Cod Catches from Demersal and Pelagic Trawl Gears in the Clyde estuary: Results from an Industry-led Survey in 2016.

A report on behalf of the Clyde Fishermen's Association

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Foreword

This 'cruise report' is the first of a short series, reflecting the aspiration of the Clyde Fishermen's Association to establish a rigorous sampling scheme to monitor changes in the abundance and distribution of cod (and later other gadoid species) within the Clyde area. The Scottish Oceans Institute was approached to provide independent scientific support in early 2016. A series of surveys was then conducted in 2016, 2017 and 2018. In each survey the SOI provided observers, collected data and wrote up a cruise report detailing the methods used and the location, numbers, weights, sex and maturity states of fish caught. Trials were halted after 2018 firstly because of pressing issues resulting from Brexit which absorbed any potentially available human and other resources, and secondly because of the COVID pandemic. The reports remained as unapproved and incomplete drafts until 2022. Picking up these reports again in 2022, we have responded to reviewers' comments since made by Marine Scotland Science and have finalised all four reports in the 2016-2018 current series.

MSS comments on previous drafts included the observation that there are a number of survey-design problems that would need to be addressed in any future Clyde surveys, and that there is a lack of important detail on how the surveys were conducted. MSS pointed out that the surveys were intended to be developmental and inform future survey work and as such the design and the implementation of the surveys over the three years is too inconsistent to permit comparative time-series, and any future survey would probably need to start from scratch.

MSS suggested revisions should focus on providing spatial summaries of fish distribution and additional detail regarding the specific gear types used.

Changes made to previous drafts of the present report include minor editorial changes to language, completion of some details about vessel characteristics and the inclusion of bubble plots to provide more detail on the spatial distribution of fish catches (Figure 5) as requested. We were unable to provide more details on the trawl characteristics used in the demersal trial here. The trawl used was a 'standard nephrops trawl' but unfortunately, we could not recover further details of how this was rigged (Table 2).

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Background

The seasonal closure of a cod spawning site in the Firth of Clyde was implemented in 2001 to address concerns about the state of the cod stock in the wider area (Commission Regulation 456/2001). The measure was continued from 2002 on an annual basis by the Scottish Government (The Sea Fish (Prohibited Methods of Fishing: Firth of Clyde) Order 2002). The closure remains in place today despite some debate about the efficacy of this particular measure in terms of helping cod populations in the area recover.

The state of the Clyde marine environment was brought to general public attention following a paper published in 2010 (Thurstan & Roberts 2010) which received significant media coverage because of its dramatic claims about the highly degraded condition of the Clyde, despite the study's conclusions being based almost entirely on commercial landings data which are not a particularly reliable guide to commercial stock status or underlying environmental conditions because landings patterns are affected by management and market forces, as well as by stock availability.

A more rigorous and convincing analysis was undertaken at around the same time using a time series of scientific trawl survey data (Heath & Speirs 2011) which is likely to provide a more complete picture for those species and sizes available to the survey gear. This study concluded that in general the total biomass of commercial species has not changed significantly over recent decades but that the species composition had altered and the size structure of the main commercial stocks had become truncated, with fewer large individuals present in more recent samples.

Largely in response to these two papers a detailed and wide ranging review of the Clyde ecosystem was undertaken by Marine Scotland Science (MSS) (McIntyre et al. 2012) which provided an overview of past and present human impacts on the Clyde and describes how commercial stocks, non-commercial species and habitats have changed over time in response to those pressures. The review also provides numerous suggestions for further work that would help improve knowledge of the various factors that influence the state of the marine environment within the Clyde. One of the concluding remarks from the review is that "a comprehensive survey of demersal fish in the Clyde is required, including small fish".

More recently Clarke *et al.* (2015) used both commercial and survey data from 1986 to 2010 to examine various aspects (Catch per Unit Effort (CPUE), Spawning Stock Biomass (SSB), size distributions and Total Mortality (Z)) of the Clyde cod stock before and after the spawning area closure. They found no clear evidence of changes in these stock parameters between the two time periods and conclude that the seasonal closure was ineffective in terms of stock recovery over that timescale, but it may have provided some benefits in terms of reduced fishing mortality (F) by restricting the seasonal concentration of effort on spawning cod that had previously been a typical pattern in the area.

A criticism of using survey-derived data for estimating certain stock parameters was raised by industry previously and was presented by Turrell *et al.* (2016), and is based around the fact that survey data are typically collected using a Grande Ouverture Verticale (GOV) trawl with an approximate operational headline height of 3 metres (1.5 Fathom) which is fished under short standardised tow durations of 30 minutes in accordance with International Bottom Trawl Surveys (IBTS) protocols. Industry's argument is that these two factors (low headline height & short tow duration) mean that the survey gear is not appropriate for sampling larger cod (and potentially other whitefish species) that are capable of out-swimming short duration tows and/or which may be increasingly found higher in the water column above the vertical fishing area of the GOV trawl. To investigate if these claims were substantive, a short semi-pelagic survey was undertaken in 2014 in the northern part of the Clyde through collaboration between the Clyde Fishermen's Association (CFA) and MSS (Turrell et al. 2016). Data collected during the semi-pelagic survey were compared to demersal survey data from a similar area. The results showed that higher numbers of larger cod were caught in the longer duration and higher aperture semi-pelagic tows than in the demersal survey hauls, so the claim that standard survey gears do not adequately represent the full size spectrum of cod in the area may appear to have some validity. However, in the absence of a standardised and accepted midwater trawl survey methodology and a time series of data over more than a single season there is no obvious way to incorporate such findings into standard stock assessment procedures.

Despite all the useful work that has been carried out in recent years it is not possible to satisfactorily draw all those findings together to form firm conclusions about the current state of the cod stock within the Clyde because the various studies have used different datasets or methods which are not directly comparable and each of those datasets has particular associated weaknesses as discussed above. Because of this there continues to be debate about the state of whitefish stocks in the Clyde basin.

Following a series of discussions in 2015 between Marine Scotland (MS) and the CFA, some further ideas have been developed which the CFA believe will help provide meaningful information to inform future decisions on restrictions on fishing activities relating to the seasonal cod closure and other whitefish management measures within the Clyde. This short report describes the results from a short comparative survey that was conducted in March 2016 following the discussions in 2015, and views these recent findings in light of previous results. We also provide some suggestions for how further industry-led data collection efforts in the area, if they are to be continued, could be altered to improve comparability and help ensure that future changes in whitefish stock levels in the Clyde can be tracked and presented in a satisfactory manner.

Table 1 - Existing management measures in the Clyde. Adapted from SIFT (2015)

Spatial management measure	Site	Year	Legislation	Management
Upper Loch Fyne Voluntary Closures	South Arran	2014	South Arran Nature Conservation Marine Protected Area Order 2014	• No suction dredge, mechanical dredge, beam trawl, or demersal trawl (including seine net) is permitted inside the entirety of the South Arran MPA. • Demersal trawl only allowed within an area of 107km^2 by vessels smaller than 120 gross tonnes. • No static gear permitted within an area of 8km^2. • No fishing of any kind in Lamlash Bay No Take Zone (8km^2).
	Upper Loch Fyne and Loch Goil	2014	Upper Loch Fyne and Loch Goil Nature Conservation Marine Protected Area Order 2014	• No suction dredge, mechanical dredge, beam trawl, or demersal trawl (including seine net) is permitted inside the management area. • Demersal trawl only allowed within the derogated areas by vessels smaller than 120 gross tonnes. • No static gear permitted in the static gear area.
	Clyde Sea Sill	2014	Clyde Sea Sill Nature Conservation Marine Protected Area Order 2014	• Currently no management measures in place but the following measures have been suggested; o Prohibition on the use of any type of set nets within 2km of Sanda to mitigate the risk of black guillemot being entangled whilst foraging. o Prohibit the use of demersal mobile gear on some of the circalittoral sand and coarse sediment communities. This is the proportion of the habitat with little or no mobile demersal fishing activity and is not driven by a target proportion of habitat. The area to be managed would represent all the component biotopes. o This prohibition would also apply to suction and hydraulic dredging, both boat and diver operated.
No Take Zone (NTZ)	Lamlash Bay	2008	The Inshore Fishing (Prohibition on fishing) (Lamlash Bay) (Scotland) Order 2008 (SSI 2008/317)	• Prohibition of all fishing for sea fish in the 2.6km^2 area of Lamlash Bay, Arran.
Marine Conservation Order	South Arran	2014	The South Arran Marine Conservation Order 2014	• Three sites within the South Arran MPA prohibiting commercial mobile fish gear
Special Protected Area (SPA)	Inner Clyde Estuary	2000	EC Directive (79/409/EEC)	• 1826.02 ha area designated for redshank. • Currently no marine management measures in place.

