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Marine Stewardship Council Accreditation of North Minch *Nephrops* trawl fishery

Year 2 Scientific Report

December 2010

Bycatch in the North Minch *Nephrops* Trawl Fishery

Ms. Rosanna Milligan
Prof. Douglas Neil

Bycatch in the North Minch *Nephrops* Trawl Fishery

Rosanna Milligan, Douglas Neil

Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow

Year 2 Scientific Report to the Marine Stewardship Council

In relation to

Accreditation of North Minch *Nephrops* trawl fishery

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Introduction

The Scottish fisheries for the Norway lobster, *Nephrops norvegicus* are extremely valuable, with landings of this species worth an estimated £104 million in 2007 (Keltz & Bailey, 2009). 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* fishery 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 IVa 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 include dredging, trawling and creeling vessels which predominantly target *Nephrops* and other shellfish in the north and south Minches to the east of the Outer Hebrides. *Nephrops* was the most valuable landed species in Stornoway in 2008, with a landings value of approximately £2.62 million (the total value of all landed species was approximately £2.75 million). Commercial whitefish stocks in Area VIa as a whole are believed to be at extremely low levels (Keltz & Bailey, 2009), and unlike mixed-fishery fleets in other areas, whitefish have a relatively low value to the fishermen working out of Stornoway and little bycatch is landed.

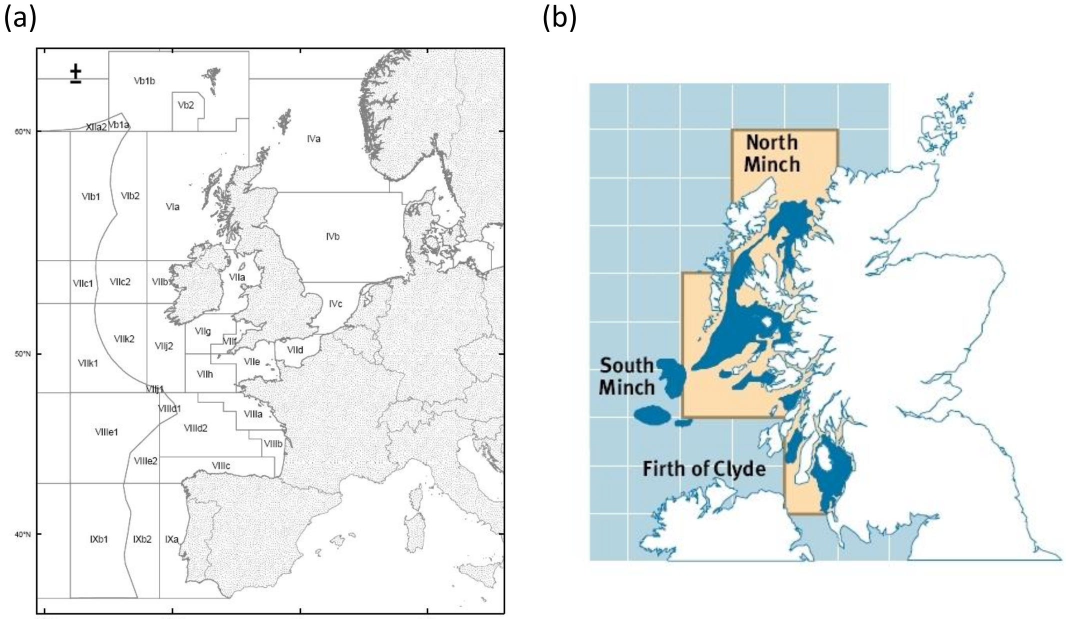


Figure 1: Map showing (a) ICES Areas in the west of Europe and (b) Functional Units within ICES division VIa (adapted from Keltz and Bailey, 2009).

However, due to the extreme decline of commercial fish stocks in the West of Scotland, fisheries managers are increasingly concerned about the impact of commercial fishing practice where species belonging to depleted stocks are captured as bycatch. This is particularly true of single-species *Nephrops* trawl fisheries which (because they are only targeting *Nephrops*, not whitefish) are permitted to fish using smaller-mesh gear compared to mixed-fisheries. 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 (ICES, 2005) and minimum codend mesh sizes of 70mm for single-rig and 80mm for twin-rig gear (Bergmann *et al.*, 2002), whereas a minimum codend mesh size of 120 mm is enforced in mixed fisheries (ICES, 2005). Consequently, the capture of undersize roundfish is a much greater problem in the single-species fisheries as there is less opportunity for the fish to escape the gear (e.g. Briggs, 1985, Stratoudakis *et al.*, 2001, Catchpole *et al.*, 2007, Catchpole & Revill, 2008).

Twelve 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 will be examined through the current project, and the specifications of these vessels are provided 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 14th April 2009, the requirements of which define several of the major aims of this work.

Table 1: List of trawler vessels supplying *Nephrops* to Young's Seafood in 2008

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	70	90
Flowing Stream	1969	SY822	16.68	24.81	119	Single rig	70	90
Kaylana	1978	SY21	17	24.9	284	Twin rig	95	90
Laura Ann	1971	SY586	16.42	24.18	164	Single rig	70	90
Northern Star	1968	SY11	16.46	24.05	149	Single rig	70	90
Ocean Spirit	1979	SY21	13.1	23.6	134	Single rig	70	90
Sharon Rose*	1974	SY190	16.98	27.42	244	Twin rig	95	90
Wavecrest	1968	SY337	16.34	23.15	134	Single rig	70	90
Shiegra	1971	SY7	17.03	24.95	131	Single rig	70	90
True Vine	1974	KY7	15.24	23.43	171	Single rig	70	90
Lead Us	1972	SY144	15.51	24.37	274	Single rig	70	90
Faithful Friend	1970	FR615	18.26	unknown	235	Single rig	70	90

* Sold in 2009 and replaced by the *Silver Chord*, SY101.

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 1 and have been taken from the Certification Report by Moody Marine (Andrews *et al.*, 2008).

