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Professor Graham Shimmield

Director's Introduction

In writing this Introduction, I am conscious that SAMS is entering the third era of its long history. Under its former name of the Scottish Marine Biological Association (SMBA), Millport on the Isle of Cumbrae was the research headquarters. In 1967, the SMBA moved to Dunstaffnage and subsequently operated under NERC's direction and Grant-in-Aid. Now, at the start of the new millennium, the Association is once more under its own management and striving to recreate the state-of-the-art facilities necessary to continue the delivery of international quality marine science. Rising to this challenge and adjusting to the change has not been easy for the staff and SAMS Council alike. In late March I received a letter from Dr Clifford Mortimer, Director at Millport 1955-66 and now in the USA, discussing the move from Millport and from which I quote. "Although that move would mean a break with the great Marshall and Orr tradition and an uprooting of staff and families, the advantages seemed to me compelling. These were: better access both to sheltered sea lochs and to the Atlantic continental shelf; and availability of a secondary school, to aid retention of staff with families. After years of persuasion, the Council authorized me to survey sites on the west coast. Dunstaffnage was easily the winner."

This letter came at a most propitious time and provided me with the personal incentive to continue the hard work necessary to achieve the desired changes in management structures and facilities so necessary for the future. I am also reminded that there are still staff at Dunstaffnage who are veterans of the Millport move. Perhaps most insightful were Dr Mortimer's comments on the scientific reasons for the relocation. The very same arguments for location and access to the marine environment have formed the cornerstone of our new "Northern Seas Programme", recently funded as a core-strategic grant from the NERC for five years.

Over this past year we have seen new developments come on-line that were heralded in last year's *Annual Report*. For the first time in our history, undergraduates form part of the scientific community with the first entrants to the new BSc in Marine Sciences. Our second cohort will arrive at Dunstaffnage shortly. Right at the end of the reporting year the University of the Highlands and Islands project received full designation as a Higher Education Institution (HEI) and is now formally known as the UHI Millennium Institute. Immediately thereafter, SAMS participated in our first Research Assessment Exercise in common with all other universities throughout the UK. The results of this benchmarking exercise will be known in mid-December, and will mark the change from a Research Council laboratory to a full HEI organisation. Other notable milestones include the completion of the Data Warehouse building and the appointment of Chris Rydings as our new IT manager, and the erection of the Lander Building and upgrading of the floating pontoon, part of the Joint Infrastructure Fund award to Aberdeen University (Professor Monty Priede) in association with St Andrews and Bristol Universities.

This Annual Report marks the final time that NERC and SAMS science at Dunstaffnage are separated scientifically and financially. Next year our report will concentrate on the integrated Northern Seas programme and associated commissioned research. Here, we highlight the success of the SAMS Fellows, including the second Honorary Chair to Professor John Gage, awarded by the University of Aberdeen. Dr John Gordon's work has never been more relevant to the state of deep-sea ecosystems in the face of continued pressure from the fishing industry. His work is internationally recognised, reflecting most creditably on SAMS desire to support world-class marine science. Dr Ray Leakey's Fellowship has been confirmed and extended, with a strong research group developing in both pure and applied marine microbial ecology. Our two younger NERC Fellows, Drs Angela Hatton and Geraint Tarling, continue to advance significantly our knowledge in biogenic trace gases and macrozooplankton ecology, respectively. Geraint will leave us shortly to join the excellent zooplankton group at the British Antarctic Survey, continuing the legacy of staff exchange between our two organisations! Drs Maeve Kelly and Tracy Shimmield have won significant research funding during the year, enabling them to address marine issues from the west coast of Scotland to the Arabian Sea. Finally, the core Marine Science Degree lecturing team of Drs Keith Davidson, Mark Inall, John Howe and Axel Miller has been augmented by the recent appointment of Dr Anuschka Miller, who will also double as the Activities and Public Relations Manager.

One key element of SAMS' reputation is the work of the Honorary Fellows. Over the past few years, John Blaxter, Margaret Barnes, Clive Craik, Jack Matthews, Geoff Glasby and most recently, Robin Gibson, have all continued to dedicate their scientific activity to the Association. I am particularly honoured to host this considerable pool of intellectual capability and to provide a continuing outlet for their creativity and scientific curiosity. SAMS is much the richer for their contribution.

This brings me to my final remarks. Firstly, I believe that Scottish marine science is in a renaissance period, not only at SAMS, but also with our friends and colleagues in the universities and institutes. I particularly single out the recent confirmation of the status of the University Marine Biological Station at Millport under the direction of Professor Rupert Ormond. We both share a common goal of strengthening the bond between our two laboratories, and ensuring a continuing future with appropriate partnership. Secondly, Anuschka Miller fills the shoes vacated by the incomparable Helen Anderson. Helen supported me through the first five years of this job in so many ways, and it was with real sincerity born of friendship and respect, that SAMS Council and I said farewell to her on 1st May. Finally, a major thank you to all the staff at Dunstaffnage, from top to bottom, for contributing to this Report with the help of the editor, Robin Harvey. They have provided the inspiration and, with the membership, will create the strength in Scottish marine science for the future.

Graham B Shimmield, FIBiol, FRSE
Director SAMS and DML

Dr Tracy Shimmield

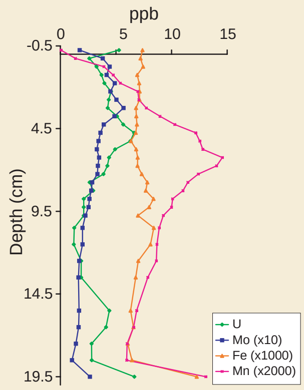


Fig. 1 Pore water concentration profiles in a sediment core from the Arran Deep, Clyde Sea Area.

Geochemistry

The past year has seen the Geochemistry group continue its research in both coastal and deep ocean environments, including Scottish sea lochs, the Clyde Sea Area, the North Sea, the Northern Atlantic and the northern Scotia Sea, Antarctica. Advances in the instrumentation available to marine scientists have enabled more detailed *in situ* investigations of the processes affecting the redistribution of chemical elements between seabed sediments and the overlying water column. These techniques have been used in the North Sea to investigate the biogeochemistry of drill cuttings piles and in regions of the Clyde Sea and Loch Etive, where fluxes across the benthic boundary layer have been studied.

An additional area of marine science in which the group has expertise is in palaeoceanographic research. The question "*Do Scottish sea lochs hold the key to past and present environmental change?*" is being addressed through the European funded HOLSMEER (late HOLocene and Shallow Marine Environments of EuRope) project and the SAMS Northern Seas Programme (2001-2006).

Finally, the group continues to use radionuclides as tracers of marine processes and was involved this year in a study which investigated rates of carbon cycling and its export from the surface waters in the North Sea.

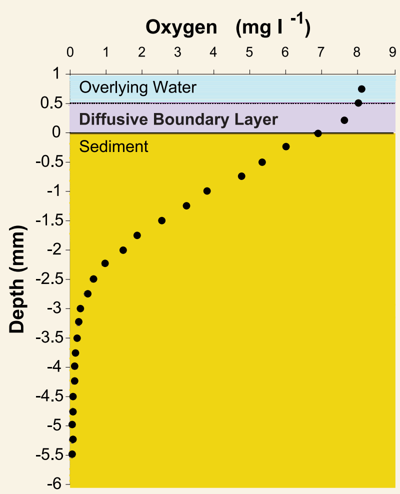


Fig. 2 *In-situ* pore water oxygen microprofile from the Clyde Sea Area obtained with the *Profilur* lander.

Oxygen penetration in sediments from the Clyde Sea Area

The measurement of sediment pore water concentrations of trace metals and diagenetic parameters (O_2, HS^- and pH) allows quantification of fluxes of materials to the overlying water (Figs 1 & 2). These fluxes are controlled by a variety of transport mechanisms including molecular diffusion, bioturbation and bioirrigation, turbulent processes induced by the movement of the overlying water, and advective processes caused by the bioroughness of the seabed. The relative importance of each process at a site depends on its prevailing hydrodynamics, sediment characteristics and faunal composition. In areas of high organic matter decomposition, steep depth-associated concentration gradients develop, often resulting in elevated concentrations of dissolved metals. These steep gradients make sample acquisition and measurement without disturbance-induced artefacts extremely difficult. The challenge, therefore, is to devise suitable measurement and sampling techniques that allow *in-situ* measurement of key constituents at sufficient resolution. The *Profilur* lander (Fig. 2) is equipped with microelectrodes with a sensing tip diameter of < 10 µm and 90% response time of 1s. These are driven into the sediment at 25 µm increments, allowing the distribution of these constituents to be measured at a very high spatial and temporal resolution without significant disturbance to the sediment structure.

E Breuer (DML), **T Shimmield and T Sawyer** (SAMS)

HOLSMEER (late HOLocene and Shallow Marine Environments of EuRope)

Scandinavian and northern waters of NW Europe are now considered to be the barometer for climate change and human impact throughout the Northern Hemisphere. HOLSMEER is a project supported under the EC energy, environment and sustainable development (1998- 2002) programme of the Fifth Framework, involving 13 partner laboratories throughout Europe. It explicitly addresses the question of the natural variability of the north Atlantic circulation over the last 2000 years. It will utilise long-term instrumental time-series of marine and atmospheric parameters to calibrate proxy observations, thereby extending the marine record to the period before systematic recording of environmental parameters was undertaken. In this way it will provide a basis for establishing the natural variability of the ocean component of the global system in the critical North Atlantic region prior to significant anthropogenic forcing.

It is estimated that nearly a quarter of all terrestrial sediment transported to the oceans during the last 100,000 years now resides in fjordic or sea loch basins. These sediments provide the annual resolution and environmental sensitivity necessary to reveal the extent and effects of environmental fluctuations with time in northern coastal areas. In collaboration with colleagues at St Andrews University, we are presently studying deep cores from Loch Etive to establish whether they contain a high-resolution long-term record of environmental change. By using natural (^{210}Pb) and man-made (^{137}Cs) radionuclides (Fig. 3) it is possible to establish sedimentation rates over the past 150 years. ^{14}C dating will be used to determine the age of deeper sediments.

T Shimmield (SAMS) **and GB Shimmield** (SAMS/DML)

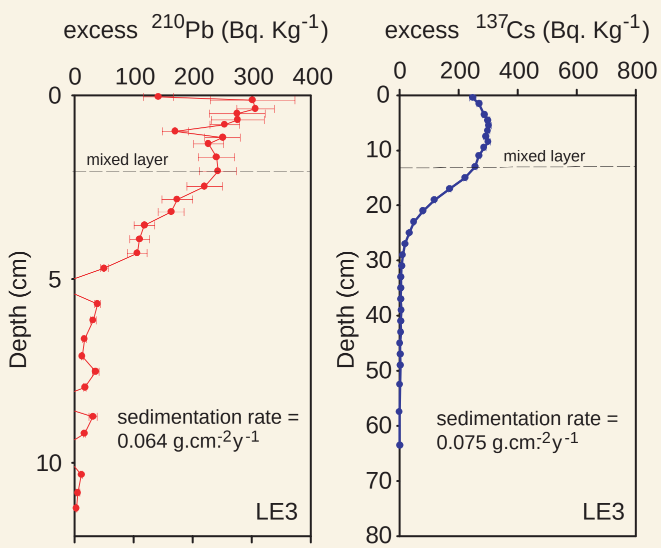


Fig. 3 ^{210}Pb and ^{137}Cs activity profiles in a sediment core from Loch Etive.

Fig. 4
The upper basin of Loch Etive, where sediments up to 60 m thick allow studies of processes acting over a range of time scales to be undertaken.

A Record of Climate Change from Loch Etive

Paleoclimatic records in the sediments of Lochs Etive and Sunart have been studied as part of a collaborative EC-funded project with the University of St Andrews and the British and Norwegian Geological Surveys. Loch Etive in Argyll on the west coast of Scotland (Fig. 4) is a 30 km long and up to 150 m deep sea loch, scoured out by ice over the last 11,000 years. Following a week of surveying using high-resolution marine seismic equipment and the collection of cores from RV *Calanus*, the processes that have shaped the loch are beginning to emerge.

Initial results from the seismic survey and core analysis reveal a 30-60 m thick sediment layer that has accumulated on the floor of the loch since the last glacial re-advance (termed the Younger Dryas stadial) 11,000 -10,000 years ago. The shape and acoustic character of the sediments include 'pods' of sediment fed into the loch from rivers, a well-laminated post-glaciomarine or modern drape of soft sediments and well-laminated to transparent older glaciomarine sediments. The glaciomarine sediments display truncation, mounding and onlapping suggesting a dynamic glacial environment possibly as a result of glacial ice melting back up the loch as the climate warmed (Fig. 5). Sediments were rapidly deposited in an isolated glacial lake that was cut off from the sea, as sea levels were much lower at this time. In places throughout the loch, the decay of plant material produces methane, the gas-rich sediments producing a chaotic 'gas-blanking' acoustic effect on the seismic profiles which masks the highly-laminated nature of the sediments. Examination of the collected cores reveals that the oldest sediments are grey glaciomarine sands and grey glaciomarine sandy silts, laminated in the deepest part of the loch, overlain by greeny-grey and greeny-black modern homogeneous watery muds. The age of the sediment can be accurately determined by ^{14}C dating of the abundant shell material within the sediment, notably of the bivalve *Arctica islandica*.

JA Howe (SAMS/UHI), **T Shimmield** (SAMS), **WEN Austin** (St Andrews University), **J Derrick and D Wallis** (British Geological Survey) **and O Longva** (Norwegian Geological Survey)

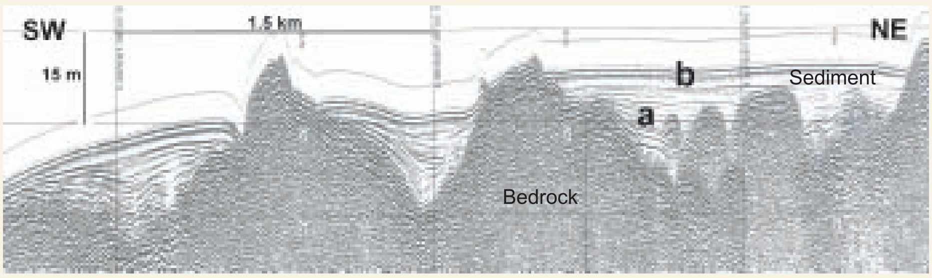


Fig. 5 Sub-surface boomer seismic reflection profile (1b FP:12:58-13:12) from the inner basin of Loch Etive. The profile displays the general geometry of the loch sediments. The irregular granitic bedrock is glacially-scoured into hollows in which sediments accumulate. a: Well-laminated-transparent acoustic character with onlapping, truncated and mounded reflectors, overlain by b: Well-laminated acoustic character. The sediments display a scoured moat around seafloor obstacles, such as bedrock outcrops, the result of weak tidal flow. Water depth approximately 30-40 m.

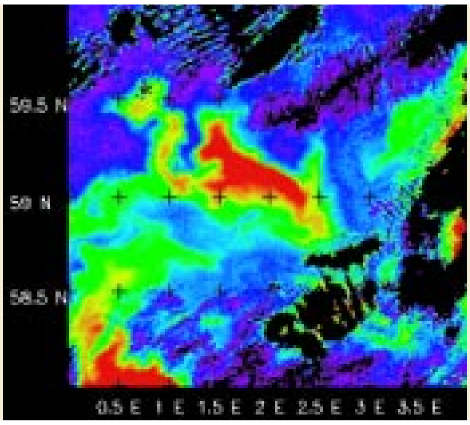


Fig. 6 Remote sensing image of a study patch containing *E. huxleyi* (orange colour).

DISCO - Dimethyl Sulphide Biogeochemistry within a Coccolithophore Bloom - ^{234}Th and POC export

In June 1999 a multidisciplinary cruise to the northern North Sea onboard the RRS *Discovery* investigated aspects of a bloom of the coccolithophore *Emiliania huxleyi* (Fig. 6). Although this study was focused on determining the role of this alga in the marine sulphur cycle by measurements of dimethyl sulphide (DMS), the opportunity was taken to investigate rates of carbon cycling and export from the surface waters. The uptake and export of carbon and nutrients are driven by biological productivity in the surface ocean. The rates of these processes, for example the particle flux to the deep sea during the lifetime of a plankton bloom, can be variable. By using radioactive tracers with half-lives spanning appropriate time scales, rates of these processes can be calculated. The naturally occuring short-lived radioisotope ^{234}Th (half life 24.1 days) is one such particle-reactive tracer and has been used to estimate upper-ocean particulate organic carbon (POC) export in many of the world's oceans. Measurement of ^{234}Th in seawater samples allows the particulate flux of ^{234}Th to be calculated and applied to measurements of POC to estimate a POC flux rate throughout the water column.

Measurements were taken on four days in June 1999 and the POC export flux is shown in Figure 7. The total particulate ^{234}Th flux and POC flux increased to a maximum on the 25th June, corresponding to an increase in numbers of, and scavenging by, biological particles and their subsequent downward flux from surface waters.

JM Foster (SAMS) **and GB Shimmield** (SAMS/DML)

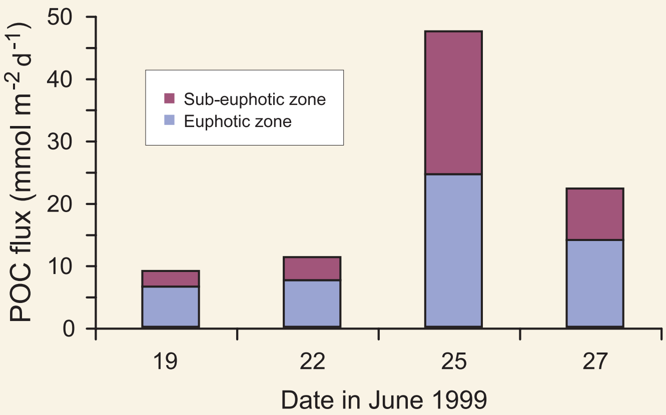


Fig. 7 Particulate organic carbon flux observed during the DISCO cruise, June 1999.

Professor John Gage

Deep-sea Benthos

Benthic community activity and biomass in biogeochemical processes at the deep-ocean bed - NERC BENBO Thematic Programme

Participation by the Deep-Sea Benthic Group in the NERC BENBO thematic programme has ended this year. Our work has provided the biological ground-truthing of a wide variety of biogeochemical processes at the deep-sea benthic boundary. The BENBO programme used three contrasting NE Atlantic sites to determine the effects of large-scale environmental variables on biogeochemical cycling in the deep-ocean benthic boundary layer. Our aims were to characterise the benthic metazoan communities in order to estimate total respiratory carbon demand and determine the faunal contribution to particle mixing at the ocean floor.

Results from samples collected on two research cruises in 1998 were presented at the Deep-Sea Biology Symposium in Galway in June 2000. Data on the benthic metazoan communities cover the full size spectrum from meiofauna to megafauna. Biomass and size composition differed markedly at the three sites, with total metazoan (> 45 µm) organic carbon biomass at Site B (1,100 m) being 38 times that at A (3,500 m). The relative proportion of megafaunal biomass size declines with increasing depth, while the meiofauna become correspondingly more important (Fig. 8a). The depth-related trend towards greater importance of small organisms is enhanced with respect to respiratory carbon demand (Fig. 8b).

Analyses of samples collected from large animal burrows show that bioturbation has a major effect on sediment geochemical profiles. Radionuclide and organic contents characteristic of the sediment surface indicate the recent subduction of superficial material by the burrow occupant. Closer similarity between burrow material and adjacent, sub-surface sediment allowed other burrows to be identified as relicts.

The SAMS results have significantly broadened our understanding of benthic community processes occurring in the deep NE Atlantic and made an important contribution to meeting the overall objectives of the BENBO Programme. Work on bioturbation alone serves to show how benthic organisms play an overwhelmingly important role in mediating solute fluxes at the deep-sea bed. Publication of results is the main task for the year ahead.

DJ Hughes, PA Lamont and JD Gage (SAMS)

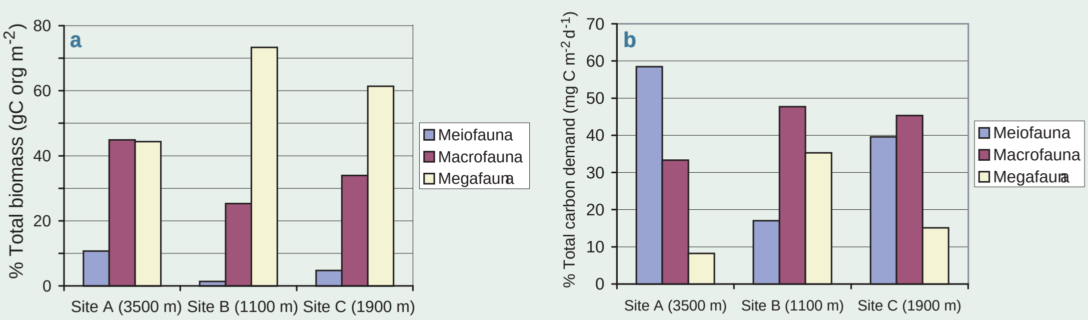


Fig. 8 Contribution of three major size classes to metazoan community biomass **(a)** and respiratory carbon demand **(b)** at the BENBO study sites.

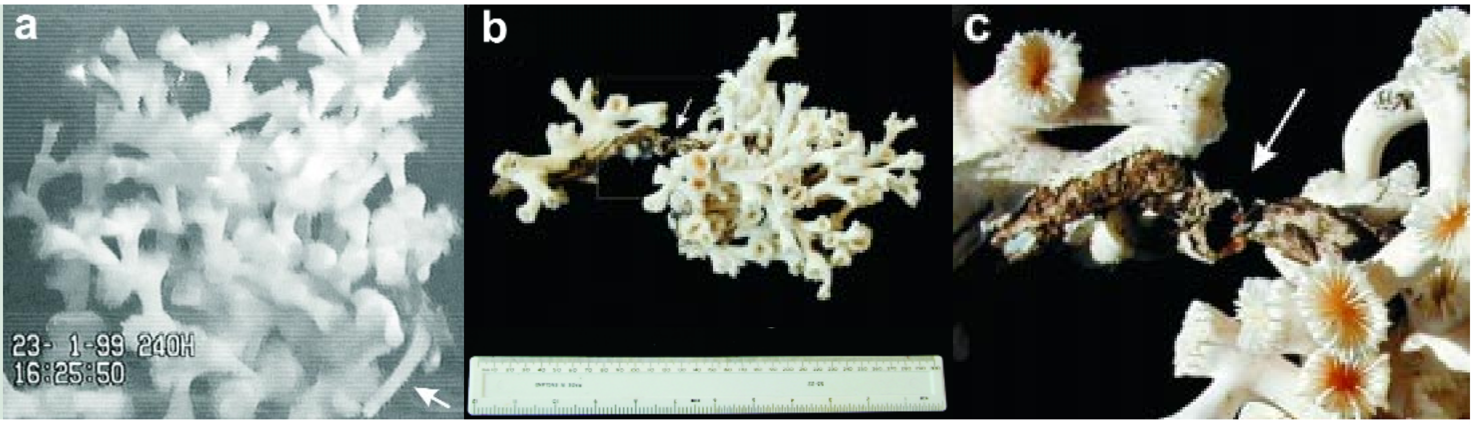


Fig. 9 **(a)** Video frame grab under infra-red illumination showing a colony of *Lophelia pertusa* from which *Eunice norvegica* (arrowed) is extending from its tube to feed on the floor of the aquarium. **(b)** Two colonies of *Lophelia pertusa* joined by *Eunice norvegica*. The ruler shown is 30 cm long and the point connected by the polychaete worm is marked with an arrow. **(c)** The polychaete connected the two coral colonies by joining two ends of parchment-like tube.

The Atlantic Coral Ecosystem Study (ACES)

SAMS is one of ten partners across five European countries in this EU project which began in January 2000.

Dr Murray Roberts took part in an RRS *Discovery* cruise in July and August 2000 to the Darwin Mounds, a recently discovered deep-water coral province off NW Scotland, where box core samples were obtained for study of biodiversity associated with coral structures. Non-destructive investigation of the coral ecosystems has been pursued through the development of an autonomous lander at SAMS which was deployed in July 2001 close to the Sula Ridge, a massive deep-water coral formation off Norway. This Coral Monitoring Lander is designed to record the near bed particle field and current regime and to take photographs throughout its deployment.