	Ailsa Craig	1990	EC Directive (79/409/EEC)	• 99.94 ha area designated for seabird species. • Currently no marine management in place for marine area.
Site of Special Scientific Interest (SSSI)	Ballochmartin Bay	1985	EC Directive (92/43/EEC)	• Protected for littoral sediment (Marine) Sandflats
	Kames Bay	1985		• Littoral sediment (Marine) Sandflats
	Ruel Estuary	1986		• Littoral sediment (Coast) Saltmarsh
	Inner Clyde	1999		• Littoral sediment (Coast) Saltmarsh
Marine Consultation Area	The Cumbraes	1980	N/A	• Intertidal zone
	Loch Ryan	1980s	N/A	• Native Oyster beds
Cod Box	Area 1	2016	The Sea Fish (Prohibited Methods of Fishing) (Firth of Clyde) Order 2016	• From 14th of February to 30th of April all trawling except trawling for *Nephrops* or scallops is prohibited inside box 1.
	Area 2			• From 14th of April to 30th of April all trawling except scallop dredging is prohibited inside box 2.
Gareloch			Clyde Dockyard Ports of Gareloch and Loch Long Act 2011	• Annual prohibition of mobile or active gear from 1st January to 31st December within Loch Long, Loch Long and Gareloch.
Loch Ryan		2004	2004 (276) SSI Schedule 1 of prohibition of fishing	• Annual prohibition of mobile or active gear from 1st January to 31st December except dredging for mussels and oysters within Loch Ryan.
Ballantrae Banks		2004	2004 (276) The Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order	• Mobile or active gears are prohibited from the 1st of February to the 30th of April each year in the designated area.
Clyde		1984	Inshore Fishing (Scotland) Act 1984	• 1 Jan to 30 April all Clyde closed to herring fishing north of a line from Mull of Kintyre to Corsewall Point. The target species needs to represent at least 50% of the catch. Herring by-catch, maximum 50 kg per boat.
Upper Loch Fyne Voluntary Closures	Loch Shira		N/A	• Members of the Clyde Fishermen's Association have implemented a voluntary agreement which prohibits the use of mobile gear in waters less than 15m depth within Loch Shira
	Upper Loch Fyne		N/A	• Members of the CFA and the Argyll Fisheries Trust have implemented a voluntary agreement not to trawl in waters shallower than 50m at the head of the loch, north of Dunderave Point
	Otter Narrows	2014	N/A	• Members of the SFF have implemented a voluntary agreement that prohibits the use of all commercial gear within the area

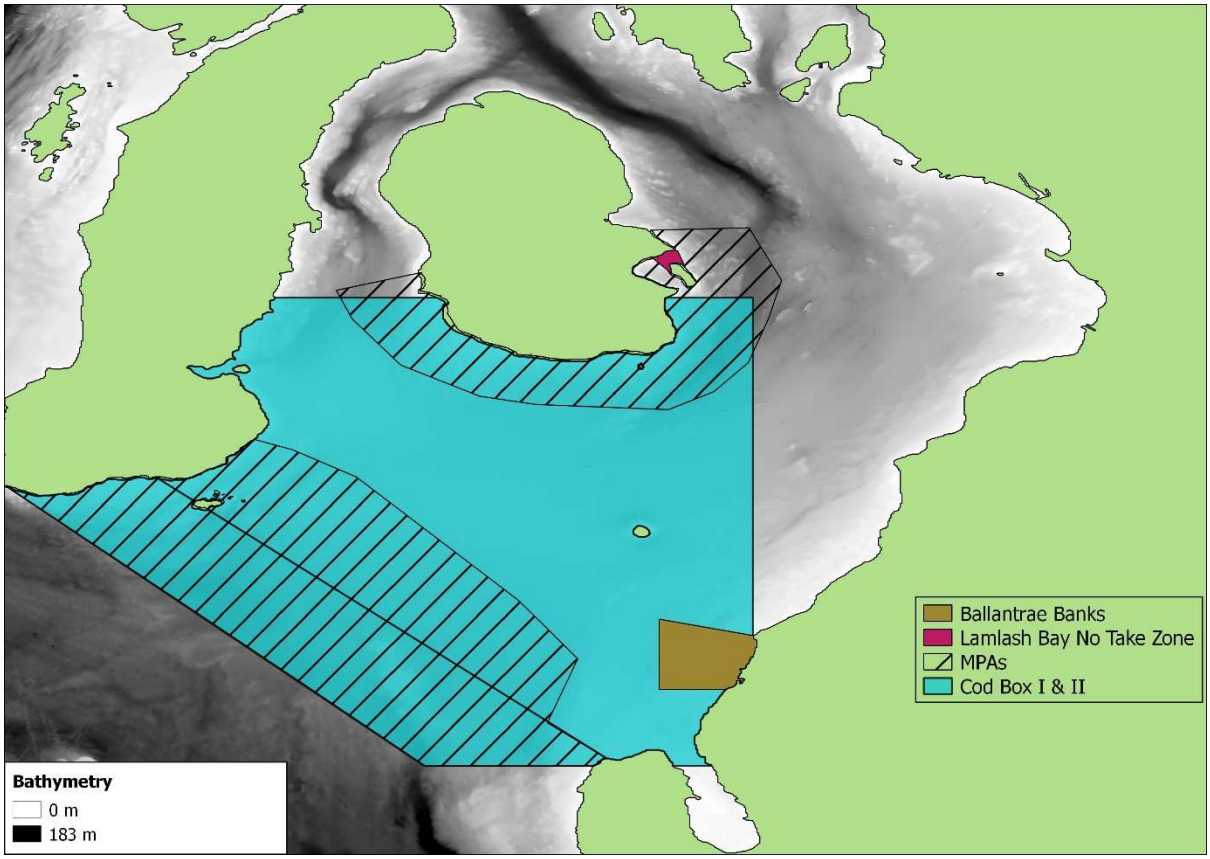

Figure 1 - Map showing the main spatial management measures in the southern Clyde

The Clyde Fishermen's Association Proposal

In early 2016 the CFA in collaboration with the Scottish Fishermen's Federation (SFF) proposed, designed and agreed to fund a survey with the overall aim of improving the current understanding of different aspects of the cod population within the Firth of Clyde. The SFF helped with all aspects related to the survey design and data collection protocols. The survey was designed primarily to address three specific pre-agreed objectives:

1. To collect data on the geographical distribution and relative catch rates of cod within the seasonal closure area.
2. To investigate the vertical distribution of cod within the water column.
3. To provide baseline data for future survey comparability.

The SFF agreed to provide an experienced fisheries observer to undertake catch sampling and recording of operational and environmental data. An independent observer was provided by the Scottish Oceans Institute (SOI) at the University of St Andrews to provide survey, sampling and data management oversight. Staff at the SOI also agreed to assist the CFA with data analysis and report preparation. The CFA provided suitable vessels, gear and crew for the survey.

Survey Design and Data Collection

The survey was carried out in two distinct stages. Firstly a two day trip with the vessel FV Atlas was conducted using a traditional nephrops trawl. Sampling followed standard bottom trawl survey techniques designed to determine the distribution and relative catch rates of cod within the seasonal spawning area. The second stage was also carried out during a two day trip, but with the vessel FV Gleaner, and involved using an adaptive pelagic trawl survey method to determine if cod were also present in the water column, above the effective fishing height of the nephrops trawl, within the same general area. The details of each survey stage and the data collection protocols are provided in the following sections.

Demersal Survey

The demersal survey was carried out on 23rd and 24th March 2016. The vessel deployed a traditional nephrops trawl (Table 2), so no derogation was required under Article 3(1) (a) of the Sea Fish (Prohibited Methods of Fishing) (Firth of Clyde) order 2016. However the CFA obtained a derogation to permit the use of a nephrops trawl for scientific purposes under Article 3(1) (b) of the Sea Fish (Prohibited Methods of Fishing) (Firth of Clyde) order 2016.

Prior to commencement of the survey, the CFA provided details of trawl locations and sampling protocols to the relevant authorities. Trawl station locations were randomly selected from within a predetermined grid pattern (Figure 2) and each tow was conducted within the defined grid cell limits close to each nominal station position. The exact tow track within each cell was determined by the skipper of the vessel to ensure the survey was carried out safely and efficiently. Eleven hauls (Figure 3) were conducted in total, though the final haul was foul so did not provide any useful data. Initial tow durations (measured from when the gear reached the fishing depth until the winches are engaged for haulback) ranged from 50 to 95 minutes but after discussions with the skipper about the analytical benefits of keeping tow durations standardised the final five hauls all had 60 minute durations.

All cod caught were sampled for length, sex and maturity in accordance with methods used in the ICES International Bottom Trawl Manuals. Otoliths for age determination were also collected from two fish at each centimetre interval where possible.

