The Scottish Association for Marine Science NEWSLETTER 27

SAMS

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ARCTIC SEA ICE AND GLOBAL CLIMATE SEE PAGES 10-11

April 2003

Final JGOFS Open Science Conference

A Sea of Change

5 - 8 May 2003

US National Academy of Sciences
Washington DC

Website: www.uib.no/jgofs

For further details: Roger.Handson@jgofs.uib.no

35th International Liège Colloquium on Ocean Dynamics and NATO Advanced Research Workshop

Dead and Dying Seas

5 - 10 May 2003
Liège, Belgium

http://modb.oce.ulg.ac.be/Colloquium
Fax: +32 4 3662355

9th Congress of the International Society for Developmental and Comparative Immunology

29 June - 4 July 2003

University of St Andrews

http://www.st and.ac.uk/%7Eseeb/compimmu/Poster.htm

For further information contact: Dr Val Smith, Tel: +44 1334 463474, Email: vjs1@st-andews.ac.uk

Freshwater Biological Association

Symposium for European Freshwater Sciences (SEFS3)

13 - 18 July 2003

University of Edinburgh
Email: sefs3@fba.org.uk
Website: www.sefs.info

Summer School on the Modelling of Arctic Climate

14 - 25 July 2003

University of Alaska, Fairbanks

For more information contact:
Professor Vladimir Alexeev
Email: valexeev@iarc.uaf.edu

Institute of Paleontology, University of Erlangen & SAMS

2nd International Symposium on Deep Sea Corals

9 - 12 September 2003
Erlangen, Germany

For further details: Website: www.cool-corals.de

Registration: cool-corals@pal.uni-erlangen.de

Next Underwater Optics meeting at PHOTONEX exhibition 2003

8 - 9 October 2003

National Agricultural Centre, Coventry

For more information please contact:
Michael Wall
Tel: 01256 844443

AWI, CADIC & Hamburg University

Interactions between the Magellan Region and the Antarctic & Antarctic Benthic Deep-Sea Biodiversity

International Symposium & Workshop

19 - 24 October 2003

Ushuaia, Argentina

Website: www.tierradelfuego.org.ar/cadic/ibmant.htm
Email:ibmant@tierradelfuego.org.ar

American Fisheries Society 4th World Fisheries Congress

Reconciling Fisheries with Conservation

2 - 6 May 2004

Vancouver, Canada
www.worldfisheries2004.org

contents

Front cover photo © Jeremy Wilkinson, SAMS: A Maridan autonomous underwater verhicle surrounded by ice floes along the East Greenland ice edge during February 2001.

Views expressed in this Newsletter are the views of the individual contributors and do not necessarily reflect the views of SAMS.

About SAMS

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

SAMS is funded by an agreement with the Natural Environment Research Council for its Northern Seas Programme, by commissioned research for public and private organisations, and by donations and subscriptions from its 600 members from around the world.

SAMS Membership

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

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

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

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

For further information and application forms please contact the editor.

Editor

Dr Anuschka Miller

SAMS, Dunstaffnage Marine Laboratory, Oban, Argyll PA37 1QA, UK

Tel (+44) (0) 1631 559300
Fax (+44) (0) 1631 559001

Email aham@dml.ac.uk

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

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Dear **SAMS** member

Dr Anuschka Miller, EDITOR

Research into environmental and climate changes in Northern Seas and the Arctic Ocean plays an increasingly prominent role at SAMS, and SAMS is currently a prime contributor to Arctic research in the UK. The permanent relocation of the Sea Ice Research Group around Professor Peter Wadhams from Scott Polar Research Institute to SAMS greatly strengthens and complements the ongoing activities, and demonstrates SAMS' commitment to this area of research. On pages 10 and 11 Peter Wadhams introduces his group's research activities with respect to the interactions between Arctic sea ice and climate change – a chilling subject.

SAMS has long been involved in deep-sea research with two very active and highly respected research groups, Professor John Gage's Deep Sea Benthic Group and Dr John Gordon's Deep Sea Fish Group. To mark John Gordon's retirement, this Newsletter carries two articles featuring his exciting research into the biology of deep-water fish.

This month the world celebrates the 50th anniversary since Watson and Crick published the structure of the DNA. Our understanding of how life works has been advanced significantly since, and molecular biology has become a vital tool in investigating the evolutionary relationships between different species. On page five

Johanna Fehling, a SAMS/UHI PhD student, describes her use of molecular biology to study phytoplankton species that may cause amnesic shellfish poisoning.

This Newsletter is packed with several intriguing articles. I would like to encourage you - in the words of James Watson - to make time to read and wonder: 'It is necessary to be somewhat underemployed if you want to do something significant.'

SAMSnews

Professor Graham B. Shimmield, DIRECTOR

DEEP-WATER FISH RESEARCH AT SAMS

This edition of the SAMS Newsletter marks another milestone in the evolution of the Association. Within these pages you will find exciting descriptions of cutting edge marine science taking place in the oceanic realm many miles from our familiar coastal zone. Over the past three decades, Dr John Gordon has provided a unique insight into the life history and habitat of little-known deep-sea fish inhabiting the darkest depths of the oceans. In the early years of his work, this was perhaps regarded as somewhat esoteric but the progressive advance of deep-water fishing technology has made John's work highly relevant to the study of ecosystem sustainability in the deep sea. With his formal retirement at the very end of last year, SAMS records its sincere appreciation for the dedication and professional conduct that John has demonstrated, and the unique link he has created between the science of deep-sea fish and the reputation of the Association. Of course retirement is something of a misnomer, and we are delighted that John joins the ranks of illustrious SAMS Honorary Fellows who continue to contribute significantly to our knowledge of the marine environment.

