

Application of harvest control rules (HCR) using length-based indicators for shellfish stocks and fisheries

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Abstract:

A number of important crustacean stocks in the Scottish fisheries are considered to be data-limited. In the absence of data from scientific surveys to support a stock assessment, reliable commercial catch data together with length frequency data of sampled catches can be used to support an indirect assessment of stock status. Length-based indicators are a simple tool to describe the length frequency distributions of catches. Appropriately selected indicators can help to evaluate the presence of very large individuals in the catches and exploitation with regard to maximum sustainable yield and give catch advice. We developed a length-based sex-structured population model, parameterized for European lobster *Homarus gammarus*, to simulation-test the suitability of selected length-based indicators in harvest control rules for the management of data-limited crustacean stocks. We compared the harvest control rules in terms of the risk of falling below a SSB threshold, variability in catch advice, and speed of recovery from overexploitation.

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Evaluating regional designs for the on-shore sampling of North Sea demersal fisheries

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There has been an increase in the number of fish stocks subject to analytical assessment by the International Council for the Exploration of the Sea (ICES) in recent years, which in turn requires that data for a greater diversity of species are collected, while at the same time maintaining adequate sample sizes and operating within existing resource limits.

A particularly important aspect of the input data to many fish stock assessments is the numbers of fish landed and discarded by age or length by commercial fishing vessels. These data are currently collected on a national basis, through data collection programmes that reflect the priorities, commitments, and budgetary considerations within individual nations. The combined output of these national schemes is far from optimal for estimating the catch of mixed demersal species in a particular region.

Here we evaluate potential regional designs for the biological sampling of the demersal landings from the North Sea. We use a simulation model to mimic the on-shore sampling landings from individual fishing trips, the data sampled being the collated logbook and sales note data provided by Belgium, Denmark, England, France, Germany, Netherlands, Scotland and Sweden.

We replicate two-stage sample selection involving firstly the arrival location (port) and date, and secondly the voyage. We estimate total landed tonnages, by species and by country, as a proxy for the age distributions and length distributions that are, in reality, collected. The designs evaluated included stratification by country with the current national effort allocation, a regional major & minor port stratification, and a within country major & minor port stratification; the present sampling effort

being reallocated on a regional basis for the latter two designs.

Results suggest that the present national designs are less efficient than a simple random sample, and that a regional approach using the country major & minor port stratification would provide better estimates both for the differing fish species and for individual countries.

These designs are based within a statistical sampling framework (e.g. Kish, 1965; Lumley, 2010; Thompson, 2012) and the principles can be applied to many forms of marine data collection.

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Environmental drivers of landings variability in Shetland creel fisheries

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Abstract

Catch rates of crustaceans in creel fisheries are closely linked to a range of environmental factors. Environmental effects on landings of brown crab (*Cancer pagurus*), velvet crab (*Necora puber*) and European lobster (*Homarus gammarus*) from creel fisheries in Shetland were investigated using data from a fishers' logbook programme. The study aimed to identify relationships between the spatiotemporal landings per unit effort (LPUE) of each species and variables including sea surface temperature (SST), chlorophyll *a* concentration (Chl *a*), tidal current speed and wind speed and direction. Exploratory time series analyses in four areas using generalised additive mixed models (GAMMs) revealed that differenced SST and Chl *a* (with seasonal trends removed) had very little effect on LPUE of any species. Wind speed also had little effect and wind direction had very subtle effects which were not spatially consistent for each species. LPUE increased with tidal current speed in one area, before declining at higher speeds. LPUE followed similar seasonal trends for each species, with the highest landings generally occurring in late summer and early autumn for brown crab and lobster, and in late autumn and early winter for velvet crab. It was suggested that seasonal cycles in LPUE are linked not only to absolute temperatures, but to biological processes that also follow seasonal cycles, such as moulting and reproduction. Further investigation into spatiotemporal differences in catch composition, such as sex and size ratios, would improve interpretation of results and help devise management strategies in relation to seasonal biological processes of each species.

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Climate change and sandeels: can we ignore the direct effects of temperature?