Table 1: Conditions of the MSC certification to be undertaken by the University of Glasgow

Condition 3
Cod Bycatch & Discards
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.

Action required:
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.

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.

Relevant Scoring Indicators: 2.1.4.2, 2.3.1.3

Condition 4
Spurdogs
There is a small bycatch of spurdogs in the nephrops fishery. This species is listed on the IUCN Red List as an endangered species.

Action required
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.

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.

Relevant Scoring Indicators: 2.1.4.2, 2.3.1.3

Year 2: Objectives and Progress

The aims and milestone objectives for achieving the conditions of certification were outlined by the University of Glasgow at the beginning of 2009. The aims for year two were as follows:

Condition 3: Cod bycatch and discards

Jan 2010 – Dec 2010

- Implement YoungsTrace self-assessment system across the *Nephrops* trawl fleet in Stornoway.
- Continue monitoring catches and length, sex and condition of cod from *Nephrops* trawls across the fleet at regular intervals (6-8 weeks) and compared to the data from the self-assessment system (*Glasgow University, UMBSM*).
- Examine data set to identify evidence of spatial or temporal trends in bycatch rates of cod which could be used to advise fisheries management in the area.

Milestones December 2010:

1. Working self-assessment system for monitoring cod bycatch aboard Stornoway *Nephrops* trawl vessels
2. Complete data set of cod bycatch for two years.

Summary of Progress

Scientific analysis of the bycatch from a commercial *Nephrops* trawler was carried out between December 2009 and June 2010 and combined with data collected during year 1 (Dec 2008 – Oct 2009) allowing the abundance and biomass of cod in the catches to be analysed over the course of the study. Biometric data have also been collected on all individual cod captured during each surveys.

Due to unforeseen technical problems the YoungsTrace system was not available to begin trials with during 2010. An alternative logbook system has been introduced until YoungsTrace is operational, and self-assessment methodologies have been trialed and tested.

Analysis of all survey data collected between December 2008 and June 2010 is complete. Analysis of the self-assessment data is ongoing.

Condition 4: Spurdog bycatch and discards
Jan 2010 – Dec 2010 - Implement YoungsTrace self-assessment system across the *Nephrops* trawl fleet in Stornoway. - Continue monitoring catches and length, sex and condition of spurdog from *Nephrops* trawls across the fleet at regular intervals (6-8 weeks) and compared to the data from the self-assessment system (*Glasgow University, UMBSM*). - Examine data set to identify evidence of spatial or temporal trends in bycatch rates of spurdog which could be used to fisheries management in the area. Milestones December 2010: 1. Working self-assessment system for monitoring spurdog bycatch aboard Stornoway *Nephrops* trawl vessels 2. Complete data set of spurdog bycatch for two years.

Summary of Progress

Scientific analysis of the bycatch from a commercial *Nephrops* trawler was carried out between December 2009 and June 2010 and combined with data collected during year 1 (Dec 2008 – Oct 2009) allowing the abundance and biomass of spurdog in the catches to be analysed over the course of the study. Biometric data have also been collected on all individual cod captured during each surveys.

Due to unforeseen technical problems the YoungsTrace system was not available to begin trials with during 2010. An alternative logbook system has been introduced until YoungsTrace is operational, and self-assessment methodologies have been trialed and tested.

Analysis of all survey data collected between December 2008 and June 2010 is complete. Analysis of the self-assessment data is ongoing.

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 year one, these have included:

- A meeting with members of the gear technology group at Marine Scotland to discuss the findings from year one with a view to developing technical recommendations for reducing the bycatch in the North Minch *Nephrops* fishery.

Next Steps

The analysis of the survey data from years one and two is now complete, but analysis of the self-assessment data is currently ongoing, and this report should therefore be treated as a preliminary draft until the work is completed.

To complete the next objectives, it is imperative that the self-assessment scheme developed during year 2 continues to run during year 3 and that consultations with the skippers, fishermen and other stakeholders continue to ensure that an effective working relationship is maintained between the researchers at Glasgow University and those involved with the fishing industry.

[MUIR TO COMPLETE INTENTIONS FOR YEAR 3]

Project Summary: Year 2

The major aims for the survey work in year two were to validate the proposed self-assessment methodologies and to collect additional data on the bycatch composition which could be combined with the existing data collected during year one.

The first section of this report will therefore discuss the updated results concerning the bycatch composition and abundance of cod and spurdog between December 2008 and June 2010. The second section will discuss the self-assessment methodology and the validation study that was conducted in March and June 2010.

Methodology

Part A: Catch Composition

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 done over the course of a number of survey trips, which were carried out over four days every two months between December 2008 and December 2009 and over three days in March and June 2010.

The survey trawls of approximately two hours duration were carried out on board the MV '*Comrade*' SY337 (16.65m, 355kW), a single-rig vessel which used two different otter trawl nets while fishing commercially: a lighter 'disc' net (Fig. 4) and a heavier 'hopper' net (Fig. 5). In order to determine whether the net type had an effect on the overall catch composition, both nets were fished during each sampling trip. Care was taken to ensure that any effects caused by using different gear types could be distinguished from the effects of other factors during analysis of the data.

Study Area

The trawl sites for the initial monitoring work were chosen following discussion with the skipper, and were intended to be as representative of commercial fishing grounds in the area as possible. To this end, the precise locations of each tow were selected by the skipper to ensure data were collected about 'real' commercial catches. The GPS tracks for the tows made between December 2008 and December 2009 are shown in Figure 3.

Care was taken to ensure that the sampling regime was scientifically meaningful however, and would allow clear statistical analysis at the end of the survey. Two broad sampling areas were chosen for sampling within the North Minch, one to the south of Stornoway (south site) and one to the south-east (east site).

