



MASTS Annual Science Meeting 2011

22-24 August 2011 at Heriot Watt Conference Centre

“SCIENCE TO UNDERPIN SCOTLAND’S MARINE PLAN”

Day 1: Monday 22nd August 2011

- 9.00-9.30 Coffee and Registration
- 9.30-9.50 Opening Ceremony (Linda Rosborough – Head of Marine Scotland & David Paterson – MASTS Executive Director)
- 9.50-10.20 Invited Speaker: Dr J. Baxter (Principle Advisor, Marine Ecology, Scottish Natural Heritage). “MARINE RESEARCH: Making it relevant in 2011”
- 10.20-11.20 Healthy & Biologically Diverse: Science Session (Chaired by Prof U. Witte)
- D Green: A fish migration data and information resource: The living North Sea Project Web-GIS
 - M Heath: Ecosystem limits to fisheries yields from the North Sea simulated with an end-to-end food web model
 - D Spiers: Modelling the Large Fish Indicator: multispecies modelling in support of an ecosystem approach to management
 - P Wright: Changing reproductive investment in cod and haddock
- 11.20-11.50 Coffee
- 11.50-1.05 Healthy & Biologically Diverse: Science Session (Chaired by Prof I. Priede)
- P Fernades: Investigations of the marine fauna in the closed areas around Rockall: progress in the development of underwater visual survey techniques
 - T Linley: Associated ichthyofauna of cold water reefs: observations from baited photographic lander deployments
 - P Donohue: Application of proteomics to assess the impact of ocean acidification on marine organisms
 - A Watts: The trophic dynamics of *Nephrops norvegicus* are found to differ between two fishing areas off the West coast of Scotland; A cautionary tail!
 - M Roberts: The Mingulay reef complex: approaching a decade of research into the ecology of Scotland’s only known inshore cold-water coral reef
- 1.10-2.20 Lunch & Networking opportunities
- 2.20-3.35 Healthy & Biologically Diverse: Science Session (Chaired by Dr W. Sanderson)
- H Burdett: Low pH induces a new pathway for the release of DMSP from coralline algae
 - M Burrows: Wave fetch, tidal flow and ocean colour as influences on subtidal rock communities
 - M Wilkinson: Seaweeds on Microtidal Shores and in Sealochs in relation to Water Framework Directive Classification
 - D Mayor: Food quality affects carbon cycling in deep-sea sediments

- D Russell: Linking breeding and foraging regions in a spatially segregated population
- 3.35-4.05 Coffee
- 4.05-5.40 Marine Systems & Dynamics: Science Session (Chaired by Dr J. Hansom)
- W Ritchie: The Scottish Coastline: Variations and Research Priorities
 - L Boehme: Animal platforms for monitoring marine systems, dynamics and habitats
 - A Cunningham: Light penetration, stratification and photosynthesis in Scottish sea lochs
 - S Hughes: Physical variability in Scottish Waters: examining variability in the last decade (2000-2009) in the context of long term decadal and multidecadal variability
 - N Kamenos: Enhanced summer warming in the East Atlantic over the last 650 years and the response of marine zooplankton
 - C Macleod: Using An Ecological Theory-Based Framework To Model How The Distributions Of Marine Species Are Likely To Respond To Future Changes In Climate
- 5.40-6.10 Market Opportunity and Commercialisation (Elaine Morrison and Clive Reeves, Scottish Enterprise)
- 6.10-6.20 Day One Closing Remarks (Prof David Paterson)
- From 6.30 Posters, Bar & Buffet. There will be in excess of 60 poster presentations.

Day 2: Tuesday 23rd August 2011

- 9.00-9.30 Invited Speaker: Prof C. Heip (Royal Netherlands Institute for Sea Research)
"Marine Biodiversity & Climate Change in Europe"
- 9.30-11.05 Productive Seas: Science Session (Chaired by Dr A. Hughes)
- G Bell: The development of new aquafeed ingredients: Effects of "alternative feeds" replacing fishmeal and fish oil (FM & FO) with plant-based alternatives in Atlantic salmon (*Salmo salar*)
 - R Houston: Genetic marker discovery using RAD sequencing and application to improve disease resistance in aquaculture
 - N Salama: Sea lice dispersal in Loch Linnhe
 - J Zou: Characterisation of the interferon (IFN) gene locus in rainbow trout *Oncorhynchus mykiss* reveals remarkable complexity of the IFN system in salmonids
 - I Boyd: Accounting for the needs of dependent species in harvest rules for forage fish

- C Gollety: Effect of *Ascophyllum nodosum* harvesting on biodiversity and ecosystem functioning
- 11.05-11.35 Coffee
- 11.35-12.35 Productive Seas: Science Session (Chaired by Prof J. Side)
- K Alexander: Interactive Marine Spatial Planning: Siting tidal energy arrays at the Mull of Kintyre
 - C Carter: Mapping underwater ambient noise in the Sound of Islay tidal-stream flow: a potential tidal energy extraction area
 - C Sparling: Behavioural changes among harbour seals (*Phoca vitulina*) around an operational tidal turbine
 - B Wilson: Are tidal-stream energy sites also porpoise hot-spots?
 - Mike Weston: Introducing the International Conference on the Environmental Interactions of Marine Renewable Energy Devices.
- 12.45-1.45 Lunch & Networking opportunities
- 1.45-2.45 Clean & Safe: Science Session (Chaired by Dr M. Russell)
- D Lusseau: Population consequences of whale-watching disturbances on cetaceans
 - C Harris: Quantifying the effects of noise associated with marine renewable energy developments on marine mammals
 - J Dobson: Assessment of Eutrophication in Scottish Marine Waters
 - C Robinson: Towards an integrated assessment of marine environmental status using monitoring of contaminants and their effects in mussels (*Mytilus edulis*)
- 2.45-3.15 Coffee
- 3.15-4.00 Governance Discussion Session (Prof D Paterson & T Stojanovic)
- T Stojanovic: The development of a governance baseline for Scottish coasts and seas
- 4.00-4.45 Executive Panel session and JRT discussions (led by Prof D Paterson)
- 4.45-5.00 Conference Closing Remarks & Student Poster Prize Giving (Prof David Paterson)
- 5.10-6.10 Posters & Bar. There will be in excess of 60 poster presentations.
- 7.30-late ASM Conference Dinner

Abstracts for Oral Presentations

Invited Speaker: Dr John M Baxter (Principle Advisor, Marine Ecology)



MARINE RESEARCH: Making it relevant in 2011

The days when the topic of research could be whatever took one's fancy are gone. The pressures on resources and the drive for ever greater value for money means that more and more research has to have an applied component.

Over the last 20 years there have been an increasing number of drivers that have focused attention on the marine environment. The need to comply with the EU Habitats Directive was the first, followed by the Water Framework Directive and then more recently the OSPAR Biological Diversity and Ecosystem Strategy, the Marine Strategy Framework Directive and the Marine (Scotland) Act 2010. If the aspirations/commitments under these various drivers are to be met there are a lot of questions that need to be answered.

Scotland's Marine Atlas highlights the main pressures on marine habitats and species and identifies where there are issues with their current state.

Through MASTS and the combined resources it commands there is a critical mass of marine research expertise that can be called on. It is important that everyone (the researchers, the customers (decision makers and policy advisers), and funders) work together to deliver what is needed.

- The customers need to understand the constraints in undertaking research, the costs involved, the risks, and the academic priorities and pressures.
- The scientists need to understand the requirements of the customer, the need for clear, timely answers to questions and the need to give informed advice on the basis of the best available information.
- The funding councils need to understand the nature of these new ways of working, adapt their criteria and rationale when awarding funding accordingly.

Healthy & Biologically Diverse

A Fish Migration Data and Information resource: The Living North Sea Project Web-GIS

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Abstract: The Living North Sea (LNS) project (www.livingnorthsea.eu) is funded by the European Interreg North Sea Program and seeks to identify key issues and solutions for fish migration. Fifteen partners are working on re-connecting the rivers and deltas around the North Sea region. The project focuses on addressing knowledge gaps about fish populations that depend on free movement between the North Sea and freshwater systems; provision of innovative fish migration measures; collaborating with local water management authorities and policy makers; and creating greater public awareness about the Living North Sea and its aims and future achievements.

Data and information resources are very important to people and organisations ranging from the general public to the environmental manager. Provision and ease of access to such resources is also important. Internet technology has provided rapid and easy access to multiple and a disparate source of information in many different formats including text, images, video, and sound. Much of this information often has a spatial component and can be presented in the form of maps.

Web-GIS provides the opportunity to make spatial information in the form of maps widely available to the public, government, education and commercial organisations. Web-based Geographical Information Systems (GIS) also provide a powerful means to access spatial information with the added functionality to pan, zoom, and query the information. The LNS Web-GIS is an ongoing element of the LNS project which will provide a data and information resource for fish migration data from sea to source. Datasets provided by the many partners of the LNS project are being prepared to input to the Web-GIS. The web-based spatial information is currently being developed in a number of different formats using

web mapping software such as TimeMap, Mapserver, and Google Earth.

A GIS portal highlights the mapping capability of fish migration in the LNS website. It has been developed to help users quickly and easily access GIS maps, their associated data, and other GIS related information. It is also a one-stop solution for GIS users to access maps related to fish species distribution, migration, river barriers, and migratory patterns in the North Sea region. A key consideration in the development of the Web-GIS will be inclusion of the INSPIRE data directive (<http://inspire.jrc.ec.europa.eu/>) as a guideline for metadata and the data model to ensure compatibility of the multiple sources of geospatial datasets. This paper presents an overview of the LNS project with a special focus on the development of a web-based GIS.

Ecosystem limits to fisheries yields from the North Sea simulated with an end-to-end food web model

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Abstract: Most estimates of maximum sustainable yield, upon which fisheries management targets are partly based, assume that productivity and predation rates are constant in time or at least stationary. This means that there is no recognition of the potential for interaction between different fishing sectors. Here, an end-to-end ecosystem model is developed to explore the possible scale and mechanisms of interactions between pelagic and demersal fishing in the North Sea. The model simulates fluxes of nitrogen between detritus, inorganic nutrient and guilds of taxa spanning phytoplankton to mammals. The structure strikes a balance between graininess in space, taxonomy and demography, and the need to constrain the parameter-count sufficiently to enable automatic parameter optimization. Simulated annealing is used to locate the maximum likelihood parameter set, given the model structure and a suite of observations of annual rates of production fluxes between guilds. Simulations of the impact of fishery harvesting rates showed that equilibrium yields of pelagic and demersal fish were strongly interrelated due to a variety of top-down and bottom-up food web interactions. The results clearly show that management goals based on simultaneously achieving maximum sustainable biomass yields from all commercial fish stocks are simply unattainable. Trade-offs between, for example, pelagic and demersal fishery sectors and other properties of the ecosystem have to be considered in devising an overall harvesting strategy.

Modelling the Large Fish Indicator: multispecies modelling in support of an ecosystem approach to management

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Abstract: The need for ecosystem approaches to fisheries management, in contrast to existing single-species methods, is now well established. One approach is to use univariate indicators within a pressure-state-response framework. The Large Fish Indicator (LFI), defined as the proportion of the total demersal fish biomass that is attributable to fish with body lengths greater than 40cm, is one such metric which has been shown to be sensitive to fisheries-induced changes. In the North Sea the LFI calculated from the International Bottom Trawl Survey (IBTS) fell from about 0.3 in 1983 to a low of 0.05 in 2001 and then showed a modest recovery as fishing mortality on some stocks has reduced. While the calculation of the LFI from survey data is straightforward, its use in conjunction with models aimed at informing management decisions is much more difficult. Whole ecosystem models generally do not provide sufficient size structure, while community size-spectrum models do not have the species resolution to capture the effects of management decisions on individual stocks. In fact modelling the LFI in full would require coupled length-structured models for an impractically large number of species. We addressed this problem using a computationally efficient “partial ecosystem” model focussed on set of eleven North Sea species which were modelled with full length structure together with a size-spectrum caricature of the rest of the ecosystem. The model was driven by historical time series of fishing mortalities, and the output was used to generate a modelled partial LFI. We show firstly that a partial LFI, calculated from the survey data using the modelled demersal species only, is highly correlated with the full LFI. Secondly we show that the model is able to capture the historical trends in the LFI, thereby demonstrating the feasibility of using partial community models in management scenarios with ecosystem level objectives.

Changing reproductive investment in cod and haddock

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Abstract: Understanding the causes of variation in life history of exploited species is important to the development of appropriate management targets and the evaluation of good environmental status. However, as the expressed traits reflect an interaction between environmental and genotypic influences, assessing the relative contribution of each to variation in the wild is very challenging. This paper reviews recent experimental and comparative field studies designed to disentangle sources of variation in reproductive investment of cod and haddock. Environmental manipulation experiments were used to elucidate the proximate mechanisms underlying maturation. These demonstrated the positive effect of temperature during the maturation assessment window. However, when this information was incorporated into an individual based model simulating temperature dependent growth and maturation, the increasing trend towards early maturation seen in the wild could not be explained. Field applications of the probabilistic maturation reaction norm similarly indicated that there was a downward shift in the lengths at 50% probability to mature (L_{p50}) in haddock and cod that could not be explained from temperature trends. Moreover, the downward trends differed geographically in relation to population structure and long term exploitation patterns. Common environment experiments suggested there was a genetic component to population differences in maturation. Together these findings appear consistent with the concept of fisheries induced selection of maturation schedules.

Investigations of the marine fauna in the closed areas around Rockall: progress in the development of underwater visual survey techniques

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Abstract: The number and area of protected seas is set to increase under various international commitments. Due to the destructive nature of traditional fish sampling methods, such as bottom trawling, new methods are required to survey the marine fauna in these areas. Visual surveys allow for non-invasive sampling of the marine environment, but typically they are conducted in shallow waters and cover short distances. Many of the new marine protected areas are distant, very large, and in deep water, such as those around the Rockall plateau west of Scotland, which are closed to protect habitats of the deep-water coral *Lophelia pertusa*. Marine Scotland Science has developed visual survey methods to estimate the abundance of anglerfish (*Lophius piscatorius*), a valuable commercial fish species which is sparsely distributed in and around these closed areas. A towed video chariot was deployed at depths of over 300 m and speeds of up to 5 knots, equipped with lights and cameras to enable visual surveying. This paper describes the visual survey methods employed to survey anglerfish and reports on some of the results obtained to date. Estimates of anglerfish density are comparable to those obtained from traditional trawling methods. The visual method has the additional benefit of providing information on the abundance and distribution of other marine fauna such as the deep-water corals. The latter application is in development and will require some image analysis techniques to quantify the area occupied by the coral. These and other potential improvements are discussed in the light of future work to develop effective optical technologies for surveying marine fauna.

Associated ichthyofauna of cold water reefs: observations from baited photographic lander deployments

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Abstract: The permanent closure of the Darwin Mounds, approximately 100 nautical miles (190 km) north-west of Cape Wrath, to bottom fishing represented the first offshore Marine Protected Area (MPA) in the United Kingdom and the first European Commonwealth example of an offshore fisheries closure for nature conservation (rather than fish stocks). This set the legal precedent for the protection of other sites within Europe and led a way of navigating the complex interaction between fisheries and conservation legislation. Currently the EU is focusing on ecosystem based management; spanning the breach between conservation and fisheries management. Fishermen themselves have commented that destruction of a cold water reef has noticeable impacts on fishing success in that area.

Oceanlab's BRIL (Biogenic Reef Ichthyofauna Lander) was designed specifically to study how deep reef forming corals can influence fish assemblages. By deploying BRIL in reef and non-reef areas comparisons can be made between fish species assemblages, localised abundance and fish size. BRIL has generated a unique dataset after deployments in three distinct European sites: Eastern Norwegian Sea, Porcupine Seabight/Rockall Trough and Ionian Sea. These sites, intended as representative of the variation seen in European cold water reefs, may allow comparison not only between reef and non-reef habitats but also between Europe's reefs. This presentation will outline the preliminary findings of these lander deployments.

This research forms part of the EU FP7 CoralFISH project.

Application of proteomics to assess the impact of ocean acidification on marine organisms

Authors: P Donohue (1), H Burdett (1), E Aloisio (2), P Calosi (2), H Findlay (3), S Widdicombe (3), M Cusack (1) & N Kamenos (1,4)

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Abstract: All living organisms respond to environmental changes through changes in the expression of multiple genes and proteins. Ongoing environmental changes, in particular decreasing ocean pH (ocean acidification or OA, as a result of increasing seawater pCO₂), represent additional environmental stimuli which may induce expression changes in marine organisms. Maerl (red coralline algae or rhodoliths), *Lithothamnion glaciale*, are a marine biogenic calcite which is likely to be structurally very sensitive to increasing seawater pCO₂. Significantly, maerl performs a crucial role in maintaining marine biodiversity, ecosystem provision and impacts on the climate system including cloud nucleation and ozone stability. Therefore any OA induced changes at the molecular level, in particular expression changes related to the biomineralisation, may have an unprecedented impact on marine ecosystems. Here we examined the maerl proteome under control conditions (seawater pH 8.0, T = 12 °C, Salinity 35) and analysed quantitative expression changes of distinct proteins known to be involved in biomineralisation, in response to acidified conditions (pH 7.7). This study presents evidence of how OA may affect this calcifying marine organism based on molecular level analysis and highlights the benefits of using this systems based approach to investigate the effects of OA in marine systems.

The trophic dynamics of *Nephrops norvegicus* are found to differ between two fishing areas off the West coast of Scotland; A cautionary tail!

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Abstract: The Norway lobster *Nephrops norvegicus* is a benthic decapod crustacean that is both a scavenger and an active predator. This talk will describe the trophic dynamics *N. norvegicus* populations in relation to environmental variables, both spatially and seasonally within two West of Scotland *Nephrops* fishing grounds. Stable isotope analysis and fatty acid analysis have been used alongside other techniques as nutritional indicators for this species. These results are considered in relation to the food sources available in different sites and seasons. They indicate that there are differences in both $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ between the sites, and that these differences apply to a range of species occupying different trophic levels. Fatty acid concentrations in *N. norvegicus* also indicate that the North Minch has greater prey diversity than the Clyde Sea Area. Certain biotic and abiotic factors are considered to explain these differences.

The Mingulay reef complex: approaching a decade of research into the ecology of Scotland's only known inshore cold-water coral reef

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Abstract: Cold-water framework-forming corals can form appreciable deep-water biogenic reefs that persist for millennia and provide habitat for highly diverse animal communities. This talk will review interdisciplinary study of one such reef complex formed by *Lophelia pertusa* in the northeast Atlantic Ocean. The Mingulay reef complex was first mapped using multibeam echosounder in 2003 with further mapping in 2006 revealing previously unknown live reef areas. Habitat characterisation with seabed video confirmed distinctive mounded bathymetry was formed by reefs of *L. pertusa* with surficial coral debris dated to almost 4000 years BP. Benthic lander and mooring deployments revealed two dominant food supply mechanisms to the reefs, a regular rapid downwelling of surface water delivering pulses of warm fluorescent water and periodic advection of high turbidity bottom waters. Closed chamber respirometry studies suggest *L. pertusa* may respond to periodic seawater warming with rapid increases in metabolic rate. By integrating information from geophysical surveys of the seabed with the hydrographic surveys of the water column we have been able to examine the factors important in determining the occurrence of attached epifaunal species across the Mingulay reef complex and how these may be used to explain beta turnover (species turnover) in cold-water coral habitats. This analysis supports environmentally deterministic (niche) over random stochastic (neutral) processes as important in controlling beta diversity. Future studies to record Holocene reef development at Mingulay from vibro-cores collected through the reef mounds are now underway and the Mingulay coral reefs are currently being considered as a future conservation area.

Low pH induces a new pathway for the release of DMSP from coralline algae

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Abstract: The release of dimethylsulphoniopropionate (DMSP) by marine algae has major impacts on the global sulphur cycle and may influence local climate through the formation of dimethylsulphide (DMS). However, the effect of global change on DMSP/DMS (DMS(P)) production by algae is not well understood. This study examined the effect of low pH on DMS(P) production and epithelial cell morphology of the free-living red coralline alga *Lithothamnion glaciale*. Three pH treatments were used in the 80 day experiment: (1) current pH level (8.18, control), (2) low, stable pH representing a 2100 ocean acidification scenario (7.70) and (3) low, spiked pH (7.75, with a 3-day spike to 6.47), representing acute variable conditions that might be associated with leaks from carbon capture and storage infrastructure, at CO₂ vent sites or in areas of upwelling. DMS(P) production was not significantly enhanced under low but stable pH conditions, indicating that red coralline algae may have some resilience to OA. However, intracellular and water column DMS(P) concentrations were significantly higher than the control when pH was low and spiked. Cracks were observed between the cell walls of the algal skeleton in both low pH treatments. It is proposed that this structural change could cause membrane damage that allows DMS(P) to leak from the cells into the water column, with subsequent implications for the cycling of DMS(P) in coralline algae habitats.

