Investigations into the Seasonal movements of a UK Shark species.

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Tope (Galeorhinus galeus) is a common elasmobranch in the North East Atlantic. Occurring globally, it has suffered severe exploitation in some areas, even earning itself the name 'soupfin shark'. Being one of the first examples of a species of elasmobranch protected by a Marine Protected Area, and how that protection failed, it is of worldwide conservation interest, yet data on its movements and behavior are scarce.

Here we show the results from a data storage tagging study with tags deployed in Southern Scotland that recorded depth and temperature to inform us on the vertical movements of tope. Data from DSTs show mature tope moving off the continental shelf to depths ~800 m over winter and, in some cases, appear to change their vertical behavior in different habitats. There also appears to be variation in diurnal diving behavior between males and females in some instances.

Further to this, we present analysis of mark and recapture data from the Scottish Shark Tagging Programme to investigate seasonal movements. This data shows that maximum depth increases with size and that there appears to be some level of site fidelity. It appeared that most tope remained within 500 km of their tagging site, although some mature females had a larger, more southerly range, including connectivity with the Mediterranean and Canary Islands.

This study provides the first insight into the seasonal movements of tope in the NE Atlantic in relation to the water column and is a valuable contribution to our understanding of this species.

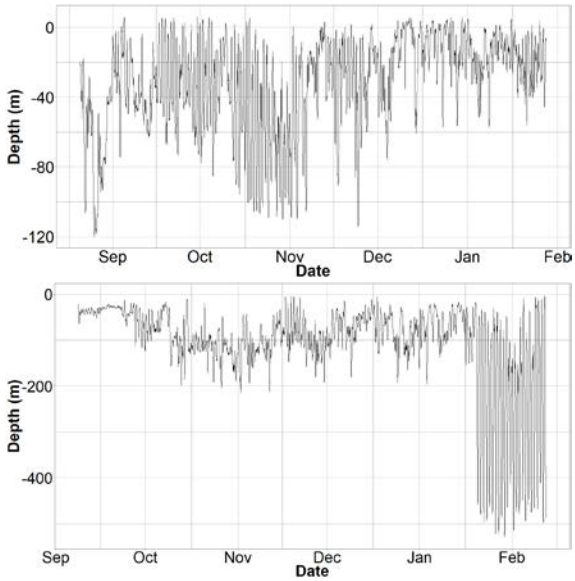

Figure 1: Depth plots from 2 male tope tagged in August 2014.

Thanks to: the Scottish Shark Tagging Programme, the UK Shark Tagging Programme and Glasgow Museums Tagging Programme for providing the mark and recapture data; all the anglers who have volunteered their time to undertake tagging and data gathering; Ian Burrett for assistance with deployment of data storage tags in South Scotland; the members of the public who returned the tags. This work was funded by research grants from the Fisheries Society for the British Isles and Scottish Natural Heritage and a studentship from the Marine Alliance for Science and Technology in Scotland.

Modelling Blue whiting adults migrations influenced by their biophysical environment

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The northeastern Atlantic population of blue whiting, *Micromesistius poutassou*, has shown large stock fluctuations for the recent decades. As a commercially important fish species, building a spatial population dynamic model would both enable better understanding and forecasting. Climate variations seem to be the main cause of the observed stock fluctuations. It is known that variations in the strength of the subpolar gyre affect adult distribution on their spawning grounds off the British Isles and may explain stock fluctuations by changes in recruitment. Therefore, modelling the spatial dynamics of blue whiting requires the cautious inclusion of environment drivers. Here, we focus on modelling adult movement.

Observations have shown that mature adults go to their main spawning grounds off the British Isles from February to April and they then migrate to their main feeding area in the Norwegian Sea where they stay over the summer and winter. Here, we explored whether modelled migration influenced by biophysical drivers would be enough to generate these observations. Our first hypothesis is that food changes in space and time play a significant role in migration decisions and at least partly explain the migration to the Norwegian Sea. However, hydrodynamics present at the average swimming depth suggest that migration paths might also be well affected by currents. Temperature may also influence selection of suitable habitats. Using an established particle tracking model, initially designed to model fish eggs and larvae, we explored methods to integrate adult migration behaviours that would follow environment gradients.

From our results, northerly currents are advantageous for this migrating fish and might amplify the main attraction to the Norwegian Sea as feeding area. Food gradients might start to affect migrating paths around May and lead migrating adults to settle in the Norwegian Sea for feeding in summer. However, the environmental factors used in this study seem to be insufficient by themselves to make adults move from the spawning grounds into the Norwegian Sea in the time suggested by previous field observations, and imply that other processes are involved.

Because of the potential relationship between subpolar gyre dynamics and adult distribution on the spawning grounds, a similar investigation should be applied to spawning migrations as well, where temperature and salinity would be factors of greater importance in selecting suitable spawning habitats. The final model will produce connectivity

matrices which will be used in a spatial growth model for blue whiting.

Towards a more sustainable fishery management – could Remote Electronic Monitoring be the key?