Aquarium observations have investigated the response of *Lophelia pertusa*, and any commensal fauna, to variations in environmental parameters such as sedimentation and temperature. These data help assess coral sensitivity to natural and anthropogenic stressors. Coral polyp behaviour has been recorded using time-lapse video under infra-red illumination to remove potentially confounding effects of light on the behaviour of coral polyps and, more significantly, on any associated fauna such as the polychaete *Eunice norvegica*. Early results indicate that polyps on the same pseudocolony expand and contract independently of one another. To date there is no clear evidence for any diurnal pattern but the results from long-term field observations may influence future aquarium studies. It seems that the behaviour of the symbiotic tubicolous polychaete worm *Eunice norvegica* may be important to the development of *Lophelia* reefs. The worm's parchment tube was observed to join separate small fragments of live *Lophelia* (Fig. 9).

Initial investigations on environmental stressors have examined the effect of sand deposition on polyp behaviour (tentacle expansion) and physiology (respiration rate), but further work awaits availability of new supplies of coral. To simulate the effect of enhanced suspended particle load in the bottom current, polyp behaviour before, during and after sand deposition, has been recorded using time-lapse infra-red video. To control for potentially confounding effects of variable particle size and toxicity, a pure silica sand mined for optical glass manufacture has been chosen. Preliminary results (Fig. 10) suggest that sediment has a negative impact on polyp extension and is likely to reduce feeding efficiency. A closed chamber respirometry system has been developed and used to measure respiration rates of *Lophelia pertusa* before and after exposure to sand deposition.

JM Roberts and JD Gage (SAMS)

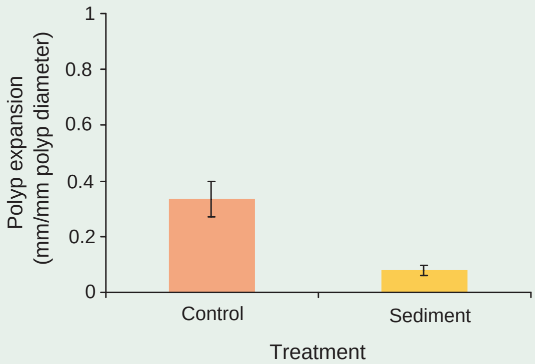


Fig. 10 The extension of *Lophelia pertusa* polyps exposed to sand deposition at 0.1 (±0.09) mg cm^{-2} min^{-1} (*sediment treatment*) compared to those not exposed to sand deposition (control). Mean ± SE polyp expansion normalised to calyx diameter (mm expanded per mm calyx diameter) is shown during the 24 h period when corals were exposed to sediment.

Macrobenthos community and deep-sea fishing impacts on the Hebridean margin

Analysis of box core samples taken prior to 1998 from the area of the NERC Shelf Edge Study on the continental margin lying to the west of Barra was completed for the Atlantic Frontier Environmental Network (AFEN) consortium. The results from this work and from the new surveys conducted in 1998 are incorporated in a report, published during 2000 as a CD ROM, describing the baseline environment against which it is hoped any future change might be gauged.

Commercial fishing in the area started a few years after SAMS sampling began and there is now an established deep-sea fishery using aggressive seabed trawling techniques. Hence it is possible that changes in the benthic fauna might have already taken place on this section of the continental slope. We have been analysing SAMS archived box core samples dating back to the mid-1970s, and therefore pre-dating the trawling in the area, to see if we can detect any changes in the composition of the macrobenthic community.

Although confidence limits cannot at present be placed around many of the data, results suggest change in numbers of species and in representation of major macrobenthic taxa has occurred through the time period. Box cores taken in more recent years are being examined to extend the time period covered by the data from several years before to more than a decade after the estimated start of trawling in the area.

PA Lamont and JD Gage (SAMS)

Benthic community in the Faroe Shetland Channel

Bhavani Narayanaswamy, sponsored by AFEN, successfully completed her PhD on the Macrobenthic Ecology of the West Shetland Slope. This work has graphically illustrated how the unusual hydrographic conditions on the West Shetland Slope influence the benthic macrofauna in unexpected ways.

Sampling bias was investigated by including in the analysis the 250 µm-to-500 µm size fraction - previously unstudied in the deep-sea samples. This resulted in an increase in both species diversity and species richness. Faunal abundance was also seen to increase by an average of 40% per station when the smaller size fraction was included (Fig.11). In the sampling area, water temperature appeared to be the major environmental variable controlling benthic macrofaunal distribution (especially in terms of standing stock), polychaete species diversity, feeding modes and restriction of polychaete species to specific depth horizons. This finding is at odds with the generally accepted paradigm of biological interactions and habitat heterogeneity being the major factors structuring the deep-sea community. Other environmental variables such as sediment grain size and total organic carbon also influenced macrofaunal distribution, although to a lesser degree. On the West Shetland Slope temperature effectively replaces depth as the ‘master’ variable controlling the benthic macrofauna.

This study has shown that in order to achieve adequate discrimination between stations in this area, macrofauna should be identified to species level.

B Narayanaswamy (University of Southampton)

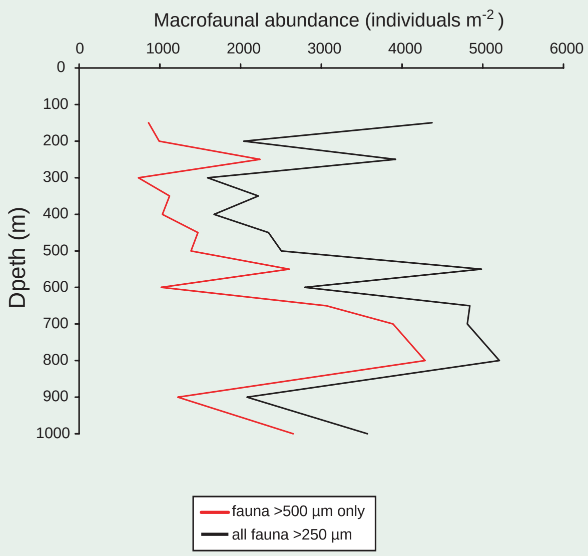


Fig. 11
Macrofaunal abundance values from the West Shetland Slope. The inclusion of the 250-500 µm fraction resulted in a large increase in number of individuals at the sampling stations.

Dr John Gordon

Deep-water Fish

SAMS was involved in several of the tasks of the European Commission DGXIV Study Project ‘Environment and biology of deep-water species *Aphanopus carbo* in the NE Atlantic: basis for its management’ (BASBLACK), including the co-ordination of the feeding studies. The final report of BASBLACK was submitted in June 2000.

A special issue of *Fisheries Research*, containing a selection of papers presented at a theme session on deep-water fish and fisheries held at the ICES Science Conference in 1998, was published in 2000. Dr Gordon was Guest Editor and of the 27 papers in the issue, 11 are attributable to the EC FAIR Deep-fisheries project co-ordinated by SAMS.

Dr Gordon completed his term (1995-2000) as Chair of the ICES Study Group on the Biology and Assessment of Deep-sea Fishery Resources by presenting the report of the 2000 meeting to ICES Advisory Committee on Fisheries Management. He is Co-convenor of the NAFO Scientific Symposium on Deep-water Fisheries to be held in Cuba in September 2001 and will be the ICES representative.

SAMS was a partner in a JNCC Contract on the *Effects of fishing on deep-water species to the west of Britain* together with CEFAS (co-ordinator) and IFREMER (France) and the final report is now being prepared. SAMS was also contracted by JNCC to write a short status report on deep-water fish and fisheries. It was aimed at non-specialists with an interest in and a concern for the fishery.

Otolith microchemistry as a means of identifying stocks of deep-water demersal fish (OTOMIC)

This 3-year EC shared-cost FAIR 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 and assess their usefulness for stock discrimination. The deep-water species selected were the bluemouth *Helicolenus dactylopterus*, hake *Merluccius merluccius* and smooth grenadier *Nezumia aequalis*, found in both the eastern North Atlantic and Mediterranean, and the roundnose grenadier *Coryphaenoides rupestris* (Fig.12), which is widely distributed throughout the North Atlantic. A wide range of elements has been detected in whole otoliths and those that are potentially useful for stock discrimination include lithium, magnesium, manganese, chromium, rubidium, strontium, yttrium and barium. Preliminary results indicated that whole otoliths may be used to discriminate reasonably well between specimens of

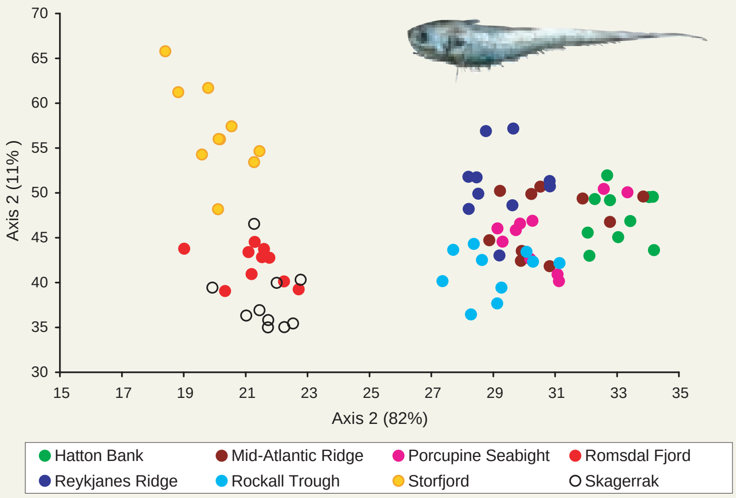


Fig. 12 Discriminant analysis for roundnose grenadier in the NE Atlantic, based on solution ICP-MS data for whole otoliths. Samples from the Norwegian fjords and the Skagerrak are characterised by significantly lower levels of barium and higher levels of strontium, rubidium and manganese than samples from other areas. Samples from Storfjord had significantly higher levels of manganese than all other areas and samples from the Skagerrak had higher levels of lithium.

each species recovered from the different areas. The effects of otolith handling and storage have been investigated for three species and the results suggested that freezing the fish prior to otolith extraction had very little effect on the potentially useful elements.

Laser-ablation ICP-MS was used to determine differences in the elemental composition of otoliths of *C. rupestris* from the core to the outer edge, in order to ascertain whether the individuals had migrated through different water masses. Initial results indicated that some elements often have their highest concentration within the otolith core, although this was not always the case. Levels of manganese, for example, were highest in the core region for *C. rupestris* samples from the Rockall Trough, but lowest in the core for samples from Storfjord (Norway). However, data from whole otolith solution-based ICP-MS (Fig.12) indicated that *C. rupestris* otoliths from Storfjord contained much higher overall levels of manganese than Rockall Trough otoliths, possibly as a result of manganese cycling in a fjordic environment.

JDM Gordon, S Swan, GB Shimmield and P McGarr (SAMS)

Distribution and biology of anglerfish and megrim in waters to the West of Scotland (Monk/Megrim)

This two-year EC shared-cost Study Contract was coordinated by SAMS. The overall aim of the work on anglerfish was to study its distribution and biology. In collaboration with Fisheries Research Services, Aberdeen, SAMS was specifically involved in the sub-tasks on anglerfish age validation and stock identification by means of otolith microchemistry. Age estimation of anglerfish using otoliths is difficult and this has led to the use of an alternate structure, the ‘fishing lure’ or illicium, being used for some stocks. Published length-at-age estimates from the two calcified structures differ, but there have been no validation studies to determine which estimates are the most accurate. In this project, age estimation studies were undertaken on both otoliths and illicia using both micro- and marginal-increment analysis. The findings suggest that sectioned otoliths provide more precise age estimations than illicia, and have identified a possible source of ageing error in illicia, based on the pattern of early growth.

The elemental composition of whole otoliths was determined using solution-based ICP-MS. The chemical composition of the otolith core is likely to contain the ‘chemical signature’ of the spawning/early nursery area. Consequently, only otoliths from fish within their first year of life were used. The results suggested limited exchange between locations during some period of the early life-history.

JDM Gordon and D Woodroffe (SAMS),
P Wright (Fisheries Research Services)

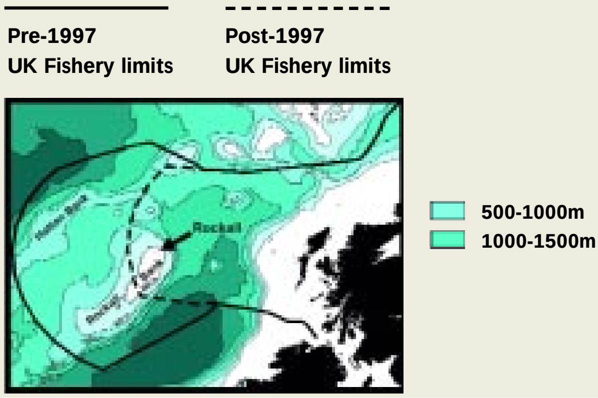


Fig. 13 Waters to the west of Scotland at depths from 500-1000 m support a mixed Fishery in UK and International waters.

Fishing impacts

Mr Crozier's UHI PhD studentship on the *Impact of deep-water fisheries on elasmobranch populations of the Northeast Atlantic* has continued. An international mixed fishery for a number of species including sharks is now well established in the waters to the west of Scotland (Fig. 13). The landings of two deep-water sharks, the Portuguese dogfish *Centroscymnus coelolepis* and leaf-scaled gulper shark *Centrophorus squamosus* at the port of Lochinver were sampled throughout the year. Figure 14 shows the total landings for both species since January 1999. This monthly sampling programme also collected data on landings of all deep-water fish. The total lengths of the deep-water sharks were measured and information was collected for investigations of their reproductive biology.

Elasmobranch material was also collected during two deep-water research cruises of the FRV *Scotia* in April and September 2000. In all, 74 stations were sampled with depths ranging from 200 to 1500 m. The length, weight and sexual maturity were recorded for all elasmobranch species. The quarterly series of sampling trips on board French commercial trawlers also continued throughout the year. A total of 140 hauls, ranging in depth from 500-1500 m, were sampled over six fishing trips. Data were collected on weight and composition of discards per fishing haul, including deep-water elasmobranchs. As only two sharks, the Portuguese dogfish and leaf-scaled gulper shark, are landed by the commercial fishery, historical survey data, new surveys and commercial trips are essential for assessing discards and hence the impact of the fishery on all elasmobranch fishes.

JDM Gordon (SAMS) **and P Crozier** (UHI)

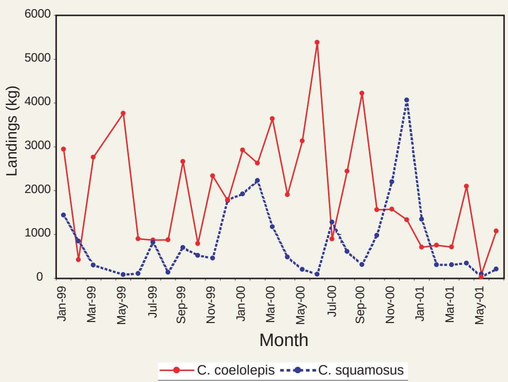
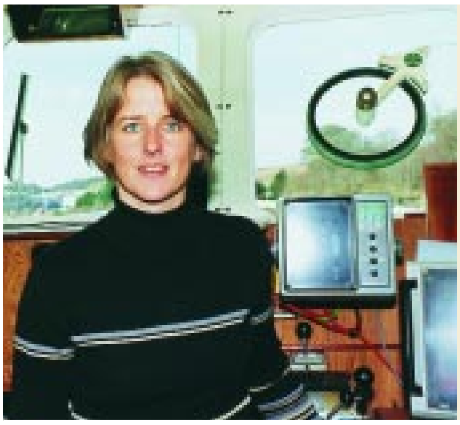


Fig. 14 Total landings of the two deep-water shark species at Lochinver from January 1999.



Dr Maeve Kelly

Invertebrate Biology and Mariculture

Our research continues to explore biological functions in species of commercial relevance. This year saw the completion of the EC funded project *Commercially Viable Sea Urchin Cultivation.* Other aspects of our research include dietary studies of sea urchins, the ecological impact of urchin grazing in the wild and the continuation of investigations on toxin retention in king scallops.

Commercially Viable Sea Urchin Cultivation

Sea urchin roe is a luxury food product for which there is a large and under-supplied market. As wild-fishery landings continue to decline, research effort into echinoculture increases. This project addressed the technical obstacles preventing sea urchin cultivation from becoming an economically viable industry. The research remit was broad and included polyculture, the improvement of product (roe) quality (Fig. 15), the potential bio-accumulation of fish medicines and the formulation of new urchin diets. Our approach using polyculture - growing sea urchins alongside salmon - remains unique. A system was designed which utilised the existing aquaculture infrastructure and facilitated the simultaneous handling of sea urchins and salmon. The urchin containers developed are an advance on previous designs in terms of ease of handling, accessibility and durability.

Juvenile urchins of *Psammechinus miliaris* reared in the SAMS hatchery (Fig. 16) proved robust and survivorship was high, even when small (8 mm test diameter) urchins were transferred to the sea. The average size of 1-year-old urchins was 16 mm; the market demands an urchin of at least 40 mm horizontal test diameter. It was found that growth rates could be increased by adjusting diet and stocking density.

An inherent part of the project was the optimisation of roe quality in addition to quantity. A pre-harvest (or finishing) pelleted diet was developed to enhance roe colour. While further research is required into the fate and expression of dietary pigments, a significant advance has been achieved by identifying the microalga *Phaeodactylum tricornutum* as one which enhances roe colour in *P. miliaris.* A study on lipid-synthetic pathways in echinoids indicated that it is not essential to incorporate expensive animal-origin oils in urchin feeds to produce the accelerated gonad growth that occurs when the urchins are reared on salmon feed. By adopting a fully integrated approach, from brood stock selection to perfecting the end product for the market, this research offers a model of echinoculture methods that can make an industry independent of vulnerable wild stocks. Market demand for urchin roe remains high and there is no evidence of any consumer resistance to a farmed product (Fig 17). The opportunity now exists for market demand to be met by expanding cultivation effort.

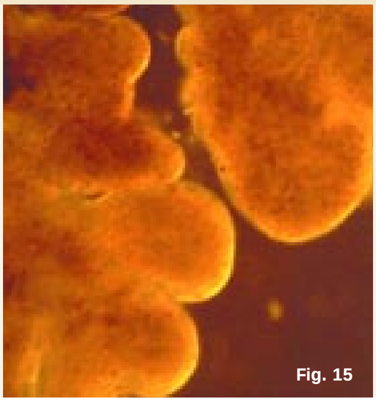


Fig. 15

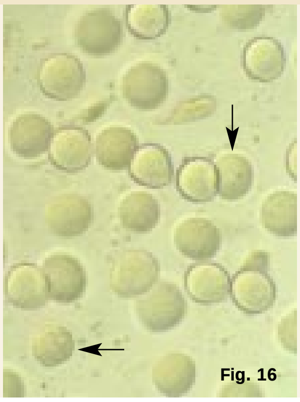


Fig. 16

Fig. 17

Fig. 15 The lobes of the ovary in *P. miliaris*, illustrating the desired colour of the food product.

Fig. 16 *Psammechinus miliaris* eggs undergoing fertilisation; the fertilisation membrane (arrowed) can be seen lifting off the surface of some eggs.

Fig. 17 *Psammmechinus miliaris*, of marketable size.

Sea urchin diets and the ecological impact of urchin grazing

The sea urchin *Psammechinus miliaris* is an opportunistic omnivore. Dense populations (over 300 individuals per m^2) are found intertidally and subtidally in Scottish sea lochs. This study combines detailed investigations of the effect of diet (animal versus plant material) and the partitioning of energy between somatic and gonadal growth with an assessment of the role of this dominant grazer in structuring the biodiversity of inshore communities.

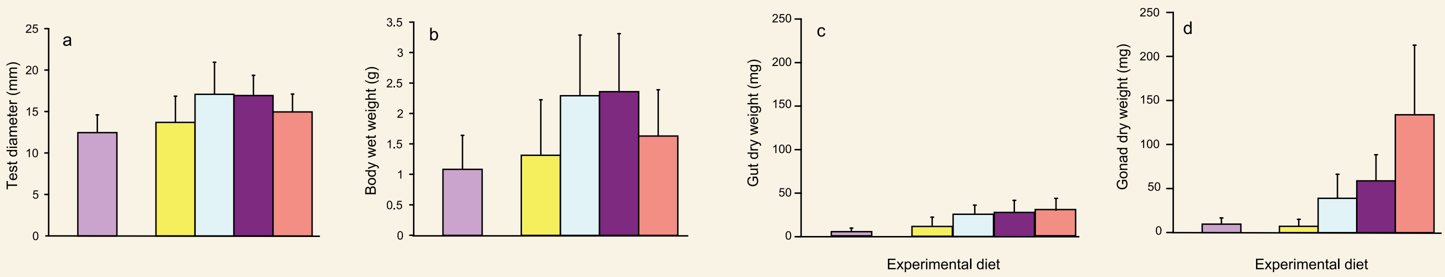
Individual urchins were fed two natural diets, the macroalga *Laminaria saccharina* or the mussel *Mytilus edulis*, and two artificial diets, a commercial salmon feed or a new urchin diet. Energy allocation, mean feeding rate and absorption efficiency were affected by diet. Salmon diet, which has high concentrations of protein and lipid, promoted gonad production. The mussel and new urchin diets both promoted good somatic and gonadal growth while the mussel diet produced slightly larger gonads, possibly as a result of its higher proportion of animal protein. The macroalga, however, produced neither somatic nor gonadal growth (Fig. 18). These results show the potential adaptive importance of the absorption of food components on growth and reproductive development in this echinoderm. A detailed knowledge of the urchins' energy budget will facilitate future work on optimising artificial diets and culture conditions.

Sea urchin grazing affects the abundance and distribution of species in near-shore communities. Individual *P. miliaris* were given a choice of different sizes of the mussel *Mytilus edulis* and barnacles *Semibalanus balanoides* and *Elminius modestus*. The urchins exhibited size selectivity for prey items. Urchins (38.1/46 mm test diameter) preferred mussels 13.4/17.8 mm shell length and barnacles of less than 7.5 mm length. Field-based experiments were also conducted to ascertain the extent to which urchin grazing regulates community structure. Urchins were removed from selected areas and the subsequent changes in the encrusting invertebrate communities and macroalgal growth are being assessed.

Fig. 18 Mean test diameter, wet weight and dry gut and gonad weight (± standard deviation) for *Psammechinus miliaris* at the beginning of the experiment (control group) and four months later after feeding on the four experimental diets.

Key to diets

Control — Algae — Artificial diet — Mussel — Salmon diet



ASP in king scallops: managing variation

Characterising the variation in Amnesic Shellfish Poison (ASP) toxin levels among individual scallops is a necessary part of developing sound management practices following a harmful algal bloom. Our work revealed that levels of the ASP toxin domoic acid (DA) in gonad tissue of *Pecten maximus* varied considerably (range 0.13-75.5 µg DA g^{-1}, n = 170). Consequently, large numbers of individuals are needed for composite samples to accurately reflect mean population toxicity (Fig. 19). This degree of variation, however, precludes the ability to predict gonad toxicities reliably from routine sampling of whole scallop or visceral tissue.

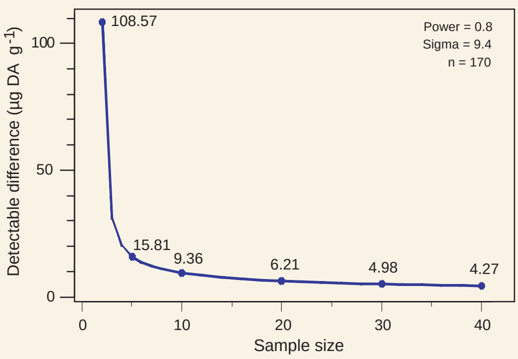
In addition, gonadal toxin levels between groups of individuals only 25 m apart were found to differ significantly. This indicates that microhabitat differences influence ASP toxicity in scallop populations. Where toxicities are extremely variable, it may be more informative to monitor tissues individually. The occurrence of gonadal toxicities exceeding the statutory 20µg DA g^{-1} limit was not homogeneous among locations (range 1.5-10%). Values for individual toxin variability at a given locality thus allow populations with a low frequency of individuals with elevated gonad toxicity to be distinguished (Fig. 20). This helps to establish the real level of risk to human health that consumption of a given population poses. Such strategies could prove applicable to the aquaculture and diver sectors of the industry, as both distinguish and harvest discrete beds of scallops. Risk assessment models should be considered to assess ASP toxicity, to maintain public safety standards and ensure optimum utilisation of the high-quality king scallop resource.