Wave fetch, tidal flow and ocean colour as influences on subtidal rock communities

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Abstract: Community assemblages on subtidal rock change markedly along gradients of wave energy, tidal flow and turbidity. The importance of these assemblages for rare and delicate species, for shellfish, as nursery areas for fish and for their contribution to ecosystem functioning in coastal areas has long been recognised, and much assemblage data has been collected in the UK to support conservation. To derive site-specific conditions for subtidal biodiversity records, I applied a rapid method of calculating a large high-resolution (200m scale) map of wave exposure <5km from the UK coastline. Satellite-derived estimates of ocean colour, influenced by phytoplankton and suspended sediment, and tidal flows from hydrodynamic models were also extracted for each site. Regression analysis on community ordination scores showed species composition and abundance shifting from algae to suspension feeding animals with depth and in areas of high chlorophyll and tidal flow, and a major shift in the assemblage along wave action gradients: from delicate forms in wave-shelter to robust species able to take advantage of the high flows found in wave-exposed communities. The strongest positive influence on species diversity was found to be the presence of the kelp, *Laminaria hyperborea*: sites with 0% cover had a median of 6 species, while those with >40% cover had a median of 22 species. *L. hyperborea*, and thus the most diverse communities, are found in areas of estimated low chlorophyll concentrations and in the most wave-exposed environments, which are often but not always in areas of high tidal flow.

Seaweeds on Microtidal Shores and in Sealochs in relation to Water Framework Directive

Classification

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Abstract: The monitoring tool adopted by the UK for quality assessment of intertidal rocky seashores for the EC Water Framework Directive is based on seaweed biodiversity. It uses the number of species present under specified conditions, modified for the subhabitat diversity, together with supporting elements of the proportions of species in different colour groups, as known opportunists, and in certain functional groups. A high quality shore would be expected to have a large number of species. On some Scottish shores a possible anomaly arises where shores of expected high quality have a naturally low number of species. In this situation a small change in the species proportions in the supporting elements, due to chance, can have a disproportionate effect on the calculated quality rating and give a possible misclassification of the shore. These situations are (i) the microtidal shores of part of Islay and Kintyre, with spring tidal range less than 1m, and (ii) the rocky intertidal of some sealochs. These habitats and their seaweed communities are described and examples given to substantiate this argument. Not all microtidal shores present a problem as will be shown by considering the physically different microtidal shores of County Antrim which are not species poor.

Food quality affects carbon cycling in deep-sea sediments

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Abstract: Deep-sea sediments cover >70% of Earth's surface. They represent an interface between the biological- and geological-cycles of carbon, sequestering megatonnes of organic material annually. Concentrated pulses of highly labile unicellular algae and refractory zooplankton faecal pellets are both reported to reach the deep seabed following the collapse of the spring bloom in surface waters. These organic substrates differ markedly in their biochemical composition or 'quality'. Very little is known about how food quality affects the rates and pathways of organic carbon cycling in deep-sea sediments. This study examined how equal quantities of 'high quality' diatoms and 'low quality' copepod faecal pellets affected carbon mineralization and growth by deep-sea sediment-dwelling animals and bacteria. Identical experiments were conducted in May and October to examine seasonal differences in the biological response. Diatom-derived carbon was always mineralized ~3 times faster than faecal pellet-derived carbon without concomitant increases in growth. Bacteria dominated the biological carbon uptake in all experiments. Counter-intuitively, high-quality food consistently resulted in lower bacterial growth efficiencies. These results illustrate that bulk organic carbon flux is not necessarily a good predictor of carbon mineralization rates in deep-sea sediments. This study demonstrates how little we know about the mechanism(s) governing the balance between carbon sequestration and mineralization in one of the largest habitats on Earth.

Linking breeding and foraging regions in a spatially segregated population

Authors: D Russell, B McConnell, C Duck, C Morris & J Matthiopoulos

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Abstract: In species which have potentially spatially segregated foraging and breeding regions, linking these regions is key to the successful management of populations. Such linkages are a pre-requisite to understanding how poor foraging performances or disturbances in the non-breeding season may be manifested in the breeding population. Grey seals (*Halichoerus grypus*) breed in aggregations and the link between the areas in which they forage and breed is not known. Currently, understanding potential disturbances caused by development of at-sea structures on marine mammals, such as seals, is of high priority. This is especially important given that some grey seal breeding grounds have been designated Special Areas of Conservation (SACs). However, currently we do not know the proportion of animals in foraging regions which are affiliated with an SAC and thus protected under European legislation. Here, we develop a hidden process Bayesian framework to estimate the transition probabilities, and surrounding uncertainty, between four foraging and breeding regions. To do this we use two types of data, population estimates and telemetry data. We discuss the transitions probabilities and what implications they may have.

Marine Systems & Dynamics

The Scottish Coastline: Variations and Research Priorities

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Abstract: Recently estimated to be 18,000km long with only 307km of defensive structures, the coastline is overwhelmingly natural and remarkably varied. It is also composed of mainly inherited landforms that are changing very slowly, sometimes imperceptibly. Sometimes described as "hard and/or high" and found in the full range of energy settings, these prevalent types contrast with relatively less extensive "soft and/or low" shorelines that presently contain most economic activity and population centres. Irrespective of its taxonomy, every coastline responds within a range of timescales to 7 factors, summarised as Geology, Land Processes, Marine Processes (mainly wave driven), Sediment Supply, Sea Level Changes, Biological Factors and Human Interference. Exposure to waves as modified by bathymetry are the key variables, especially for the more mobile shoreline types. This "any coast" factor analysis approach (which is clearly a mixture of independent and dependent variables) provides a systematic method to attempt to understand and explain present-day geomorphology and possible future trends.

On local and regional scales coastal "problems" and "opportunities" abound, and most need some level of geomorphological input, especially if there is a need to consider adaption and change scenarios. Arguably, within the MASTS research strategy, three general areas seem to be of particular importance, i.e. Where rivers meet the sea (at all scales); More quantitative methodologies (including more attention to statistical and accuracy parameters); Coastal intervention and engineering (especially soft solution methods).

Examples from around the coastline will be used to illustrate the interaction of the key factors and to provide a brief explanation for the selection of the priority research areas.

Animal platforms for monitoring marine systems, dynamics and habitats

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Abstract: Over the past decade, miniature electronic data recorders and transmitters have revolutionized the way we study marine animals. Only very recently, animal-borne instruments have also been designed and implemented that provide in situ hydrographic data from parts of the oceans where little or no other data are currently available (even from beneath the ice in Polar Regions). Ocean data is delivered from animal-borne instruments via satellites in near real-time to operational centres enriching the Global Ocean Observing System. Here, we describe the only animal-borne instrument capable of recording and transmitting temperature, conductivity, pressure, oxygen and fluorescence profiles in near real-time. It is designed, built, tested and made available to researchers world-wide by the SMRU Instrumentation Group at the University of St Andrews. Because we now have enough information for many marine species to predict where they will go (within reasonable limits) and can direct sampling effort to particularly interesting and productive regions and maximize data return, these instruments can target particularly data poor regions. For example, we have now delivered more than 250,000 CTD profiles from poorly sampled Polar Regions, often where no other data existed. Examination of the geographical coverage emphasizes how this animal platform data complements other sources. Marine mammals have provided >70% of all CTD data available south of 60 degrees; their coverage of the Arctic is also growing rapidly. We discuss some of the pioneering studies in the Polar Regions, but also around the UK to show, how biologging devices can play an important part in monitoring Scotland's Seas providing essential information about changes in climatic conditions, marine and coastal habitats and marine mammal populations.

Light penetration, stratification and photosynthesis in Scottish sea lochs

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Abstract: The fjordic waters of the west coast of Scotland are economically important, ecologically vulnerable, and physically very different from other UK coastal regions. One of their distinctive features is the inflow of relatively high volumes of fresh water into bodies which have restricted interchange with the open sea. This creates hydrographically and optically complex structures which present considerable challenges for the formulation of coupled hydrodynamic/ecosystem models of this region. A particular challenge arises in quantifying relationships between freshwater input, the spectral nature of the underwater light field, and the ability of phytoplankton cells to utilise this light for carbon fixation. This talk presents results from a programme of in situ measurements, ship-board radiocarbon incubations and radiative transfer modelling in these waters which gives some insight into the factors that have to be taken into account in formulating such relationships. As part of this work, a semi-analytical model of the dependence of euphotic depth on the concentrations of optically significant seawater constituents has been developed and tested. The results provide interesting insights into physical constraints on the distribution of primary productivity in fjords and adjacent coastal waters. They also provide tools for predicting the effect of increased coastal erosion and river flows on the productivity of shelf sea ecosystems, and are therefore relevant to concerns regarding the response to increased regional temperatures of northern shelf seas.

Physical variability in Scottish Waters: examining variability in the last decade (2000-2009) in the context of long term decadal and multidecadal variability

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Abstract: The Scottish coastal long term monitoring project is a multidisciplinary project aimed at developing an understanding of ecosystem variability in Scottish coastal waters. Using monitoring data at more than 12 stations around the coast of Scotland supplemented with additional meteorological and oceanographic datasets, variability in the last decade is examined and the key drivers discussed. The data are analysed to determine how the temporal patterns of variability at each site relate to the key drivers (oceanic and atmospheric forcing or local forcing such as river runoff). Four of the coastal monitoring stations are very long (25 years+) which allows the recent observations to be put into context of the longer term variability in coastal waters and further offshore. Comparison of the coastal data from Scottish Waters is made with timeseries of data from across the North Atlantic, gridded sea surface temperature (SST) datasets and modelled datasets. The variability measured at shallow water coastal sites is compared to the patterns of broad scale variability observed across the region and data are analysed to show how the temporal and spatial pattern of variability in both temperature and salinity relates to our understanding of ecosystem change over the same time period.

During the decade 2001-2009 sea temperatures in Scottish waters were higher than normal with maximum temperatures observed in 2003. Salinity shows marked inter-annual variability and no clear trend, with 2001 and 2006 standing out as individual years with low salinity. In offshore waters there was a trend of increased salinity over the decade, but this is not seen at coastal stations. In many parameters, variability during the decade was high, particularly in the second half. Large changes occurred from year to year and season to season with little persistence, making it difficult to summarise conditions overall. Marked changes were observed in oceanographic and atmospheric indices during the mid 1990's and as a consequence conditions in the decade of 2000-2009 have been very different to previous decades. Whilst there is no doubt that the atmosphere is an important driver of changes in the ocean, the NAO Index cannot be considered to be a suitable measure of atmospheric variability over the decade of 2000-2009.

Enhanced summer warming in the East Atlantic over the last 650 years and the response of marine zooplankton

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Abstract: Modelling and measurements have shown that Atlantic marine temperatures are rising. However, low resolution of those records 1) masks regional details critical for determining the rate and extent of climate oscillations and 2) prevents robust determination of climatic impacts on marine ecosystems. To address both issues, a fortnightly resolution marine climate record from 1353-2006 was constructed for North East Atlantic shallow inshore waters using a novel proxy and compared to changes in marine zooplankton abundance. Since 1353, summer marine temperatures increased more than winter temperatures. Rising temperatures were characterized by a ~5-65 year temperature oscillations which began in 1700 indicating that such oscillations in climate may only be a recent but widespread phenomenon. Critically, enhanced summer warming led to a fall in abundance of the copepod *Calanus finmarchicus*, a major food item for cod. The abundance of *C. finmarchicus* is projected to be lower in 2040 than at present. Enhanced summer warming appears to affect productivity near the base of the marine food web with potentially significant knock-on effects for marine fisheries during the next few decades.

Using An Ecological Theory-Based Framework To Model How The Distributions Of Marine Species Are Likely To Respond To Future Changes In Climate

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Abstract: Knowing where a species occurs is essential for the successful implementation of most conservation and management strategies. However, climate change is expected to result in distributional changes, meaning that current distributions may not reflect where many species will occur in the future. Thus, it is important for conservation and management to know how the distribution of marine species will respond to anticipated changes in climate. Investigating how species distributions are likely to respond to climate change is not straight-forward. Empirical studies are not a viable option for many, if not most, marine species due to a lack of sufficient data. In contrast, a modelling framework based on ecological theory would provide a better starting point for both understanding how marine species distributions respond to climate change and predicting future species distributions under different climate change scenarios. As well as being easier to develop with the available data, such an approach is likely to be more widely applicable than empirical studies, which can usually only be applied to the region where they were conducted. We demonstrate how such a theory-based framework could be applied using four key Scottish marine species as case studies. Based on key concepts of ecological niche theory, models of species distributions in relation to climate were created, using a combination of physiological, habitat and thermal niche modelling approaches. These models were then quantified for each species using data collected from the northeast Atlantic between 1970s and 2000s. Model performance was then tested using independent contemporaneous data sets for current distribution and by making hindcast of how the ranges of these species responded to climatic variability between 1930 and 2010 in this region. In addition, we show that these models can be successfully applied not just to the northeast Atlantic but throughout the ranges of individual species. Thus, we demonstrate that such models can markedly outperform empirically-derived models. Once the predictive ability of such models has been validated, they can confidently used to make prediction of likely future distributions of each species under different climate change scenarios, and so provide the type of information on likely future distribution of marine organisms required to incorporate the likely impacts of climate change into conservation and management strategies.

Invited Speaker: Prof Carlo Heip



ROYAL NETHERLANDS INSTITUTE FOR SEA RESEARCH



Marine Biodiversity and Climate Change in Europe

Two of the main challenges facing human society (and the biosphere) in the next decades are biodiversity loss and climate change. Both have received intensive scientific and societal attention over the last years and an extensive literature now exists addressing the main observations, models, consequences and mitigation and adaptation strategies. In the marine environment changing patterns of temperature, currents, global weather patterns and so on are now reasonably well understood and predictability of their future change has increased substantially, with less but still large uncertainty. At the same time it is recognized that besides indirect impacts from climate change also direct human impacts extend far beyond coastal areas and now cover large parts of the oceans. These impacts through fisheries, transport, pollution, acidification and so on will also change with the changing climate and the very rapid and important developments in the socio-economic environment of the last decade: the increasing wealth and consequent increased ecological footprints of newly industrialized nations, with different cultural backgrounds and life styles, the changing maritime transport due to the melting of the arctic ocean ice in Summer and the enlargement of the Panama canal, the increased exploration of deeper waters for living marine resources, oil, gas, minerals and perhaps gas hydrates in the future, blue biotechnology and so on.

Understanding the drivers of change and evaluating their effects is important but at the same time the exploration of existing marine biodiversity is still going on with new discoveries being made all the time. The links between the large scale changes in the marine environment and the changes in marine biodiversity due to the multitude of factors described above are therefore still difficult to predict. Moreover, changes in phenology and life cycles of key species, in community composition with changing dominance patterns and regime shifts, in dispersal rate and susceptibility to invasions, in food web structure and so on, as linked to climate change, will have different and often contrasting effects on ecosystem functioning. As this is the case, and prediction of the future state of biodiversity from first principles is probably impossible, the need for adequate monitoring of the marine environment becomes all too evident. European and global efforts for monitoring of biodiversity are in their infancy, but the political interest still exists and the scientific support should be strong and adequate.

Productive

The development of new aquafeed ingredients: Effects of “alternative feeds” replacing fishmeal and fish oil (FM & FO) with plant-based alternatives in Atlantic salmon (*Salmo salar*)

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The continuing growth of aquaculture production globally, as well as continued expansion of salmon production in Norway and Scotland, has led to concerns regarding supply of traditional marine-derived raw materials, namely fish oil (FO) and fishmeal (FM). For that reason, recent research activity has been directed towards reducing reliance on these finite and limiting marine products and investigating the potential for alternative raw materials, particularly those derived from terrestrial plant products (PP). Recent EUFP5 & 6 projects have established that salmon can be grown on reduced levels of either FO or FM without reducing growth performance. However, when both FO and FM are reduced and replaced with maximum levels of vegetable oil (VO) and PP some reduction in growth was observed. This effect may be due to an imbalance of micronutrient minerals and vitamins due to FO & FM replacement. However, using such maximum replacement diets with low FM and high PP, salmon can be a net producer of marine protein. One benefit of reducing FO & FM as well as the use of decontaminated FO in fish feeds is a reduction in the flesh deposition of persistent organic pollutants (POPs). While plant products can replace FO & FM other Omega 3-rich products have also been studied in feeding trials including the use of algal meals and oils. Currently the low availability of FO & FM is leading to supply problems for feed producers. For that reason a number of genetically modified plant products are being developed as potential sources of Omega 3 fatty acids. In addition, UK grown legumes are being considered as replacements for other protein sources, including FM and imported soya products.

Genetic marker discovery using RAD sequencing and application to improve disease resistance in aquaculture

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Abstract: Next-generation sequencing technology is providing new opportunities for genome characterisation and the high resolution mapping of economically important traits in farmed species. Restriction-site associated DNA (RAD) sequencing is a method of genome-wide sampling that can rapidly provide high-throughput SNP marker detection and simultaneous verification in genomes with or without a reference sequence. We have applied this method to Atlantic salmon from a commercial breeding program with resistant or susceptible genotypes at a major disease resistance QTL. The initial results indicate the discovery of tens of thousands of putative markers, including several novel SNPs linked to the QTL. Experiments are underway to further verify these markers, and to perform population-wide screening of QTL-linked SNPs.

Sea lice dispersal in Loch Linnhe

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Abstract: Farmed aquaculture in Scotland produces some 144,000 t of Atlantic salmon (*Salmo salar*) and is Scotland's most valuable food export with an estimated contribution over the last two years of £1 BN towards the economy, and providing important employment in remote and island communities. Sea lice are ubiquitous, ectoparasitic copepods in marine environments. In Scotland, salmon and sea trout (*Salmo trutta*) are predominately affected by the specialist louse *Lepeophtheirus salmonis* and the more generalist species *Caligus elongatus*. High parasitic loads can lead to diminished health status for both farmed and wild fish, therefore €33 M is spent annually controlling lice by the aquaculture industry in Scotland. In order to understand the transmission of lice within the marine environment between salmonid populations it is important to understand their dispersal patterns to determine how such host and parasite populations may interact.

Previous work by Marine Scotland Science has demonstrated that it is possible to estimate dispersal patterns of sea lice in a small fjord like system (Loch Torridon), using coupled biological and oceanographic models. We have therefore applied similar principles to develop a model for the larger, more complex Loch Linnhe system. This system spans some 60 km from the mouth at the Sound of Mull and Firth of Lorn to the head at Loch Eil and contains ten fish farms with a combined consented production biomass of 13270 t operated by two companies.

The hydrodynamic model output was produced by the Scottish Association for Marine Science (SAMS) using a 100 m horizontal resolution Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) model forced by the predominant south-westerly winds, tides, and freshwater inputs from rivers and adjoining lochs. The movement vectors were used in a particle-tracking model to transport particles representing sea lice from sources. As the louse particles are

transported they mature from passively dispersed non-infective nauplii to become infectious copepodids as a function of temperature and suffer mortality with time and a natural decay term. This allows for transmission distributions to be obtained under constant wind forcing.

The modelled distributions were used to provide information for planning lice sampling locations for validation of the model predictions. Thirty plankton sampling stations were highlighted as well as ten sites for sentinel cage moorings. The biological sampling of the lice population was conducted in May 2011 along with recordings of the physical environment at various locations to enable further hydrodynamic development and validation. Initial results indicate that the lice larvae can be transported over distances of up to 30 km from their source, before becoming infectious. The route of transportation also demonstrate that it is not necessarily the case that nearest neighbour sites are interacting, and that long distance interactions can occur.

Further sampling is planned for autumn 2011 as are additional modelling scenarios based on variable wind directions. Additional model scenario predictions will be assessed using further sampling in the upcoming years. Acoustic tracking of wild salmonids is being undertaken in order to assess where wild fish and lice may interact. The model will be used to evaluate where concentrations of lice occur under recorded environmental forcing and to provide advice on the management of salmon farms through testing a range of production scenarios on sea lice dispersal.