ABOVE: SAMS Director Professor Graham Shimmield (right) with Deputy First Minister Jim Wallace (centre) and local MSP George Lyon during a recent visit to SAMS. The visitors explored advances in SAMS research projects and viewed the progress of the new laboratory complex at Dunstaffnage.

SAMS WELCOMES NEW SEA ICE GROUP

With the formal retirement of Dr Gordon, we welcome Professor Peter Wadhams, formerly Professor of Ocean Physics at Cambridge University, along with his polar marine science research group. This significant move will advance the core science programme of SAMS, with emphasis on the Northern Seas, and will take the laboratory's expertise a step further, into the ice-covered seas of the Arctic. Peter took a degree in physics at Cambridge University and began his career in marine science by acting as assistant to the senior scientist on the Hudson-70 expedition of 1969-70, a Canadian oceanographic expedition which accomplished the first circumnavigation of the Americas. The work of Hudson in the Antarctic and Northwest Passage inspired Peter to do his PhD at the Scott Polar Research Institute (SPRI) on the interaction of ocean waves with sea ice. During this research he gained his first submarine experience when he sailed with HMS *Oracle* to measure waves under ice in the Fram Strait between Spitsbergen and

Greenland. Peter did postdoctoral research in Canada at the Frozen Sea Research Group in Victoria B.C., working on the impact of oil spills on Beaufort Sea ice. He then returned to SPRI to set up a research group that has become the UK's leading sea ice research centre. He served as Director of SPRI from 1987 to 1992. His research has ranged over the whole field of polar marine science, dealing with the vital questions of how the interactions between ocean, ice and atmosphere in high latitudes affect the climatic balance of the Earth. He has been three times to the North Pole in British submarines, studying ice thickness and ocean properties, and designing joint experiments with remote sensing aircraft. This work has helped to show a remarkable thinning of some 40% in Arctic sea ice over the past twenty years, one of many major climatic changes now occurring in the Arctic. He has worked on ice mechanics, measuring the flexure and break up of ice floes and tabular icebergs with strainmeters designed and built in SPRI, on the physics of the marginal ice zone, the oceanographic properties of eddies and coastal polynyas, and on ice dynamics and pressure ridges. He is a winner of the Polar Medal and the Italgas Prize for Environmental Sciences, and the author of the standard textbook on sea ice "Ice in the Ocean".

Other members of the research group who have made the move to Dunstaffnage include Jeremy Wilkinson, Nick Hughes and Martin Doble. All have extensive experience of working in ice-covered seas of the Arctic and Antarctic.

NEWS OF THE NEW BUILDING

The physical infrastructure at Dunstaffnage marks a permanent change to the skyline of the peninsula. The new laboratory combines the aesthetics of a modern, purpose-built scientific laboratory made of renewable materials (western red cedar exterior cladding) with high tech, computer controlled air handling for the spacious laboratories and offices. Earlier this month, we were delighted to entertain a visit from the Deputy First Minister, Mr Jim Wallace, and our local MSP, George Lyon. Both were impressed by the new facilities under construction, and the landmark that represents one of the most important construction projects in north Argyll in recent years.

HIGHER EDUCATION NEWS AT SAMS

Finally, I am delighted to record some significant achievements in the education programme for SAMS. Dr Maria Otero-Villanueva has just graduated with the first SAMS/UHI PhD for her work on green sea urchins. Mar is currently working in applied aquaculture research in Viet Nam.

Secondly, the Marine Science course team are to be congratulated on achieving an outstanding result in the Quality Assurance Agency evaluation of environmental sciences in the UHI. The QAA recorded the top grade of *commendable* in both teaching and learning, and learning resources, for the BSc degree at SAMS. This evaluation places the degree in the top category of Earth, Environmental Science and Environmental Studies in Scottish Universities. Further details will be published on the QAA and UHI websites.

2003 has begun with a tremendous all round set of achievements for the research and educational objectives of the Association. I close with a sincere thank you to all our friends and supporters over the past year, and I look forward with you to the new developments that we will soon be celebrating. ●

THE 13TH ANNUAL NEWTH LECTURE, 6 NOVEMBER 2002

'Biotechnology Meets the Sea – a Recipe for Success'

Dr Jo Oliver, Project Executive of the European Centre for Marine Biotechnology (ECMB), delivered the prestigious annual Newth Lecture to an audience of about 70 guests at Dunstaffnage Marine Laboratory on Wednesday 6 November 2002. ECMB is the latest development within what is rapidly turning into the "SAMS Group", and the lecture aimed to communicate to SAMS members what marine biotechnology is, and what is envisaged to develop within the new company.

It's a common misconception to consider marine biotechnology merely as biotechnology applied to the marine environment, for example to clean up oil spills or combat bio-fouling on boats and piers. It has much more to offer and refers as much to the exploration and exploitation of compounds and processes from the unparalleled structural and physiological diversity of marine organisms, providing solutions to a variety of today's problems from health and nutrition to cosmetics and mariculture.

Access to an established and well-equipped marine science research organisation such as SAMS with its advanced knowledge of marine life, its easy access to diverse marine environments, its large range of sampling opportunities and equipment, as well as its excellent culture facilities provided through the Culture Collection of Algae and Protozoa (Marine) and the sizeable aquarium thus makes for a logical and highly advantageous environment for a marine biotechnology centre. ECMB aims to conduct both its own commercial research – building on and expanding the microbial and molecular biology research ongoing at SAMS – and to act as a business incubator from which homegrown and independent commercial companies can develop. Its vision is to be part of a network of similar facilities across the globe between which individuals, groups and companies can move freely to enhance both collaboration and market development. This project is part-funded by the European Regional Development Fund.

