanographic Partnership Program.

SEA ICE BUOYS

Following the completion of the NERC grant which funded the development and deployment of six novel ice buoys in the Antarctic in 2000, further development work is continuing under a collaborative arrangement with the Scott Polar Research Institute (SPRI). A number of ice buoys were prepared for deployment in the Odden region of the Greenland Sea in late winter 2001, but ice conditions proved to be unsuitable and only one deployment was made (Fig. 44). The collaboration with SPRI is set to take an exciting step forward with the relocation of the SPRI sea ice group to SAMS in the summer of 2002. A number of new technologies for the study of ice dynamics and the slow thinning of the Arctic ice are under evaluation.

DT MELDRUM, OC PEPPE, DJ MERCER, W THOMSON, RB BARR and J WATSON (SAMS)

Fig. 44. Ice build up on board the RV *Jan Mayen* during a cruise to the Odden region of the Greenland Sea in spring 2001. Ice buoy deployments made during this cruise are part of a major new collaboration between the Scott Polar Research Institute and SAMS.

Fig. 43. The prototype HOMER profiler system is prepared for deployment to the bottom of Loch Etive. The buoyant central glass sphere, containing an electronics package and a number of sensors, is repeatedly released and retrieved by a winch in the seabed package. Data are transferred between the sphere and the seabed docking station via an infra-red link. This profiling technology is being developed at SAMS to furnish a number of research initiatives with a key new instrumentation capability.

SAMS/UHI MILLENNIUM INSTITUTE EDUCATION ACTIVITIES

DR AXEL MILLER

Last year we were able to report a landmark resulting from the relationship between SAMS and UHI, as the first cohort of undergraduate students was enrolled onto the UHI BSc Marine Science degree. In the current academic year we are equally delighted to report the continued healthy development of our undergraduate teaching activity at SAMS, the highest possible outcome from the quintennial UHI Academic Partner Review, and our excellent performance in the 2001 Research Assessment Exercise.

BSC MARINE SCIENCE

The SAMS contribution to the teaching of tertiary-level marine science in Scotland has been strengthened considerably over the reporting period. Two cohorts of BSc Marine Science undergraduates are now in place, and the course has received high praise from our External Examiners. Recruitment for the coming academic year is up on 2001-2 and, in preparation for the additional teaching load associated with running three levels (H1-H3) simultaneously, Dr Anuschka Miller – 'new-blood' Lecturer in Marine Life Sciences – has been recruited to the core team.

When the Open University Validation Service (OUVS) granted accreditation to offer the degree in September 1998, this was on condition that the North Highland College (NHC) should hold responsibility for administrative and support services, over an initial period of four years, prior to revalidation. This arrangement has allowed SAMS to observe academic procedures and develop the necessary structures to enable those functions to be carried out by SAMS in the future. Over the last few months staff have been preparing documentation for revalidation by OUVS in autumn 2002, after which time it is envisaged that SAMS will become the 'responsible partner' for all academic, administrative and support activities. This will be crucial to SAMS, allowing us to extend the current BSc to include Honours provision, essential to the capitalisation of SAMS role in the UK tertiary education sector.

2001 RESEARCH ASSESSMENT EXERCISE

UHI was invited to participate in the 2001 RAE just six weeks prior to the final submission deadline. Environmental Sciences was highlighted as an area of strength in the UHI research portfolio and a submission was developed over the four weeks prior to the deadline. UHI Research Committee (through Chair, Professor Graham Shimmield) took the 'strategic lead' on our participation, with Dr Axel Miller and Jane Foster (SAMS) and Dr Stuart Gibb (NHC) leading preparation of the documentation. The submission encapsulated the breadth of environmental science activity across the UHI, but 11 from the 13 'research active' staff submitted were from SAMS.

It was with great pleasure that we received a Grade 4 for the submission (5* being the highest grade). This has served to emphasise the strong reputation of SAMS amongst the national and international academic community. In addition to the block-grant funding to result from this success, the grading will also lead to the allocation of research development funding and postgraduate studentship funding from the Scottish Higher Education Funding Council in the future.

AEJ MILLER (SAMS)

REPORTS FROM THE SAMS HONORARY FELLOWS

MARINE ORNITHOLOGY

Every year, counts are made of the numbers of seabirds breeding in a study area extending along the mainland coast between Mallaig and West Loch Tarbert, including Loch Fyne. These provide an indication of changes in population size and have shown that the most characteristic species of this sealoch habitat, the terns and gulls, have decreased by 30-50% since 1987. In 2001, as in previous years, selected colonies were protected from mink by trapping prior to the start of egg laying. Although not all colonies are affected by mink, those that are affected usually produce no or almost no young. This tends to be repeated year after year until, eventually, surviving adults abandon the site. Comparison of the productivity (the number of young fledged per breeding pair) of colonies protected in this way with that of unprotected colonies allows us to estimate quantitatively the effects that mink are having on seabird breeding success.

In practice, only a few seabird species can be used in this way. The breeding success of terns is so affected by other factors, such as other predators, food shortage and a neurotic temperament, that in many years it is impossible to obtain useful results by this method. Only one other group, the gulls, are numerous enough both as individuals and as colonies to allow such comparisons, and the most numerous and therefore the most suitable species are the Common Gull and the Herring Gull. As in previous years, therefore, much effort was concentrated on these two species, and results in 2001 from the study area as a whole are given below in Table 1.

Over the six years of the study, mink were approximately halving the productivity of these two species in this area. Application of this finding to a simple population model suggests that this is sufficient to explain the reductions in the breeding populations of gulls and terns that have occurred since 1989 described in earlier reports. While the overall reduction in study area numbers is not obvious to casual observers, the disappearance of all breeding seabirds from a smaller area, such as a sealoch or sound, is much more noticeable. Areas such as the Creag archipelago in Loch Linnhe and all islands in Lochs Creran, Caolisport, Crinan and most of Loch Sunart have become empty in this way, while in others such as Loch nan Uamh and Loch nan Ceall, seabird numbers are greatly reduced and in rapid decline after well-documented annual breeding failures caused by mink predation.

Protection of selected colonies from mink has been carried out since 1995-97 (depending on area). Unlike many unprotected colonies, those protected from mink have usually bred successfully each year and have grown or maintained their numbers and biodiversity. Because of mink control, sealochs such as Ailort, Teacuis, Leven, Etive, Feochan, Melfort, Craignish, Sween and West Loch Tarbert (or parts of these lochs) still hold the small, mixed seabird colonies that are characteristic of the sealoch habitat.

JCA CRAIK (SAMS HONORARY FELLOW)

TABLE 1

	Pairs (colonies)	Fledged young	Fledged/pr	Mink reduced productivity by
Common Gull				
Mink removed	899 (19)	760	0.845	
Mink not removed	471 (31)	182	0.386	54%
Herring Gull				
Mink removed	1386 (7)	1145	0.826	
Mink not removed	6791 (46)	4266	0.628	24%

These methods have now been in use for several years. A summary of the percentage by which mink reduce productivity from what it would have been in the absence of mink, measured as above, is given below:

	1996	1997	1998	1999	2000	2001	Mean
Common Gull	ca 75	42	57	58	49	54	56%
Herring Gull	nm	53	68	53	35	24	47%

ZOOPLANKTON

Following the conclusion of the EC MAST Project - the Physiological Ecology of a Planktonic Crustacean (PEP) and Dr Geraint Tarling's subsequent research programme (p.36), I have continued to collaborate with Dr Tarling in preparing work for publication. Two more papers have been published in the course of the past year. As Director of Studies for Toby Jarvis, UHI PhD student, I have continued to provide supervision. Since the departure of Dr Tarling, I have assumed primary responsibility for this in Toby's final year before submission of his thesis, due later in 2002.

With Dr PC Reid, Director of the Sir Alister Hardy Foundation for Ocean Science, I was joint convenor of the Symposium held in Edinburgh in August 2001 to celebrate the 75th anniversary and to record the achievements of the Continuous Plankton Recorder Survey. The proceedings are due to be published.

As Secretary of the International Association of Biological Oceanography, I was involved in the planning of five symposia, all containing a strong component of biological oceanography, at the Joint IAPSO/IABO Assembly in Argentina in October 2001.

After a few years as a Trustee of the Hebridean Whale & Dolphin Trust, I assumed the chairmanship of the Trust at the AGM held in Tobermory in August 2001. The Trust had recently received a major award as part of the NADAIR Project which aims to promote the economy and communities of the North Argyll islands. Four members of staff are being appointed, and an ocean-going ketch is being acquired which will greatly enhance the educational and research work of the Trust.

Having followed with great interest the development of the UHI Degree in Marine Science, with which I had been involved at the start, I was pleased to resume an active part when I was invited to be Deputy Chairman of the SAMS-UHI Marine Science Quality Assurance Committee at its inception in January 2002.

JBL MATTHEWS (SAMS HONORARY FELLOW)

IT SERVICES

MR CHRIS RYDINGS

The IT Department within SAMS houses the core IT Services for the UHI Millennium Institute and SAMS itself. The scope of these services has broadened over the last year to include and develop new technologies for the use of more mobile devices that are common place now within research and commercial environments. With this change for mobile solutions, our equipment and its configuration have had to change to allow such emerging technology to be incorporated into the existing infrastructure.

DATA MESSAGING SERVICE

The GroupWise system has been recently upgraded to the latest level of GroupWise version 6. Although this is only on the UHI Millennium Institute mailing system, it is hoped that the SAMS e-mail system can follow suit shortly.