Characterisation of the interferon (IFN) gene locus in rainbow trout *Oncorhynchus mykiss* reveals remarkable complexity of the IFN system in salmonids

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Abstract: Virus diseases represent a significant threat to the aquaculture industry worldwide, with many well known and problematic diseases of salmonids. We are still learning about the complexity of fish antiviral responses, and until this is achieved it is difficult to predict ways that might enhance disease resistance by modulation of such genes or pathways. One of the important groups of molecules involved in antiviral defences in vertebrates generally are the interferons. We now know that teleost fish possess multiple type I Interferons (IFNs) that are induced after viral infection and exhibit conserved antiviral properties. They are secreted peptides with comparable molecular size to their counterparts in higher vertebrates and act on the target cells via their surface receptors. They can be divided into two subgroups; group I and II type I IFNs, based on the position of the cysteine (C) amino acid residues that are involved in formation of intracellular disulphide bonds. Group I IFNs containing 2 cysteines (C1 and C3) and are universally present in all teleost species, whilst to date group II IFNs containing 4 cysteines are found in only salmonids and cyprinids. Recent studies have shown that the IFN genes have been extensively expanded in salmonids, with more than 12 genes identified in the Atlantic salmon. The salmonid IFNs can be divided into four phylogenetic groups, named IFN-a, -b, -c and -d, where IFN-a and -d are group I IFNs and IFN -b and -c belong to group II IFNs. In this study, we have characterised two new groups of IFNs in salmonids, named IFN -e and -f, by sequencing the IFN loci in the rainbow trout genome, and analysed their expression in fibroblast like and macrophage like cell lines in response to stimulation with a viral mimic (poly I:C). Our data demonstrate that the IFN system of salmonids is more complex than previously realised.

Accounting for the needs of dependent species in harvest rules for forage fish

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Abstract: Some long-term studies of marine predators, mainly seabirds and seals, have revealed relationships between prey density and indices of predator performance. Information from several marine ecosystems of the world indicate functional relationships between predator performance and food availability. These functional relationships generally exhibited non-linearity and it may be possible to define thresholds, or tipping points, in these relationships. These are caused in part by the behavioural plasticity of predators that allows them to harvest sufficient food above some threshold of prey density. Below the threshold, predators have difficulty obtaining sufficient food and this is reflected by rapid changes in demographic or foraging parameters. These non-linear functional relationships thresholds are a fundamental feature of predator-prey relationships that may be used to quantify the minimum forage fish biomass needed to sustain marine predators. They could provide precautionary reference points above which prey abundance should be maintained by fisheries managers. A remaining challenge is to move beyond simple empirical determination of these relationships to ones that are grounded in theories of foraging and energetics.

Effect of *Ascophyllum nodosum* harvesting on biodiversity and ecosystem functioning

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Abstract: First, a study of the metabolism of *Ascophyllum nodosum* canopy-dominated shores, measuring the CO₂ fluxes at the rock-air interface, showed that the canopy formed by *A. nodosum* and its epiphytes is always responsible for over 75% of both the benthic community gross primary production and the community respiration. Secondly, we tested the effect of the presence or absence of the canopy and the relationship between the diversity associated to the zone and its functioning. *A. nodosum* being a harvested alga, we tested the impact of more or less severe canopy cuts on the algal and animal diversity as well as on the global metabolism of the zone. These elements were thus measured on (1) an intact control zone, (2) a zone where the canopy was cut at 80 cm, (3) a zone where the canopy was cut at 20 cm, and (4) a zone without canopy. This two-year survey showed that an 80 cm harvest does not affect either the algal and animal diversity or the metabolism of the zone. On the contrary, a 20 cm harvest affects the biomass and the density of the canopy as well as the animal diversity during the first year only. On the no-canopy zone, a *Fucus vesiculosus* canopy progressively developed and attained 100% cover after a year and a half. The average length, biomass and density of *A. nodosum* together with the average number of macroalgal species were negatively affected all along the study while the density and average number of the macrofauna did not show any difference with the control after a year and a half. Finally, the global metabolism is comparable between the non-impacted or weakly impacted zones and the no-canopy zones where *F. vesiculosus* replaced *A. nodosum*.

Interactive Marine Spatial Planning: Siting tidal energy arrays at the Mull of Kintyre

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Abstract: Much of the coastline around the world is already committed to a variety of uses. This means that the expansion of offshore activities - particularly offshore renewable energy - are likely to lead to conflict and hence opposition to these developments. This has led to an increased requirement for Marine Spatial Planning, and increasingly this is carried out in the context of the 'Ecosystem Approach' (EA). We demonstrate a novel method to facilitate implementation of the EA. Using a 'touch table' and stakeholder workshops we gathered data and facilitated negotiation of spatial trade-offs at a potential site for tidal renewable energy off of the Mull of Kintyre (Scotland).

Conflicts between the interests of tidal energy developers and commercial and recreational users of the area were identified. Use preference and concerns of local stakeholders were highlighted. Social, cultural and spatial problems associated with conversion of common pool to private resources were also revealed. The method identified important gaps in existing spatial data and helped to fill these through interactive user inputs. The process developed a degree of consensus between conflicting users on the best areas for potential development.

Mapping underwater ambient noise in the Sound of Islay tidal-stream flow: a potential tidal energy extraction area

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Abstract: The deployment of marine renewable devices, particularly in Scotland, is generally expected to accelerate in the near future. Marine renewables are well placed to provide a significant contribution to our energy needs in the future because of the abundance of wave and tidal-stream resource in UK coastal waters. However, one potential barrier to the deployment of tidal-stream devices is the perceived collision risk to marine mammals. Marine mammals have excellent sensory perception and underwater agility, but existing collision parallels have shown that marine mammals - though capable - do not always avoid hazards; fatalities due to ship-strikes and by-catch are well documented. Marine mammals' primary sense is hearing; sound is used for communication, navigation, prey detection and obstacle avoidance. Consequently, this study is the initial stage of an investigation into the acoustic interaction between emerging tidal-stream devices and marine mammals. Suitable areas for the deployment of tidal devices are straits, sounds and headlands where fast moving currents are found. Whilst there is much data regarding ambient noise in deep water, there is very little information describing shallow water tidal-stream areas. This study measured the ambient noise levels in the Sound of Islay on the west coast of Scotland using drifting hydrophones. The drifters were deployed upstream of the survey area and allowed to flow with the tidal-stream. Data were collected on both ebb and flood tides over a four day period. The observed sound levels were then mapped to describe the soundscape. The maps highlight ambient noise heterogeneity in the area. Further work will include investigations to explain the patterns observed and to assess temporal and geographical variations. Ultimately, this will lead to a synthesis of results to inform the debate regarding the collision risk to marine mammals from marine renewable devices.

Behavioural changes among harbour seals (*Phoca vitulina*) around an operational tidal turbine

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Abstract: Scotland's Seas are playing a major role on the world stage with regard to renewable energy and the Scottish Government has set ambitious targets for renewable energy. However, there is a great deal of uncertainty surrounding the impacts of tidal energy devices on marine mammals, in particular the risk of direct collision. As part of ongoing monitoring of the environmental impacts of the SeaGen tidal turbine in Strangford Narrows, Northern Ireland, thirty-six Electronic tags, containing GPS receivers, were glued to the fur of harbour seals (*Phoca vitulina*) in and around Strangford Lough. The deployment occurred in three groups: before (2006), during (2008), and after (2010) the installation of the turbine. Together, they provide the first detailed information on the behaviour of marine mammals close to an operational commercial-scale tidal energy device.

There was no overall difference between the three deployments in the frequency with which seals travelled through the Narrows past the location of the turbine, although inter-individual variation in the extent of transit behaviour was high. Transits generally occurred more frequently during slack water than when the current was running.

In 2010, when the turbine was operational, the frequency of transits by tagged seals was reduced when the turbine was on, relative to when it was off. Although there was some evidence that the transit locations of tagged animals varied between years, indicating a degree of local avoidance of the turbine, no statistically significant effects were detected between years in the distribution of locations at which seals passed the turbine site.

This study shows that the operation of the turbine did not act as a barrier to the seals' movements. The alteration in the behaviour of the seals suggests that models of collision risk based on local animal abundances may require refinement.

Are tidal-stream energy sites also porpoise hot-spots?

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Abstract: Harmful collisions between marine mammals and tidal turbines are a significant environmental concern for this rapidly developing industry. Modelling work suggests that the overlap between harbour porpoises and tidal turbines may be significant but assumes that porpoises use sites suitable for tidal-energy extract equally to other areas. The porpoise literature is split whether these sites might be hot-or cold-spots for this species. In this study we investigate porpoise density in two West of Scotland sites of interest to tidal-stream developers. We used standard survey techniques (visual and acoustic boat surveys and moored porpoise detectors) but redesigned them for use in water that could be moving at speeds similar to vessel speed. Results showed that porpoises, though present, were at very low density in both sites. These findings are discussed in relation to the implications for developments at these sites, implications for other tidal-energy sites and the suitability of existing techniques for working in these habitats. Thoughts on new methodological advances will also be presented.

Introducing the International Conference on the Environmental Interactions of Marine Renewable Energy Devices

Author: Mike Weston

This conference will take place in Kirkwall, Orkney, during the week commencing 30th April 2012.

Relevant subjects include:

- Energy Resources, for example wave, tidal, and meteorological measurements
- Physical and Biophysical Modelling
- Environmental Interactions, for example observations of devices in relation to currents, sediments, benthic and pelagic species, migratory birds and marine mammals
- Studies into disturbance and contamination in ecosystems
- Ecological methodologies and study design
- Marine Acoustics
- Engineering and Technical Challenges - for example concerning moorings, seabed survey, navigation and positioning
- The sustainability of the marine renewables industry, and shaping of national and international policy and regulation
- Socio-economic investigations: for example, regarding community, stakeholder, heritage, archaeological and cultural considerations

Potential contributors should be aware that there is also an ambition to publish a special issue of a peer-reviewed journal after the conference, and authors wishing to have their work considered for inclusion in this should state so clearly when submitting their abstract, and must ensure that they subsequently produce material of a suitable standard.

Abstracts should consist of a one-paragraph summary (ca. 100 words), a list of 3-5 key words, the contact details of all the authors, and a correspondence address. This should be submitted by email to the conference organiser for consideration by the Scientific Steering Committee at eimr@agendaevents.co.uk by 30 November 2011. It is intended that the programme will be finalised by the end of January 2012.

Informal enquiries about the conference may also be sent to the same address.

Clean & Safe

Population consequences of whalewatching disturbances on cetaceans

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Abstract: Humans seeking to observe wildlife in their natural habitat can disrupt the activity of the individuals they target. It has been proposed that these behavioural reactions emerge from animals perceiving a 'stalking' human as a potential predation risk. Animals repeatedly exposed to these interactions, in locations where wildlife tourism is established, have to therefore accommodate for the presence of risk in their habitat and adapt their behavioural ecology accordingly. Whalewatching, taking tourists to see whales and dolphins, is the fastest growing activity in the marine tourism sector. Most coastal cetacean populations on Earth are now exposed to some form of whalewatching in all or part of their home range. Understanding the influence of whalewatching on cetacean population dynamics is therefore important to manage these activities at a global scale.

We are here interested in understanding whether repeated elicitation of these behavioural disturbances can lead to influences on the population growth rate of the targeted species. This question is crucial to understand whether non-lethal human impacts might still influence the conservation status of the animal populations that are exposed to behavioural disturbances.

We combine findings from a number of recent studies on both odontocetes and mysticetes to show that whalewatching interactions disrupt the activity budget of targeted individuals. We show that repeated exposure to these anthropogenic disturbances impairs the energetic budget of

individuals by decreasing foraging opportunities and increasing energy expenditure. When the exposure rate reaches thresholds at which the whalewatching occupied habitat becomes inadequate, individuals will abandon this part of their home range. However, in situations when whalewatching is pervasive throughout the individual's home range, females will stop investing in offspring to meet the added energetic demands; hence, leading to decreased survival of yearling (calving success).

The population growth rate of long-lived, slow reproducing species is most sensitive to the survival probability of adult females. This acts as a selection pressure that shapes the life history strategy and behavioural ecology of these species, females prioritising their survival probability over other vital rates. We argue that we can expect our findings to be general effects of repeated exposure to anthropogenic activity disturbances in such species. While variation in the survival of yearling is less likely to affect population growth rate, the effect sizes we observed can still lead to impact on population trajectories.

Quantifying the effects of noise associated with marine renewable energy developments on marine mammals

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Abstract: Increasing awareness and concern over the impacts of sound in the marine environment has resulted in governmental demands on industrial and military users of the oceans to carry out increasingly comprehensive environmental impact assessments. In 2005, in response to a military initiative, we developed a statistical algorithm (SAFESIMM) for estimating sonar impact on marine mammals. This provides a quantitative evaluation of the risks of sonar exposure to marine mammals, whilst accounting for uncertainties in our knowledge of marine mammal densities and the likely biological consequences of exposure to sound. Our solution is a general framework comprising of a sound propagation model, a simulation model and databases of marine mammal data. Output from the sound propagation model is combined with probabilistic information on the location of marine mammals through time to give sound exposure histories for simulated animals. These sound exposure histories determine the probability that each individual will suffer a temporary or permanent shift in the threshold of hearing or modification of its behaviour. At the conclusion of the simulation, the probability of impact and the expected number of individuals affected are calculated, with associated uncertainties.

More recently marine renewable developments have raised concerns over impacts of underwater noise on marine mammals. As technologies progress and countries look to supplement energy demands, development is moving closer to shore. In many countries developments are planned within or around the 12 nm territorial waters limit and often multiple, simultaneous developments are planned, giving the potential for cumulative effects. Thus, we are adapting our software to be

relevant over the spatio- temporal scales of coastal renewables developments and the types of sounds produced. We will describe SAFESIMM and illustrate its potential for use in risk assessments through a theoretical representation of a renewables development 12nm from coastal dolphin and seal populations.

Assessment of Eutrophication in Scottish Marine Waters

Authors: J Dobson, C Scanlan, M Baptie & T McCormack.

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Abstract: Eutrophication of marine waters (enrichment of waters by nutrients leading to an undesirable disturbance to the ecosystem) is assessed for several EU Directives (Water Framework Directive, Urban Waste Water Treatment Directive, Nitrates Directive and the recently introduced Marine Strategy Framework Directive) and the OSPAR Strategy to Combat Eutrophication. Assessments are based on an agreed set of criteria which take into account:

- Evidence of nutrient enrichment
- Evidence that nutrient enrichment leads to enhanced algal growth
- Evidence that enhanced algal growth leads to an 'undesirable disturbance' to the ecosystem.

Nutrient enrichment is indicated by a 50% increase above background concentrations measured in winter. Enhanced algal growth is indicated by macroalgae and phytoplankton assessment criteria that have recently been developed for assessment of Environmental Status for the Water Framework Directive. The Macroalgal Bloom (MAB) tool assesses the spatial extent of algal mats on intertidal areas and the phytoplankton tool assesses abundance and species composition.

Symptoms of an undesirable disturbance include organic enrichment of sediments and removal of oxygen by the degradation of organic matter from both sediments and the water column.

Application of these assessment criteria indicate that there is no evidence of enhanced algal growth in Scottish coastal waters but there is evidence of enhanced algal growth the transitional waters of Montrose Basin and the Ythan estuary.

The main source of nutrients in these estuaries is agriculture and they both lie in Nitrate Vulnerable Zones which were designated under the Nitrates Directive (91/676/EEC) in 2002-2003. Action programmes to reduce nitrate inputs are in place in designated Nitrate Vulnerable Zones. Monitoring will continue to assess whether these action programmes are effective in reducing the symptoms of eutrophication.

Towards an integrated assessment of marine environmental status using monitoring of contaminants and their effects in mussels

Authors: C D Robinson (1), M Gubbins (1), B Lyons (2), J Bignell (2), J Thain (2), T Bean (2), L Webster (1), J Dobson (3) & I M Davies (1)

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Abstract: Descriptor 8 of the EU Marine Strategy Framework Directive (MSFD; 2008/56/EC) requires that, in order to achieve Good Environmental Status, "Concentrations of contaminants are at levels not giving rise to pollution effects". The International Council for the Exploration of the Sea (ICES) and OSPAR established a Study Group on the Integrated Monitoring of Contaminants and their Effects (SGIMC) in order to develop methodologies suitable for use in assessing environmental status. This group produced a report (SGIMC, 2011; available from the ICES website) aligned to the requirements of the MSFD & providing advice on how to undertake an integrated assessment of contaminants & their biological effects. This advice was used for an integrated assessment of contaminants and their effects in mussels from the Clyde and Forth estuaries and Firths. Mussels were collected from four sites along expected pollution gradients in the Clyde (2010) & four sites in the Forth (2011) & were transported to a nearby laboratory for examination and sampling. Analyses in mussels included contaminant concentrations (trace metals, PAHs, PCBs, brominated flame retardants), lipid content, condition index, stress-on-stress, genotoxicity (Comet assay), lysosomal membrane stability, histopathology and gametogenesis. Dissolved concentrations of hydrophobic contaminants were determined by passive sampling. Gradients of contaminants & effects were observed for both regions. Available data were compared with recognised Assessment Criteria to determine whether concentrations & responses were close to background, or indicative of contaminant effects. Data for both estuaries/Firths indicate localised areas where significant pollutant effects occur in mussels & hence where the requirements for GES are not attained. The data will be used to demonstrate the approach to conducting integrated assessments on larger spatial scales.

Poster Abstracts

Poster Board 1: **Marine Resource & Biodiversity Economics at SAC**

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Abstract: Since 2008, when the Scottish Agricultural College (SAC) took the lead in valuing the costs and benefits of the UK Marine Bill, SAC has been developing expertise in marine resource economics to complement the already established research emphasis on environmental economics. The primary focus within SAC's marine resource economics team is the definition, classification and valuation of coastal and marine ecosystem services, although SAC has secondary emphases of aquaculture and fisheries economics. Following the research done for the UK Marine Bill, SAC coordinated what is known as the Quantitative Assessment undertaken for The Economics of Ecosystems and Biodiversity (TEEB) project, which involved linking the outputs of bio-physical modelling carried out by the Dutch Environment Agency with environmental valuation, using a large-scale geographical information system. The study determined the benefits and costs to global ecosystems of various global scenarios, such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), an increase in the extent of Protected Areas, trade liberalization, etc. Currently, SAC is leading the economic analysis for the European Project "Options for Developing Ecosystem Based Marine Management" (ODEMM), which focuses on both the definition and valuation of coastal and marine ecosystem services, and on the establishment of regulatory and private sector costs for management-option driven case studies situated across the EU's four regional seas. This poster summarises SAC's marine resource economics research to date, and provides highlights of the recent and complementary environmental economics research being undertaken at SACs.

Poster Board 2: **Succorfish**

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Abstract: The SC2 Succorfish tracking system has been developed in conjunction with Seafish to:

- 1) provide a more affordable alternative to current VMS systems;
- 2) provide access to marine protected areas by monitoring location to within one metre;
- 3) exceed European VMS legislation for 15m+ vessels (and 12m+ vessels from 2012) offer the latest GSM/GPRS technologies and easy to use online interface system; and
- 4) provide E-log ready software for 15m+ vessels and offer very low running costs to users.

Healthy & Biologically Diverse

Poster Board 3: Juveniles connect isolated grenadier aggregations in the NE Atlantic

Authors: J Augley, S Devalla, C Robinson, P J Wright & F Neat
Student?: No

Marine Scotland Science

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Abstract: Endemicity in a deep sea Macrourid species, Roundnose Grenadier (*Coryphaenoides rupestris*) at the scale of bathymetric features, seamounts and banks, was investigated using otolith trace element chemistry. Population structuring at the ocean basin scale has previously been found in this species. However, it is not known whether there is substantial mixing within ocean basins either during the adult or juvenile phases. Otolith material taken from the edge of adult grenadier otoliths was found to have significantly different trace element chemistry between Rosemary and two other areas: Rockall and the edge of the European Continental shelf, such that discriminant analysis classification success was 89%. However, comparisons with otolith sections formed during the juvenile stage suggested that adults from all three areas may have originated from a common pool of juveniles. Hence, whilst adults appeared to remain segregated, presumably due to limited horizontal movements, local adult aggregations were connected by juveniles similar to a Gotelli (1991) 'propagule rain' system.

