Hidden diversity: Coral/carbonate - faunal associations

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Most deep water biological research focuses on the fauna that can be seen either living on/within the sediment or the animals living on hard substrates such as exposed bedrock/carbonates. Very little work has been undertaken on the animals that actually reside inside carbonate structures e.g. coral, as it is often not realized that these animals exist.

When sampling Senghor and Ampere seamounts in the North Atlantic, coral/carbonate samples were sometimes collected as a by-product when attempting to collect soft-sediment for infaunal analysis. On several occasions when sampling the summit plateau of Ampere seamount, large pieces of coral/carbonate were snagged when using long line hooks. By contrast in the South West Indian Ocean carbonate structures and corals were actively sampled to investigate the diversity of the associated fauna living on the outside of the corals. Samples were collected using the *Kiel 6000* ROV, as well as the HYBIS.

In the laboratory fauna that were visibly attached to or inhabiting the branches of the carbonates and corals were removed and identified. The large coral and carbonate pieces were broken into smaller more manageable pieces then weighed individually prior to dissolution in acetic acid. The coral/carbonate was left in the acid for a set period of time before the acid being poured through a stack of 250 µm and 32 µm sieves to collect the macro- and meio- fauna. Photographs were taken of the partially dissolved material prior to being returned to the acid solution. This process continued until no coral/carbonate material remained.

The results show a wide ranging number of individuals and fauna collected (even after standardization). The age of the coral/carbonate appeared to influence the number of fauna found inside it. The older the appearance of the coral the more fauna generally found.

In general polychaetes, sipunculids and sponges were the most abundant fauna. The polychaetes were mostly dominated by the syllids, sabellids and polynoids.

Preliminary results from Ampere seamount indicate that ~50% of the total number of individuals collected came from dissolving the coral/carbonate material, yet they only contributed to 7% of the total biomass. This is in contrast to the results of Hutchings and Weate (1978) who found that fauna collected from crushing the coral material and also from acid dissolution contributed to <27% of the total fauna collected.

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Long-term trends in UK ex-vessel fish prices and the impact of imports, exports and aquaculture production.

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The ex-vessel price of fish is an important factor when determining the economic impacts of fisheries management decisions, since the revenue of the fishery is determined by this price along with the catch . For example earnings due to reduced catch may be compensated for somewhat by an increase in the ex-vessel price. Normally when modelling the economic impacts associated with fisheries (assuming the fishery is not so small that its impact on price is negligible) a simple inverse price-quantity relationship is used. However, although seasonal trends can often be seen to follow an inverse price-quantity relationship, few fish price data actually conform to a clear inverse relationship between price and landings in the long term, so assuming this type of relationship may lead to erroneous conclusions when modelling economic effects. Evidence has been found of market integration between different fish species (Jaffrey et al., 1999, Nielsen et al., 2012) and across international markets in Europe (Nielsen et al., 2009), suggesting simple inverse relationships between catch and price may not be appropriate for a single species or a single national market. In addition, the price of fish can also be impacted by changes in demand over time caused by changing consumer behaviour, along with the globalisation of the seafood market and an increasing reliance on aquaculture (Asche et al., 2005).

Here, we consider average annual market prices for each fish species in the UK, adjusted with the CPI, to identify links between the prices of different species of fish and the long term relationship between annual UK price and landings. As expected very few trends in the average annual price of a species can be explained well by an inverse relationship between price and landings of that individual species, either into the UK or in Europe. The prices of many different species are found to be linked (particularly amongst demersal fish), however even considering the landings of linked and similar species, landings alone appear to have limited ability to explain long term changes in fish prices, with much of the variability left unexplained. Overseas trade is perhaps the most important reason for this; most seafood consumed in the UK is imported and the UK is a net importer of fish. Both imports into the UK and exports out the UK have increased dramatically over the past 50 years, weakening the relationship between fish price and UK landings. The explosion of aquaculture production in the UK (particularly over the past 20 years) also offers a competing source of seafood which decreases the demand (and hence price) for wild fish. The effects of these variables are therefore considered as well, to determine if a relationship can be found between average annual ex-vessel price and the supply of fish (of different species) from fisheries landings, overseas trade and aquaculture production.

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LIGHT TO DARK: INVESTIGATING NOVEL PATHWAYS LINKING PHOTOPERIODIC CUES TO THE BRAIN-PITUITARY-GONAD AXIS IN ATLANTIC COD.

