# Bycatch in the North Minch *Nephrops* Trawl Fishery

## Year 3 Report
## December 2011


**Mr. Muir Glendinning**
**Prof. Douglas Neil**
**Ms. Rosanna Milligan**

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# Introduction

The fishery for the Norway lobster, *Nephrops norvegicus* is currently the second most valuable species landed in Scotland with a estimated value of £76.6 million in 2010 (Marine Scotland, 2011). The fisheries in Scotland are effectively divided between a mixed fishery in the North Sea which captures and lands *Nephrops* and whitefish, and a single-species *Nephrops* fishery in the West of Scotland. It is the *Nephrops* fisheries in the North Minch area in the West of Scotland which is the focus of this report.

The North Minch fisheries are managed under ICES Area VIa and Functional Unit (FU) 11 (Figure 1). Many of the Scottish vessels working in this area are based in the port of Stornoway on the Isle of Lewis, and predominantly target *Nephrops* and other shellfish in the Minches to the east of the Outer Hebrides. In 2010 *Nephrops* was the most valuable landed species in the Stornoway district, with a landings value of approximately £5.91 million (Marine Scotland, 2011).

Many commercial whitefish stocks in Area VIa are still believed to be at extremely low levels (Keltz and Bailey, 2010), and the impact of commercial fishing practice where species belonging to depleted stocks are captured as bycatch, are still of concern to fishery management.

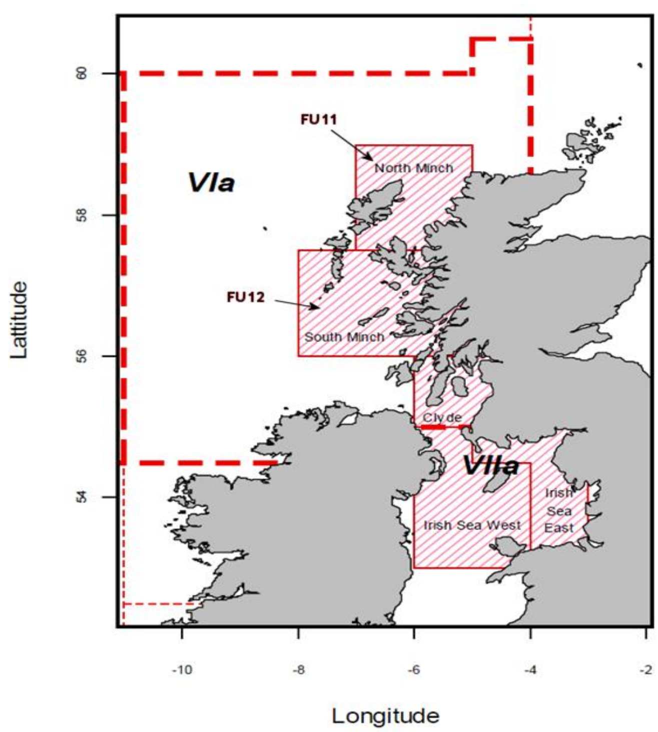



**Figure 1**. Map showing Functional Units within ICES division VIa in the west coast of Scotland (ICES, 2011).

Single-species *Nephrops* trawl fisheries are particularly prone to higher levels of bycatch as they are permitted to fish using smaller-mesh gear (because they are only targeting *Nephrops*, not whitefish). Current management measures implemented in the single-species *Nephrops* fisheries in the west of Scotland include a minimum landing size (MLS) of 20mm carapace length and minimum codend mesh sizes of 80mm for single-rig fishing gear (ICES, 2011). Consequently, the capture of undersize roundfish is potentially a much greater problem in the single-species fisheries (in comparison to mixed fisheries which have a codend mesh size of 120 mm) as there is less opportunity for the fish to escape the gear e.g. (Briggs, 1985, Catchpole et al., 2007, Stratoudakis et al., 2001, Catchpole and Revill, 2008).

Nine of the trawl vessels operating out of Stornoway currently supply *Nephrops* to Young's Seafood Ltd. either as whole animals (largely for export) or 'tails' (largely for the domestic market), and are equipped with the 'YoungsTrace' system, which has been designed to track each individual catch from the fishing vessel through the landing, processing and transportation stages and to the final consumer. It is this particular sector of the fleet that was examined through the current project, and the specifications of its vessels are shown in Table 1. Thanks to the use of the 'YoungsTrace' traceability system and the results of an earlier pilot study carried out by Milligan *et al.* during 2007-2008, the trawlers using the system to target *Nephrops* in the North Minch were awarded Marine Stewardship Council (MSC) accreditation on 14$^{th}$ April 2009, the requirements of which define several of the major aims of this work.

**Table 1.** List of trawler vessels in the unit of certification fleet supplying *Nephrops* to Young's Seafood Ltd in 2011

| Vessel name | Year Built | Registration | Length (m) | GRT | Power (KW) | Gear Type | Codend mesh size (mm) | SMP size (mm) |
|---|---|---|---|---|---|---|---|---|
| Comrade | 1963 | SY337 | 16.65 | 23.16 | 355 | Single rig | 80 | 120 |
| Sheigra | 1971 | SY7 | 17.03 | 24.95 | 131 | Single rig | 80 | 120 |
| Wavecrest | 1968 | ST337 | 16.34 | 23.15 | 134 | Single rig | 80 | 120 |
| Kaylana | 1978 | SY21 | 17 | 24.9 | 284 | Twin rig | 80 | 120 |
| Northern Star | 1968 | SY11 | 16.46 | 24.05 | 149 | Single rig | 80 | 120 |
| Ocean Spirit | 1979 | SY21 | 13.1 | 23.6 | 134 | Single rig | 80 | 120 |
| Silverchord | 1973 | SY101 | 16.4 | 24.5 | 257 | Twin rig | 80 | 160 |
| True Vine | 1974 | KY7 | 15.24 | 23.43 | 171 | Single rig | 80 | 120 |
| Heather Isle | 1966 | SY47 | 17.65 | Unknown | 171 | Single rig | 80 | 120 |

## Conditions of MSC Certification

The Certification Report for the Stornoway *Nephrops* fishery outlined four conditions which must be met over the four years following accreditation, two of which will be met by the University of Glasgow. These conditions are described in Table 2 and have been taken from the Certification Report by Moody Marine (Andrews, 2009).

**Table 2.** Conditions of the MSC certification to be undertaken by the University of Glasgow

| |
|---|
| **Condition 3**<br>**Cod Bycatch & Discards**<br>Interactions occur between nephrops fisheries and cod populations. Cod is recognised as being in a depleted state and MSC certified fisheries are required to be prosecuted so as to promote rebuilding of depleted target and by-catch species.<br><br>**Action required:**<br>Measures should be identified and implemented to minimise catches of cod and future catches should be reported in relation to the proportion of cod in nephrops catches, data from previous years and the relative status of the cod stock. Measures should remain in force until cod recovery has been achieved, and further measures adopted to prevent the nephrops fishery from having adverse effects on the recovered stock.<br><br>**Timescale**: Measures to minimise cod bycatches in the nephrops directed fishery should be identified within 2 years of certification. Testing of measures should take place within 3 years of certification. Effective measures to reduce cod bycatch should be fully implemented within 4 years of certification.<br><br>**Relevant Scoring Indicators**: 2.1.4.2, 2.3.1.3 |
| **Condition 4**<br>**Spurdogs**<br>There is a small bycatch of spurdogs in the nephrops fishery. This species is listed on the IUCN Red List as an endangered species.<br><br>**Action required**<br>Measures should be identified and implemented to minimise bycatch of spurdog. Measures should remain in force until spurdog recovery has been achieved, and further measures adopted to prevent the nephrops fishery from having adverse effects on the recovered stock.<br><br>**Timescale**: Measures to minimise spurdog bycatches in the nephrops directed fishery should be identified within 2 years of certification. Testing of measures should take place within 3 years of certification. Effective measures to reduce spurdog bycatch should be fully implemented within 4 years of certification.<br><br>**Relevant Scoring Indicators**: 2.1.4.2, 2.3.1.3 |

## Years 1 and 2: Progress Summary

The Year 1 progress report (Milligan et al., 2009) describes the work carried out between December 2008 and December 2009, as well as an analysis of the catch composition between December 2008 and August 2009, and should be referred to for details on the methodologies and data analysis. However, a brief summary of the work carried out is included below for reference.

Between December 2008 and December 2009, a scientific analysis of the bycatch from a commercial *Nephrops* trawler was carried out allowing the proportion of cod in the catches to be determined over the course of the year. Biometric data were collected on all individual cod and spurdog captured during these surveys, though analysis of the data was ongoing at the time that the report was published.

Overall, it was found that sample month was a significant predictor of catch composition, suggesting that temporal variations through the year play a role in determining what the fishermen are catching. Due to unforeseen technical issues the YoungsTrace system was not available to use in trials during 2009, and all data were therefore obtained solely from research trips onboard the *MV Comrade.*

The Year 2 progress report (Milligan and Neil, 2010) describes the work completed between January 2010 and December 2010. One of the major aims was to collect additional data on the bycatch composition which could be combined with the existing data collected during year one. Spatial and temporal variations in catch composition were identified, with the majority of catches dominated consistently by predominantly pouts (*Trisopterus* spp.), whiting, lesser-spotted dogfish Crustacea (such as pandalid shrimp), and Cnidaria (such as the tall sea pen and the 'golf ball anemone', *Actinauge richardii*). Catches of cod and spurdog were very low in virtually all catches, and although differences in the capture rate between the sites was recorded, it was unclear whether this result was meaningful.

In Year 2 the self assessment scheme of bycatch and discards was also trialled and validated. Once validated, this scheme would allow skippers and crew to monitor the levels of bycatch in their own catches, providing improved data concerning which species are most affected by trawl fishing. Analysis showed that a commercial fishing crew were able to sort their catches as effectively as a scientific team, with no loss of data quality. In addition, small random samples of the catch were shown to correspond well with the rest of the catch and would provide adequate baseline data on the overall catch compositions. Some of the more sensitive and less common species may be missed, but suitable data on specific species would be reported by fishermen in logbooks at periodic intervals.

## Year 3: Objectives and Progress

The aims objectives and milestones for achieving the conditions of certification were outlined by the University of Glasgow at the beginning of 2009. The aims for Year 3 were as follows:

| **Condition 3: Cod bycatch and discards** |
|---|
| **Jan 2011 – Dec 2011**<br>• As new technical measures become available (through ongoing research at FRS), catches obtained with these on trial vessels will be tested against the existing data on cod bycatch.<br>• Periodic monitoring of cod bycatch to evaluate self-assessment data.<br>• Comparative analysis of new technical measures to minimize cod bycatch with previous data set.<br>If a clear spatial \ temporal trend is identified, alterations to fishing practice will be tested<br><br>Milestones December 2011:<br>1. Evaluation of the effectiveness of new technical measures in reducing cod bycatch.<br>2. Evaluation of self-assessment scheme across the entire *Nephrops* trawl fleet. |

| **Condition 4: Spurdog bycatch and discards** |
|---|
| **Jan 2011 – Dec 2011**<br>• As new technical measures become available (through ongoing research at FRS), catches obtained with these on trial vessels will be tested against the existing data on spurdog bycatch.<br>• Periodic monitoring of spurdog bycatch to evaluate self-assessment data.<br>• Comparative analysis of new technical measures to minimize spurdog bycatch with previous data set.<br>• If a clear spatial \ temporal trend is identified, alterations to fishing practice will be tested.<br><br>Milestones December 2011:<br>1. Evaluation of the effectiveness of new technical measures in reducing spurdog bycatch.<br>2. Evaluation of self-assessment scheme across the entire *Nephrops* trawl fleet. |

## Summary of Progress

Scientific analysis of the bycatch from the whole fleet of commercial *Nephrops* trawlers landing MSC prawns to Youngs Seafood Ltd was carried out between July 2010 and November 2011. This was achieved using random sub-samples obtained from the skippers of the vessels and from scientific observer surveys during commercial fishing operations. Observer trips also facilitated the periodic collection of cod and spurdog data which would be combined with data collected during Years 1 and 2, allowing that data set to be continued.

Due to unforeseen technical problems the YoungsTrace system was not available to be used as planned in conjunction with the random sub-samples collected during the survey period. An alternative logbook system, introduced until YoungsTrace was operational, was therefore continued.

Analysis of all survey data collected between July 2010 and November 2011 and an evaluation of the self-assessment scheme across the entire *Nephrops* trawl fleet is complete. No technical measure was trialled during this time.