Poster Board 4: A re-evaluation of the prevalence and seasonality of *Hematodinium* sp. infection in Norway lobsters (*Nephrops norvegicus*) in the Clyde Sea area, Scotland

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Abstract: For the past 20 years an annual mortality of Norway lobsters (*Nephrops norvegicus*) due to infection by the dinoflagellate parasite *Hematodinium* has been reported from the Clyde Sea area (CSA), Scotland. The number of patently-infected animals reaches a peak in the spring, but they are not detectable by visual methods at other times of the year. We present results from a study which aimed at establishing the existence of sub-patent infection between the annual peaks of patency, & to estimate its prevalence, using a combination of immunoassay (ELISA) and molecular (PCR) techniques. Two hypotheses were tested: (1) that infection develops over the months between the peaks of infection, and (2) that sub-patent levels of prevalence matching those at peak patency occur throughout the year. The combined results revealed sub-patent levels of infection throughout the year which were comparable to those at the patent infection peaks in the spring. Logistic regression analysis of these data predicts that size and month of sampling significantly affect the probability of finding infected hosts ($p < 0.01$ and $p < 0.05$ respectively), but that sex does not. It is therefore proposed that the *Hematodinium* sp. infection of *N. norvegicus* in the CSA should no longer be described as a 'seasonal infection', but rather that the patent infection be described as 'seasonally apparent' and it is suggested that infected cohorts carry infection from one year to the next. The new prevalence data have been added to the existing published and unpublished data available for the *Hematodinium* in the CSA, forming an 18 year data series. The implications of these new prevalence data will be discussed in relation to *N. norvegicus* ecology, historical prevalence values & the interaction of infected *N. norvegicus* with fishing gears.

Poster Board 5: **Variation in the phytoplankton community in Scottish waters over the last decade**

Authors: E. Bresnan, S L Hughes, S Fraser, A L Amorim, K Smith, P Walsham, L Webster, B Berx, J Rasmussen & S Hay

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Abstract: Marine Scotland Science operate a long term monitoring station 5 km offshore from Stonehaven in the North East of Scotland (56° 57.8' N, 02 ° 06.2' W). Temperature, salinity, nutrients, phytoplankton and zooplankton are monitored on a weekly basis. A number of changes in the phytoplankton community have been observed since the time series began in 1997. During the early part of the time series the spring bloom was dominated by *Chaetoceros* species however since 2001, dense blooms of this genus are no longer observed and *Skeletonema* has become more abundant. From the beginning of the decade until 2004, chlorophyll values during the spring bloom were reduced. During this period a change in the species dominating the summer *Dinophysis* population was also observed. The dinoflagellate genus *Ceratium* has decreased in abundance since 2000. Variation in the physical/chemical parameters and zooplankton community have also been observed during this time period.

Poster Board 6: **The importance of microphytobenthos in shallow coastal lagoons: a comparative analysis with phytoplankton**

Authors: A C Brito (1), C Facca (2), A Newton (3), T F Fernandes (4), P Tett (5)

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Abstract: Shallow coastal lagoons, especially the ones with clear waters and lighted bottoms, are likely to have large microphytobenthos (MPB) communities. MPB is an important component of these systems, representing up to 99% of the chlorophyll concentration when compared to phytoplankton. It is therefore expected that MPB resuspension plays a key role in the dynamics of phytoplankton due to the tide and wind action.

Water samples were collected twice per month inside and outside Ria Formosa lagoon (Portugal), for nutrients and chlorophyll a (chl a). Sediment samples were also collected for MPB chl a. Samples from Venice lagoon (Italy) were also obtained, at least once per month, for chl a analysis. A truncated Fourier Series was fitted to the data to investigate the seasonal and high-frequency components of the time-series. In the Ria Formosa, the best significant fit for MPB was obtained considering the sum of 26 wave pairs (sin and cosine), which explained 30% of the variability. The seasonal cycle (1-3 waves) explained only 5% of the total variability and the higher frequency temporal variation (4-26 waves) explained 25% of the variability. Fitting 26 waves to MPB means that variability is explained by waves with variation of 14 days. Within-day variability which includes spatial heterogeneity explained 61% of the variability. The best fit for phytoplankton inside the lagoon was obtained considering the sum of 24 wave pairs. Outside the lagoon the best fit was obtained using only the sum of 16 wave pairs. For both cases, the sum of waves explained more than 67% of the variability and the seasonal cycle (1-3

waves) explained more than 33% of the variability. It is expected that primary producers in the water column have a strong seasonal factor due to the direct effect of the solar cycle, which is the case of other clear waters (e.g. in Loch Creran, Scotland). In the Venice lagoon, which has very weak tides, the best fit for MPB was obtained using 10 wave pairs. However, the best fit for phytoplankton was obtained with only 3 wave pairs. The variability of Dissolved Available Inorganic Nitrogen (DAIN) in Ria Formosa was explained by the sum of 26 wave pairs both inside and outside the lagoon, showing no differences in the temporal variation and explaining more than 58% of the total variability. These results clearly suggest the importance of MPB resuspension in the phytoplankton community of Ria Formosa, which is likely to be the consequence of tidal forcing.

Poster Board 7: **The Biodiversity and Ecology of Senghor Seamount (N Atlantic)**

Authors: A Chivers (1), B E Narayanaswamy (1), P Lamont (1), R Turnewitsch (1), A Dale (1) and H Mair (2)

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Abstract: Seamounts are considered unique habitats of the deep sea environment which are likely to contribute significantly to global biodiversity. For this reason, interest in seamount research has gathered particular momentum over the past five years in an effort to understand the physical, geochemical and biological characteristics of seamount ecosystems. Seamounts are often typified by highly rich and diverse communities of predominantly large suspension feeding organisms, such as gorgonians and antipatharian corals which are often the focus of seamount research. By comparison there have been few studies that have focused on the less enigmatic but no less important infauna. The NERC funded TopoDEEP program aims to assess the influence of kilometre-scale topography on the geometry, of amongst other things, the taxonomic and functional composition of the benthic community and the flux of particulate organic material from the surface to the deeper ocean. It is also crucial to understand the fluid dynamics (residual flow and tides) of these systems and their influence upon the macrofaunal community and flux of organic matter.

Macrofaunal sampling was undertaken utilising a megacorer and boxcorer along a northerly transect from the summit ~150m to the base ~3500m of the seamount. A reference station was also included 40nm to the north and deemed to be uninfluenced by seamount topography. All samples were routinely sieved on a 0.25mm mesh. Total macrofaunal abundance reveals peak values at the summit ~150m and intermediate stations ~1500m and as expected polychaetes appear to dominate the macrofaunal community. Although abundance at the summit station is high, these communities appear to be dominated by polychaetes, isopods, ophiuroids and bivalves. At the intermediate station ~1500m, communities are dominated by gastropods, isopods and polychaetes whereas at the deeper station and the reference station there were a few individual polychaetes, tanaids and isopods.

Poster Board 8: **Impacts of climate forcing on estuarine ecosystems: a focus on the Eden estuary's transitional zone habitats, East Scotland**

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Abstract: Estuaries are important and valuable ecosystems in terms of biodiversity, ecosystem services and socioeconomics. However they are at risk of undergoing habitat fragmentation and loss of heterogeneity with potential impacts to habitat health and ecosystem function through hydrological alteration, increased erosion, re-suspension and mobility of sediment and inorganic & organic pollutants.

This multidisciplinary research evaluates the specific impacts that climatic drivers will have on the habitats of an estuarine ecosystem. Recent global & local models for medium / high emissions scenarios (UKCIP, MCCIP, SNIFFER) suggest the East coast of Scotland will experience increased seasonality in precipitation with concomitant seasonality in river inflow, changes in relative sea level and a decrease in average wind speeds, accompanied by increased storminess & wave surges. Such changes may impact on the differences in the duration and magnitude between ebb and flood tidal currents ("tidal asymmetry"), which impact on residual sediment transport, estuarine morphology and spatial distribution of habitats.

This research has adopted a 4D approach (time lapse) for sequential data analysis, to capture the short term periodicity within the system, for comparison with available historical data. Specific short term data includes swath bathymetry, intertidal topography, tidal regime, near bed current velocities, conductivity, temperature, aerial photography & selected biological data. Comparative historical data includes river inflow, meteorological data, previous physical / biological surveys & archived aerial photography. Analysis of inflow time series data, has confirmed the predicted changes in seasonality, with a change in increased proportion of total annual flow occurring between October and March

since 1968. Provisional results from time lapse bathymetry show greater spatial change in morphology during the winter months, evident as outer channel migration dominated by ebb mega ripples. Rectified historic aerial photographs show decadal differences in annual migration rates, which correspond to decades of higher / lower total river inflow.

Analysis of this data, using appropriate statistical techniques will elucidate trends in relation to climatic signatures. Determining rates of change experienced within the Eden estuary will improve the modelling of impacts from predicted future climate change within estuarine ecosystems.

Poster Board 9: **Physical impact on a biodiversity hotspot**

Authors: R Cook (1), F Gell (2), R H F Holt (3), T Holt (4), C Lindenbaum (3), J S Porter (5), R Seed (1), L R Skates (3,6), T B Stringell (3) & W G Sanderson (3,5)

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Abstract: Biogenic reefs in the British Isles are often biodiversity hotspots, uncommon, and frequently subject to conservation management. These habitat types, with high levels of physical complexity, are thought to be rapidly degraded by physical impacts such as towed bottom fishing gears. In 2008 a pair of furrows, consistent with an otter trawl, were found passing through a monitoring station on a horse mussel (*Modiolus modiolus*) reef in the Irish Sea. This provided us with a unique opportunity to directly investigate the effect of physical impact on the epifauna and infauna of the reef.

Using divers we recorded the abundance of epifauna from video records of fixed quadrats before and twice after the impact event. We also collected infaunal samples from impacted and two control plots. Multivariate community analysis found significant differences in the epifauna attributable to the impact: declines in erect fragile fauna occurred and there was no recovery one year later. The abundance of infauna at impacted sites also declined for 73% of the taxa, with bivalves being the most affected taxonomic group. These changes were in keeping with the observed reduction in benthic physical complexity of the horse mussel reef and, the persistence of this change a year later emphasises the sensitivity of this type of community to mobile fishing gear. As far as the authors are aware this is the first study to make direct observations of physical impact on a temperate biogenic reef community of this type.

Poster Board 10: **Assessment of ecosystem health in marine environments focussing on the benthos**

Authors: F Culhane (1), P Tett (2) & T F Fernandes (3)

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Abstract: This study evaluates current methods and approaches used in the assessment of ecosystem health in transitional and coastal waters. Specifically, this study considers outcomes of structural and functional macrozoobenthos based assessment methods by evaluating and comparing the performance of a range of standard benthic abundance indices and the results of a novel approach focussing on intrinsic biological characteristics.

The EU Marine Strategy Framework Directive specifies the protection of environmental status including 'structure, function and processes' of ecosystems. Currently used indicators of ecosystem status are based mainly on structural components of the ecosystem such as abundance, biomass and species richness, or derivatives thereof. Structural properties display high natural variability making interpretation of small changes difficult. However, disturbance theory suggests structural properties can change rapidly beyond a certain threshold where resistance is exceeded and once damaged, recovery is difficult or impossible. Indicators of function are expected to be less variable and therefore may allow detection of trends towards disturbance while recovery still remains possible. Functional indicators require development and testing. In this study, the performance of a working measure of function, biological traits analysis, was compared with structural indicators in assessing impacted and unimpacted sites. Results indicate that complementarity of approaches is important in the assessment of quality of coastal and transitional benthic aquatic systems.

Poster Board 11: **Development of a Baited Underwater Camera System to Monitor Scottish Inshore Fish Populations**

Authors: K M Dunlop (1), D Bailey (1), G Ruxton (1) & M Scott (2)
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Abstract: Baited underwater camera systems (BUCs) represent an efficient method to survey marine scavengers and carnivores. The method was developed to study previously-inaccessible marine environments such as the abyssal plains, and is now used in a wide range of coastal systems. BUCs are non-destructive and relatively inexpensive, as are dive surveys, but also offer a greater depth range and a permanent record of the survey. The bait attracts fish into the camera field of view where they can be identified and counted from which comparisons between populations can be drawn. The method has been commonly used to evaluate the success of marine protected areas.

Inshore fish populations in Scotland have experienced substantial declines and it is essential that accurate information is available on the dynamics of these populations to ensure effective management practices are implemented. A BUCs has been developed through the Scottish Industry Science Partnership scheme 'Development and evaluation of methods for surveying fish populations in near shore waters' to provide a method to monitor Scottish inshore fish populations. Fish counts have been developed into density estimates using fluid dynamics models to plot the area of influence of the bait plume and stochastic mathematical models to simulate the dynamics of the population that generated the number and rate of arrivals observed in the camera. This has allowed time and spatial comparisons to be made with density estimates from other methods. This presentation will outline the development and principles of the system and present findings of the dynamics of Scottish carnivorous fish populations.

Poster Board 12: **GPS tracking of breeding northern fulmars (*Fulmarus glacialis*) – differences in distribution between Scottish colonies?**

Authors: E W J Edwards (1), J Matthiopoulos (2), C Needle (3) & P M Thompson (1)
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(3) Marine Scotland Science

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Abstract: The northern fulmar is one of the most abundant seabirds in the North Atlantic. Having undergone a well-documented population expansion over the last 200 years, fulmars breed ubiquitously on coasts from north of the Arctic Circle to Spain. They are wide-ranging marine predators and scavengers, and one common theory put forward to explain the expansion is that they have benefitted from the provision of an energetically cheap and easily available food source in the form of discards from the whaling and fishing industries. In recent years, some fulmar populations have been in decline, which may be attributable to changes in environment or fishing practices. Recent technological advances have enabled tracking of seabirds in greater numbers and on smaller budgets than previously possible. Previous dietary studies have shown variation in use of fisheries discards between breeding colonies, but this has not previously been linked to heterogeneity in foraging areas. Fulmars were tracked using GPS loggers during early chick-rearing at breeding sites in Orkney (2010 and 2011) and on St Kilda (2011) to assess the degree of overlap of foraging range for birds from two oceanographically distinct Scottish colonies whilst constrained by breeding. I present some early results and analysis from my first field season.

Poster Board 13: **Ghost loci in basal animal genomes resolve the origin of Hox and ParaHox loci**

Authors: O M Ramos, D Barker & D EK Ferrier
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Abstract: Homeobox genes are crucial for developmental biology and transcriptional control. The most renowned example of animal homeobox genes, the Hox genes, and their evolutionary sisters, the ParaHox genes, have key roles in patterning the antero-posterior axis during embryogenesis in bilaterian animals. Besides their importance, their evolutionary origin is still a hotly debated topic. The two main reasons for this controversy are Hox/ParaHox gene absence from some basal lineages as well as the poorly resolved phylogenies of the non-bilaterian sequences most similar to the bilaterian Hox and ParaHox genes. These problems make it difficult to infer the timing of the origin of these genes with confidence, and so alternative methodologies are needed. The recent availability of whole genome sequence data from non-bilaterian lineages opens up possibilities for a better resolution of the competing ideas. We used a genome-scale signal that sheds light on the origin of the Hox and ParaHox loci, which is independent from homeobox phylogenies and can accommodate gene loss. Our approach using synteny (conserved gene neighbourhoods) reveals that *Trichoplax adhaerens* has a ParaHox gene, *Trox-2*, within a ParaHox locus. Also, a distinct *T. adhaerens* locus is homologous to Hox loci of cnidarians and bilaterians, but without a Hox gene. We name such a locus a "Ghost" Hox locus. Extending this methodology to the recently sequenced sponge genome, of *Amphimedon queenslandica*, we found distinct "Ghost" Hox and ParaHox loci. We conclude that distinctive Hox and ParaHox loci are a universal feature of all animals and the last common ancestor of animals possessed both of them.

Poster Board 14: **Genetic structure of different Norway lobster (*Nephrops norvegicus*) populations using restriction fragment length polymorphism technique (RFLP)**

Authors: H che Harun & D M Neil
Student?: Yes

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Abstract: *Nephrops norvegicus* (Linnaeus, 1758) is one of the most commercially valuable marine decapods in the Europe. This species has been exploited throughout its geographic range from the Mediterranean Sea to Icelandic waters, with the UK being the largest fishing country. The present study aimed to identify the genetic structure of *N. norvegicus*, and to gain information regarding the differentiation of Scottish from Iceland populations. This information is crucial for conservation and future stock management of the species. The PCR-RFLP technique has been used to characterize a 1.4kb segment of the Cytochrome Oxidase subunit I (COI) gene. A total of 78 individuals, from three sites in Scotland and one from Icelandic waters, were amplified and used for restriction analysis. Each of the variations found in the study was then confirmed by sequencing. A total of 14 haplotypes, constructed from the banding pattern, were designed, although 2 were excluded as inconsistent. No significant differences were found among the populations ($F_{ST} = 0.018$), with 75% of the haplotypes being unique to one population and only 8% being found in all populations. The present study has thus confirmed the low variability in *N. norvegicus* populations reported from previous studies on Scottish, Iceland as well as other populations. However a larger sample size is needed to confirm the finding.

HCH would like to acknowledge her support from The Ministry of Higher Education, Malaysia and University of Malaysia, Kelantan

Poster Board 15: **Larval mortality rates and population dynamics of Lesser Sandeel (*Ammodytes marinus*) in the northwestern North Sea**

Authors: M R Heath (1), J Rasmussen (2), M C Bailey (3), J Dunn (2), J Fraser (2), A Gallego (2), S J Hay (2), M Inglis (4) & S Robinson (2)
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Abstract: Intense fishing of a stock of sandeels (*Ammodytes marinus*) on the sand banks off the Firth of Forth, northeast Scotland, during the 1990's led to a decline in catch per unit effort to uneconomic levels and collateral failures of piscivorous seabird breeding success at nearby colonies. A prohibition on fishing in 1999 was followed by a short-term recovery of stock biomass, but then a sustained decline to very low levels of abundance. Demographic survey data show that despite the decline in stock, recruit abundance was maintained implying an increasing larval survival rate, and that the stock decline was not due to recruitment failure. To verify this hypothesis we analysed a 10-year long data set of weekly catches of sandeel larvae at a nearby plankton monitoring site to determine the patterns of larval mortality and dispersal. We found that the loss rate of larvae up to 20 d age decreased over time, corresponding with the trend in survival rate implied by the stock demography data. The pattern of loss rate in relation to hatchling abundance implied that mortality may have been density dependent. Our study rules out increased larval mortality as the primary cause of decline in the sandeel stock.

Poster Board 16: **Changes in species diversity and size composition in the Firth of Clyde demersal fish community (1927 – 2009)**

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Abstract: Following the repeal in 1962 of a long-standing ban on trawling, yields of demersal fish from the Firth of Clyde, southwest Scotland, increased to a maximum in 1973 and then declined until the directed fishery effectively ceased in the early 2000s. Since then, the only landings of demersal fish from the Firth have been by-catch in the Norway lobster fishery. We analysed changes in biomass density, species diversity and length structure of the demersal fish community between 1927 and 2009 from scientific trawl surveys, and related these to the fishery harvesting rate. As yields collapsed, the community transformed from a state in which biomass was distributed across numerous species (high species evenness) and large maximum length taxa were common, to one in which 90 per cent of the biomass was vested in one species (whiting), and both large individuals and large maximum length species were rare. Species evenness recovered quickly once the directed fishery ceased, but 10 years later, the community was still deficient in large individuals. The changes partly reflected events at a larger regional scale but were more extreme. The lag in response with respect to fishing has implications for attempts at managing a restoration of the ecosystem.

Poster Board 17: **Contemporary and historical forcing of biodiversity on the Mingulay Reef Complex, western Scotland**

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Abstract: Hundreds of animal species inhabit the complex of inshore *Lophelia pertusa* reefs off western Scotland. Our research investigates trends in this biodiversity across multiple spatial scales and more recently we began examining how historical factors shaped reef communities at Mingulay. At scales of tens of metres to several kilometres, species richness and composition are driven primarily by environmental variability or stochastic biological processes such as predation and patchiness: the importance of which varies depending on the functional ecology of the species being investigated. Mingulay coral mounds initiated at least as early as the mid-Holocene, and have experienced palaeoceanographic fluctuations; thus, contemporary reef communities and those from the past could have derived from various sources. Reefs at Mingulay are bathed by a mixture of waters that varies in relation to the North Atlantic Oscillation (NAO) including the inshore Scottish Coastal Current, the oceanic warm saline Shelf Edge Current carrying Eastern North Atlantic Central Water (ENAW), and the North Atlantic Current (NAC) that may bring sub-Arctic intermediate water (SAIW). Reef communities generally cluster into a group of amphi-Atlantic boreal-temperate species. These fauna are more similar to those from *Lophelia* habitats on the Faroe Bank and Darwin Mounds than they are to those from fossil and living coral reefs in the Gulf of Cádiz, Bay of Biscay, Porcupine Seabight and Scandinavia. However some communities from different years have a higher frequency of warmer water species associated with sub-tropical gyre circulation. On-going macrofaunal analyses will continue to examine effects of hydrography and interannual variability on coral reef faunal biodiversity and biogeography.