My PhD Project

Poisonous Plankton

Johanna Fehling, SAMS/UHI

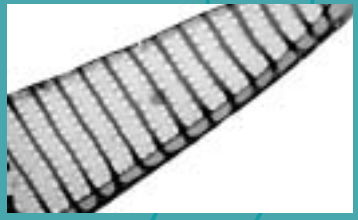
Phytoplankton contributes approximately 50% of Earth's primary production. In coastal waters the microscopic algae serve as a critical food source for various filter-feeding animals including zooplankton, shellfish and finfish. Algal blooms can thus be beneficial to aquaculture and wild fisheries operations. Some 40 plankton species, however, have the capacity to produce potent toxins. When these organisms occur in high numbers, their toxins can find their way through fish and shellfish into humans. It is thus important to understand the temporal and spatial distribution of harmful algal species, as well as the conditions that influence toxin production.

Four types of shellfish poisoning due to algal blooms are known to date: paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), neurotoxic shellfish poisoning (NSP) and amnesic shellfish poisoning (ASP). PSP, DSP and NSP are caused by dinoflagellates, whereas ASP is caused by diatoms of the genus *Pseudo-nitzschia*.

Perhaps due to statutory shellfish monitoring programmes, no ASP event has yet been recorded in Scotland. However, both toxic and non-toxic species of the genus *Pseudo-nitzschia* have been found in Scottish waters, and the need to understand their distribution and physiology underlies my PhD project.

The genus *Pseudo-nitzschia* contains about 22 species of which nine are capable of producing the neuro-toxin domoic acid. An analogue of the amino acid glutamate, domoic acid binds strongly to glutamate receptors in the brain, causing nerve cells to transmit impulses continuously until they die. Domoic acid causes illness, neurological damage and sometimes death in higher vertebrates. Toxicity varies within and between species. Some strains produce domoic acid, others don't. Most ASP events around the world have been caused primarily by *Pseudo-nitzschia multiseries*, *P. pseudodelicatissima*, and *P. australis*.

Johanna taking a water sample in the Lynn of Lorne.



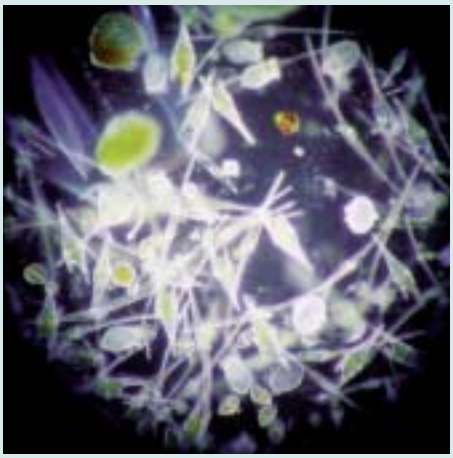
TEM picture of *P.australis*, 10000x magnification © J Fehling, SAMS/UHI

In 1999 and 2000, domoic acid was detected at concentrations above internationally accepted limits in western Scottish waters, primarily within the tissue of the King Scallop, *Pecten maximus*. Consequently most Scottish scallop harvesting areas were closed for periods of more than six months. These events coincided with multi-species algal blooms composed of several potentially toxic *Pseudo-nitzschia* species. In some areas these blooms were dominated by *P. australis*.

To identify which strains of *Pseudo-nitzschia* occur in Scottish waters and to determine which of them are capable of producing domoic acid, a phytoplankton monitoring programme commenced in November 2000. A station in the Lynn of Lorne near Dunstaffnage Marine Laboratory was sampled weekly from spring to autumn and fortnightly during the winter months. Supporting measurements included inorganic nutrients in the water and hydrological parameters which influence phytoplankton blooms. Results from two years of monitoring show that the appearance of different *Pseudo-nitzschia* species follows a seasonal pattern. In the spring diatom bloom we mostly find a type of *P. delicatissima* (which so far has not produced domoic acid in cultures). The toxic species *P. australis* was found to be present in our waters from early to late summer, with highest cell numbers of up to $6x10^4$ cells dm^{-3} in August.

I also collected phytoplankton samples and measured environmental parameters along the Ellett Line (between mainland Scotland and Rockall and beyond) in October 2001 onboard RV *Discovery*. High cell numbers of a potentially toxic *Pseudo-nitzschia* belonging to the *P. seriata* group were found on the shelf but rarely offshore. Diatoms belonging to the *P. delicatissima* group on the other hand were more prominent in open ocean than shelf waters.

Laboratory cultures of different *Pseudo-nitzschia* species and strains were established by isolating cells from plankton net samples.



Phytoplankton sample from the North Atlantic

To investigate the environmental parameters that favour toxin production, growth experiments under various inorganic nutrient limitations were conducted with the established cultures. Results showed that *P. australis* produces domoic acid during the exponential growth phase in contrast with other *Pseudo-nitzschia* species. Toxin production was further found to be greater under silicate than phosphate limitation.

Toxic and non-toxic *Pseudo-nitzschia* species have similar morphologies. Identification to species level therefore requires electron microscopy and genetics. By sequencing the large subunit rDNA most cultures could be identified. The rDNA sequences of some gene regions are used to estimate the genetic and evolutionary relatedness of toxic and non toxic *Pseudo-nitzschia* populations and strains. I acquired the relevant molecular evolution techniques during an international workshop on molecular evolution sponsored by the National Science Foundation, NASA, and the Josephine Bay Paul Centre for Comparative Molecular Biology and Evolution at the prestigious Marine Biological Laboratory at Woods Hole in the summer of 2001. My participation in this inspirational workshop was kindly funded by SAMS. I am now analysing the sequence data from the isolated Scottish *Pseudo-nitzschia* cultures to build phylogenetic trees to relate Scottish species to other algae from around the world. ●

Johanna Fehling is a third year UHI PhD student working under the supervision of Dr. Keith Davidson (SAMS), Dr Christopher Bolch (formerly SAMS, now University of Tasmania), and Professor Paul Tett (Napier University). She obtained her degree from Kiel University in Germany.