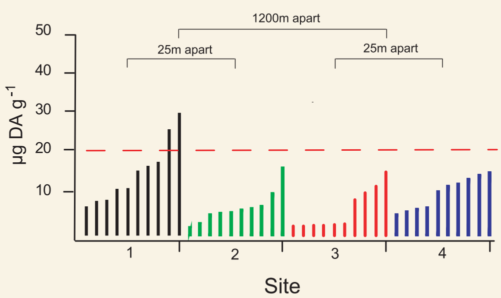
MS Kelly, M Otero Villanueva and DA Campbell (SAMS)

In conjunction with Loch Duart Ltd; Red Mills Ltd; Necton, Portugal; Xplora Products; Nutreco ARC; Demarne Bros, France; The Institute of Aquaculture, University of Stirling; Universidade Catolica Portuguesa; The Scallop Association; NOAA, USA and CCAP-SAMS

Fig. 19 (right) Sample sizes required to detect significant differences (±DA level as shown) between separate scallop populations.

Fig. 20 (far right) Individual DA toxicity levels (µg DA g^{-1}) in scallop gonads from sites within Tobermory Bay. Dashed Line = statutory limit (20 µg DA g^{-1} of tissue).





Dr Ray Leakey

Microbial Ecology

Planktonic micro-organisms form complex and productive communities which are central to a variety of important biogeochemical processes. They comprise unicellular microalgae and bacteria, along with protozoans which consume both algae and bacteria. Research at SAMS has continued to examine aspects of the ecology of these communities via both field and laboratory studies. Three new projects are reported below. One study improves our fundamental understanding of predator-prey interactions within microbial communities and another investigates the role of planktonic algae in stimulating foraging by commercially reared halibut larvae. The third is concerned with the role of planktonic micro-organisms in coastal eutrophication.

Modelling microbial predator-prey interactions and nutrient cycling

Mathematical models allow the investigation of complex interactions and relationships within planktonic microbial communities. In order to further understand such interactions, we have parameterised a mathematical predator-prey model to predict the growth of a planktonic protozoan *Oxyrrhis marina* feeding on an algal prey *Nanochloropsis oculata* under different nutrient conditions.

Dissolved and particulate carbon and nitrogen were measured in batch cultures of *N. oculata* grown in the presence and absence of *O. marina*. An existing mathematical model was then used to synthesise and analyse the experimental data. For the successful simulation of the observed predator-prey interactions it was necessary to modify the model functions determining rates of carbon and nitrogen metabolism of *O. marina*. The final model formulation then successfully simulated the observed predator-prey dynamics between *O. marina* and *N. oculata* (Fig. 21).

The results demonstrate the importance of algal prey nutritional composition and protozoan nutrient regeneration in determining the dynamic behaviour of the two species. They also indicate the importance of information on protozoan cellular physiology in understanding the ecology of planktonic microbial communities.

C Kúttner (University of Edinburgh), **R Leakey** (SAMS) **and K Davidson** (SAMS/UHI)

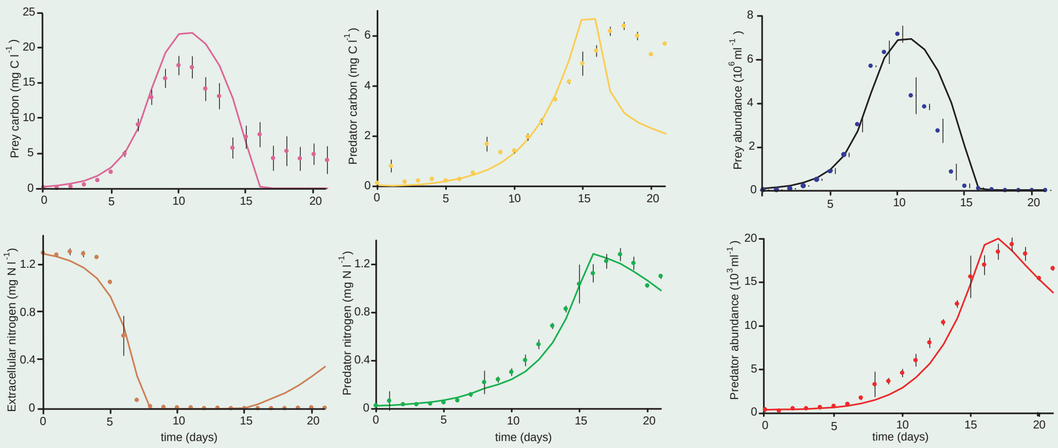


Fig. 21 Model simulations for the dynamics of the protozoan predator *Oxyrrhis marina* feeding on the microalgae prey *Nanochloropsis oculata*. Experimental measurements = (•). Model simulation = (___).

The role of microalgae in enhancing Atlantic halibut larval survival

The aim of this new project is to derive an optimal microalgal environment for foraging by commercially reared halibut larvae. 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).

The hatchery process for halibut is now relatively well established, but is still constrained by low cumulative survivals (*c*.12 %) over the yolk sac incubation and first feeding period. The economics of hatchery production are currently being hampered by the losses at this stage. During first feeding the halibut larvae are fed *Artemia* sp. nauplii (Fig. 22). The presence of microalgae with the *Artemia* nauplii appears to enhance the initiation of feeding and subsequent survival. The reasons for this effect have yet to be resolved but previous research suggests that the larvae obtain minimal nutritional benefit from the algae. Our experiments will therefore focus on the ways in which algae may alter larval behaviour and the quality of water in their rearing tanks. Preparations have now been made for these experiments which will be conducted at both DML and SFIA, Ardtoe during 2001.

N Auchterlonie, RS Batty and Y Corripio (CCMS-DML) **and R Leakey** (SAMS)

The role of pelagic micro-organisms in nutrient cycling through coastal waters

This new project will provide estimates of pelagic ecosystem parameters and an assessment of relevant underlying processes, in order to help construct simplified screening models for the assessment and prediction of eutrophication in coastal waters. The research forms part of an EU Framework V research programme *Oceanographic applications to eutrophication in regions of restricted exchange* (OAERRE) and will be undertaken in collaboration with scientists from the Universities of Napier and Wales Bangor, and several other EU countries.

The OAERRE programme aims to understand the physical, biogeochemical and biological processes involved in eutrophication in coastal marine regions of restricted exchange (REEs), especially lagoons, bays and fjords. Ecosystem processes in REEs will be described by basin-scale parameters in simple box models derived from detailed research models and the results of process studies at sites that exemplify a range of hydrographic and enrichment conditions.

Research at SAMS will include the measurement of microbial system parameters in the Clyde Sea during 2001. The ability of coastal waters to process anthropogenic nutrient inputs is in part dependent upon the taxonomic composition and activity of the planktonic microbial community. The activities of heterotrophic microorganisms (bacteria and protozoa) can, for example, lead to the entrapment of nutrients in surface waters, as can the activities of flagellate microalgae. The ratio of heterotrophic to total microbial biomass, and the ratio of flagellate-dominated to total microplankton biomass, will therefore be measured. In addition, relationships between protozoan grazers and their algal and bacterial prey will be investigated. These microbial data will then be used to parameterise a detailed research model of pelagic processes in the Clyde and other REEs.

E Foulland and K Jones (CCMS/DML), **R Leakey** (SAMS)

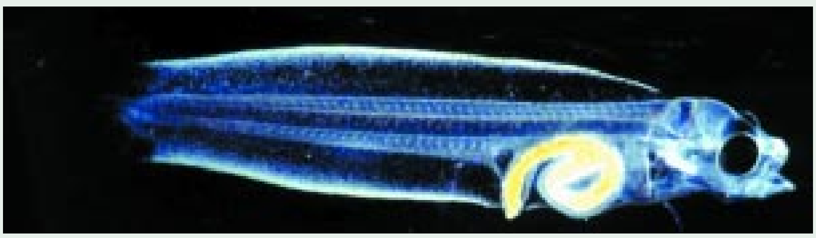


Fig. 22 First-feeding halibut larva, *c*. 11 mm in length, with the gut filled with *Artemia* nauplii.

Dr Geraint Tarling

Zooplankton Dynamics

This year has seen the expansion of the zooplankton dynamics group to include new NERC-funded projects that supplement the core activities of the group. The first of these new studies is examining the effect of advection on zooplankton in the Irish Sea using state-of-the-art physical and biological models. The results are providing crucial information for future sampling strategies in this region. The second new study is carrying out bioassays of anti sea lice chemicals on non-target copepod species. Although bioassays on these chemicals have been carried out by other organisations, this study is unique in being funded independently of chemical manufacturers and in being aimed specifically at the copepod species most at risk. The bioassay study is also proving to be useful in the interpretation of results from the field-based campaigns that are monitoring zooplankton communities in the vicinity of salmon cages. This monitoring study is now entering its second year and has achieved a comprehensive coverage of sites and a high degree of temporal continuity.

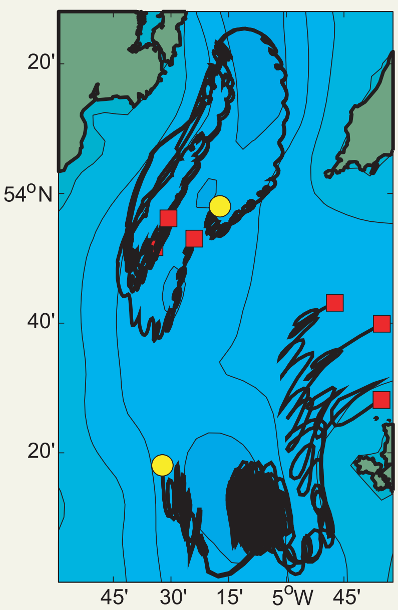
July 2000 saw the completion of a 15-month field sampling campaign in the Clyde Sea that collected data through a combination of moored and ship-based acoustic devices and multiple net systems. The campaigns generated one of only a handful of multi-parameter datasets lasting longer than a few months within British waters, which is testimony to the hard work of everyone involved in the programme. The unique coverage of the data has already been incorporated into several physical and biological papers and will be the resource for a great deal of future analysis.

Modelling the advection of zooplankton in the Irish Sea

The definition of plankton as wandering organisms is a misnomer for many zooplankton species since they are able to maintain or vary their horizontal distribution by adjusting vertical position in the presence of current shear (the variation of current strength with depth). Zooplankton have a pivotal role in the marine food web by preying on smaller grazers and phytoplankton whilst functioning as a food source for higher trophic levels including fish, seabirds and marine mammals. Consequently, variability in zooplankton distribution, species composition, behaviour, biomass, and biochemical characteristics may greatly affect the population dynamics of these commercially and, in many cases, endangered species. The Zooplankton Dynamics Group is using a modelling approach to investigate mechanisms that are thought to link zooplankton behaviour and environmental variability and to develop models incorporating physical factors.

Models of zooplankton diel vertical migration are coupled to depth-and time-resolved flow fields representative of the Irish Sea in order to investigate how the physical factors create hydrographic regimens which interact with the behaviour of the organisms leading, possibly, to enrichment and retention of zooplankton. Results to date indicate that retention is enhanced when vertical migration is taken into consideration; areas of deep water become foci for enrichment. When biologically feasible variability is included, such as variation in swimming velocity, results suggest that small changes may be amplified and result in population distributions diverging and becoming patchy (Fig. 23). These results will have implications when considering fish recruitment and the transfer of energy and nutrients, including sequestrated atmospheric carbon, from the productive coastal seas to the deep ocean.

S Emsley (SAMS), **G Tarling** (NERC Research Fellow) **and MT Burrows** (DML)



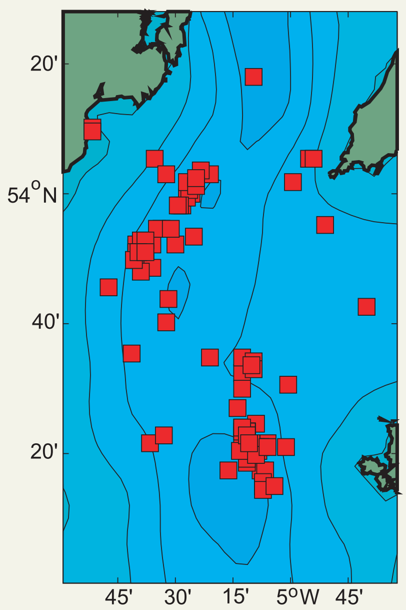


Fig. 23 Lagrangian trajectories of diel migrating particles within a flow field representative of April in the Irish Sea. County Down in NW, Isle of Man in NE and Anglesey in SE. Depth contours every 25 metres; (yellow circle) initial position; (red square) final position. (left) Two examples of the trajectories of 3 particles starting from the same position but with different swimming velocities showing divergence. (right) Positions of particles that are retained within the grid after 30 days showing retention and enrichment above deeper regions.

Fig. 24
Adult copepod *Acartia clausi* used in toxicity tests. This calanoid copepod is commonly found in Scottish sea lochs.

The effect of sea lice chemotherapeutants on zooplankton communities

Infestations of parasitic copepods or ‘sea lice’ on farmed salmonids cause devastating damage when present in large numbers. To control sea lice infestations, the salmon farming industry uses chemotherapeutants that are toxic to crustaceans and target specific life stages of sea lice. Planktonic copepods (Fig. 24) are of prime importance in marine ecosystems and have a similar life cycle to parasitic copepods; hence they are also likely to be adversely affected by sea lice treatment chemicals.

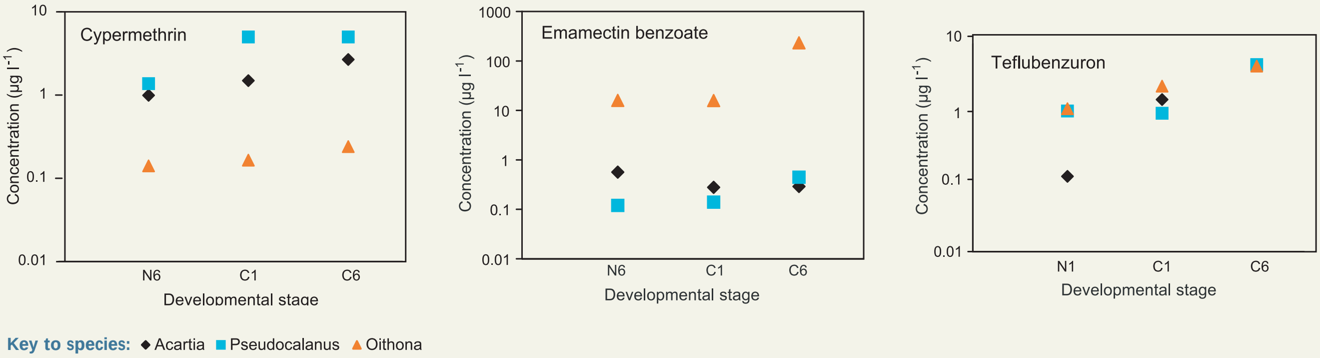
A number of new treatments are now being used world-wide and much effort has gone into ensuring that these meet environmental regulatory standards. However, concerns have been raised that these chemicals may still pose an ecosystem threat.

The study of the impact of sea lice treatment chemicals on zooplankton communities in three Scottish sea lochs undertaken by our group forms part of a multidisciplinary project funded by the Veterinary Medicine Directorate and the Department of the Environment, Transport and the Regions. Long-term sampling programmes are monitoring the potential ecological impacts of two treatment chemicals, cypermethrin and emamectin, currently licensed for use in Scotland. To date, changes observed in the zooplankton community during sea lice treatments are most likely related to advection and life history rather than the treatments.

A complementary project funded by NERC is investigating the toxicity of three treatment chemicals, cypermethrin, emamectin and teflubenzuron, to planktonic copepods commonly found in Scottish coastal waters. For each species and chemical, the comparative sensitivity of three life stages is being determined using laboratory bioassays. Results to date indicate that sensitivity varies considerably with chemical, copepod species and life stage (Fig. 25). The nauplii are generally the most sensitive life stage, while differences in sensitivity between copepods appears to depend on the relative activity of the species and the physiological action of the chemical. Sluggish species are more affected by stimulants (cypermethrin) and least affected by depressants (emamectin). Teflubenzuron only affects moulting stages (nauplii and pre-adults). Results from the laboratory bioassays will aid in the interpretation of plankton community responses by identifying sensitive species and life stages.

K Willis (SAMS) **and G Tarling** (NERC Research Fellow)

Fig. 25
Toxicity of sea lice chemotherapeutants to different life stages of three planktonic copepods. Acute toxicity values (48 h EC50 immobility) for nauplii (N6), subadult (C1) and adult (C6) copepods exposed to cypermethrin, emamectin benzoate and teflubenzuron.



Seasonal patterns in the zooplankton of the Clyde Sea

The rich zooplankton communities that inhabit the Clyde Sea undoubtedly influence the economic importance of the fishery in this region. One of the most abundant species is *Calanus finmarchicus*, a species that dominates many of the mesozooplankton communities throughout the North Atlantic ocean. The species performs a normal diel vertical migration of ascent at dusk and descent at dawn, which affects its advection and predation risk. There are also indications that individuals also perform midnight sinking behaviour where they descend and then re-ascend during a limited period of the night. Closer analysis of this pattern is complicated by the fact that near-surface and deeper water sub-populations are often present throughout the night making it impossible to measure the degree of vertical exchange using traditional acoustic and net-sampling methods. However, acoustic Doppler current profilers (ADCPs) can obtain averaged measurements of the velocity of individuals that may reveal such vertical exchange. The backscatter and vertical velocity measurements made by a 300kHz ADCP during August show a pattern that was typical over the 15 months duration of the deployment. Sound-scattering layers (SSL) were revealed at approximately 75 m, which dispersed through the water column during the night and re-formed around dawn (Fig. 26 lower). The accompanying vertical velocity records from the same instrument showed upward values during the start of dispersion and downward values during re-aggregation (Fig. 26 upper). Furthermore, there was a band of high downward velocities around the midnight period. Net-samples showed that *C. finmarchicus* was the only species found in the vicinity of this band. Examination of the timing of this midnight sinking over the course of the year revealed important information on the life-history strategy of these organisms.

G Tarling (NERC Research Fellow)

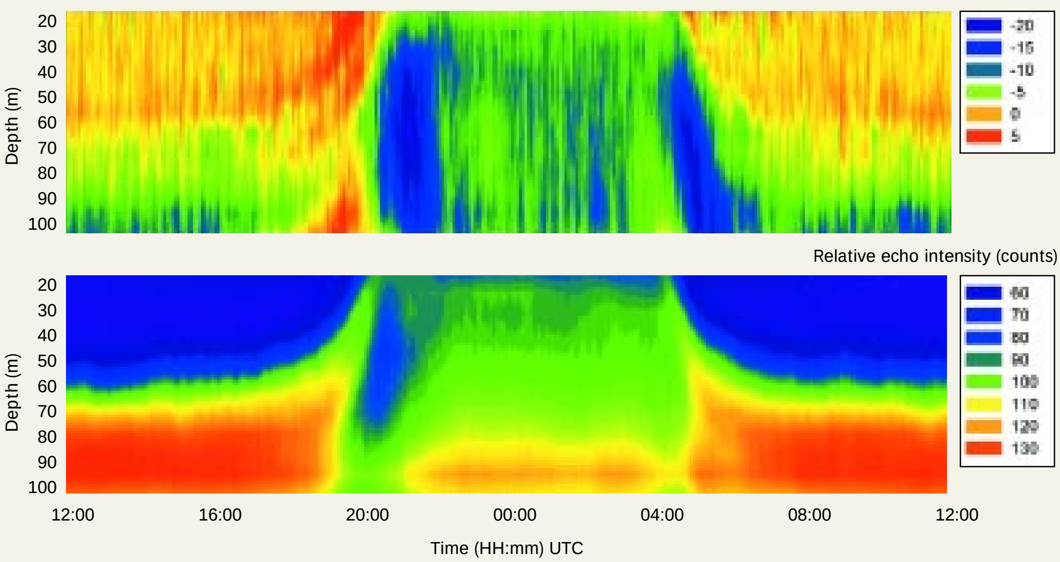


Fig 26: (upper) vertical velocity (mm. s^{-1}) and **(lower)** relative backscatter (-dB) profiles from a 300 kHz broadband Workhorse acoustic Doppler current profiler moored at 120 m in Inchmarnock water, Clyde Sea, August 1999. Profiles are averaged over 6 days.

Dr Angela Hatton

Marine Biogenic Trace Gases

There are considerable similarities between the biogeochemical cycles of reduced nitrogen and sulphur. These cycles are known to be coupled in the marine atmosphere and it has been suggested that this is also the case in the oceans. Dimethylsulphide (DMS) is the major volatile sulphur species in ocean surface waters and hence the dominant source of biogenic sulphur to the atmosphere. It is generated via the breakdown of dimethylsulphoniopropionate (DMSP), a compatible solute produced by marine phytoplankton. Once in the atmosphere, DMS is oxidised to form aerosol particles that may be deposited in rain or snow, contributing to the natural acidity of precipitation. The methylamines (MAs), on the other hand, are produced via the breakdown of the phytoplankton compatible solutes glycine betaine and trimethylamine-N-oxide (TMAO), and may be an important source of alkali to the atmosphere. It is thought that aerosol particles generated from either DMS or MA's may form cloud condensation nuclei, increasing cloud albedo and reflecting solar radiation. Current evidence suggests that sea air exchange may represent only a small sink for oceanic DMS and MAs, and that active cycles exists within ocean surface waters. Another potential sink for these compounds is via their oxidation to dimethylsulphoxide (DMSO) or its nitrogen analogue TMAO. However, the role that these oxidation processes play in the nitrogen and sulphur cycles has yet to be defined since the analysis of DMSO and TMAO in seawater has been problematic. One of the aims of this research group has been to develop techniques which allow us to address this and to understand the role that DMSO and TMAO play in the marine sulphur and nitrogen cycles.

Photochemical oxidation of DMS to DMSO

A network of production and utilisation pathways has been proposed for DMS. Many of these are reasonably well established, but the relative importance of some, such as photo-oxidation, are poorly quantified. Previous research had suggested that DMS might be removed from the water column via photo-oxidation, leading to the formation of DMSO. This conclusion, however, was based solely on the removal rate of DMS, and no measurements of DMSO were made. To address this, experiments were conducted on board RRS *Discovery* in the northern North Sea in June 1999, to assess the rate of removal of DMS and the rate of production of DMSO due to both UVB and visible light. Results showed that DMS could be photochemically removed by both forms of radiation, with approximately 30% of the total DMS being removed by visible light. Under natural light the photolysis turnover time of DMS ranged from 2.7 to 9.5 days and the turnover rate constant ranged from 0.1 to 0.37 d^{-1} for the upper 20 m of the water column. These rate constants are comparable to those for the atmospheric removal and bacterial consumption of DMS. In addition, results showed that DMSO could be photochemically produced at rates of between 0.07 and 1.203 nmol dm^{-3} d^{-1}, but interestingly also indicated that most of the DMSO was generated by visible light. It is concluded that under visible wavelengths of light most of the photochemically removed DMS will be photo-oxidised to DMSO, but that at wavelengths less than 315 nm (UVB) a second potential DMS photolysis pathway exists, leading to the photolysis of DMS. These results may prove to have significant implications for our understanding of how photochemistry influences the cycling of DMS, particularly in the Southern and Arctic Oceans where ozone depletion may result in increased levels of UVB radiation.