## Collaboration with other Institutes

Since the beginning of this project, and in line with the recommendations from the MSC certification report, Glasgow University has continued to foster links with scientists in other institutes. In addition to the meetings conducted during Years 1 and 2, these have included:

- Continued correspondence with Marine Scotland gear technology group leader, Mr Barry O'Neill, including progress updates with regard to new *Nephrops* gear technology
- Contact with Dr Niels Madsen, Senior Research Scientist at DTU Aqua Research Laboratory in Denmark regarding the possible link up between the two institutions to trial alternatives to a selection grid e.g. the SELTRA trawl concept.
- Correspondence with team leader Dr. Dave Righton at CEFAS regarding Project MB5201: *Assessing survivability of bycaught porbeagle and spurdog and furthering our understanding of movement patterns in UK marine waters* (Completion date Sep 2012).
- Information sought from lead scientist Dr Veerle AI Huvenne of the National Oceanography Centre Southampton who led a survey trawl on North Shiant Bank in the Minch. Completed on research cruise JC060 on behalf of JNCC/SNH. http://www.eu-hermione.net/cruise-blog/145-roving-again. Information to follow.

## Next Steps

Our intentions for year 4 will be determined as a result of discussions with Young's Seafood Ltd.

# Project Report: Year 3

## Section 1: Catch composition and key species

The major aim for the survey work in year three was to analysis the sub-samples received from the whole fleet of trawlers. Provision of these sub-samples were included as part of the self-assessment scheme which was set up and validated during year 2. The data received would provide additional information on bycatch at the fleet level and would also provide information for the continual monitoring of cod and spurdog. Additional observations on *Funiculina quadrangularis* were also completed at the request of the certification body Moody Marine. Consultations with fishermen were also held with a view to gathering information on fishing behaviour, with particular focus on bycatch and discards.

The first two sections of this report will therefore describe the analysis obtained from the samples received from the self-assessment scheme, in addition to evaluating the schemes overall effectiveness. The third section will outline a set of recommendations enabling the fishery to minimise its impact on the marine ecosystem.

## Part A: Catch Composition across using self assessment and observer data

### Methodology

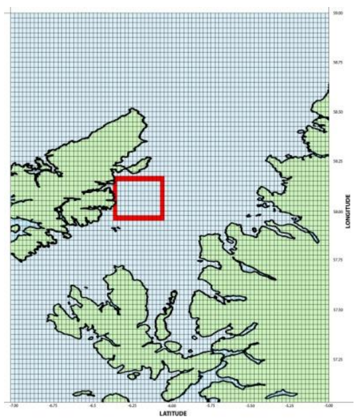
One of the main aims of this project was to determine the extent of discarding within the Stornoway *Nephrops* trawler fleet, and the total species composition of the catches. This was achieved over the course of a number of survey trips during Years 1 and 2; however only one vessel (MFV Comrade) was used in those surveys. During Year 3, random samples were obtained from other vessels within the fleet, as well as the MFV Comrade, enabling levels of bycatch to be recorded across the whole fleet. Random samples from commercial catches were provided in two forms:

1. Samples provided solely by the fishermen, and
2. Samples provided by the fishermen when a scientific observer was present.

Samples provided by fishermen were to be collected on a regular basis throughout the year with skippers asked to provide additional details on Atlantic cod and spurdog abundance in the catch from one haul once a month (see Section 2). Cod and spurdog recordings were to be logged into paper logbooks along with additional information concerning that particular catch such as date, time of haul, depth, GPS coordinates and type of fishing gear used.

Observer samples were collected throughout the year by skippers in the presence of a scientific observer. The observer trips were carried out on board vessels of different age, power and gear type. These included both single and twin rig vessels using "clean" and also "intermediate disc" ground gear on various commercial fishing grounds in the North Minch. The GPS tracks for the tows made between November 2010 and December 2011 are shown in Figure 2. Summary data for each trawl are displayed in Table 3.

(a)



(b)

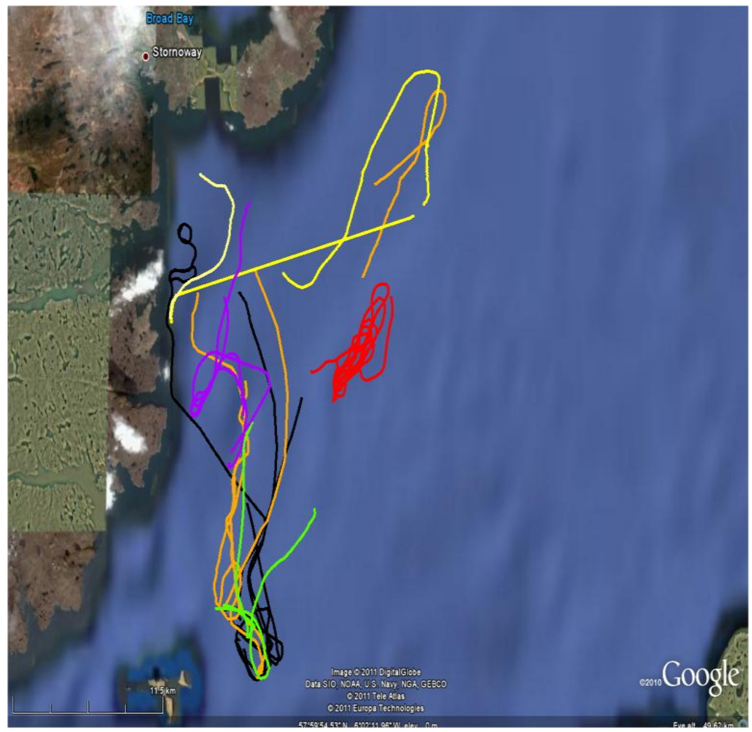



**Figure 2.** Maps of the study area: (a) The limits of the sampling area are highlighted by the red box and (b) Individual GPS tracks of each tow are shown and colour-coded by month: Bright Green: November 2010; Orange: January 2011; Yellow: April 2011; Red: June 2011; Purple: July 2011; Black: October 2011; Maps generated using Google Earth.

The number of trawls varied between fishing season, but two or three daily trips were completed every 7-8 weeks depending on fishing and climatic conditions. Physical data was also recorded to aid the subsequent analysis of the catches, including:

- Trawl date and time and duration (minutes),
- Decimal GPS location (shot and haul points),
- Mean trawl depth (metres; average of start and end depths),
- Gear type - Single or twin rig (Clean, disc or hopper),

To ensure that the processed data would be scientifically meaningful, care was taken not to bias the sampling regime. Each day, one haul was randomly selected and a random sub-sample of the whole catch was obtained. This was achieved using a shovel to fill a large fish box of bulk, before any processing by the crew commenced. All hauls were also observed for total cod and spurdog abundance, and these individuals were recovered, landed and boxed. All samples were stored on ice on the vessels and then frozen at -20°C at the premises of Young's Seafood Ltd. in Stornoway before being transported on ice to the University of Glasgow by haulier approximately one week after capture. The samples were re-frozen at -20°C on arrival at the university and stored until they were required.

**Table 3.** Summary data for each observer trawl

| Trawl ID | Vessel | Date | Time Shot | Duration (mins) | Average Depth (metres) | Gear Type | GPS Shot | GPS Haul |
|---|---|---|---|---|---|---|---|---|
| COM-231110H1 | Comrade | 23/11/2010 | 810 | 260 | 95 | SR-Disc | 58°02'N 6°15'W | 57°56'N 6°17'W |
| COM-231110H2 | Comrade | 23/11/2010 | 1240 | 290 | 100 | SR-Disc | 57°56'N 6°17'W | 57°59'N 6°09'W |
| COM-260111H1 | Comrade | 26/01/2011 | 830 | 285 | 128 | SR-Disc | 58°03'N 6°15'W | 57°55'N 6°17'W |
| COM-260111H2 | Comrade | 26/01/2011 | 1330 | 255 | 129 | SR-Disc | 57°54'N 6°14'W | 58°03'N 6°15'W |
| SHE-270111H1 | Sheigra | 27/01/2011 | 805 | 300 | 104 | SR-Disc | 58°06'N 6°14'W | 57°56'N 6°17'W |
| SHE-270111H2 | Sheigra | 27/01/2011 | 1320 | 265 | 140 | SR-Disc | 57°56'N 6°17'W | 58°05'N 6°19'W |
| WAV-280111H1 | Wavecrest | 28/01/2011 | 805 | 350 | 123 | SR-Clean | 58°09'N 6°05'W | 58°06'N 6°06'W |
| KAY-060411H1 | Kaylana | 06/04/2011 | 715 | 345 | 125 | TR-Clean | 58°06'N 6°12'W | 58°08'N 6°01'W |
| KAY-060411H2 | Kaylana | 06/04/2011 | 1340 | 525 | 99 | TR-Clean | 58°08'N 6°02'W | 58°04'N 6°21'W |
| KAY-060411H3 | Kaylana | 06/04/2011 | 1835 | 160 | 75 | TR-Clean | 58°05'N 6°21'W | 58°09'N 6°18'W |
| COM-080611H1 | Comrade | 08/06/2011 | 515 | 345 | 92 | SR-Disc | 58°03'N 6°10'W | 58°02'N 6°08'W |
| COM-080611H2 | Comrade | 08/06/2011 | 1130 | 260 | 88 | SR-Disc | 58°02'N 6°08'W | 58°02'N 6°08'W |
| COM-080611H3 | Comrade | 08/06/2011 | 1615 | 235 | 93 | SR-Disc | 58°02'N 6°08'W | 58°04'N 6°06'W |
| COM-080611H4 | Comrade | 08/06/2011 | 2030 | 115 | 83 | SR-Disc | 58°04'N 6°05'W | 58°05'N 6°04'W |
| SHE-260711H1 | Sheigra | 26/07/2011 | 710 | 285 | 115 | SR-Disc | 58°05'N 6°17'W | 58°00'N 6°16'W |
| SHE-260711H2 | Sheigra | 26/07/2011 | 1145 | 300 | 117 | SR-Disc | 58°01'N 6°16'W | 58°02'N 6°15'W |
| SHE-260711H3 | Sheigra | 26/07/2011 | 1710 | 285 | 113 | SR-Disc | 58°02'N 6°15'W | 58°08'N 6°14'W |
| SHE-111011H1 | Sheigra | 11/10/2011 | 0825 | 265 | 105 | SR-Disc | 58°05'N 6°15'W | 57°55'N 6°15'W |
| SHE-111011H2 | Sheigra | 11/10/2011 | 1310 | 240 | 111 | SR-Disc | 57°55'N 6°15'W | 57°55'N 6°15'W |
| SHE-111011H3 | Sheigra | 11/10/2011 | 1725 | 165 | 103 | SR-Disc | 57°55'N 6°15'W | 57°59'N 6°15'W |
| COM-121010H1 | Comrade | 12/10/2011 | 0720 | 270 | 104 | SR-Clean | 58°02'N 6°10'W | 57°55'N 6°15'W |
| COM-121011H2 | Comrade | 12/10/2011 | 1225 | 285 | 102 | SR-Clean | 57°55'N 6°15'W | 57°58'N 6°14'W |
| COM-121011H3 | Comrade | 12/10/2011 | 1745 | 255 | 55 | SR-Clean | 57°58'N 6°13'W | 58°07'N 6°20'W |

**Data Analysis**

Analyses of the abundance and biomass of bycatch species or groups were carried out using PRIMER 6 software (Clarke & Gorley, 2006). In order to ensure that trends were accurately identified and analysed, the numbers of each species and the weights of the major groups in each haul's sub-sample were standardised prior to analysis, to give numbers and weights per sub-sample. Multivariate analyses were then carried out on both transformed and untransformed data. The untransformed data were examined to determine the gross relationships between the 'real' catches, for which the analyses would give most weighting to the dominant species (including *Nephrops*, which is the most commercially significant species). More subtle relationships arising as a result of the rarer species were examined by fourth root transformation of the data, counteracting the effect of the highly abundant or high biomass species groups, and giving more notice to the rarer species in the catch.

Where comparisons between samples were examined, the abundance and biomass data were converted to a similarity matrix using the Bray-Curtis similarity index.

Multi-Dimensional Scaling (MDS) and cluster analysis were used to determine the relationships between the bycatch 'communities' from each haul, and ANOSIM analyses were used to determine the significance of factors in explaining the differences in these communities. In general, MDS analyses were restarted at least 100 times, and 99 permutations were used for ANOSIM tests, and. In each case, significance was taken as $p < 0.05$. Temporal effects were tested at the season level i.e. Spring, Summer, Autumn and Winter as there were insufficient samples to test time over monthly periods.