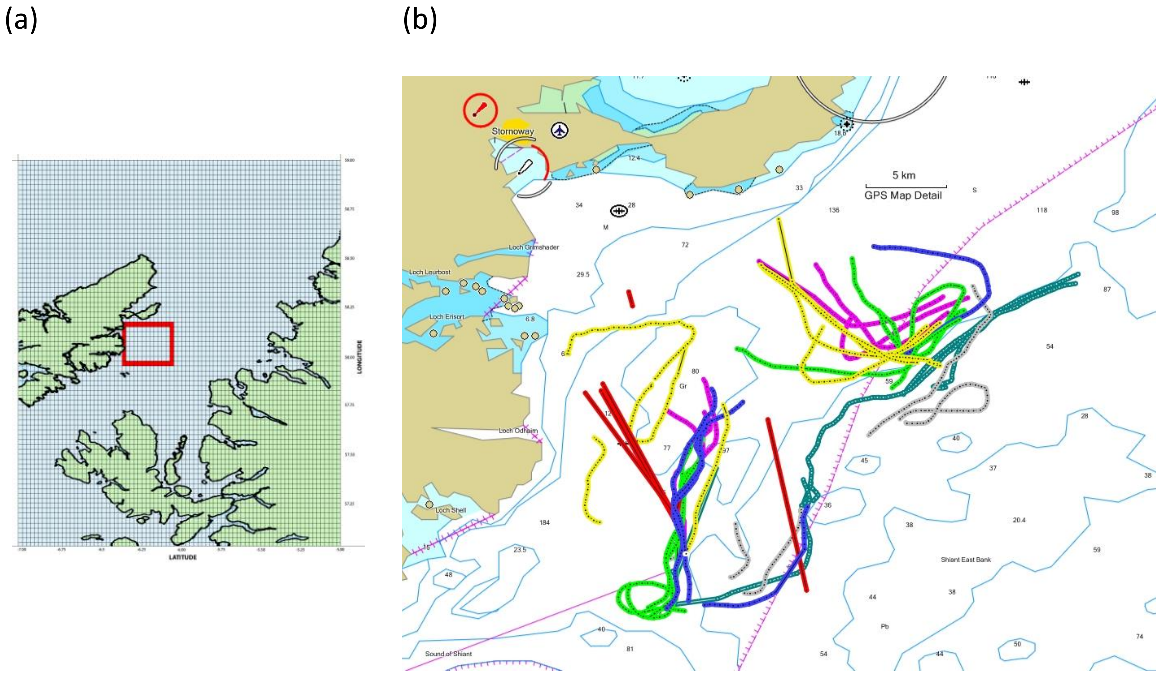


Figure 3: Maps of the study area: (a) The limits of the sampling area are highlighted by the red box and (b) Individual GPS tracks of each tow are shown and colour-coded by month: Red: December 2008; Blue: February 2009; Bright Green: April 2009; Yellow: June 2009; Pink: August 2009; Grey: October 2009; Dark Green: December 2009.

One or two trawls were made each day, and physical and environmental data were recorded to aid with subsequent analysis of the catches, which were:

- Trawl date and time,
- Trawl duration (minutes),
- Decimal GPS location (shot and haul points),
- Mean trawl depth (metres; average of start and end depths),
- Gear type (light or hopper),
- Tidal range (difference between maximum and minimum tidal heights on each day),
- Wind direction and speed.

Summary data for each trawl are displayed in Table 1. Trawls COM8, COM21 and COM33 were considered invalid due to fouling of the gear and have not been included in any analysis of catch composition.

Once each catch was recovered on board, the entire animal bycatch was sorted into major groups (roundfish, flatfish, invertebrates and elasmobranches) while the crew sorted the *Nephrops* according to their normal working practice (into graded whole

Nephrops and tailed *Nephrops*). If a second trawl was made, it would be hauled and sorted in the same manner, and the catches from each haul stored separately until the vessel was back in the harbour. Weighing the catch at sea was not possible due to the motion of the vessel.

On return to the harbour, the major groups from each catch were weighed to the nearest 0.1kg and then sorted separately into individual species. All species were recorded and the numbers of individuals per species were counted. The weights of all roundfish and flatfish species were recorded separately, but the weights of the elasmobranchs were pooled into ‘sharks’ and ‘rays & skate’, while invertebrates were weighed according to phylum or sub-phylum (Cnidaria, Annelida, Mollusca, Crustacea, Echinodermata, and Ascideacea) due to the low mass of most species.