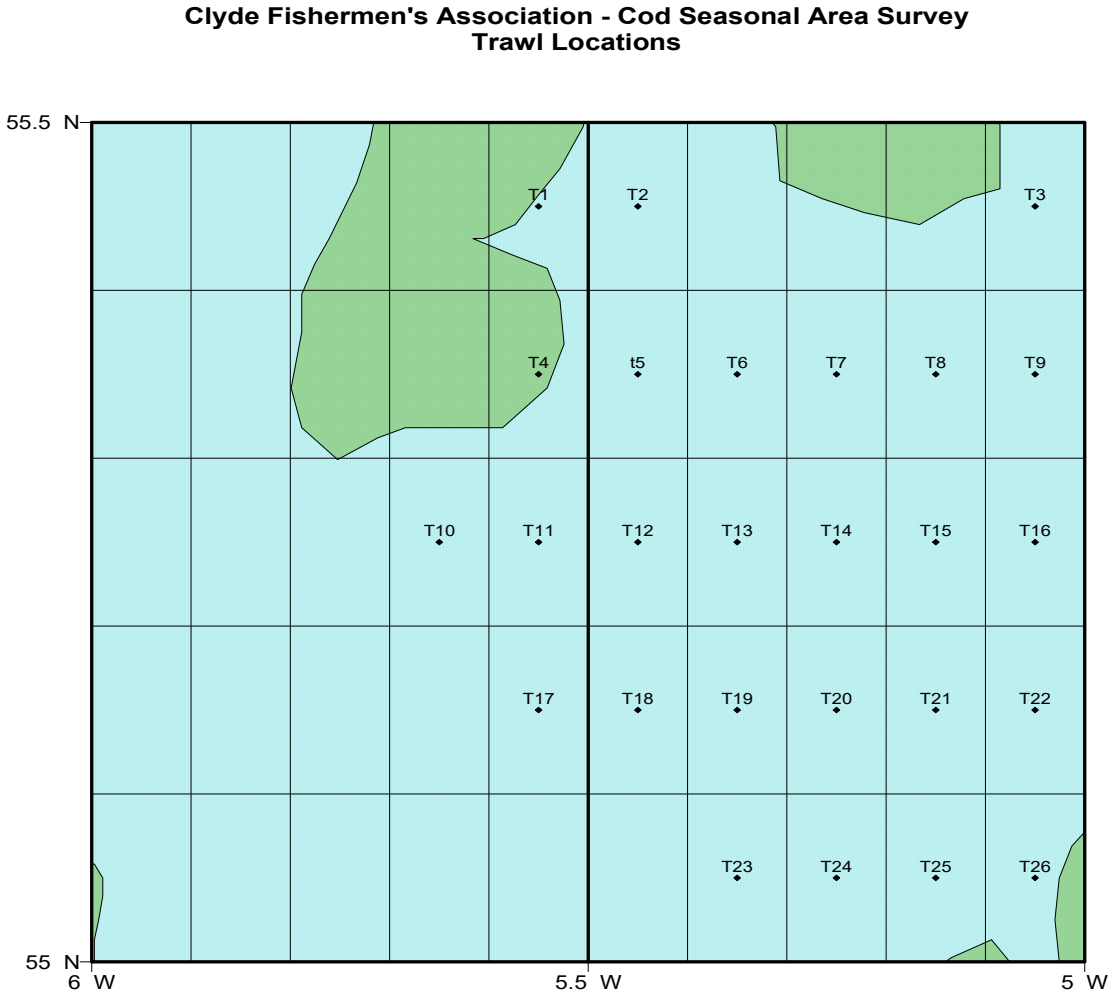

Figure 2 - Predetermined trawl stations for the demersal survey used for randomised selection.

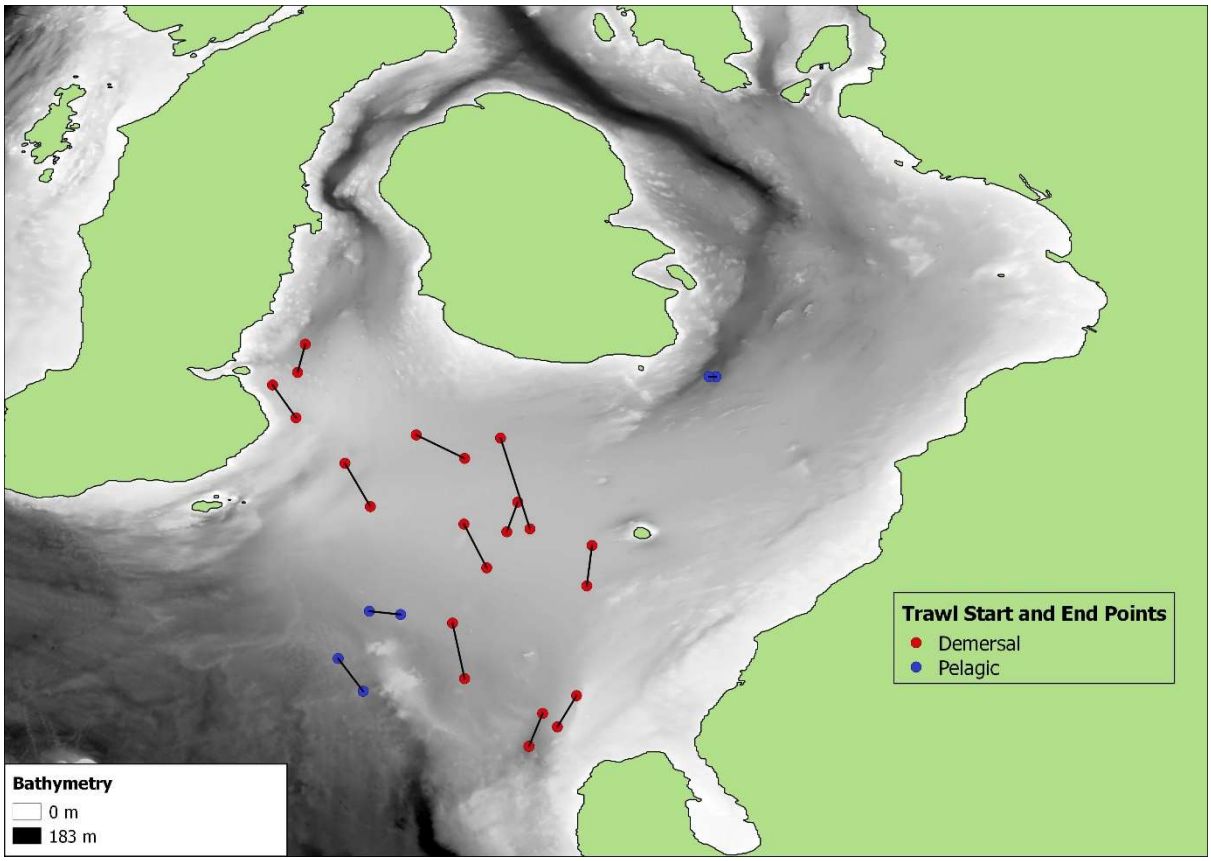

Figure 3 – Actual tow positions (start and end points indicated) of the demersal and pelagic surveys.

Pelagic Survey

The second survey was carried out on 29th and 30th March. The vessel deployed a mid-water trawl (a prohibited method of fishing), so prior to the trip departure the CFA obtained a derogation to allow the survey to be conducted within the Area described by Article 3(1)(a) and 3(1)(b) of the Sea Fish (Prohibited Methods of Fishing) (Firth of Clyde) order 2016.

There was some initial uncertainty about the best way to conduct the pelagic survey. However, it was agreed that because the survey was restricted to two days, it was unrealistic to expect randomly selected stations at various depth strata to provide meaningful information on the relative distribution and abundance/catch rates of cod. Consequently the second (pelagic) survey aimed simply to assess if cod were found higher in the water column and to provide length distribution data to compare against other datasets, but it was not expected to produce quantitative data that might be used for estimating overall catch rates or abundance. Initially, it was anticipated that trawl locations would be determined by the vessel following a pre-determined grid pattern, deploying the net in locations where echo sounder information suggested that fish may be present in mid-water. However, following discussions between CFA skippers and SFF staff, it was concluded that it would be more helpful to establish if there were any spawning cod in certain areas to see if they still followed the same behavioural pattern around spawning time that had previously been observed by skippers. Consequently it was agreed that the pelagic tows would be conducted in four different areas as follows:

1. The south end of the Arran trench where, traditionally, the indigenous Clyde cod stock would normally congregate before spawning. This area takes in depths between 40-60 fathom and runs from Pladda, north to Brodick bay and is in close proximity to the South Arran MPA.
2. A shallow water (20fth) area running from Rhu Stafnish, southeast towards Stranraer Loch. This is the area where fishermen used to observe male cod congregating before spawning.
3. An area of deeper (35-40fth) water lying to the West side of the Ballantrae banks where fishermen would traditionally expect to find the female cod in abundance.
4. An area to the southwest of the Mermaid shoal.

The exact tow track within each general area was determined by the skipper of the vessel to ensure the survey was carried out safely and efficiently. Only three hauls (Figure 3) were completed within the allotted survey time. Haul durations ranged from 5 to 6.5 hrs. The longer haul durations used in the pelagic survey were justified by the fact the CFA and SFF expected the pelagic gear to catch larger cod which are thought to be able to out-swim shorter duration tows, so longer duration tows would likely provide a more complete picture of the length distribution of cod higher in the water column. This approach is consistent with the semi-pelagic tow durations reported in Turrell *et al.* (2016) which averaged 7 hours.

All cod caught were sampled for length, sex and maturity in accordance with methods used in the ICES International Bottom Trawl Manuals. Otoliths for age determination were also collected from 2 fish at each centimetre interval where possible.

Table 2 - Vessel and gear details

Vessel Name	Atlas	Gleaner II
Administrative Port	CAMPBELTOWN	CAMPBELTOWN
Port Letters and Numbers	CN258	CN777
Overall Length	16.8M	23.9M
Registered Tonnage	66	182
Engine Power	276	585
Year Built	1973	1987
Fishing Circle	Not recorded	60 Fth
Vertical opening	Not recorded	13-24M
Depth of headline	Not recorded	20-36M
Depth of footline	Demersal	1M from seabed
Cod end mesh size	100mm	120mm
Spread	Not recorded	17 Fth

Results

Eleven demersal and three pelagic trawls were completed, but one of the demersal hauls was fouled, and has been excluded from the results.