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Sandeel energy value and abundance can vary dramatically year-to-year. This can reduce breeding success of sandeel dependent seabirds, especially those that are limited to carrying one fish at a time. Large declines in sandeel abundance off the Scottish east coast have been linked with climate change. The route from recent climate change to sandeel declines is poorly understood. Temperature rises may have detrimental effects on sandeel physiology, or impact sandeel prey and predators. Here we consider the influence of direct effects through temperature and indirect effects through food on sandeel size and energy levels using a new dynamic energy budget model. The model is parameterized and tested using survey data from the Firth of Forth between 2000 and 2008, and empirical data on sandeel. Body mass was assumed to consist of structure and reserves. Fish size and condition determined the partitioning of ingested food between structure and reserves. The model reproduces observed changes in sandeel length, weight and energy. Fluctuations in food levels were the predominant influence on year-to-year changes in size. In contrast, annual variation in temperature had a minor effect. We therefore conclude that indirect effects of climate change are likely to be greater than direct effects on sandeels.

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Fine-scale movements, activity patterns, and catchability of European lobsters within a north-east fishery

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Movement is a fundamental aspect of many species lifecycles and depending on the study species can be of both ecological and commercial importance. *Homarus* spp. lobsters are some of the best researched benthic organisms. However, movement patterns of the European lobster (*H. gammarus*) can be highly variable (Moland et al. 2011; Skerritt et al. 2015) and despite its commercial importance knowledge gaps still exist regarding its spatial ecology. Acoustic transmitters were fitted to 58 European lobsters caught off the Northumberland coast ($n = 44$, 2013 and $n = 14$, 2016). High-resolution spatially-explicit data was gathered on their movements using a VEMCO Positioning System (VPS) (Amirix Systems Inc., Halifax, Canada) consisting of twelve hydrophone receivers covering an area *ca.* 1.5 km. During the most recent deployment (April - May 2016) a series of commercially available parlour traps were baited and placed within the VPS to investigate lobster activity rates, visitation rates, and movement patterns around a bait source. Entrances to traps were closed prior to deployment to prevent the recapture of tagged animals. The assumption that trap catches are representative of the true population is one major limitation in using fishery-dependent data for stock assessment as the accuracy of catch rate, as a proxy for abundance, depends on how well other external factors that affect catch rate are understood (Maunder & Punt 2004). Individual responses to a bait source can potentially be identified, through either a change in speed of an individual (Skajaa et al. 1998) or an acuteness in the change of direction (Watson et al. 2009). In addition to gear selectivity many environmental variables such as habitat composition (Tremblay & Smith 2001), temperature (Fogarty 1988) and current flow (Howard & Nunny 1983) affect the ability of traps to catch lobsters; catchability of animals can be further influenced by interactions with conspecifics, and individual qualities such as, size, sex and

reproductive status. By investigating the effects of environmental and oceanographic conditions on individual movement patterns and activity rates, in the presence and absence of spatially-explicit bait sources, this study aims to better understand behavioural responses to baited traps. The results from this work will begin to address the knowledge gaps surrounding the spatial ecology and behavioural interactions of European lobsters, and are of direct relevance to stock-assessments and marine protected areas, contributing to the further development of successful, sustainable, evidence-based fisheries.

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Development of a platform for fine scale spatial assessment of fishing activities around Scotland

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The advancement of tracking technology allows fisheries managers to obtain huge amounts of vessel movement data. The implementation of Automatic Identification Systems (AIS), has opened up the potential for the analysis of inshore fishing activities at fine spatial scales. However, this fast-growing process results in large amounts of data and has so far not been adequately followed up by development of procedures to manage and integrate vessel movement data sets. A large amount of raw AIS data (>90 million rows of information) was collected over a six month period as an output from the European Fisheries Fund project 'Evidence Gathering in Support of Sustainable Scottish Inshore Fisheries'. A database to collate and analyse fishing activity was developed using open-source software platforms. PostGreSQL with PostGIS and QGIS provided a valid platform for the analysis of the AIS and contingent vessel data, these platforms are user friendly, free, and have considerable online support. Using these platforms potential applications for fisheries management are presented and include: accurate spatio-temporal depiction of fishing grounds around Scotland, examining compliance with spatial or temporal fishing regulations, and development of fishing "home ranges" which could be used to provide objective comparative measures of the impact of spatial fishing restrictions on a per vessel or per region basis.