## Results

### Species composition and broad trends

A total of 17 valid random sub-samples were used in the final analysis (from a total 30 received) with the target species *Nephrops* being the most dominant species in the catches by both abundance (approx. 81% of sample on average) and wet weight (approx. 63% of sample on average). The bycatch was typically dominated by small juvenile fish, particularly whiting, haddock and pouts and also small crustaceans. Table 4 shows the five most abundant bycatch species by number, while the dominant species by wet weight are shown in Table 5. In each case, the values have been averaged across all samples.

Two species were recorded that had not previously been recorded during Years 1 and 2. These were the tope shark *Galeorhinus galeus* and the sea bass *Dicentrarchus labrax*. An updated species list is given in Appendix 1.

**Table 4.** The five most dominant species (by number as a percentage) occurring in random sub-samples.

| Species | Proportion of random sample by number |
|---|---|
| Norway pout (*Trisopterus esmarkii*) | 3.15% |
| Whiting (*Merlangius merlangus*) | 2.51% |
| Squat lobster (*Munida rugosa*) | 1.72% |
| Pink shrimp (*Pandalus borealis*) | 1.69% |
| Haddock (*Melanogrammus aeglefinnus*) | 1.12% |

**Table 5.** The five most dominant species (by wet weight as a percentage) occurring in random sub-samples.

| Species / Group | Proportion of random sample by weight (kg) |
|---|---|
| Whiting (*Merlangius merlangus*) | 12.23% |
| Haddock (*Melanogrammus aeglefinnus*) | 5.57% |
| Sharks & Rays | 3.42% |
| Hake (*Merluccius merluccius*) | 2.9 % |
| Crustacea | 2.7 % |

The mean proportion of each major group by wet weight is shown in Figure 3. Overall, *Nephrops* comprised the largest component of the catches (mean = 63%), with non-target bycatch organisms accounting for the remaining 37%.

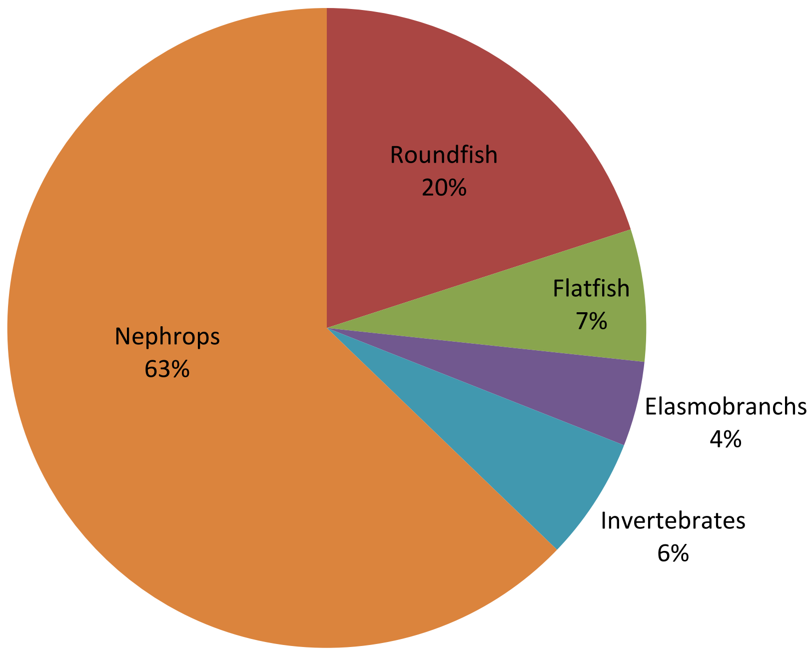



**Figure 3.** Mean overall catch composition from observer and validated random sub-samples from December 2010 to October 2011.

**Relationships Between Catches: Species Abundance**

The abundance data were standardised (to account for differences in catch volume) and fourth-root transformed prior to analysis. An ANOSIM (**AN**alysis **O**f **SIM**ilarity) test was carried out to determine whether any factors including sampling season or vessel had a significant influence on the similarity between catches. (ANOSIM is testing the hypothesis that there are no differences between random sub-samples in the species catch composition). This test showed a significant effect of season on transformed data only (ANOSIM: global $R = 0.392$, $p = 0.04$).

To visualise the relationships between the species abundance of catches, non-parametric 2D Multi-Dimensional Scaling (MDS) ordination was carried out, with the season of capture indicated in each case (Fig 4). These data generally show clustering by most of the boats on the untransformed data with a few outliers. Fourth root transformed data shows slight clustering by season, although the stress (simplistically, a measure of the error) of the 2D plot is relatively high (0.21). Better separation by season is apparent in the 3D plot, but this cannot be shown here.

Bubble plots were plotted for individual species, thus allowing the effect each species has on the relationships between samples to be displayed. Bubbles are superimposed onto each point on the 2D MDS plot, with the size of each bubble being proportional to the abundance in that sample.

**A)** **B)**

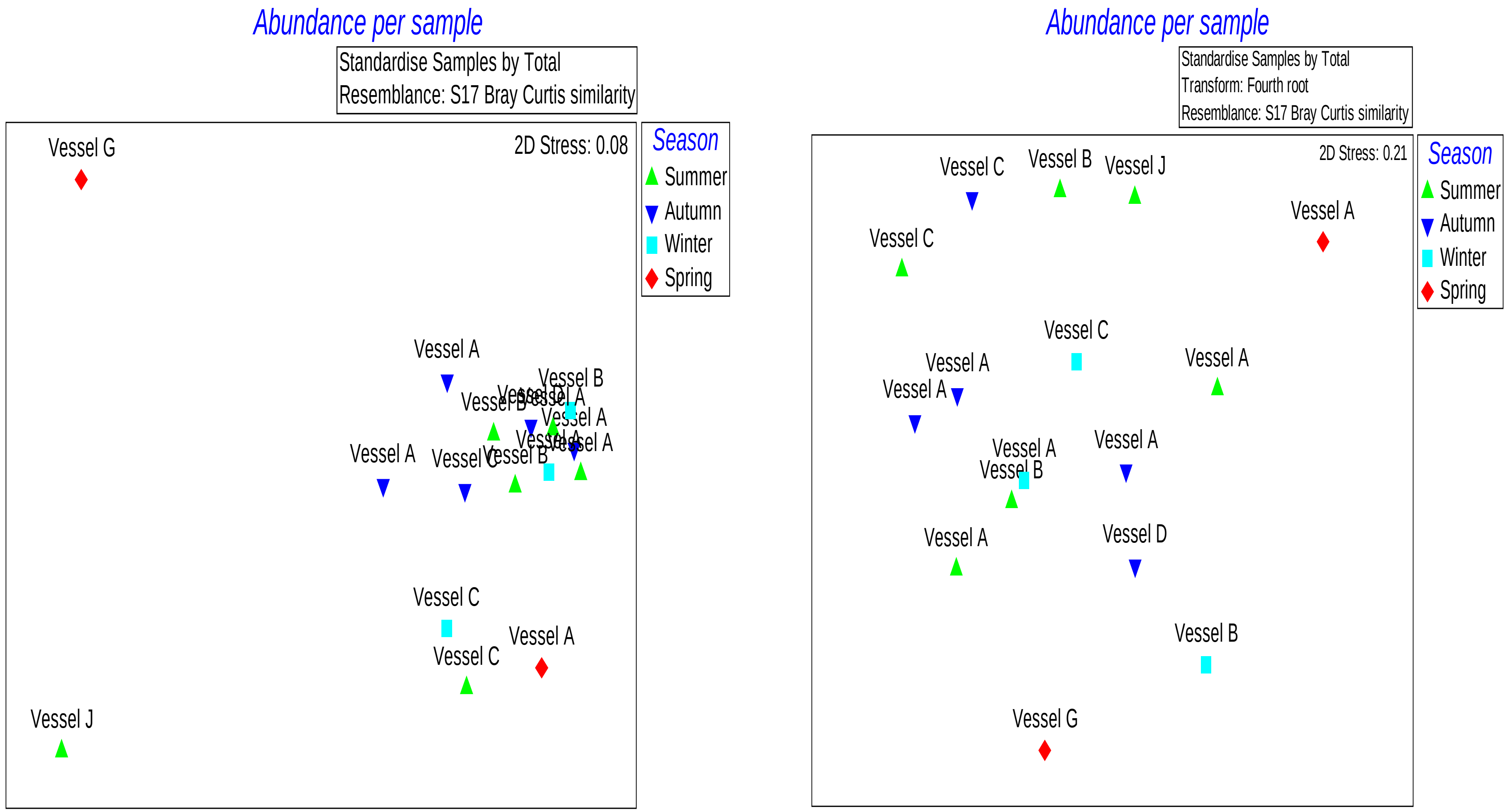



**Figure 4.** 2D MDS plot showing the relationships between the catches for each vessel and month for A) non-transformed data and B) fourth root transformed data. (ANOSIM for untransformed data: season and vessels $p > 0.05$; ANOSIM for transformed data: Season $p = 0.038$, and vessels $p > 0.05$). The season is indicated for each catch.

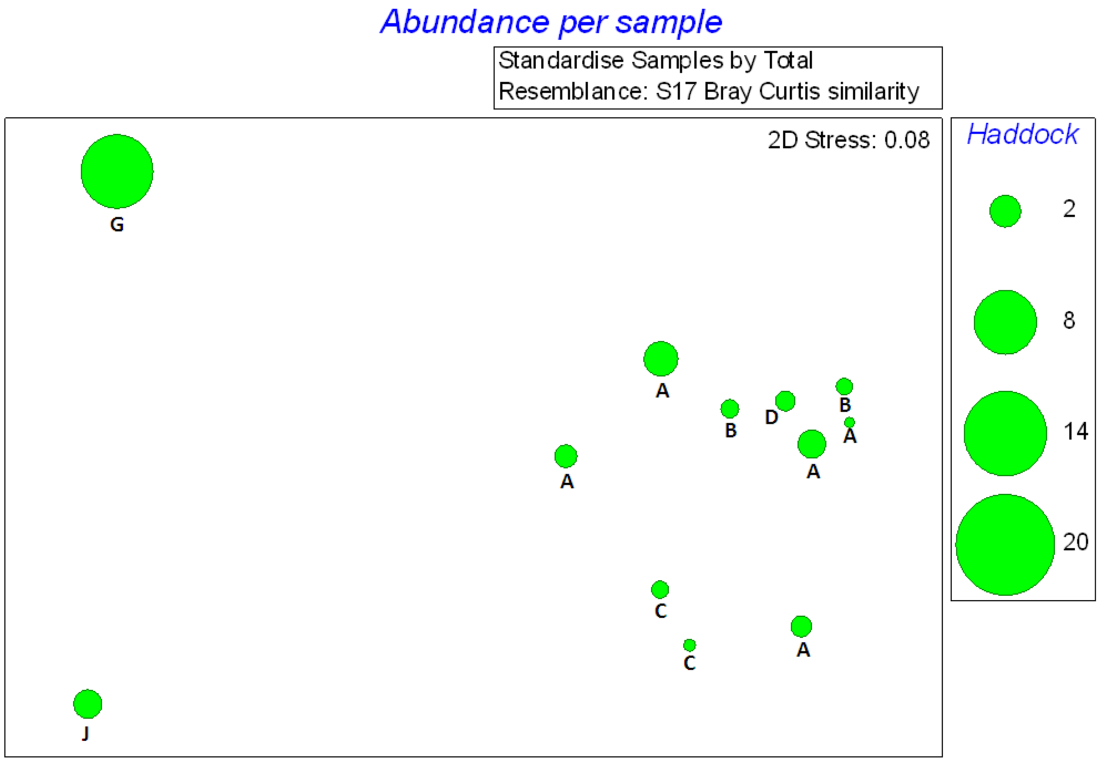



**Figure 5.** Bubble plot of number of haddock over a 2D MDS ordination of untransformed abundance data (from Figure 4 A). In this instance vessels are represented by a letter.

### Relationships between catches: Biomass

The biomass data were standardised (to account for differences in catch volume) and analysed before and after fourth-root transformation. ANOSIM analysis showed season and vessel were significant for explaining similarities between the catches but only for the transformed data, (Season: R = 0.645 p = 0.013; Vessel R = 0.434 p = 0.03). Testing for similarities between catches using gear type as a factor was not possible due the lack of repeat samples for twin-rig gear. A 2D MDS ordination of these data is shown in Figure 6.