The pelagic survey had fewer hauls and considerably longer mean tow durations than the demersal survey meaning direct comparisons of some parameters (i.e. catch rates) between the demersal and pelagic datasets should be made with caution. Haul durations within each survey also varied from 50 to 95 minutes in the demersal survey, and from 5 hours to 6.5 hours in the pelagic survey. This also complicates between-haul comparisons within each survey because differences in tow duration will likely impact the size selectivity of the gear as larger fish tire less quickly than small fish so shorter tows would be expected to under-sample larger fish if they are present. Consistency of operational aspects such as tow durations is essential for making robust comparisons (of various parameters) between tows or between surveys. Nevertheless we can still use these data to provide a reasonable indication of comparative catches by calculating a catch rate from the catch numbers and tow duration data from each haul to produce an estimated catch per hour per haul, but the above caveats should be borne in mind.

Details of the total fishing time and mean haul durations from each survey are summarised in Table 3.

Table 3 - The number of hauls and average haul durations from the 2016 demersal and pelagic surveys.

	All	Demersal	Pelagic
Total Hauls	13	10	3
Total duration (mins)	1735	655	1080
Mean duration (mins)	133.46	65.5	360

Catch Rates

Calculated catch rates from the pelagic survey were lower on average than those from the demersal survey, but the difference was not statistically significant (Mann-Whitney U test – non-parametric unpaired two-sample compares the distribution of the two samples, $p > 0.05$) largely due to the high variability in the demersal catch rates (range 2.7 – 169 cod per hour, see Table 4 and Figure 4) and the low sample size of the pelagic survey (3 hauls) (Table 3).

The very high variability in catch rates (standard deviation in the demersal survey of 53.2 - Table 4) was caused by two particularly productive trawls in the demersal survey (DEM2 and DEM4). Upper and lower 95% confidence limits of 11 and 82 fish per tow were calculated by bootstrapping the sample with replacement (10,000 resamples) with a mean tow time of 1.08 hours.

The overall catch rate of cod > 30cm was only marginally lower for the demersal survey because just 4 fish (out of 369 in total) below 30cm were caught. No fish below 30cm were caught in the pelagic survey.

The catch rate of larger cod (>50cm) was considerably lower than the overall cod catch rate in the demersal survey (a fall of 34 to 7 cod per hour) but this difference was not so great in the pelagic survey (a drop of 20 to 17 cod per hour) and this is the initial suggestion of a difference in the size distributions between the two survey gears (Table 4). This indication is borne out by the length frequency distributions provided in the following section.

The mean catch rate calculated in kg/hour (based on total catch weight estimates (from the skipper) and from calculated weights using standard length/weight relationships) was, as might be expected, also higher in the pelagic survey because of the higher numbers of larger cod in the catch.

Table 4 - Catch rates of cod obtained of the two surveys.

	All	Demersal	Pelagic
Total catch (kg)	1426	451	975
Cod (n)	738	369	369
Cod >30cm (n)	734	365	369
Max CPUE (n/hour)	-	169.1	24.6
Min CPUE (n/hour)	-	2.7	10.8
Mean CPUE (n/hour)	25.5	33.8	20.5
Standard Deviation of catch rates (CV)	46.5 (1.6)	53.2 (1.62)	7.7 (0.39)
Mean CPUE >30 cm (n/hour)	25.4	33.4	20.5
Mean CPUE >50 cm (n/hour)	-	7.05	17.06
Mean CPUE estimate (kg/hour)	49.3	41.3	54.2

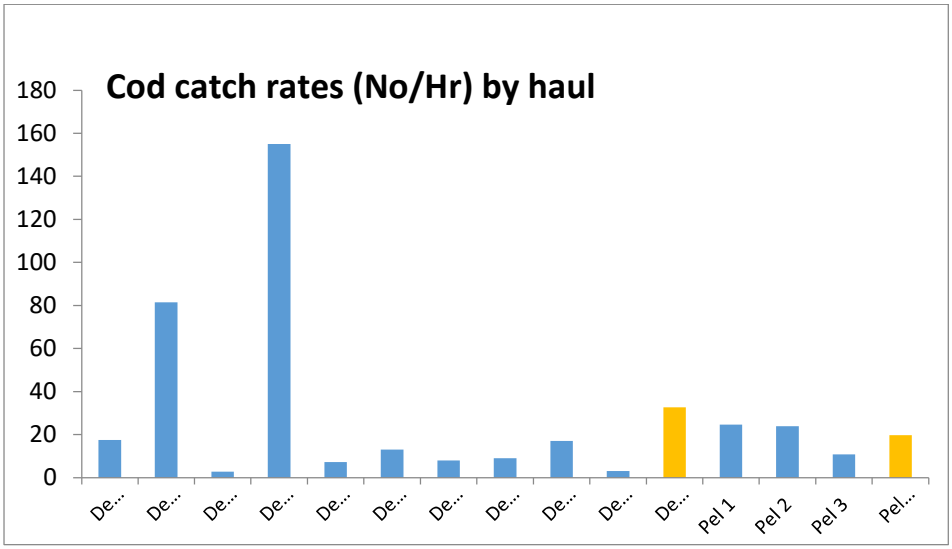

Figure 4 - Calculated cod catch rates per haul for the demersal and pelagic surveys.

Catch rates for the demersal and pelagic surveys are plotted below in a bubble chart to show the relative differences in cod numbers caught per hour between the two trawl types and between sample locations.

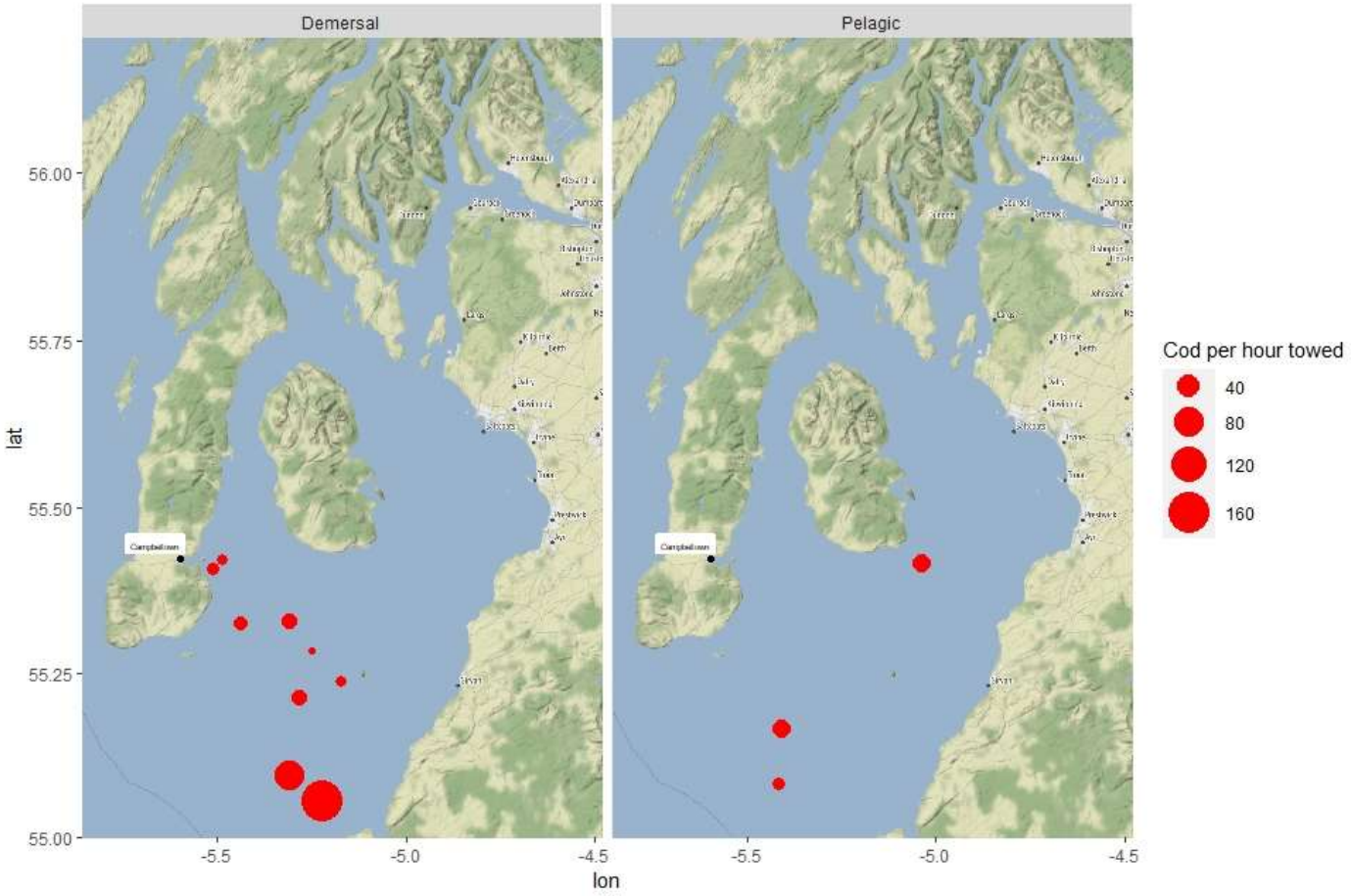

Figure 5 - Bubble plots of the number of cod caught per hour of trawling for the demersal and pelagic surveys

The observed CPUEs (n/hour) for each survey haul were used to interpolate across the wider survey area (using ordinary kriging in SAGA software (www.saga-gis.org)) to try and give an indication of the possible relative densities of cod within the wider cod box between the areas covered by the survey tows. Clearly this analysis is based on fairly limited data so should be interpreted with caution, but the resulting plot (Figure 6) clearly indicates an area of higher

CPUE situated in the southern part of the cod box during the period the survey was conducted. Relative CPUE throughout the rest of the cod box was much more uniform, even though some of those tows were in very close proximity to the area with higher observed CPUE which may indicate aggregation behaviour related to spawning.