Current issues being looked at are:

- Mobile device technology.
- Virus and spamming technologies.
- Consolidation of current systems.

DATA WAREHOUSE SERVICE

The Data centre has increased its loading with more servers being added all the time. These increase existing functionality and also allow a certain amount of 'future proofing' to be carried out.

Current issues being looked at are:

- Fire-walling the Data Centre to give more security.
- Increasing the amount of data being held and transferred. (Currently at 24 Terabytes).
- Building fail-over system for increased reliability for core systems.

HELPDESK SERVICE

The Helpdesk service has been a resounding success from its launch last year. It has handled over 8,000 calls and created a central point of focus for call handling and administration for all of the academic partners as well as giving SAMS the ability to look at current issues and reliability. Among these are:

- Reviewing current loading for extra re-sourcing of staff to cater for increased workload.
- Extending services beyond SAMS and the UHI Millennium Institute to look at commercial options available.
- Gaining accreditation for the current service via the Helpdesk Institute.

Overall the IT department within SAMS has had a busy 12-month period with many Projects completed well within timescales and quite a few waiting to be started. The year ahead appears to be heading in the same direction.

C RYDINGS (SAMS/UHI)

SCIENTIFIC SERVICES

RESEARCH VESSELS

The Laboratory continues to operate two research vessels, RV *Calanus* and RV *Seòl Mara*, with state-of-the-art navigation and marine sampling equipment. *Calanus* gained a new Master during the year, following the retiral in 2000 of George McMillan after 28 years of service to SAMS. His replacement, Roddy MacNeil, has spent several years as Master of a large standby vessel in the North Sea. He brings with him a vast knowledge of Marine Health & Safety Regulations, which increasingly apply to smaller vessels such as our own.

Both vessels had busy programmes throughout the year with *Calanus* spending time away from her home base on a number of occasions. She had her annual refit at Corpach boatyard near Fort William in February 2002. A new grey water tank was fitted and a survey of areas of wood rot in the planking on the port side of the upper deck level resulted in the replacement of several planks. During the refit, a close inspection of the corroded state of the brake drums on the original CTD/Hydro winch resulted in its being condemned for Health & Safety reasons. After consideration of the high cost of repair, it was decided to replace it. A new winch is currently being assembled and will be installed soon. A new central heating boiler was fitted outwith the refit. During the year, a prototype bilge monitoring system was installed on *Calanus* by members of staff from Banff and Buchan College of Further Education. This was left on board for several months and provided the college with excellent data. They propose to commercially manufacture such units.

SAMS acquired a new contract during the year to supply scallops from a number of areas to the west and south of Oban to the Food Standards Agency in Aberdeen, as part of the research into amnesic shellfish poisoning. The University of East Anglia chartered both vessels for their summer oceanography fieldwork course. This proved successful and enquiries have been made for next summer's course. Dr John Watson of the University of Aberdeen successfully obtained holographic images in mid-water in Loch Creran from HOLOCAM.

Calanus spent 116 days at sea during the year (passage time not included) while *Seòl Mara* was at sea for 152 days. The following organisations chartered the vessels; the University of Cambridge, Napier University, Edinburgh University, Fugro UDI, NIOZ Texel, the University of East Anglia, Dames & Moore and the Food Standards Agency.

During the year the pontoon was taken away for its five-yearly inspection and refit. During the refit, a 1.5 tonne Palfinger crane was fitted to its deck for use by the AUTOMERS programme. A new much larger causeway is also currently being manufactured on which will run a 1 tonne motorised trolley, allowing the safe transportation of large heavy items onto the pontoon.

J WATSON (SAMS)

DIVNG AND SMALL BOATS

DIVING UNIT

The past year saw the establishment of the UK National Facility for Scientific Diving at Dunstaffnage. This development evolved from the old NERC Centre for Diving and gives the unit a stronger role in advising and guiding scientific diving regulation on a national scale. Incorporated within the National Facility is the Royal Yachting Association (RYA) recognised powerboat school. In addition to this new development, the Unit continues to act in support of the scientific diving and small boat operations of SAMS. The Dunstaffnage Hyperbaric Unit had its busiest year on record.

UK NATIONAL FACILITY FOR SCIENTIFIC DIVING (NFSD)

The UK National Facility for Scientific Diving was established in 2001 with initial NERC support for two years (recently extended by a further five years). The objectives of the Facility are primarily to provide advice, guidance and training for all diving and small boat operations involving NERC staff. The NFSD funding also provides a secure funding base for the UK Scientific Diving Supervisory Committee (SDSC), which is the body recognised by the Health and Safety Executive as representative of the scientific and archaeological sector under the 1997 Diving at Work regulations. In 2001 the NFSD facilitated the first meeting for NERC Diving Officers and diving contractors since the introduction of the regulations. During the year, site-based audits were conducted at most NERC-associated diving units and these will be completed in 2002. The NFSD facility initiated a number of diving-related courses during the year and the programme will continue and expand in 2002.

DIVING SUPPORT FOR SAMS SCIENCE ACTIVITIES

In 2001, the diving unit supported 402 person dives in support of the SAMS science programme and employed 18 personnel on diving operations. These included maintaining fish count and sub-sea temperature time-series, surveying biofiltration arrays around fish farms, taking benthic cores beneath fish farms, mapping reef module deployments on the artificial reef, assessing benthic lander operations and mapping patterns of bioturbation. The year also saw the Unit expand its underwater imaging equipment pool with new digital stills and digital video equipment. Problems in providing an underwater method for recording temporal changes in sub-sea structures have been overcome with the development of a video mosaic array (Fig. 45).

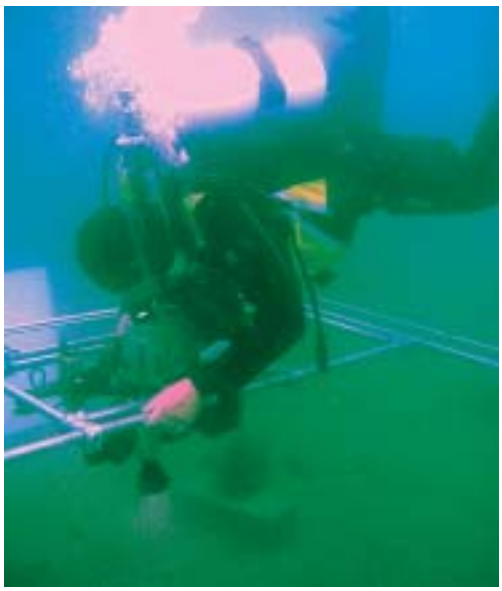


Fig. 45.
Recording biological community pattern using the new photo mosaic array.

DUNSTAFFNAGE HYPERBARIC UNIT

2001 was the busiest year for the hyperbaric recompression chamber at Dunstaffnage since treatments began in 1972. The Hyperbaric Unit received 33 divers, of whom 30 were eventually treated for decompression sickness (commonly referred to as 'the bends'). The divers mainly came from the Oban and Sound of Mull areas, but cases were also received from as far north as Sutherland, as far west as South Uist and as far south as Millport, in the Clyde. One patient was also treated at Dunstaffnage after contracting decompression sickness and receiving their primary treatment in the Caribbean. The unit at Dunstaffnage remains one of the busiest in the UK. Unfortunately, during the same period, there were also three deaths resulting from diving accidents in the region covered by the Facility.

In 2001, staff from the Dunstaffnage Hyperbaric Unit continued to act as technical advisers on the NHS-sponsored audit of recompression chambers in Scotland. Audit visits were made to Shetland, Orkney, Aberdeen, Skye, Lewis and Cumbrae during this period, and the reports are aiding revision of emergency recompression provision in Scotland. By invitation, the Scottish audit team also audited all the recompression facilities in northern and southern Ireland in 2001-2, again with staff from the Dunstaffnage Hyperbaric Unit providing technical expertise. Our accumulated expertise in downloading and analysing information from decompression computers resulted in Dunstaffnage staff providing expert witness support at fatal accident inquiries related to recreational diving accidents.

RYA SCHOOL

The Unit continues to provide training and testing of science-related powerboat requirements. In 2001-2 this included a seamanship module for students on the UHI Marine Science degree, which also included the students being awarded Level 1 and Level 2 RYA Powerboat certification. In 2002, it is hoped to expand the courses delivered to offer Advanced Powerboat certification.

MDJ SAYER and S THURSTON (SAMS)

AQUARIUM

The past year has seen the completion of the new seawater pumping system supplying the lab with pristine filtered seawater. Water is now drawn through two sub-sand intakes buried below the low water line in the horseshoe bay to the north-west of the laboratory. The new pumphouse is situated at the top of the beach and houses the two new pumps, priming tank, switch gear and pipework. These allow each pump to draw water up either intake line and pump it down either delivery line, providing maximal flexibility of operation.

This system replaces the original cove pumphouse and the associated intakes, pumps and pipes which are now in excess of 30 years old. All the seawater coming into the aquarium will now be filtered thus reducing problems with seaweed and shells blocking pipes and valves and settlement of mussels and barnacles in pipes and tanks. The new pipelines are buried underground to prevent damage from exposure to the elements and possible vandalism. Since the intakes are situated below the low water line there will no longer be the need to recirculate water within the building at low spring tides. A new air compressor has also been installed to provide a constant flow of clean compressed air to the aquarium, aquarium annexe and the air conditioned rooms.