A Hatton (NERC Research Fellow)

Development of a method for the determination of TMAO in aqueous samples

Recent studies have shown that the breakdown of TMAO and quaternary amines may be a significant source of ammonia (NH_3) and methylamines in the marine environment. These compounds are capable of evasion across the sea air interface where they are an important source of alkali to the troposphere and thus play a significant role in the regulation of atmospheric pH. Although methods exist for the analysis of TMAO in some biological samples, they lack the sensitivity required for measurement of TMAO in natural waters. We have now developed a new, safe and sensitive technique for the determination of TMAO in aqueous and biological media. The technique exploits a highly efficient and selective enzyme to convert TMAO to TMA, which is then resolved and quantified using a combined flow injection-ion chromatographic technique. The method has been shown to be sensitive, with a limit of detection of 1.35 nmol dm^{-3}. The response of the system was linear for both fresh- and seawater standards (Fig. 27; R^2 =0.997 and 0.993 respectively) and precision (RSD) for standards in the range 40-600 nmol dm^{-3} was within 3%. The specificity and competitive inhibition of the enzyme has been addressed and the applicability of the technique has been demonstrated on a number of contrasting natural water and biological samples. Due to its sensitivity, this new method offers great potential in studies of the occurrence of TMAO in the marine environment and establishment of the role and significance of TMAO in the biogeochemical cycle of nitrogen.

A Hatton (NERC Research fellow)
and S Gibb (Thurso College, UHI)

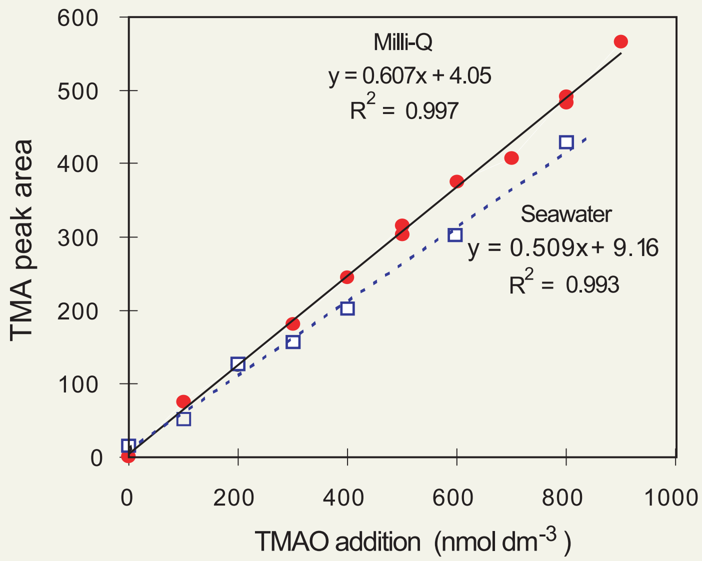


Fig. 27 Regressed calibration data for the determination of TMAO in Milli-Q and aged seawater using enzymatic reduction in conjunction with Flow Injection Gas Diffusion - Ion Chromatography

Analysis of TMAO and TMA in fish tissue

TMAO is widely distributed in marine organisms, where together with quaternary amines it is thought to function in osmoregulation. TMAO can be accumulated by cells in response to salinity stresses and is also thought to be involved in the regulation of cellular nitrogen toxicity, to contribute to the positive buoyancy of marine animals and to act as a cryo-protectant in cold-acclimated fish. During storage TMAO can be reduced to trimethylamine (TMA), one of the volatile bases responsible for the characteristic smell of spoiled sea fish, and its presence is often used as a subjective organoleptic indicator of seafood quality. An experiment was conducted to assess the level of TMAO present in different fish types and to study the conversion of TMAO in decaying fish material. Samples from fresh whiting, mackerel and cod were extracted and analysed immediately for TMAO and TMA. In addition, a series of pre-weighed portions of mackerel were left to spoil for several days. Samples were extracted and analysed on a daily basis.
The samples of fresh fish all contained high concentrations of TMAO relative to those of TMA. In each case TMA represented less than 1% of the total trimethylamines (TTMA). Lowest concentrations of TMAO were found in the sample of cod. In the time series experiment changes in relative abundance of TMAO and TMA were observed while TTMA remained fairly constant throughout the study (Fig. 28), clearly demonstrating the conversion of TMAO to TMA.
In this experiment the reaction progressed rapidly, with >95% of TMAO being converted to TMA within 2 days and the most significant change occurring over the first day. These preliminary results clearly demonstrate the applicability of this technique to the analysis of TMAO and TMA in fish tissue.

A Hatton (NERC Research fellow)
and S Gibb (Thurso College, UHI)

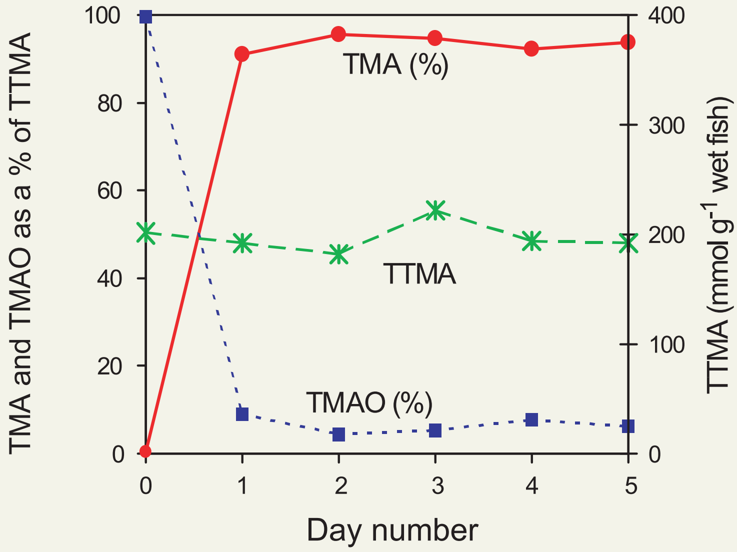


Fig. 28
The reduction of TMAO to TMA during spoilage of mackerel muscle tissue. TTMA = total trimethylamine = TMAO + TMA.

Dr Axel Miller

SAMS/UHI Millennium Institute

This has been a year of landmarks resulting from the relationship between SAMS and UHI. In autumn 2000 the first cohort of undergraduate students were enrolled onto the UHI BSc Marine Science degree and the second cohort of UHI postgraduates arrived. On 1st April 2001 UHI was formally designated by the Scottish Executive as a Higher Education Institution (HEI) - the UHI Millennium Institute.

UHI BSc Marine Science

In September 1998, SAMS gained Open University Validation Service (OUVS) accreditation to offer the degree, making it the first course of its kind in Scotland. Four marine science lecturers at SAMS have been responsible for the main subject-centred components of the course: Principles of Physics, Geology, Biology and Chemistry, with additional modules in Computing, Mathematics and Marine Science. Students are able to study full-time or part-time at SAMS, in collaboration with Argyll College and in partnership with Orkney College and Moray College, who are responsible for delivery of specific elements of the course. In their first year (level H1) students have been able to take modules in the principles of science, along with computing, mathematics and communications technology. This year the prelude to the Easter vacation was a week-long field course based on and around Loch Etive, where students (Fig. 29) were given first-hand experience of marine sampling, laboratory analysis and data handling techniques.

UHI Postgraduate Research Activities

Historically SAMS has hosted postgraduate students registered with universities from across the UK, Europe and beyond. Through engagement with UHI, we now host our own postgraduates, with full responsibility for academic support and quality assurance through the OUVS. A total of 12 UHI PhD students are based at SAMS, in fields across the portfolio of our research activities i.e. physical oceanography, biogeochemistry, fish biology, phytoplankton ecology, ecological modelling, aquaculture and palaeoceanography. In a recent Institutional Review, SAMS was praised for the quality of the postgraduate student support and for the rigour of our monitoring procedures. At the Scottish Marine Group meeting in March, one of the final year students, Maria del Mar Otero-Villanueva, so impressed a member of the audience with the graphics of her presentation that he spontaneously presented an extra prize to her!

AEJ Miller (SAMS and UHI Research School Convenor)

Fig. 29 BSc Marine Science students and lecturers enjoying their field course aboard RV *Calanus*, on Loch Etive.

Dr Keith Davidson

Research Activities

Dynamics and modelling of algal and protozoan populations

Primary production by phytoplankton forms the base of the marine food chain. Current research within the group aims to develop a greater understanding of the growth dynamics of particular phytoplankton groups and their protozoan predators. To achieve this we are utilising an integrated approach using an experimental laboratory microcosm and an outdoor mesocosm together with mathematical modelling.

Two NERC grants are funding investigations of the role of protozoans as predators of phytoplankton. The first project, part of the PRIME thematic programme, is an experimental study using laboratory microcosms and seeks to trace carbon-nitrogen (CN) budgets and identify trophic selection associated with microzooplankton grazing. In particular we have been studying the predator/prey interaction between different species of phytoplankton and the heterotrophic microzooplankter *Paraphysomonas vestita* (Fig. 30). Results from these experiments have highlighted that selective predation by microzooplankton occurs when a choice of phytoplankton prey is available and also when prey are of different nutritional value in terms of C:N ratio. Such prey selection has implications for the dynamics of marine food webs as it plays a potentially crucial role in determining the quantity and ratio of carbon and nitrogen passed further up the food chain.

The second project involves mathematical modelling, and is funded by the Marine Productivity special topic. The work seeks to compare mathematical models of microzooplankton of different levels of sophistication, and to determine the level of physiological detail that needs to be included in models to achieve accurate predictions. The results of the experimental studies are now being incorporated within our models to attempt to quantify the influence of prey selection by microzooplankton on the food web as a whole.

Other research during the year has concentrated on the investigation of microbial food web dynamics, especially diatom growth. Outdoor mesocosm experiments were conducted during June 2000 at the Trondheim Marine Systems Large-Scale Facility. Funding from a NERC small grant has allowed us to utilise results from these mesocosms as test beds for models of diatom growth. Work is also continuing on a UHI-funded Ph.D studentship to study potentially toxic diatoms of the genus *Pseudo-nitzschia*.

K Davidson (SAMS/UHI), **E Roberts, A Mitra and J Dearman** (SAMS), **P Burkill and A Taylor** (PML), **L Gilpin** (Napier University) **and J Fehling** (UHI)

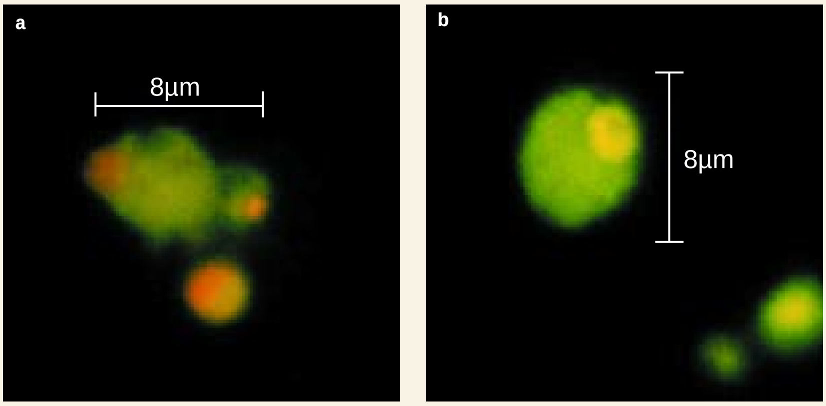


Fig. 30 Two methods of investigating protozoan predation; **(a)** using live phytoplankton prey *Nannochloropsis oculata* seen fluorescing red and **(b)** using fluorescently labelled phytoplankton, seen fluorescing yellow. In both **(a)** and **(b)** the larger body is the protozoan predator *Paraphysomonas vestita*. Ingested prey are visible within it, allowing quantification of ingestion rates.

Dr Mark Inall

Physical oceanography

During the year the Marine Physics Group has doubled in size, from 2 to 4. In October we were joined by Finlo Cottier, a sea-ice physicist from Cambridge, now employed at Dunstaffnage under the EU FPV project OAERRE, which commenced this year. OAERRE science began in the Clyde Sea with observations from 3 ships, including the Bangor University RV *Prince Madog*, allowing us to quantify vertical and horizontal exchanges between the Clyde Sea and the North Channel. An extensive observational campaign in Loch Etive during June 2001, also under OAERRE, moves our attention now to a fundamentally different type of fjord.

SAMS' contribution to the physics component of OAERRE follows on logically from a NERC-funded project in the Clyde Sea, which ended in June 2001. Two key results emerged from the Clyde Sea project (Fig. 31) - the confirmation that internal waves significantly modify deep-water properties during periods of deep-water isolation, and that the internal tide loses a significant proportion of its energy through friction with the sea bed. These results were disseminated at the bi-decadal International Symposium of Stratified Fluid Flows and at the Annual meeting of the European Geophysical Society.

A UHI Ph.D student, Damian Likely, was the second addition to the Marine Physics Group. His project, on the generation of internal tides over the Wyville-Thomson Ridge, began with sea-going in May 2001 on the FRS vessel *Scotia* with co-supervisor Bill Turrell. The project integrates well with the new SAMS Northern Seas Programme, using data from the FRS Faroe-Shetland Channel moorings and the forthcoming SAMS research cruise on RRS *Discovery*.

ME Inall (SAMS/UHI), **C Griffiths and F Cottier** (SAMS),
W Turrell (Fisheries Research Services, Aberdeen)
and D Likely (UHI)

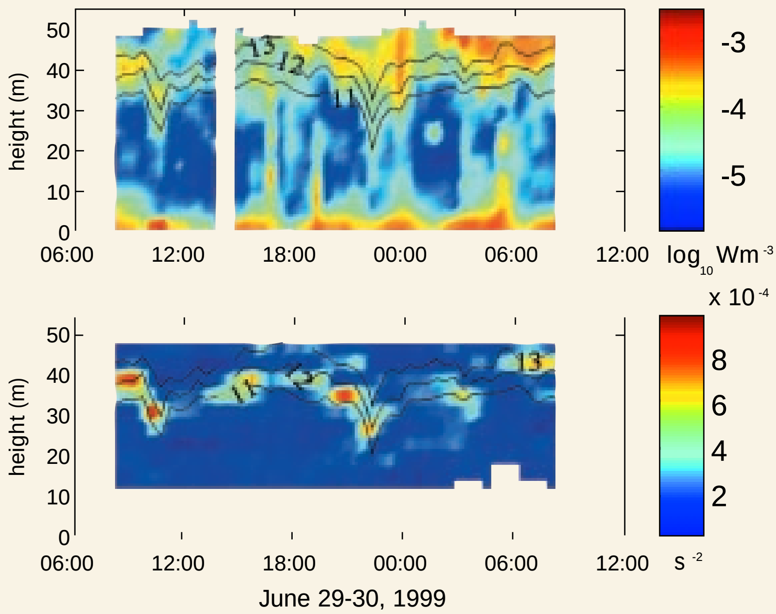


Fig. 31 Contours of energy dissipation rate in the Clyde Sea with isotherms overlaid **(upper)**, and contours of the shear squared computed from current measurements **(lower)**. The internal tide can be seen in the vertical movement of the isotherms, as can energy dissipation, both within the thermocline and in the bottom boundary layer.

Dr John Howe

Sediments and oceanic circulation

Work in the North Atlantic has concentrated on depositional processes and the influence of climate change on oceanic circulation over the last 20,000 years. In collaboration with colleagues at the Southampton Oceanography Centre and the British Geological Survey, a study of the processes that produce sediment waves on the seafloor south of the Wyville-Thomson Ridge in the northern Rockall Trough has continued. The continental margin off north-west Britain has a variety of bottom-current influenced sediment mounds and 'drifts'. These include (1) elongate drifts - both single- and multi-crested (2) sheeted drift forms, varying from gently domed to flat-lying and (3) isolated patch drifts, including moat-related drifts around the base of seamounts (Fig. 32). Associated fields of localised sediment waves are developed with the elongate and gently domed, broad sheeted drifts.

In October 2000 a Ph.D student, Clara Morri, began work at Dunstaffnage on the problem of deciphering the influence of deglaciation on the deep-water sediments of the North Atlantic. Working from a commercial dataset of cores and seismic reflection profiles, she has produced a map of the seabed processes which will prove invaluable in future detailed work on the core material.

J Howe (SAMS/UHI), **C Morri** (UHI), **D Stow and D Masson** (Southampton Oceanography Centre), **M Stoker and M Akhurst** (British Geological Survey)

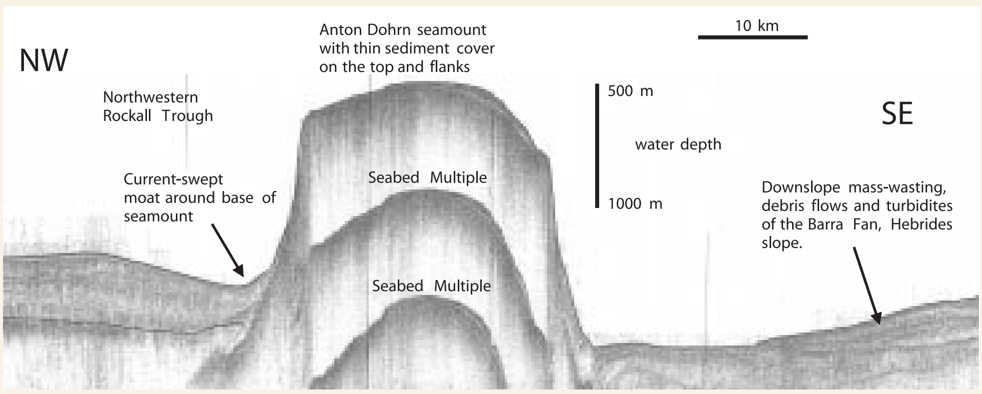


Fig. 32 Seismic reflection profile across the Anton Dohrn Seamount to the west of the Hebrides in the central Rockall Trough, north east Atlantic. Data originally collected on behalf of the UK Rockall Consortium. Seabed multiple traces are artefacts.

Fig. 33 Common Tern

Reports from the SAMS Honorary Fellows

Marine ornithology

Seabird 2000 is a nationwide census of breeding seabirds taking place in 1999-2001. As our contribution, in summer 2000 a complete count was made of five gull and two tern species breeding in a study area lying along the mainland coast between Mallaig and West Loch Tarbert. Results are summarised in Table 1.

Terns are notable for their astonishing beauty and elegant fishing technique, but they appeal to our imaginations in many other ways. Arctic Terns make the longest migration of all bird species. The British Isles are at the southern limit of their circumpolar breeding range. They breed as far north as dry land extends, their most northerly breeding site being at the northern tip of Greenland (83° 40'N). Shortly after breeding, Arctic Terns migrate to the Antarctic where they spend the boreal winter/austral summer among the pack ice, as far as 74°S. For a bird no heavier than a Blackbird, but much more dashing, streamlined and long-winged, the most demanding part of this 30,000 km round trip must be the 3000 km crossing of the southern ocean.

Common Terns (Fig. 33) are also long-distance migrants but in a lesser league, spending the winter on the shores of west Africa. Table 2 gives countries where chicks ringed in the Oban area have been recovered in winter (mostly killed by local children, who use the rings for necklaces). Evidently most of our Common Terns winter in Senegal.

The 768-pair colony of Common Terns (Table 1), on a small skerry in the Sound of Mull, continues to be the largest colony of the species in the British Isles. It has maintained this distinction annually since the last national seabird census in 1987. The villagers of nearby Craignure see Common Terns as one of their most numerous and characteristic summer visitors. However, there are now long stretches of coast between Mallaig and Campbeltown where terns are rarely if ever seen.

The main reason for the loss of these and other breeding seabirds from many parts of Argyll and Lochaber has been widespread annual breeding failures caused by American mink. In 2000, as in previous years, attempts were made to stop these losses and to save the more important of the surviving colonies. Mink control was carried out at 27 seabird breeding sites in 12 sealochs and sounds, and seabirds bred successfully at 23 of the 27 sites (Table 3). Mink definitely caused complete breeding failure at one of the sites and were strongly suspected as the cause of very low productivity at another two, while mink definitely caused near-complete failure at a trapped site where no mink had been caught. Quantitative comparisons with colonies where mink had not been removed again showed that mink control greatly improved breeding success for most species.

JCA Craik (SAMS Honorary Fellow)

Table 1. Numbers of gulls and terns breeding in study area in 2000

Species	*Total number of pairs (number of colonies)*	*Number of pairs at largest colony*
Herring Gull	8609 (82)	800
Common Gull	1498 (62)	368
Lesser Black-backed Gull	1153 (22)	400
Great Black-backed Gull	696 (73)	65
Black-headed Gull	188 (9)	139
Common Tern	1269 (19)	768
Arctic Tern	373 (14)	140

Table 2. Winter recoveries of Common Terns ringed as chicks near Oban

Country	*Number of recoveries*
Mauritania	5
Senegal	26
Gambia	1
Guinea	12
Sierra Leone	2
Ghana	8
Togo	2
South Africa	1

Table 3. Six-year summary of progress of mink-seabird project

Year	*Number of sealochs and sounds where mink were controlled*	*Number of seabird colonies in those sealochs & sounds*	*Number of those colonies where birds bred successfully*
1995	2	5	4
1996	8	11	8
1997	10	14	12
1998	10	20	20
1999	10	24	23
2000	12	27	23

Zooplankton

Investigations of the macroplankton and mesoplankton of the Clyde Sea have continued with particular emphasis on diurnal vertical migration, its causes and consequences. Following the completion of the SAMS component of the EU MAST 3 PEP Project, my role has changed to providing support, advice and assistance to Dr Geraint Tarling, NERC Research Fellow, who now leads the Zooplankton Dynamics Group. We have continued to work up data from PEP and have further developed studies of vertical migration patterns in the Clyde Sea with the continued use of ADCP and the MOCNESS multinet. The results are being interpreted and assessed in relation to external cues (proximate causes) and survival strategies (ultimate factors).

As secretary of the International Association for Biological Oceanography (IABO), I have been involved in preparing for the forthcoming Joint Assembly of IAPSO and IABO, '2001: An Ocean Odyssey', to be held in Argentina in October. The Assembly comprises a series of symposia on particular themes. Many of these have a strong biological component and are promoted by and through IABO.

Since retiring three years ago as Secretary of the MARS Network of European Marine Stations, I have continued as editor of the *MARS Newsletter*. For the last two years I have served as a trustee of the Hebridean Whale & Dolphin Trust which is based in Tobermory and I have recently taken on the chairmanship of the Scientific Committee. The trust has charitable status and is dedicated to the conservation of whales, dolphins and the marine environment through research, education and working within Hebridean communities. The trust draws heavily on volunteer support and relies - quite successfully for the most part - on grants from conservation bodies. It stands to benefit greatly from liaison and collaboration with the scientific community, particularly with Dunstaffnage. I aim to encourage and facilitate that contact.

JBL Matthews (SAMS Honorary Fellow)

Mr Chris Rydings

Data Warehouse Services

The new Data Warehouse building (Fig. 34) was completed in December 2000 and went 'live' one month later. It now houses the UHI Millennium Institute's core operating systems and has been tailored to provide the following services:

Data Messaging Service

Full support is provided for Novell GroupWise E-mail clients, currently around 12,000 and expected to rise to 20,000 in the future. This involves the upgrading and continual maintenance of both the servers and the operating system, including client maintenance. Statistical data are provided for the partner colleges including SAMS.

Data Warehouse Service

This provides the housing and back-up/disaster recovery service for both SAMS & UHI. The purpose-built data warehouse has the ability to handle approximately 80-100 servers including their components, switches and the UPS system. The back-up/ recovery system currently backs-up SAMS and UHI systems contained within the building, but the service will go University-wide towards the end of 2001. The Data Warehouse also handles all student data through the DITA/OLIB systems and maintains these with outside suppliers to ensure integrity throughout the UHI Wide Area Network.

Helpdesk Service

A 24-hour, 7-day helpdesk is now available to all UHI academic partners. Traffic volume is expected to be around 500-600 calls per week, with individual partners filtering out local calls.

The future

What lies ahead for the Data Warehouse? Planning is underway for the provision of the back-up service to all partners who require this facility. Demand is currently around 1 terabyte daily but is expected to rise to 8 terabytes at peak demand.

The Data Messaging service will be consolidated to SAMS by the end of the year, allowing better maintenance and control. This service will also look at the SAMS E-mail accounts and bring them up to date and into the UHI set-up. Demand for the Helpdesk service is growing each week, with local schools and other colleges considering signing up to this for their own use. The UHI Executive Office in Inverness and the Data Warehouse are in discussion with the Scottish Executive regarding funding of this service.

C Rydings, S Phillips and N Longman (SAMS/UHI),
K Smalley and G Ryan (DML)

Fig. 34 The new SAMS Datawarehouse building.