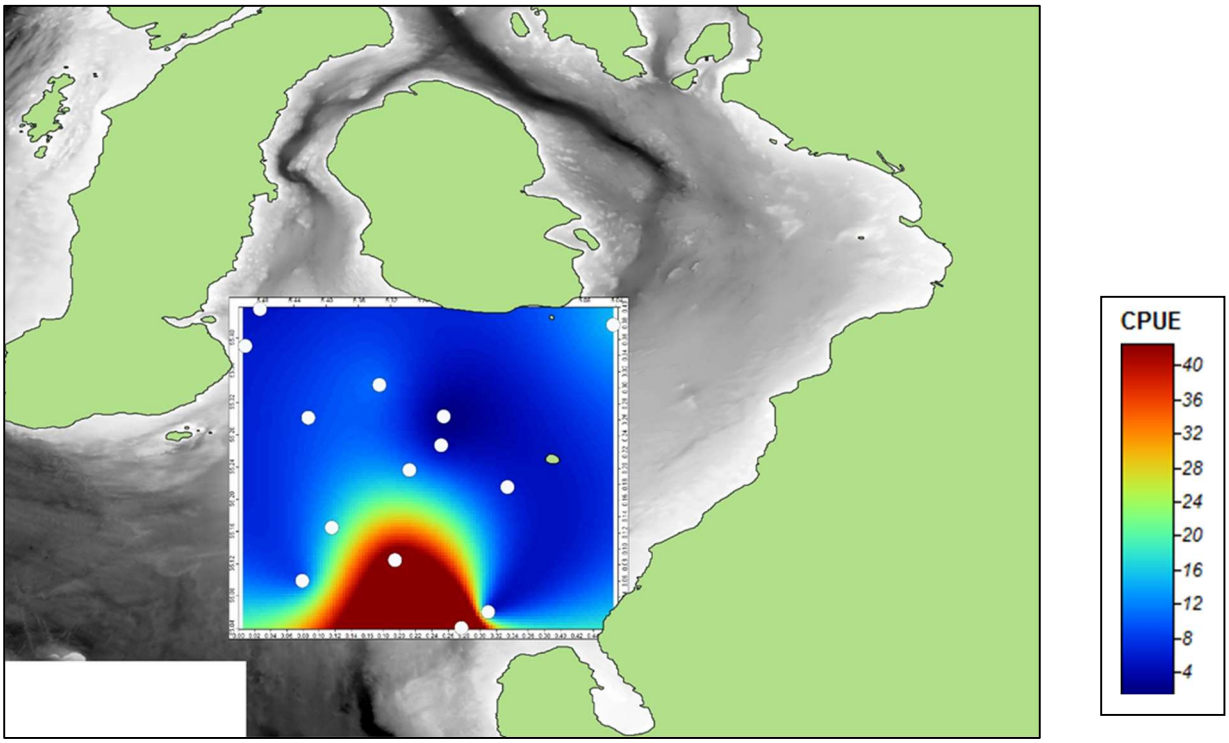

Figure 6 - Interpolated CPUE within survey area.

Length Frequency Distributions

The length frequency distributions in Figure 7, Figure 8 and Figure 9 show that overall the demersal survey caught smaller fish than the pelagic survey. The mean length of cod in the demersal survey was 45.5 cm but fish as small as 14 cm were caught, whereas the mean length in the pelagic survey was considerably larger at 59.2 cm, with very few fish below 40 cm caught (3 of 369).

We also compared the observed length distributions from the current study with data from the Turrell *et al.* (2016) study (Figure 9), which took place in February 2014, predominately in the northern part of the Clyde basin and also used a high aperture semi-pelagic trawl with a mean footrope fishing height of 4m off the seabed (range 0-70m).

Results from a Kolmogarov-Smirnov test (which compares the position and shape of a distribution) are shown in Table 5 and confirm that the length frequency distributions from the current demersal and pelagic surveys were highly significantly different ($p < 0.0001$), while the current pelagic survey distribution was only slightly significantly different ($p < 0.05$) from the Turrell *et al.* (2016) data. These findings are visually represented most clearly in the cumulative length frequency distributions presented in Figure 10.

Table 5 - Results of K-S tests

	D value	D crit	p
Demersal vs Pelagic	0.6233	0.05	< 0.0001
Turrell et al vs Pelagic	0.1105	0.05	< 0.05