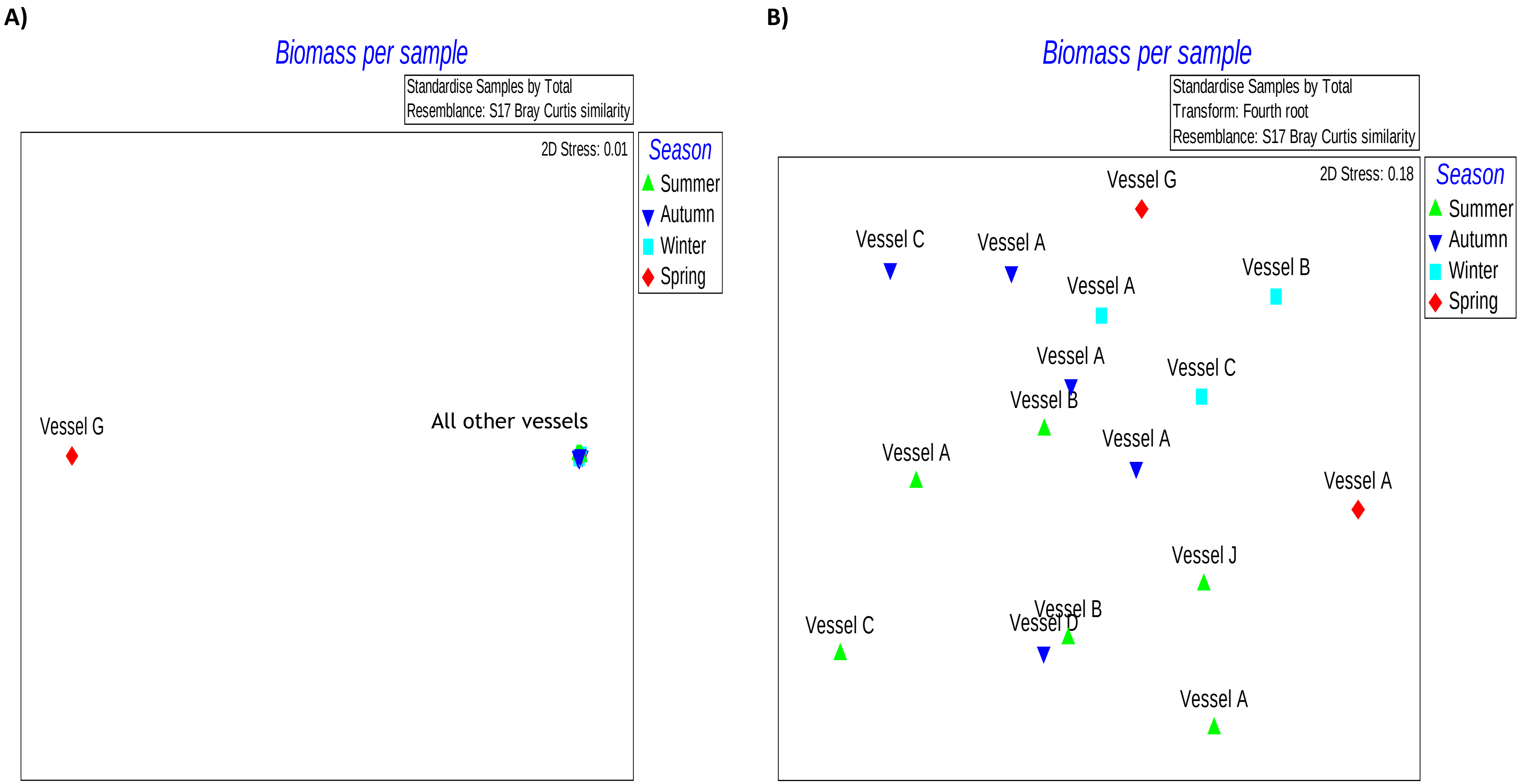



**Figure 6.** 2D MDS plot showing the relationships between the catches for each vessel for A) non-transformed data and B) fourth root transformed data. (ANOSIM for untransformed data: season and vessels $p > 0.05$, ANOSIM for transformed data: season $p = 0.01$, vessel $p = 0.03$). The season is indicated for each catch.

### Discussion

The results obtained from the analysis of the random sub-samples show a temporal variation in both abundance and biomass catch composition data. Vessel effects were only significant on the transformed biomass data, which examines the catch composition at the finer scale, though the stress levels on this test were relatively high. Generally, the results indicate the absence of any trends between samples provided by different vessels. The one possible exception to this is the outlying result produced by one twin-rig vessel (Vessel G). The sample obtained was reliable and subsequent bubble plot analysis highlighted a larger proportion of haddock in the catch composition compared to other samples (Figure 5). Whilst it is only one sample and there may be other factors contributing to this result, it may indicate an underlying trend that has previously been noted in the scientific literature. The report for 2005 of the ICES Working Group on the Assessment of Northern Shelf Demersal Stocks noted that in the Irish Sea the use of twin-rigs increased the proportion of roundfish bycatch in *Nephrops* fisheries, compared with single rig otter trawl (ICES WGNSDS Report, 2006). Therefore, it may be useful to investigate this further by increasing the sampling frequency of twin-rig vessels during Year 4. No significance could be measured for gear effects on catch composition (due to lack of replicate samples).

The data obtained from the MFV Comrade during Years 1 and 2 are generally representative of the whole fleet as the target species to bycatch ratios in this study are similar to those reported by Milligan and Neil (2010). All these observations suggest that the vessels of the Stornoway fleet are fishing in broadly the same manner, with no one boat catching a larger amount of any one species compared to any other boat.

## Part B: Key Species Cod and Spurdog

### Methodology

Cod and spurdog were obtained both from sub-samples provided by fishermen, and from observer trips. Samples provided by fishermen were to be collected on a regular basis throughout the year with skippers asked to provide additional details on Atlantic cod and spurdog abundance in the catch from one haul once a month (see Section 2). Cod and spurdog recordings were to be logged into paper logbooks along with additional information concerning that particular catch such as date, time of haul, depth, GPS coordinates and type of fishing gear used. All hauls carried out on observer trips were also inspected for total cod and spurdog abundance, and these individuals were recovered, landed and boxed.

The analyses were performed on samples of fish delivered to the University of Glasgow, as described in Section A: Methodology. Before analysis the samples were allowed to defrost at room temperature for at least 24 hours. The sex and total length (rounded down to the nearest 5 mm) and total weight of each individual fish were recorded, as well as the weight of the viscera and of the gonads.

## Results

### Cod

Although paper logbooks were provided to the fishermen for the additional self sampling data on cod, no data were in fact received from them. However all cod were recorded on the scientific observer trips, enabling data on the catch rates by number and weight to be extended from the first two years (Figure 7). A total of 55 cod were collected and analysed from 23 trawls between December 2010 and October 2011. Catches of cod were low throughout the study period and were rarely recorded in any of the random sub-samples. The average length of these cod was 41.4 cm (MLS = 35 cm) with undersized individuals comprising 24% of the total. The length-frequency distribution of captured cod is shown in Figure 8.

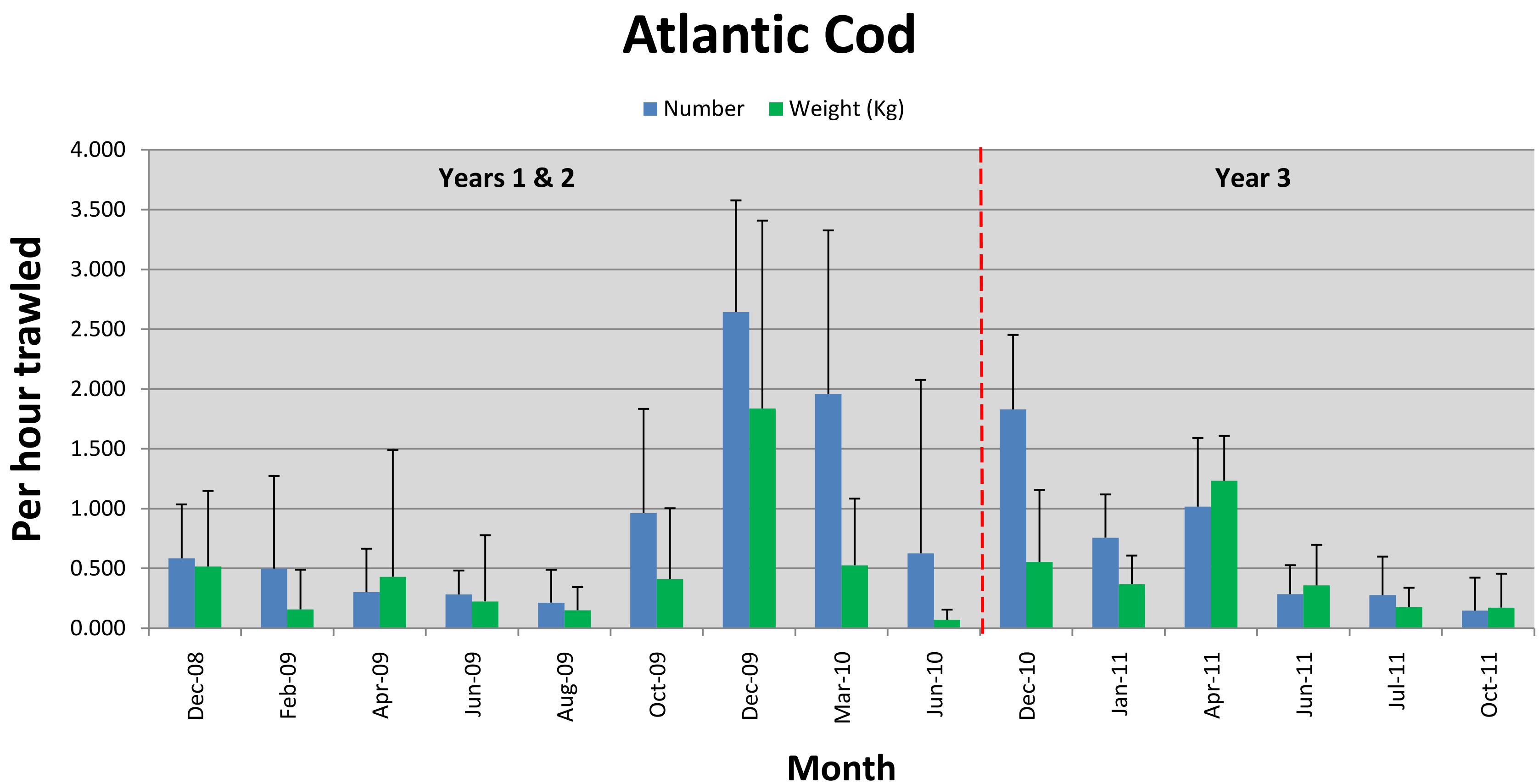



**Figure 7:** Mean number and weight of Atlantic cod captured during the first three years of the study. The red dotted line indicates the cross-over from sampling one vessel (MFV Comrade) during Years 1 and 2 to sampling other vessels in the fleet during Year 3. Error bars represent one standard deviation.