The aquarium has continued to support a large number of projects over the past year. The invertebrate biology and mariculture group have continued their extensive use of the facilities with their sea urchin breeding and on-growing programme. The deep sea benthos group has continued its studies of the deep water coral *Lophelia pertusa* in the air conditioned rooms while fish physiology work has been conducted in the aquarium and aquarium annexe. Other groups that have made use of the aquarium facilities include the zooplankton dynamics and ecology and behaviour groups.

A KEAY (SAMS)

LIBRARY

The Library at Dunstaffnage holds a large amount of material gathered during the 100-year-plus history of the Association. It continues to be heavily used by scientific staff, visiting workers, SAMS members and students. Space has been provided for a small reading-room / library area for the UHI BSc Marine Science Degree students, supervised by Averil Wilson.

A journals review was carried out during the year to ensure that journal subscriptions provide support for the changing research needs of the Laboratory. Our holdings are extended by the receipt of reports and other exchange material from Institutes world wide. Plymouth Marine Laboratory kindly continues to provide its current awareness bulletins, which are available on-line via the SAMS local area network, along with the Library's own book-list, journal-list, publications database and other services such as Research Day and Funding Guide.

E WALTON (SAMS)

OBITUARY

DAVID ELLETT

David was born and brought up in Norfolk, completing his formal education at Great Yarmouth Grammar School in 1952 with A-levels in physics and geography. It is an enormous testament to the man's 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. In some ways he achieved a higher form of recognition than most: the automatic adoption of his name by the oceanographic community for the major hydrographic section that runs from Scotland to Rockall and beyond - the Ellett Line.

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'. His first job, working with Arthur Lee, foreshadowed the type of painstaking task that was typical of the rest of his working life - drawing up and checking the provisional mean monthly surface temperature and salinity charts for the north Atlantic from all available sources. Over the next decade or so, he absorbed and mastered the science (and art) of hydrography by participation in wide-ranging cruises to the Barents Sea, North Sea, Irish Sea, Atlantic, and further afield to the equatorial Indian Ocean. These cruises included, 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 which remain highly topical to this day. Spells as an oceanographic observer on both Irish and UK Weather Ships during this period marked the beginnings of his long interest and involvement with Ocean Weather Ships and their data.

The '50s and '60s saw the emergence of ocean variability as a major research theme, following on Arthur Lee's pioneering work on the 'Warming in the North', when such a protracted wave of warmth passed though the Atlantic subpolar gyre as to influence the global mean temperature curve. David brought his key qualities of meticulous observation and interpretation to this crucial area of study, and with Arthur Lee published in the mid-'60s important, lucid and pioneering new works on the role of the various overflows in the formation of the Atlantic's deep water masses. These seminal works are still in use today.

The Rockall Trough, the deep channel that lies immediately to the west of the Scottish shelf, was to be David's main working area and interest to the end of his career (Fig. 46). Right up until his official retirement in 1994, he thoroughly explored these waters, deploying the first long-term current meter moorings in the Trough in 1975, planning and then participating in the JASIN Air-Sea Interaction Experiment in 1978, recovering the

Fig. 46 David Ellett at work during his final cruise. Photo: Martyn Harvey

first unequivocal evidence of a Slope Current west of Scotland in 1979, and making the first direct measurements of overflow crossing the Wyville-Thomson Ridge in 1987-88. His many campaigns led to more than 80 publications and working visits to sister institutions in Germany, Japan and the USA. 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 aboard RRS *Challenger* 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 quickly built up a respected Marine Physics Group that combined intellectual acumen with formidable success in winning lucrative contracts from the likes of MAFF and the Department of Energy. 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 would have derived greatest satisfaction from being designated a Data Quality Evaluator for the World Ocean Circulation Experiment (WOCE) and from the adoption, both as a name and as a landmark concept, of 'the Ellett Line' by the research community. The use of its time-series to record the arrival-time of particular vintages of Labrador Sea Water, established 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. Fittingly, David's 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 his 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.

David James Ellett, born Great Yarmouth, Norfolk, 22 July 1934; died Oban, Argyll, 5 October 2001.

SAMS ACTIVITIES REPORT

Besides research and higher education, SAMS organises scientific meetings, undertakes public understanding of science events, and produces a Newsletter for its membership.

The European Network for Arctic-Alpine Multidisciplinary Environmental Research (ENVINET) held its 3rd General Meeting at SAMS in January. SAMS further co-organised a conference on *Benthic Dynamics* with the University of Aberdeen, and the *Symposium on the occasion of the 70th anniversary of the Continuous Plankton Recorder Survey of the North Atlantic* in Edinburgh, with the Sir Alister Hardy Foundation for Ocean Science.

Two Scottish Marine Group meetings were organised by SMG convenor Dr Hamish Mair (Heriot-Watt University). Stirling University hosted a meeting on *Marine Progress on Rio + 10*, where authoritative speakers considered sustainable development in the marine environment since the 1992 Earth Summit. At the postgraduate presentation meeting at the University of Aberdeen, the SAMS prize for the best presentation went to Richard Corner (University of Stirling), while Colin MacLeod (University of Aberdeen) won the SEPA prize for the best visual presentation.

The 12th annual Newth lecture was delivered by Professor Peter Wadhams from the Scott Polar Research Institute on *Convective Chimneys in the Greenland Sea*.

Dr Murray Roberts organises a seminar series at Dunstaffnage featuring the latest research developments in marine science. These events are free and open to the public.

The BA Festival of Science at the University of Glasgow saw SAMS team up with the National Museums of Scotland to host a session on *Marine science – can it really save our oceans?* SAMS contributed six public lectures on sustainable aquaculture, deep-water corals, artificial reefs, decommissioning of oil platforms, challenges for marine technology, and algal blooms. Dr Liz Cook and her papier-mâché giant sea urchin *Spikey* interacted with over 300 school children during the BA Young Persons sessions.

The SAMS Open Evening 2002 – a National Science Week event supported by COPUS - informed 220 visitors about our research activities and the latest developments in marine science (Fig. 47). SAMS further participated at large trade shows including *Oceanology International* and *Aquaculture International*, as well as having a stand at the annual Argyllshire Gathering in Oban.

SAMS supported a week-long marine biology field course for inner city teenagers at the University Marine Biological Station Millport by seconding Dr Anuschka Miller as a tutor. Links with Oban High School were re-established, when staff spent two days teaching about marine food webs, while our first year undergraduates talked to sixth formers about the Marine Science degree course. SAMS staff also gave talks to local primary schools during the year.

Dr Mike Burrows has been working with artist Niki Holmes (b consultants) on a SciArt project to create artificial rockpools of interest and value to both the scientific and artistic community, at a site near Hartlepool.

The SAMS website – maintained by Dr Liz Cook – has had about 600,000 direct and indirect hits over the reporting period.

Visitors to the laboratory included Scottish Deputy Finance Minister Peter Peacock MSP, Argyll and Bute MP Alan Reid, and Scottish MEP Elspeth Attwooll. Peter Timms (Vice President) and Ken Abernethy (Chief Executive) from Argyll and the Island's Enterprise toured the laboratory, as did UHI Chief Executive Professor Robert Cormack and UHI Board of Governors Chairman Professor Colin Mackay. Delegates from the Association of Scottish Shellfish Growers conference visited SAMS, as did representatives from the Akademi Norr who came to exchange experiences of developing higher education in remote areas. MSc courses from various UK universities came to Dunstaffnage for tours, talks and fieldwork.

ANUSCHKA MILLER (SAMS)

Fig. 47. *Luscious Lucy* - a new giant deep-water fish model - was a great winner with children at the SAMS Open Evening during National Science Week in March 2002.

Secretary's Report

The 87th Annual General Meeting of SAMS took place on 6 November 2001 at Dunstaffnage Marine Laboratory. Dr Ian Graham-Bryce chaired the AGM at which the members unanimously supported the revisions to the Articles of Association proposed by Council. As a result a wholly owned trading company SAMS Research Services Limited was set up. The transactions of that company are included in the accounts submitted by Council.

Professor Sir Frederick Holliday, Professor AD McIntyre, Dr JH Steele, Professor Sir William Stewart, and Professor SA Thorpe were elected as Vice Presidents for a period of one year. Sir Cyril Lucas stepped down. Dr Alexander Tudhope and Dr Paul Thompson were elected to Council for a period of three years. Professor Peter Boyle retired after six years service to SAMS but was asked to remain ex officio as Chair of the Financial and General Purposes Committee to ensure continuity during the construction of the new building. Dr P Newton and Mr A Munro were nominated as observers on Council for a further year. Messrs Scott Moncreiff were appointed auditors for the Association.

The AGM was immediately followed by the Twelfth Newth Memorial Lecture given by Professor Peter Wadhams of the Scott Polar Research Institute in Cambridge. The lecture was entitled *Convective Chimneys in the Greenland Sea*.

The Board of SAMS met at Dunstaffnage on 6 November to discuss SAMS strategy, the new building developments and the relationships with NERC and UHI Millennium Institute (UHI). Four meetings of Council were held during the course of the year.

The information included in SAMS' 2001-2002 Accounts differs from that in previous years for two reasons. Firstly, the treatment of certain funding has been altered because SAMS is a registered charity. It thus has to comply with the requirements of SORP 2000, 'Accounting by Charities' issued in October 2000 by the Accountancy Standards Board. Where such changes have been made, however, comparative figures in the statement of financial activities have been restated to ensure comparability. Secondly, the inclusion of the activities of the wholly owned subsidiary require figures to be shown for the SAMS charitable activities under the heading of the Company and SAMS and its subsidiary under the heading of the Group or Consolidated Statements.