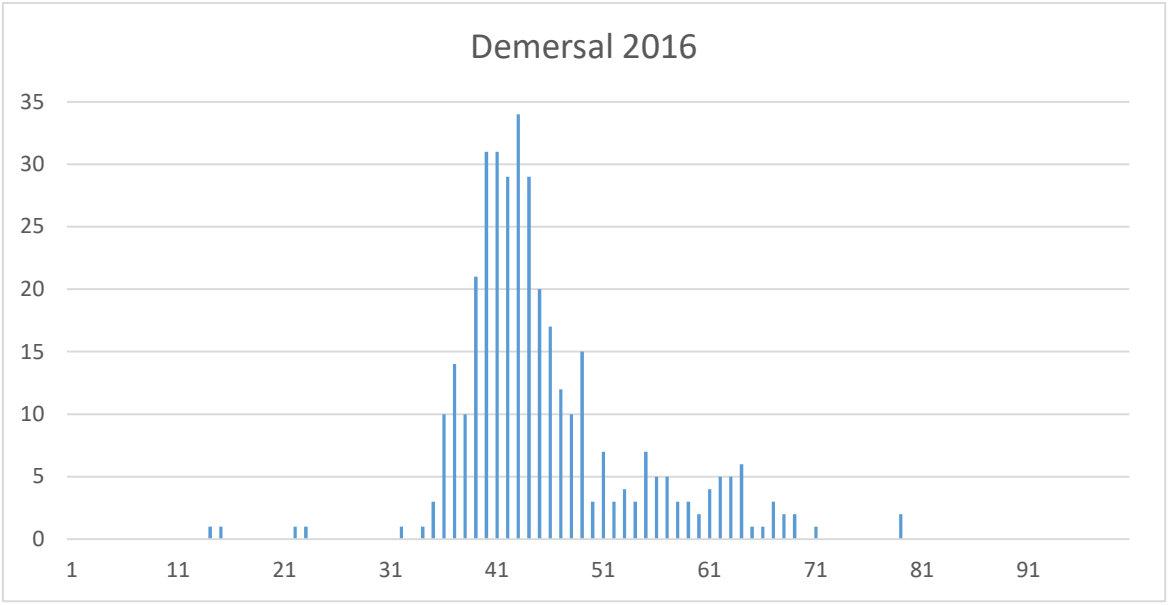

Figure 7 - Length/frequency of cod from demersal survey

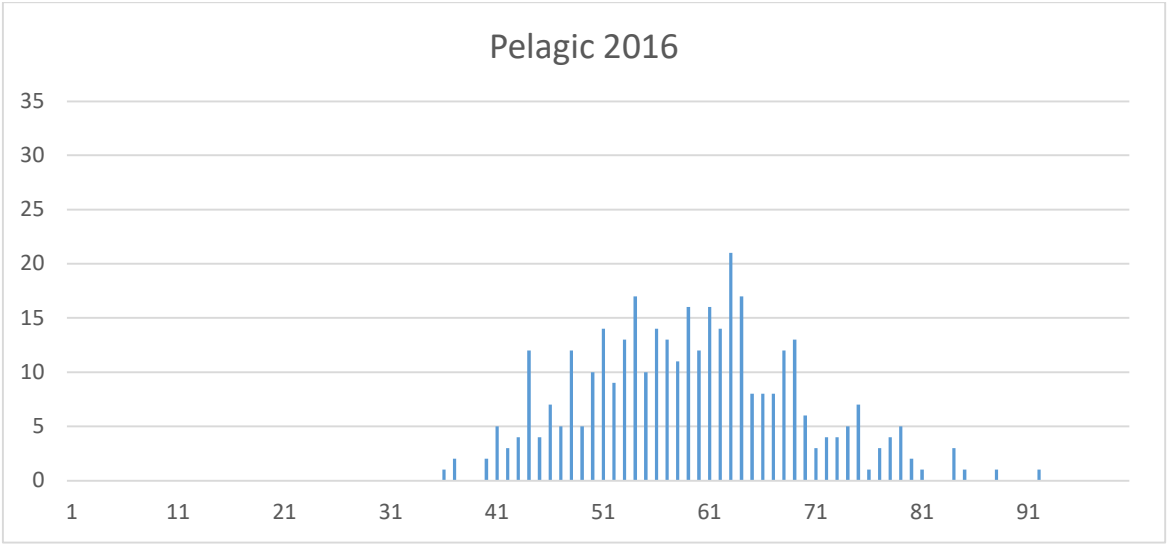

Figure 8 - Length/frequency of cod from pelagic survey

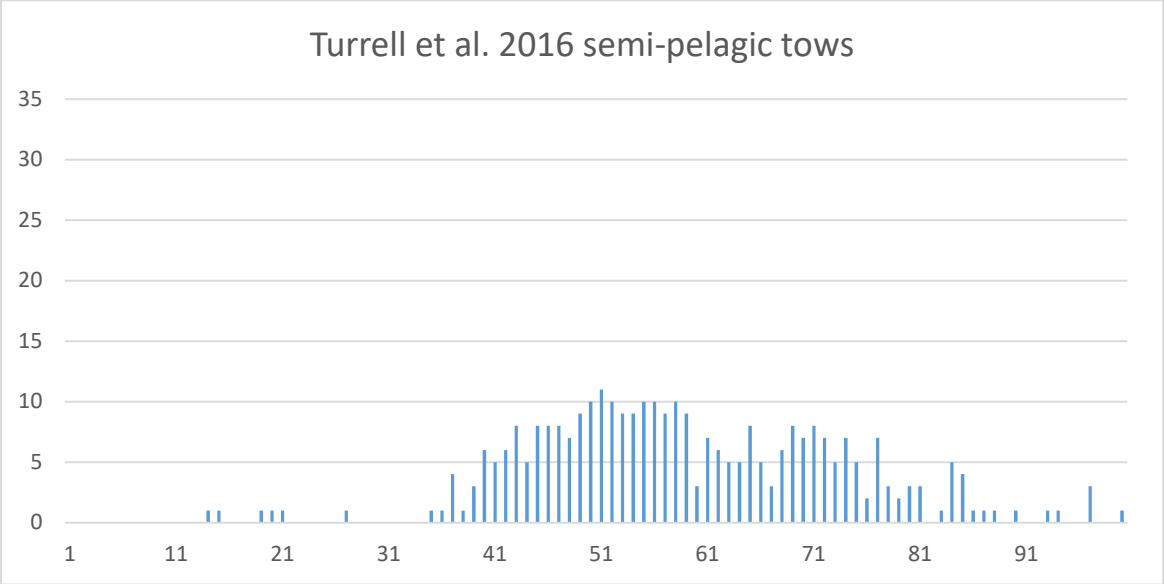

Figure 9 - Length/frequency of cod from Turrell et al. survey

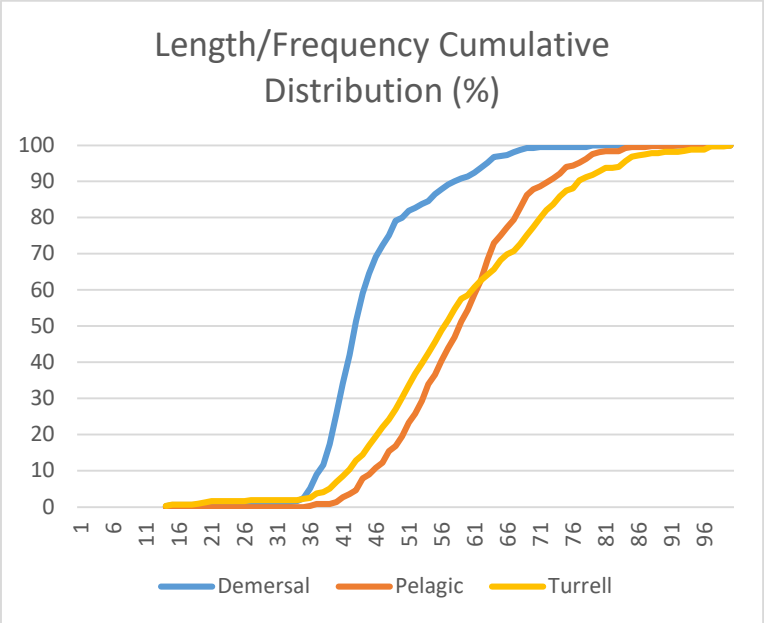

Figure 10 – L/F cumulative distributions

Sex Ratios

The pelagic trawl catches were dominated by female fish (85%), compared to the demersal trawl catches (18%). Table 6 shows the count and proportions in the two surveys. Figure 11 shows the spatial distribution of sex ratios by means of pie charts for each of the demersal and pelagic tow positions. The 3 pelagic tows are easily identifiable as the charts with the majority of female fish in the catch. There is little or no difference in the sex ratios between tows of the same type, and the difference between the two gear types is likely due to females swimming higher in the water column than males during the spawning season. Nevertheless this finding, and particularly when viewed in light of the sex specific length distributions (absolute and cumulative) presented in Figure 7 - Figure 14, indicates that the higher aperture pelagic gear is more effective at sampling a component (larger females) of the population that do not appear to be as well represented in the lower lift, shorter tow demersal trawl catches.

Table 6 - Count and proportions of cod sex

	Count			Proportion	
	Male	Female		Male	Female
Pelagic	56	313		0.15	0.85
Demersal	302	67		0.82	0.18