Fish in deep water

Dr John Gordon, SAMS

It was on the maiden fishing voyage of RRS *Challenger* in 1973 that I saw my first catch of deep-water demersal (bottom–living) fish from 800 m in the Rockall Trough. Everything in the catch was unfamiliar and, for me, it opened a whole new world. The direction of my science changed and so began a lifelong interest in deep-sea fish and fisheries. My last cruise as a SAMS employee - in August 2002 to the Bay of Biscay onboard the French vessel *l'Atalante* - had as dramatic an effect on me as the *Challenger* cruise. Studying live deep-water fish with the aid of the remotely operated vehicle (ROV) *Victor* led me to change many of my ideas that had been based on observations of trawl caught deep-sea fish specimens.

Deep-sea fish have quite fragile skins that are easily damaged. Although I had often seen photographs or videos of them in their natural state and surroundings, it was a joy to be able to watch them, at will, for days on end on video screens strategically placed throughout the working areas of the ship.

The objective of the Vital cruise (www.ifremer.fr/vital) was to determine and compare the abundance of deep-water fishes in three distinct areas of the continental slope of the Bay of Biscay at depths between 1100 and 1500 m. This was achieved by using the ROV *Victor* to carry out visual transects, by deploying a lander with a baited camera, and by chartering a commercial trawler. This article describes some of my impressions of the visual transects carried out by the *Victor*.

Before the cruise, I had naively assumed that the ROV would be deployed and recovered at fairly frequent intervals and had boarded the ship armed with my laptop and plenty of work to occupy myself between deployments. It came as a complete surprise to find that the *Victor* was only deployed once in each of the three areas, but on each occasion continuously provided data for more than 70 hours. The three study areas were chosen to provide contrasting habitats. The Meriadzek Terrace and the St Nazaire Terrace are similar in topography, but only the former has been subjected to significant commercial fishing. The Belle Ile Canyon, as the name suggests, is bisected by steep-sided canyons and is not commercially exploited. To visually estimate fish abundance, the *Victor* followed a fixed zigzag transect of c. 300 m long lines separated by c. 60 m short lines at predetermined depths on the slope. The *Victor* surveyed these transects at a speed of approximately 0.25 m s^{-1} and at 0.8 m above the bottom.

The scientific party was divided into six pairs of observers who did a two-hour watch in the control room, along with the three ROV pilots. The observers were surrounded by an array of video screens showing the images from the many cameras, fixed forward, manoeuvrable and downward pointing. The fixed forward directed camera was used to estimate fish abundance. The field of vision was calibrated by placing a measured chain on the seabed. The result was a virtual horizontal line on the screen, and the role of the observers during their two hour watch was to count and, where possible, identify the fish appearing on the screen. Fish first observed either below the line or first appearing above the line and subsequently crossing it were used to estimate the abundance. Fish outside the quantitative field were recorded and provided useful information on the behaviour of the fish in relation to the presence of the ROV. It was difficult not to become distracted watching the skills of the pilots as they steered the *Victor* - especially in the area of the canyons - or to cast the odd glance at the downwardly directed camera. Off watch, we analysed the video recordings, identifying doubtful species and making observations on the behaviour of the fishes.

One of our first overall impressions was the patchiness in the distribution of the fish fauna. On some transect lines fish were very sparse, while on others they were appearing so fast that one had to resort to pressing the "panic button" to identify a section of the recording that

ROV *Victor* is launched from the French vessel *l'Atalante* in the Bay of Biscay in August 2002.

Cut-throat eel *(Synaphobranchus kaupi)* is a very abundant inhabitant of deeper waters.

Tripod fish *(Bathypterois dubius)* sits on the seabed on modified fins waiting for food to pass by.

would have to be re-analysed at a later date. The tripod fish *Bathypterois dubius* (see picture) sits on the bottom on modified fins, using two long modified fin rays to sense prey. This "sit and wait" feeding strategy is most efficient where a steady flow of water passes the fish. It was therefore no surprise to find tripod fishes aggregated in areas such as the top of ridges where the bottom currents are enhanced. The patchiness of other species, especially pelagic fishes, is more difficult to explain and will require a detailed analysis of behaviour in relation to all the other environmental information collected during the cruise.

The most abundant species observed at all depths was the cut-throat eel *Synaphobranchus kaupi* (see picture). This fish is seldom caught by commercial trawls, but in the SAMS surveys in the Rockall Trough and in similar work with Nigel Merrett in the Porcupine Seabight (southwest Ireland), it was the most abundant species at mid-slope depths in the catches of a fine-meshed trawl fished on a single warp. In a preliminary overview of the results of the Vital cruise presented to the 2002 ICES Annual Science Conference, we showed that estimates of abundance of this eel from ROV visual observations and from SAMS trawl data, albeit from different areas, were of a similar order of magnitude.

In recent years, the amount of essential biological information on northeast Atlantic deep-sea fish has been steadily increasing. For effective fisheries management, however, there remains a real need for more information on the behaviour of deep-sea fish, both in relation to their habitat and to fishing gears. The recent work by Pascal Lorance and Franz Uiblein using the French manned submersible *Nautile* is opening up new windows, and the results from the Vital cruise will greatly increase our knowledge.