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The waters around Scotland support numerous commercially important fish stocks. Managing the fisheries to ensure sustainable exploitation is a challenging task, especially now, given the recent implementation of the Landing Obligation and forthcoming changes under Brexit.

Satellite tracking is used to monitor fishing activity (e.g. AIS, VMS). However, a new system called Remote Electronic Monitoring (REM) was recently developed. It integrates CCTV cameras installed on fishing boats, with various activity sensors (e.g. winch pressure, engine RPM) and GPS data which can give a clearer insights into fishing activity.

Although currently a compliance tool, REM has the potential to provide data for scientific purposes. It provides video footage, which can be analyzed by scientists to collect data on the numbers, length and species of fish, which are caught and retained by the vessel. These data are one of the input requirements for stock assessment, the results of which are used to provide fisheries management advice.

Our research aims to explore the utility of REM data as part of a fisheries management strategy from a scientific and compliance point of view. Hence, we modelled a known stock and simulated data collection from this stock through conventional observer sampling (2% coverage at 100% accuracy) and novel REM sampling (50% coverage at 70% accuracy).

A standard stock assessment was carried out using the data generated by each sampling method separately. On the basis of the stock assessment results, management decisions were made which involve setting and implementing a Total Allowable Catch (TAC) for the next year. The analysis explores different levels of management implementation error (such as over quota catches) which is assumed to depend on REM coverage of the fleet. The whole process was repeated for 30 years to identify the long-term impact of the different sampling methods.

This work highlights the strength of REM as a tool for data collection and compliance, which allows for robust stock assessment and its long-term benefits for a sustainable fishery.

Variation in sediment nutrient content and benthic community traits across gradients of natural and fishing disturbance

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Microbial processing of organic matter and recycling of nutrients in coastal waters is strongly influenced by sediment properties. In particular, rates of organic matter mineralisation and nutrient exchange in fine-grained, impermeable, anoxic sediments are orders of magnitude lower than in oxygenated permeable sediment (Huettel *et al.*, 2003). Hence, low-permeability seabed habitats serve as nutrient sinks, and biogeochemical rates are sensitive to sediment mixing and resuspension by benthic faunal activity, water movement and anthropogenic activities. Coastal marine ecosystems face altered sediment disturbance regimes due to changing environmental conditions and fishing activity patterns, highlighting a need to predict the impact on future ecosystem function. However, availability of data on key seabed sediment properties, especially sediment permeability, is poor.

Within the Firth of Clyde, fishing effort overwhelmingly targets the Norway lobster (*Nephrops norvegicus*), a burrowing decapod that inhabits the extensive areas of fine-sediment seabed. Despite a widespread recognition of the importance of seafloor integrity for the maintenance of ecosystem function, predicting the ecological effect of changes in physical disturbance regime is challenging. Boosted nutrient exchange in low-permeability sediments may also be accompanied by changes in water column turbidity and vertical mixing that increase light attenuation in surface waters and constrain primary production. Moreover, demersal fishing has been shown to modify benthic community structure, potentially leading to altered bioturbation rates.

Here we present the results from three research cruises carried out in the Firth of Clyde in 2017 and 2018 to characterise seabed sediment physical properties and the variation in seabed nutrient content and benthic community structure across gradients of fishing and natural disturbance. The results show that in situ measurement of sediment permeability for the Firth of Clyde are among the lowest measured anywhere to date. We extend generalised relationships between permeability and grain size to fine silts and muds and produce a permeability map for the Clyde. We use outputs from a hydrodynamic model of the Clyde sea (Sabatino *et al.*, 2016) to estimate natural disturbance due to water movement. We show how pore-water nutrient concentration and benthic community traits, including bioturbation potential and taxon body size, vary across gradients of disturbance.

The findings will be used to parameterise and validate the StrathE2E model (Heath, 2012) to assess the ecosystem consequences of fishing in the Firth of Clyde.

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Spatio-temporal distribution of blue sharks (*Prionace glauca*) in the North Atlantic Ocean: an analysis of population structure, habitat preference and fishing pressure vulnerability

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The blue shark (*Prionace glauca)* is one of the most abundant and widespread shark species globally. However, it is also the most heavily exploited, with high numbers caught as bycatch in pelagic longline fisheries and as target catch in the international finning industry. The movement, distribution and population structure of blue sharks in all the major oceans is complex and so far poorly understood. Further, stock assessments in the North Atlantic are highly uncertain, making estimates and prediction of population health and status difficult and ambiguous. An essential prerequisite to effective management and protection of North Atlantic blue sharks is improved understanding of spatio-temporal distribution and vulnerability to exploitation. In this study, the spatio-temporal distribution of blue sharks in the North Atlantic is analysed in relation to population structure, habitat preference and fishing pressure vulnerability. GIS-based spatial statistics and mapping, and multi-variate regression modelling are used to analyse a previously unexamined UK-based tag-and-recapture database spanning more than 20 years (1995-2016). Major hotspots of distribution were identified near the Mid-Atlantic Ridge, the Azores and in the Bay of Biscay. The consistent high density of juvenile and sub-adult recaptures near the Azores provides further support for the use of the area as a major blue shark nursery. The Azores were also identified as an area of overlap between blue shark distribution and high longline intensity. Further, juvenile and mature sharks were found to have distinct habitat preference in relation to SST, chlorophyll-a concentration and depth, with juveniles preferring shallower, cooler and more productive waters. This study therefore concludes that juvenile blue sharks in the North Atlantic are both inadvertently over-targeted by longline fisheries, and potentially more susceptible to global warming-induced oceanic changes. Given the importance of juvenile survival to total population growth, the North Atlantic blue shark stock may not be as stable and resilient as previously thought. This study identifies policy gaps in blue shark management, and suggests that the Azores region be prioritized for protection and conservation resources.