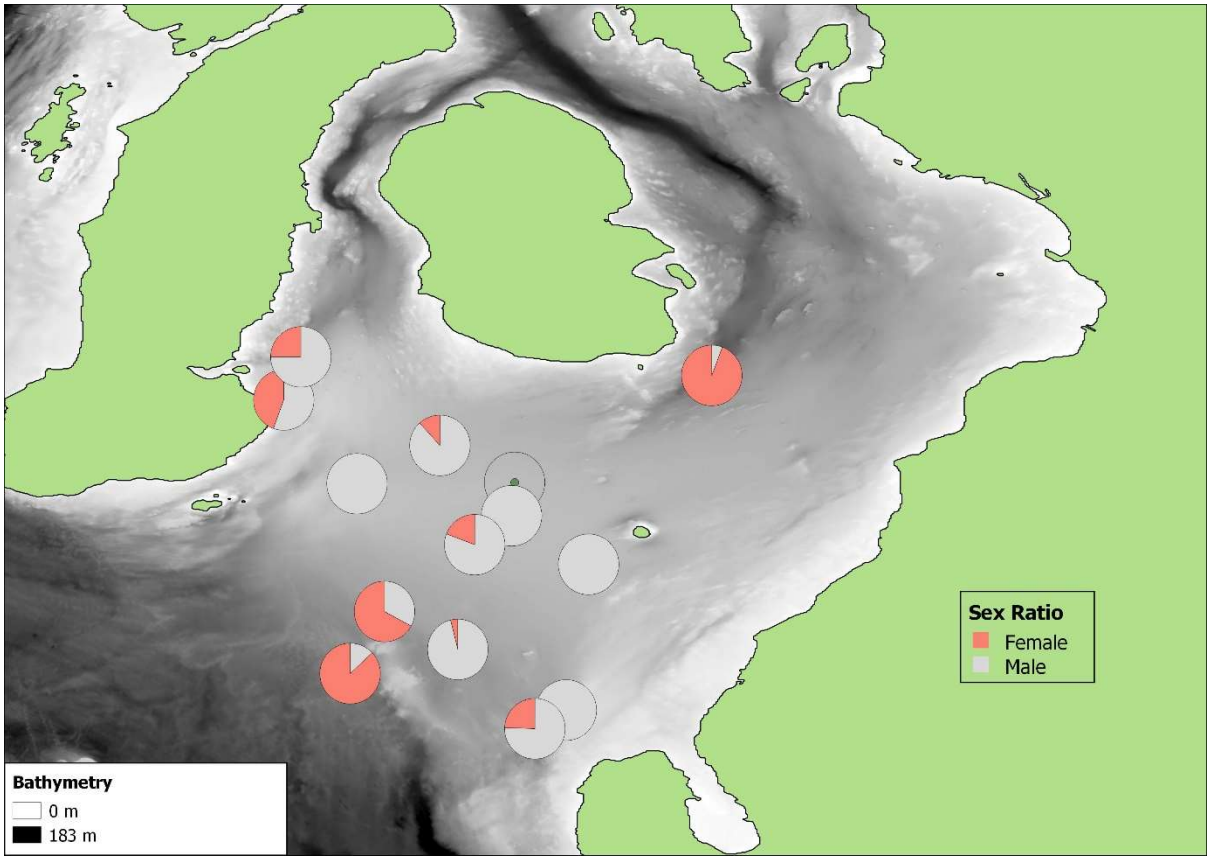

Figure 11 - Sex ratios map

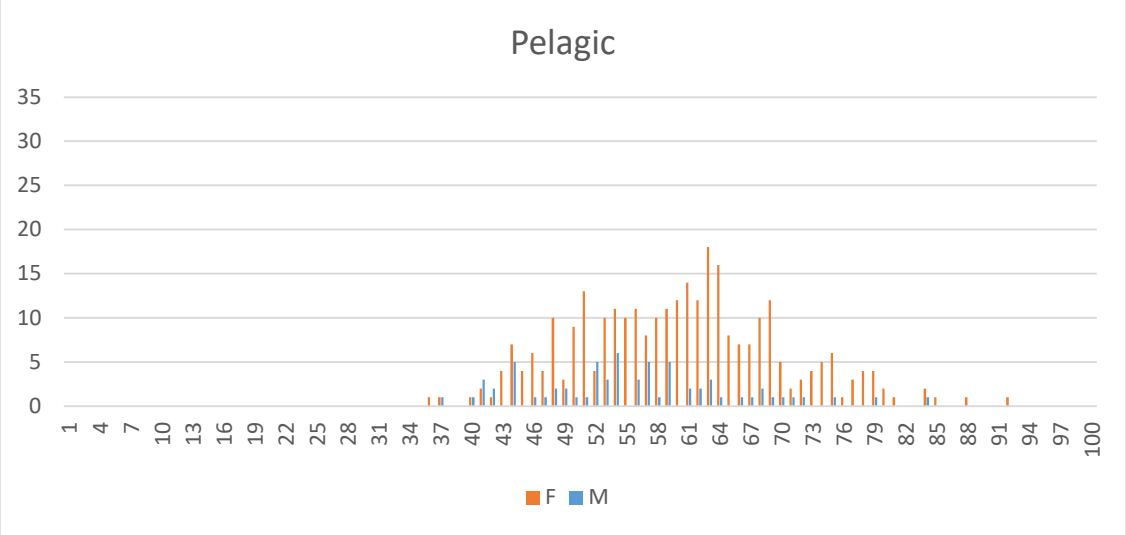

Figure 12 - Pelagic cod length distribution histogram, split by sex

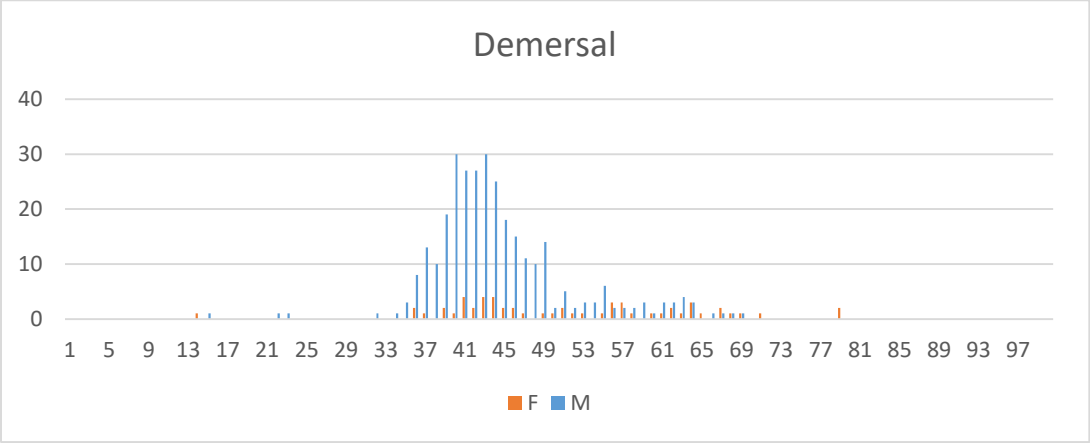

Figure 13 - Demersal cod length distribution histogram, split by sex

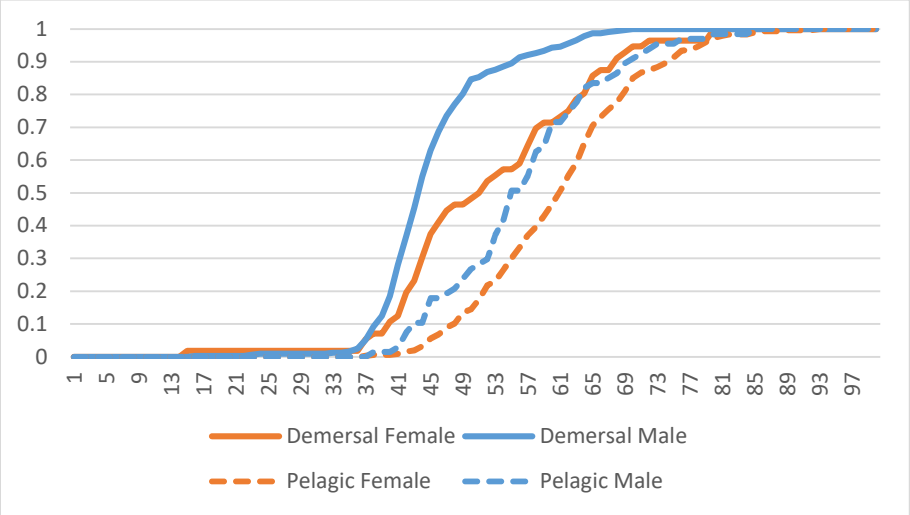

Figure 14 - Cod length cumulative frequency

Maturity Stages

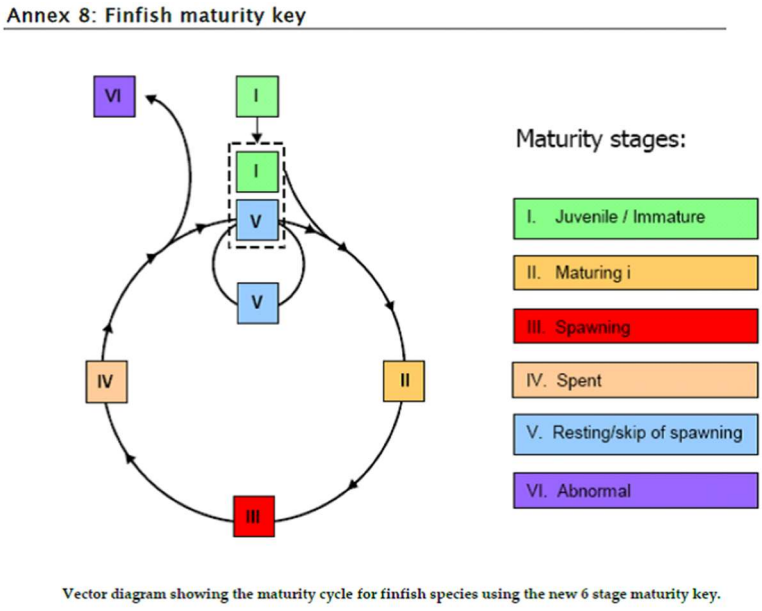

Figure 15 - Finfish maturity key

The maturity stages of cod sampled from the demersal and pelagic surveys are shown in Table 7. For both trips, the majority of cod were in spawning condition (stage III) as would be expected given the timing of the surveys. In the demersal catches a small number (4) of immature fish were caught and two of those specimens were taken in the same tow. The pelagic survey caught a higher proportion of 'spent' (stage IV) cod compared to the demersal survey (Figure 16) and this may be explained by the fact that the pelagic survey occurred one week later than the demersal survey.

Table 7 - Maturity stages

Maturity Stage	I	III	IV	VI		Total
Demersal	4	340	25			369
Pelagic		221	147	1		369

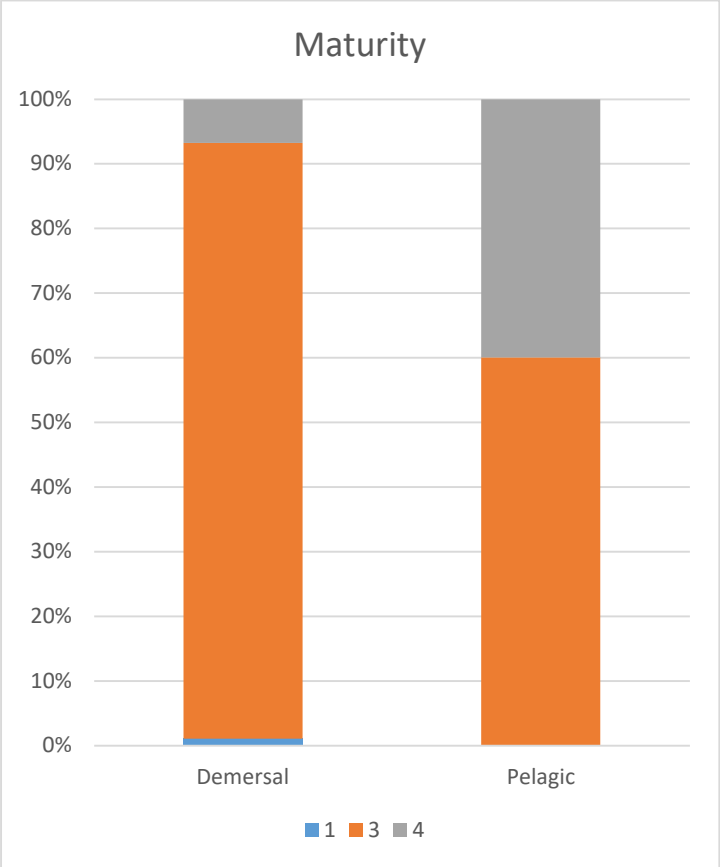

Figure 16 - Proportions of maturity stages

Figure 17 shows how the maturity stages varied spatially across the survey area. Trawl DEM8 stands out as having a high proportion of immature fish, although the sample size was low (2 immature out of 9 cod). Trawl PEL1 has by far the highest proportion of 'spent' (stage IV) fish, which is interesting as it is further inshore than other sampling locations, near the end of the deep water trench to the East of Arran.