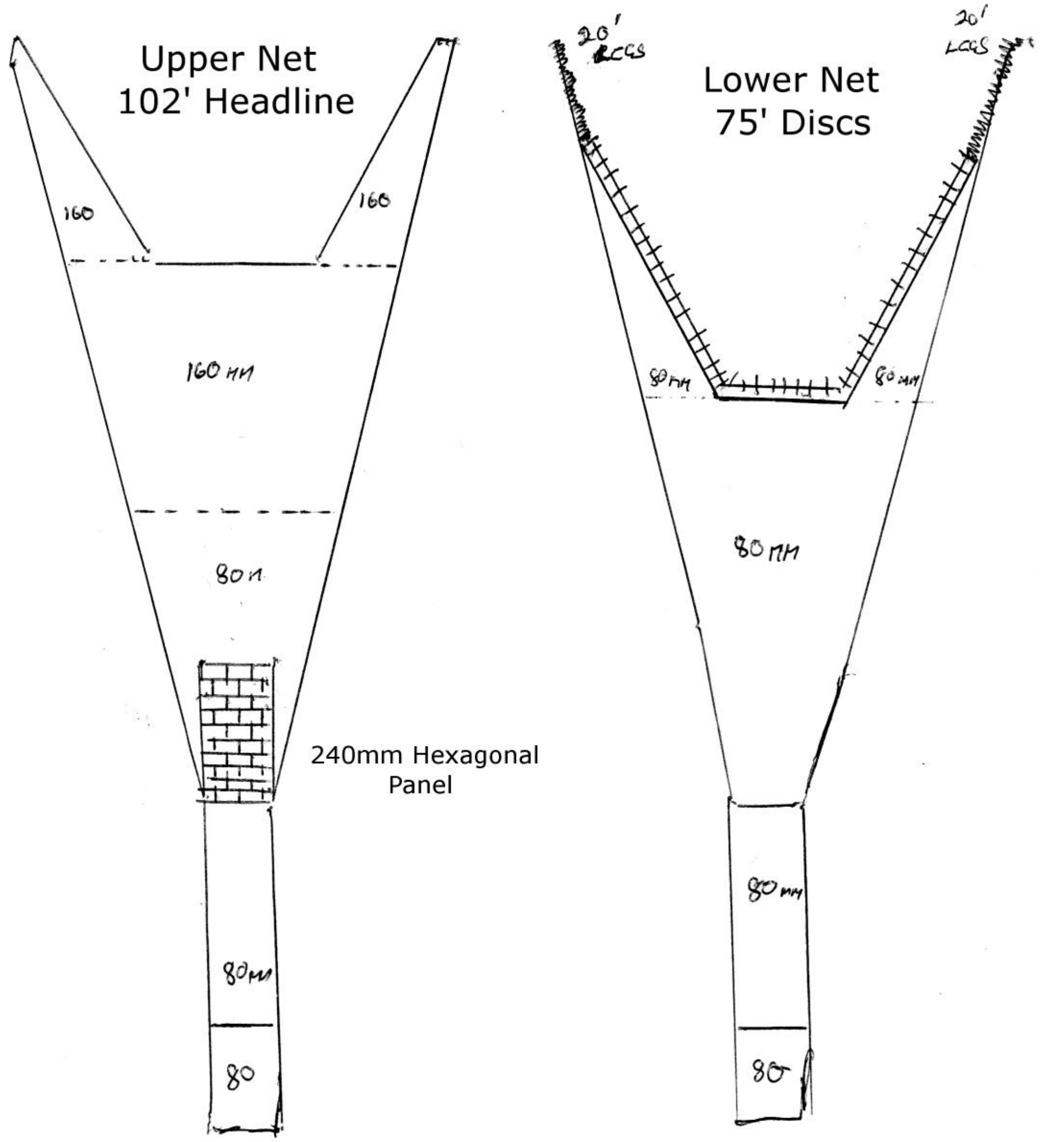


Figure 4: 'Light' trawl net used by *MV Comrade.*

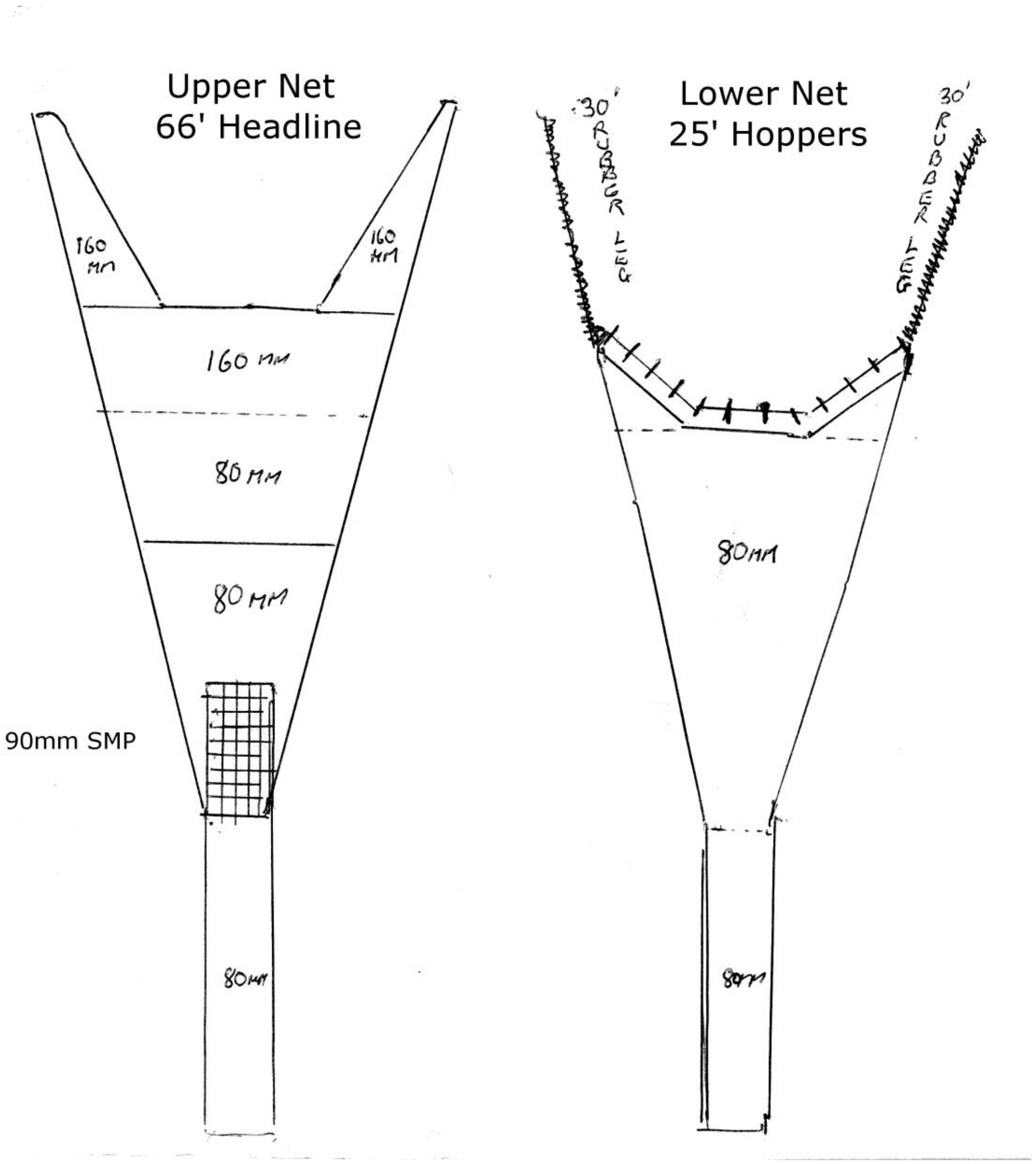


Figure 5: ‘Hopper’ trawl net used by *MV Comrade.*

Table 1: Summary data for each trawl

Trawl ID	Date	Vessel Name	Time Shot	Duration (mins)	Avg Depth (m)	Gear Type	Site	GPS Start	GPS End
COM1	08/12/2008	Comrade	13:48	145	90	Disc	South	58°07'N 6°18'W	58°07.48'N 6°18.11'W
COM2	09/12/2008	Comrade	09:52	123	82.5	Hopper	South	58°03.273'N 6°12.542'W	57°57.554'N 6°10.973'W
COM3	10/12/2008	Comrade	09:24	135	122.5	Hopper	South	58°04.172'N 6°19.294'W	57°59.900'N 6°16.323'W
COM4	10/12/2008	Comrade	12:04	138	115	Hopper	South	57°59.900'N 6°16.323'W	58°00.086'N 6°16.015'W
COM5	11/12/2008	Comrade	09:32	138	117.5	Hopper	South	58°04.411'N 6°19.211'W	58°00.160'N 6°16.342'W
COM6	11/12/2008	Comrade	12:05	130	120	Hopper	South	58°00.160'N 6°16.342'W	58°04.11'N 6°19°9'W
COM7	10/02/2009	Comrade	13:09	135	107.5	Disc	South	58°02.938'N 6°15.044'W	57°56.944'N 6°16.637'W
COM9	11/02/2009	Comrade	13:45	120	75	Disc	South	57°57.071'N 6°15.095'W	58°00.348'N 6°10.921'W
COM10	12/02/2009	Comrade	10:15	120	112.5	Disc	South	58°03.816'N 6°13.551'W	58°00.143'N 6°16.381'W
COM11	12/02/2009	Comrade	12:45	120	102.5	Hopper	South	58°00.131'N 6°16.376'W	58°06.255'N 6°14.811'W
COM12	13/02/2009	Comrade	10:18	164	115	Hopper	East	58°08.936'N 6°07.977'W	58°05.425'N 6°06.933'W
COM13	21/04/2009	Comrade	10:25	125	120	Hopper	South	58°02.616'N 06°15.538'W	57°57.247'N 6°16.258'W
COM14	21/04/2009	Comrade	13:30	130	140	Hopper	South	57°56.870'N 6°15.904'W	57°57.762'N 6°18.103'W