Poster Board 18: **A new study: Comparative ecosystem dynamics of estuarine systems in Scotland and Australia**

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Abstract: Estuaries are of crucial importance to the provision of goods and services on a global scale. This includes influences on fisheries, coastal protection, pollutant amelioration, nutrient turnover, and as sites of carbon fixation and sequestration. Anthropogenic impacts are putting increasing pressure on ecosystems and the functions they undergo, thereby inhibiting services provided. These impacts can be exacerbated by climate change. Few studies have directly compared estuarine ecosystem function across continents and the majority of studies focus on northern hemisphere estuaries. The purpose of this study is to assess and determine the functional differences between Scottish and Australian (New South Wales) estuaries through the comparison of trophic dynamics and functional metrics. The selected estuaries (Scotland: Eden and Tay, Australia: Port Hacking and Hawkesbury) vary in the nature and speed of carbon turnover and primary functional attributes. There is little evidence as to the consequences of these variations and on the impact of climate change. Through an understanding of the functional consequences an insight can be gained into the resilience of the different systems and changes in system metabolism brought about by climate change.

Poster Board 19: **Antiviral activity of the Mx protein in salmonids cells**

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Abstract: Interferon (IFN) is a group of cytokines involved in the defence against viral infections. Type I IFN includes many different subtypes and is responsible for the innate early antiviral mechanism. Cells responding to type I IFN by producing a large number of molecules with direct or indirect antiviral properties. Among those, the Mx protein has been initially discovered as conferring resistance to Myxoviridae. Although the basis of its antiviral property is not fully understood, it is believed that its accumulation in the cells interferes with the viral protein trafficking and particle packaging resulting in a general inhibition in viral propagation.

In fish, the Mx protein and its coding gene have been used a marker of type I IFN activity for many years. It is now clear that type I IFN is responsible for the early defence against viruses. However, the inherent contribution of the Mx protein to this viral resistance and its spectrum of action are unknown. Here we describe the isolation of a double recombinant Chinook Salmon Embryo cell line CHSE-TOF5-MX8 that expresses the rainbow trout Mx1 protein under the control of doxycycline (DOX) within the inducible expression TET-OFF system. This new cell line was characterised by real time PCR and the effect of an over-expression of Mx on the level of resistance to a collection of viruses and isolates was measured. The assessment of resistance was carried out using a method adapted from the traditional end-point viral titration. Using this system, it will be possible to highlight very accurately the evading strategies of some classes of fish viruses and to evaluate the contribution of the fish innate immune system to the general resistance to viruses.

Poster Board 20: **Biodiversity and Calcification in Scottish Bryozoans and the Potential Implications of Climate Change on these Communities**

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Abstract: Since the industrial revolution the increase in atmospheric CO₂ released from the burning of fossil fuels has had wide ranging climatic impacts worldwide. Climate change has been particularly significant for the marine environment where the rise in atmospheric CO₂ over the last century has led to sea temperature rises, an increase in oceanic acidification and a corresponding decrease in seawater carbonate saturation. Organisms with calcium carbonate skeletons and shells are susceptible to dissolution by ocean acidification however the effects of changing environmental conditions on carbonate deposition, mineralogy and calcification processes are not yet well understood for all calcifying organisms.

This MASTS Ph.D. study aims to bridge part of this knowledge gap by investigating the relationship between environmental conditions and calcification processes in marine Bryozoa. The phylum Bryozoa comprises sessile, suspension feeding invertebrates which are crucial components of benthic marine ecosystems and are vital for the acid buffering capacity of our oceans. Bryozoa skeletons exhibit varying combinations of the calcium carbonate polymorphs, aragonite and calcite, within their skeletons and can incorporate different minerals within deposited calcite. The large mineralogical and geochemical skeletal spectrum exhibited by bryozoans makes them an ideal model organism for investigating changes in calcification caused by climate change.

In understanding the vulnerability of calcium carbonate and the calcification processes to changing environmental conditions we will be in a far better position to gauge the potential future impacts of climate change on our marine communities.

Poster Board 21: **Absorption efficiencies and basal turnover of carbon, nitrogen and fatty acids in *Calanus* spp.**

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Abstract: Stoichiometric theory can provide insights into the factors controlling an organism's growth. It is underpinned by substrate utilisation efficiencies that relate to key physiological processes such as absorption efficiencies (AEs) and biomass turnover. These parameters are seldom investigated. We used a 5-day food deprivation experiment to investigate basal turnover rates of biomass carbon, nitrogen and essential polyunsaturated fatty acids (PUFAs) and the effect of short-term fasting on nitrogen isotope signatures in *Calanus* spp. We also fed diatoms to *Calanus* spp. and compared the elemental, fatty acid and isotopic composition of their faecal pellets to that of their food, providing insights into AEs and digestive isotopic discrimination. Starvation-induced losses of carbon, nitrogen and PUFAs demonstrate that homeostatic organisms must ingest all of these substrates in substantial quantity to achieve positive net growth. We found no evidence for nitrogen fractionation in copepod tissues during starvation. This supports the suggestion that dissimilatory protein pathways in marine crustaceans are non-discriminating. Gut AEs typically followed the sequence: PUFA > nitrogen > carbon, although low AE for the PUFA 22:6(n-3) was a notable exception. Egested material was significantly depleted in ^{13}C and ^{15}N relative to the ingested food. We attribute this to isotopic discrimination at the macromolecular level, indicating that food quality contributes to the isotopic signature of a consumer organism. The significant basal turnover rates and variable AEs for essential PUFAs and nitrogen demonstrate that organisms cannot be assumed to utilise all nutritious substrates with the same, high efficiency, even when scarce in the diet.

Poster Board 22: **Consequences of rapid ocean acidification, associated with leakage from geological carbon storage, for benthic ecosystem processes and functions**

Authors: F Murray (1), S Widdicombe (2), L McNeil (2) & M Solan (1)
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Abstract: Whilst a range of biological effects of ocean acidification have been documented within the context of long term environmental change, the short term ecological consequences of rapid acidification associated with a failure of subsea carbon capture infrastructure have received little attention. Here, we report the findings of a short term exposure experiment designed to mimic the effects of leakage from a benthic carbon dioxide storage site on an ecosystem process (particle bioturbation) and associated levels of ecosystem functioning (nutrient cycling) for a functionally important species (*Amphiura filiformis*). We show that, following rapid acidification, individuals of *A. filiformis* become less active and exhibit emergent behaviour typical of a stress response. Such behaviour results in a significant reduction in particle bioturbation and leads to changes in nutrient cycling. Our findings demonstrate that the effects of short term exposure to ocean acidification are not lethal but that they can have immediate functional consequences that are likely to have cascading effects that cannot be detected using post-hoc environmental impact assessments that rely on taxonomic inventories.

Poster Board 23: **The diversity and status of the deepwater fish of the continental slope west of Scotland over the past decade**

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Abstract: The European continental shelf slope to the west of Scotland begins at depths of around 250 m and falls away to over 2000 m. The slope supports a diverse assemblage of fishes (> 200 species), several of which are commercially valuable and have been exploited in recent decades. Several lines of evidence suggest these fisheries severely impacted the fish populations with declines in some species in excess of 50 % of the estimated virgin biomass. Concerns were also raised over the fish community as a whole and whether biodiversity was under threat or has been adversely impacted. In 2003 a TAC system was introduced in attempt to manage the deep sea stocks in this area more sustainably. Since then it is not clear whether this has succeeded in halting declines in populations and or biodiversity. This paper presents two findings from a decade of surveys of the deep-water fish community on the Northeast Atlantic continental slope to the west of Scotland that covered the period of introduction of management by TAC. First, the relative abundance of a common family of deepwater fish, the grenadiers (Macrouridae), was analysed. All seven species that spanned the bathymetric range of the slope showed strong trends with depth, but little overall change over time. Second, using all species records, an analysis of biodiversity was made to test for temporal, spatial and bathymetric trends. There were clear patterns with respect to depth and space, but little in the way of change over the past decade. Together these analyses suggests that the recent reduction and regulation of deepwater fishing in this area may have been sufficient to halt the decline in numbers of at least one major family of fishes and that biodiversity has not significantly degraded over the past decade.

Poster Board 24: **Life with and without seaweed on the sandy beaches of the Outer Hebrides – an ecological spatial comparison**

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Abstract: In winter the beaches of the Outer Hebrides receive large amounts of storm-cast kelp, which has been posed as a readily accessible feedstock for biofuel. However, in-situ primary production is typically low on beaches, and several studies have shown that many coastal organisms rely on the import of detached kelp for food. In this study it is hypothesised that Hebridean beaches with high loads of seaweed support a greater abundance of surf zone fauna, intertidal macrofauna and birds than those without. To test this hypothesis beaches with high and low loads of seaweed were sampled and differences in community structure studied.

Surf-zone samples were collected with a beam-trawl and hand held push-net over a 10 day period in April 2011 (8 beaches), and bird counts were conducted during the spring migration period in May 2010 (21 beaches). The volume of seaweed present on the beach and in the surf zone was quantified on each occasion. Chlorophyll-*a*, beach slope, beach width, salinity, temperature, total suspended solids and wave height were also quantified for each beach for which surf zone fauna were sampled. The results show that the amount of detached seaweed in the surf zone is positively correlated to overall abundance ($R^2 = 0.71$) and biomass ($R^2 = 0.43$) of resident macrofauna. However, on beaches with high loads of seaweed the surf-zone fauna are less diverse and comprise more opportunistic species. Abundance and biomass of inhabiting macrofauna show no correlation to Chlorophyll-*a* and total suspended solids. Bird abundance shows a very strong positive linear correlation ($R^2 = 0.9107$) to the % cover of seaweed on the beach, indicating the importance of seaweed subsidized beaches as a feeding ground to birds during the spring migratory period.

Poster Board 25: **Grey seal parturition date changes – individual and colony trends**

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Abstract: During the last 20 years the mean pupping dates of colonies of grey seals in the Orkney Islands (Scotland) have become later while in the nearby Scottish Hebrides they have become earlier. Mean values however, are unable to reveal the individual level processes behind these changes. Candidate explanations for later colony pupping dates include demography (mortality of early breeding old females or increased recruitment of later breeding young females, immigration or emigration) and physiology (later implantation/ extended gestation) possibly linked to environmental causes.

We used birth date data collected from over 400 seals over the period 1979-2009 during a long-term study of female grey seals on the Hebridean colony of North Rona to investigate how birth dates were affected by age and maternal condition and how they changed in relation to mean date of birth at the colony.

North Rona's mean birth date has fluctuated around 8 October over the last 20 years but as the colony's pup production has decreased, the duration of the season has contracted. Individual birth dates varied from 23 September to 26 October, maternal partum masses ranged from 127-243kg (mean 186.5kg) and ages ranged from 4-36. Individual seals had different birth dates (GLM: $F_{1,294}=8.994$, $P<0.001$) and greater maternal partum masses accompanied earlier birth dates. Although some individuals ($n=27$) had remarkably stable pupping dates, shifting by only 2-3 days over a decade, there was evidence of a quadratic effect of age on some individuals' birth dates working to shift young, late pupping females' birth dates earlier, towards the colony mean, then getting later again. Older mothers were less successful at rearing pups, irrespective of their masses at parturition. This suggests selective pressure on colony pupping dates that favours "prime" mothers giving birth around the mean pupping date, but some experience physiological decline in reproductive performance related to age.

Poster Board 26: **The role of the Mid Ocean Ridge in Ecology of the North Atlantic**

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Abstract: The Census of Marine Life MARECO project (Patterns and processes of the ecosystems of the northern mid-Atlantic, <http://www.mar-eco.no>) and its UK parallel, NERC-funded Consortium project ECOMAR (Ecosystem of the Mid-Atlantic Ridge at the Sub-Polar Front and Charlie Gibbs Fracture Zone, <http://www.oceanlab.abdn.ac.uk/ecomar/>) has undertaken an extensive study of the photosynthetically-supported life on the Mid-Atlantic Ridge. The question was: Compared with a hypothetical North Atlantic basin with no Mid Ocean Ridge, what is the effect of the presence of a ridge on biomass, biodiversity and wider ecology of the North Atlantic? Surveys focused on the segment of the ridge between the Azores and Iceland particularly in the region of the sub polar front where the North Atlantic current (Gulf Stream) crosses the ridge following a discontinuity at the Charlie-Gibbs Fracture zone.

The Mid Atlantic Ridge (MAR) extends over an area of 3,704,404 km² or 45.7% of lower bathyal habitat (depths 800- 3500m) in the North Atlantic. Swath bathymetry shows that the MAR has a terraced structure with Flat plains (slope <5°) comprising 37.65% of the area surveyed, gentle slopes (5-30°) 56.70% and steep slopes (>30°) 5.65%. All except the steepest cliffs and rocky outcrops are covered with soft sediment which drapes over >95% of the MAR area. Soft sediment infauna and epifauna therefore dominate the benthic ecology of the MAR. Biomass per unit area is similar to or less than that recorded at similar depths around the ocean margins. Most species are already known from other parts of the Atlantic Ocean although interesting new discoveries were made including three new species of Acorn worm (Hemichordata, Enteropneusta). However with increased use of deep water ROVS it is likely that these species will be found to occur in areas such as West of Scotland, which hitherto have only been studied using conventional trawling techniques.

Analysis showed that for, Fishes, Holothurians, Cephalopods, Decapods and Euphausiids the fauna showed stronger affinity with eastern Atlantic

margin rather than the western Atlantic. Population genetic studies showed limited barriers to gene flow. It is concluded that there is no evidence that the MAR enhances mid ocean production or biomass but that the MAR plays a major role in population ecology of many bathyal species hitherto known mainly from the ocean margins. The MAR has an important effect on deep water fauna of the West of Scotland.

Poster Board 27: **Cold-water Coral Outreach – developing the Lophelia.org website**

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Abstract: The first port of call people make for information is the internet. With googling a word in its own right any science outreach activity planned today almost always includes a significant web-based component. This poster will give a light-hearted summary of the development of www.lophelia.org, a website devoted to cold-water corals and the threats they face. Originally launched in late 2005 the site is designed to be accessible and interesting with information arranged using a series of 'Go Deeper' links that take the visitor through gradually more detailed information culminating in a list of primary literature and technical reports. With this intrinsic design the site can cater to anyone from school children working on projects through to scientific colleagues looking for particular information in one of the website's Case Studies, or Conservation Status summaries. As part of 2010's International Year of Biodiversity Lophelia.org has been completely redesigned and now uses a variety of social media to help spread the word about cold-water corals and their conservation. This poster will include a 5-minute documentary on cold-water corals recorded for Lophelia.org by the naturalist and broadcaster Sir David Attenborough.

Poster Board 28: **Monitoring highly variable MPAs: the utility of control charts**

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Abstract: Managing MPAs in the UK has marked an expansion of national marine monitoring efforts. However, monitoring biodiversity necessarily focuses on benthic habitats other than just the comparatively stable and/or depositional habitats where variability is low.

Coastal saline lagoons are rare habitats in the UK and are often protected as MPAs. Cemlyn lagoon (Anglesey, Wales) is a small marine protected area containing a rare and specialist invertebrate fauna. We set out to develop a programme of monitoring to inform the management of the site which is challenged by high variability and the desire not to damage it.

The lagoon had a salinity regime that varied by 35PSU and temperature that varied by 25°C. Tidally induced patterns were seasonally exaggerated and the effects of rainfall and wind were stochastically superimposed. Our results emphasised the value of high frequency sampling of the physical environment using data loggers, and interpretation of results using control charts to inform site management. This approach detects ecologically important patterns from a highly variable background. We applied a multivariate control chart analysis to lagoonal infauna for the first time and interpreted changes at monitoring stations using statistically derived control limits and those empirically derived from other lagoons, thereby developing a management indicator that encompasses local and national variation.

This study suggests that control charts have utility as tools for assessing highly variable and poorly known habitats in Marine Protected Areas: new

data are tested against extant 'acceptable values', providing an out-of-control early warning and a starting point for investigation and management.

Until now, creating statistically and contextually meaningful targets for lagoon condition and assessing ecological quality under European Directives (Habitats; WFD) has been elusive, because high variation makes type or reference conditions hard to describe. Furthermore, the majority of extant anthropogenic pressure indices use high abundances of stress-tolerant species and low diversity and evenness, conditions that are natural for lagoons but do not appear to impact on the approach we have taken here.

Poster Board 29: **Bathyal benthic macrofauna of the North Eastern Atlantic – Comparisons between the Mid-Atlantic Ridge and European Continental Margin**

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Abstract: The Mid-Atlantic Ridge (MAR), Atlantic Ocean, hosts a range of vulnerable deep-sea habitats and species. OSPAR has recognised the ecological importance of the MAR with the establishment of six marine protected areas covering a total area 285,000 km² in the North Eastern Atlantic. Recent studies have revealed that the MAR accounts for a large proportion of bathyal benthic habitat in the North Atlantic Ocean and mostly comprises of soft-sediments. However, there is a limited understanding of the soft-sediment benthic macrofauna of the MAR, particularly when compared to continental margins. Replicate samples for macrofaunal community analysis were collected with the megacorer from four MAR stations (48° to 54°N, depth: 2500 to 2800 m) during the RRS James Cook 48 cruise in the summer of 2010. Initial findings of macrofaunal community patterns from the MAR will be presented and comparisons drawn with the continental margins of the North Eastern Atlantic Ocean.

Poster Board 30: **Movement patterns of bottlenose dolphins on the west coast of Scotland – insights into coastal distribution, corridor usage and the consequences for marine renewables**

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Abstract: Globally, bottlenose dolphins show considerable variation in their degree of mobility; some communities may be long-term resident within highly limited ranges while others appear nomadic. Even though occupying ecologically similar habitats, both these extremes are exhibited by two neighbouring bottlenose dolphin communities on the west coast of Scotland. Despite being fundamentally important to many aspects of spatial management, the factors that drive these seemingly similar communities to have such different ranging patterns are poorly understood. Scotland is rapidly becoming the focus for marine renewable developments as offshore wind, wave and tidal-stream energy extraction, which will require considerable construction activities with the potential to pose risks to nearby cetaceans, such as underwater noise (e.g. hearing damage, masking sounds of prey and predator, impact on communication), collision risk and habitat loss. Tidal and wind power installations are planned for several areas of Hebridean waters such as off Tiree and Islay. However, the possible impact, both in their operation and construction, on marine life is still poorly understood. Bottlenose dolphins are a priority species for conservation under international and national legislation. Hence, non-intrusive research concentrating on more detailed habitat use by the species in particular areas and on the potential impacts of these new technologies on marine mammals is required. Understanding how and when bottlenose dolphins use areas targeted for development has the potential to provide an effective means of mitigation by timing activities to ensure that dolphin presence and construction of marine renewables don't coincide. Data obtained from photo-identification (dedicated photo-ID trips and assembling data from broader scale community) and by passive acoustic monitoring, will be used to develop an understanding of the temporal and spatial patterns of dolphin movement off western

Scotland, and to assess whether these techniques can be used as mitigation tools during the construction of marine renewables by timing activities to when dolphins are unlikely to be in the vicinity.

Poster Board 31: **Nutritional biomarkers of starvation in *Nephrops norvegicus* and their use in the field**

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Abstract: *Nephrops norvegicus* (the Norway lobster) feeds in a predatory and scavenging manner. They appear to be non-selective feeders, since the species composition of foregut contents closely matches the species diversity of available prey, such as crustaceans, echinoderms, polychaetes and molluscs. This study looks at whether or not starvation occurs in *N. norvegicus* at different times of year, due to food availability or some life history strategy (e.g. avoiding predators when females are brooding eggs within burrows). A range of nutritional biomarkers of starvation were developed and tested and their appropriate time scales determined. Then these biomarkers were measured in *N. norvegicus* collected from the Clyde Sea Area and the North Minch (both off the west coast of Scotland). The findings provide insights into the annual feeding behaviours of both male and female *N. norvegicus*, and whether brooding females undergo nutritional limitation.