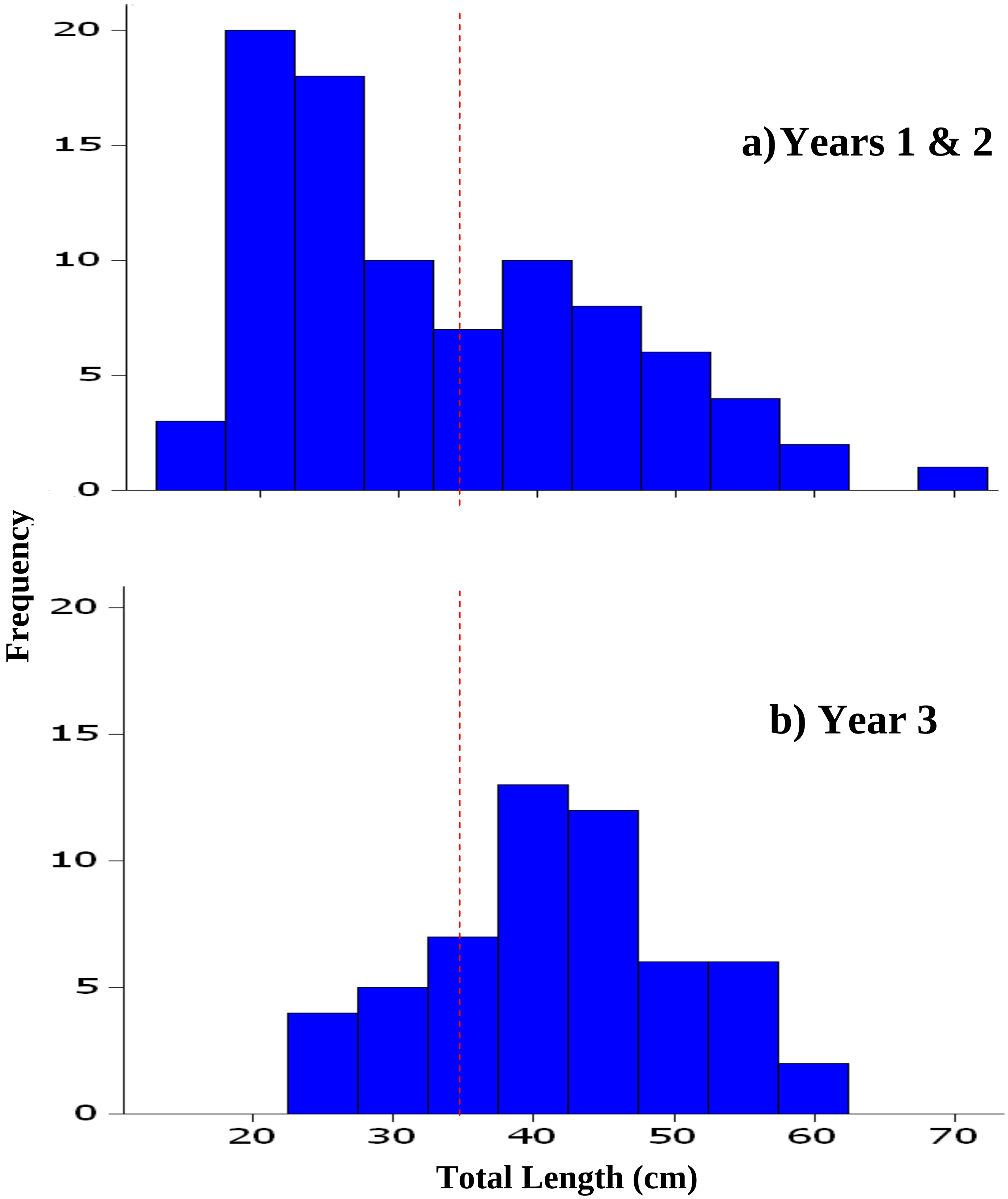



**Figure 8.** Length-frequency distribution of all Atlantic cod captured during the study period, a) Years 1 and 2: Dec-08 to Jun-10 b) Year 3: Jul-10 to Oct-11. The red dotted line indicates minimum landing size (35 cm).

**Spurdog**

A total of 157 spurdog were recovered from all the trawls made between December 2008 and October 2011. The lengths and weights of the seven animals captured in December 2008 and October 2011 were recorded on board the fishing vessel, but all other specimens were brought back to the University of Glasgow for more detailed examination. The numbers of spurdog captured during each survey trip are given in Table 6, and the length distributions for each month are shown in Figure 9.

**Table 6.** Numbers and mean lengths of spurdog captured between December 2008 and October 2011

| Month | Sex | Number captured | Mean length (cm) (± 1 SD) |
|---|---|---|---|
| Dec 2008 | M | 6 | 63.0 (± 18.5) |
| | F | 0 | |
| Feb 2009 | M | 0 | |
| | F | 0 | |
| Apr 2009 | M | 0 | |
| | F | 0 | |
| Jun 2009 | M | 27 | 26.2 (± 2.4) |
| | F | 29 | 25.2 (± 3.1) |
| Aug 2009 | M | 5 | 30.5 (± 4.0) |
| | F | 4 | 29.8 (± 5.1) |
| Oct 2009 | M | 5 | 72.3 (± 3.1) |
| | F | 0 | |
| Dec 2009 | M | 23 | 75.8 (± 3.5) |
| | F | 1 | 95.0 |
| Jun 2010 | M | 0 | |
| | F | 0 | |
| Dec 2010 | M | 1 | 74 |
| | F | 1 | 78 |
| Jan 2011 | M | 0 | |
| | F | 0 | |
| Apr 2011 | M | 24 | 31.8 (± 4.39) |
| | F | 23 | 30.4 (± 4.07) |
| Jun 2011 | M | 0 | |
| | F | 1 | 70 |
| Jul 2011 | M | 0 | |
| | F | 0 | |
| Oct 2011 | M | 5 | 37.3 (± 9.27) |
| | F | 2 | 31 (± 0.71) |

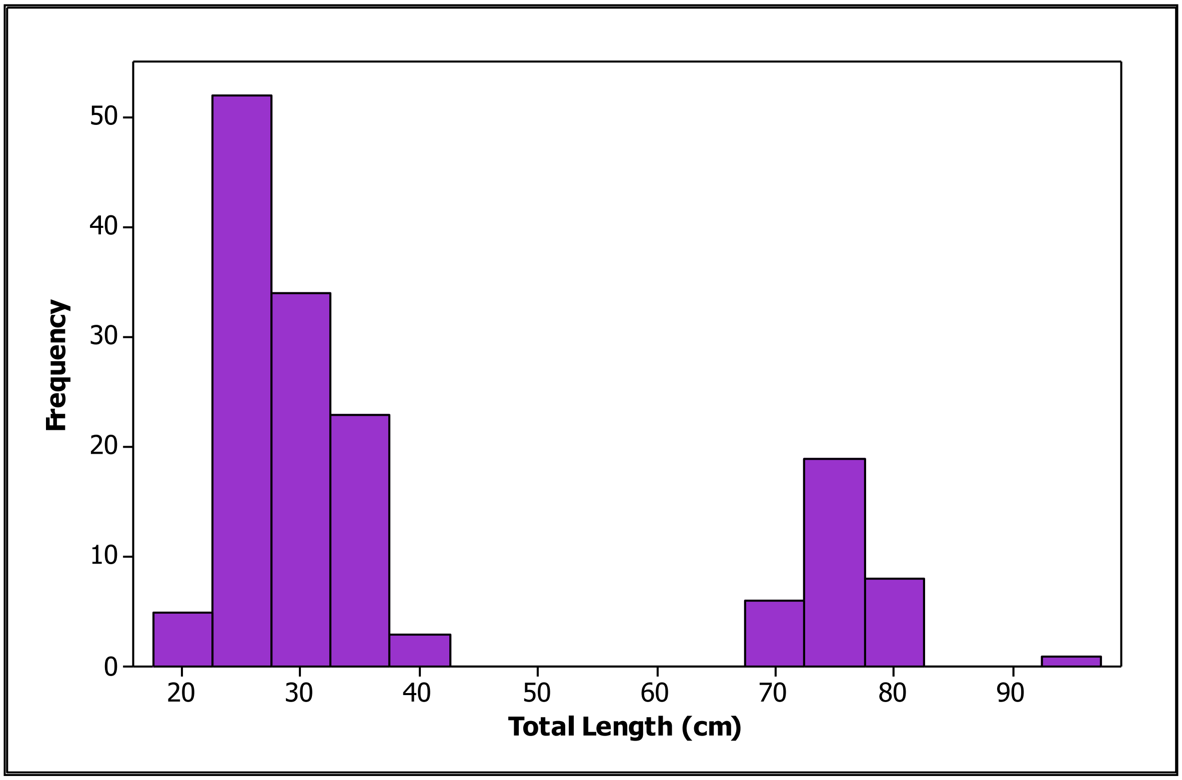



**Figure 9.** Length-frequency distribution of spurdog captured between December 2008 and October 2011.

**Discussion**

Cod and spurdog numbers have been consistently low throughout the study period, which makes spatial and temporal trends difficult to identify. Furthermore, the lack of information volunteered by the fishermen detailing numbers of cod and spurdog captured at periodic intervals has meant that no additional information on this population has been obtained as planned. Despite this, catch rates obtained from observer trips over the past 12 months show a low incidence of cod per haul. Rebuilding and conserving cod stocks in Scottish coastal waters remains a priority for fisheries management in Scotland. However, a recent report by Marine Scotland Science suggests that there is insufficient bycatch by the *Nephrops* trawler fleet to have a large impact on mature West of Scotland cod, and that only a small increase in observed biomass trajectories will occur if the fleet moves to a clean catch of *Nephrops* (Bailey et al., 2011). The results for spurdog follow similar trends to those obtained in the previous years, when the majority of spurdog caught were immature schooling juveniles. The most valuable individuals in terms of recruitment and stock recovery are mature females (Pawson et al., 2009), but since 2008 only 3 mature females have been recovered from all trips.

## Part C: Additional studies

Two additional studies, on spurdog survivability and on the seapen *Funiculina*, were carried out at the request of the certification body Moody Marine.

## C1: Spurdog Survivability Pilot Study

The objective of this small pilot study was to investigate the short-term post-capture mortality of spurdog which are caught as bycatch during trawling for the target species *Nephrops norvegicus*.

### Methodology

All spurdog were caught during commercial fishing operations in the North Minch area, Scotland. The vessels were either single or twin rig *Nephrops* trawlers using a clean or small disc *Nephrops* net with a with a diamond mesh cod end of 80 mm and a 120 mm square mesh panel positioned 12 m from the codend. Trawl duration commenced during daylight hours and was measured from the time the winches began lowering out the trawl gear to the time they restarted. The gear was hauled back from the sea floor and lowered into the processing hopper where it remained until the crew were ready to begin sorting the catch. Spurdog were removed from the catch and visually inspected for signs of life, with close attention being paid to the presence of respiratory functioning of the gills and mouth. Those that showed any sign of life were carefully placed in a container of fresh seawater, where they were allowed to recover. Animals were inspected for recovery every 15 minutes until up to a maximum time of three hours when they were then classified as being dead or alive. The seawater was replenished every 30 minutes. Dead spurdog were frozen and transported to Glasgow University where they were allowed to defrost at room temperature and biometric measurements were recorded (length, weight and condition). Any individual spurdog that survived were returned to the sea after analysis.

### Results

A total of 55 spurdog were obtained from four separate hauls out of a total of 13 trawls performed between April and October 2011. The depth of the trawling ranged from 49 m to 142 m, and the average trawl duration was 4.91 hours. Haulback of the gear ranged from 15 to 20 minutes and processing of the catch took up to 3 hours 45 minutes. The spurdog were a mixture of male and females but were primarily juveniles (96%). Of the 55 spurdog obtained, only two individuals showed signs of recovery after 3 hours, resulting in a 96.4% mean mortality rate. Due to fishing operations the maximum time for analysis was restricted to three hours. Summary data for each trawl in which spurdog were caught and subsequently assessed for their survival are provided in Table 7.

**Table 7.** Summary details describing number of Spurdog caught in *Nephrops* trawls and the subsequent mortality rate after 3 hours of observation. SR = Single rig, TR = twin rig.

| Vessel | Date | Gear | Trawl time (hrs) | Haulback (hrs) | Process (hrs) | Sex | Number Captured | Mean Length (cm) (±1 SD) | Number of fish alive after recovery from catch (%) | Number of fish alive after observation period | Number of mortalities after 3 hrs | Mortality rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vessel G | April 2011 | TR-Clean | 4.75 | 0.33 | 1.50 | M<br>F | 24<br>23 | 31.8(±4.39)<br>30.4(±4.07) | 4 | 1 | 46 | 97.9 |
| Vessel A | June 2011 | SR-Disc | 5.75 | 0.25 | 3.45 | F | 1 | 70 | 0 | 0 | 1 | 100 |
| Vessel C | Oct 2011 | SR-Disc | 4.41 | 0.25 | 2.50 | M<br>F | 4<br>2 | 28.1(±4.13)<br>31 (±0.71) | 0 | 0 | 6 | 100 |
| Vessel A | Oct 2011 | SR-Clean | 4.75 | 0.33 | 2.50 | M | 1 | 73.8 | 1 | 1 | 0 | 0 |
| Total | | | Mean = 4.92 | Mean = 0.29 | Mean = 2.49 | | 55 | | 5 | 2 | 53 | Mean = 96.4 |

**Discussion**

This survivability pilot study highlights the vulnerability of spurdog to demersal trawling. Spurdog are especially vulnerable to intense over-fishing compared to most teleosts due to their k-selected life history strategy (i.e. slow growth and maturation) and the fact that they have a long gestation period (up to 22 months), produce very few young, typically have long life spans, and generally occupy a high position in trophic food webs (Stevens et al., 2000).