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In temperate climes, photoperiod has been identified as the strongest environmental cue for entraining the seasonal behaviours of mammals and birds, including seasonal reproduction. Over the last decade, several of the key molecular drivers involved in the photoneuroendocrine cascade have been elucidated. The transcription factor Eya3, along with TSHβ and the deiodinases - Dio2 and Dio3, have all been identified as key drivers of maturation in mammalian and avian seasonal breeders. Increased expression of Eya3 during advancing photoperiod (increasing day length) has been found to play a stimulatory role in the reproductive cycle of long-day breeders such as the hamster and the Japanese quail[1, 2], as well as an inhibitory role in the reproductive cycle of sheep and goats (short-day breeders[3, 4)]. Despite a growing understanding of this system among mammalian and avian models, little is yet known of the role Eya3 plays in the maturation cycle of fish.

In this study, we analysed the photoperiodic regulation of the Eya3-TSHb-Dio2 cascade in Atlantic cod. Fish were exposed to either continuous light (reproductive inhibition) or simulated natural photoperiod (reproductive stimulation) from July to December. Monthly expression was analysed through qPCR, demonstrating a strong activation of pituitary Eya3 under declining photoperiod. As this coincided with the onset of secondary gametogenesis, these results suggest that Eya3 may play a stimulatory role in the photoneuroendocrine cascade of Atlantic cod.

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Development of a bioeconomic model of seal impacts on West of Scotland fisheries

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In the north Atlantic Ocean, the 20th century has been marked by a change in fish stocks resulting in the depletion of high value commercial fish such as the Atlantic cod (*Gadus morhua*) or the Atlantic herring (*Clupea harengus*). Meanwhile, scientists have noticed an increase in the grey seal (*Halichoerus grypus*) population. This situation has created significant conflicts between fishermen and conservationists as regards to the role that grey seals may have played in the stock depletion. This is all the more intensified by the fact that fishermen see their costs increase due to seal damage to gear or fish. Currently, opinions are still divided, and it seems that further studies need to be done to measure the impact of seals on fisheries and to propose future seal and fishery management.

The only way to assess correctly the effects of seals on fisheries is to consider the economic impacts. However, published work investigating the economic impacts of seals on fisheries is rare or incomplete. Indeed the seal-induced fishery loss should be compared to fishery profits to quantify seal impacts but this is hardly examined. Hence, it is necessary to fill this gap by developing more studies, notably using bioeconomic modelling, to enable scientists to draw management strategies to mitigate the seal and fishery conflicts.

We developed a bioeconomic model able to quantify the economic impact of grey seal predation on West of Scotland cod, haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) fisheries. We used seal diet data from the Sea Mammal Research Unit to create a biological age-structured model accounting for seal predation on these three species. Including seals in this multispecies model as one of the predators would allow us to obtain a better assessment of the fish natural mortality due to seal predation. The model also includes a multifleet component which enables us to be as close as possible to the current organization of the West of Scotland fisheries for demersal fish. Other main species caught by demersal trawlers have been included within the model (saithe, *Nephrops*, anglerfish, hake, megrims and ling) so it is assumed that these species with cod, haddock and whiting explained most of the revenues of the mixed demersal fishery in West of Scotland The biological model is linked to an economic model accounting for fisheries revenues and costs. It is assumed that the fishery follows the characteristics of an open-access fishery which reaches a bioeconomic equilibrium when the revenues equal the total costs. Running the model to the bioeconomic equilibrium enables to test different management strategies on seal but also on fisheries.

Preliminary results have shown that the bioeconomic equilibrium is marked by a collapse of the three species of interest no matter the number of seal present when an unrestricted supply of the other fish is available. The model is also sensitive to the stock-recruitment relationship. It is then important to work on these characteristics of the model to make it as realistic as possible.

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The absence of abyssal *Coryphaenoides spp.* (Macrouridae) in the northern South Fiji Basin and depth range flexibility in *Bassozetus sp.* (Ophidiidae) in their absence.

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Beyond notable exceptions, such as seamounts, vents and seeps, the abyssal plane is considered to be relatively homogenous globally. Abyssal species distributions are often on the oceanic or global scale. One such circumglobal species is the Abyssal grenadier (*Coryphaenoides armatus*) (Cohen *et al.*, 1990), a scavenging species easily attracted to bait (King & Priede, 2008).

In a series of cruises exploring the abyssal/hadal interphase around the New Hebrides (to the north of the South Fiji Basin) and the (more southern) Kermadec trench, baited landers were used to attract scavenging fish within view of cameras. The edge of the Kermadec Trench could be considered a classical depth progression: from about 4000m onwards *Coryphaenoides armatus* gives way to its deeper congener *C. yaquinae* (Jamieson *et al.* 2012) and eventually to the Cusk eel *Bassozetus sp.* which extends beyond 6,000m.