COM15	22/04/2009	Comrade	07:45	270	114.5	Hopper	East	58°06.857'N 6°08.082'W	58°04.285'N 6°17.517'W
COM16	23/04/2009	Comrade	10:15	135	120.5	Hopper	South	58°01.991'N 6°15.285'W	57°56.680'N 6°17.304'W
COM17	23/04/2009	Comrade	13:15	135	133.5	Hopper	South	57°56.980'N 6°17.381'W	58°02.595'N 6°15.186'W
COM18	24/04/2009	Comrade	09:45	120	117.5	Hopper	East	58°08.578'N 6°09.132'W	58°06.822'N 6°04.684'W
COM19	24/04/2009	Comrade	12:25	125	104.5	Hopper	East	58°06.554'N 6°04.795'W	58°02°595'N 6°15.186'W
COM20	16/06/2009	Comrade	10:06	139	107	Hopper	South	57°58.765'N 6°15.884'W	58°03.362'N 6°14.186'W
COM21	16/06/2009	Comrade	13:00	125	147.5	Hopper	South	57°59.818'N 6°19.334'W	58°02.639'N 6°19.562'W
COM22	17/06/2009	Comrade	09:25	125	123.5	Hopper	East	58°07.836'N 6°11.555'W	58°06.332'N 6°06.104'W
COM23	17/06/2009	Comrade	12:15	132	117	Hopper	East	58°06.441'N 6°05.593'W	58°06.310'N 6°10.308'W
COM24	18/06/2009	Comrade	09:45	120	93.5	Hopper	South	58°05.766'N 6°15.821'W	58°04.415'N 6°17.227'W
COM25	18/06/2009	Comrade	12:15	120	78.5	Hopper	South	58°04.595'N 6°17.096'W	58°05.412'N 6°20.576'W
COM26	19/06/2009	Comrade	09:20	120	104	Disc	East	58°08.371'N 6°12.852'W	58°05.086'N 6°05.831'W
COM27	19/06/2009	Comrade	11:30	155	112.5	Hopper	East	58°05.151'N 6°06.509'W	58°08.361'N 6°12.813'W
COM28	11/08/2009	Comrade	10:00	120	118.5	Disc	East	58°08.376'N 6°10.595'W	58°06.776'N 6°05.265'W
COM29	11/08/2009	Comrade	12:00	150	116	Hopper	East	58°07.274'N 6°04.461'W	58°06.615'N 6°09.162'W
COM30	12/08/2009	Comrade	10:10	120	129	Disc	South	58°03.093'N 6°15.043'W	57°58.640'N 6°16.357'W

(cont. overleaf)

