Smartrawl: a system to eliminate discards and bycatch in fisheries

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Abstract

Discards and bycatch (Fernandes *et al.*, 2011) are one of the main threats to fisheries sustainability. According to the most recent estimates (Pérez Roda, 2019), around 46% of total global annual discards (4.2 million tonnes), were from bottom trawls. In Europe, the practice is banned through the Landings Obligation, but there is no effective means of preventing it, so it continues more or less unabated (EFCA, 2019).

This presentation describes the Smartrawl, a technological solution to the problems of discards and bycatch. The system consists of a stereo camera, a computer, and an innovative gate, all of which are inserted into the trawl extension - the part of the trawl just before the cod-end (where fish are caught). The stereo camera takes images of fish passing by, and the computer, employing artificial intelligence algorithms, will then size these and identify them. Based on user selected preferences of species and size, the computer then sends a message to the gate to either close, thus catching the fish, or open, releasing the fish (or other animal) into the water, unharmed.

Crucial to the function of the system is an understanding of how quickly fish pass by. Trials have been conducted which have generated over 200,000 images which have been analysed. Fish passage rates ranged from 1 fish every 0.5 s to more typical rates of one fish every several seconds. Faster rates were associated with patches of small haddock, which are the most numerous demersal fish in the North Sea. The gate was, therefore, designed with a response time of 0.5 seconds. However, the provisional AI algorithms, by virtue of being run on the local, small PC, can take longer than that to run. The algorithms also need large numbers (several thousand per species) of high-quality images to be trained, and we also report how image quality has been improved.

The system is still in development, but most of the components have been built and tested. The presentation highlights the next steps and plans for further trials to test the system in the field.

Acknowledgements

The Smartrawl project has been funded by Fisheries Innovation Scotland, through their membership organisations, chief amongst which was Marine Scotland: all of their support is gratefully acknowledged. The system was designed with the assistance of Vivek Chacko (University of Aberdeen) and Richard Nielson (University of Aberdeen). John Polanski (Aberdeen) and Shaun Fraser (UHI) are thanked for running field trials.

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Current status of whitefish stocks in the Firth of Clyde (West coast of Scotland)

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The Firth of Clyde is one of the main grounds of the Scottish Nephrops (*Nephrops norvegicus*, or Norway lobster) trawl fishery. However, this fishery also catches demersal fish species such as cod, haddock and whiting. Almost 100% of fish bycaught is discarded due to trawlers not possessing licenses to land whitefish and the fish caught being below the minimum conservation reference sizes. Even though targeted fishing for whitefish ended in early 2000s [1], there are still no signs of cod and whiting recovery in the Clyde. One hypothesis is that fish discards in the trawl fishery for prawns is sufficient to maintain a high mortality rate on the stocks, thus hindering their recovery.
This study examines this hypothesis by estimating the quantities of cod, haddock and whiting discarded in the Nephrops fishery, and assessing the fishing mortality and current abundance of fish biomass.
We developed an age-structured stock assessment model that tracks annual cohorts of fish through time and uses the survey index information (as annual indices of relative abundance) and commercial catch data. The model can account for the high proportion of zero values in the data and was implemented using Bayesian inference through Markov Chain Monte Carlo algorithms for parameter estimation. The model was applied to the three main species of whitefish in the Firth of Clyde.
Results show high levels of mean fishing mortality (mean $F>1$) for all three stocks and low levels of spawning biomass (less than half of estimated catches), with a range of sensitivity tests all supporting this finding. The scale of the estimated mean fishing mortality might be unrealistically high because of migration effects out of the Clyde not accounted for in the model. Nevertheless, mean fishing mortality has decreased substantially for the three stocks within the last 10-15 years (up to 50% decrease), and is correlated, albeit weakly, with mean fishing mortality estimated by ICES [2] for adjacent stocks of the west coast of Scotland and the Irish sea. Despite this decline, it appears likely that mortality resulting from the Nephrops fishery is a significant factor in the lack of recovery of the whitefish stocks in the Firth of Clyde.