Poster Board 32: **Fish Communities on a Shallow-Water Methane Derived Carbonate Reef**

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Abstract: Methane-Derived Carbonate Reefs (MDCRs) are rock-like mineral and carbonate rich structures formed as a by-product of gas seeping from the seabed into the saltwater environment. Few such structures are known in shallow-water (<20m).

Since 2004 we make annual assessments of the fish community on 'Holden's Reef', a MDCR within a Welsh MPA. We also compared the fish fauna of two MDCR reefs to two comparable rocky reefs in 2010. This is the first study of the fish assemblages on a temperate shallow-water MDCRs.

Marine Systems & Dynamics

Poster Board 33: Impact of silver nanoparticles on estuarine microbial communities

Authors: V E Bravo (1), M Winson (1), J S Porter (1), L Paterson (2) & M G J Hartl (1)
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Abstract: Silver ions have antibacterial activity, a property that is maintained and possibly enhanced in nanoparticulate form. Consequently, the rise of nanotechnology has led to the increased use of silver nano-particles (Ag-NPs) in a wide variety of applications, such as health and personal care products. As much of the silver is disposed of through domestic waste water, the question arises whether the accumulation in the receiving estuarine environment could negatively affect the functioning of resident bacterial communities that play an important role in biogeochemical processes. In this study we highlight the ecological role of natural bacterial communities and try to predict whether these could be negatively impacted by exposure to Ag-NPs.

Samples of sediment and water were taken from the Firth of Forth estuary to investigate the bacterial composition at three different locations. Bacteria were isolated from these samples by culturing on different media (tryptone for heterotrophic bacteria; NH₄-NO₂ media for nitrifying bacteria). A range of phenotypic characteristics and 16S rRNA gene sequencing was used to identify species.

We are currently investigating the effects of Ag-NPs on the bacterial communities and preliminary results indicate that these exhibit species-specific antibacterial activity. Growth of *Pseudoalteromonas* sp was found to be inhibited by Ag-NPs at 10mgL⁻¹, a concentration five times lower than for a wild-type strain of *Escherichia coli*. These effects are being quantified through bacterial growth, biological oxygen demand (BOD) and NH₄ oxidation rate. Furthermore, ecotoxicological biomarkers relevant to microorganisms, such as lipid peroxidation and DNA damage, are being developed.

Poster Board 34: Carbon flows and niche differentiation in deep-sea benthic communities

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Abstract: The benthic food web of the deep Faro-Shetland Channel was modelled using the linear inverse modelling methodology. The reconstruction of carbon pathways by inverse analysis was based on benthic oxygen uptake rates and biomass data. Tracer flow data, as revealed by a stable isotope labelling experiment with ¹³C-labelled phytodetritus, were used as a measure for the selection of the best food web solution. Based on the flow values of the best model solution, carbon deposition was estimated at 2.2 mmol C m⁻² d⁻¹ and approximately 69 % of that, was respired by the benthic community. Bacteria were being responsible for the major part of total respiration and labile detritus consumption, leaving merely 2 % of the deposited labile phytodetritus for consumption by metazoa. Refractory detritus was the basal food resource for nematodes whereas macrofauna seemed to obtain the major part of their metabolic needs from bacteria. Labile detritus transfer was well-constrained, based on the data from the stable isotope labelling experiment, but appeared to be of limited importance to the diet of the examined benthic organisms (<1 % and 5 % of carbon requirements of nematodes and macrofauna respectively). Predation on nematodes was generally low and the diet pattern of carnivorous polychaetes suggested a high degree of omnivory. Overall, this study provided a unique insight into the functioning of a deep-sea benthic community and demonstrated how conventional data can be exploited further when combined with state-of-the-art modelling approaches.

Poster Board 35: **Studying the impacts of ocean acidification and warming on key UK calcifying biogenic habitats**

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Abstract: Cold-water corals (CWC) are among the most three-dimensionally complex deep-sea habitats known and are associated with high local biodiversity. Similarly, maerl beds have been shown to be extremely important nursery areas for both invertebrates and vertebrates. Predicted rises in atmospheric CO₂ concentrations are set to reduce oceanic pH and the availability of carbonate ions for these calcifying organisms, a process termed 'ocean acidification'. The aim of the project is to therefore assess the impact of ocean acidification upon growth, physiology and structural integrity of Scottish maerl and CWC, and to consider whether it will impede the ecosystem engineering function they perform. Short-term stressor experiments (~ 1 month) will be contrasted with long-term incubations in microcosms (18 month), whereby the organisms are subject to a range of temperate and pCO₂ treatments and their physiological responses recorded. These long-term experiments form part of the 5 year UK Ocean Acidification (UKOA) research program jointly funded by the Department for Environment, Food and Rural Affairs (DEFRA), the Natural Environment Research Council (NERC) and the Department of Energy and Climate Change (DECC).

Poster Board 36: **Comparative patterns of usage by UK seal species**

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Abstract: Grey and harbour seal telemetry data from 1995-2010 were combined with aerial survey data from 1996-2009 to produce a map of estimated usage around Scotland for each species. Grey seals show wide-ranging usage out to the continental shelf west and north of Scotland, as well as high usage at known foraging sites such as Stanton bank. By contrast, harbour seals concentrate around the coast closer to their comparatively more disaggregated haul-out sites, particularly in the Minch, Inner Hebrides and Orkney.

Harbour seals show reduced spatial usage compared to grey seals but aggregated at much higher levels of concentration. These differences in spatial usage suggest that grey seals prefer haul-out sites with direct access to deeper water, whereas harbour seals are concentrated towards coastal inlets, implying differences in habitat preference between species. Higher grey seal prevalence is also demonstrated in areas where harbour seals have declined.

Poster Board 37: **How can we achieve healthy demographics in Scotland's fish stocks?**

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Abstract: Over recent decades key commercial fish stocks in the North Sea and elsewhere have undergone dramatic shifts in size distribution towards smaller-sized individuals. This changing demographic composition is due to a combination of growth overfishing, warming temperatures and possibly genotypic changes. Increasing size truncation has deleterious consequences for stock reproductive rates and maximum sustainable yields and impairs the resiliency of stocks to perturbations. Consequently rebuilding size structure has become an explicit aim of European policy. The Marine Strategy Framework Directive compels Scotland to achieve Good Environmental Status (GES) by 2020; a key qualitative criterion for GES is that commercially exploited fish stocks exhibit a population age and size distribution that is indicative of a healthy stock. Operationalising this criterion for management purposes requires being able to objectively assess the well-defined aspects of the "health" of any given size distribution relative to some pre-determined benchmark. To address this requirement I review how and why asymptotic body sizes have decreased in a number of commercial species in the North Sea. A quantitative framework for estimating the health of size structures is presented which is based on two specific considerations: the size-dependency of reproductive rates and the relative exploitation of immature versus mature individuals. Using this framework, achievable benchmarks for size structure can be established to function as stock-specific reference points. Management options can then be evaluated with respect to how effective they are in rebuilding a healthy size structure bearing in mind that while some of the factors that determine size structure can be regulated (e.g., discarding, fishing mortality rates) others are entirely beyond management control (e.g., warming) or potentially irreversible (e.g., genetic shifts).

Poster Board 38: **Effect of current speed on capture rates of live zooplankton by *Lophelia pertusa***

Authors: C Orejas (1), L Wicks (2), A Gori (3), K Last (4) & J M Roberts (2)
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Abstract: *Lophelia pertusa* is the most abundant reef-building cold-water coral, and forms important structural habitats in shelf and seamount settings around the world. However, little is known of their feeding ecology and trophic status. Prey capture rates of *L. pertusa* were estimated under conditions designed to simulate the natural environment, with colonies of *L. pertusa* collected from the Mingulay reef complex (Sea of Hebrides, UK). This is the first time feeding trials with *L. pertusa* have been carried out using naturally-occurring zooplankton as opposed to aquarium-grown prey (e.g. *Artemia salina*) or frozen food material. Clear differences were observed between the three current speeds; *L. pertusa* successfully captured zooplankton between 2 and 5 cm s⁻¹ whereas at 10 cm s⁻¹ significant zooplankton capture could not be detected. Understanding fundamental biological parameters, such as feeding ecology, in cold-water corals are a vital prerequisite if we are going to predict their potential vulnerability to future change. Feeding ecology of *L. pertusa* was examined in greater detail through experiments conducted aboard the RRS Discovery in summer 2011, primarily assessing the effect of diet on capture rates.

Poster Board 39: **A 3D hydrodynamic model, coupled to a particle tracking model of Mingulay Reef Complex**

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Abstract: The Mingulay Reef complex is located to the east of the island of Mingulay in the Sea of Hebrides. The area was first mapped using multibeam echosounder in 2003 with further mapping in 2006 revealing several reefs formed by the cold-water reef framework-forming coral *Lophelia pertusa*. The suspension-feeding epifaunal communities rely on the delivery of phytoplankton, zooplankton and organic matter derived from near-surface primary productivity. The lateral and vertical advection of particles therefore plays an important role in the functioning of coral ecosystem. The water flow determines the supply of food particles and larvae. Previous studies revealed that the Mingulay complex have two dominant food supply mechanisms to the reefs, a regular rapid downwelling of surface water delivering pulses of warm water and periodic advection of high turbidity bottom waters.

A 3D hydrodynamic model, coupled to a particle tracking model has been applied to study in detail the circulation patterns and the water transport for a better understanding of food supply, larvae transport and sediment movement. This modelled information has been integrated into a 3D GIS, using ArcGIS 9, thus providing a user interface for visualization interrogation of results and as an input into other spatial modeling projects.

Poster Board 40: **Transcriptomic responses of genetically resistant and susceptible Atlantic salmon fry to infectious pancreatic necrosis virus challenge.**

Authors: J E Bron (1), R D Houston (2), J H Ireland (1), W G Starkey (1), B J McAndrew (1), D Guy (2), A E Tinch (2), S C Bishop (2) & J B Taggart (1)
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Abstract: Disease continues to represent one of the major constraints to Atlantic salmon aquaculture worldwide. Whilst many disease problems have been reduced or eliminated by the development and use of medicines, vaccines and improved management regimes (e.g. furunculosis, vibriosis), many remain problematical for the industry. Infectious pancreatic necrosis (IPN) a viral disease of salmon causes an estimated loss of £5-10M to the UK aquaculture industry. This disease is highly contagious and has the unusual characteristic of affecting farmed salmon during two specific windows of the life cycle. In the freshwater phase of the salmon life cycle, IPN outbreaks in fry have been observed for several decades, with up to 70% mortality. In the marine environments, the emergence of problematic IPN outbreaks (up to 40% mortality) is more recent, coinciding with the dramatic expansion of salmon aquaculture. With clear evidence that IPN resistance in families from a commercial supplier, Landcatch Natural Selection (LNS), has a genetic basis, we have identified markers for resistance to IPN and localised them to a specific region of the salmon genome. As a direct result of this research LNS have used marker assisted selection to provide commercial eggs and smolts genetically enhanced for resistance to IPN. Part of our research program aims to determine which genes are differentially expressed between genetically resistant and susceptible fish following IPN challenge and to identify specific genes (and gene pathways) that may be underlying the genetic resistance. This is being explored by broad spectrum microarray analysis and targeted qPCR validation of material taken from the same families used in the QTL study. In this presentation we will provide an overview of the approaches taken and the project findings to date.

Productive

Poster Board 41: **Research, management and recent developments in the marine archaeology of Scotland**

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Abstract: Research and management in coastal and marine archaeology has expanded on an international scale. In Scotland this has informed subjects from maritime history to submerged prehistory and represents long timescales from modern history to at least the last 12,000 years. In order to meet the growing energy demands of a low-carbon economy, offshore sectors are exploiting resources in an unprecedented manner. New development requires planning permissions and a comprehensive environmental impact assessment that includes cultural heritage. In Scotland work has begun in order to assess the archaeological potential and heritage resources in the submarine environments. It is envisioned that marine archaeology will be integrated into the greater discourse of marine sciences in Scotland (as this is becoming commonplace throughout Europe). This poster will demonstrate our experience relating to the initial interrogation and consolidation of marine data, and seascape characterisation in support of sustainable development linked to Scotland's maritime heritage and marine archaeological potential.

Poster Board 42: **High-throughput analysis of genes differentially expressed between two populations of *Lepeophtheirus salmonis* differing in emamectin benzoate susceptibility**

Authors: S Carmichael (1), A Nisbet (2), A Tildesley (1), K Gharbi (3), P Skuce (2), J E Bron (1), J H Ireland (1), J B Taggart (1) & A Sturm (1)
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Abstract: *Lepeophtheirus salmonis* (Krøyer, 1837) is an ectoparasitic copepod that parasitises salmonid fishes and represents a potential problem for cultured and wild salmonids. One of the compounds currently employed to treat *L. salmonis* infections of Atlantic salmon is emamectin benzoate, used as an in-feed pre-mix (SLICE®, Intervet / Schering Plough Animal Health), for which reduced treatment efficacy has been observed in major Atlantic salmon culturing countries. Two different *L. salmonis* strains are maintained in laboratory culture at the Institute of Aquaculture. While the first strain was isolated prior to the use of a majority of current antiparasitics and is therefore susceptible to all common anti-sea louse treatments, the second strain has shown reduced sensitivity to emamectin benzoate. Suppression Subtractive Hybridisation (SSH) was employed to generate two subtracted cDNA libraries that are enriched for genes differentially expressed between the two *L. salmonis* strains in the absence of drug treatment. Roche 454 sequencing technology was used to generate sequence reads from the pooled subtracted cDNA libraries and contiguous sequences assembled from these reads were functionally annotated to provide template for 60mer oligonucleotide probe design. These probes will be included on our existing 15K Agilent microarray, designed for the study of *L. salmonis* gene expression, including factors relevant to sensitivity to emamectin benzoate. There were a number of potentially differentially expressed genes identified between the two populations, including those previously associated with drug resistance such as Cytochrome P450 enzymes and ABC transporters that may represent candidates for further study. Microarray experiments are currently on-going to study differential gene expression changes in these *L. salmonis* populations to sublethal emamectin benzoate exposure. We present the preliminary results of this study.

Poster Board 43: **Local immune response in Atlantic salmon *Salmo salar* infested with sea louse *Lepeophtheirus salmonis***

Authors: B Collet (1), T Wang (2), P McLachlan (1), P Cook (1), S McBeath (1) & C Collins (1)
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Abstract: Expression levels of key immune genes were analysed to characterise the type of local immune response in Atlantic salmon *Salmo salar* following infestation with the sea louse *Lepeophtheirus salmonis*.

Atlantic salmon infested with copepodids were sampled after 3, 14 and 21 days corresponding to the parasite stages copepodid, chalimus III and pre adult, respectively. From each fish, two intact skin samples and 4 to 8 damaged skin samples at the sites of attachment of parasites were dissected and stored in RNAlater at -80 °C until processed. Total RNA was purified, DNase treated and cDNA synthesised. Gene expression levels for cytokines, transcription factors and cell markers genes were measured by quantitative real-time PCR.

Preliminary results suggest that genes encoding for the receptor for the interleukins 4 and 13 were induced in the damaged skin. This is characteristic of a Th2 immune response which proved to be unable to counteract the course of infestation as fish became heavily infested at day 21.

We can hypothesise that *L. salmonis* interaction with its salmon host, through surface or excreted parasite molecules, results in the induction of an inappropriate host immune response.

Poster Board 44: **Field study evidence of the depth distribution of *Lepeophtheirus salmonis* larvae: census data collected by trawling at three depths**

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Abstract: The salmon louse, *Lepeophtheirus salmonis* (Krøyer, 1837), is an ectoparasitic marine copepod principally parasitizing salmonids. Models to aid control and predict infection are informed by field tests (Gravil, 1996) studies in bags (Heuch, 1995) laboratory studies on light sensitivity (Novales Flamarique, 2000). Gillibrand and Willis predict either an even distribution by depth or bimodal depth distribution if estimates of copepodid behaviour are included (Gillibrand, 2007).

This study is a field investigation of the diel vertical distribution of planktonic sea lice larvae. Three depths were sampled during daylight and night by plankton trawl using bongo nets. Sealice larvae (both naupliar and copepodid stages) were found by day and night at all depths tested (to 20 metres) but their viability and infectivity is not known. The copepodid stage was found to be concentrated near the surface at both times (day and night) whilst naupliar stages were dispersed more evenly through the water column and may move upwards at night.

This supports inclusion of behaviour in models, as by Gillibrand and Willis. Light intensity is a factor in larval dispersion with depth. Copepodids have been reported to swim up towards an <ON> signal, whilst naupliar stages swim up to an <OFF> signal. A combination of the light levels recorded, water clarity and the measurements reported by Novales Flamarique, predicts copepodids could detect the moon at 25 meters depth. This may explain the concentration near the surface. For nauplii, the low light levels at night may explain the larger numbers recorded as they move up above their lower limit of detection. Using similar calculations, during the day nauplius I larvae may have concentrated above 17 metres and nauplius II above 20 metres. Study of the interaction at the species' peak response wavelengths following attenuation by sea water may aid prediction.

Poster Board 45: **The genome of the fish pathogen *Saprolegnia parasitica*: adaptation to the fish host**

Authors: I, De Bruijn (1), R Jiang (2), B J Haas (2), C Russ (2), C Nusbaum (2), B M Tyler (3), C J Secombes (1) & P van West (1)
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Abstract: Watermoulds (oomycetes) are destructive pathogens of aquatic animals and terrestrial plants. *Saprolegnia* species cause Saprolegniosis, a disease that is characterized by visible white or grey patches of filamentous mycelia on the body or fins of freshwater fish. *Saprolegnia parasitica* is economically one of the most important fish pathogens, especially on catfish, salmon and trout species, causing millions of pound losses to the aquaculture business worldwide. A high quality assembly of the *Saprolegnia parasitica* genome of 53 Mb was generated and annotated with help of RNA seq data derived from multiple life stages of the pathogen. With the first animal pathogen oomycete now sequenced, comparative genome analysis between oomycete plant and animal pathogens enables the identification of candidate proteins specific for animal pathogenicity. Only 40% proteins of *S. parasitica* have homologs of more than 50% sequence similarity to other known oomycetes. The largest plant pathogen effector families in the plant pathogenic *Phytophthora* species, including conventional RXLR's, Crinkler (CRN) and Necrosis Inducing Proteins (NIP) are absent in *Saprolegnia*. In contrast, *Saprolegnia* possesses one of the largest sets of proteases among eukaryotes, with about 200 more than typical fungal pathogens. Other expanded protein domain families compared to other oomycetes appear to function at the exterior or cell surface of the pathogen. Strikingly, among the domains that are unique to *S. parasitica*, the largest groups are all associated with pathogenesis. Comparison of *Saprolegnia* and *Phytophthora* indicates that different hosts greatly affect the evolution and weaponry of plant and animal pathogen genomes.

Poster Board 46: **The Solway Firth – a case study of transboundary issues in Marine Spatial Planning**

Authors: F Edwards (1), P Taylor (2), P Matthews (1), A Hull (1), K Johnson (1) & J S Porter (1)
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Abstract: Advances in technology, pressure to find alternative sources of energy and an increase in the public's perception of the natural marine environment and its potential, have been major factors driving the development of Marine Spatial Planning (MSP). Whilst the UK Marine Policy Statement provides overarching guidelines, each nation has developed its own approach to planning within its waters. Differences between these approaches will be highlighted in a range of areas where a national boundary straddles across a marine ecosystem. The Solway Firth is one such area and this has been recognized in joint statements by the respective governments. To produce a workable and robust plan these differences must be identified and minimized.

In order to identify potential problems for MSP within the Solway, initial research will focus on the environment of the Firth and its governance, the interactions between key stakeholders, as well as the Scottish and English approaches to planning. Further research will consider examples of projects where transboundary issues have already been addressed. These will include the Solway Tweed River Basin Management Plan and one of the current European MSP projects.