Trawl ID	Date	Vessel Name	Time Shot	Duration (mins)	Avg Depth (m)	Gear Type	Site	GPS Start	GPS E'Nd
COM31	12/08/2009	Comrade	13:00	120	110	Hopper	South	58°00.995'N 6°15.934'W	58°04.571'N 6°15.140'W
COM32	13/08/2009	Comrade	09:35	120	121	Hopper	East	58°08.494'N 6°12.893'W	58°07.315'N 6°05.461'W
COM33	13/08/2009	Comrade	11:55	120	117.5	Disc	East	58°07.7'N 6°05.3'W	58°07.7'N 6°11.5'W
COM34	14/08/2009	Comrade	09:50	120	104	Hopper	South	58°03.589'N 6°16.656'W	58°03.569'N 6°16.656'W
COM35	14/08/2009	Comrade	12:15	125	106	Disc	South	57°59°4'N 6°16°5'W	58°06.571'N 6°15.140'W
COM36	27/10/2009	Comrade	10:00	120	104	Disc	South	58°03.3'N 6°14.6'W	57°58.5'N 6°13.5'W
COM37	28/10/2009	Comrade	10:00	120	104	Disc	South	58°02.9'N 6°14.5'W	57°58.2'N 6°14.7'W
COM38	28/10/2009	Comrade	12:45	130	108.5	Hopper	South	57°58'N 6°14.7'W	58°02.8'N 6°14.8'W
COM39	29/10/2009	Comrade	10:00	120	107	Disc	East	58°08'N 6°04.6'W	58°02.7'N 6°08.4'W
COM40	29/10/2009	Comrade	12:45	125	87.5	Hopper	East	58°02.7'N 6°08.'W	58°03.1'N 6°06.8'W
COM41	30/10/2009	Comrade	10:00	150	98	Disc	South	58°02.4'N 6°14.'W	57°57.9'N 6°14.'W
COM42	30/10/2009	Comrade	12:30	90	88.5	Hopper	South	57°57.4'N 6°13.4'W	58'N 6°11.2'W
COM43	08/12/2009	Comrade	11:50	120	102	Disc	South	58°03.9'N 6°11.5'W	58°00.4'N 6°11.1'W
COM44	09/12/2009	Comrade	10:20	120	97.5	Disc	East	58°04.1'N 6°07. 'W	58°08.'N 6°00.'W
COM45	09/12/2009	Comrade	12:55	135	94	Hopper	East	58°07.7'N 6°00.'W	58°04.3'N 6°05.7'W
COM46	10/12/2009	Comrade	10:20	120	118.5	Disc	South	58°01.9'N 6°14.6'W	57°57.9'N 6°14.6'W
COM47	10/12/2009	Comrade	13:05	120	98.5	Hopper	South	57°57.2'N 6°14.6'W	58°01.2'N 6°11.1'W
COM48	11/12/2009	Comrade	10:20	150	93.5	Disc	Both	58°5.7'N 6°04.9'W	58°00.5'N 6°10.8'W
COM49	22/03/2010	Comrade	10:55	120	119.5	Disc	South	58°02.45'N 6°14.6'W	57°58.2N 6°15.9'W
COM50	22/03/2010	Comrade	13:30	120	100	Disc	South	57°58.1'N 6°14.3'W	
COM51	24/03/2010	Comrade	09:50	125	116	Disc	South	58°02.8'N 6°15.3W	57°57.7'N 6°16.0'W
COM52	24/03/2010	Comrade	12:30	125	149	Disc	South	57°57.5'N 6°16.0'W	57°59.6'N 6°18.0'W
COM53	25/03/2010	Comrade	08:20	100	106	Disc	South	58°04.0'N 6°15.9'W	58°00.0'N 6°15.8'W
COM54	25/03/2010	Comrade	10:30	110	117.5	Disc	South	58°00.0'N 6°16.1'W	58°04.5'N 6°13.2'W
COM55	15/06/2010	Comrade	10:15	120	100	Disc	South	58°02.3'N 6°14.0'W	57°58.1'N 6°14.8'W
COM56	15/06/2010	Comrade	12:45	118	104.5	Disc	South	57°58.0'N 6°14.4'W	58°03.0'N 6°14.3'W
COM57	16/06/2010	Comrade	10:10	120	105	Disc	South	58°03.0'N 6°14.5'W	57°54.7'N 6°19.4'W
COM58	16/06/2010	Comrade	15:45	120	106.5	Disc	South	57°58.4'N 6°14.4'W	58°03.2'N 6°14.6'W
COM59	17/06/2010	Comrade	09:50	125	104.5	Disc	South	58°03.4'N 6°14.6'W	57°58.8'N 6°14.4'W
COM60	17/06/2010	Comrade	12:25	80	95	Disc	South	57°58.8'N 6°14.3'W	58°04.8'N 6°14.9'W

Because pouts (*Trisopterus* sp.) were so abundant in some catches, it was occasionally not possible to count every individual. In such cases, at least three groups of 100 individuals were selected randomly from the total and weighed, and the average weight for 100 animals was then calculated. All Norway pout were then weighed, and the total weight was divided by the average value to give an estimate of the total number present in each catch.

Part B: Key Species

After the numbers and weights of each species had been recorded, all cod and spurdog were stored on ice and frozen. All samples were stored on ice and frozen at -20°C by Young's Seafood Ltd. in Stornoway before being transported on ice to the university by haulier approximately one week after capture. The samples were refrozen at -20°C on arrival at the university and stored until they were required.

Cod

The samples of fish were allowed to defrost at room temperature for at least 24 hours before analysis. The total length (rounded down to the nearest 5mm) and total weight of each individual fish was recorded, as well as the sex and the weight of the viscera and of the gonads.

Spurdog

The examination of the spurdog samples was carried out mainly by final year undergraduate student, Ms Ola Wands, as part of a final-year Honours project, to allow more thorough data collection and analysis to be carried out on this species. Samples of spurdog were allowed to defrost at room temperature for at least 24 hours before dissection, and the total length, total weight, sex, viscera weight, gonad weight and liver weight were recorded. The dorsal spines were also removed to allow the age of each individual to be estimated. The methodology for aging spurdog is well established, and involves counting the growth bands which appear on the dorsal spines, was according to the method of Holden and Meadows (1962). This technique was validated by Campana *et al.* (2006) using bomb dating which demonstrated that one calcified band on the spine corresponded to one year of growth. 'Double bands' were counted as a single year, and spines were not aged if the tip was noticeably worn, as such estimates would not be accurate. Spines were considered to be the same age whether the first band was black or white. It should be noted that this method is problematic if carried out by untrained personnel and can be subject to errors (Holden & Meadows, 1962). Expert confirmation of the ages may therefore be obtained if required.