The Council was served by the Finance and General Purposes Committee chaired by Professor P Boyle and Professor M Cowling, the Research and Strategy Committee chaired by Professor G Boulton and the Activities Committee chaired by Professor C Todd.

Membership of the Association

At 18 September 2002 total membership was 544(484), including 41(32) Corporate and 83(72) students. (Figures for 31 August 2001 are shown in brackets)

Contents

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

Company Information

Directors: (styled Members of Council)	Dr Ian J Graham Bryce (President) Mr W Balfour Professor GS Boulton Professor PR Boyle Professor MJ Cowling Mrs MM Crawford Dr A Goodlad Dr R Ormond Mr R Sankey Dr P Thompson Professor CD Todd Dr AW Tudhope Mrs J Twelves
Association Director:	Professor GB Shimmield
Secretary:	Mrs EB Walton
Registered office:	Dunstaffnage Marine Laboratory Oban Argyll PA37 1QA
Company Registration Number:	SCO 009292
Charity Recognition Number:	SC 009206
Auditors	Scott-Moncrieff 25 Bothwell Street Glasgow G2 6NL
Bankers	Bank of Scotland Station Road Oban PA34 4LL
Solicitors	Wright, Johnston & Mackenzie 21 St Vincent Place Glasgow G1 2EQ

Council Report

The Council present their annual report and the audited financial statements for the year ended 31 March 2002.

Principal Activity

The principal activity of the Company is to promote the study of marine science through research and education.

There have been no changes in principal activity since the last annual report.

Business Review

This report includes the additional activities formerly undertaken by NERC at the Dunstaffnage Marine Laboratory. The activities include the Northern Seas Programme embodied in the Agreement between NERC and SAMS, signed in April 2002. The same Agreement returns the management of the building, vessels and administration to SAMS from NERC and the costs of this management and administration now appear in the SAMS accounts (see Notes on the Financial Statements numbers 7 and 8 specifically). Equally, a number of Research Grants and Contracts were transferred from NERC to SAMS on 1 April 2001, along with sales of research and other services (See Notes on the Financial Statements numbers 3 and 6).

Results for the year of the Group

The results for the year are detailed on page 5 of the Financial Statements. The surplus taken to reserves is £2,153,877 (2001 deficit £368).

The Council confirms that on a fund by fund basis, the assets of £2,890,691 are adequate to fulfil the objectives of the Company.

Reserves Policy

The Policy is to retain sufficient funds required to meet the cost of salaries, insurances and other regular commitments to allow for orderly wind down of the organisation or to allow for the sums necessary to meet the cost of replacement of computer equipment.

Council is aware that the reserves of SAMS have been depleted to match UHI funding of Marine Science Degree lecturing staff and that they need to be replenished to meet the above objectives in the event of a significant drop in funding.

For the future the need for reserves has been cushioned by the two year notice period specified in the NERC/SAMS Agreement that was signed by SAMS on 16 April 2002.

Risk statement

On 16 April Members of Finance and General Purposes Committee were joined by the President and other members of Council for a seminar on risk assessment led by Scott Moncrieff, SAMS Auditors, to examine the major strategic, business and operational risks which SAMS as a charity face. The risk assessment was presented to the full Council at which it was agreed to implement a risk management strategy, which comprises:

- an annual review of the risks which SAMS as a charity may face
- the establishment of systems and procedures to mitigate those risks identified in the plan
- the implementation of procedures designed to minimise any potential impact on SAMS as a charity should any of those risks materialise.

Investment Policy and Performance

The Council has considered the most appropriate policy for investing funds and has found that short to medium term investment of funds should be held in a mixture of current and investment accounts to optimise interest earned.

The Council

The individuals who are styled the 'Council' are all directors of SAMS. Each acts as a trustee on behalf of the Members and all are guarantors of the Company, of an amount not exceeding £1 each during the period of their appointment and for a year after their resignation. The Council is appointed in accordance with SAMS' Memorandum and Articles of Association.

The members of the Governing Council during the year were:

	Date Appointed
Dr Ian J Graham Bryce (President)	1 August 2000
Mr W Balfour	6 November 2001
Professor GS Boulton	27 October 1997
Professor PR Boyle	16 November 1998
Professor MJ Cowling	6 November 2000
Mrs MM Crawford	1 November 1999
Dr A Goodlad	6 November 2000
Dr R Ormond	6 November 2000
Mr R Sankey	6 November 2000
Dr P Thompson	6 November 2001
Professor CD Todd	27 October 1997
Dr AW Tudhope	6 November 2001
Mrs J Twelves	6 November 2000

Equal Opportunities

SAMS is committed to provide full opportunity for the development of individuals' talents by using criteria based on merit and job performance alone in employment related decisions. It is further committed to prevent discrimination on grounds of gender, marital status, race, colour, ethnic or national origins, age, religious belief, sexual orientation or disability.

Statement of Councils' responsibilities in relation to the financial statements

Company law requires the Directors and Trustees of SAMS (styled the Council) to prepare financial statements for each financial year which give a true and fair view of the state of affairs of the Charitable Company and the Group and of the surplus or deficit of income over expenditure of the Group for that period. In preparing those financial statements, the Council is required to:

- select suitable accounting policies and apply them consistently;
- make judgements and estimates that are reasonable and prudent;
- state whether applicable accounting standards have been followed, subject to any material departures disclosed and explained in the financial statements;
- prepare the accounts on the going concern basis unless it is inappropriate to presume that the group will continue in business.

The Council is responsible for keeping proper accounting records which disclose with reasonable accuracy at any time the financial position of the group and to enable it to ensure that the financial statements comply with the Companies Act 1985. Council has a general responsibility for taking such steps as are reasonably open to it to safeguard the assets of the group and to prevent and detect fraud and other irregularities.

By order of Council
EB Walton
Secretary

30 September 2002

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

INDEPENDENT AUDITORS' REPORT TO THE MEMBERS OF THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE
for the year ended 31 March 2002

We have audited the consolidated financial statements of The Scottish Association For Marine Science for the year ended 31 March 2002 set out on pages 5 to 15. These financial statements have been prepared under the historical cost convention as modified by the revaluation of certain fixed assets and the accounting policies set out on page 7.

Respective responsibilities of directors and auditors

As described in the Statement of The Council's Responsibilities the charitable company's directors are responsible for the preparation of the financial statements in accordance with applicable law and United Kingdom Accounting Standards.

Our responsibility is to audit the financial statements in accordance with relevant and regulatory requirements and United Kingdom Auditing Standards.

We report to you our opinion as to whether the financial statements give a true and fair view and are properly prepared in accordance with the Companies Act 1985. We also report to you if, in our opinion, the Council's Report is not consistent with the financial statements, if the charitable company has not kept proper accounting records, if we have not received all the information and explanations we require for our audit, or if information specified by law regarding directors' remuneration and transactions with the charitable company is not disclosed.

We read the Council's Report and consider the implications for our report if we become aware of any apparent misstatements within it.

Basis of opinion

We conducted our audit in accordance with United Kingdom Auditing Standards issued by the Auditing Practices Board. An audit includes examination, on a test basis, of evidence relevant to the amounts and disclosures in the financial statements. It also includes an assessment of the significant estimates and judgements made by the Council in the preparation of the financial statements, and of whether the accounting policies are appropriate to the charitable company's circumstances, consistently applied and adequately disclosed.

We planned and performed our audit so as to obtain all the information and explanations which we considered necessary in order to provide us with sufficient evidence to give reasonable assurance that the financial statements are free from material misstatement, whether caused by fraud or other irregularity or error. In forming our opinion we also evaluated the overall adequacy of the presentation of information in the financial statements.

Opinion

In our opinion the financial statements give a true and fair view of the state of affairs of the charitable company and its subsidiary as at 31 March 2002 and of their incoming resources and application of resources, including their income and expenditure, in the year then ended and have been properly prepared in accordance with the Companies Act 1985.

Scott-Moncrieff
Chartered Accountants
Registered Auditors
25 Bothwell Street
Glasgow

30 September 2002

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

CONSOLIDATED STATEMENT OF FINANCIAL ACTIVITIES INCORPORATING A CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT For the year ended 31 March 2002

		2002 Unrestricted funds £	2002 Restricted funds £	2002 Total £	2001 Total restated £
Incoming Resources					
Northern Seas programme		2,093,974	134,127	2,228,101	294,000
NERC research grants		448,674	-	448,674	254,604
UHI teaching income		109,151	186,938	296,089	76,179
		2,651,799	321,065	2,972,864	624,783
From operating activities					
Activities in furtherance of its objectives	3	1,584,882	52,799	1,637,681	916,077
Activities in generating funds					
Investment income		7,500	-	7,500	3,117
NERC lease payment	4	-	1,600,000	1,600,000	-
Others		327,037	-	327,037	-
Total incoming resources		4,571,218	1,973,864	6,545,082	1,543,977
Resources expended					
Cost of generating funds	5	19,269	-	19,269	6,326
Charitable expenditure:					
Cost of activities in furtherance of the objectives	6	2,610,224	-	2,610,224	1,115,246
Support costs	7	977,965	-	977,965	-
Management and administration	8	622,211	161,536	783,747	422,773
Total charitable expenditure		4,210,400	161,536	4,371,936	1,538,019
Total resources expended		4,229,669	161,536	4,391,205	1,544,345
Net incoming resources/(resources expended) before transfers and tax		341,549	1,812,328	2,153,877	(368)
Taxation		-	-	-	-
Transfers between funds		-	-	-	-
Net incoming resources/(resources expended)		341,549	1,812,328	2,153,877	(368)
Fund balances brought forward at 1 April 2001		158,432	578,382	736,814	737,182
Fund balances carried forward at 31 March 2002		499,981	2,390,710	2,890,691	736,814

All disclosures relate only to continuing operations.