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Outer Hebrides Early Adopters and Creel Limitation Pilot Trials – A case study in inshore fisheries co-management

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In November 2020 Marine Scotland, in collaboration with the Western Isles Fishermen's Association and the Outer Hebrides Regional Inshore Fisheries Group, initiated two pilot projects to run in parallel for two years to:

1. Assess the potential to role out a low cost tracking system on 10m and under vessels (Early Adopters Pilot – EAP)
2. Introduce creel limits to reduce the increase in creeling effort (Creel Limitation Pilot – CLP)

These initiatives were linked as the 40 vessels involved in the EAP were also party to the CLP involving ~140 vessels.

The development of CLP was founded on calls from fishers in the Western Isles for limits to be set on the maximum number of creels that could be deployed by a vessel of given size. The fishers recognized the significant increase in creeling effort that had been taking place and needed to formalize with Scottish Government a mechanism to limit creeling effort.

The EAP was designed to further inform Marine Scotland's intention to introduce tracking of all commercial fishing vessels of 10m and under operating in Scottish coastal waters. The objectives of the EAP were to assess the operational challenges of equipping and monitoring the fishing activities of a subset of vessels involved in the CLP, including the development of novel processes to identify fishing activity and estimate creel numbers deployed. An App was also developed to encourage reporting of catch and landings that could be linked to fishing track.

The EAP and CLP have taken place against the backdrop of major political, economic and social challenge including EU Exit, the COVID-19 pandemic and now the cost of living crisis. Teasing out the, impacts, costs and benefits of the EAP and CLP within the context of such perturbations is challenging. The need to inform future policy in this area requires that we do so.

We will report on the progress of the EAP and CLP which is due to end in November 2022 and explore some of the lessons learned with respect to the development of co-management approaches in the context of the inshore fishery.

Acknowledgements

We gratefully acknowledge the support of Duncan Mckinnes and all members of the Western Isles Fishermen's Association and Outer Hebrides Regional Inshore Fisheries Group. Marine Scotland staff; Stuart Bell, Chloe Aird, Linda Blackadder, Kay Barclay and Jim Watson have provided invaluable support and guidance throughout. This work has been funded by Scottish Government.

Essential spawning grounds of Scottish herring: current knowledge, challenges and ongoing research

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Atlantic herring (*Clupea harengus*) helped to generate local income, identity, and societal change in Scotland for centuries. Their numbers on the west coast of Scotland have been in steady decline since the 1980s, but in spring 2018/2019, large herring shoals were observed on the west coast for the first time in decades, at a formerly important spawning ground. This highlighted the importance of maintaining suitable benthic spawning grounds, which these fish rely upon for egg deposition. However, information on exact location, characteristics, and status of historic and contemporary spawning grounds, if existing, is not easily accessible. We therefore performed an exhaustive literature search, dating as far back as 1884, using scientific databases, grey literature, a query for automated search of comprehensive historical reports, and fisher interviews (Frost and Diele 2022). We present current knowledge on Scottish herring spawning grounds and discuss challenges arising from methods currently used to recognize these grounds. Knowledge gaps regarding spawning season, as well as the location and environmental status of spawning grounds, particularly relevant for Scotland's west coast, are also identified.

Based on the importance of specific environmental variables for herring reproductive success, protection of herring spawning grounds should be, but currently is not, incorporated into marine management plans. This would require additional data on spawning grounds, including local ecological knowledge rarely considered. These knowledge gaps are now being addressed through the collaborative Edinburgh Napier University-led "West of Scotland Herring Hunt" (WOSHH) project, which seeks to identify and produce evidence for the conservation and potential restoration of herring spawning habitat on the west coast of Scotland. In addition to conducting interviews and collaborative field work along the Scottish west coast, WOSHH will shortly provide a new citizen-science 'herring hunt' web-app to help collect signs of spawning herring and aid the identification (and evaluation) of spawning grounds.