Previous short-term survivability studies (Rulifson, 2007, Mandelman and Farrington, 2007) have demonstrated the resilience of spurdog when subjected to stress and physical damage encountered during the trawling process. In these studies mortality rates ranged from 0 – 50% with Rulifson (2007) suggesting that many spurdog are able to tolerate and survive the stress and injury associated with the trawling process. Results from the present preliminary study suggest that spurdog caught as bycatch in the Stornoway *Nephrops* fishery have very high mortality rates. Milligan and Neil (2010) previously noted the moribund state of spurdog captured during 2008/2009 in the same fishery, with none appearing to cope well with the trawling process. The present study supports these previous observations but it should be stressed that these new observations are only preliminary and not conclusive. Therefore any inference should be made cautiously. Furthermore, comparisons with this present study and the studies of Rulifson (2007) and also Mandelman and Farrington (2007) should also be made with caution, due to differences in experimental design. Nevertheless, this present study indicates the trend of high spurdog mortality in the Stornoway *Nephrops* fishery. Tow duration, codend weight and species composition are likely reasons for the high rates of mortality. Tow duration in the Stornoway *Nephrops* fleet averages around four hours and in this particular study it was close to five hours. The survivability studies of Rulifson's (2007) and Mandelman and Farrington (2007) were based on tow times of no more than 90 minutes (compared to 345 minutes in this present study). Thus, tow time is perhaps the biggest factor which may influence the short term survivability of spurdog in this fishery. Longer tows will have a greater weight of both target and bycatch animals in the codend leading to increased stress encounters and potential injury. Furthermore, in some cases the potential time for any individual animal to be subjected to stress within the catch can amount to as much as 9.45 hours if the trawl time, haulback of gear, and catch processing times are all considered.

## C2: The sea pen *Funiculina quadrangularis*

Although a previous study by Milligan and Neil (2010) quantified the presence of the sea pen *Funiculina* within the codend of the net (Figure 10), there is the possibility that these results may have under-represented the abundance of *Funiculina* in the final analysis of bycatch. Often, *Funiculina* may become lodged and trapped in sections of the fishing gear other than the codend (Figure 11), so that the impact of the trawling is not being fully recorded. The aim of this small observational study was to note the presence/absence of *Funiculina* occurring on the trawl gear out-with the codend of the net.

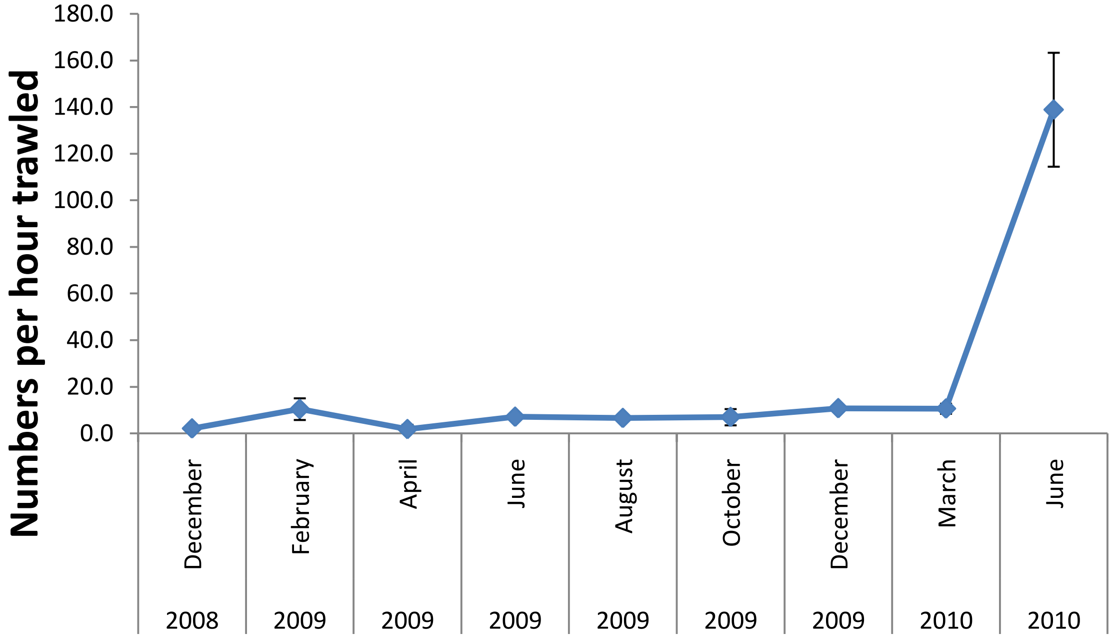



**Figure 10.** Occurrence of *Funiculina quadrangularis* caught in *Nephrops* fishing gear on commercial fishing grounds in the North Minch. Mean number per hour trawled was 21.7 (± 14.7 S.E.). From Milligan and Neil (2010).

**Figure 11.** *Funiculina* entangled around floats attached to the bridles (left) and individuals protruding from the codend extension (right).

**Methodology**

Observations were carried out in daylight hours between April 2011 and October 2011 in the North Minch area on the west coast of Scotland. The vessels were either single or twin rig *Nephrops* trawlers using a clean or small disc *Nephrops* net with a diamond mesh codend of 80 mm and a 120 mm square mesh panel positioned 12 m from the codend. Trawl duration varied between 4.75 and 5.45 hours and was measured from the time the winches began lowering out the trawl gear to the time they restarted to recover it. The trawl gear was inspected prior to each trawl, to ensure that no *Funiculina* were present before lowering the net into the sea. Observations were related to a four-point scale: Absent (0), Present (=1), Present (2-4), Present (≥5). Observations were compromised to some extent by the dangers associated with the crew handling the gear and the rough sea conditions.

**Results**

Figure 12 shows the occurrence of *Funiculina* in different sections of the fishing gear recorded during haulback of the net. Nets from five different trips were observed and results were expressed as a percentage of observations, using the four-point scale of occurrence. The highest occurrence was found in the top and bottom panels with approximately 70% of observations for that particular section showing five or more *Funiculina* present (point 5) on each haul. Lower numbers of *Funiculina* were recorded in the warps, doors and sweep sections of the gear. On one occasion *Funiculina* were recovered and counted from the codend of one of the nets (n = 410) in addition to observing their presence on other sections of the gear (n ~ 30). This resulted in a combined value of ~ 92 *Funiculina* per hour of trawling time and whilst this value was above the mean reported by Milligan and Neil 2010 (Figure 10), it is certainly not the highest recorded over the study period. These values also allow for a very broad estimation of an additional 5-10% to be added to the codend abundance to give the total trawling impact, as an approximation.

Additional observations of *Funiculina* recovered from the gear showed that many individuals appeared intact from the top of the axis (where many of the polyps are concentrated) to the terminal peduncle (which is used to attach to the substrate). It is unclear if there was any internal damage to the axial rod or the polyps. However, there were also individuals that had been damaged by the fishing process, with axial rods that were split or completely broken.

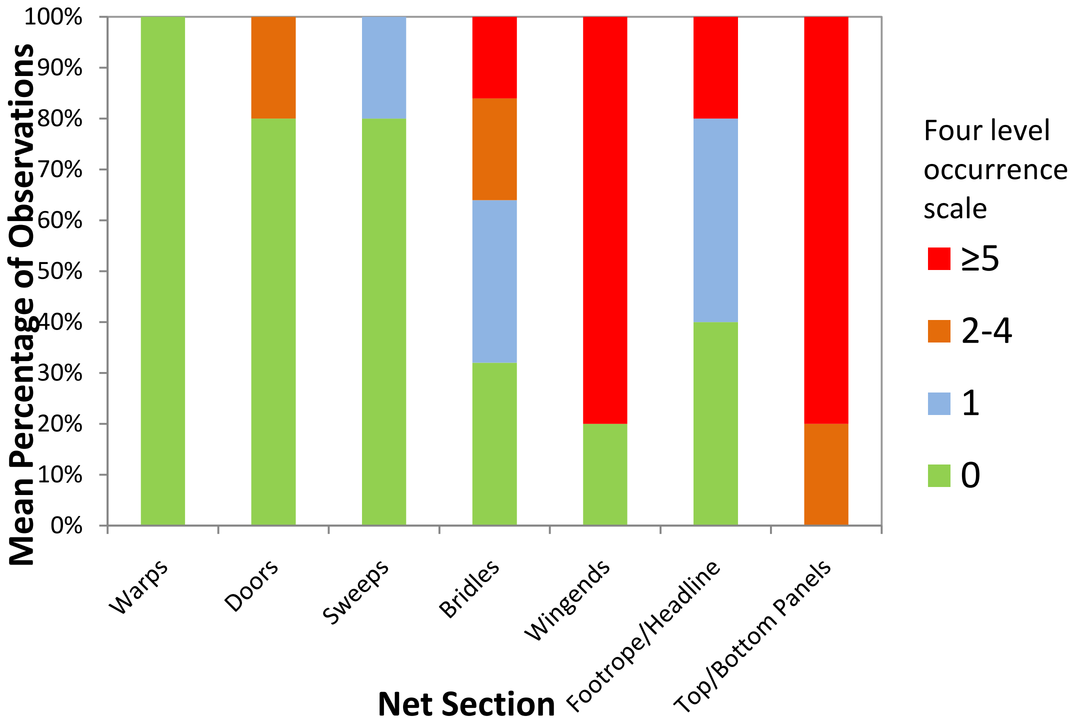



**Figure 12.** Mean percentage of *Funiculina* observations recorded in specific sections of the net using four-point scale.

**Discussion**

This study has demonstrated that *Funiculina* are susceptible to capture on various sections of the fishing gear other than the codend, and have a particular vulnerability to being entrapped in the wings and the top and bottom panels of the extension. Therefore the occurrence of *Funiculina* in the Stornoway *Nephrops* fishing gear appears to be under-represented, if only the bycatch from the codend is analysed. However this is a relatively minor under-estimate (5-10%) although it does not take into account those individuals dislodged but not retained by the fishing gear whilst the nets continue to fish on the seabed. Greathead (2007) notes that *Funiculina* distribution will be greatly influenced by the level of physical disturbance by demersal trawling, as it is unable to withdraw into the sediment. However, it has been shown that *Funiculina* can withstand some level of disturbance where they are able to bend away if objects physically smother or are dragged across them, and even re-anchor themselves back into the substrate after displacement (Kinnear et al., 1996), There is the possibility that some *Funiculina* individuals caught in the gear of the Stornoway fleet and returned to the sea may be able to survive the trawling process, but further work has to be completed before this is definitive. Despite its limitations, this short study nevertheless provides a better indication of the total trawling impact on this species.

# Section 2: Self-Assessment of bycatch & discards

The support of the Stornoway fishing fleet is vital if the objectives of the certification conditions set out by the MSC are to be fulfilled. Conditions 3 and 4 of certification relate to bycatch of two sensitive species caught within the catch of the Stornoway *Nephrops* fishery. However, due to their heterogeneous spatial distribution and high temporal variability (Bellido et al., 2011), accurate estimates of bycatch and discards occurring within the fishery can only be obtained from sampling programmes (Rochet et al., 2002). Generally, data can be collected by scientific observers only a few times per year, and then on only a few vessels, due to high costs and insufficient manpower. Thus, spatial and temporal trends cannot be properly identified, and considerable time and money would have to be invested in order to monitor the long term catch composition across the fleet. As a result, a self-assessment sampling programme was designed and implemented in the Stornoway *Nephrops* fleet to enable scientists to analyse information on the distribution and abundance of bycatch species from commercial fishing trawls. Self-assessment schemes are popular (Catchpole and Gray, 2010) due to the lower cost of collecting a greater number of samples, compared to observer-only schemes (Uhlmann et al., 2011). Furthermore, they can provide information on the fishery over the long-term, with crews free to work as normal with no extra people on board. Depending on the methods used, such a system need not significantly disrupt normal working practice.

## 2.1 Self-Assessment methodology

The proposed self-assessment scheme was originally based on the methods developed and used during the scientific surveys in Years 1 and 2, and required crews to sort one or two trawls per calendar month into five groups: *Nephrops,* Invertebrates, Roundfish, Flatfish and Sharks, Rays & Skate. However, it was generally felt that sorting an entire catch required too much time, and the methodology was therefore adjusted and a simpler protocol was introduced. In this revised scheme skippers were asked to provide a random sub-sample of the whole catch and record cod and spurdog abundance in the catch at regular intervals. This sub-sample was then frozen and transported to the University of Glasgow for more detailed analysis of the species composition, weights and numbers. The YoungsTrace system was intended to allow additional information on cod and spurdog bycatch to be recorded, as well as catches of *Nephrops* and the vessels activity (e.g. trawling, hauling the gear, travelling). However, technical problems with the YoungsTrace system throughout the sampling programme resulted in no data being received from this source. Therefore, paper logbooks were regularly distributed to all vessels for the purpose of recording cod and spurdog abundance, along with information concerning that particular catch such as date, time of haul, depth, GPS coordinates and type of fishing gear used. The number of sub-samples received from each vessel is shown in Table 8.