Poster Board 47: **ABC transporters as potential drug resistance factors in the salmon louse *Lepeophtheirus salmonis***

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Abstract: The salmon louse (*Lepeophtheirus salmonis*) is a crustacean ectoparasite commonly occurring on wild and farmed Atlantic salmon (*Salmo salar*). Currently, chemical treatments are the principal means of salmon louse control on fish farms. However, the continued reliance on few licensed anti-parasitics potentially promotes the risk of development of drug resistance in salmon lice. The large gene family of ABC transporters contains proteins involved in substrate transport across biological membranes, including cellular drug efflux pumps that have been linked to drug resistance phenotypes in cancers, pathogens and parasites. Here we report the isolation of ABC transporters in the salmon louse and present first studies into their relevance as biochemical factors affecting susceptibility to antiparasitic drugs. Searching publicly available EST databases, 13 ABC proteins were found in *L. salmonis*, of which seven are potential drug transporters. Non-toxic concentrations of cyclosporin A, an inhibitor of several ABC drug transporters, increased salmon louse susceptibility to emamectine benzoate (EMB), the active ingredient of the anti-sea louse drug SLICE® (Intervet/Schering Plough Animal Health). This suggests that ABC proteins contribute to the detoxification of EMB, and could be a potential therapeutic target. The complete coding sequence of a salmon louse P-glycoprotein called SL-PGY1 was obtained. Expression studies of this and other salmon louse ABC proteins are ongoing and will be presented.

Poster Board 48: **Echinoculture: A Model of Diversification for the Scottish Aquaculture Industry?**

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Scottish Association for Marine Science

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Abstract: In 2007 salmon production accounted for 97% of the total Scottish aquaculture production. This reliance on a single species raises real questions of environmental and economic risk for the aquaculture industry. This risk has led to the drive towards diversification of the industry in terms of both species and products. As such there is a need to develop novel species for the aquaculture industry. As a phylum echinoderms offer a number of interesting possibilities for the aquaculture industry to develop new culture species and products. Using echinoderms as a case study, the potential as aquaculture species and the current state of development of three species of echinoderms is described.

Poster Board 49: **Sunlight, Seaweed and Biogas: renewable energy from farming at sea**

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Abstract: The economic and environmental viability of dedicated terrestrial energy crops is in doubt but the culture of seaweed (macroalgae) at sea for subsequent anaerobic digestion to produce biogas is a source of renewable energy well worth re-examining. Here we present the potential and pitfalls of seaweed as an energy crop in a Scottish and global context that does not compete with food for land, fresh water or fertiliser.

Poster Board 50: **Measuring changes in ecosystem service values for the deep sea**

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Abstract: Deep-sea areas supply human society with valuable ecosystem services, including the provision of food, the regeneration of nutrients, oxidation of methane and sequestration of carbon. They are also important habitats for marine biodiversity, including high profile species such as cold water corals, although most deep-sea species are unfamiliar to the general public. The supply of ecosystem services from deep sea areas around the UK coastline is threatened by a number of factors, such as oil extraction or bottom-trawl fishing. Several policy initiatives are in place to respond to these threats, including draft Marine Protected Area legislation. The aim of this project is to estimate economic values for changes in ecosystem service flows from the deep sea. As a first step, we review what is known about the economic value of deep sea ecosystem services and the main problems faced in quantifying change. We then describe a choice experiment which was used to investigate preferences of the Scottish general public for different conservation management actions in deep sea areas in the North East Atlantic. The attributes used include distance of protected areas from the coast, nature of biodiversity being protected, which sectors of the economy are restricted in activities and the costs to taxpayers and consumers.

The first results from the focus group meetings, preceding the choice experiment survey, are discussed in this paper.

Poster Board 51: **Characterising dendritic cells in fish**

Authors: P Johansson (1), J Zou (1), C J Secombes (1), Y Corripio-Miyar (1) & B Collet (2)

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Abstract: Dendritic cells present antigens to naïve T cells and are fundamental for the generation of adaptive immunity in mammals. Costimulatory signals received from dendritic cells and relevant cytokines are essential for the proliferation and generation of memory cells. Strong and long-lasting memory T cells responses hold the keys to successful vaccine development. Agents that activate dendritic cells and that can be used as molecular adjuvants are essential components for vaccine effectiveness, which in turn is important for disease control in aquaculture. Dendritic cells have been identified in humans, mice, birds, reptiles and amphibians. Previous studies indicate that dendritic cells exist in fish after discovery of structures in salmonids similar to Birbeck granules, a morphological hallmark of epidermal Langerhans cells in mammals. DC-like cells have recently been described in zebrafish, in which they were enriched by their affinity for lectin peanut agglutinin and characterised in zebrafish using one of the cell surface markers, CD209. Small fractions of cells with dendritic phenotype have also been reported in medaka fish using the chemokine receptor *cxcr3a*, a marker of cells of innate immunity. Detection of dendritic cells requires several surface markers since there is no marker exclusively expressed by dendritic cells. In order to find dendritic cell surface markers the genome and expressed sequence tag (ESTs) databases maintained by NCBI were used to predict homologues in rainbow trout (*Oncorhynchus mykiss*) using human nucleotide sequences as queries. Putative markers of DC-SIGN (DC-specific ICAM-3-grabbing non-integrin)/CD209 and DC-LAMP (lysosomal-associated membrane protein)/CD208, two markers expressed on the surface of dendritic cells, were found and have subsequently been identified and cloned in rainbow trout. To study whether DC maturation occurs in a similar manner in fish as in mammals, the expression patterns of DC-SIGN/CD209 and DC-LAMP/CD208 will be determined using quantitative RT-PCR in tissues from healthy fish and fish infected with a virus. A polyclonal antibody has been raised against the peptides derived from one putative DC-SIGN marker and the antibody will be used to isolate and further characterise the trout dendritic cells with techniques such as Western blotting, immunocytochemical staining and FACS analysis.

Poster Board 52: **Genomics of LC-PUFA biosynthesis in Atlantic salmon**

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Abstract: Farmed Atlantic salmon comprises 40% of Scotland's agricultural exports and has a global retail value of over £1bn. Our research focuses on the biochemistry and genes of the physiologically critical omega-3 long-chain polyunsaturated fatty acid (LC-PUFA) biosynthetic pathway, and shows how detailed knowledge of genome structure leads to insights into salmon evolution and ecology, and enhances farming practises. In vertebrates LC-PUFA biosynthesis involves desaturation and elongation of essential C18 PUFA. The extent to which a species can produce LC-PUFA varies, and is dependent on their complement of fatty acyl desaturase (Fad) and elongase (Elovl) enzymes. In contrast to other marine fish species that contain single genes, salmon contain multiple Fad and Elovl genes for LC-PUFA biosynthesis. In consequence salmon have higher capacity for LC-PUFA biosynthesis than species such as sea bass or sea bream that produce negligible amounts. These results have implications for feed formulation, and in nutritional trials salmon are able to tolerate higher levels of dietary C18 PUFA, as found in vegetable oils, than sea bass or bream. Interestingly the salmon gene duplicates are very similar, clearly having arisen recently during evolution, possibly as a consequence of genome duplication at some point congruent with the evolutionary emergence of Salmonids. Thus, a single ancestral fish gene has been duplicated and neo-functionalised in salmonids, enabling the acquisition of a complete pathway for LC-PUFA biosynthesis. We suggest that this has enabled Salmonids to colonise nutrient poor freshwater habitats that are dependent on terrestrial plant inputs, and has allowed the substitution of scarce fish oils with sustainable vegetable oils in farmed salmon diets. In contrast, in marine systems protist phytoplankton produce abundant LC-PUFA with the result that many non-salmonid fish have not been under evolutionary pressure to evolve efficient LC-PUFA biosynthesis. Therefore salmon LC-PUFA biosynthesis reflects a rare example of gene duplication, followed by neo-

functionalisation that can be linked to evolutionary and ecological processes. More generally, the imminent availability of the salmon genome sequence will catalogue all duplications, shed light on molecular mechanisms enabling neo-functionalisation and provide insight into fundamental evolutionary questions, underpinning the conservation requirements of wild salmon and parallel sustainable development of aquaculture.

Poster Board 53: **An integrative approach to understand the growth and lineage-specific biology of Atlantic salmon**

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Abstract: The Atlantic salmon farming industry is worth close to a billion pounds to the Scottish economy, accounting for almost 40% of all exported food. In 2010, production of Scottish salmon reached 150,000 tons and this figure is rising year on year. The sustainability of the industry requires understanding of this species' biology, particularly the basis of important traits like growth, smoltification and disease resistance. Our principal aims for this MASTS funded research are: 1) to understand how growth of the edible part of the fish, the skeletal muscle, is controlled at the molecular level, particularly its interaction with the environment and other tissues and cell-types, and 2) to identify and characterize genes specific to the Salmonid fish lineage, hypothesized to have important unknown roles in salmon biology. A challenge to molecular research with salmonid species is that their common ancestor experienced an event where the entire genome content was doubled, including all the genes. Importantly, 50-75% of genes have been retained as duplicates, and it is common for them to change in both their sequence and patterns of expression. Thus, a full understanding of how Atlantic salmon genetics influences its biology requires both expertise in molecular evolution and an appreciation of approaches that can distinguish gene duplicates experimentally. This poster gives details of the integrative approach we are employing and provides examples of our results. We show how we have exploited a growing repository of sequence data for Atlantic salmon and employed bioinformatics and molecular evolutionary approaches to identify/characterize lineage-specific and duplicated genes of interest before executing laboratory experiments to determine their functions.

Poster Board 54: **Factors affecting benthic impacts at Scottish fish farms**

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Abstract: The factors affecting patterns of benthic biology and chemistry around 50 Scottish fish farms were investigated using linear mixed-effects models that account for inherent correlations between observations from the same farm. The abundance of benthic macrofauna and sediment concentrations of organic carbon were both influenced by a significant, albeit weak, interaction between farm size, defined as the maximum weight of fish permitted on site at any one time, and current speed. Above a farm size threshold of between 800 and 1000 t, the magnitude of effects at farms located in areas of elevated current speeds were greater than at equivalent farms located in more quiescent waters. The counterintuitive effect of current speed at farms above the threshold size suggests that the physical properties of the seabed at these locations favour the accumulation of organic wastes and/or that the underlying communities have a lower assimilative capacity.

Sediment concentrations of total organic matter were influenced by an interaction between distance and depth, indicating that wind-driven resuspension events may help reduce the accumulation of organic waste at farms located in shallow waters. The analyses presented here demonstrate that the production and subsequent fate of organic waste at fish farms is more complex than is often assumed; in isolation, current speed, water depth, and farm size are not necessarily good predictors of benthic impact.

Poster Board 55: **Copper contamination in marine sediments: Implications for ecosystem function**

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Abstract: Elevated concentrations of copper are found in the sediments beneath salmon farms. This arises due to the periodic flaking of copper-based antifouling paints and because salmon feeds provide copper in excess of dietary requirements. Very little is known about how copper in the sediments underlying fish farms affects the functioning of the resident communities. We used 10-day mesocosm experiments to investigate how increasing concentrations of copper affected nutrient recycling with and without the active sediment-reworking crustacean, *Corophium volutator*. We also examined how copper concentration affected the sediment microbial community composition using compound-specific phospholipid fatty acid isotope ratio mass spectrometry. The concentrations of key nutrients were affected by significant interactions between copper concentration and the presence of *C. volutator*. Sediment microbial communities and their carbon isotopic signatures also changed in response to both the addition of copper and *C. volutator*. This study illustrates that copper impacts on nutrient cycling in marine sediments are complex, and likely operate in a context-specific manner.

Poster Board 56: **Developing and testing approaches for Marine Spatial Planning: the case of aquaculture**

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Abstract: A fundamental goal of the Scottish Marine Bill is to streamline regulation and develop a new framework to coordinate and manage activities' around Scotland's coast. This study will evaluate and explore the application of different approaches, using Geographic Information Systems (GIS), to the development of a Scottish marine spatial planning framework, with a particular focus on decision-making for future aquaculture sites. Integral to this study will be the accurate assessment of the spatial distribution of human activities and their associated pressures, along with mapping of marine landscapes and determination of the nature of biological communities. Due to the need to integrate and manage all these factors, GIS will be used to capture, organise, analyse and display all types of geographically referenced information. Additionally, quantified empirical data on geographical characteristics, activities, impacts, and other relevant information, as well as statistical associations and probabilistic representations will be combined within a GIS-based model. This will allow for any uncertainty associated with the outcomes of proposed spatial planning scenarios to be visualised. This can then be applied and tested using historical data to proposed aquaculture sites. The model developed could be used to limit the location of future sites to only those areas where their impacts/effects will be manageable. This is of particular importance as poor site selection can result in adverse environmental conditions and eventually in the failure of aquatic enterprises. The potential for intensive aquaculture to bring about detrimental effects on the marine environment has led to their tight regulation by several governing bodies including the Scottish Environment Protection Agency (SEPA), the Crown Estate Commission (CEC) and the Scottish Government]. To date regulations have been largely focused on site (local scale) impacts of farms; however it has become clear that effects may be observed over broader spatial scales. To this end the assessment of impacts and conflicting or competing uses using GIS would allow for focus to be moved to encompass a larger scale of effects. Furthermore, application of GIS to provide spatial decision making support in aquaculture would be an advantageous tool in developing new Integrated Coastal Zone Management (ICZM) as supported by the Crown Estate and Scottish Natural Heritage.

Poster Board 57: **Larval transport in 3-D: the role of vertical positioning in larval dispersal and colonisation of offshore renewable structures**

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Abstract: The construction of marine renewable energy devices will alter the availability of shallow water hard habitat around the UK. These structures may act as artificial islands, encouraging changes in species ranges by acting as stepping-stones for dispersal across biogeographic boundaries. For marine organisms with pelagic larvae, the vertical positioning of larvae in stratified coastal flow fields can be an important determinant for transport, dispersal, and patterns of population connectivity. Between-species differences in larval buoyancy may drive differential transport of larval assemblages, resulting in distinct patterns of connectivity. Combining laboratory measurements of larval sinking rate with three-dimensional plankton sampling, this study explores the effects of larval buoyancy on the dispersal of acorn barnacles on the Scottish west coast. Initially, the acorn barnacle *Semibalanus balanoides* is used to quantitatively determine changes in density at progressing life-cycle stages. However, between-species variations in larval density may be a driver of varying depth distributions of both larval and adult communities. Divergence in the vertical positioning of sub-tidal and inter-tidal larvae may also explain previously observed horizontal variations in larval distributions of these species. For many species, larval density and other physiological properties can be important when assessing the potential biogeographic impacts of marine renewable energy device installation as well as for the effective development of marine protected areas, a current UK policy objective.

Poster Board 58: **Assessing Bycatch in a Nephrops Trawl Fishery**

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Abstract: An assessment of the bycatch composition from the Stornoway-based Nephrops trawl fishery was carried out between December 2008 and June 2010 to identify and quantify the animal bycatch occurring in this fishery. A total of 57 two-hour survey trawls were carried out aboard the MV Comrade, and in each case, the entire catch was sorted into 'target' and 'bycatch' animals. Every bycatch species was identified and counted, and the weights of the major taxa and the target catch were recorded. Subsamples of Nephrops and important bycatch species (cod, spurdog, whiting and haddock) were collected from each sampling trip and all data were compared against environmental measures recorded for each trawl.

Overall, a total of 94 species were captured during the study, of which the pouts (*Trisopterus* spp.), whiting, lesser-spotted dogfish and crustaceans were typically the most dominant by number and weight, and a significant temporal effect was evident in the data. The occurrence of cod and spurdog was relatively low, with only 99 and 110 respectively being captured over the entire period (representing 0.8% and 0.1% of the average catch biomass respectively).

This work establishes a baseline data set for bycatch composition within this Nephrops fishery, from which investigations across the rest of the fleet can be made, with a view to decreasing the occurrence of bycatch animals within the catches.

This work was supported by a grant from the European Fisheries Fund (EFF) through Marine Scotland, and by Young's Seafood Ltd.

Poster Board 59: **Ensuring product quality of langoustines (*Nephrops norvegicus*) in the post-harvest phase**

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Abstract: Recent studies of the fisheries for langoustines, *Nephrops norvegicus* (L.), have illustrated the negative effects of the physiological stresses of capture processes and of pathogens on the exploitation of live animals and their products, and have identified mitigating measures. Firstly, measurements of post-mortem autolytic and spoilage processes have identified the existence of a post-capture 'handling window' of several hours which allows the whole or tailed products to be preserved, by icing or freezing, without detriment to quality. Commercial consortia of Scottish fishermen are exploiting this opportunity to extend product shelf-life by freezing at sea within this handling window. Secondly, the well-documented infections of Scottish *N. norvegicus* populations by the dinoflagellate *Hematodinium* sp. not only provide examples of pathogen-induced mortality, but also have effects on post-harvest products including vivier transport losses and changes in post-mortem degradation leading to earlier organoleptic rejection. Under commercial conditions these effects can be mitigated by post-capture visual screening, but only during the periods of peak patent infection when parasitized animals are visually identifiable. Thirdly, having established that trawl capture of *N. norvegicus* is highly stressful, but that these animals have powerful physiological mechanisms of recovery, procedures for on-board recovery of animals destined for vivier transport to distant European markets have been implemented commercially, with significant improvements in survival rates. Wider implementation of such mitigating procedures during the harvesting of wild-caught crustaceans such as langoustines will contribute to a more sustainable exploitation of these valuable marine resources.

Poster Board 60: **The effects of immune stimulation on transcriptomic responses of muscle in salmon**

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Abstract: Efficient aquaculture requires basic knowledge regarding both fish health and growth. This research explores the relationship between immune function and muscle growth and physiology two key areas of research in both genomics and mariculture JRTs. The effect of immune stimulation on gene expression and subsequent energy balance of fish is not fully understood. In mammals immune stimulation results in major transcriptional changes in muscle including an increase in the expression of genes related to protein degradation. The aim of this study was to investigate the effects of immune stimulation on fish muscle RNA. Primary muscle cell cultures which were stimulated with trout recombinant (r) IL-1 β in order to simulate an acute proinflammatory immune response. Additionally the in vivo effects of acute immune stimulation were assessed in Atlantic salmon following intraperitoneal injection of lipopolysaccharide (LPS, a bacterial cell wall immunostimulant) during the parr smolt transformation. In primary myocyte culture rIL-1 β causes increased expression in immune genes including IL-1 β , IL-6 & TNF- α , however no clear change was observed in the expression of genes related to protein degradation pathways at the times examined. Following in vivo stimulation with LPS significant differences were found between the expression of immune genes at different stages of smolting, suggesting varying immune function at this developmental stage. No obvious changes were found in the expression of genes related to protein degradation. Further analysis will help understand how salmonid muscle responds to inflammation caused by an immune response.

Poster Board 61: **Biomethane from Macro Algae**

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Abstract: Recent oil and gas shortages highlighted the dependency of UK and Europe on foreign fuel supplies. The latest global estimates suggest fossil fuel reserves are peaking and will run out or become inaccessible within 40 years. Therefore, intensive efforts to accelerate the development of renewable biofuels are ongoing. Recent studies commissioned by the Crown Estate highlight the potential of Scotland's marine bioresources for the production of biofuels. The 'BioMara' Project (a Scottish Irish collaboration) aims to develop sustainable methods for Biomethane and bio-ethanol production from macro and microalgae. This presentation outlines the approach and preliminary results for biogas production from macroalgae using anaerobic digestion (AD).

Locally sourced *Alaria esculenta*, *Ascophyllum nodosum*, *Fucus serratus*, *Fucus vesiculosus*, *Laminaria digitata*, *Laminaria hyperborea*, *Saccharina latissima* and *Saccorhiza polyschides* were harvested for AD studies. The effects of physico-chemical pre-treatments, and both terrestrial and marine sourced inoculums on biogas production were assessed. Micro scale (100 ml) batch digestion trials were used to evaluate the biomethane production potential of selected species under mesophilic conditions. The most promising algal species were tested further in 1 litre digesters to assess the quality and quantity of biogas produced.

Our preliminary results show that limited quantities of biogas were produced from *Ascophyllum nodosum*, *Fucus vesiculosus* and *Laminaria hyperborea* under the conditions tested. While the *Alaria esculenta*, *Laminaria digitata*, *Laminaria hyperborea*, and the sugar kelp *Saccharina latissima* produced significantly more biogas. This supports the potential of macro-algae as a sustainable feedstock for anaerobic digestion. Additionally, the nutrient contents of solid and liquid digestates offer potential as compensation bio-fertilisers for agriculturally deficient soils. Further studies will optimise processing and pre-treatments to maximise Biomethane production.