During the 1980s, John Mauchline and I carried out detailed studies of the diet of about 70 species of deep-sea fish from the Rockall Trough. From these studies I had some preconceived ideas as to how the fish might behave and it was surprising how often these ideas turned out to be completely incorrect. Fish that I had assumed would be active predators in the water column were often found to be sitting on the bottom.

Marks caused by trawl doors and nets were frequently observed on the Meriadzek Terrace. The impact of trawling on the benthos, especially in the deep sea, is becoming a cause for concern (see SAMS Newsletter (2002) 25: 12). The data on the distribution of the marks and the continuous visual record from the downwardly directed camera will make an interesting study.

In the canyon area it was difficult to follow the pre-determined transects. However, observing how different species had filled niches on the steep slopes was extremely fascinating. On one of my watches we spotted a cable stretched across the canyon. It was encrusted with colourful crinoids and anemones (see picture) and was an interesting diversion from counting fish.

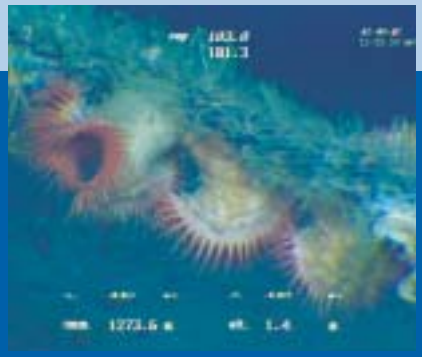
Now, as a SAMS Honorary Fellow, I am looking forward to spending some time with colleagues from IFREMER, helping to work up some of the fascinating data that the Vital project has yielded.

I thank Verena Trenkel and Pascal Lorance for inviting me to participate in the Vital Project. It was certainly one of the most memorable experiences of my career, made all the more pleasant by good company, some excellent wine and a bond well stocked with Caribbean Rum!

A deep-water kitefin shark (*Dalatias licha*)

The rabbitfish *(Chimaera monstrosa)* swims gracefully with its modified pectoral fins.

Deep-water scorpion fish *(Trachyscorpea cristulata echinata)* frequently observed sitting on the seabed.



A deep sea cable stretching across a canyon is encrusted with colourful anemones and crinoids.

The roundnose grenadier *(Coryphaenoides rupestris)* a commercially exploited deep-water species.

Wildlife – one of Scotland's greatest marine resources

Dr Chris Parsons, Hebridean Whale & Dolphin Trust/University Marine Biological Station Millport and **Neil Black,** VisitScotland

When you talk about marine resources, the first thought is of fishing and perhaps of marine mineral resources such as oil deposits. If you were asked to comment on the state of these resources, the reply would probably be with a depressed tone and heavy heart. But at least one of Scotland's marine resources is bucking the trend and is expanding in value at a ferocious rate. This resource is marine wildlife, which is rapidly becoming one of Scotland's biggest tourist attractions, particularly in rural coastal areas.

Tourism is one of Scotland's largest industries, employing almost 200,000 people (8% of the Scottish workforce) and injecting annually £4 billion into the Scottish economy (5% of the GDP).

But the importance of Scotland's marine wildlife for the country's tourism industry has only been recognised in recent years. Marine wildlife tourism is defined as "any tourist activity with the primary purpose of watching, studying or enjoying marine wildlife"[1]. A review of this sector of the tourism market in 1998 estimated that it was directly worth over £9.3 million to the Highlands and Islands Region, and in 1996 supported over 400 jobs[1]. When one considers the indirect income from marine wildlife tourism, for example the cost of the tourists' hotel, restaurant bills and gift shop purchases, an estimated £57 million was generated, and employment was provided for as many as 2,670 people[1].

Marine wildlife tourism has a particularly significant impact in several rural coastal communities. On the Island of Mull a survey conducted in 1999 found that of all the possible tourism activities that could be undertaken on the islands, boat trips to watch marine wildlife ranked second (after visiting the Isle of Iona)[2]. Marine wildlife tourism was estimated to contribute directly (*i.e.* through ticket sales) over £0.65 million per year to the economy of the island[2]. In addition, the indirect income accruing from accommodation, food and purchases made by marine wildlife tourists was estimated to increase the annual income by a further £8.6 million. To put this into context, fisheries on Mull have an annual value of £3 million[3].

The value of marine wildlife to the economy is increasingly being recognised by the island's human population, as attested by a more recent study which found that local inhabitants considered marine wildlife to be one of the main reasons that attracted visitors to Mull (second only to the island's scenery)[4].

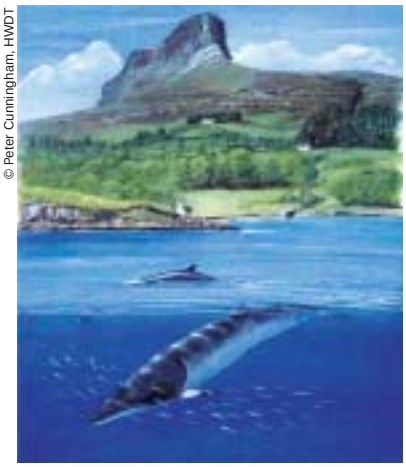
The wildlife resource of the coastal and marine environment – the vast seabird colonies (many of international renown), the waders and wildfowl, the sea duck, the grey and common seal populations, the whales, dolphins, porpoises and otters - combine to give Scotland a growing and developing niche market in coastal and marine wildlife-watching.

Of these animal groups, cetaceans were ranked as the most influential draw for tourists[5], which is particularly promising for the tourism industry of Western Scotland – arguably the site of the greatest abundance and diversity of cetaceans in northern Europe.