Fisheries policy in the Faroe Islands: Managing for failure?

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The abstract should be submitted to masts@st-andrews.ac.uk, in an editable format, by 16:00 Friday 27th July 2018.

The Faroe Islands have gone through several different fisheries management regimes for their demersal home fleet in the last seven decades – open access, regulated open access, a licensing system, a brief period of individual transferable quotas, and, since 1996, an effort quota system, where the main control component consisted of fishing days (Guttesen, 1980, 1991, 1992; Jákupsstovu et al., 2007; Nolsøe, 1964).

The Faroese demersal stocks are severely overexploited and there is risk the commercially important cod and haddock stocks cannot replenish (ICES, 2017a, 2017b). The Faroese economy relies heavily on the fishing industry and the fleet is largely unprofitable.

In this paper, we describe and analyse the main characteristics of the above regimes and developments in policy to identify problems that have caused mismanagement of the stocks.

We then compare this to the management of the Faroese pelagic and distant-water fleets, which have largely been managed with TAC and in collaboration with coastal states, to identify policy inconsistencies.

We conclude that Faroese authorities have 1) persistently believed that fishing effort can be directed away from overfished stocks but have failed to do so; 2) shown systematic short-sightedness in management of their fishery; 3) demonstrated an inability to sacrifice jobs for the sake of profitability and sustainability, and 4) that the pelagic fishery, which is managed jointly with other coastal states, has been managed rationally, is more sustainable and more profitable, indicating that the Faroese are able to manage their resources rationally but have largely been unwilling to make the hard choices when it comes to the home fleet.

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Investigating impacts of the EU CFP landing obligation on the fishers of Shetland.

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Negotiations for Britain's exit from the European Union (Brexit) could have huge implications for UK fisheries. A move away from European Union Common Fisheries Policy could present positive opportunities for Scottish fisheries to establish more effective and reactive fisheries management systems – managing sustainable stocks alongside economic growth. Prior to any policy adaptation, it is imperative to understand current factors affecting fish stocks and model how these factors may influence future stocks.

Using ecosystem network analysis to explore marine systems we evaluate past and present dynamics to estimate future impacts of the Landing Obligation (LO) (aka discards ban). In building an Ecopath with Ecosim (EwE) model of northern North Sea (ICES IVa); we aim to determine how the LO may affect both the ecosystem and economy of Shetland fisheries. An ecosystem approach allows for understanding the dynamic networks occurring between fish stocks and pressures affecting them. Current EwE models focus on the entire North Sea to answer a wide range of policy questions. EwE northern North Sea model focusses on catch, discards and diets within International Council for the Exploration of the Sea (ICES) area IVa, to represent specific mixed fisheries surrounding the Shetland Isles. The model uses up to date survey data, discard estimations and fish stomach records. Model outputs aim to inform evaluation of adaptive management strategies, maximising sustainability and economic benefit for fisheries.

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Using a sandeel growth model to investigate climate-driven bottom-up effects on sandeels and seabirds

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The lesser sandeel, *Ammodytes marinus*, a key prey species for seabirds and other top predators in the North Sea, shows clear spatial and interannual variation in size and phenology, which can have large consequences for its predators. This variation is hypothesised to be the result of differences in the sandeel zooplankton prey, but this has not been investigated on a larger scale. An improved understanding is urgently needed in order to predict how sandeels will respond to climate-driven changes in zooplankton communities and what this may mean for their predators, many of which have shown steep declines in recent decades.

Here, a sandeel growth model is introduced that can be used to address this issue. This model is adapted from MacDonald et al. (submitted) and takes time series of food conditions as input and produces daily estimates of sandeel body size. Furthermore, it predicts when sandeels, who spend most of the year buried in the sand, are available in the water column and thus more accessible to predators. As such, the model provides a link between sandeels and its zooplankton prey and produces output relevant to sandeel predators: sandeel size and phenology.

Future plans to use the model for investigating climate-driven bottom-up effects on sandeels and seabirds are also discussed. First, running the model using existing zooplankton data and comparing the output with data from sandeel surveys will allow us to determine whether differences in zooplankton conditions can explain observed spatiotemporal patterns in sandeel size and phenology. Second, model output of sandeel size and phenology will be compared to the breeding success of sandeel-eating seabirds. Finally, through combining the established links between zooplankton, sandeels and seabirds, we can investigate how sandeels and seabirds will be impacted by ongoing and projected climate-driven changes in the North Sea zooplankton community.

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