Poster Board 62: **Unpacking historic salmon records**

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Abstract: The time a salmon spends at sea before returning to spawn is a critical determinant of its commercial value, but historical records contain only observations of the weight or length of fish captured. To date, time spent at sea (sea-age) has had to be determined by microscopic examination of scale-rings (analogous to growth rings in trees). We demonstrate a new statistical modelling technique which permits accurate determination of sea-age from records of the size of a captured salmon and the day of the year on which it was captured. We show that a single statistical model produces excellent sea-ageing performance throughout Scotland. We demonstrate the utility of this methodology by unpacking a 120 year historical catch record for the River Tweed and illustrating the long-term changes in the sea-age-composition of the stock.

Poster Board 63: **SREBP, LXR, and lipid biosynthetic mRNA levels are modulated by lipid depletion, cholesterol or long chain polyunsaturated fatty acids in Atlantic salmon cells**

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Abstract: A greater understanding of the control of lipid homeostasis in fish will be critical for the formulation of new sustainable aquaculture diets, now required to overcome the limited availability of fish oil. The aims of the present study were to identify Sterol Regulatory Element-Binding Protein (SREBP) genes in Atlantic salmon and to characterise their response, and the response of other potential target and regulatory genes including liver X receptor (LXR), to cholesterol and long-chain polyunsaturated fatty acids (LC-PUFA) in an established salmon cell line, SHK1. Two cDNAs for SREBPs homologous to mammalian SREBP-1 and SREBP-2 were characterised. Salmon SREBP-1 and SREBP-2 mRNAs were each expressed at similar levels in a range of tissues, with highest expression in pyloric caecae. We identified three groups of genes whose expression responded differently to the treatments. One group of genes, including cholesterol biosynthetic genes, showed increased expression in response to lipid depletion but supplementary cholesterol or LC-PUFA had no further effect. The expression of a second group of genes belonging to fatty acid biosynthetic pathways, including fatty acid synthase, $\Delta 6$ and $\Delta 5$ fatty acyl desaturases, also increased after lipid depletion but this was abrogated by cholesterol or by LC-PUFA. The expression of a third group of genes including acyl-CoA oxidase, HMG-CoA reductase and Elovl5 elongase was increased by cholesterol treatment but was not affected by lipid depletion or by LC-PUFA. This same pattern of expression was also shown by liver X receptor (LXR), indicating that acyl-CoA oxidase, HMG-CoA reductase and Elovl5 are possible direct targets of LXR. This suggests that salmon Elovl5 may be regulated differently from mammalian Elovl5, which is an indirect target of LXR, responding to LXR-dependent increases in SREBP-1. Furthermore, the results show that SHK1 cell line represents a useful model system for the study of the molecular mechanisms of lipid homeostasis in salmon.

Clean & Safe

Poster Board 64: **Tributyl tin oxide (TBTO) disrupts signalling by peroxisome proliferator-activated (PPAR), glucocorticoid (GR) and mineralocorticoid receptors (MR) at low environmentally relevant concentrations**

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Abstract: It is well documented that certain common environmental contaminants can interfere with sex steroid signaling in fish. Much less is known on the potential of pollutants to disrupt other endocrine axes. Here, we report high-throughput assays to identify chemicals interacting with piscine peroxisome proliferator-activated receptors (PPARs), glucocorticoid receptors (GRs) and mineralocorticoid receptor (MR). Our transactivation assay uses a fish cell line to transiently express protein chimera between the ligand-binding domain of the studied receptors and the DNA-binding domain of the yeast protein Gal4. Compared to assays based on full length receptors, this approach circumvents interference of endogenous receptors of the expression system. Chimeric GAL4 constructs were based on plaice (*Pleuronectes platessa*) PPAR sequences cloned in our laboratory before, and on European flounder (*Platichthys flesus*) GR and MR cDNAs isolated in this study. PPAR α and PPAR β were activated by fibrate drugs and by phthalate monoesters, both of which occur as water pollutants. GR was inhibited by the plasticisers bisphenol A and butylbenzyl phthalate. The marine priority pollutant tributyl tin oxide (TBTO) antagonised activity of all receptors studied, showing activity at environmentally relevant concentrations of TBTO (1–100 nM). Given the ubiquitous and persistent nature of TBTO, the possibility that chronic environmental effects are occurring via disruption of PPAR or corticosteroid signalling in fish should be further investigated.

Poster Board 65: **In situ monitoring data collected by the Scottish Environment Protection Agency**

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Abstract: Water quality monitoring equipment is deployed from buoys at five locations around the Scottish coastline in order to provide high frequency environmental data, as part of SEPA obligations to monitoring the marine environment. High frequency monitoring provides information on short term changes in water quality that are missed by lower frequency spot sampling.

In situ monitoring equipment gathers information on dissolved oxygen; water temperature; salinity, turbidity and chlorophyll-*a* at 15-30 min intervals. The data from each of these parameters is used to assess the state of the marine environment using agreed standards.

Chlorophyll data is used to indicate the biomass of phytoplankton for eutrophication assessments. Concentrations greater than 15 µg/l (as a 90 percentile in the growing season of April – September) are taken to indicate accelerated growth of phytoplankton.

Dissolved oxygen is consumed by the degradation of organic matter and the data is used to indicate water quality. Daily mean dissolved oxygen results are assessed against Water Framework Directive standards.

The data for these parameters are recorded continuously from buoys in Campbeltown Loch, Dunoon, Firth of Clyde, upper Forth estuary, Firth of Forth and the Ythan estuary. Results show that there is no evidence of accelerated phytoplankton growth in Scottish coastal waters and dissolved oxygen concentrations are at least good at all sites except the upper Forth estuary. Dissolved oxygen in the upper Forth estuary is consumed by organic rich sediments mixed in to the water column by the strong tidal currents leading to low dissolved oxygen concentrations during the biggest Spring tides in summer. Monitoring results are available on the SEPA web site.

Poster Board 66: **Contaminants in mussels**

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Abstract: Hazardous substances are released to the environment as a result of man's activities such as manufacturing, pest control and the burning of fossil fuels. Trace metals may also be released naturally by leaching from rocks and soils. Although the use of some substances has been banned (PCBs and some brominated flame retardants) they continue to enter the environment as a result of historical use. Water soluble contaminants may remain in solution. Less soluble contaminants are more likely to be incorporated onto particulate matter in the water column and deposited on the sea bed. Contaminants may be bio-accumulated, that is, absorbed into animal tissue by ingestion from particulate matter or absorption from solution.

Contaminant concentrations in mussels are compared to measured background concentrations to assess the degree of contamination. Trace metal concentrations are also compared to safe food limits and trace organic concentrations are compared to concentrations that may cause harm to the organism.

Trace metals are measured in blue mussels (*Mytilus edulis*) annually at rural (Shellfish Waters) sites and in the vicinity of discharges of hazardous substances. Cadmium concentrations are low at all sites however concentrations of lead and mercury were above background but below EC food limits at some sites. The EC food limit for lead was exceeded in mussels close to a harbour in the Firth of Forth.

A range of trace organic contaminants was measured including CBs, PAH and PBDEs. Concentrations were highest in the Forth and Clyde estuaries where they occasionally exceeded the Ecotoxicological Assessment Criteria.

Poster Board 67: **The widespread exposure of Scottish harbour seals (*Phoca vitulina*) to biotoxins from harmful algae**

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Abstract: The abundance of harbour seals in many regions around Scotland continues to decline yet the causes for this remain unknown. Several harmful algal (HAB) species of phytoplankton are now found regularly in Scottish waters, often producing large and prolonged blooms during spring and summer. In 2010 we investigated the extent of exposure to biotoxins from HABs among harbour seals at various sites around Scotland. Diatoms of the genus *Pseudo-nitzschia* are repeatedly reported, including species that produce domoic acid (DA), a potent neurotoxin. Although DA has a short half-life in body fluids, it persists for several days in faecal material, making this a useful matrix for exposure estimation. Faecal samples from seal haulout sites (n=262) collected during spring/summer were analysed for the presence of DA using ELISA and LC-MS/MS as a confirmatory tool. Analysis of the DA positive samples showed a significant correlation between the results obtained using these two methods ($R^2 = 0.918$, n=6). Along the east coast, including Shetland and Orkney, the proportion of positive samples (>2ng/g) was 48% (n=190) and in the Outer Hebrides it was 43% (n=23), whereas along the north and the west coasts the proportion of positive samples was only 12% (n=49). DA is most likely to have been ingested by seals which preyed on demersal benthivores such as flatfish and squid where high levels of DA have been detected (up to 1.3µg/g). Of added concern is the presence of saxitoxin-producing dinoflagellates *Alexandrium* spp in Scottish waters. Analysis results of faecal samples by ELISA suggest harbour seals can also be exposed to saxitoxin and its derivatives (33% positive, >40ng/g, n=18). Whilst toxin uptake is likely to be through chronic rather than acute exposure this may still have population level consequences. Increasing evidence suggests low level sub-convulsant exposure affects immunity in

marine mammals and neonatal exposure in laboratory animal models causes domoate-induced neurological changes which results in increased seizure susceptibility in adulthood.

Poster Board 68: **Optimisation of nucleic acid extraction from mixed liquor to permit characterisation of microbial digestion community and assess vulnerability to silver nano-particles**

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Abstract: The EU Water Framework Directive places obligations on member states in connection with the quality of water bodies, including coastal waters, and the integrity of wastewater treatment methods is assumed in meeting those obligations. Expanding use of a range of silver nano-particle species, including as an anti-microbial agent in consumer toiletries and clothing, may impact on the integrity of wastewater treatment methods if the microbial community exhibits vulnerability to silver nano-particle toxicity. Microbial digestion is used to reduce concentrations of key influent contaminants, including nitrogen, phosphorous and BOD. The compositions of the bacterial communities involved in these treatment processes vary from one facility to another, are dynamic, and are poorly characterised both with respect to constituent species and their function. Addressing these characterisation deficiencies is essential to allow meaningful evaluations of the vulnerability of microbial digestion processes to silver nano-particles exposure. Community constituent identifications based on 16S rRNA are amongst the best attainable and facilitate subsequent attribution of function, but depend upon the optimisation of nucleic-acid extraction and purification techniques. Optimisation must consider both the properties of the environmental sample, and the co-output objectives - maximum yield, minimisation of PCR inhibiting contaminants, and maximisation of nucleic-acid quality. Assessment of a matrix of extraction and purification techniques provides the building blocks for this optimisation, while use of multivariate modelling allows the most appropriate combination of methods to be selected based on environmental sample properties. Results from the individual methods

and the structure of the optimisation model are presented.

Poster Board 69: **Characterization of multiple vitellogenin genes in sand goby (*Pomatoschistus minutus*) and effects of ethinyl-oestradiol upon levels of vitellogenin mRNA**

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Abstract: Vitellogenins (VTG) are phosphoglycolipoprotein precursors of yolk proteins and in teleosts VTGs are synthesized normally only in the livers of fertile females. VTGs are incorporated into maturing oocytes and subsequently catabolised to yolk proteins which are utilized in embryonic development. The sand goby (*Pomatoschistus minutus*) is a small, marine, benthic teleost, which inhabits the coastal waters of Europe and has been used as a sentinel species for oestrogenic endocrine disruption in male teleosts with VTG as a biomarker.

Suppressive subtractive hybridisation was used to make a cDNA library rich in genes whose expression is up-regulated by 17-alpha-ethinyl-oestradiol in male sand goby liver. We have sequenced 267 clones and BLAST searches identified 72.3% of these to be VTG. Sequence assembly showed three distinct VTG genes in this species.

RT-PCR and rapid amplification of cDNA ends (RACE) was used to gain the full cDNA sequences. The nucleotide sequences were translated to reveal the deduced protein sequences, then aligned with reference sequence to show that, sand goby VTGA (1650aa) and VTGB (1646 aa) have full length domain structures comprised of Lipovitellin heavy chain- Phosvitin- Lipovitellin light chain- Von Willebrand factor domain (vWFD) while VTGC (1238aa) lacks the phosvitin and vWFD domains. Bayesian inference of phylogeny was performed with homologous teleost vitellogenin amino acid sequences.

Sequence-specific primers were derived and qPCR assays were developed to quantify sand goby liver, VTG transcripts. Intrinsic levels of VTG mRNAs in

females varied among VTG type (VtgA>VtgC>VtgB) and trace levels were observed in males. Exposure to EE2 induced VTG expression in males and increased VTG expression in females maintaining the intrinsic relative mRNA levels.

Poster Board 70: **Effects of environmental pollutant exposure on the flounder hepatic transcriptome: Pathways of ecotoxicity and novel biomarkers**

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Abstract: In many industrialized estuaries fish are exposed to complex and largely uncharacterized mixtures of chemical pollutants, each one of which may only be present at sub-toxic levels. We have been using a cDNA microarray to investigate gene expression in European flounder obtained from several UK estuaries of differing pollutant status with the aim of understanding contaminant effects and to discover novel biomarkers of exposure. The results show that gene expression profile can predict site, although it has been difficult to relate overall expression signatures to pollutant level against a background of many and varied natural environmental variables in different estuaries. By using mesocosms containing polluted sediments from contaminated UK estuaries, and comparing gene expression profiles in flounder exposed to clean sediments, we have shown that flounder respond by increasing the expression of genes belonging to apoptotic and innate immune pathways. In both the environmental studies and the controlled mesocosm experiment, one of the most highly up-regulated genes was Diablo/SMAC. Diablo/SMAC is a proapoptotic protein which sensitises cells to apoptosis in response to intracellular chemical damage. We are currently studying Diablo/SMAC in environmentally- and laboratory-exposed fish to investigate its utility as a general biomarker of multiple-pollutant exposure.

Poster Board 71: **Metabolomics of different tissues from the Norway lobster, *Nephrops norvegicus*: A first approach to determine biomarkers of environmental health in a crustacean**

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Abstract: Environmental metabolomics is a rapidly-growing field as its measurements can show the functional status of an organism at the molecular level. This information is obtained by determining the low-molecular-weight metabolite composition of tissues. Since the metabolites from metabolic pathways incorporate both genetic and environmental signals during expression, the potential exists to identify species-specific biomarkers for environmental health in different ecosystems. In this study, this emerging technology has been applied to different tissues of the Norway lobster, *Nephrops norvegicus*, a prominent member of the marine macrobenthic community on soft sediments. Specimens were captured monthly for a year by otter trawl from two Scottish sites, in the Clyde Sea area and the Minch, and metabolites were extracted from homogenized tissues ('head pastes') and from individual organs, the hepatopancreas, and gonads. These extracts were then analyzed using the 1D 1H and 2D 1H-1H homonuclear correlation NMR spectroscopy (COSY). From these analyses we determined that the major compounds in each of these samples were chitin, small molecular weight polysaccharides, a fatty acid and the pigment astaxanthin. However, differences between samples in different seasons, from different sites, and the various tissues could not be determined as the concentrations of these compounds within the samples were likely too low to be detected by NMR spectroscopy. Therefore, HPLC with full scan HRESIMS- Orbitrap was used to determine differences between the samples. These results were analyzed using principle component analysis (PCA) in order to find relationships between the samples. In this way,

differences in metabolite composition were evident between sites and seasons. Thus, hepatopancreas samples from different sexes and seasons were found to be significantly different, while female gonad samples were not significantly different between seasons. Identification of the compounds found was, however, very limited as the databases available have as yet recorded few metabolite identifications for marine organisms. Future research would be necessary in order to identify the compounds found, but once this is achieved these compounds could be used to determine biomarkers for *N. norvegicus* health within an ecosystem.

Poster Board 72: **Marine Litter: A Problem in Scotlands' Seas**

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Abstract: Scotland's vision is for 'clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long-term needs of nature and people'. There are many challenges to deal with in supporting this vision, one of which is that of marine litter.

Marine litter is the collective term for 'any persistent manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environments' (ICES, 2010). It has two sources – land based (approx. 80%) and sea based (approx. 20%). Marine litter is found everywhere in the world's oceans, not only close to densely populated areas but also in remote areas far from obvious sources (UNEP, 2005). Marine litter is made up of a variety of materials but the greatest concern at present is of plastic litter, due to its resistance to degradation and the fact that a large proportion of plastic floats and therefore has the ability to travel long distances in the oceans (Ryan et al., 2009). Plastics degrade very slowly, over hundred-year time scales, and are prone to breaking up into small particles. For example, a single one-litre plastic drinks bottle could break down into enough fragments to put one fragment on every mile of beach in the entire world (Moore, 2002). Concerns about the impact of micro-plastics have been growing over recent years as it appears that the abundance of micro-plastic litter has increased over the last few decades. The widespread presence of micro-plastics and the capacity of plastic particles to absorb, transport and release pollutants is of concern and may be a route by which toxic chemicals can enter the food chain. Micro-plastics already contain a range of potentially harmful substances such as flame retardants, plasticisers and antimicrobials, increasing the potential pollutant burden (Mouat et al., 2009).

The Marine Strategy Framework Directive (MSFD) requires EU Member States to put in place measures to achieve Good Environmental Status (GES) in their marine waters by 2020. By July 2012 Member States must determine the characteristics

of GES for their marine waters and set appropriate targets and indicators to ensure these will be achieved. There are eleven descriptors for which Good Environmental Status (GES) must be achieved. Descriptor 10 is for marine litter and states that 'Properties and quantities of marine litter do not cause harm to the coastal and marine environment.'

In support of this descriptor, at Marine Scotland Science (MSS) we have been monitoring the composition and abundance of marine litter on some of our research cruises since 2009. This preliminary data shows that marine litter is found in all areas of Scotlands' seas. In heavily populated/industrialised areas such as the Firth of Clyde the litter consists mainly of consumer type litter – i.e. drinks bottles and cans, food wrappers, clothing items. In more remote areas, such as the Minches, it is predominantly of fishing/shipping related rubbish such as buoys, lobster pots, fishing nets, wires and polypropylene ropes. We have also begun preliminary work on the investigation of the occurrence of micro-plastics in the water column, using a neuston net to trawl just below the sea surface to collect any small particles.

Marine litter is a mostly preventable problem, but due to the range of sources and the pathways by which it enters the marine environment it is difficult to tackle. We will discuss the developing understanding of the situation in Scottish waters based on recent MSS monitoring and historical data.

Poster Board 73: **Are Scotland's Seas Clean and Safe with respect to persistent organic pollutants?**

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Abstract: The marine environment acts as a sink for many hazardous substances, including persistent organic pollutants (POPs). Over the last 30 years a number of these substances have been highlighted as a cause for concern and have been the subject of extensive study and international regulation. Many of these compounds are known to bioaccumulate and biomagnify and some have been found in areas remote from sources or emissions (e.g. Arctic) as a result of long-range atmospheric transport. Historically the biggest source of hazardous substances to the environment was from heavy industry (steelworks, mining and gasworks). In more recent times increased regulation and closure of some of these industries has reduced contaminant inputs from such sources. However, due to the persistent nature of many hazardous substances, high concentrations can still be found in marine sediments, particularly in industrialised areas, as a result of these historical inputs.

Monitoring of hazardous substances in the Scottish marine environment is required so as to ensure that Scotland fulfils its international obligations to OSPAR and under EU legislation and to assess progress towards achieving Scotland's vision of clean and safe seas. Marine Scotland has undertaken the analysis of a range of contaminants in the marine environment for more than a decade. This has included the analysis of legacy POPs such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) as well as more recent contaminant groups, including polybrominated diphenyl ethers (PBDEs) in sediment and biota. Temporal and spatial trends were investigated by Scottish sea area and the concentrations assessed against internationally agreed assessment criteria, where available. Rules were developed for the aggregation of the contaminant data across each sea area. An overall assessment for each sea area was then assigned, looking at the frequency of sites or strata within each sea area that were above or below the

relevant assessment criteria. Scotland's seas were found to be mainly clean and safe, except in some localised areas, due to past industrial discharges. There were few temporal trends for sediment or fish liver, but where they were present the trend was downwards.

Poster Board 74: **Cod in a web: a partial-ecosystem approach to modelling cod in the North Sea**

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Abstract: We present a new and general modelling approach for coupled length-structured fish populations, and apply it to North Sea cod and its main predators and prey. The model includes a target set of fish species which are modelled with full length structure from egg to adult, together with a highly simplified representation of the rest of the ecosystem. The food requirements for growth, maintenance and reproduction are used to calculate predation mortalities on the prey. The model was confronted with time series of stock biomass, recruitment, and landings, as well as survey data on length distributions, and diet data. The results show that herring predation on early life history stages of cod is dynamically important, and that high herring abundance may play a role in the decline of stocks even during periods of declining fishing pressure. We show that the maximum sustainable yield of cod is strongly dependent on herring abundance, and we predict that current levels of cod exploitation may become unsustainable if herring recruitment returns to historical high levels.