Whale and dolphin-watching has been recognised as one of the fastest growing sectors in the world tourism market, expanding at an annual rate of 12.1% through the 1990s[6]. Recent estimates claim that whale-watching now attracts more than 9 million participants a year and generates over US$1 billion[6].

Whales and dolphins are certainly a valuable commodity in Western Scotland: in 2000 it was estimated that 242,000 tourists were involved in cetacean-related tourism activities in Western Scotland, either in the form of whale-watching trips or going to cetacean-themed visitor centres[7]. The direct annual income from cetacean tourism activities was estimated to be £1.77 million[7]. In some remote coastal areas, cetacean-related tourism accounted for as much as 12% of the area's total tourism income[7].

The survey further determined that 23% of whale-watchers visited Western Scotland specifically to go on whale-watching trips, spending an additional £5.1 million in the area[7]. As well as the above tourists, 16% of surveyed whale-watchers stayed in Western Scotland an extra night as a result of going on a



HOW OUR VISITORS SEE US

	English	Scottish	USA	German	French	Italian	Spanish
Beautiful Scenery	94	91	96	94	90	97	95
Friendly people	82	74	85	87	77	77	86
Wildlife landscapes	n/a	n/a	n/a	n/a	87	74	66
Unspoilt environment	n/a	n/a	n/a	n/a	77	75	79
Nature & Wildlife	n/a	n/a	n/a	n/a	68	74	60
Good place to relax	85	81	67	72	63	61	75

Tourism Attitudes Survey 1999 (UK, USA, Germany) 2001 (France, Spain, Italy)

Given evidence from our visitors to Scotland (above), it is clear that sustainable marine wildlife tourism has an important role to play within the continuing development of Scotland's tourism portfolio.

Sustainabile tourism is a key driver for economic activitiy across Scotland and sustains many small businesses and remote rural and island communities.

whale-watching trip, which contributes a further £0.9 million in tourism expenditure. The total gross income generated by cetacean-related tourism in rural Western Scotland was estimated at £7.8 million[7].

This may seem a relatively moderate amount when compared with more well-developed whale-watching industries in areas such as Alaska (annually worth US$89 million[6]). But it is in fact greater than in other tourism destinations such as the Azores, Iceland or South Africa [6,7], which might be more readily associated with whale-watching tourism; and the Scottish marine wildlife tourism industry is growing rapidly.

One important aspect of using marine wildlife, such as whales, as a tourism resource rather than a material resource, is that tourism is usually non-consumptive and thus sustainable. It can also be more profitable: it was for example estimated that the non-consumptive tourism utilisation of cetaceans for whale-watching to rural, coastal communities in Western Scotland was three times greater than the value of the consumptive utilisation of cetaceans through commercial whaling for rural, coastal communities in Norway[7].

This goes to prove that marine wildlife, such as whales and dolphins, can provide notable financial benefits. It also follows that protection of this resource, whether it be by legislation or by the designation of marine protected areas, does not need to be a barrier to marine resource use and local businesses, but conversely can be highly profitable.

In times where many coastal towns and villages are suffering economic depression and an uncertain future as the result of the decline of fishing and other traditional industries, the popularity, growth and potential of marine wildlife tourism is providing a ray of hope to some communities. If properly promoted and managed, marine wildlife tourism will bring more and more income into these areas, and will hopefully do so sustainably for a long time into the future.

For further information on sustainable tourism in Scotland visit www.greentourism.org.uk ●

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A REFLECTION OF THE QUALITY OF THE VISITOR EXPERIENCE TO COASTAL AREAS IS HIGHLIGHTED STRONGLY IN THE PREVIOUS WINNERS OF THE TOURISM AND ENVIRONMENT SCOTTISH THISTLE AWARDS

2002	Scottish Seabird Centre – North Berwick
2001	Bressa Boats – Shetland
2000	Hebridean Whale and Dolphin Trust – Mull
1999	Shetland Wildlife Tours
1995	Nairn Seafront Tourism Management Programme
1994	Sea Life Surveys – Mull
1993	Dolphin Ecosse – Cromarty

AUTUMN MEETING, THURSDAY 31 OCTOBER 2002, UNIVERSITY OF STIRLING

Marine Stewardship - Safeguarding our Seas

At the autumn meeting of the Scottish Marine Group around 80 guests listened to six invited speakers explore different aspects relevant to Scotland arising from the government's vision and strategy for the management of the marine environment as laid out in the first Marine Stewardship Report.

Alison Douglas from the Marine Environment & Wildlife Branch at the Scottish Executive considered Marine Stewardship in Scotland, while Martyn Cox, Coastal Project Officer of Scottish Coastal Forum, explored the role of coastal fora. Dr Stephen Atkins, Team Leader of the JNCC's Irish Sea Pilot, shared some experiences gained for nature conservation at the 'regional sea' scale in the Irish Sea Pilot. Richard Park from the Scottish Environment Protection Agency explained the Agency's drive for integrated ecological monitoring of coastal and transitional waters, while Dr James Parker spoke on behalf of the UK Offshore Operators Association on the future challenges for the offshore industry. Neil Black from VisitScotland introduced the audience to some figures and thoughts about Coastal and Marine Tourism, much of which is summarised in the article on the left. SAMS would like to thank the speakers for providing a stimulating day of discussion on issues of marine management.