Dr Mike Burrows

Ecology and Behaviour of Coastal Organisms

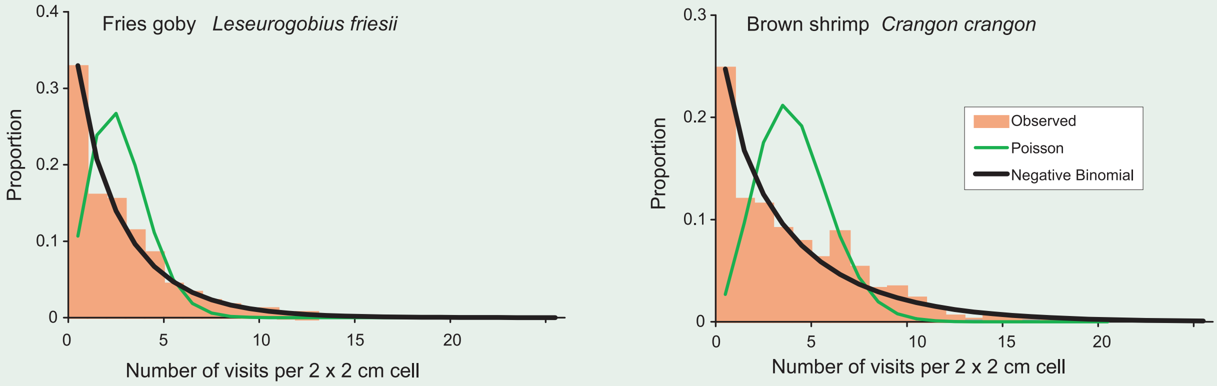
Our research is focused on understanding the role played by key species in the functioning of marine systems, with special emphasis on the role of behaviour and physiology in relationships between consumers and resource species. We are examining some of the ecological mechanisms that structure populations and communities and, ultimately, biodiversity in ecosystems. The behaviour of individual animals, especially foraging and habitat selection, can largely determine the outcome of interactions between species at different trophic levels.

Patchy impacts of surface foraging on sediment

Underwater video has revealed much of the behaviour of surface-living animals on the bottom of sea lochs. By day, the Fries goby *Leseurogobius friesii*, and the brown shrimp *Crangon crangon* made extensive and intensive foraging movements. By night the emergence and movements of *Nephrops norvegicus* were revealed with infra-red lights. When analysed, the most striking feature of the movement trajectories was a great degree of small-scale patchiness in the frequency of visits to small areas of seabed. Frequency distributions of visits conformed closely to theoretical predictions assuming that the data conform to a negative binomial distribution (Fig. 35). A model was used to simulate foragers with different rates of turning to determine the role of movement patterns in patchiness of impacts by surface living animals. The model was successful in explaining differences in patchiness among the three species: shrimp moved in straighter paths and had a less patchy distribution of visit counts compared to gobies. Unexplained differences in patchiness between different areas may be due to the presence of patchy features such as prey and burrows.

LA Nickell, MT Burrows, L Robb and R Harvey (DML)

Fig. 35
Comparison of observed proportional frequencies of visits by brown shrimp and Fries goby to 2x2 cm areas over 24h, with predicted Poisson and negative binomial distributions. The observed data conform closely to the negative binomial.



A comparison of underwater mapping of biogenic features using diver and ROV observations

In the last decade, there has been an upsurge in remote techniques for underwater imaging that can help to bridge the gap in resolution of data between small-scale observation by divers and large-scale sea floor surveys using acoustic techniques such as side-scan sonar. In collaboration with Plymouth Marine Laboratory and Plymouth University we have studied the effects of disturbance created by the activity of megafaunal bioturbators on infaunal community structure. Diver and ROV techniques for mapping biogenic features on the seabed were compared quantitatively.

The work was carried out 10 km north of Oban in Loch Creran and at Jennycliff Bay in Plymouth Sound. Both areas support populations of megafaunal burrowers, including the crustaceans *Nephrops norvegicus*, *Goneplax rhomboides* and *Callianassa subterranea*, the echiuran worm *Maxmuelleria lankesteri* and the Fries goby *Leseurogobius friesii*, together with a number of bivalves, holothurians and anemones. Areas of the seabed were mapped directly by divers and with video images from an ROV. Comparative analysis of feature positions and measurements revealed that both ROV and diver-mapping provide high-quality, quantitative data and that there was good correlation between the techniques. Diver mapping was constrained by dive time, so that the mapped area was inversely related to feature density. However, especially in low visibility, divers were able to examine features more closely than the ROV and to manipulate objects to provide additional information about faunal identity. The ROV provided a permanent record that could be analysed subsequently, unconstrained by diving depth or bottom time. The success of each technique depends on operational and environmental conditions but, where possible, both should be used to complement one another. In the context of the wider study on megafaunal burrowers as agents of disturbance, these results are important because they allow us to make comparisons between different environments at varying depths, in the full knowledge of the biases and degree of agreement between different techniques.

LA Nickell and MT Burrows (DML)

Fig. 36
Location of long-term sampling stations around Sullom Voe, Shetland.

Ecosystem response to environmental change

Synchrony of population changes across a spatial network of sites can tell us much about the scale of the dominant factors causing the changes, and can give clues as to the nature of those factors. Dispersal and disturbances are thought to be the primary influences on synchrony. Large-scale events such as storms cause broad-scale changes, while processes driven by species interactions such as predation may have only local influence - unless synchronised by another factor like larval dispersal. In addition, synchrony has strong implications for the design of cost effective monitoring schemes. If population changes occur simultaneously at many sites, fewer sampling sites will be needed to assess the status of the species than if population trends are peculiar to each locality.

Construction of the then-largest oil terminal in Europe in Shetland in the late 1970s resulted in a monitoring programme (Fig. 36) that has continued yearly since 1981. The rocky shore dataset is unrivalled in terms of the diversity of species assessed each year. The data presented an opportunity to assess synchrony in changes of rocky shore species and compare this with the biology and ecology of the species. The most synchronous was the barnacle species *Semibalanus balanoides* (Fig. 37), with long-lived planktonic larvae, while one of the least was the dogwhelk *Nucella lapillus* which lays egg-capsules directly on the shore. However, analysis of the trends in synchrony among the species showed that differences could not simply be explained by mode of reproduction and degree of dispersal. Higher-shore species tended to be more synchronised, suggesting that influences like weather might be important for animals and plants exposed for long periods during the tidal cycle.

MT Burrows (DML)

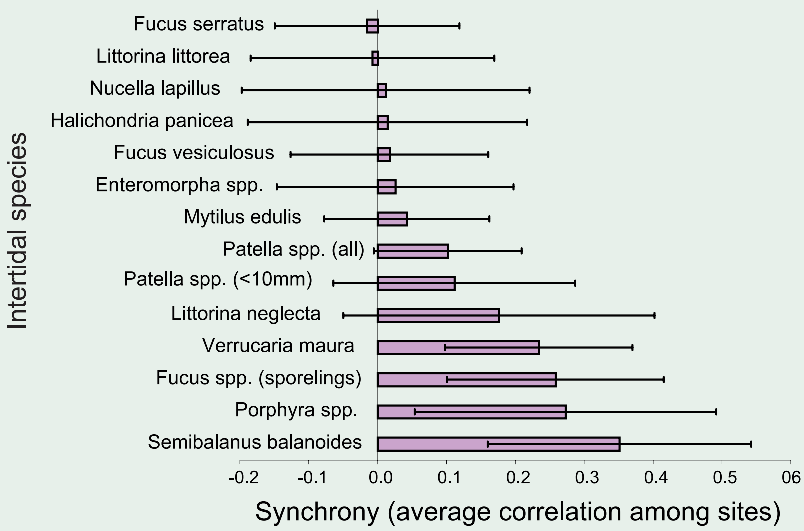


Fig. 37
Analysis of spatial synchrony of changes in rocky shore populations around Sullom Voe, Shetland (1981-2000). Average correlations among sites are shown for selected species. Limits are 95% confidence intervals generated by bootstrap analysis.

Dr Bob Batty

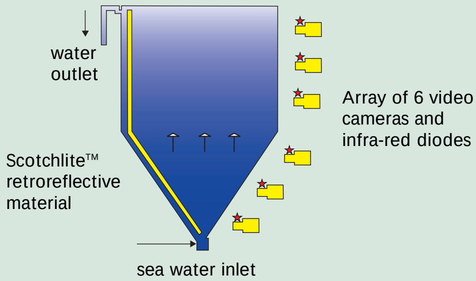


Fig. 38 Diagrammatic representation of hatchery silos, in which halibut spend their yolk-sac phase of development, showing arrangement for video surveillance.

The effect of salinity on the distribution of Atlantic halibut larvae in rearing silos

This 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 a collaboration with scientists from the British Marine Finfish Association, Glasgow University and the Sea Fish Industry Authority (SFIA). Although the hatchery rearing process for halibut is now relatively well established, low and very variable cumulative survival, averaging only 2% between fertilisation and metamorphosis, remains a problem.

To encourage feeding, larvae must be in good condition and damage during the yolk-sac stage must be avoided by providing them with the ideal environment. Yolk-sac larvae are negatively buoyant and tend to sink head-first through the water column and for this reason have been cultured in complete darkness in conical tanks (silos) with upwelling water (Fig. 38). Larvae may suffer damage through contact with tank surfaces and the surface tension layer; their large external mechanosensory neuromasts being particularly vulnerable. The distribution of larvae has been followed during development using an array of infra-red sensitive cameras and illuminators (Fig. 38). Larvae tend to be nearer the bottom of the tank early in development and to move near the surface towards the end of the yolk-sac phase (Fig. 39). Changes in salinity can also have a significant effect on distribution. Low salinity causes larvae to be nearer the bottom of the tank and subsequent increases in salinity can cause an accumulation at the surface. Figure 40 shows a sudden move towards the surface at 24 days when salinity increased again after a fall. Accumulations at the surface or bottom of the tank lead to damage to sense organs and to increased risk of infection and spread of disease.

It is clear that a stable salinity regime within yolk-sac silos is important for ensuring long-term survival of halibut larvae. Further experiments will focus on the use of a low salinity layer near the surface to prevent surface accumulation and adjustment of salinity during the yolk-sac period with high salinity at the beginning and reducing salinity towards the end.

RS Batty, NA Auchterlonie and Y Corripio (DML)

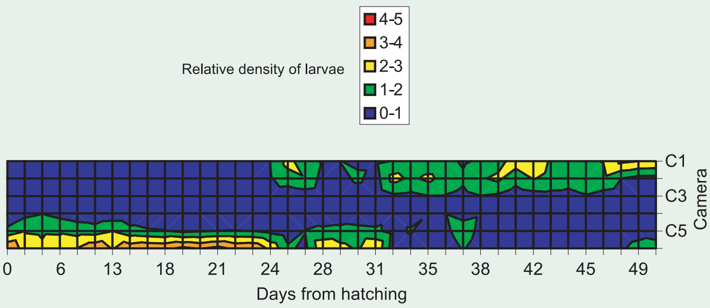


Fig. 39 Plot showing the changing vertical distribution of yolk-sac larvae in silos during development.

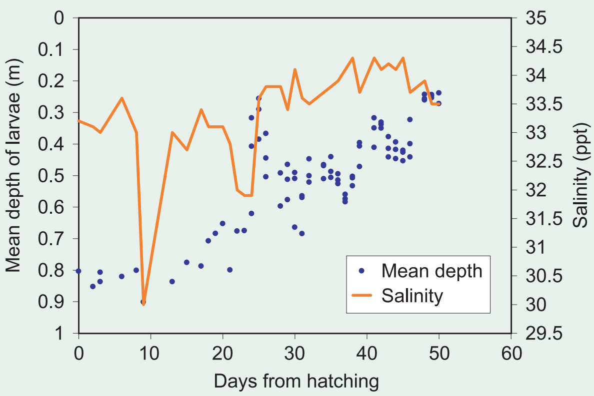


Fig. 40 Changes in the depth distribution of halibut larvae in a variable salinity regime.

Dr Martin Sayer

Fish Biology, Fisheries and Mariculture: environmental variation, manipulation and mitigation

The ability of marine animals to grow, reproduce and survive is continually influenced by the environment they live in and the condition of that environment. Natural variability in the marine environment and associated anthropogenic influences are concentrated in inshore coastal waters that support fisheries and mariculture industries, as well as providing a valued habitat for the early life stages of fish species of commercial relevance. Our research is focused on the inshore marine environment in relation to the health and condition of the animals that live and grow there. In addition to investigating the effects of natural variance on wild fish species, projects also examine how artificial reefs can be employed in habitat manipulations of relevance to commercial fishery management and how biofiltration methodologies may mitigate nutrient inputs from mariculture.

Environmental variation: fish biology and inshore fisheries

Rocky subtidal habitats make up around one third of the UK coastline. However, because of the difficulty in applying traditional survey techniques to such complex habitats, there is little quantitative information on the fish assemblages found there. A visual survey programme was established in 1995 and is providing long-term data on the abundance patterns of the dominant species on the west coast of Scotland. The project has also established a continuous record of daily average temperature at the survey sites since 1995.

The fish populations in these habitats are dominated by a small number of resident species such as wrasse, gobies and gadoids, most of which occur in greater numbers during the summer months (Fig. 41). Data indicate that distinct winter and summer assemblages also occur. The rocky subtidal is an important nursery area for the juvenile stages of the Atlantic cod *Gadus morhua*. 0-group cod (Fig. 42) settle into shallow rocky areas around late June and remain localised for the duration of the first summer, with greater densities associated with the more complex habitats. The abundance patterns of these juveniles are subject to considerable inter-annual variation and our data indicate that winter seawater temperature may be an important factor driving this. Abundance of juvenile cod was low following relatively warm winter seawater temperatures, while wrasse and gobies occurred in greater numbers in such years. This work, including physiological experiments, is continuing to enable a fuller understanding of the relationship between winter seawater temperature and year class strength of the major rocky subtidal species.

S Magill and MDJ Sayer (DML), and **M McFadden** (Heriot-Watt University)

Fig. 41 (right) Numbers of fish recorded in visual surveys at two shallow rocky sites on the west coast. **(a)** all species, **(b)** juvenile cod from the Firth of Lorne only.

Fig. 42 (far right) Juvenile cod spend their first year in shallow rocky subtidal areas.

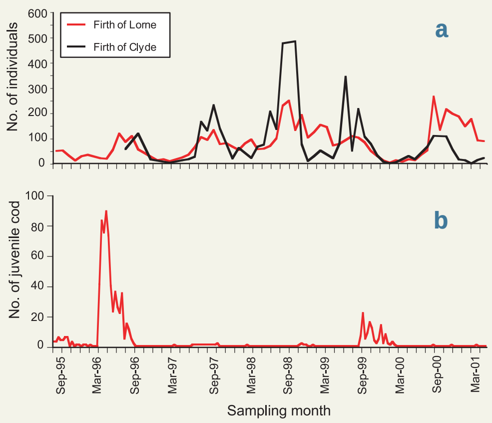


Fig. 43
Pennatula phosphorea, one of several sea pen species occurring in British waters.

Environmental manipulation: Artificial reefs

The Loch Linnhe experimental artificial reef complex, the largest experimental artificial reef in Europe, is now licensed for deployment. Yeoman (Morvern) Ltd, the industrial partners on the project, are currently producing *ca* 2000 tonnes of concrete blocks per month. The extensive biological and physical characterisation research which has been underway at the site since its inception has greatly assisted in the design of experiments to look at the impact of habitat modification on the surrounding area. This work has been funded by Yeoman (Morvern) Ltd, the EU PESCA programme and local Enterprise Companies. Early experiments will concentrate on the impact of the reef structure on two benthic faunal groups. One is the sea pen *Pennatula phosphorea* (Fig. 43), a patchily distributed member of the large surface-dwelling fauna. Also abundant at the site are brittle stars of the genus *Amphiura*. These may form an important food source for animals living on the reef including scavenging crustacea such as lobsters. A detailed assessment of the current abundance of *Amphiura* at the site has been undertaken and post-deployment comparisons will reveal the extent and possible mechanism of the impact that the reef has on this characteristic species.

Routine visual assessments of the large animals living on the seabed at the reef site revealed a previously undescribed species of foraminifera. These single-celled protists are normally microscopic, but not only is the new species visible to the naked eye, it can also be easily located and individuals flagged in the field. Time-lapse video recording of the new species has revealed that it exists in a number of forms and that it alternates between a feeding form (Fig. 44a) and a consolidated form (Fig. 44b). This type of behaviour has not previously been recorded in the foraminifera and the function of the consolidated form remains a mystery. The massive size of the new species (cell volumes up to 14 cm^3), its sustained longevity in aquaria, and its abundance and ease of collection make it a fascinating discovery that has been received enthusiastically by the global foraminifera research community.

TA Wilding (DML) **and MDJ Sayer** (DML)

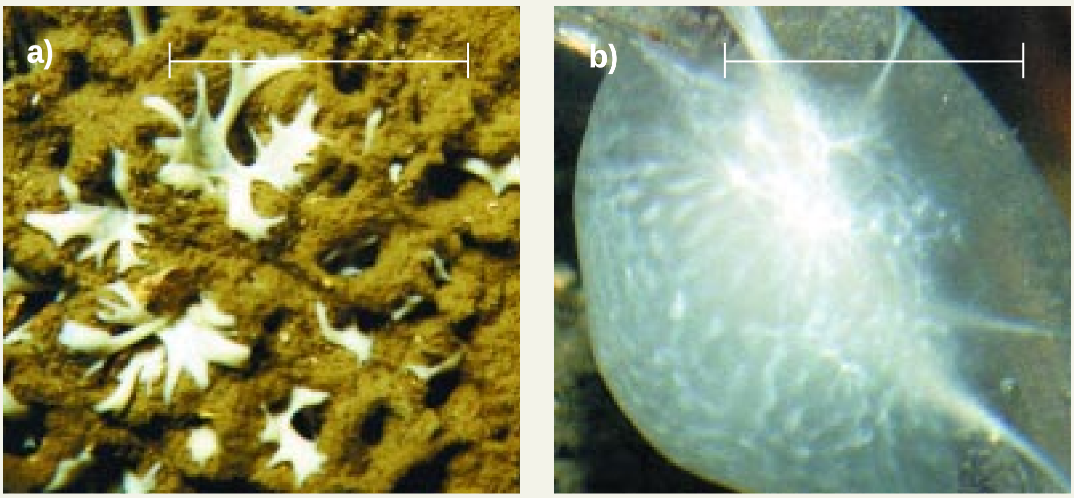


Fig. 44
The undescribed species of foraminiferan from the Firth of Lorn in **(a)** feeding form and **(b)** consolidated form. Scale bars are 15 mm in **(a)**, 10 mm in **(b)**.

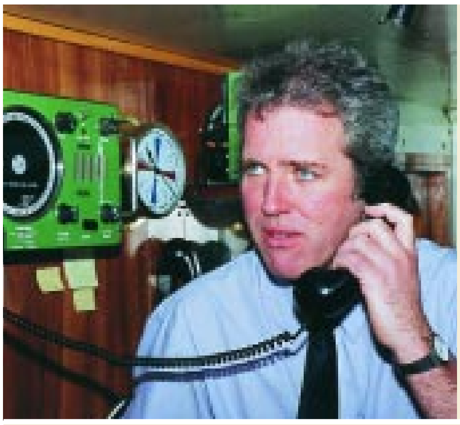
Photos © T Wilding

Environmental mitigation: Biofiltration in Aquaculture

Intensive mariculture produces significant accumulations of organic matter on the underlying seabed, which can have substantial effects on the composition of benthic and epibenthic marine organisms. In severe cases of organic enrichment, the health and growth rates of the target culture species can also be impacted with deleterious effects on the economic performance of the farm. A 3-year project, BIOFAQs, funded by the EU, began in December 2000 and aims to demonstrate the effectiveness of ‘biofilters’ (biological filters) in reducing the environmental impact of intensive mariculture. This pan-European project includes partners from the United Kingdom, Israel, Slovenia and Greece and is being co-ordinated by SAMS (see www.sams.ac.uk/biofaqs).

The project has 3 main objectives: to quantify the effectiveness of biofilters in reducing the impacts of mariculture across Europe from both an economic and environmental perspective; to determine the best design and placement of the biofilters, accounting for differences in geography, hydrography, and nutrient inputs between countries and finally, to examine the environmental and regulatory options governing the use of the biofilters at the end of their life-span.

EJ Cook, KD Black and MDJ Sayer (SAMS-DML)



Dr Kenny Black

Coastal Impacts Research Group

The ecological effects of sea lice medicines

This project aims to determine the ecological effects of sea lice treatments used in salmon culture. The main sponsors are MAFF VMD, DETR, SERAD, SNH and SQS and the science consortium involves Plymouth Marine Laboratory, FRS Aberdeen, SEAS Ltd, SAMS and various sub-contractors. SAMS is responsible for co-ordination of the field programme with the salmon farming and pharmaceutical industry, for modelling and hydrography, for statistical analysis and for experimental design. The project is initially funded for 3 years and has the following main objectives:

- to model the dispersion and/or deposition of farm wastes, including each of several sea lice treatment chemicals (bath treatments e.g. cypermethrin, and in-feed treatments e.g. emamectin) in the marine environment and to incorporate terms relating to the toxicity of these chemicals to certain parts of the ecosystem e.g. the macrofauna.

- to determine the effects of each of several sea lice treatment chemicals on zooplankton, phytoplankton, meiofauna, macrofauna, macroalgae and littoral assemblages (Fig. 45) in the environment post-treatment.

- to identify significant correlations between ecosystem responses, time and medicine concentration to determine the proportion of the observed environmental variance attributable to the treatments, against a background of responses due to other parameters such as waste organic materials, nutrients and natural variation.

Data on all these parameters have been collected for roughly 18 months at 3 sites representing a wide range of environmental conditions, all of which use the bath treatment cypermethrin as their major anti-sea lice medicine. The research consortium is currently undertaking an intensive study of in-feed treatment at a new site.

KD Black, C Cromey, T Nickell and P Provost (DML)

Fig. 45
Ecological Effects: Monitoring the succession of intertidal species on settlement panels near a fish farm.

Development of monitoring guidelines and modelling tools for environmental effects from Mediterranean aquaculture (MERAMED)

In northern Europe, Canada, Tasmania and Chile, considerable efforts have been made to assess interactions between aquaculture and the environment. Most models, guidelines, monitoring procedures and environmental quality standards are, however, directed toward salmon farming, while very little is known of fish farming impacts in the Mediterranean. In the last decade, aquaculture of sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus auratus*) has experienced exponential growth in the region. This process needs to be controlled in order to ensure a sustainable development of the aquaculture industry and to consider other aspects of an integrated management of the coastal zone, including tourism, fisheries, and environmental protection.

As part of an EU award, we are developing a model designed to predict the environmental impacts arising from fish cage farms in the non-tidal waters of the Mediterranean. Special emphasis will be given to the impacts of solid wastes (uneaten feed and faeces) from cage farms (Fig. 46) containing sea bass and sea bream and on the interactions between farmed and free-living fishes, focusing on farm effluent flux and biodiversity. The model will build on the experience gained in modelling impacts at salmonid cage farms in Scotland (DEPOMOD) where model simulations of environmental impacts are now a key component of fish farm monitoring. Current models configured for tidal waters include modules to estimate sedimentary deposition areas and rates and the response of benthic infauna under varying feed inputs and production levels. To simulate impacts in Mediterranean conditions, a similar modular approach will be taken to allow for the easy inclusion of terms which might be significant, such as consumption of waste food particles by wild fish around the cages.

KD Black, C Cromey and P Provost (DML)

Fig. 46
A marine cage farm in Greece where we will be making hydrographic and meteorological measurements to model dispersion of particulates.

Table 4 Concentration of fatty acids in surface sediments at stations from three sites in differing Scottish environments.