Using high-resolution vessel movement data to improve accuracy of locations of commercial fisheries for Marine Spatial Planning

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Abstract

Vessel Monitoring Systems (VMS) provide valuable data to fisheries organisations to map distributions of fishing effort and support marine spatial planning for offshore renewable energy and Marine Protected Areas developments. However the low temporal and spatial resolution of VMS data (average polling frequency of 2 hours) may lead to biased estimates of spatial fishing effort as landings data may not be linked accurately to VMS pings. It also limits marine spatial planning by restricting the visualisation of fleet responses to management actions (Bastardie *et al.*, 2010; Catarino *et al.*, 2014). To overcome these limitations, the tracks of vessels can be reconstructed (Russo *et al.*, 2011). Different approaches have been applied: state-space modelling (Lee *et al.*, 2010; Vermard *et al.*, 2010), random walks (Bertrand *et al.*, 2007), and cubic Hermite spline interpolation (Hintzen *et al.*, 2010). The cubic Hermite spline (cHs) interpolating algorithm has been developed specifically for VMS-like data by Hintzen *et al.* (2010) and allows quantifying the error by calculating the distance between high-resolution vessel movement data and interpolated VMS tracks. It is easy and fast to compute and leads to acceptable results.

This study reviews the performance of vessel tracks interpolation methodologies for scallop dredgers and *Nephrops* trawlers using the conventional straight line interpolation and cubic Hermite splines. A GPS-driven Effort Monitoring dataset that contains a subset of vessel positions at high spatial resolution along with their heading and speed was assumed to represent the real track and was used as a reference to quantify the accuracy of the methodology. This reference dataset was down-sampled to generate lower resolution (30, 60, 90 min) and VMS-like (120 min) datasets to quantify mean, median, and maximum deviance of interpolations for varying polling frequencies. Based on previous studies, a speed threshold of 5 knots was used to distinguish fishing activity from steaming. In this study, the cubic Hermite spline interpolation was performing 40% better on average than the straight-line method for scallop dredges and 37% better for *Nephrops* trawls. Overall the deviance was greater for scallop dredgers than for *Nephrops* trawlers and increased with polling frequency. Additionally, speeds higher than 5 knots impacted the performance of interpolation as deviance was higher after interpolating pings associated with steaming.

Estimating the real tracks of vessels precisely would allow mapping fishing effort distribution at high resolution and improve the representation of the

spatial extent of commercial fisheries in marine spatial planning (Kafas *et al.*, 2012).

Key words: Vessel Monitoring Systems (VMS) – fishing effort – vessel tracks interpolation – cubic Hermite splines – deviance

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Science-based management advice for native oyster fisheries and regeneration projects

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Native oyster populations throughout the world have declined significantly in the 19th and 20th Centuries. Declines have largely been through overexploitation, combined with disease, pollution, invasive species and, in the case of the European native oyster (*Ostrea edulis*), sporadic, unpredictable reproduction. The focus in recent years has shifted to increased protection and interest in restoring populations. Partly based on commercial considerations, this is also owing to the growing recognition of the environmental importance of native oysters. For example, native oyster beds can provide complex habitat for other species and act as refugia for other fishery target species. This presentation will discuss the findings of three years' research carried out in the Lough Foyle native oyster (*Ostrea edulis*) fishery. The fishery is located on the border between Northern Ireland and the Republic of Ireland and currently supports ca. 50 boats (all under 10m). Field surveys and experiments, combined with laboratory investigations and an extensive review of over 150 years' literature, have produced advice and recommendations for fishery management and development of future regeneration projects. Areas studied included reproductive activity and links to physical water conditions; size-fecundity relationships between adult oysters and larval production; examination of current and possible future landings regulations; development of closed areas; natural and artificial larval collection; and investigation of potential competitors and disease threats. There are also many lessons to be learnt from government reports from the 1800s and anecdotal evidence dating back to the 1600s which the project has brought together with the aim of making sure this knowledge is accessible to today's researchers and managers. The project has also developed recommendations for future surveys and research. In addition to native oyster management, the findings have wider relevance to fisheries

management of other species, designation of marine protected areas, and encouraging stakeholder engagement. This presentation is aimed at highlighting the need to continue research into *O. edulis* and drive regeneration projects forward. Much of the impetus for regeneration has been driven by European Union environmental directives and it is therefore especially important to ensure that this is not lost in view of the recent UK decision to leave the European Union.

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