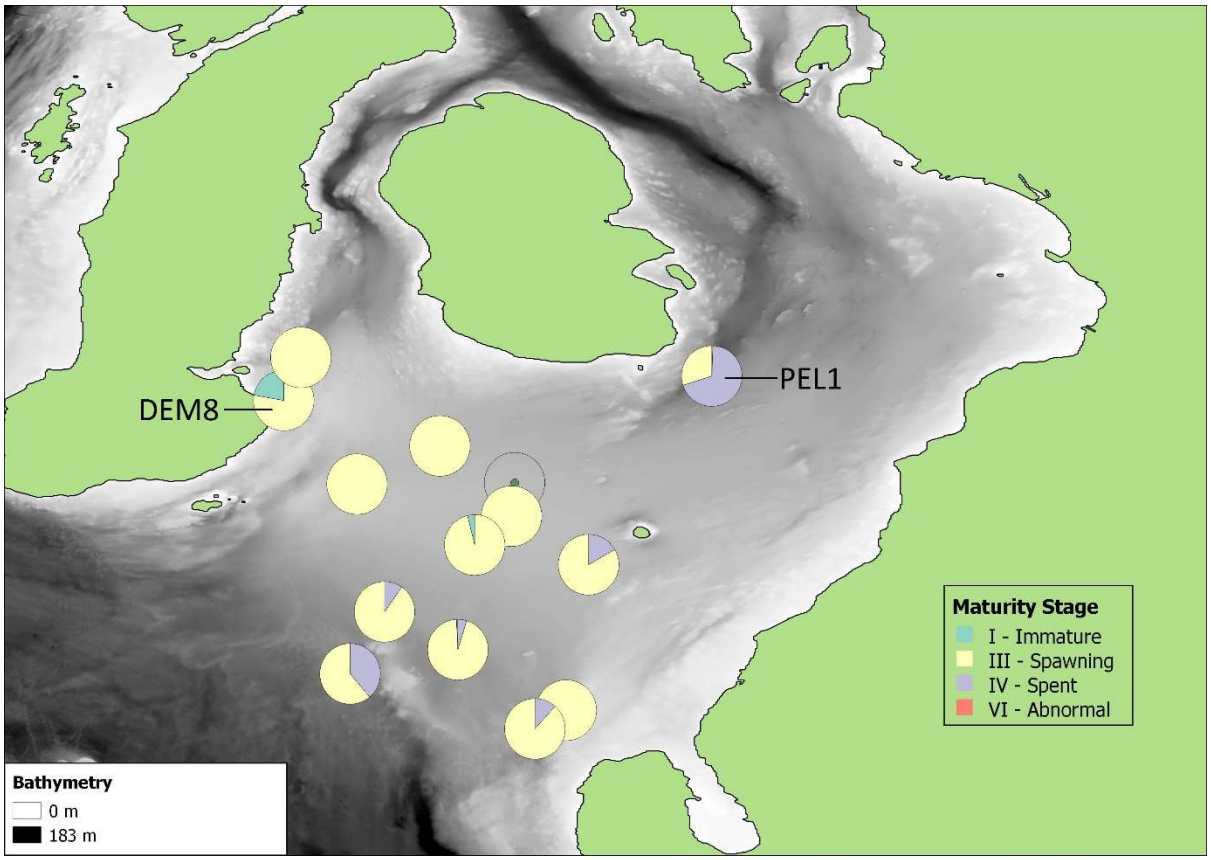

Figure 17 - Spatial variation in maturity stages map

Discussion

Ideas surrounding an enhanced fishery sampling scheme for the Clyde cod stock have been discussed over a number of years. Turrell et al. (2016), in response to requests from the CFA, conducted a semi-pelagic trawl survey in the deep basins of the northern Clyde estuary in February 2014. The 2014 survey found that semi-pelagic gear caught predominantly large cod (>30cm) whereas standard scientific tows had been catching predominantly smaller fish (<30cm). The number of fish caught in the semi-pelagic trawls per hour towed was much lower (7 fish per hour) than in the scientific tows targeting young fish (16 cod per hour). The survey demonstrated the presence of some large cod in the deeper water of the upper Clyde basin, but as a one off survey did little to determine the status of the spawning stock.

Turrell et al. suggested follow up work that included testing the extent to which white fish (including cod) are present on the Great Plateau (the entrance to the Clyde Estuary) in March and whether fish are on the bottom or midwater, as well as a variety of questions covering sediment encroachment, phosphorescence, herring growth, herring distribution and the effects of climate change.

In this report we have focused on the issue of cod in and around the closed area that is intended to cover the Clyde cod stock spawning ground. The survey conducted in March 2016 provides information on the size distribution, catch rates, sex ratios and spawning condition of cod in the lower Clyde. Otoliths were collected, but as yet no aging has been carried out on these, and a sample of whole fish has been frozen for possible diet studies and possible stock structure investigations (DNA/ Isotope Analysis) should funds become available.

Our overall aims were to collect data on the geographical distribution and relative catch rates of cod within the Clyde seasonal closure area, to investigate the vertical distribution of cod within the water column and to provide baseline data for future survey comparison.

Our results are hard to compare with those of Turrell et al. (2016) whose survey was conducted a month earlier and in the upper reaches of the Clyde Estuary. Nevertheless, catch rates of cod in semi-pelagic trawls in the 2016 survey were substantially higher than those reported from 2014, (20.5 fish per hour: 7 fish per hour) quite probably because the 2016 tows were made on or near the spawning zone where mature cod aggregate to spawn in March. Differences in gear design and towing duration and speed may also have played a role.

The average cod catch rate in the 2016 demersal tows described above (33.8 fish per hour) was more than double those reported by Turrell et al. (2016) from other scientific surveys (16 cod per hour), but variance between tows in the 2016 survey was high. Bootstrapped 95% confidence limits on the number of fish caught per tow of 11 to 82 fish show that our sample is not statistically different from that obtained by Turrell et al. (2016). Furthermore, differences in tow locations, timing and gear design and use may all confound reliable comparisons. Further work is needed to compare tows made in this survey with tows made during routine groundfish surveys.

For catch rates to provide unequivocal evidence of relative abundance we must either have some idea of what constitutes 'high abundance' catch rates in a specific gear type or we need a standardised fishing method that is used repeatedly from year to year to detect trends. While the catch rates we observed seem higher than those observed in other surveys, they could well be explained by factors other than an actual increase in cod abundance. Put simply, we do not have an agreed benchmark against which to measure the observed catch rates.

The distribution of the cod caught during the present survey confirmed that the area fished contained a high proportion of spawning or spent fish at the time of the survey, indicating that we were indeed fishing a spawning area and that the spawning area probably exceeds the area we fished. Highest densities were caught at the southern end of the fishing zone, suggesting that in future years sampling further south may also be warranted. Immature fish (stage I) were only caught at the most northerly sampling station close to the Mull of Kintyre, and no maturing (II) or resting (V) fish were reported. The larger proportion of spent fish in the semi-pelagic gear compared to the demersal gear seems most likely to be due to the passage of time (1 week) between the two samples, given the relatively short (50-60 days) spawning period of cod (Kjesbu 1989).

A striking feature of the cod catches was that the ratio of females to males was much higher in the semi-pelagic trawls and vice versa in the demersal trawls (Table 6). This is a reflection of the spawning habits of cod, where the females are higher in the water column than the males, which form competing groups near the seabed vying for spawning opportunities with females (Rose 1993; Hutchings et al. 1999).

The length frequency distributions of cod demonstrate that fish in the semi-pelagic trawls were substantially larger than those in the demersal trawl, and that overall in both trawls females were significantly larger (59cm average) than males (46cm). Furthermore, the fish in the semi-pelagic trawl were larger than those caught in the 2014 survey, always bearing in mind differences in timing and location.

Again, as with the catch rates, the apparent increase in the mean length of fish suggests that there could have been an increase in older fish in the sampled population since 2014, though the same caveats apply.

The 2016 survey provides a useful basis for continued sampling in future years to identify trends in the size (and age) structure of the population, to better define the extent of the spawning area and to track trends in catch rates using two different methods. It will be important to standardise gear operations (1 hour demersal tows, 6 hours semi-pelagic tows) and to maintain the same gear characteristics (mesh sizes, cod end diameter, tunnel length, sweep etc.) for future sampling if we are to be able to make useful comparisons in future years.

Routine groundfish surveys by Marine Scotland Science will continue to provide a separate and independent metric by which to monitor cod recovery west of Scotland, but with just two or three haul locations in the Clyde region per year, with the demonstrable high variability in catch rates between haul locations in this area, and with the fishing characteristics of the GOV trawl used in the bottom trawl surveys, these data will not (and are not designed to) provide any fine scale description of the recovery of what is recognised as a separate, though small, local cod stock.

A well-controlled, randomised and standardised annual industry-led survey would at least allow trends in catch rates and size (and age) distributions to be tracked more effectively than has been done to date for the Clyde cod stock.

Conclusion

The present study has demonstrated the ability of industry to lead a dedicated trawl survey to monitor the recovery of the Clyde cod stock that may result from the seasonal fishery closure in the Clyde basin. Catch rates were difficult to interpret as other surveys have used different gear types or fished in other parts of the basin. Nevertheless, the size distribution may suggest a slight increase in mean size of fish caught off the bottom compared with 2014. No age determination has yet been conducted, though otoliths have been collected. Routine surveys conducted by Marine Scotland Science, though useful in the broader context of the west of Scotland, would be improved and augmented if a regular annual sampling scheme were to be implemented with the aim of closely monitoring changes in the fish length / age distribution and catch rates.

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