Data Analysis

Analysis of the abundance and biomass of bycatch species or groups was 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 in each haul and the weights of the major groups per haul were standardised by trawl duration prior to analysis, to give numbers and weights per haul per hour respectively. 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), while more subtle relationships arising as a result of the rarer species could be examined by transforming the data to down-weight the highly dominant species.

Where comparisons between samples were examined, the abundance and biomass data were converted to a similarity matrix using the Bray-Curtis similarity index. The environmental data were normalised, then converted to a similarity matrix using Euclidean distance. The GPS positions were converted to a decimal scale before inclusion in the data set.

Multi-Dimensional Scaling (MDS) and cluster analysis were used to determine the relationships between the bycatch 'communities' from each haul, and BEST and ANOSIM analyses were used to determine the significance of environmental parameters or factors in explaining the differences in these communities. In general, 99 permutations were used for BEST and ANOSIM tests, and MDS analyses were restarted at least 100 times. In each case, significance was taken as $p < 0.05$.

Diversity indices were also calculated and compared between trawls.

Calculating the Number of *Nephrops*

In order to have complete abundance data for the entire catch it was necessary to include the numbers of *Nephrops* present. However, since there were so many individuals in each trawl, the numbers had to be estimated from the biomass rather than counted directly.

Estimates were made by weighing several groups of 100 *Nephrops* from each of the 'discarded' (whole animals only), 'tails' and 'whole' categories, and determining the mean weight for each. In this case, animals in the 'whole' category were not graded by size (they were recorded as a 'mixed' grade), therefore allowing any estimates to be comparable to the original biomass measures. The approximate numbers of *Nephrops* in the total catch could then be calculated. Since the mean proportion of whole discarded *Nephrops* was calculated to be 0.21 of the total discarded component on average, this factor could be applied to give an estimate of the weight of the whole discarded animals only and converted to an abundance estimate. The mean weight of 100 animals from each category is shown in Table 2.

Table 2: Mean weights of 100 whole Nephrops from the 'whole' and 'discarded' components, and the mean weights of 100 Nephrops tails. One standard deviation for each group is indicated.

Catch Component	Mean weight of 100 (kg)	Standard Deviation
Discarded	1.39	0.45
Tails	1.12	0.13
Whole	3.88	0.28

Condition Indices

Condition indices were also calculated for the fish and spurdog samples where possible, using Fulton's Condition Index (K):

$$K = \frac{\text{Weight (g)}}{\text{Length (cm)}^3} \times 100$$

Where the carcass weight (i.e. the weight of the body after the viscera are removed) was known, the Somatic Condition Factor (SCF) was calculated as follows:

$$SCF = \frac{\text{Carcass weight (g)}}{\text{Length (cm)}^3} \times 100$$

This index is similar to Fulton's condition index, but does not take 'fullness' of the animal into account, and is potentially therefore a more accurate measure of the long-term condition of an individual. Both indices produce values close to one, and the higher the value, the better the condition of the animal is assumed to be.

These indices are suitable for animals that show an isometric growth pattern (weight increases as the cube of the length).

The Gonadal Somatic Index (GSI) was also calculated for cod, haddock and whiting samples from February 2009 onwards, to help verify the maturity status of the animals. The GSI was calculated as follows:

$$GSI = \frac{\text{Gonad weight (g)}}{\text{Total wet weight (g)}}$$

Results

Species Composition and Broad Trends

From nine survey trips comprising 57 valid trawls, a total of 85 species were recorded, including 24 species of roundfish, 9 species of flatfish, 8 species of elasmobranch, and 45 species of invertebrate (including *Nephrops*). A list of the species present is given in Table 3.

On average *Nephrops* was the most dominant species in the catches by both abundance (approx. 1045 captured per hour of trawling on average) and wet weight (approx. 36.3kg captured per hour of trawling on average). The bycatch was typically dominated by a few common species which were present in virtually all sampled catches. Table 4 shows the five most abundant bycatch species by number (per hour of trawling) while the dominant species by wet weight (per hour of trawling) are shown in Table 5. In each case, the values have been averaged across all tows and have been standardised by trawl duration.

Table 4: The five most dominant species (by number) occurring in sample trawls and the average number captured in each trawl.

Species	Average number per hour trawled
Trisopterus spp.	212
Pandalid shrimp	115
Whiting	60
Tall Sea Pen	21
Actinauge richardi	18

Table 5: The five most dominant species (by wet weight) occurring in sample trawls and the average biomass captured in each trawl.

Species / Group	Average biomass per hour trawled (kg)
Sharks	5.1
Trisopterus spp.	3.3
Whiting	2.7
Cnidaria	2.0
Crustacea	1.6

Table 3: List of species recorded from 57 trawls between December 2008 and June 2010