There are no gains or losses other than the surplus for the year.
The notes on pages 64 to 72 form part of these accounts.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

CONSOLIDATED BALANCE SHEET
31 March 2002

	Note	2002 £	2001 Restated £
Fixed assets			
Tangible assets	12	1,205,678	680,646
Investments	13	40,316	40,345
		1,245,994	720,991
Current assets			
Debtors	14	1,947,239	324,224
Cash at bank and in hand		822,033	166,833
		2,769,272	491,057
Creditors: amounts falling due within one year	15	(1,124,575)	(475,234)
Net current assets/(liabilities)		1,644,697	15,823
Net assets		2,890,691	736,814
Reserves			
Restricted	17	2,390,710	578,382
Unrestricted		499,981	158,432
		2,890,691	736,814

COMPANY BALANCE SHEET
31 March 2002

	Note	2002 £	2001 Restated £
Fixed assets			
Tangible assets	12	1,096,376	680,646
Investments	13	40,316	40,345
		1,136,692	720,991
Current assets			
Debtors	14	1,907,610	324,224
Cash at bank and in hand		765,162	166,833
		2,672,772	491,057
Creditors: amounts falling due within one year	15	(1,040,293)	(475,234)
Net current assets/(liabilities)		1,632,479	15,823
Debtors due in more than one year	16	130,000	-
Net assets		2,899,171	736,814
Reserves			
Restricted	17	2,390,710	578,382
Unrestricted		508,461	158,432
		2,899,171	736,814

CONSOLIDATED CASH FLOW STATEMENT
For the year ended 31 March 2002

	Note	2002 £	2001 Restated £
Net cash inflow from operating activities	21	1,334,211	79,229
Returns on investments and servicing of finance	22	7,500	3,117
Net cash inflow/(outflow) from Capital expenditure	22	(686,511)	6,659
Increase/(decrease) in cash		655,200	89,005

These financial statements were approved on behalf of the Council on 30 September 2002 and were signed by:

MJ COWLING
Chair of Finance and General Purposes Committee

The notes on pages 64 to 72 form part of these accounts.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

1. Accounting policies

Status

The Scottish Association for Marine Science (SAMS) is a company limited by Guarantee and not having a share capital. The liability of the Members who constitute SAMS is limited to £1 per member.

The affairs of SAMS are managed by an elected Council of Members, who constitute Directors of the Company for Companies Act purposes. The Association is a registered charity, Scottish Charity Number SC009206, and is not liable to income tax nor corporation tax on its income under the Income and Corporation Taxes Act 1988.

The following accounting policies have been applied consistently in dealing with items which are considered material in relation to the company's financial statements.

Basis of accounting

The financial statements have been prepared in accordance with applicable accounting standards and under the historical cost convention as modified by the revaluation of investments. The financial statements have been prepared in accordance with the Statement of Recommended Practice 'Accounting by Charities' (SORP 2000) issued in October 2000.

Comparative figures in the statement of financial activities have been restated to ensure comparability with the current period.

Basis of consolidation

The consolidated financial statements incorporate the financial statements of the company and its subsidiary drawn up to 31 March each year.

Income

Income represents NERC core grants receivable in the year, other research income receivable from outside bodies and other miscellaneous income. All core NERC grants are recognised as revenue in the year they are received. Other funds received of a revenue nature are credited to deferred revenue income and credited to the Income and Expenditure Account as the related research costs are incurred.

Resources expended and funds

Direct charitable expenditure represents the full cost of the research performed. It includes the cost of direct staff, consumable stocks and indirect costs. Fundraising and publicity expenditure represents the cost of obtaining funds for research, promoting the work of the Association and recruitment of staff. Management and administration expenditure represents the necessity of compliance with statutory and constitutional requirements, and any other costs which are not direct charitable expenditure or fundraising and publicity expenditure.

Funds totalling £2,390,710 are restricted. Otherwise all funds of the group relate to unrestricted funds.

Fixed assets and depreciation

Depreciation is provided by the company to write off the cost less the estimated residual value of tangible fixed assets by equal instalments over their estimated useful economic lives as follows:

Property	50 years
Vessels	25 years
Fittings and Equipment	5 – 8 years

Grants receivable for the purchase of assets were deducted from the value of the fixed asset in previous years. This year however, the policy has been to credit income received for capital grants to the income and expenditure account as a restricted fund.

Investments

Investments represent property and bank balances for the Sheina Marshall Bequest and the Yonge Fellowship.

Foreign currency transactions

All foreign currency gains and losses are taken to the income and expenditure account as incurred. Monetary assets and liabilities denominated in foreign currencies are translated at the rate of exchange ruling at the balance sheet date.

Taxation

Income is stated net of VAT and expenditure includes VAT where applicable.

The Association is a registered charity and therefore no provision for corporation tax is required on the results for the year.

The group's financial statements include the relevant corporation tax in respect of the consolidated subsidiary where material.

Leases

Where the company enters into a lease which entails taking substantially all the risks and rewards of ownership of an asset, the lease is treated as a finance lease. The asset is recorded in the balance sheet as a tangible fixed asset and is depreciated over its estimated useful life or the term of the lease, whichever is shorter. The finance charges are allocated over the period of the lease in proportion to the capital amount outstanding.

All other leases are accounted for as operating leases and the rental charges are charged to the profit and loss account on a straight line basis over the life of the lease.

Pensions

SAMS participates in the Universities Superannuation Scheme, a defined benefit scheme which is externally funded and contracted out of the State Earnings-Related Pension Scheme. The fund is valued every three years by a professionally qualified independent actuary using the projected unit method, the rates of contribution payable being determined by the trustee on the advice of the actuary. In the intervening years, the actuary reviews the progress of the scheme. Pension costs are assessed in accordance with the advice of the actuary, based on the latest actuarial valuation of the scheme, and are accounted for on the basis of charging the cost of providing pensions over the period during which the company benefits from the employees' services.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

2. Activities of SAMS

The negotiations with NERC reported last year were concluded by the signing by SAMS of an Agreement with NERC on 16 April 2002. Some of the NERC activities were found to be likely to exceed the Inland Revenue limits for trading activity by charities. SAMS therefore took legal and financial advice and decided to manage this development by setting up a wholly owned trading subsidiary. This was put to members and agreed at the AGM on 6 November 2001 and the subsidiary, known as SAMS Research Services Limited began trading on 2 January 2002.

3. Analysis of income received

	2002 Unrestricted funds £	2002 Restricted funds £	2002 Total £	2001 Total £
Furtherance of objectives				
Computing Services	177,563	-	177,563	89,368
Research Grants	757,636	52,799	810,435	552,542
Research Contracts	428,607	-	428,607	274,167
Scientific Services	201,902	-	201,902	-
Sales of Cultures	19,174	-	19,174	-
Total	1,584,882	52,799	1,637,681	916,077

Project income received	2002 £	2001 £
Coastal Impact Research	498,707	219,915
Biogeochemical Fluxes	378,245	-
Geochemistry	230,981	84,993
Pelagic Plankton	164,134	237,531
Marine Technology	575,975	108,888
Deep Sea Fish	102,737	98,018
Deep Sea Benthos	148,245	99,472
Ecology and Behaviour	218,340	-
Animal Environment Interaction	203,122	-
Computing Services	158,277	-
Marine Physics Group	88,574	211,685
Marine Algal Research Group	184,364	-
Shared Research Cruise	101,004	-
	3,052,705	1,060,502

4. NERC lease payment
This represents a payment received from the Natural Environment Research Council as compensation for dilapidations and lease payments that will not be paid in future years.

5. Cost of generating funds

	Unrestricted Funds 2002 Staff cost £	2002 Other £	2002 Restricted funds £	2002 Total £	2001 Total £
Marketing, publications and newsletters	-	10,269	-	10,269	6,326
Salaries	9,000	-	-	9,000	-
	9,000	10,269	-	19,269	6,326

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

6. Cost of scientific activities in furtherance of the objectives

	Unrestricted Funds 2002 Staff cost £	2002 Other £	2002 Restricted funds £	2002 Total £	2001 Total £
Coastal Impact Research	209,026	211,915	-	420,941	197,118
Biogeochemical Fluxes	322,669	117,980	-	440,649	-
Geochemistry	148,122	51,775	-	199,897	96,372
Pelagic Plankton	134,565	37,028	-	171,593	169,608
Marine Technology	83,007	227,702	-	310,709	97,600
Deep Sea Fish	82,339	57,042	-	139,381	169,781
Deep Sea Benthos	149,517	24,627	-	174,144	151,726
Ecology and Behaviour	189,619	14,531	-	204,150	-
Animal Environment Interaction	65,744	31,996	-	97,740	-
Computing Services	138,548	8,920	-	147,468	19,510
Marine Physics Group	74,160	9,251	-	83,411	189,741
Marine Algal Research Group	97,619	21,518	-	119,137	-
Shared Research Cruise	-	101,004	-	101,004	23,790
	1,694,935	915,289	-	2,610,224	1,115,246