**Table 8.** Random sub-samples received from each vessel between July 2010 and October 2011

| | Vessel A | Vessel B | Vessel C | Vessel D | Vessel E | Vessel F | Vessel G | Vessel H | Vessel I |
|---|---|---|---|---|---|---|---|---|---|
| **Jul-10** | - | - | - | - | - | - | - | - | - |
| **Aug-10** | **Yes** | **Yes** | - | - | - | - | - | - | - |
| **Sep-10** | **Yes** | **Yes** | **Yes** | **Yes** | - | - | - | - | - |
| **Oct-10** | **Yes** | **Yes** | - | - | **Yes** | - | - | - | - |
| **Nov-10** | - | **Yes** | - | - | - | - | - | - | - |
| **Dec-10** | - | - | - | - | **Yes** | - | - | - | - |
| **Jan-11** | - | - | - | - | - | **Yes** | - | - | - |
| **Feb-11** | - | - | - | - | - | - | - | - | - |
| **Mar-11** | **Yes** | - | **Yes** | **Yes** | - | **Yes** | - | - | - |
| **Apr-11** | - | - | - | - | - | - | - | - | - |
| **May-11** | - | **Yes** | - | **Yes** | - | - | - | - | - |
| **Jun-11** | - | - | - | - | - | - | - | - | - |
| **Jul-11** | **Yes** | - | **Yes** | - | - | - | - | - | - |
| **Oct-11** | - | - | - | - | - | - | - | - | - |

### 2.2 Validating the Self-Assessment Methodology

Self-sampling programmes may be prone to systematic sampling errors that may bias the data received from the fishermen. The quality of the data is important if any inferences are to be made which may lead to management measures being introduced aimed at reducing bycatch rates within the fishery. However, bias may occur if the fishermen are to record data which they believe may be detrimental to fishery in the short term, for example, recording high catch rates of sensitive species. Sub-samples that are not truly random would also be a source of bias if, firstly, the fishermen are not prepared to allow larger, more valuable animals in their catch to be included in the sub-sample, and secondly, that they select animals which they perceive to be a true reflection of a typical catch.

To assess whether the data obtained from the skippers using the self-assessment system were reliable, samples were cross-checked against scientific observer samples which were obtained around the same date and within the same fishing area. This *post hoc* method compared the size distribution of the carapace lengths of the target species, *Nephrops* in each sample. A mean carapace length distribution obtained from a fisherman sample that was significantly smaller than the observer sample suggested a sampling bias. Furthermore, a high prevalence of the smallest size class (discards) of

*Nephrops* or missing values in the largest most valuable size class measured in the sample also suggested sampling bias, and the sample was therefore rejected. In addition, a sample was rejected if the total biomass was below 5 kg. Post hoc analysis revealed samples below this weight threshold are more likely to be influenced by the presence of a few large individuals and therefore can be less representative of the whole catch.

### 2.3 Results

A total of 20 random sub-samples were received from all vessels in the Stornoway fleet between July 2010 and October 2011. The screening process resulted in 8 of these being acceptable (**A** sub-samples: Mean 7.11 kg, Range kg 6.7– 11.78 kg) and 12 of these being rejected (**B** sub-samples: Mean 3.33 kg, Range 1.37 kg – 6.06 kg) either due to the fact that the total weight of the sub-sample was below the notional minimum deemed necessary to be truly representative of a typical catch or as a result of cross-checking with a set of 8 scientific sub-samples (**S**). An example of this cross-checking process is shown in Figure 13, which presents a graphical summary of the size class distribution of *Nephrops* in two fishermen's sub-samples (**A** and **B**) and the scientific sub-sample (**S**) obtained around the same time from the same fishing location using the same gear configuration. These size classes are those typically used by fishermen who grade *Nephrops* whilst processing at sea in preparation for landing them to the harbour-side market. The fishermen's sub-sample **B** includes a large percentage of discards compared to the other two sub-samples, whilst there are also no large prawns present in sub-sample **B**. Combined with a statistical test, a judgement can be reached whether to accept or reject the sub-sample. In this instance a Kruskal Wallis test was used. Analysis showed a significant difference between the median carapace lengths of *Nephrops* of the Fishermen's sub-sample **B** and the other two sub-samples $H(2) = 33.56$, $p = 0.000$. This suggests that the methodology used in taking the sub-sample may have been incorrect (e.g. by it happening after the processing has started, or because the large, more valuable prawns had been extracted from the sub-sample).

The mean proportions of each major group (by wet weight) in the sub-samples received from fishermen or taken by the observer are shown in Figure 14. Overall, analysis of catch composition shows that the two methods of collection produce results that are reasonably similar in terms of catch composition. However, Figure 15 highlights how the composition of a small sub-sample (**B**) may deviate from a normal catch composition. In this instance a sample weighing 2.47 kg was received and the inclusion of a few larger heavy fish species (red gurnard) appeared to bias the results towards a composition high in roundfish. Red Gurnard are normally relatively rare in the catch (typically only representing 1.4% of roundfish in the whole catch, Milligan and Neil (2010)) in comparison to other fish species. This particular sub-sample suggested red gurnard represented 50% of the roundfish biomass in the catch but the likelihood of them occurring in such a high biomass in the whole catch seems unlikely.

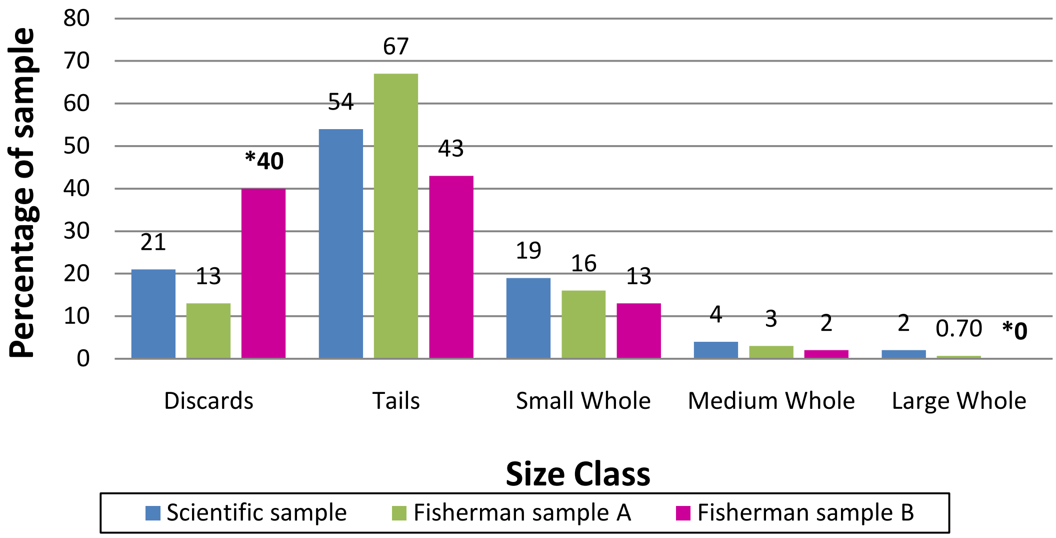
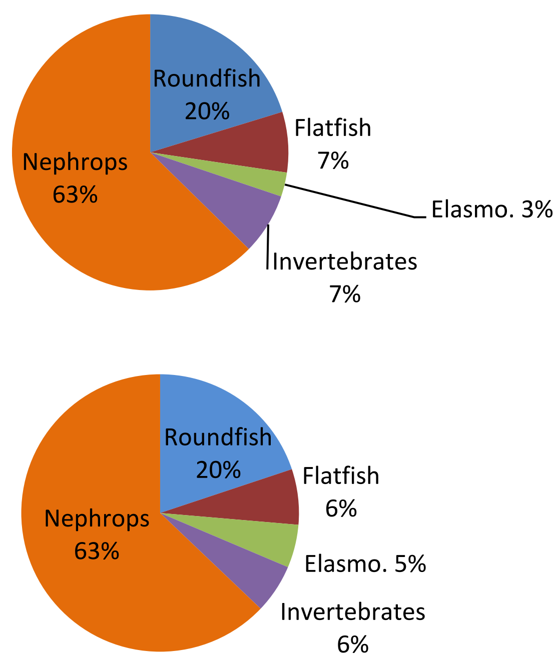



**Figure 13.** *Nephrops* obtained from individual random sub-samples either from a scientific (**S**) observer or fishermen (**A** and **B**). Note the large proportion of discards and the lack of large whole prawns in fishermen's **B** sample.

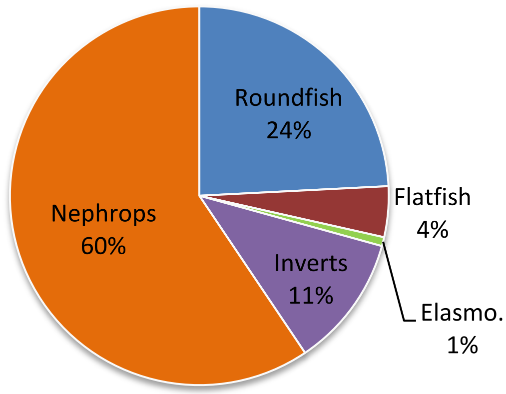
a) Fishermen only Sub-samples (**A**)




b) Observer only Sub-samples (**S**)

**Figure 14.** Mean catch composition of random sub-samples by wet weight grouped by: a) acceptable (**A**) sub-samples supplied by fishermen (n=8) or b) those obtained by the scientific observer (n=8) (**S**).

Acceptable sub-sample (**A**)
Total weight of sample = 11.8 kg




Rejected sub-sample (**B**). Total weight of sample = 2.47 kg

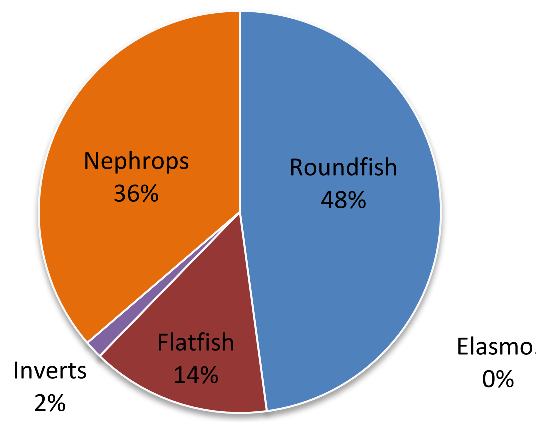



**Figure 15. C**atch composition by wet weight of selected individual random sub-samples supplied by fishermen, representative of the acceptable (**A**) and rejected (**B**) categories

### 2.4 Feedback from Fishermen

Informal discussions were held with the fishermen to establish their views on the self-assessment methods for measuring their own bycatch. The general consensus was that most skippers interviewed did not have a problem participating in the amended scheme of supplying random sub-samples. Though in periods of poor fishing when there are fewer prawns on the grounds then they are less likely to give away a proportion of their catch as a sample. Financial constraints placed on the vessels over the past twelve months have resulted in fewer crew members being onboard for processing the catch, and therefore making it even less feasible that sorting the bycatch into groups is possible. Skippers are reluctant to record numbers of individual species (cod and spurdog) as they fear that more management measures will be placed upon the fishery, for example closed areas, should they voluntarily disclose such information. In general, skippers are unaware of the importance of long-term monitoring of their bycatch, with many feeling it is no benefit to the fishery.

### 2.5 Discussion

The random sub-samples analysed in this study have been shown to correspond well to the catch composition of the whole catch reported on the same fishery in previous years. For example, the catch composition ratio for target species and bycatch analysed during Years 1 and 2 produced a mean ratio of 61% target species (*Nephrops*) to 39% non-target species (bycatch). The ratio of target species to non-target species obtained from the validated sub-samples (i.e. categories **A** + **S**) during Year 3 produced a similar result, with a ratio of 63% : 37%. Furthermore, analysing *all* the fishermen samples without validating them for reliability (i.e. categories A + B), produces a *Nephrops* to bycatch ratio of 61% : 37%. However, there appears to be some variability within some of bycatch groups with the rejected samples (category **B**) and so these sub-samples are only useful for the broad analysis i.e. target species : bycatch ratio. For a more descriptive analysis providing greater detail of the bycatch composition, then larger subsamples are required. Whilst we expected some of the rarer species to be absent from the sub-samples, and data on these could be collected through periodic monitoring by fishermen and/or an onboard observer, the continual supply of very small samples (<5 kg) has resulted in analysis at a much lower level than we would have hoped for. Nevertheless, the results demonstrate how a validation process whereby cumulative evidence is gathered (such as a sample size threshold, the presence /absence of small, large or tailed *Nephrops*) when assessing samples, can preserve data quality.

The self sampling protocol introduced into this particular fleet is one that has had success in other fishing areas, due to its simple concept and ease of application onboard commercial vessels (Lordan et al., 2011). The quality of samples received from fishermen has been variable and although the final analysis of the bycatch composition is encouraging, there is a caveat that if the sub-samples are very small (< 5 kg), the data are of limited value. Small samples are less likely to be representative of the whole catch and the presence of a few large animals can skew the results and consequentially the results can be misleading.