Dr Hamish Mair from Heriot-Watt University, who convenes the SMG, had organised the event with the help of Dr Donald McLusky at Stirling. SAMS would like to express its sincere appreciation to Dr Mair for his continued voluntary convenorship and the thoughtful and careful attention given to organising a balanced programme of events for the marine science community in Scotland. We are also indebted to the University of Stirling for the free use of their facilities, which allows the SMG meetings to remain open to all and free of charge. ●

Arctic Sea Ice and

THE NEW SAMS SEA ICE GROUP INTRODUCES ITS LATEST PROJECTS

Professor Peter Wadhams, SAMS

The move of the Sea Ice and Polar Oceanography group, led by Professor Peter Wadhams, from Scott Polar Research Institute in Cambridge to SAMS, coincides with the launch of three new European Union research projects which seek to understand the interactions between Arctic sea ice and climate change. We are partners in all three projects, and Peter is Co-ordinator of one, GreenICE.

GreenICE

GreenICE, or Greenland Arctic Shelf Ice and Climate Experiment, aims to measure the changes in the structure and dynamics of sea ice that have occurred in recent years in a key region of the Arctic Ocean - the little-explored zone north of Greenland -, and to see whether these can be related to the long-term (> 2,000 years) variability in the same region as revealed by sediment cores. The project has six partners, comprising SAMS, the Geological Survey of Denmark and Greenland (GEUS), the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven (AWI), the Danish Meteorological Institute, the Danish Technical University, and Kort og Matrikelstyrelsen (KMS), the Danish state mapping agency.

Over the past 20-30 years dramatic evidence has been acquired from submarine voyages under ice that its thickness is diminishing. Comparisons of voyages done during the summer months show a thinning of more than 40% in areas covered by UK and US submarines. We are less sure about the trend during winter months, and also in regions not yet covered by submarines, which includes the EEZ north of Greenland. The cause of this thinning is most likely a mixture of global warming and a switch in the Arctic atmospheric circulation which occurred a decade or so ago as a result of a change of phase of the Arctic Oscillation, the main mode of variability of the Arctic atmosphere. To understand these changes properly, we need a system that will map the Arctic ice thickness over long periods and in remote areas. The approach that we are developing is to use drifting ice buoys, which transmit data by a satellite link such as the Iridium system. But how do drifting buoys measure ice thickness? A recently developed theory suggests that the tiny oscillations that are always observed on the ice surface, known as flexural-gravity waves and originating from ocean waves passing into the distant ice edge, have a spectral peak at a frequency that is a function of ice thickness. By monitoring the spectrum of these waves, we can track changes in ice thickness. We have designed a buoy, which measures these waves using a strainmeter or tiltmeter array, transmitting data by satellite. It is our intention to deploy such a buoy on an ice camp to be set up by the Danish Government in spring north of Greenland, a camp from which GEUS colleagues will carry out sediment coring to examine how the ice climate of the region has varied over much longer time scales.

Polastern embedded in winder sea ice in the Arctic Ocean, while scientists man-haul equipment to measure ice thickness.

The Danish ice camp programme has, however, been delayed for a year, so we are transferring the first season's research to a drifting ship, the German icebreaking research vessel *Polarstern*, and to an ice camp in the Beaufort Sea. *Polarstern* will enter the ice north of Svalbard and will drift for a three-week period in April, while AWI carries out a meteorological programme. The SAMS group, comprising Nick Hughes, Martin Doble and Duncan Mercer, will carry out the buoy work and will drill an array of holes around the buoy using a hot water drill. Other partners will measure ice thickness over larger scale grids around the ship using an electromagnetic induction coil mounted on a sledge and a helicopter (AWI), and will map the freeboard of the ice using a scanning laser mounted in a Twin Otter (KMS). At the same time Peter Wadhams and Jeremy Wilkinson of SAMS, together with Steve Wells (Geos Ltd.), will take a similar buoy to an ice camp established by the US in the Beaufort Sea north of Prudhoe Bay, Alaska, where it will form part of a multidisciplinary research programme involving 30 scientists, and will record data at the same time as the buoy on the ice near *Polarstern*. In 2004 we will focus on establishing the originally planned camp over the Lomonosov Ridge north of Greenland.

Global Climate

Sampling frazil ice in the water column off East Greenland over the side of a research ship.

SITHOS

The second project, SITHOS (Sea Ice Thickness Observing System), is linked to GreenICE *via* the work of *Polarstern*, and focuses on testing the ice buoy system as one element in an Arctic basinwide ice thickness mapping programme designed to test models of Arctic ice changes. It is co-ordinated by Dr Stein Sandven of the Nansen Environmental and Remote Sensing Centre in Bergen.

IRIS

The third project, IRIS (Ice Ridging Information for Decision Making in Shipping Operations), is co-ordinated by Dr Mikko Lensu of the Ship Research Laboratory at the Helsinki University of Technology. This programme has the practical purpose of improving the routing and design of Arctic shipping by advancing the representation of pressure ridges in ice mechanics models. First, new methods are to be developed to determine and forecast the extent of ridging. These parameters will then be included in ice information delivered to ships, and used to improve on-board route selection. The delivery will be *via* a graphics system called IceView, which permits satellite images of ice to be displayed on a map and analysed automatically on-line to produce an optimum route to destination. Data linking satellite imagery, pressure ridge dimensions and forces on ships will be collected from field programmes in the Baltic Sea (using the tankers and cargo vessels of the two shipping companies involved, Fortum and Wagenborg) and the Arctic Ocean. We will also carry out pressure ridge analyses from our extensive collection of under-ice profile data collected from British submarines. The next Partners' Meeting on this project will take place in Oban in August.