7. Support costs

Vessels	139,537	40,478	-	180,015	-
Scientific support	154,969	11,418	-	166,387	-
Buildings	153,238	478,325	-	631,563	-
	447,744	530,221	-	977,965	-

8. Management and administration

Meetings	-	3,084	-	3,084	533
Bursaries	-	3,519	-	3,519	3,680
Council expenses	-	8,997	-	8,997	6,709
Postage and telecom	-	54,279	-	54,279	3,182
Insurance	-	38,792	-	38,792	8,465
Library and printing	-	49,026	-	49,026	14,975
Other professional fees	-	57,864	-	57,864	7,496
Travel, subsistence and interviews	-	38,715	-	38,715	9,258
Bank charges	-	37	-	37	-
Exceptional pension payment	-	7,731	-	7,731	-
Depreciation	-	-	161,507	161,507	71,210
Administration, services and equipment	-	64,273	-	64,273	-
Administration salaries	295,894	-	-	295,894	50,964
Gain on disposal of fixed assets	-	-	-	-	(19,000)
Exchange differences	-	-	-	-	5,935
Sundries and subscriptions	-	-	29	29	1,395
UHI	-	-	-	-	257,971
	295,894	326,317	161,536	783,747	422,773

Direct charitable and commercial expenditure and management and administration costs include	2002 £	2001 £
Auditors' remuneration		
- audit services	6,000	3,000
- other services	27,482	24,350
Depreciation	161,507	71,210

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

9. Remuneration of the members of the Council

The non-executive Council members received £8,223 in tota (2001: £6,132) remuneration, in the form of travel expenses, from SAMS during the year.

10. Staff numbers and costs

The average number of SAMS employees during the year, analysed by category, was as follows:

	Number of employees 2002	Number of employees 2001
Scientific	21	19
Scientific services	9	7
Office/Management	10	10
	40	36

The remuneration of SAMS employees was as follows:

	2002 £	2001 £
Salaries	858,570	685,946
Social security costs	59,251	52,724
Other pension costs	102,935	82,801
	1,020,756	821,471

The remuneration of the employees of NERC working for the Association was as follows:

	2002 £	2001 £
Salaries	1,222,067	-
Social security costs	91,522	-
Other pension costs	118,445	-
	1,432,034	-

The number of SAMS staff with emoluments greater than £50,000 was

	2002 No	2001 No
£50,000 - £60,000	-	1
£60,001 - £70,000	1	-

The total pension contributions paid by the company on behalf of the above member of staff were £8,824 (2001: £8,180).

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

11. Investment Income

	2002 £	2001 £
Interest receivable	7,500	3,117

12. Tangible fixed assets

(a) The Group

	Property £	Vessels £	Fittings & Equipment £	Total £
Cost				
At 1 April 2001	1,047,049	416,678	2,028,702	3,492,429
Additions	215,928	-	473,909	689,837
Disposals	-	-	(3,298)	(3,298)
At 31 March 2002	1,262,977	416,678	2,499,313	4,178,968
Depreciation				
At 1 April 2001	548,680	416,678	1,846,425	2,811,783
Charge for year	11,712	-	149,795	161,507
On disposals	-	-	-	-
At 31 March 2002	560,392	416,678	1,996,220	2,973,290
Net book amount				
At 31 March 2002	702,585	-	503,093	1,205,678
At 31 March 2001	498,369	-	182,277	680,646

(b) The Company

Cost				
At 1 April 2001	1,047,049	416,678	2,028,702	3,492,429
Additions	106,626	-	473,909	580,535
Disposals	-	-	(3,298)	(3,298)
At 31 March 2002	1,153,675	416,678	2,499,313	4,069,666
Depreciation				
At 1 April 2001	548,680	416,678	1,846,425	2,811,783
Charge for year	11,712	-	149,795	161,507
On disposals	-	-	-	-
At 31 March 2002	560,392	416,678	1,996,220	2,973,290
Net book amount				
At 31 March 2002	593,283	-	503,093	1,096,376
At 31 March 2001	498,369	-	182,277	680,646

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

13. Investments

	The Group		The Company	
	2002 £	2001 £	2002 £	2001 £
Sheina Marshall Bequest				
Flat at cost	25,673	25,673	25,673	25,673
Bank balances	13,107	13,136	13,107	13,136
Debtor	1,536	1,536	1,536	1,536
	40,316	40,345	40,316	40,345

On 21 November 2001, the company acquired the entire issued ordinary share capital of SAMS Research Services Limited for a consideration of £1. SAMS Research Services Limited is incorporated in Scotland, and its principal activity is the provision of marine and research support services.

14. Debtors

	The Group		The Company	
	2002 £	2001 £	2002 £	2001 £
Trade debtors and grants due	417,499	190,325	417,499	190,325
Other debtors	1,418,541	133,899	1,418,541	133,899
VAT debtor	19,128	-	-	-
Prepayments and accrued income	92,071	-	71,570	-
	1,947,239	324,224	1,907,610	324,224

15. Creditors: amounts falling due within one year

Payments received in advance	512,575	253,086	512,575	253,086
Deferred creditors	187,176	-	187,176	-
Taxation and social security	21,735	4,582	21,735	4,582
Sundry creditors and accruals	403,089	217,566	318,807	217,566
	1,124,575	475,234	1,040,293	475,234

16. Debtors due in more than one year

Due from subsidiary company	-	-	130,000	-

(see also note 17)

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

17. Restricted funds

Group and Company

	1 April 2001 (as restated) £	Income £	Expenditure £	31 March 2002 £
Fixed asset funds	534,944	373,864	(161,507)	747,301
Property development fund	-	1,600,000	-	1,600,000
Sheina Marshall Bequest	40,345	-	(29)	40,316
Yonge Fellowship	3,093	-	-	3,093
At 31 March 2002	578,382	1,973,864	(161,536)	2,390,710

The financial statements have been prepared in accordance with SORP 2000. Prior to compliance with SORP 2000, capital grants were credited to fixed assets. These grants are now recognised as restricted income in the year in which they are received and the depreciation is recognised as an expenses against the restricted fund. The effect of this is to increase the prior period opening reserves by £534,944 to recognise the restricted fund and reduce the capital grants set against fixed assets by the same amount.

The property development fund is an amount donated by NERC to finance the building of the new laboratory. This amount has been loaned to the subsidiary company, SAMS Research Services Ltd, to develop the new laboratory at Dunstaffnage.

The Sheina Marshall Bequest is an amount left by the late Dr Sheina Marshall OBE, DSc to SAMS. The sum bequested was used by SAMS to purchase a dwelling property in Oban which is used to accommodate visiting researchers.

The Yonge Fellowship is to commemorate the late Professor Sir Maurice Yonge. Awards will be made from the fund to suitable marine science projects. Recently the funds have been used to support Marine Science Lecturers jointly funded by UHI.

18. Lease commitments

	2002 Property	2001 Property	2002 Other £	2001 Other £
Leases which expire:				
Within one year	-	-	11,156	-
Within two to five years	-	-	4,456	-

19. Capital commitments

	Group		Company	
	2002	2001	2002	2001
Contracted for	7,492,000	-	78,000	-

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

20. Pension Commitments

The company participates in the Universities Superannuation Scheme, a defined benefit scheme which is externally funded and contracted out of the State Earnings-Related Pension Scheme. The assets of the scheme are held in a separate trustee-administered fund. It is not possible to identify each institution's share of the underlying assets and liabilities of the scheme and hence contributions to the scheme are accounted for as if it were a defined contribution scheme. The cost recognised within the surplus/deficit for the year in the income and expenditure account being equal to the contributions payable to the scheme for the year.

The latest actuarial valuation of the scheme was at 31 March 1999. The assumptions which have the most significant effect on the result of the valuation are those relating to the rate of return on investments (ie the valuation rate of interest) and the rates of increase in salary and pensions. In relation to the past service liabilities the financial assumptions were derived from market yields prevailing at the valuation date. It was assumed that the valuation rate of interest would be 4.5% per annum, salary increases would be 3.6% per annum and pensions would increase by 2.6% per annum. In relation to the future service liabilities it was assumed that the valuation rate of interest would be 5.5% per annum, including an additional investment return assumption of 1% per annum, salary increases would be 3.5% per annum and pensions would increase by 2.5% per annum. The valuation was carried out using the projected unit method.

At the valuation date, the market value of the assets of the scheme was £18,870 million (including an estimated £55 million in respect of outstanding bulk transfer payments due) and the value of the past service liabilities was £17,427 million. The assets therefore were sufficient to cover 108% of the benefits which had accrued to members after allowing for expected future increases in earnings.

The company contribution rate required for future service benefits alone at the date of the valuation was 16.3% of salaries but it was agreed that the company contribution rate will be maintained at 14% of salaries. To fund this reduction of 2.3% for the period of 11 years from the date of the valuation (the average outstanding working lifetime of the current members of the scheme) required the use of £561 million of the surplus. It was also agreed, following the valuation, that £201 million of the surplus would be used to fund certain benefit improvements. This left a past service surplus of £681m (including the Supplementary Section) to be carried forward.

Surpluses or deficits which arise at future valuations may impact on the company's future contribution commitment. The latest formal valuation was at 31 March 2002 but the new rates are not yet available.