Healthy (and abundant) spawning grounds would increase the chance for herring to rebuild inshore populations (where and when possible), with potential positive social and economic impacts, as well as improve general biodiversity. A more inclusive and ecosystem-based approach to herring management, encompassing targeted actions to protect essential spawning habitat, would contribute towards Scotland's Blue Economy vision and Nature Positive commitments.

Acknowledgements

We thank all collaborators/ contributors. WOSHH is funded by the William Grant Foundation.

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Biomass and the Large Fish Indicator in a changing North Sea Ecosystem

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Recently, fish species richness in the North Sea has increased, driven by increased occurrence of species with an affinity for warmer waters (Lusitanian). This process is known as tropicalization, an increase in richness caused by movement of species from warmer and more diverse waters into historically cooler, less diverse waters. Evidence for this in coastal regions and in the North Sea is strong, though trends in abundance of Lusitanian species at the haul level has not been published previously. Therefore, it is important to investigate whether abundance of Lusitanian species has also increased alongside richness as this will likely have a greater impact on the ecosystem. Equally, little research has focused on how these changes may affect ecosystem health and current quality objectives. One such quality objective is the Large Fish Indicator (LFI). This is the proportion of fish above a specific length (50cm in the North Sea) within the total community. This has declined from historic baselines in the North Sea but has been recovering in recent years. Lusitanian species often grow faster, mature earlier, and reach smaller sizes compared with species from cooler waters. Since typically the North Sea was dominated by species from cooler waters (Boreal) the increase in occurrence of Lusitanian species has the potential to negatively impact LFI recovery and may mask recovery seen in Boreal species.

This paper looks to further investigate whether the recent increases in Lusitanian richness have also led to an increase in abundance (using biomass) and what impact, if any, this may have on the LFI. Data was taken from the International Bottom Trawl Survey for the North Sea between 1983 and 2020. Haul data was converted from number at length data into using weight-length relationships as reported in Fung et al. 2012. Biomass density was then calculated by dividing the calculated biomass by the reported swept-area (downloaded from ICES-DATRAS) as per the method used by OSPAR. Boreal (cold water) and Lusitanian (warm water) species were analysed separately to investigate how shifts in thermal affinity may impact these measures as the ecosystem changes.

Though biomass of both Lusitanian and Boreal species fluctuated between years, there was no clear increase in Lusitanian biomass over the study period. A slight declining trend was observed in Boreal biomass, though this is difficult to state definitively due to the fluctuating nature of the data. These fluctuations were largely driven by key commercial species such as whiting (Lusitanian) and haddock (Boreal). The beginnings of a recovery in the LFI was reported by OSPAR in 2017. Interestingly, this increase in the LFI after 2000 was seen in both Lusitanian and Boreal species. However, Lusitanian LFI was much lower overall than Boreal LFI (0.1 compared to 0.2 for Boreal).

This study suggests that increases in Lusitanian biomass have not been observed despite the increases seen in Lusitanian richness. However, the difference in the LFI between Boreal and Lusitanian species highlights the potential impact an increase in Lusitanian biomass could have on the overall LFI in the North Sea if this is observed in the future. The general utility of the LFI as a measure for fish community health in a changing North Sea is also discussed.

Acknowledgements

We'd like to thank the NERC through the SUPER DTP for funding this project

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Integrated system to improve inference of fishing activity from geospatial data