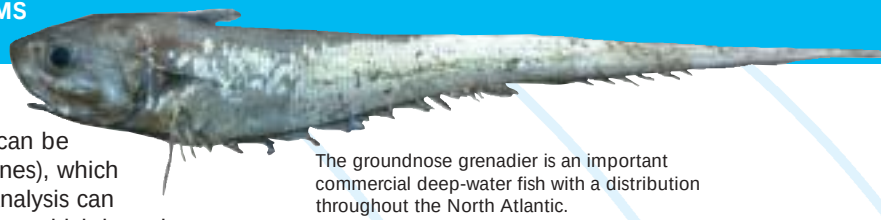
Even in winter, ice break-up can occur suddenly, endangering researchers and producing huge heat fluxes of up to 1000 W m^{-2}, of which frost smoke is the visible evidence.

These three linked projects carry forward our work on the role of climate change in the Arctic with hands-on studies of the sea ice itself. If, as is believed to be the case, the ice is retreating and thinning significantly, then challenging times lie ahead for developments in Arctic transport, fisheries and oil production. Most important of all, the mechanisms by which climate change is amplified in the Arctic mean that the far North is acting as Man's most useful indicator of climate change in action.

Ice drilling and coring from *Polarstern*.

Deep-water fish reveal more than their age

Sarah Swan, John Gordon and Tracy Shimmield, SAMS



The groundnose grenadier is an important commercial deep-water fish with a distribution throughout the North Atlantic.

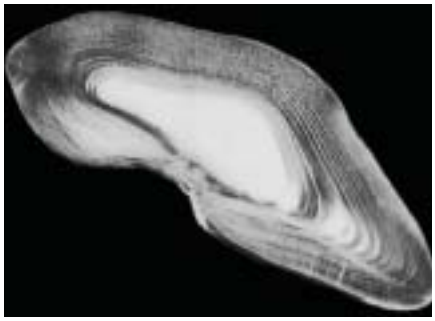
Fish are cold-blooded animals whose growth is temperature dependent. Seasonal changes in growth can be readily seen in the ring structure of the otoliths (earbones), which can thus be used to estimate the age of fish. Otolith analysis can furthermore unlock valuable information on life histories, which have been notoriously difficult to obtain for deep-water fish species, but are crucial for fish stock identification and fisheries management.

Otoliths are calcareous accretions located within the semi-circular canals of bony fish and are associated with hearing and orientation. They grow throughout the life of the fish and are mostly composed of calcium carbonate, crystallised onto a proteinaceous matrix. They are precipitated from the surrounding fluid, the endolymph, which determines the elements available for incorporation. The endolymph is derived from the blood plasma, which itself is regulated by the physiology of the fish. The processes of element incorporation are complex, but experiments have shown that salinity and temperature of the surrounding seawater are among the controlling factors.

Unlike other calcareous structures in living organisms, otoliths are thought to be metabolically inert, and the non-essential trace elements incorporated during otolith growth may therefore provide a record of the environment to which the fish was exposed. If a species migrates from one area or depth zone to another, where the water is of a somewhat different chemical composition, it should be possible to distinguish changes in the elemental signature from different parts of the otolith. If the inner part or nucleus of the otolith - which represents larval and early juvenile development - has a similar elemental signature in specimens from different areas, this could indicate that these fish might originate from a common spawning stock. By examining changes in elemental concentration from the otolith nucleus to the outer edge, we may be able to identify significant events, such as a change from a pelagic to a bottom-living existence.

ICP-MS allows accurate measurements of a wide range of elements present in minute concentrations.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can be used to simultaneously measure a wide range of elements from individual otoliths. These can be detected at concentrations in the region of parts per billion. Two methods of sample analysis can be utilized.



A fish otolith – here sectioned – contains information on age and life history of its bearer.

Elemental concentrations can be determined from solutions of whole otoliths, or from selected parts of the otolith using a laser-ablation technique.

Why is this relevant to deep-water fishes? In recent years, deep-water fisheries have developed extremely rapidly, to compensate for the decline in traditional shelf fisheries. Little is known about the biology and life histories of many of these species, and there are concerns about the sustainability of the fisheries. Most deep-water species are widely distributed and may be found in international waters. Research studies have been somewhat limited and reporting of landings is often inadequate. Until we have a better knowledge of stock identity, spawning areas and migration patterns, it is difficult to scientifically assess and effectively manage deep-water fisheries.

One of the deep-water species studied at SAMS is the roundnose grenadier (*Coryphaenoides rupestris)*, an important commercial fish that occurs throughout the North Atlantic. Although it is rarely caught in the colder waters of the Norwegian Sea, small populations exist in the Skagerrak between Norway and Denmark and in some deep Norwegian fjords. Roundnose grenadier is thought to live for more than seventy years. Its distribution depth ranges from about 500 to 2000 m. Evidence from a study in the Skagerrak suggests that the larvae and early juveniles are pelagic in deep water and only adopt a benthopelagic lifestyle after their first year. It is during this pre-settlement stage that the otolith nucleus is formed.

Analysis of the elemental concentrations in whole otoliths of roundnose grenadier shows a good separation between the samples from the Norwegian fjords and the Skagerrak, and those from sampling locations from the wider northeast Atlantic, affirming the view that these may be isolated populations. Samples from Storfjord, Norway were characterised by high concentrations of manganese, which laser-ablation ICP-MS found to increase towards the otolith edges. This increase in manganese concentration coincides with the stage at which the fish move into deeper water and may be evidence of manganese cycling in a fjordic environment.

We would like to thank Terrie Sawyer for ICP-MS sample analysis. This work was part-funded through the EC FAIR (OTOMIC) CT98/4365 project. Audrey Geffen (University of Liverpool) and Beatriz Morales-Nin (Institut Mediterrani d'Estudis Avançats, Spain) were other partners in this project.