The total pension cost for the company was £102,935 (2001: £82,801). The contribution rate payable by the company was 14% of pensionable salaries.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE FINANCIAL STATEMENTS
Year ended 31 March 2002

21. Reconciliation of operating surplus/(deficit) of income over expenditure to net cash inflow from operating activities

	2002 £	2001 £
Surplus/(deficit) of income over expenditure	2,153,877	(368)
Net investment income	(7,500)	(3,117)
Depreciation charge	161,507	71,210
(Gain) on sale of tangible fixed assets	-	(19,000)
(Increase) in debtors	(1,623,015)	(57,530)
Increase in creditors	649,342	88,034
Net cash inflow from operating activities	1,334,211	79,229

22. Analysis of gross cash flows for headings netted in the cashflow statement

Returns on investments and servicing of finance:		
Bank interest received	7,500	3,117
	7,500	3,117
Capital expenditure:		
Payments to acquire tangible fixed assets	(689,837)	(557,491)
Receipts from disposal of investments	28	618
Receipts from sales of tangible fixed assets	3,298	19,000
Capital Grants reclassified – prior year restatement	-	544,532
	(686,511)	6,659

23. Analysis of changes in net funds

	2001	Cash Flow movement	Other changes £	2002 £
Cash at bank	166,833	655,200	-	822,033

Reconciliation of net cash flow to movement in net funds

	2002 £
Increase in cash during the period	655,200
Net funds at 1 April 2001	166,833
Net funds at 31 March 2002	822,033

APPENDIX 1: STAFF AT 31 MARCH 2002

(* denotes Group Leader)

Director
Professor Graham B Shimmield

Geochemistry Group
Dr T Shimmield*
Dr J Howe
Mr E Breuer
Miss JM Foster
Miss S McKinlay
Miss T Sawyer

Deep Sea Benthos Group
Professor JD Gage*
Dr B Narayanaswamy
Dr JM Roberts
Mr P Lamont (part time)

Deep Sea Fish Group
Dr JDM Gordon*
Ms SC Swan

Ecology and Behaviour Group
Dr MT Burrows*
Dr RS Batty
Dr LA Nickell
Mr R Harvey
Mrs LA Robb

Animal Environment Interaction Group
Dr MDJ Sayer*
Dr CJ Brown
Dr EJ Cook
Miss S Magill
Mr TA Wilding

Marine Algal Research Group
Dr CJS Bolch*
Dr D Green
Dr M Hart
Miss P Proudlock
Mrs CN Campbell (part time)

Pelagic Plankton Group
Dr R Leakey
Dr K Davidson
Dr KJ Willis

Coastal Impacts Group
Dr KD Black*
Dr DJ Hughes
Dr MS Kelly
Dr AH Miller (part time)
Dr TD Nickell
Mr C Cromey

Biogeochemical Fluxes Group
Dr KJ Jones*
Dr E Fouilland
Dr A Hatton
Dr AEJ Miller
Dr J Overnell
Mr TD Brand
Mr SM Harvey
Ms A Wilson

Marine Physics Group
Dr M Inall*
Dr F Cottier
Dr P Provost
Mr CR Griffiths

Marine Technology Group
Mr DT Meldrum*
Dr DJ Mercer
Mr RB Barr
Mr OC Peppe
Mr W Thomson
Mr J Watson

SAMS Honorary Research Fellows
Dr M Barnes
Professor JHS Blaxter
Dr JCA Craik
Sir Eric Denton
Dr RN Gibson
Dr GP Glasby
Professor JBL Matthews
Dr TH Pearson

Data Warehouse Manager
Mr C Rydings

IT Services
Miss N Longman
Mr R McKinnon
Mr S Phillips
Mr GC Ryan
Mrs K Smalley

Database Manager
Mr SJ Gontarek

Activities Manager
Dr AH Miller (part time)

Company Secretary
Mrs EB Walton

Director's Secretariat
Miss J McLoughlin
Mrs P Claxton (part time)

Health & Safety Adviser
Mr IA Ezzi

Personnel
Ms CM Bonomy
Mrs L Thomson

Programme Administrator
Mrs A Black

Librarian
Miss EJ Walton

Accounts
Mrs P Claxton (part time)
Miss E Dudman
Mrs F Hart
Mrs L Lamb

Reception
Mrs J MacAskill

Aquarium Manager
Mr A Keay

Electrical Maintenance
Mr BH Clark
Mr J Hill

Building Maintenance
Mr DN Mackinnon
Mr AC Black

Storeman
Mr G Webster

Ships: RV *Calanus* and RV *Seòl Mara*
Mr RA MacNeil (Master)
Mr SF Douglas (Motorman)
Mr D McAlpine (Bosun)
Mr J MacFarlane (Engineer)
Mr GJR Murphy (Mate)
Mr N Smith (Deckhand)

Diving and Small Boats
Dr S Thurston
Mr RW Wood

APPENDIX 2: PUBLICATIONS AND REPORTS

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WILLIS, KJ and **TARLING, GA**, 2001. Zooplankton assemblages. In: Ecological effects of sea lice treatments: Annual Progress Report. PAMP Annual Report (ed. TD Nickell), pp. 30-46.

APPENDIX 3: POSTGRADUATE RESEARCH PROJECTS

(SUPERVISORS' NAMES IN PARENTHESES)

Degrees Awarded during the Reporting Year

S Craig, Ph.D, The University of Aberdeen. *The developmental plasticity of Loliginid squid; developmental biology and biochemical composition of the eggs of the squid* Loligo forbesi *Steenstrup*, (P Boyle, **KD Black** and **J Overnell**).

V Edwards, Ph.D, Napier University. *Yield of marine phytoplankton chlorophyll from dissolved organic nitrogen under eutrophic conditions.* (P Tett, **KJ Jones**, S Bury and R Park)

Ongoing Research

O Costa, Ph.D, The University of Plymouth. *Brazilian coral reef biogeochemistry.* (M Attrill, M Nimmo, **AEJ Miller**)

S Cousins, Ph.D, University of Aberdeen and FRS. *An Investigation of the processes involved in* Pecten maximus *contamination by Amnesic Shellfish Poisons.* (S Gallagher, **MS Kelly**, B Eddie, A Taylor)

P Crozier, Ph.D, The University of the Highlands Millennium Institute. *The impact of deep-water fisheries on elasmobranch populations in the north east Atlantic.* (**JDM Gordon** and P Vass)

L Darrock, Ph.D, The University of East Anglia. *Dimethylsulphoxide: origin, fate and cycling.* (PS Liss, G Malin and **AD Hatton**)

R Dean, Ph.D, The University of the Highlands and Islands Millennium Institute. *Biogeochemical cycling in fish farm sediments.* (**TM Shimmield, KD Black** and P Gillibrand)

J Fehling, Ph.D, The University of the Highlands and Islands Millennium Institute. *Amnesic shellfish poisoning in Scottish waters.* (**K Davidson, CJS Bolch** and P Tett)

SA Fleming, Ph.D, The University of Glasgow. *Mercury accumulation in deep-sea fish.* (RW Furness, IM Davies and **JDM Gordon**)

T Jarvis, Ph.D, The University of the Highlands and Islands Millennium Institute. *The vertical export of material caused by zooplankton vertical migration.* (**GA Tarling, JBL Matthews** and GC Hays)

V Jones, Ph.D, The University of Liverpool. *Organic nitrogen biogeochemistry.* (GV Wolff and **AEJ Miller**)

JB Kristoffersen, Ph.D, The University of Bergen. *Life history of mesopelagic fish in Norwegian waters.* (AGV Salvanes and **JDM Gordon**)

D Likely, Ph.D, The University of the Highlands and Islands Millennium Institute. *An investigation into the internal tide north of the Wyville-Thomson Ridge.* (**ME Inall** and W Turrell (FRS, Aberdenn))

P-S Loh, Ph.D, The University of the Highlands and Islands Millennium Institute. Terrigenous organic carbon in Scottish sea loch sediments. (**J Overnell**, A Reeves (University of Dundee), **SM Harvey** and **AEJ Miller**)

A MacDonald, M.Phil, The University of the Highlands and Islands Millennium Institute. Salmonid survival in an upland river. (**AEJ Miller**, N Chisholm)

A Mitra, Ph.D, The University of the Highlands and Islands Millennium Institute. *The Influence of micro-zooplankton on marine productivity.* (**K Davidson** and KJ Flynn)

S Mormede, Ph.D, The University of Glasgow. *Contaminants in deep-water fish stocks.* (IM Davies, **JDM Gordon** and RW Furness)

C Morri, Ph.D, The University of the Highlands and Islands Millennium Institute. *North Atlantic deglaciation: its impact on deep-water depositional environments.* (**JA Howe**, MS Stoker and **GB Shimmield**)

D Nairn, Ph.D, The University of the Highlands and Islands Millennium Institute. *Sense organ development in cultured halibut larvae and implications for first feeding.* (**RS Batty** and C Cutts)

O Obajimi, Ph.D, The University of the Highlands and Islands Millennium Institute. *Antioxidant and anti-phospholipase activity by marine carotenoids.* (I Glen and JD McKenzie)

M del Mar Otero-Villanueva, Ph.D, The University of the Highlands and Islands Millennium Institute. *Energy partitioning: growth and reproductive strategies in the sea urchin* Psammechinus miliaris. **(MS Kelly** and G Burnell)

G Spyres, Ph.D, The University of Plymouth. *Dissolved organic matter dynamics over the Iberian Shelf.* (M Nimmo, **AEJ Miller**, P Worsfold)

S Ware, Ph.D, University of London. *Inshore fisheries ecology.* (RJA Atkinson, **MDJ Sayer** and N Bailey)

RG Waller, Ph.D, University of Southampton, School of Ocean and Earth Sciences. *Gametogenesis and larval biology of deep-sea corals.* (PA Tyler and **JD Gage**)