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Geospatial data obtained from vessel tracks is an important source of information with fisheries management and marine planning applications. These analyses can provide information on fishing grounds (Mendo et al., 2019) as well important measures of fishing effort. These data can improve the resilience of fishing industry by providing objective metrics by which to assess the impacts of management measures and spatial squeeze resulting from offshore renewable energy developments for example. Whilst (Mendo et al., 2019) use spatial data to reliably identify hauling events, identifying when gear is shot is more problematic as vessel spatial data provides few characteristics synonymous with this event. This makes it more difficult to calculate, for example, the time that the gear was in the water, which is important to understand fishing effort (Lifentseva, 2022).
In order to improve the prediction of the exact location of both hauling and shooting events an integrated system has been designed and is currently being tested on an inshore vessel deploying pots. The integrated system for inferring fishing activity consists of a tracking device, an Inertial Movement Unit (IMU) and two active Radio Frequency Identification (aRFID) tags. The tracking device provides GNSS position, speed and track. The IMU records the movement of the vessel in the 6 Degrees Of Freedom (DOF: linear surge, sway and heave; rotational roll, pitch and yaw) by measuring the acceleration with an accelerometer, the rotation speed with a gyroscope and the true heading with respect to magnetic north. The aRFID tags are placed inside the first and last creels in a string and communicate with the tracking device via Bluetooth indicating their presence whilst on board the vessel. Details are summarized in Table 1.

Table 1. Description of the elements within the ISIFA

Unit	Sensor	Data
Tracker	GNSS+GSM	Lat-Lon + speed ($m \cdot s^{-1}$)
	Accelerometer	ms^{-2}
IMU	GNSS+GSM	Lat-Lon
	Magnetometer	nanotesla
	Accelerometer	$m \cdot s^{-2}$
	Gyroscope	$rad \cdot s^{-1}$
aRFID	Bluetooth	Presence/Absence

As an example, Figure 1 plots the georeferenced points obtained during a fishing trip with the tracker (orange stars), and the IMU (black circles). Based on previous work, (Mujal-Colilles et al., 2022), tracker position reporting for these static gear vessels has been optimized to record location every 30 seconds which explains the differences in point density within Figure 1. Nevertheless, both the IMU and the Tracker yield similar geo-positional data.

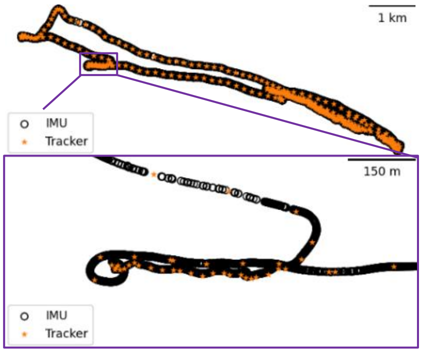

Figure 1. Comparison of the lat-lon points obtained by the two devices fixed at the vessel

Figure 2 is an analysis of the associated IMU data showing high resolution movement data. The grey section shows data associated with the fishing trip. During the hauling process, the magnetometer data has a specific pattern. By analyzing a combination of track and IMU data, with the time and position of hauling and shooting being validated through the aRFID tags, we hope to detect signatures in vessel movement that can be more reliably used to infer the deployment of fishing gear.

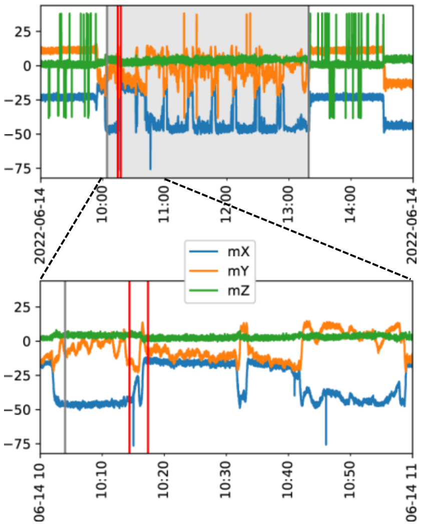

Figure 2. Three-component magnetometer data. Red lines indicate the presence of the aRFID onboard.

Acknowledgements

We gratefully acknowledge the support of John Chater and Lee Gardner for their invaluable support – allowing us to install equipment on their vessel and accompany them on fishing trips. The Scottish Government Nature Restoration Fund supported the purchase of the aRFID tags.

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