Station	*Depth (m)*	*Substrate*	*Lipids (µg per gram wet weight)*
Slope - N1000	1000	Sandy mud	1 - 14
Shelf - MD6	103	Sandy mud	23
Shelf - MD4	316	Shelly mud	38
Shelf - MD7	259	Very soft mud	61
Loch Etive - RE5	145	Very soft mud	32
Loch Etive - RE2	40	Very soft mud	42

Comparison of lipid contents from ocean to coast

Organic material on the sediment surface may originate from terrestrial or marine production and may have been altered through a range of biological processes such as recycling and degradation or by purely chemical pathways. The lipid composition of the surface organic matter can provide insight into both primary sources and some of the secondary processes that alter its composition. In addition, the amount of lipid remaining in surface sediment should be a function of the rate of production moderated by the length of the transport path. Once incorporated in sediments, lipids are readily available to deposit feeding animals which may transport such material while reworking the sediment. We have looked at lipids in sediment cores from three sites: N1000 at 1000 m off the Scottish shelf to the west of Barra; at three stations within and adjacent to a shelf depression west of the Island of Muck (MD 4, 6 & 7) and at two stations in Loch Etive; RE5 at the deepest part of the upper basin and RE2 near the head of the loch. Differences in lipid content between the three areas are striking, with very low concentrations off the shelf, high levels in the sea loch sediments and very high lipid concentrations in the most depositional station in the Muck depression (MD7 - see table 4). Fatty acids characteristic of terrestrial sources were, as expected, most abundant at the Loch Etive stations, with relatively little at the Muck depression and little or none at the shelf slope station.

Consideration of the down-core profile of individual fatty acids from the three Muck stations revealed a dramatic difference in the distribution of lipids with depth (Fig. 47). This suggests that the two stations within the depression (MD4 and MD7) had greater levels of bioturbation than at the station from the surrounding shelf (MD6).

KD Black (SAMS), **A Roberts** (University of Hertfordshire) **and M Penston** (Napier University)

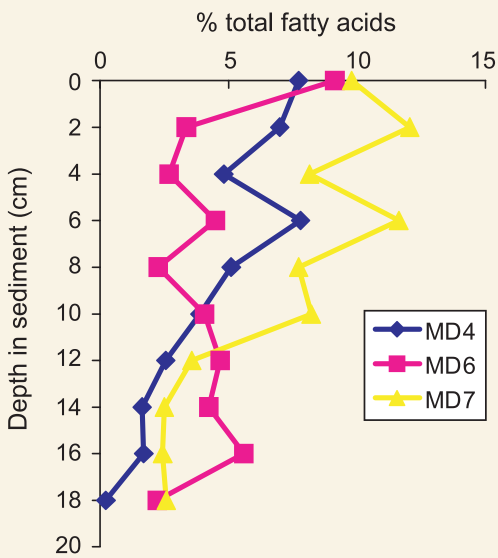


Fig. 47
Polyunsaturated fatty acids as a proportion of total fatty acids at sampling stations near Muck on the Scottish shelf.

Dr Christopher Bolch

Marine Algal Research Group

This new grouping (MARG) incorporates research projects in the area of marine algal biology and genetics, the staff and activities of the Culture Collection of Algae and Protozoay- Marine (CCAP-M), and the Molecular Genetics Facility which hosts molecular research projects and other SAMS research requiring access to molecular facilities and expertise. Our research aims to describe patterns of algal genetic diversity and biogeography, understand evolutionary processes in marine algae, and examine mechanisms and interactions which lead to algal toxicity and harmful algal blooms. Current projects are focused on:

- Molecular systematics, population genetics, biogeography and phylogeny of toxic algae.

- Molecular and physiological interactions between marine algae and bacteria.

Biogeography of toxic phytoplankton

There is concern that harmful algae may be spreading across the globe aided by human activities. To understand the sources and dispersal mechanisms, we must understand global distribution and patterns of genetic variation of these species and their related non-toxic counterparts. Our group is continuing studies of the global distribution and genetic variation of the paralytic shellfish poisoning dinoflagellates *Gymnodinium catenatum* (Fig. 48) and *Alexandrium minutum* (Fig. 49) using DNA sequencing and DNA fingerprinting. Both are suspected of having been transported around the globe in shipping ballast water. For *Alexandrium minutum*, the data indicate that Australian populations consist of an endemic Tasman Sea strain on the eastern coast, but that southern and western populations have been introduced from Europe. In comparison, *G. catenatum* shows much less differentiation between populations and geographical patterns have been difficult to determine. Recent work has, however, identified biochemical markers (toxins) and a genetic marker called a “snip” (SNP, single nucleotide polymorphism) in *G. catenatum*. Using both of these markers we are currently identifying the likely source of a number of suspected introductions.

CJS Bolch (SAMS), **DH Green** (New Zealand Science and Technology Fellow), **AP Negri** (Australian Institute of Marine Science), **M de Salas and GM Hallegraeff** (University of Tasmania, Australia), **SI Blackburn** (CSIRO, Australia) **and MJ Holmes** (National University of Singapore)

Fig. 48
The chain-forming toxic dinoflagellate *Gymnodinium catenatum*.
Scale bar = 10 µm.

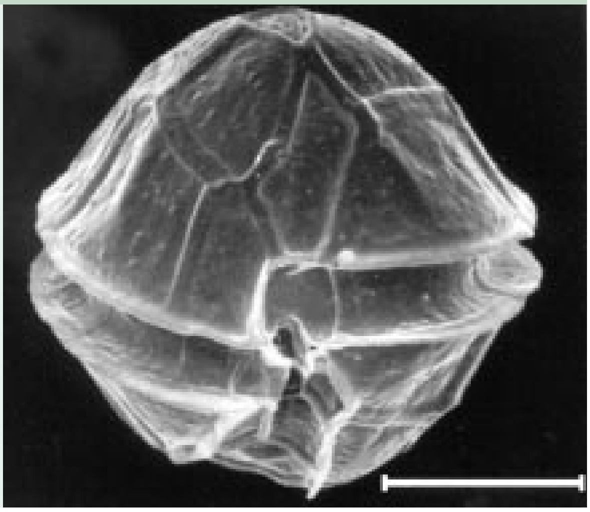


Fig. 49
Alexandrium minutum viewed with the scanning electron microscope.
Scale bar = 10 µm.

Life-cycle and bacterial induction of paralytic shellfish toxins in *Gymnodinium catenatum*

Work by SAMS scientists and collaborators indicates that neurotoxins produced by the dinoflagellate *Gymnodinium catenatum* are significantly influenced by both the sexual life-cycle and the bacteria which grow on or around the dinoflagellate cell. Current work aims to determine how this interaction affects toxin production and how specific molecular signalling and physiological interactions between the host algal cell and its bacterial flora may regulate algal cell toxicity. The long-term aim is to understand how the toxins are produced and to develop means of interfering with toxin production in order to alleviate the impact of toxic algal blooms.

DH Green (SAMS-hosted New Zealand Science and Technology Fellow), **CJS Bolch** (SAMS) **and AP Negri and L Llewellyn** (Australian Institute of Marine Science)

Culture Collection of Algae and Protozoa - Marine (CCAP-M)

The Culture Collection of Algae and Protozoa-Marine (CCAP-M) is the national living collection of marine algae and protozoa. The collection is supported by NERC through SAMS to continue its national functions as (1) a store of global algal and protozoan diversity and (2) a supplier of verified, traceable algal cultures to the UK/European science, industry and aquaculture communities. The collection of more than 550 algal strains includes more than 420 species across 116 genera and 16 algal classes; over 220 strains are bacteria-free. CCAP-M continues to be the dominant supplier of marine algal cultures in Europe. We have reinforced this leading position by continued growth in our customer base, sales and income during 2000-2001 (Fig. 50). We now supply cultures to over 30 countries on all continents. More than 800 individual cultures were supplied during the year 2000. Due to the difficulty of transporting live cultures in excess of 3-4 days, the bulk of sales are confined to 19 European countries. Our customer-base is in excess of 350 institutions with sales currently split 51% academic and 49% industrial/commercial.

During 2000, CCAP-M instituted substantial changes to our financial system and operations while maintaining a seamless transition for our customers. All marine orders, invoicing and payments are now processed through SAMS-DML. A sophisticated catalogue and culture order database, developed by CCAP-Windermere, has improved our ability to track and monitor our culture supply, invoicing and income, and respond to changes in our customer-base. A new CCAP catalogue was published by the UK National Culture Collection (UKNCC) organisation in March 2001, which lists all current strain data and provides taxonomic information and culture recipes. A regularly updated and searchable

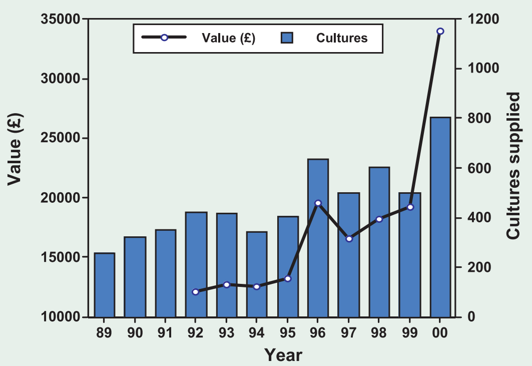


Fig. 50
Cultures supplied by CCAP-M and income generated for the 12 years 1989-2000.

catalogue is now available via the UKNCC website at www.ukncc.co.uk or at CCAP's own page at www.ife.ac.uk/ccap/. An order form to obtain a hard copy can be found on the SAMS web page.

CCAP-M is embarking on a five-year programme to build collection diversity and uniqueness and to increase the range of services and advice available to customers and researchers. To aid this move, the collections activities are being aligned more closely with strategic science at Dunstaffnage. The collection supports several SAMS-based research projects within MARG and other science groups at SAMS by providing culture facilities, algal cultures, and culturing advice and support.

CJS Bolch, CN Campbell, P Proudlock, C Smalley (SAMS) **and J Cocker** (placement student)

Toxic *Pseudo-nitzschia* species in Scottish Waters

In 1999 and 2000, domoic acid (DA), the toxin responsible for amnesic shellfish poisoning (ASP), was detected above internationally accepted limits in western Scottish waters, primarily in King Scallops (*Pecten maximus*). This caused the closure of the majority of Scottish scallop harvesting areas for periods exceeding six months. The algal blooms responsible contained several species of diatom known to produce DA. The dominant species, *Pseudo-nitzschia australis*, and two other species have been isolated into laboratory culture. *P. australis* has been confirmed to produce DA, *P. pungens* and *P. cf. delicatissima* do not produce detectable levels of DA. The blooms and their toxicity may depend on environmental conditions such as temperature, salinity, light and nutrients, all of which influence physiology and potentially the production of DA. This research aims to identify and isolate DA producing species of *Pseudo-nitzschia* in Scottish waters and examine the effect of environmental parameters on domoic acid production. A phytoplankton sampling programme has commenced in the Firth of Lorn (Fig. 51), with weekly sampling from spring to autumn and bi-weekly sampling at other times. This will allow us to track changes in toxic algal abundance and species composition compared to shellfish toxicity, while also obtaining fresh algae for a variety of laboratory studies.

J Fehling (UHI), **K Davidson** (SAMS/UHI) **and CJS Bolch** (SAMS)

Fig. 51
UHI Ph.D student Johanna Fehling collecting water samples in the Firth of Lorn.

Dr Ken Jones

Biogeochemistry

Processes of Vertical Exchange in Shelf Seas (PROVESS)

PROVESS is an interdisciplinary study of the role that vertical mixing plays in determining the structure and function of marine ecosystems and in the exchange of materials between the seabed and the overlying water column. Funded through the EU MAST 3 programme, it has brought together physical and biological oceanographers, pelagic biologists, biogeochemists and mathematical modellers from European countries. The project has applied new advances in turbulence theory to develop coupled physical-biological models for shelf seas and applied new measurement techniques to measure turbulence *in situ* and relate this to primary production and benthic nutrient and oxygen exchanges.

Following previous years' cruises in the northern and southern North Sea, effort at Dunstaffnage has focused on completion of sample analysis and data interpretation during the last year. Collaborative work between scientists from Proudman Oceanographic Laboratory and Dunstaffnage has shed new light on processes affecting mixing and nutrient supply to surface waters in stratified shelf seas. Data from *in situ* fluorometers and nitrate analysers, deployed in conjunction with bottom-mounted ADCPs and thermistor chains at a 100 m-deep station in the northern North Sea, have given a detailed picture of the autumnal erosion of a well-defined summer-stratification at that site. The data have demonstrated that in addition to the mixing contribution of wind and seabed friction, enhanced mixing across the stratification occurs when inertial shear is generated. Nitrate concentrations in the near surface layer were observed to increase dramatically coincident with the occurrence of maximum shear within the pycnocline (Fig. 52). Fluorescence measurements (Fig. 53) detect an initial increase in the chlorophyll content of the surface layers due to mixing of the chlorophyll peak located just above the pycnocline, but no phytoplankton growth response to surface nitrate enrichment was observed within the study period.

Work carried out in collaboration with the scientists from Université de la Mediterranée, Station Marine Endoume, Marseille and Napier University has investigated sediment-water coupling in the shallow Dutch coastal waters. Sediment and fluff-layer respiration, as measured by oxygen consumption, and other biogeochemical fluxes in the southern North Sea have been shown to be correlated with the spring-neap tidal cycle. Highest fluxes were observed during the neap cycle when presumably a higher proportion of sedimenting organic matter was enclosed in the overlying water, over the sediment surface and in the upper layer of the sediment. As a consequence, ammonium fluxes increased significantly, directed out of the sediment, whereas these fluxes were always lower and directed into the sediment outside this period. The nutrient profiles in the sediment layer are in good agreement with the flux results. Pigment and algae determination in the sediments showed a large predominance of diatom cells with highest chlorophyll A content during neap tides. Modelling studies and comparison of sediment and benthic oxygen uptake rates suggest that organic particulate supply to the benthos can only occur on neap tides and that most of the organic re-mineralisation takes place in the water column.

KJ Jones, SM Harvey and IA Ezzi (DML)

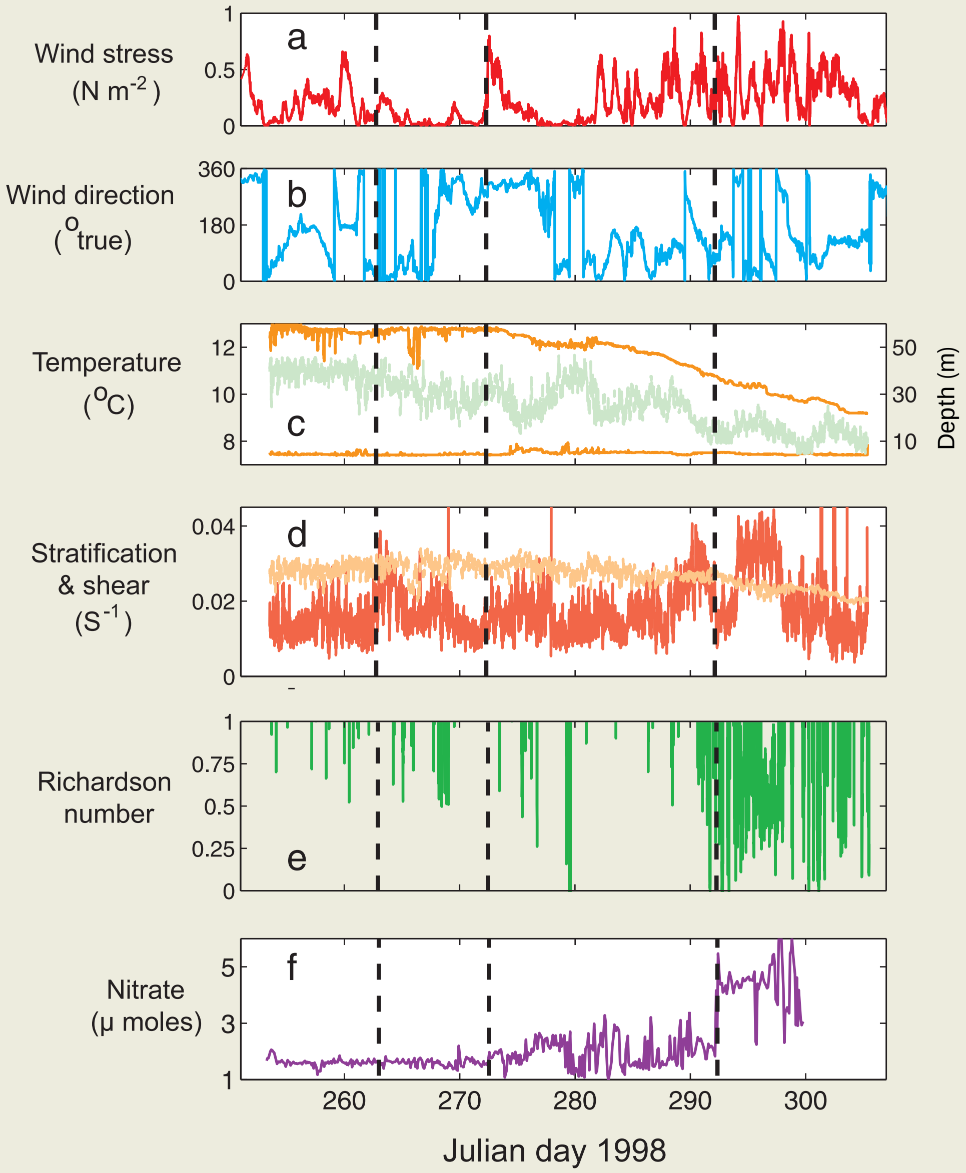


Fig.52
Measurements made at the PROVESS northern North Sea station in autumn, 1998 indicate that vertical density stratification is reduced primarily due to wind induced mixing. Moored instruments show that sudden enhanced exchange from nutrient-rich deep layers below the thermocline into the nutrient-depleted surface layers occurs indirectly when inertial shear across the stratification is largest.
a) wind stress; b) wind direction; c) temperature at 30 m (upper orange trace) and 107 m depth (lower orange trace) with pycnocline thickness (grey); d) stratification (Nmax) (orange) and shear |S|max (red); e) Richardson number at 56 m depth and f) nitrate concentration at 3 m depth.

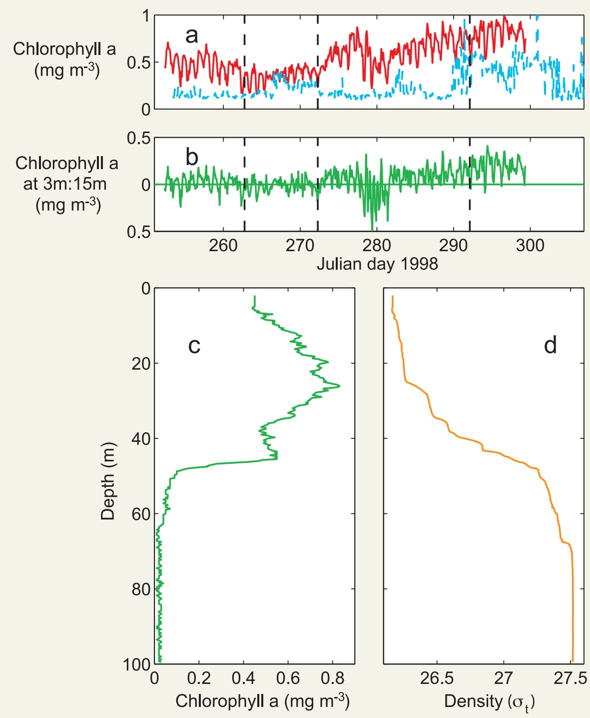


Fig. 53 Measurements at PROVESS northern North Sea station in autumn, 1998. **a)** Time series of phytoplankton biomass inferred from in situ chlorophyll A fluorescence at 3 (red line) and 40 m (blue line). **b)** Difference between chlorophyll A at 3 and 15 m depth. **c)** vertical profile of chlorophyll a from CTD on 12 September 1998. d) Vertical profile of density (σ_t).

Dr Julian Overnell

Autosub deployments in sea lochs

The NERC autonomous submersible vehicle *Autosub 2* was deployed in the upper basins of Loch Etive and Loch Fyne during the autumn of 1999 and the spring of 2000. Its task was to map the distributions of dissolved and particulate manganese and iron and of dissolved oxygen in the water column. The deep waters of the upper basins of these and several other sea lochs become isolated during periods of high freshwater input. The periods of isolation can last for a year or more, and lead to depletion of oxygen and a build up of nutrients and manganese in the water column. For these missions *Autosub 2* (Fig. 54) was equipped with a water sampler taking 400 ml samples every 4 minutes and a sensor to continuously measure the dissolved oxygen concentration. For the 2000 missions, sensors to continuously measure dissolved manganese and methane concentrations were added. The discrete water samples were filtered into dissolved and particulate fractions and these were analysed in the laboratory.

In Loch Etive, the deep water of the upper basin had been isolated for over 6 months, and the manganese concentrations are presented here. They are displayed as contours on a plot of distance along the line of deepest water of the loch against depth. It can be seen that the highest concentrations of both dissolved and particulate manganese were in the deep water as expected (Fig. 55), but what was unexpected was the measurement of significant concentrations of dissolved manganese, over 0.28 µM, in the upper part of the basin, not far from the head of the loch, in a water depth of only 20 m. These high values were near the bottom of the water column, in water which was possibly retained behind a small sill. At this position the corresponding particulate manganese was very low at less than 0.04 µM. Also unexpected was the difference in concentrations between the two deep basins at 20.5 and 22.5 km from the Firth of Lorn. This suggests that there is little exchange between the sub-basins.

J Overnell and T Brand (DML)

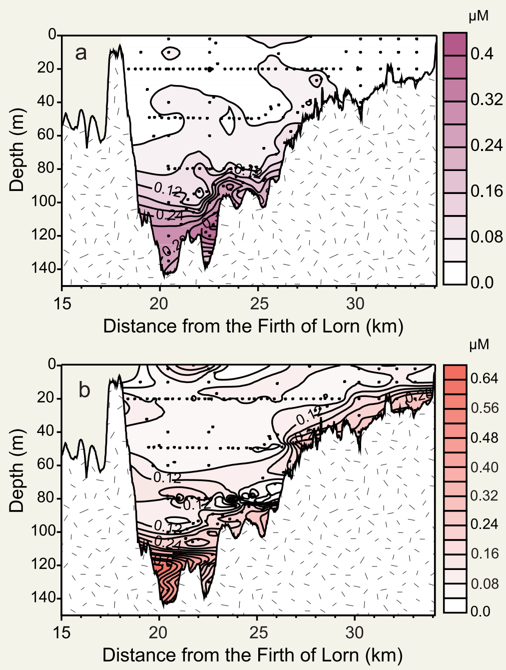
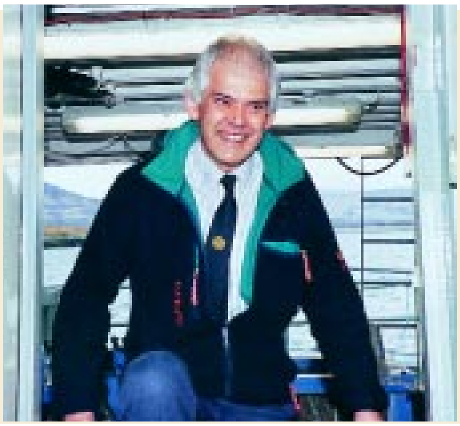


Fig. 54 (left)
The team for the 2001 missions (scientific and technical) with *Autosub 2* in Loch Fyne aboard the MV *Terschelling*.

Fig. 55 (right)
Water column particulate **(a)** and dissolved **(b)** manganese concentrations in the upper basin of Loch Etive, measured on collected water samples. The black dots represent the average position of *Autosub 2* during the 4 minute sampling period.



Mr David Meldrum

Fig. 56 The new UK Benthic Lander Centre at Dunstaffnage.

Marine Technology

The chief aim of the Marine Technology group is to develop the new instruments and techniques that are needed to keep SAMS at the cutting edge in marine science. Central to our approach is the adaptation of technologies originally developed, often at great expense, for the military and consumer markets. Outside customers such as the aquaculture industry and government departments participate in our developments through contracts and collaborative agreements. Current areas of expertise, some of which are described in more detail below, include sea bed landers, free drifting instrument packages, satellite communications, microprocessor and Global Positioning System (GPS) applications.

Benthic landers

This year saw a major boost to the laboratory with the commencement of the multi-million pound Autonomous Marine Environment Research Stations (AutoMERS) programme, supported by the Joint Infrastructure Fund (JIF). The programme, which includes SAMS in collaboration with the Universities of Aberdeen, St Andrews and Bristol, will see the creation of the first dedicated centre for lander development in the UK. The first phase at Dunstaffnage, now nearly complete, is a new building to provide storage, assembly and workshop space (Figs 56 & 57). Substantial investment in lander equipment has been backed up by the recruitment of a mechanical design engineer, Mr Willie Thomson, who has provided a significant addition to our skills base.