TA Wilding, Ph.D, Heriot-Watt University. *Environmental and ecological impacts of artificial reefs.* (**MDJ Sayer** and C Moore)

APPENDIX 4: RESEARCH GRANTS AND CONTRACT INCOME RECEIVED

Project Leader	Title	Funding body	Duration	Award
RS Batty, R Leakey	Rearing protocols for Atlantic halibut larvae during transition from endogenous to exogenous nutrition	MAFF Link Aquaculture	01/00 – 12/02	£146k
KD Black	The ecological effects of sea lice treatment agents	Veterinary Medicine Directorate of MAFF, DETR, The Scottish Executive, SNH, SNIFFER and Scottish Quality Salmon	09/99 - 08/02	£685k
KD Black	Scientific basis for the regulation of fish farms in Scotland	SEPA	11/01 – 03/02	£13k
KD Black, MDJ Sayer	Biofiltration and Aquaculture (BIOFAQs): an evaluation of hard substrate deployment peformance within mariculture developments	EU Framework V	12/00 – 11/03	Euro278k
KD Black	Modelling environmental response to aquacultural wastes in the Mediterranean (MERAMED)	EU Framework V	12/00 – 11/03	Euro177k
KD Black	Hydrographic surveys	Private Sector	04/01 – 09/01	£9k
KD Black, E Cook, K Jones, M Kelly, R Leakey, M Sayer, T Nickell, K Willis	Review and synthesis of the environmental impacts of aquaculture	Scottish Executive	02/02 – 08/02	£25k
CJS Bolch	Algal and toxin presence in shellfish	MAFF	07/01 – 12/02	£86k
E Breuer	*In situ* measurements on drill cuttings piles	UKOOA	03/01 – 12/01	£65k
MT Burrows	Marine biodiversity and climate change (MarClim)	English Nature, SNH, plus a consortium of 10 other bodies	04/01 –04/06	£45k
EJ Cook	Travel Bursary	The Royal Society	02/02 – 02/02	£1k
K Davidson	CN budgets and trophic selections within marine microbial food webs	NERC (PRIME)	02/98 – 05/01	£77k
K Davidson	Phytoplankton growth modelling under multi-nutrient limitation	NERC	07/00 – 06/01	£17K
K Davidson	The influence of micro-zooplankton on marine productivity	NERC (Marine Productivity)	01/00 – 06/01	£54K

Project Leader	Title	Funding body	Duration	Award
K Davidson, CJS Bolch	Toxic *Pseudo-nitzschia* species in Scottish waters	UHI	10/00 – 09/03	£22k
JD Gage	Atlantic coral ecosystem study (ACES)	EU Framework V	03/00 - 02/03	Euro 240k
JD Gage	Time-series monitoring of the UK's deep-water territorial seabed	NERC (CONNECT B), Atlantic Frontier Environmental Network (AFEN) and Geotek Ltd	01/02 - 06/03	£53k
JD Gage	AFEN Ph.D studentship	Atlantic Frontier Environmental Network (AFEN)	01/98 – 12/01	£30k
JD Gage	SEA 7: Desk top study (Part C)	DTI	02/02 – 08/02	£9k
ST Gontarek, CJ Cromey, KD Black	DEPOMOD 3: A Model for evaluating the effects of solids deposition from mariculture to the benthos	SEPA	07/01 – 09/01	£10k
JDM Gordon	Otolith microchemistry as a means of identifying stocks of deep-water demersal fish (OTOMIC)	EC FAIR	01/99 – 12/01	Euro213k
JDM Gordon	Effects of deep-sea fishing on fish assemblages	CEFAS	12/98 – 03/02	£10k
JDM Gordon	Development of elasmobranch assessments (DELASS)	EC DGXIV	01/00 - 12/02	Euro13k
D Green	Post Doctoral Fellowship	Foundation for Science & Technology: New Zealand	04/01 – 03/04	£85k
D Green, CJS Bolch	CCAP culture collection	Commercial Sales	04/01 – 04/02	£20k
SM Harvey	Analytical Services: Sediment sulphate reduction via the use of radioisotopes	University of Leeds	04/01 – 10/02	£4k
AD Hatton	The role of anaerobic microsites	NERC Fellowship extension	09/00 – 09/02	£80k
J Howe	Antarctic Travel Bursary	Trans-Antarctic Association	06/01 – 07/02	1k
ME Inall	SEA7: Desk top study (Part B)	DTI	02/02 – 08/02	9k
ME Inall	The impact of the internal tide on the Clyde Sea	NERC	06/99 – 06/01	£35k

Project Leader	Title	Funding body	Duration	Award
ME Inall	Environmental impact assessments	Scottish Seafish Ltd	1 year	7.8k
ME Inall, KJ Jones, RJG Leakey	Oceanographic applications to eutrophication in regions of restricted exchange (OAERRE)	EU Framework V	06/00 - 05/03	£268k
KJ Jones	Construction of photon budgets for shelf seas and an assessment of their role in determining patterns of primary production	NERC	01/99 – 06/01	£20k
KJ Jones	Factors determining the magnitude of solar fluorescence peaks in water-leaving radiance spectra from shelf seas	NERC	01/02 – 12/04	£27k
MS Kelly	Tube worm fouling on rope grown mussels	HIE, Highland Council, Crown Estate, Loch Striven Mussels, Loch Beag Mussels	03/01 – 09/01	£41k
RJG Leakey	Assessment and management of coastal pollution	British Council Higher Education Link programme	04/99 – 03/02	£24k
DT Meldrum	Radar trials support	DERA	04/01 – 08/01	£9k
DT Meldrum	Deep water observation system: Phase 1	DETR	04/01 – 12/01	£31k
DT Meldrum	Deep water observation system: Phase II	DEFRA	02/02 – 07/04	£174k
DT Meldrum	Innovative ice buoys	NERC	03/99 – 02/02	£190k
AEJ Miller	Bloom dynamics of dissolved organic matter: linking the carbon and sulphur cycles	Nuffield Foundation	02/00 – 02/02	£4k
AEJ Miller	Research support development initiative	UHI	02/01 – 02/02	£160k
JM Roberts	The impacts of oil and gas activities on deep-water corals with relation to the Salema & Bijupira development	Gardline Surveys	02/02 – 03/02	£2k
C Rydings	Data messaging service level agreement	UHI	04/01 – 03/02	£3k
C Rydings	Datawarehouse service level agreement	UHI	04/01 – 03/02	£5k

Project Leader	Title	Funding body	Duration	Award
MDJ Sayer	Recompression treatment in Scotland: technical audit and website construction	NHS Scotland	12/99 – 12/03	£40k
MDJ Sayer	NHS recompression facility	NHS	04/01- 04/02	£220k
MDJ Sayer, JDM Gordon	SEA 7: Desk top study (Part A)	DTI	02/02 – 08/02	£9k
MDJ Sayer	Artificial reef deployment technology	Foster Yeoman	02/01 – 12/01	£19k
MDJ Sayer	Marine artificial habitat manipulation: prediction and measurement of environmental impacts	NERC	09/01 – 08/04	£233k
GB Shimmield	Decadal climate variability and the El Nino Southern Oscillation: High resolution records of ocean atmosphere interactions from corals in the Central South Pacific (with AW Tudhope, Edinburgh University)	NERC	06/99 - 05/02	£7.5k
GB Shimmield	Argos Satellite Services	Commercial services	04/01- 04/02	£179k
GB Shimmield	UHI Teaching	UHI	04/01 – 03/06	£85k
GB Shimmield	Capital Equipment Grant	Millennium Commission	04/01 – 03/02	£235k
GB Shimmield	Datawarehouse Building	European Regional Development Fund, Millennium Commission and NERC	04/01 – 03/02	£218k
GB Shimmield	PhD student support	UHI	02/99 onward	£1.5k per student place
GB Shimmield	European Network for Arctic-Alpine Multidisciplinary Environmental Research (ENVINET)	EU	05/00 – 05/03	Euro20k
GB Shimmield, JD Gage, K Jones & DT Meldrum	Autonomous Marine Environment Research Stations (AutoMERS)	JIF	04/00 – 03/03	£849k
TM Shimmield	Late Holocene and Shallow Marine Environments of Europe (HOLSMEER)	EU Framework V	01/00 – 12/03	Euro72k

Project Leader	Title	Funding body	Duration	Award
TM Shimmield	Large Scale Facility Grant: Ny-Alesund	EU	03/02 –12/02	Travel & Subsistence only
TM Shimmield	Benthic processes in the Arabian Sea	NERC	10/01 – 09/04	£317k
TM Shimmield	Environmental impact of sonar at DERA testing facilities	Qinetiq	10/01 – 12/01	£8k
TM Shimmield et al.	Literature review of EIA around Dounreay	UKAEA	03/02 – 08/02	18k
GA Tarling	NERC Fellowship: Ecology of zooplankton in the Irish Sea	NERC	09/98 – 08/01	£97k
GA Tarling	The impact of sea lice treatments on zooplankton communities in the vicinity of salmon farms	MAFF/Veterinary Medical Directorate	07/99 – 08/02	£65k
GA Tarling, MT Burrows	Modelling the persistence of zooplankton in the Irish Sea using optimal vertical migration patterns	NERC	05/00 – 10/01	£76k
K Willis	The effect of sea lice chemotherapeutants on non-target planktonic copepod species	NERC	10/00 – 09/01	£18k