In the more oligotrophic northern extent of the basin toward the New Hebridies Trench the once ubiquitous *C. armatus* is noticeably lacking, as was its deeper congener *C. yaquanae*. Here the lack of Macrourid species appears to allow *Bassozetus sp.* to extend several thousand meters shallower than where the Macrourids are present.

As more data is collected on deep fish species a more nuanced picture is forming, revealing flexibility in depth ranges and notable exceptions in assumed global distributions. Differences in environmental gradients including energetic input to the area, feeding strategies and energy requirements are considered to explain this apparent community difference.

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Ocean colour remote sensing for inshore and marine energy applications.

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Ocean colour remote sensing has transformed our view of global and regional ecosystem functions in surface waters of the ocean. We are now able to visualise complex interactions between physical mixing processes and biogeochemical functions across previously unimaginable temporal and spatial scales. The availability of an unbroken time series of global ocean colour data from a series of sensors stretching back to SeaWiFS launched in 1997 means that ocean colour has been recognised as an essential climate variable with potential to reveal climate change effects at different scales.

The availability of such an extensive data set and the multiplicity of potential uses means there is increasing focus on data quality. This includes radiometric calibration of the satellite sensor itself, but just as importantly atmospheric correction of remote sensing data and performance of product algorithms to convert radiometry into useful products such as chlorophyll, diffuse attenuation, sediment concentration etc. Ground truthing ocean colour data is therefore extremely important, but often hard to achieve in practise due to limited numbers of clear coincident overpasses.

An important emerging application for ocean colour remote sensing is monitoring the environmental impact and performance of energy production installations in the marine environment. This includes establishing the effect of installing large arrays of wind turbines with associated mechanical structures on the seabed as well as the impact of submerged tidal stream devices on water mixing and sediment dynamics.

Ocean colour remote sensing is potentially useful for establishing baseline environmental conditions before arrays are installed, monitoring the impact of array construction and maintaining observations during the operational lifetime of the array. In the case of tidal stream devices, it may also be possible to identify tidal wakes from ocean colour imagery and to determine the extent of interaction with downstream devices in large arrays, potentially leading to improved operational efficiencies.

For these applications, a key limitation with the current generation of ocean colour sensors is limited spatial resolution. MODIS provides pixel widths of ~750m which are useful for establishing the broad context of an array and in cases of very large arrays, possibly evidence of environmental footprint. However, an order of magnitude decrease in pixel size is required for exploitation of the true potential of the technology. The recently launched LandSat-8 sensor provides 30m resolution on the ground, with 8 day repeat visit cycle, and spectral bands that are useful or ocean colour type algorithms, offering a step change in remote sensing capability for coastal installations.

Here we present recent results demonstrating current state of the art algorithm performance for MODIS data. We are able to demonstrate strong validation of our sediment algorithm against a long term in situ data set collected off Stonehaven (Figure1). This analysis includes both atmospheric correction and intrinsic algorithm performance, and results in sediment concentration estimates with assigned measurement uncertainties.

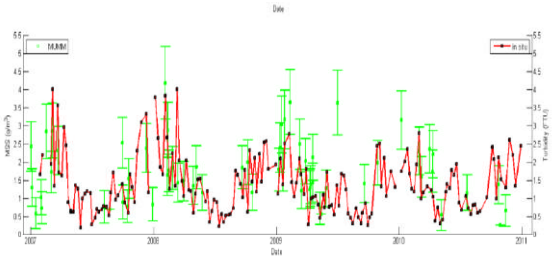

Figure 1: In situ turbidity measurements (red line) and concurrent MODIS estimates of sediment concentration (green symbols) over a four year period off Stonehaven. Error bars represent uncertainties in intrinsic algorithm performance due to potential impact of other suspended materials.

We also demonstrate the potential value of recently available LandSat-8 data. Using data from this sensor it is possible to resolve previously unseen physical and biogeochemical processes in the coastal environment, including the impact of wind farm assemblies on local sediment dynamics. A variety of other new features can be observed including aquaculture operations, shipping activities and other coastal zone features.

Looking to the future, there is considerable activity in the Scottish marine science community towards developing ocean colour capability on remotely piloted aircraft. Successful development of this capability will drive forward a further step change in spatial resolution with important potential applications for monitoring harmful algal blooms, oil spills, large predator behaviours and many other possibilities. However, in order to maximize this potential, we need to focus on development of appropriate data correction procedures to deal with pointing accuracy, sun glint and other instrumental factors. This will require a sustained effort including detailed radiative transfer modeling of sea surface interactions as well as direct observations from new platforms.