Over the course of the year we have continued to develop landers in support of the science programme. In particular a new lander has been built for studies of the cold water coral *Lophelia* being carried out by the Deep-Sea Benthic Dynamics group (Fig. 58). This multi-instrumented lander, which uses a frame based on the University of Aberdeen's ISIT lander, is to be deployed on the Sula ridge off Norway in the summer of 2001. It combines two different cameras with optical instruments and a current meter to allow correlation of biological events with the physical dataset.

As part of our ongoing work with the Geochemistry group on drill cuttings piles in the North Sea, we are adapting an *in-situ* chamber that was developed for the Deep-Sea Benthic Dynamics group through the EU ALIPOR programme. This deep-sea chamber, based on a laboratory design by Professor Gust from TUHH, Germany, was originally built to measure respiration rates under high bed-flow conditions. However in a project for Shell, in collaboration with the University of St Andrews, we are now modifying it in order to establish the critical erosion threshold of the cuttings piles.

Fig. 57 The large assembly area within the Lander Centre is equipped with an overhead crane.

Fig. 58 The coral lander about to undergo in-water tests near Dunstaffnage from the RV *Calanus*.

Fig. 57

Fig. 58

Fig. 59
RV *Polarstern* approaching the Ekström ice shelf in Antarctica. Photograph courtesy of AWI, Bremerhaven

Antarctic ice buoys

Sea ice cover has an important influence on climate, both because of its effect on global solar energy input, and because it restricts the fluxes of heat and moisture between ocean and atmosphere. However, the mechanisms of its formation and subsequent deformation are poorly understood. In 1999, GPS techniques successfully developed by the group during NERC's LOIS drifter programme were applied to the tracking of ice floes in the Odden region of the Greenland Sea as part of the ESOP programme. The order of magnitude improvement in accuracy in both space and time compared with conventional techniques allowed much better estimates of the velocity and divergence parameters needed to understand ice formation mechanisms. With our collaborators, the Scott Polar Research Institute (SPRI) of the University of Cambridge, the group was then awarded a NERC research grant to build 6 new GPS-equipped drifters for deployment in the Weddell Sea area of the Antarctic in April 2000, at the onset of austral winter. Thanks to assistance from the Alfred Wegener Institute (AWI), Mr Oli Peppe was able to complete construction of the buoys aboard the RV *Polarstern* (Fig. 59) during the journey south to the ice from South Africa. Mr Peppe went ashore at Neumayer Station on the Ekström Iceshelf to establish a differential GPS base station. Measurements from this 'fixed' station are then used to correct errors in GPS locations computed by the buoys. In fact Neumayer is not fixed, but is drifting slowly northwards with the ice, as shown by our measurements (Fig. 60). The buoys themselves, equipped with a variety of sensors to monitor sea ice formation and dynamics, were deployed in an array close to the advancing ice edge. Additional meteorological sensors, funded in part by the Meteorological Office, have allowed atmospheric pressure observations from this notoriously data-sparse area to be disseminated in near real time for use by the global forecasting community.

Our study is now yielding new quantitative information about sea ice formation and dynamics. The data will be used both to improve our understanding of sea ice physics, and to permit the building of more accurate climate prediction models. The study was also the first to conduct a detailed evaluation of the new Orbcomm two-way satellite communication system in polar latitudes. As with most such systems, optimal exploitation depends both on a detailed knowledge of the technical parameters and the results of practical trials. Through careful system design, we achieved a very high data throughput with Orbcomm, and have established the group's reputation as experts with this new technology.

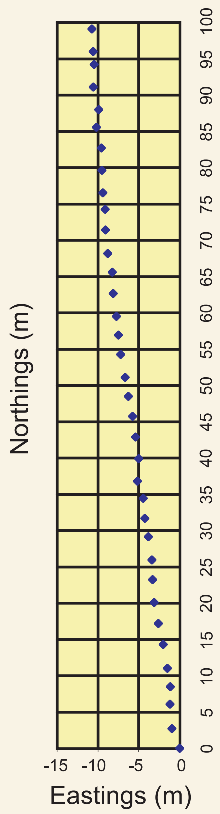


Fig. 60
Our GPS base station measurements showed the northward drift of Neumayer to be nearly 0.5 m per day. Each point is the average of one week's GPS locations.

Mini drifters

GPS-equipped drifters can also be put to good use in studying small-scale processes such as surface divergence in sea lochs and estuaries. The data are then used to refine and validate pollution dispersion models (see report by the Coastal Impacts Research Group). We have built a number of small GPS drifters, consisting of a cylindrical hull (containing rechargeable battery, GPS receiver and UHF radio link module), an antenna mast and a holey sock drogue (Fig. 61), and the design is now being marketed by a private company under a royalty agreement. The drifters have also been used recently in a Defence Evaluation and Research Agency (DERA) contract to investigate the effect of sea surface dynamics on air- and space-borne radar signatures.

The UK Deep Water Observing System (DWOS)

The group has recently been awarded a contract to undertake a scoping study for the DETR-sponsored Deep Water Observing System (DWOS). DWOS aims to implement operational monitoring of oceanic water quality throughout the water column as part of the UK's commitment to the Oslo-Paris Convention (OSPAR). The system will consist of a profiling instrument package in communication with a mother buoy, which will act as a relay station between the profiler and the control centre. Other consortium members include the Meteorological Office, CEFAS, DARDNI, FRS Aberdeen and the Proudman Oceanographic Laboratory.

DT Meldrum, DJL Mercer, OC Peppe, J Watson and E Breuer (DML) **and W Thomson,** (SAMS)

Fig. 61
A GPS mini-drifter tracks currents at 5 m depth by means of a holey sock drogue.

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.

Both vessels have continued to be used extensively. New legislation from the Marine Coastguard Agency (MCA) brought about an inspection of both vessels and recommendations to bring both up to the standard as recommended in the new Brown Code for Workboats up to 24 metres in length. This work has almost been completed.

Activity	RV *Calanus* (No of days)
Loch Etive (CTD's, moorings, coring etc)	65
Clyde (Plankton tows, moorings etc)	29
Scottish Universities	10
Replacement of Generator	16
Maintenance and lie up	87
Travel to and from the Clyde	13
	220

The original Lister generating set on RV *Calanus* was starting to show its age and was replaced by a new John Deere generating plant during the year providing a 45KVa single phase supply.

RV *Seòl Mara* spent a total of 97 days at sea on scientific projects throughout the year. Her programme of work was curtailed due to major engine failure in late August which required the installation of a new engine. This gave the opportunity not only to upgrade the power of the engine but also to achieve greater speed and fuel economy.

J Watson (DML)
Ships' Husband

Photo: T Wilding

Fig. 62
Diver coring allows the investigation of distinct seabed features.

Diving and small boats

The diving unit conducted 221 diving operations during the year, mainly in support of commissioned research programmes. This figure is consistent with previous years and will almost certainly rise as demand for diving increases at NERC's most active UK based diving unit. The diving and small boat section provides support for a number of science programmes ongoing at DML, including the sea lice project, artificial reefs, bioturbation (Fig. 62) and micro-zooplankton.

In addition to supporting science activities, the unit provides a small number of courses in recompression chamber operation, boat handling up to RYA powerboat level II and the SCUBA, nitrox user course.

The Head of Unit, Dr Martin Sayer, has been heavily involved in the NHS technical audit of recompression facilities in Scotland. It is hoped that the audits will provide the basis for a structured programme of development of hyperbaric units necessary to meet the increasing demands for high-quality recompression therapy in Scotland.

Dr Elizabeth Cook has developed the Scottish Diving Medical website. Some of the subjects covered by the website include information about recompression facilities, decompression illness (DCI) and other diving-related disorders, recognition of symptoms and emergency protocols.

The Hyperbaric Unit has undergone some modifications in the last year, notably the installation of a Heliox capability and a patient transfer system. It is expected that, with Heliox available as a therapeutic gas, patients with serious neurological decompression illness will have improved levels of recovery and in addition the number of relapses will be further reduced.

It is anticipated that the coming year will see the development of the National Facility for Scientific Diving established here at Dunstaffnage, under the overall management of Dr Martin Sayer.

R Wood, MDJ Sayer and S Thurston (DML)

Fig. 63
Controlled temperature recirculating tank system for deep-water coral studies.

Aquarium

The laboratory's aquarium facilities comprise the main aquarium and annexe, 7 air-conditioned and constant temperature rooms, and separate indoor and outdoor aquaria for the biotechnology building. All these facilities are supplied with a continuous flow of high quality seawater pumped from the Firth of Lorn.

In the past year the aquarium has seen continued development of the work on the cold water coral (*Lophelia pertusa*). This species needs water of a consistent salinity, but the salinity of seawater pumped into the building tends to fluctuate with local rainfall and snowmelt patterns. A recirculation system was developed, therefore, that allowed water collected from a depth of over 100 meters to be contained and recycled. The system collects the water after it has passed through the coral tanks (Fig. 63), then passes it through 2 settlement tanks, a particulate and activated charcoal filter, a protein skimmer and a UV water sterilisation unit before returning it to the coral tanks. Water changes are carried out at regular intervals. The corals were collected from the North Sea by a Remotely Operated Vehicle and transported to the laboratory. After the initial stress of the transfer, the corals settled in well in their new environment. We believe that this is the first time anyone in the UK has been able to keep these organisms alive in captivity for more than 3 months, with some of the corals now having been held for well over a year. This has given a unique opportunity to observe the coral in a controlled environment over a long period of time (see p. 11 for report).

In addition to the coral work, the aquarium facilities have been widely used over the past year and have accommodated work on fish physiology, animal environment interactions, invertebrate biology and mariculture, zooplankton dynamics and provided testing facilities for marine technology.

A Keay (DML)

Library

The Library at Dunstaffnage continues to be a vital resource for scientific staff, visiting workers, SAMS members and students. Some reorganisation of the ground floor area has been carried out in order to provide space for UHI Marine Science Degree course material. The Library communicates with many other scientific institutes world-wide, providing an exchange of publications and supplying photocopies of some rarer works held on site.

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 catalogue, journal, CD and publications database.

SAMS has again provided a generous grant for the purchase of books, augmented by gifts of books, conference proceedings and CDs from members of staff.

E Walton (DML)

Mr John Joyce

Obituary

John Joyce joined the staff of the newly opened Laboratory in July 1969. An electrical engineer by profession, a key element of his work involved the installation and maintenance of the electrical plant within the marine aquarium.

As the years passed, John became ever more fascinated by the endless variety of marine organisms under cultivation within the aquarium, and such was his thirst for knowledge, that under the guidance of his fish biologist colleagues, he quickly demonstrated an ability to rear and maintain a diverse range of marine animals. His dedication to this work was rewarded in the early 1980s when he was appointed Aquarium Manager. Always full of innovative ideas, John was ideally suited to this new post.

News of John's expertise in fish husbandry quickly spread and, in the mid-1980s, a major fish feed manufacturer commissioned the Laboratory to carry out a feed trial under his management. This was a new venture for the Laboratory, and so delighted was the company with John's meticulous attention to detail and organisational skills that a further series of trials was commissioned. This work continued under his management on an annual basis until shortly before his retirement due to ill health in 1998. It was due entirely to his hard work and endeavour that this ground-breaking series of commissions earned the Laboratory sufficient funds to allow the aquarium to undergo a major expansion in 1993.

Always the consummate craftsman, John insisted on the highest standards of aquarium practice and would not tolerate 'second best'. He received regular commendations from the Home Office Inspectorate on his management of the aquarium, and his attention to detail and devoted service to the Laboratory won him the highest praise from visiting research scientists at national and international level. Many scientists and students have cause to be grateful for his practical support and guidance throughout the duration of their studies.

John is survived by his sons Gavin and Jamie and he is sadly missed by his many friends and colleagues.

Fig. 64
Liz Cook explains the inner secrets of Spikey the sea urchin to a group of primary school children.

Other Laboratory Activities

Staff at SAMS and DML have continued to promote education and awareness of marine science issues by participating in a wide range of activities during the year.

Dr Liz Cook, accompanied by Spikey, a giant papier-maché sea urchin, gave the Frontiers of Science Lecture at the University of Newcastle-upon-Tyne, to an audience of over 400 school pupils, and repeat presentations at the Duchess Community High School near Newcastle and at Oban High School. Liz and Spikey also had fun engaging the pupils of 35 primary schools attending the Argyll and Bute Regional Environmental Education Forum in marine science activities. Liz represented SAMS in the Heritage Tent at the Oban Highland Games, showing the public a number of live sea creatures and answering varied questions.

The Laboratory opened its doors to schools (Fig. 64) for three days in June 2000 and to the public for an evening during National Science Week in March 2001. Staff volunteers excelled themselves at these events, laying on exciting interactive displays covering the Laboratory's research work. In March 2001, 80 Girl Guides attended three evening sessions at SAMS where they heard about the adventures and achievements of our female scientists.

Distinguished visitors during the year included the Scottish Fisheries Minister John Home Robertson MP, Alex Salmond, Member of the Scottish and Westminster Parliaments, Professor Neil MacCormack MEP, John Purvis MEP, local MP Ray Michie and George Lyon, Member of the Scottish Parliament. Groups of students from the Universities of Manchester, Plymouth, Napier, the International Symbiose Forum, Sandsli College (Bergen, Norway) and biology teachers from Gothenburg, Sweden, also came to hear about our work.

A new SAMS website was designed by Liz Cook: **www.sams.ac.uk**. The website contains information on the research programme and facilities available at the Dunstaffnage Marine Laboratory, as well as the UHI BSc in Marine Science. Links to several other websites can be found there.

The Scottish Marine Group had a successful year, holding 3 meetings at Heriot-Watt University (May), University of Stirling (October) and the University of Glasgow (March 2001). At the May meeting, the SAMS £100 prize for the best postgraduate presentation was won by Marin Greenwood of the University of Stirling. Mar Otero Villanueva of SAMS/UHI won a prize spontaneously presented by SEPA East for the best visual presentation. The October meeting consisted of invited presentations on topical issues by some of Scotland's leading marine scientists. In March, the SAMS prize was won by James Massey of Glasgow Marine Technology Centre, University of Glasgow. Dr Hamish Mair of Heriot-Watt University organised these increasingly popular and successful events.

SAMS hosted the International Science of Decommissioning Conference, the European Union ACES (Atlantic Coral Ecosystem Study) workshops, and the New Directions in Marine Science Conference organised by Rebecca Dean and Mar Otero Villanueva, two of the SAMS/UHI postgraduate students.

In November, the Newth Lecture was given by Professor Graham B Shimmield at the University of Aberdeen on *A Marine Science Plan for Europe: scientific issues to be addressed*.

The *SAMS Newsletter* continues to promote marine science in Scotland. Following Helen Anderson's retirement, the new editor is Dr Anuschka Miller.

Helen Anderson and Liz Cook (SAMS)

Secretary's Report

Secretary's Report for the year ending 31 March 2001

The 86th Annual General Meeting of the Association was held on 6 November 2000 at the University of Aberdeen by kind permission of the Principal, Professor Duncan Rice. Dr Ian Graham-Bryce, SAMS President, chaired the AGM. Professor Sir Frederick Holliday, Sir Cyril Lucas, 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. Mrs J Twelves, Dr R Ormond, Professor MJ Cowling, Dr A Goodlad and Mr R Sankey were elected to Council for a period of three years. Professor CD Todd was re-elected for a further three years. Dr P Newton and Mr A Munro were nominated as observers on Council for the NERC and HIE respectively. Messrs Scott-Moncrieff was appointed auditors to the Association. The AGM was immediately followed by the Eleventh Newth Memorial Lecture which was to be given by Geoffrey O'Sullivan, Marine Institute, Ireland. Due to inclement weather his travel plans were cancelled and the SAMS Director, Professor GB Shimmield, stood in at short notice to deliver a lecture entitled 'A Marine Science Plan for Europe: the scientific issues to be addressed'.

The Board of SAMS met at Aberdeen University on 6 November 2000 to discuss SAMS strategy, the new building developments and the relationship with NERC. Four meetings of Council were held in the course of the year.

Council was served by the Finance and General Purposes Committee, the Research and Strategy Committee and the Activities Committee, with Professors P Boyle, G Boulton and C Todd as Chairs, respectively.

At the time of auditing the 2000-01 SAMS account, no formal completion of the NERC-SAMS Agreement has been achieved. An audit conducted by the Research Councils' Independent Audit service (RCIAS) which reported on the 5th September, 2001 has identified a range of issues arising from the transfer of management and liability to SAMS from NERC. In line with its legal responsibilities, the SAMS Council is continuing to take appropriate advice and it will continue to mitigate all future risk to the Association, wherever possible.

G B Shimmield, Secretary, SAMS

Membership of the Association

Membership of SAMS at 31 August 2001 was 484, comprising 376 ordinary, 75 student, 32 corporate and one Honorary Member, Mr David Ellett.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

Scottish Charity Number : SC 009206

REPORT AND ACCOUNTS

Year ended 31 March 2001

CONTENTS

COUNCIL REPORT

Directors (styled Members of Council)

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

Dr Ian Graham-Bryce
Professor GS Boulton
Professor PR Boyle
Professor MJ Cowling
Mrs MM Crawford
Dr AC Goodlad
Professor R Ormond
Mr R Sankey
Professor CD Todd
Mrs J Twelves

Association Director
Professor GB Shimmield

Secretary and registered office
Professor GB Shimmield,
Dunstaffnage Marine Laboratory
PO Box 3, Oban, Argyll, PA34 4AD

The Council submits its report and accounts for the year ended 31 March 2001.

1. Responsibilities of the Members of Council

Company law requires the Members of Council to prepare accounts that give a true and fair view of the state of affairs of the Association and of the surplus or deficit for its financial year. In doing so the Members of Council are required to:

- select suitable accounting policies and apply them consistently
- make judgements and estimates that are reasonable and prudent
- prepare the accounts on the going concern basis unless it is inappropriate to presume that the Association will continue in business.

The Members of Council are responsible for maintaining proper accounting records that disclose with reasonable accuracy at any time the financial position of the Association and to enable them to ensure that the accounts comply with the Companies Act 1985. They are also responsible for safeguarding the assets of the Association and hence for taking reasonable steps for the prevention and detection of fraud and other Association irregularities.

2. Principal activity

The principal object of the Association is to promote the study of Marine Science through research and education.

3. Results

The Association's results for the year were as follows:

	£
Surplus for year	9,784
Surplus brought forward	148,648
Surplus carried forward	158,432

4. Members of Council

Sir David C Smith retired as President on 1 August 2000. Dr Ian Graham-Bryce, elected at the 1999 AGM, took over as President on 2 August 2000. Professor M Cowling, Mr R Sankey, Dr R Ormond and Mrs J Twelves were elected to Council at the November 2000 Annual General Meeting. All other members served throughout the year.

5. Auditors

A resolution to re-appoint Scott-Moncrieff Chartered Accountants as auditors will be put to the members at the Annual General Meeting.

By order of the Members of the Council

PROFESSOR GB SHIMMIELD
Secretary
18 September 2001

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

AUDITORS' REPORT

To the members of the Scottish Association for Marine Science (a company limited by Guarantee).

We have audited the accounts on pages 61 to 67.

Respective responsibilities of Members of Council and auditors:

As described in the Council report the Members of Council are responsible for the preparation of accounts. It is our responsibility as auditors to form an independent opinion, based on our audit, on those accounts and to report our opinion to you.

Basis of opinion

We conducted our audit in accordance with 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 accounts. It also includes an assessment of the significant estimates and judgements made by the Members of Council in the preparation of the accounts, and of whether the accounting polices are appropriate to the Association's circumstances, consistently applied and adequately disclosed.

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

Opinion

In our opinion the accounts give a true and fair view of the state of the Association's affairs as at 31 March 2001 and of its surplus for 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 G2 6NL

18 September 2001

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

INCOME AND EXPENDITURE ACCOUNT

Year ended 31 March 2001

	Note	2001 £	2000 £
INCOME			
Natural Environment Research Council			
Grant-in-Aid		294,000	263,000
Other grants and income for research projects	4	1,060,502	864,011
UHI external income		165,547	106,422
UHI bequest from Yonge Fellowship		-	37,000
Membership subscriptions and donations		9,102	7,379
Other income		11,709	41,685
Specific funds:			
Income received	11	360	4,585
Transfer to specific reserves		(360)	(4,585)
		1,540,860	1,319,497
EXPENDITURE			
Research projects	5	1,115,246	990,474
UHI		257,971	145,292
Administration salaries	6	50,964	44,782
Travel, subsistence and interview expenses		9,258	11,133
Council expenses		6,709	2,727
Postages, telephone and stationery		3,182	6,465
Printing and library		14,975	13,910
Audit fee		4,000	3,675
Other professional fees		3,496	11,570
Bursaries and small grants		3,680	2,650
Insurance		8,465	7,289
Administration, services & equipment		-	4,755
Marketing, publicity and newsletters		6,326	15,117
Meetings		533	1,909
Sundries and subscriptions		1,395	1,082
Gain on disposal of assets		(19,000)	-
Depreciation of fittings and equipment		61,058	45,848
Exchange differences		5,935	3,110
		1,534,193	1,311,788
Surplus before interest		6,667	7,709
Interest receivable		3,117	244
Surplus for the year	10	9,784	7,953

All disclosures relate only to continuing operations.

There are no gains or losses other than the surplus for the year.

The notes on pages 63 to 67 form part of these accounts.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

BALANCE SHEET
31 March 2001

	Note	2001 £	2000 £
FIXED ASSETS			
Tangible assets	7	145,702	194,365
Investments	8	40,345	40,963
		186,047	235,328
CURRENT ASSETS			
Cash at bank and in hand		164,638	75,259
ERDF account		78	506
Yonge deposit account		2,117	2,063
Debtors	9	324,224	266,694
		491,057	344,522
CURRENT LIABILITIES			
Tax and social security		4,582	5,590
Amount due to Dunstaffnage Marine Laboratory		20,795	140,973
Deferred income		253,086	161,621
Sundry creditors & accruals		196,771	58,516
VAT liability		-	20,500
		475,234	387,200
NET CURRENT ASSETS/(LIABILITIES)		15,823	(42,678)
TOTAL ASSETS LESS CURRENT LIABILITIES		201,870	192,650
CAPITAL AND RESERVES			
Reserves	10	158,432	148,648
Specific funds:			
Sheina Marshall Bequest	11	40,345	40,963
Yonge Fellowship	11	3,093	3,039
		201,870	192,650

Approved on behalf of the Council on 18 September 2001

P R BOYLE

Members of Council

M CRAWFORD

The notes on pages 63 to 67 form part of these accounts.

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

NOTES ON THE ACCOUNTS

Year ended 31 March 2001

1. Status

The Association is a company limited by guarantee. The liability of the Members who constitute the Association is limited to £1 per member. The affairs of the Association 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.

2. Accounting policies

(a) Accounting convention

The accounts have been prepared under the historical cost convention and in accordance with applicable UK Accounting Standards.

(b) Fixed assets

Assets provided by or purchased from specific grants from the Natural Environment Research Council and other bodies are included in cost of fixed assets. The amount of capital grants used for the purchase of these assets is deducted from the value of the assets.

(c) Depreciation

Capital grants received to purchase vessels are equal to the cost of the vessels and therefore no depreciation on vessels is required.

The book value of the property after deduction of capital grants is considered to be equivalent to its residual value and therefore no provision for depreciation has been made.

Depreciation on fittings and equipment has been provided so as to write off the cost in equal annual instalments over their estimated useful lives of 5-8 years.

(d)Pensions

The institution 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 institution benefits from the employees' services.

3. Activities of the Association

Most of the activities of the Association are operated in conjunction with the Natural Environment Research Council (NERC). The fixed assets of the Association have been leased to the NERC since 1989. NERC has been in negotiation with the Association since March 2000 to end the lease at the next break point (2004) and to put the relationship between the two organisations on a different footing. The Association has been active in these negotiations that are more fully explained in the Secretary's report on page 58 of the Annual Report. At the time of auditing the 2000-2001 SAMS account, no formal completion of the agreement between the Association and the NERC has been achieved. In line with its legal responsibilities the Association is continuing to take appropriate advice and it will continue to mitigate all future risk to the Association wherever possible.