Some vessels failed to participate in the programme and skippers may still have to be convinced of the benefits of such self-sampling programmes. The receipt of small or no samples may be a result of economic conditions currently faced within the industry, for example increasing fuel and vessel running costs. An extra monetary incentive for the vessels that provide samples of an adequate size and quality may be required if participation is to be maintained, This is an important point noted by other studies (Hilborn et al., 2005, Grafton et al., 2006) especially those faced with similar data collection obstacles, including 'participation fatigue'(Hoare et al., 2011). Nonetheless, these are encouraging results which indicate that the self-assessment scheme has the potential to be successful if the fleet wishes to continue with the long- term monitoring of the fishery.

## Section 3: Recommendations

In order to minimise the impact of the fishery on the marine ecosystem, and particularly on the sensitive fish species, it is important for the fishery to consider potential improvements to fishing operations that should lead to a more sustainable fishery. The following recommendations consider the data gathered by the scientists and the fishermen over the first three years of certification. If implemented these recommendations should go some way towards maintaining the diversity of the ecosystem and also addressing the conditions applied to the MSC certification.

### 3.1 Fishing gear/fishing behaviour

Finding a mechanism, either through a technical measure or by a change in fishing behaviour, for decreasing the levels of incidental bycatch rates in the fishery that satisfies all interested parties (fishermen, the client and the certification body) is a difficult task. Furthermore, there are numerous problems to be faced when attempting to reduce the impact on the populations of cod and spurdog. The two most significant of these difficulties are:

1. Most cod and spurdog caught and hauled on deck are dead, due to cumulative physiological factors such as stress and damage from other organisms whilst in the codend. The presence of a gas swimbladder in teleost fish can also lead to mortality after capture due to the inflation and probable bursting of the swimbladder as pressure decreases with decreasing depth when the net is hauled up from the seabed to the fishing vessel.
2. The bycatch of cod and spurdog in the Minch area is relatively low and their occurrence within the catch is highly variable, both spatially and temporally. Therefore any attempt to introduce spatial management measures in order to control bycatch of these species is extremely challenging.

Therefore the challenge is to find a technical solution that either prevents an individual fish from entering the fishing gear in the first place, or provides an opportunity for it to escape whilst in the net. Both of these approaches are common conservation measures used by net designers and both consider the behavioural reactions of both *Nephrops* and the associated bycatch when they are confronted with fishing gear. Different species respond in different ways as they encounter the fishing gear. Thus the design of nets which exploit these specific reactions has been shown to maximise target species capture whilst minimising bycatch of non-target species (Main and Sangster, 1982, Catchpole and Revill, 2008).

Selection grids have been introduced in many fisheries and generally work by diverting larger animals up towards an opening whilst smaller animals are allowed through a row of vertical bars and are guided towards the codend (Catchpole and Revill, 2008). Two recent trials have demonstrated the effectiveness of the Swedish grid for reducing bycatch in *Nephrops* fisheries. The first trial was completed in the Irish Sea (ICES Area VIIa) in 2009 and an early trip showed reductions of roundfish (including cod) but also a decrease in marketable prawns (BIM, 2009). However, some small modifications to the grid for a second trip showed reductions in bycatch of haddock (48%), whiting (90%) and mixed flatfishes (78%), with an increase in *Nephrops* tails (10%) and a decrease of only 0.9% in whole prawns. In comparison, no cod were caught in any of the tows. However, there were some difficulties with handling and blockages on the bar spacing. The second trial, which was conducted by the gear technology group at Marine Scotland Science, attempted to address the handling problems and blockages reported in previous trials using the Swedish grid (Drewery et al., 2011). This involved testing a lighter more flexible grid constructed of a polymer composite material able to withstand high stress loads such as those experienced during commercial fishing operations. The flexible nature of the grid was intended also to make it easier to wind onto the net drum. In addition, the grid incorporated three large gaps at the bottom, facilitating the movement of benthic material into the codend and reducing the possibility of any blockages. Results from this trial showed a significant decrease in the number of whitefish retained by the fishing gear rigged with the grid. Cod showed a 27% reduction at 23 cm length, an 84% reduction at the minimum landing size of 35 cm and a 96 % reduction at 46 cm. Whiting and haddock showed similar catch rates with a decrease of 74-82% at the MLS for both species. *Nephrops* catches showed no significant difference up to carapace length of 43 mm, although at 44 mm, 50 mm and 60 mm there were reductions of 8%, 20% and 57% respectively. The lightweight flexible construction of the grid improved their handling and manoeuvrability when the nets were fishing and also during haul-back, compared to trials that used a more rigid alloy grid. The inclusion of several gaps positioned at the bottom of the grid is a useful adaptation preventing the build up of benthic material. The flexible version is a progression from a usability aspect and also remains effective at reducing its priority aim of reducing non target bycatch.

It is this flexible grid which is recommended for use in the Stornoway *Nephrops* fishery. The grid would eliminate the larger cod and larger mature female spurdog from the codend, in addition to other larger fish species normally found in the bycatch. For example the lesser spotted dogfish *Scyliorhinus canicula* is a dominant bycatch species in the Stornoway *Nephrops* fleet and feedback from the skippers indicates that eliminating it from the codend would be beneficial for the fishermen. This is because the lesser spotted dogfish (and spurdog) damage the prawns due to their weight whilst moving around in the catch. Although there may be a loss of the larger prawns from using the grid, there is the potential for this being partially compensated by the catch being cleaner and there being less damage to the prawns.

A trial of fishing gear with a flexible grid in the Minch is therefore recommended. It would be preferable to conduct this during the early part of the year when commercial fishing activity is relatively quiet. A potential problem for interpreting the results of such a trial in terms of the efficacy of the modified fishing gear for excluding spurdog, arises from the low occurrence of this species in catches from the Minch. However, this could be overcome by testing for the exclusion of the lesser-spotted dogfish (*Scyliorhinus canicula*) from the catches. This species of elasmobranch is commonly found in catches in the Minch and although their common length (60 cm) is less than that of spurdog (100 cm) its presence/absence may indicate how spurdog would be affected by the flexible grid.

### 3.2 Best Practice for processing the catch

It is recommended that fishermen avoid areas where large aggregates of spurdog are reported, or when they begin to appear in their catches. This would involve vessels switching location to another fishing ground and contacting other vessels to report their encounter of large numbers of spurdog. Feedback from skippers indicates this is a practice which is commonly used by fishermen in the Minch, but may be limited to vessels that are in regular contact with each other. A formalised procedure whereby all vessels in the fleet are notified as soon as possible of these aggregations should be established and followed. In addition, it is recommended that crew members, if possible, identify and select out any spurdog as early as possible during the processing of the catch, and return them carefully to the sea. Although observations completed in this present report indicate a high mortality rate of spurdog in the Stornoway fleet (96.4%), some do survive and there is evidence that some are resilient to the trawling process (Rulifson, 2007).

### 3.3 Self Assessment scheme

The self assessment monitoring scheme should continue, in order to allow a long term database to be established. Long term datasets are essential for identifying trends over time, and for identifying the effectiveness such of modified fishing gear for reducing bycatch rates. Fishermen should aim to supply a sample of no less than 10 kg once a month for assessment, avoiding small samples which are more prone to bias and can be poorly representative of the catch. In order to improve their regular participation in this scheme and to ensure the supply of good quality samples it is recommended that fishermen are incentivised in an appropriate way by the client holding the MSC accreditation. Finally, it is recommended that the results from the survey work and the self assessment scheme are presented to the skippers and crewmembers of each participating vessel. This would allow the fishermen to see how the data that they are collecting is analysed, and would also give them an opportunity to better understand the patterns and distributions of species in their catches.

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**Appendix.** List of Species recorded during trawl surveys 2008-2011

**ROUNDFISH**

*Agonus cataphractus* (Linnaeus, 1758)
Alosa alosa (Linnaeus, 1758)
*Callionymus lyra* (Linnaeus 1758)
*Capros aper* (Linnaeus, 1758)
*Chelidonichthys cuculus* (Linnaeus, 1758)
*Clupea harengus* (Linnaeus 1758)
Conger conger (Linnaeus, 1758)
*Dicentrarchus labrax* (Linnaeus, 1758)
*Enchelyopus cimbrius* (Linnaeus, 1766)
Family Triglidae
*Gadus morhua* (Linnaeus 1758)
*Gaidropsarus vulgaris* (Cloquet, 1824)
*Labrus bimaculatus* (Linnaeus, 1758)
*Lophius piscatorius* (Linnaeus, 1758)
*Melanogrammus aeglefinus* (Linnaeus 1758)
*Merlangius merlangus* (Linnaeus 1758)
*Merluccius merluccius* (Linnaeus 1758)
*Micromesistius poutassou* (Risso, 1827)
*Molva molva* (Linnaeus, 1758)
*Phycis blennoides* (Brünnich, 1768)
*Pollachius virens* (Linnaeus, 1758)
*Scomber scombrus* (Linnaeus, 1758)
*Trachurus trachurus* (Linnaeus, 1758)
*Trisopterus spp.*
Zeus faber (Linnaeus, 1758)

**FLATFISH**

*Buglossidium luteum* (Risso, 1810)
*Glyptocephalus cynoglossus* (Linnaeus, 1758)
*Hippoglossoides platessoides* (Fabricius 1790)
*Hippoglossus hippoglossus* (Linnaeus, 1758)
*Lepidorhombus whiffiagonis* (Walbaum, 1792)
*Limanda limanda* (Linnaeus, 1758)
*Microstomus kitt* (Walbaum, 1792)
*Pleuronectes platessa* (Linnaeus, 1758)
*Scophthalmus rhombus* (Linnaeus, 1758)

**ELASMOBRANCHS**

*Galeus melastomus* (Rafinesque, 1810)
*Scyliorhinus canicula* (Linnaeus, 1758)
*Squalus acanthias* (Linnaeus, 1758)
*Galeorhinus galeus* (Linnaeus, 1758)
*Dipturus oxyrinchus* (Linnaeus, 1758)
*Leucoraja naevus* (Müller & Henle, 1841)
*Raja clavata* (Linnaeus, 1758)
*Raja brachyura* (Lafont, 1873)
*Raja montagui* (Fowler, 1910)

**INVERTEBRATES**

**Cnidaria**
*Actinauge richardi* (Marion, 1882)
*Adamsia carciniopados* (Otto, 1823)
*Alcyonium digitatum* (Linnaeus, 1758)
*Aurelia aurita* (Linnaeus, 1758)
*Cyanea capillata* (Linnaeus, 1758)
*Cyanea lamarcki* (Linnaeus, 1758)
Family Caryophylliidae
*Funiculina quadrangularis* (Pallas, 1766)
*Pennatula phosphorea* (Linnaeus, 1758)
*Urticina* sp.

**Mollusca**
*Aequipecten opercularis* (Linnaeus, 1758)
*Aporrhais pespelicanis* (Linnaeus, 1758)
*Arctica islandica* (Linnaeus, 1767)
*Eledone cirrhosa* (Lamarck, 1798)
Family Sepiolidae
*Loligo vulgaris* (Lamarck, 1798)
*Neptunea antiqua* (Linnaeus, 1758)
Order Nudibranchia: Species 1
*Scaphander lignarius* (Linnaeus, 1767)

**Annelida**
*Aphrodita aculeata* (Linnaeus, 1761)

**Crustacea**
*Atelecyclus rotundatus* (Olivi, 1792)
*Cancer pagurus* (Linnaeus, 1758)
*Crangon crangon* (Linnaeus, 1758)
Family Magidae
Family Pandalidae
*Goneplax rhomboides* (Linnaeus, 1758)
Infra-order Caridea: Sp. 1
*Liocarcinus depurator* (Linnaeus, 1758)
*Macropipus tuberculatus* (Roux, 1830)
*Munida rugosa* (Fabricius, 1775)
*Pagurus bernhardus* (Linnaeus, 1758)
*Pagurus prideaux* (Leach, 1815)
*Palinurus elephas* (Fabricius, 1787)
*Pasiphaea sivado* (Risso, 1816)

**Echinodermata**
*Asterias rubens* (Linnaeus, 1758)
*Brissopsis lyrifera* (Forbes, 1841)
*Echinus* sp.
*Luidia ciliaris* (Philippi, 1837)
*Marthasterias glacialis* (Linnaeus, 1758)
Order Euryalida
*Parastichopus tremulus* (Gunnerus, 1767)
*Porania* sp.
Sub-class Ophiuroidea

**Tunicata**
Class Ascidiacea