4. Other grants and income for research projects

	2001 £	2000 £
Deep-Sea Benthos	99,472	137,871
Invertebrate Surface Biology	457,030	270,860
Benthopelagic Fish	98,018	180,299
Coastal Impact	97,053	63,323
Zooplankton	62,793	47,060
Physiological Ecology of Plankton	131,761	43,644
SOAEFD	29,202	56,221
Geochemistry	84,993	64,733
	1,060,502	864,011

NOTES ON THE ACCOUNTS (cont.)

Year ended 31 March 2001

5. Expenditure on research projects	**2001**	**2000**
	£	**£**
Deep-Sea Benthos	151,726	170,026
Invertebrate Surface Biology	403,491	319,670
Benthopelagic Fish	169,781	206,257
Coastal Impact	100,478	56,329
Zooplankton	44,755	46,210
Physiological Ecology of Plankton	124,853	78,109
SOAFD	23,790	48,898
Geochemistry	96,372	64,975
	1,115,246	990,474

The work of Geochemistry includes staff and other costs incurred to complete the Centre for Coastal and Marine Sciences (CCMS) REES programme started in 1999/2000. CCMS had to cut the funding, but the work was continued by the Association as it was such an intrinsic part of the laboratory's programme. The figures for the year reflect the impact of the lack of CCMS funds.

6. Members of Council and other employees

The Association had 36 employees (2000: 34).

Staff costs comprise

Wages and salaries	685,946	651,680
Social security costs	52,724	50,379
Other pension costs	82,801	75,143
	821,471	777,202

The Members of Council received no remuneration during the year (2000: nil)

NOTES ON THE ACCOUNTS (cont.)

7. Tangible fixed assets	Property	Vessels	Fittings & Equipment	Total
	£	£	£	£
Cost	568,075	416,678	1,969,185	2,953,938
Additions	-	-	78,517	557,491
Disposals	-	-	(19,000)	(19,000)
	568,075	416,678	2,028,702	3,492,429
Capital grants	(538,528)	(416,678)	(1,742,410)	(3,164,195)
At 31 March 2001	29,547	-	298,687	328,234
Aggregate depreciation				
At 1 April 2000	-	-	140,474	140,474
Charge for year	-	-	61,058	63,537
On disposals	-	-	(19,000)	(19,000)
At 31 March 2001	-	-	182,532	185,011
Net book amount				
At 31 March 2001	29,547	-	103,760	143,223
At 31 March 2000	29,547	-	164,818	194,365

Costs totalling £26,817 have been incurred in the year in preparation for the new building project. These are mainly professional fees and the planning permission fee. In line with usual practice these items have been capitalised as part of the overall building project. If the project does not go ahead these costs would have to be written off to the income and expenditure account next year.

8.Investments	2001	2000
	£	£
Sheina Marshall Bequest		
Flat at cost	25,673	25,673
Bank balances	13,136	13,125
Debtor	1,536	2,165
	40,345	40,963

9. Debtors		
Grants due	190,325	170,763
Other debtors	133,899	95,931
	324,224	266,694

NOTES ON THE ACCOUNTS (cont.)

10. Reserves	**Vessel replacement reserve £**	**General Reserve £**	**Total £**
At 1 April 2000	15,000	133,648	148,648
Transfer for year	-	9,784	9,784
At 31 March 2001	15,000	143,432	158,432

11. Specific funds	**Sheina Marshall Bequest £**	**Younge Fellowship £**	**Total £**
At 1 April 2000	40,963	3,039	44,002
Bank interest received	41	54	95
Rental income	265	-	265
Property expenses	(924)	-	(924)
Total net (expenditure) income	(618)	54	(564)
At 31 March 2001	40,345	3,093	43,438

The Sheina Marshall Bequest is an amount left by the late Dr Sheina Marshall OBE, DSC to the Association. The sum bequested was used by the Association 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. No awards were made during the year.

NOTES ON THE ACCOUNTS (cont.)

12. Pension Commitments

The institution 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 institution 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 institution 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 institution's future contribution commitment. The next formal actuarial valuation is due as at 31 March 2002 when the above rates will be reviewed.

The total pension cost for the institution was £82,801 (2000: £75,143). The contribution rate payable by the institution was 14% of pensionable salaries.

STAFF AT 31 MARCH 2001

Director DML, Director and Secretary SAMS Unified Grade 5
Professor GB Shimmield

SAMS Staff

Unified Grade 6
Professor JD Gage

Unified Grade 7
Dr JDM Gordon

Higher Scientific Officers
Mr R Harvey (Part time)
Dr DJ Hughes
Dr JM Roberts

Scientific Officers
Mr P Lamont (Part time)
Miss A Mitra
Miss T Sawyer
Ms SC Swan
Miss D Woodroffe

Assistant Scientific Officers
Miss P McGarr

Technical/Engineering
Mr W Thomson

SAMS Research Fellows
Dr R Leakey

SAMS Research Associates
Dr F Cottier
Dr S Emsley
Dr E Fouilland
Dr M Hart
Dr MS Kelly
Dr C Moss
Dr T Shimmield
Dr KJ Willis

NERC Research Fellows
Dr A Hatton
Dr G Tarling

Activities Manager
Mrs HE Anderson (Part time)

EU Project Co-ordinator
Miss L Parkinson

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

DML Staff

Unified Grade 7
Dr RS Batty
Dr KD Black
Dr MT Burrows
Dr KJ Jones
Mr DT Meldrum
Dr J Overnell
Dr MDJ Sayer

Senior Scientific Officers
Dr C Bolch
Mr C Griffiths
Mr SM Harvey
Mr J Watson

Higher Scientific Officers
Dr NA Auchterlonie
Dr KS Black
Mr TD Brand
Mr E Breuer
Mr C Cromey
Mr IA Ezzi
Mr R Harvey (Part time)
Dr DJ Mercer
Dr LA Nickell
Dr TD Nickell
Mr OC Peppe
Dr P Provost
Mrs LA Robb
Mr TA Wilding
Dr M Williams

Scientific Officers
Mrs CN Campbell (Part time)
Ms JM Foster
Miss S Magill

Assistant Scientific Officers
Miss P Proudlock
Mr I Stewart

Institute Secretary
Mrs EB Walton

Personnel
Ms CM Bonomy
Mrs L Thomson (seconded to POL 13/01/00 - 30/06/00)

Science Programme Support Officer
Mrs A Black

Librarian
Miss EJ Walton

Accounts
Miss F Burnip
Miss E Dudman
Mrs L Lamb

Director's Secretariat
Miss J McLoughlin
Mrs L Birrell (Part time)

General Office
Mrs J MacAskill

Computing Support
Mr GC Ryan
Mrs K Smalley

Aquarium Manager
Mr A Keay

Electrical Maintenance
Mr BH Clark

Building Maintenance
Mr AC Black
Mr DN MacKinnon

Storeman
Mr G Webster

Diving and Small Boats
Dr S Thurston
Mr R Wood

Ships: RV *Calanus* and RV *Seòl Mara*
Mr SF Douglas (Motorman)
Mr F Lovie (Cook/General Assistant)
Mr J MacFarlane (Engineer)
Mr D McAlpine (Bosun)
Mr GB McMillan (Master)
Mr GJR Murphy (Mate)

UHI Staff

Lecturers
Dr K Davidson
Dr J Howe
Dr M Inall
Dr AE J Miller

Data Warehouse Manager
Mr C Rydings

Computing support
Mr S Phillips

Sandwich students carrying out their industrial placements at the Laboratory
R Saunders, University of Bradford
J Youldon, University of Bradford
J Cocker, University of Bradford
S Dixon, University of Bradford
A Roberts, University of Hartford

APPENDIX 2 - PUBLICATIONS

Refereed Publications and Peer-reviewed articles in ISI Database

ANSELL, A D, 2000. Drilling and non-drilling predation in gastropod aggregations in the intertidal zone of a New Zealand harbour. *Journal of Molluscan Studies* **66**, 419-422.

ANSELL, A D and PECK, L S, 2000. Burrowing in the Antarctic anemone, *Halcampoides* sp., from Signy Island, Antarctica. *Journal of Experimental Marine Biology and Ecology* **252**, 45-55.

ARMSTRONG, E, ROGERSON, A and **LEFTLEY, J W**, 2000. The first record of *Nitzschia alba* from UK coastal waters with notes on its growth potential. *Journal of the Marine Biological Association of the UK* **80**, 355-356.

ARMSTRONG, E, ROGERSON, A and **LEFTLEY, J W**, 2000. The abundance of heterotrophic protists associated with intertidal seaweeds. *Estuarine, Coastal and Shelf Science* **50**, 415-424.

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BERTRAND P, PEDERSEN T F, MARTINEZ P, CALVERT S and **SHIMMIELD G**, 2000. Sea level impact on nutrient cycling in coastal upwelling areas during deglaciation: Evidence from nitrogen isotopes. *Global Biogeochemical Cycles* **14**, 341-355.

BLAXTER, J H S, 2000. The enhancement of marine fish stocks. *Advances in Marine Biology* **38**, 1-54.

BURROWS, M T, SANTINI, G and CHELAZZI, G, 2000. A state-dependent model of activity patterns in homing limpets: balancing energy returns and mortality risks under constraints on digestion. *Journal of Animal Ecology* **69**, 290-300.

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CRAIK, J C A, 2000. A simple and rapid method of estimating gull productivity. *Bird Study* **47**, 113-116.

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DOMENICI, P, **BATTY, R S**, SIMILA, T and OGAM, E, 2000. Killer whales (*Orcinus orca*) feeding on schooling herring (*Clupea harengus*) using underwater tail slaps: kinematic analyses of field observations. *Journal of Experimental Biology* **203**, 283-294.

DOMENICI, P, STEFFENSEN, J F and **BATTY, R S**, 2000. The effect of progressive hypoxia on swimming activity and schooling in Atlantic herring. *Journal of Fish Biology* **57**, 1526-1538.

GAGE, J D, **LAMONT, P A**, **KROEGER, K,** PATERSON, G L J, **HARVEY, R** and **VECINO, J L G**, 2000. Patterns in deep-sea macrobenthos at the continental margin: standing crop, diversity and faunal change on the continental slope off Scotland. *Hydrobiologia* **440**, 261-271.

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MARTINEZ, P, BERTRAND, P, CALVERT, S E, **SHIMMIELD, G B**, LALLIER-VERGES E and FONTUGNE, M R, 2000. Spatial variations in nutrient utilization, production and diagenesis in the sediments of a coastal upwelling regime (NW Africa): Implications for the paleoceanographic record. *Journal of Marine Research* **58**, 809-835.

McKENZIE, J D, BLACK, K D, KELLY, M S, NEWTON, L S, HANDLEY, L L, SCRIMGEOUR, C M, RAVEN, J A and HENDERSON, R J, 2000. Comparisons of fatty acid and stable isotope ratios in symbiotic and non-symbiotic brittlestars from Oban Bay, Scotland. *Journal of the Marine Biological Association of the UK* **80**, 311-320.

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SUMIDA, P Y G, **TYLER, P A**, LAMPITT, R S and **GAGE, J D**, 2000. Reproduction, dispersal and settlement of the bathyal ophiuroid *Ophiocten gracilis* in the NE Atlantic Ocean. *Marine Biology* **137**, 623-630.

TARLING, G, BURROWS, M, MATTHEWS, J, SABOROWSKI, R, BUCHHOLZ, F, BEDO, A and MAYZAUD, P, 2000. An optimisation model of the diel vertical migration of northern krill (*Meganyctiphanes norvegica*) in the Clyde Sea and the Kattegat. *Canadian Journal of Fisheries & Aquatic Sciences* **57**, Suppl. 3, 38-50.

TRUESDALE, V W and **JONES, K**, 2000. Steady-state mixing of iodine in shelf seas off the British Isles. *Continental Shelf Research* **20**, 1889-1905.

TUDHOPE, A W, BUDDEMEIER, R W, CHILCOTT, C P, BERRYMAN, K R, FAUTIN, D G, JEBB, M, LIPPS, J H, PEARCE, R G, SCOFFIN, T P and **SHIMMIELD, G B**, 2000. Alternating seismic uplift and subsidence in the late Holocene at Madang, Papua New Guinea: evidence from raised reefs. *Journal of Geophysical Research SOL EA* **105** (B6), 13797-13807.

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Non-refereed Publications (non-refereed conference proceedings, articles and letters, NERC Cruise Reports, technical reports, abstracts etc.)

BETT, B and **ROBERTS, M**, 2000. Controversial Coral. *NERC News*, Summer 2000, p. 25.

CAMPBELL, D A, KELLY, M S, BOLCH, C, BUSMAN, M, MOELLER, P and SHUMWAY, S, 2000. ASP in the King Scallop, *Pecten maximus*, from the west coast of Scotland. July, 2000. Report for HIE, PESCA and Highland Council, 26 pp.

CROMEY, C J, NICKELL, T D and **BLACK, K D**, 2000. DEPOMOD: A model for predicting the effects of solids deposition from mariculture to the benthos. Oban: Scottish Association for Marine Science, 120 pp.

CROMEY, C J, BLACK, K D and **MELDRUM, D T**, 2000. Measurements and modelling of turbulent diffusion in Calbha Bay for Loch Duart Ltd., 23 pp.

CROMEY, C J, 2000. DEPOMOD modelling study of the Loch Earn freshwater fish farm. A study for Heriot Watt University, Edinburgh, UK, 22 pp.

GORDO, L S, CARVALHO, D S, FIGUEIREDO, I, MACHADO, P B, NEWTON, A and **GORDON, J**, 2000. Escala de maturação sexual do peixe-espada preto. Uma abordagem macro e microscópica. (The sexual maturity scale of black scabbardfish. A macro and microscopic approach). Celta Editora, 36 pp.

GORDON, J, 2000. Rockall fishery under threat from over fishing. Letter to *Fishing News*, 1 September 2000, p. 4.

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GORDON, J D M, 2000. Rockall Plateau now in international waters - the fleets move in. *Scottish Association for Marine Science Newsletter* **22**, p. 22.

GORDON, J D M and **CROZIER, P**, 2000. Fishing moves to deeper waters. *Scottish Association for Marine Science Newsletter* **22**, p. 23.

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HATTON A D, 2000. Cool Antarctic Summer. *Ocean Zone* **2**, 4-5.

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HATTON, A D and MALIN, G, 2000. Incubation experiments to investigate the biogeochemical sulphur cycle. Escape EEC MAST Contract No MAS3-CT96-0050 final report, 4 pp.

KELLY, M S, 2000. Commercially viable sea urchin cultivation. FAIR project CT98 9210 final report. SAMS, commercial in confidence, 178 pp.

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MILLER, A E J, 2000. Scotland's first BSc in Marine Science. *OCEAN Challenge*, **10**, p. 9.

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PROVOST, P G, 2000. Current speed measurements at a fish cage site, Site A 1, Lismore, Firth of Lorn. Data report for Hydro Seafood GSP Ltd, 22 pp.

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PROVOST, P G, 2000. Current speed measurements at a fish cage site, Hole Bay, Loch Sheilavaig. Data report for Marine Harvest McConnell, 13 pp.

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ROBERTS, J M, 2000. Coral colonies make a home on north sea oil rigs. *Reef Encounter* **27**, 17-18.

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ROBERTS, J M, 2000. The occurrence of *Lophelia pertusa* around the Beryl Alpha platform in the northern North Sea. Report (with CD ROM) for Mobil North Sea Ltd., January 2000. *DML/SAMS Internal Report* **218**, 18 pp. + 9 figs + appendices.

ROBERTS, J M, 2000. Review of a video tape compilation showing coral colonies from around the Brent Alpha platform in the northern North Sea. Report for the UK Offshore Operators' Association. January 2000. *DML/SAMS Internal Report* **219**, 10 pp. + 9 figs.

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SAYER, M D J and **MAGILL, S H** (2000). The factors affecting the distribution and abundance of juvenile gadoids in the rocky subtidal. Final report to the MAFF Chief Scientists Group, 24 pp.

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WILDING, T A and **SAYER, M D J**, 2000. Project Reef 2000 Final Report, May 1998-August 2000. *DML/SAMS Internal Report* **231**, 8 pp. + appendices.

Edited works

GAGE, J, LEVIN, L and WOLFF, G, (eds), 2000. Benthic processes in the deep Arabian Sea: biogeochemistry, biodiversity and ecology. *Deep-Sea Research II* **47**, iv + 375 pp.

GIBSON, RN and **BARNES, M**, (eds), 2000. *Oceanography and Marine Biology: An Annual Review* **38**, vii + 439 pp. London: Taylor & Francis.

APPENDIX 3

Postgraduate Research Projects

(Supervisors' names in parentheses)

Degrees awarded during the reporting year

N Frost, Ph.D, The University of Southampton. *Spatial heterogeneity and community stability on rocky shores.* (S J Hawkins, **M T Burrows** and M P Johnson)

B E Narayanaswamy, Ph.D, The University of Southampton. *The ecology of macrobenthos in the Faroe-Shetland Channel.* (**J D Gage**, J P Hartley and P A Tyler)

Ongoing research

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

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, **K D Black** and **J Overnell**)

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.* (**J D M Gordon** and P Vas)

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

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

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

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

S A Fleming, Ph.D, The University of Glasgow. *Mercury accumulation in deep-sea fish.* (R W Furness, I M Davies and **J D M Gordon**)

T Jarvis, Ph.D, The University of the Highlands and Islands Millennium Institute. *The vertical export of material caused by zooplankton vertical migration.*(**G A Tarling, J B L Matthews**, G C Hays)

V Jones, Ph.D, The University of Liverpool. *Organic nitrogen biogeochemistry* (G V Wolff, **A E J Miller**)

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), **S M Harvey** and **A E J Miller**)

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

S Mormede, Ph.D, The University of Glasgow. *Contaminants in deep-water fish stocks.* (I M Davies, **J D M Gordon** and R W Furness)

C Morri, Ph.D, The University of the Highlands and Islands Millennium Institute. North Atlantic deglaciation: its impact on deep-water depositional environments. (**J A Howe**, M S Stoker & **G B 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.* (**R S Batty**, 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 **J D 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. (**M S Kelly** and G Burnell)

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

S Ware, Ph.D, University of London. *Inshore fisheries ecology.* (R J A Atkinson, **M D J Sayer** and N Bailey)

T A Wilding, Ph.D, Heriot-Watt University. *Environmental and ecological impacts of artificial reefs.* (**M D J Sayer** and C Moore)

APPENDIX 4

Research grants and contract income received

DML

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	£750k
KD Black, J Overnell	Developmental plasticity of Loliginid Squid (DEMA)	NERC	10/97 - 10/00	£29k
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
CJ Cromey	DEPOMOD (version 2.3) - A model for predicting the effects of solids deposition from mariculture to the benthos	SEPA	05/00 - 06/00	£9k
CJ Cromey	Measurements of turbulent diffusion in Calbha Bay	Loch Duart Ltd.	05/00	£3k
CJ Cromey	DEPOMOD modelling study of the Loch Earn freshwater fish farm	Heriot Watt University	09/00	£2k
ME Inall, KJ Jones, R Leakey	Oceanographic applications to eutrophication in regions of restricted exchange (OAERRE)	EU Framework V	06/00 - 05/03	£268k
Meldrum, DT	Innovative ice buoys	NERC	03/99 - 02/02	£190k
J Overnell, KD Black	Measurement of dissolved and particulate manganese and oxygen concentrations using Autosub in two Scottish sea lochs (Autosub Science Missions)	NERC	03/99 - 03/01	£160k
PG Provost	Environmental measurements at west coast cage farm sites	Hydro Seafood GSP Ltd	06/00	£8k
PG Provost	Environmental measurements in Loch Earn	Heriot Watt University	06/00 - 11/00	£3k
PG Provost	Environmental measurements in Loch Creran	Hydro Seafood GSP Ltd	07/00	£4k
PG Provost	Environmental measurements at west coast cage farm sites	Marine Harvest McConnell	07/00	£3k
PG Provost	Environmental measurements at cage farm sites in Argyll	Hydro Seafood GSP Ltd	10/00	£4k
PG Provost	Environmental measurements at west coast cage farm sites	Hydro Seafood GSP Ltd	01/01	£6k
PG Provost	Environmental measurements at a site in Ross & Cromarty	Hydro Seafood GSP Ltd	03/01	£3k
MDJ Sayer	Feasibility of artificial reef deployments on the west coast of Scotland	EU PESCA Foster Yeoman Ltd Argyll & Islands Enterprise Lochaber Enterprise	11/97 - 05/00	£154k
MDJ Sayer	Juvenile gadoids in the rocky subtidal: factors affecting abundance and distribution	MAFF	04/95 - 05/00	£352k
MDJ Sayer	Artificial reef deployment technology	Foster Yeoman Ltd	02/01 - 12/01	£24k
MDJ Sayer	Recompression treatment in Scotland: technical audit and website construction	NHS Scotland	12/99 - 12/03	£40k
MDJ Sayer	Commercial scale assessment of the efficacy of the use of wrasse as control agents for sealice infestation of farmed salmon	Western Isles Enterprise	02/00 - 12/00	£2k

SAMS

Project Leader	Title	Funding Body	Duration	Award
K Davidson, CJS Bolch	Toxic *Pseudo-nitzschia* species in Scottish waters	UHI	10/00 - 09/03	£22k
K Davidson	CN budgets and trophic selections within marine microbial food webs (PRIME)	NERC	02/98 - 05/01	£77K
K Davidson	Phytoplankton growth modelling under multi-nutrient limitation	NERC	07/00 - 06/01	£17K
K Davidson	Microbial growth dynamics mesocosm experiments using Trondheim Marine Systems large-scale facility	EC	05/00 - 07/00	In kind
K Davidson	The influence of micro-zooplankton on marine productivity (Marine Productivity)	NERC	01/00 - 06/01	£54K
JD Gage	Benthic community activity and biomass at the deep-ocean bed (BENBO)	NERC	01/98 - 12/00	£103k
JD Gage	Benthic ecology of the Faeroe- Shetland Channel Ph.D studentship	Atlantic Frontier Environmental Network, (AFEN)	01/98 - 01/01	£30k
JD Gage	Benthic biological studies in the Atlantic Frontier	Geotek Ltd. on behalf of AFEN	06/98 - 04/00	£36k
JD Gage	Atlantic Coral Ecosystem Study (ACES)	EU Framework V	03/00 - 02/03	Euro240k
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	Distribution and biology of anglerfish and megrim in waters to the west of Scotland (MONK-MEGRIM)	EC DGXIV	01/99 - 03/01	Euro24k
JDM Gordon	Development of Elasmobranch Assessments (DELASS)	EC DGXIV	01/00 - 12/02	Euro13k
JDM Gordon	Deep-ocean Fisheries	JNCC	12/99 - 02/01	£4k
AD Hatton	Biogenic trace gases; NERC Fellowship	NERC	09/97 - 09/00	£100k
AD Hatton	The role of anaerobic microsites	NERC Fellowship extension	09/00 - 09/02	£80k
J Howe	Bottom-current pathways in the northern and central Rockall Trough	Rockall Oil Consortium	04/99 - 03/00	£5k
J Howe	Drill cuttings literature review (geology)	UKOOA	10/99 - 11/99	£5k
ME Inall	The impact of the internal tide on the Clyde Sea	NERC	06/99 - 06/01	£35k
MS Kelly	Commercially viable sea urchin cultivation	EC FAIR (CRAFT)	11/98 - 11/00	£390k including 50% in kind from industry
MS Kelly	Occurrence and distribution of the ASP toxin in king scallop populations on the west coast of Scotland	HIE, Highland Council, PESCA and the Scallop Association	12/99 - 05/00	£34k
MS Kelly	Accelerating growth rates in the king scallop *Pecten maximus*	Argyll and Islands Enterprise and Single Shell Systems	09/99 - 08/00	£40k
MS Kelly	Tube worm fouling on rope grown mussels	HIE, Highland Council, Crown Estate and industrial partners	03/01 - 09/01	£41k
MS Kelly	Designing and testing cost effective finishing diets for the sea urchin *Psammechinus miliaris*	Highland Council	10/00 - 12/00	£5k