ROUNDFISH	**INVERTEBRATES**
Agonus cataphractus (Linnaeus, 1758)	**Cnidaria**
Chelidonichthys cuculus (Linnaeus, 1758)	*Funiculina quadrangularis (Pallas, 1766)*
Callionymus lyra Linnaeus 1758	*Pennatula phosphorea Linnaeus, 1758*
Capros aper (Linnaeus, 1758)	*Actinauge richardi* (Marion, 1882)
Clupea harengus Linnaeus 1758	*Urticina* sp.
Enchelyopus cimbrius (Linnaeus, 1766)	*Adamsia carciniopados* (Otto, 1823)
Gadus morhua Linnaeus 1758	Family Caryophylliidae
Gaidropsarus vulgaris (Cloquet, 1824)	*Cyanea capillata* (Linnaeus, 1758)
Lophius piscatorius Linnaeus, 1758	*Cyanea lamarcki Péron and Lesueur, 1809*
Melanogrammus aeglefinus (Linnaeus 1758)	*Aurelia aurita (Linnaeus, 1758)*
Merlangius merlangus (Linnaeus 1758)	*Alcyonium digitatum Linnaeus, 1758*
Merluccius merluccius (Linnaeus 1758)	**Mollusca**
Micromesistius poutassou (Risso, 1827)	*Aequipecten opercularis (Linnaeus, 1758)*
Molva molva (Linnaeus, 1758)	*Arctica islandica (Linnaeus, 1767)*
Phycis blennoides (Brünnich, 1768)	*Loligo vulgaris* Lamarck, 1798
Pollachius virens (Linnaeus, 1758)	*Eledone cirrhosa* Lamarck, 1798
Scomber scombrus Linnaeus, 1758	Family Sepiolidae
Trachurus trachurus (Linnaeus, 1758)	Order Nudibranchia: Species 1
Family Triglidae	*Scaphander lignarius (Linnaeus, 1767)*
Trisopterus spp.	*Aporrhais pespelicanis Linnaeus, 1758*
Zeus faber Linnaeus, 1758	*Neptunea antiqua (Linnaeus, 1758)*
Alosa alosa (Linnaeus, 1758)	**Annelida**
Conger conger (Linnaeus, 1758)	*Aphrodita aculeata Linnaeus, 1761*
Labrus bimaculatus Linnaeus, 1758	**Crustacea**
	Palinurus elphas (Fabricius, 1787)
FLATFISH	*Munida rugosa Fabricius, 1775*
Buglossidium luteum (Risso, 1810)	*Pagurus prideaux Leach, 1815*
Glyptocephalus cynoglossus (Linnaeus, 1758)	*Pagurus bernhardus Linnaeus, 1758*
Hippoglossoides platessoides (Fabricius 1790)	*Cancer pagurus Linnaeus, 1758*
Hippoglossus hippoglossus (Linnaeus, 1758)	*Liocarcinus depurator (Linnaeus, 1758)*
Lepidorhombus whiffiagonis (Walbaum, 1792)	*Macropipus tuberculatus (Roux, 1830)*
Limanda limanda (Linnaeus, 1758)	*Goneplax rhomboides (Linnaeus, 1758)*
Microstomus kitt (Walbaum, 1792)	*Atelecyclus rotundatus (Olivi, 1792)*
Pleuronectes platessa Linnaeus, 1758	Family Magidae
Scophthalmus rhombus (Linnaeus, 1758)	*Crangon crangon (Linnaeus, 1758)*
	Family Pandalidae
ELASMOBRANCHS	*Pasiphaea sivado (Risso, 1816)*
Dipturus oxyrinchus (Linnaeus, 1758)	Infra-order Caridea: Sp. 1
Galeus melastomus Rafinesque, 1810	**Echinodermata**
Leucoraja naevus (Müller & Henle, 1841)	*Asterias rubens* Linnaeus, 1758
Raja clavata Linnaeus, 1758	*Luidia ciliaris (Philippi, 1837)*
Raja brachyura Lafont, 1873	*Marthasterias glacialis (Linnaeus, 1758)*
Raja montagui Fowler, 1910	*Porania* sp.
Scyliorhinus canicula (Linnaeus, 1758)	Sub-class Ophiuroidea
Squalus acanthias Linnaeus, 1758	Order Euryalida
	Parastichopus tremulus (Gunnerus, 1767)
	Echinus sp.
	Brissopsis lyrifera
	Tunicata
	Sub-phylum Tunicata

The mean proportion of each major group by wet weight is shown in Figure 6. Overall, the landed portion of the *Nephrops* catch comprised the largest component of the catches (mean = 55%), with non-target organisms accounting for 39% and discarded *Nephrops* for 6%. It should be noted that the weights of the discarded 'heads' was included in the weight of the tails since this is considered to be normal processing waste rather than bycatch or discard (A. Weetman, *pers. comm.*)

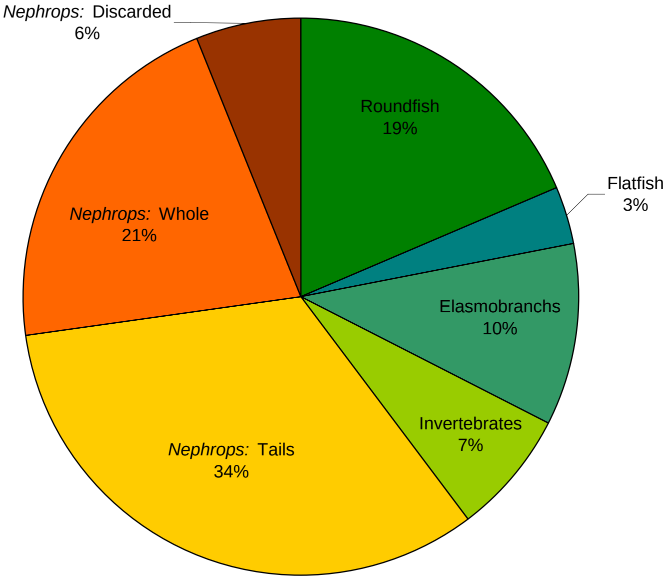


Figure 6: Mean overall catch composition from all trawls made from December 2008 to June 2010.

Figure 7 shows the mean catch weights for '*Nephrops'* (discards, heads and landed animals combined) and the bycatch groups by month. Overall, there were significant differences in the catch weights per month (ANOVA; $p < 0.05$), though *post hoc* analysis failed to determine where the differences existed. However, it is likely that they were influenced by the particularly small catches made during March 2010 which were generally smaller than those made during the rest of the period. The weights of all bycatch groups captured per hour varied significantly with month ($p < 0.01$) with the exception of the invertebrates ($p > 0.05$). More roundfish were caught in December 2008, between August – December 2009 and in June 2010 than in February – June 2009 or March 2010 suggesting a general increase in catch weights of this group over the period. It is likely that low catches of roundfish in March 2010 are indicative of low total catches during that month. There appeared to be a decline in the weights of flatfish catches over the course of the survey until December 2009 with slight increases in biomass in March and June 2010. Catches of elasmobranchs were lower in June 2009 and March and June 2010, while a higher weight of *Nephrops* was captured per hour in December 2008, April and June 2009 than October 2009 or March 2010. Values for elasmobranchs and invertebrates were log-transformed to meet the assumptions of the ANOVA.

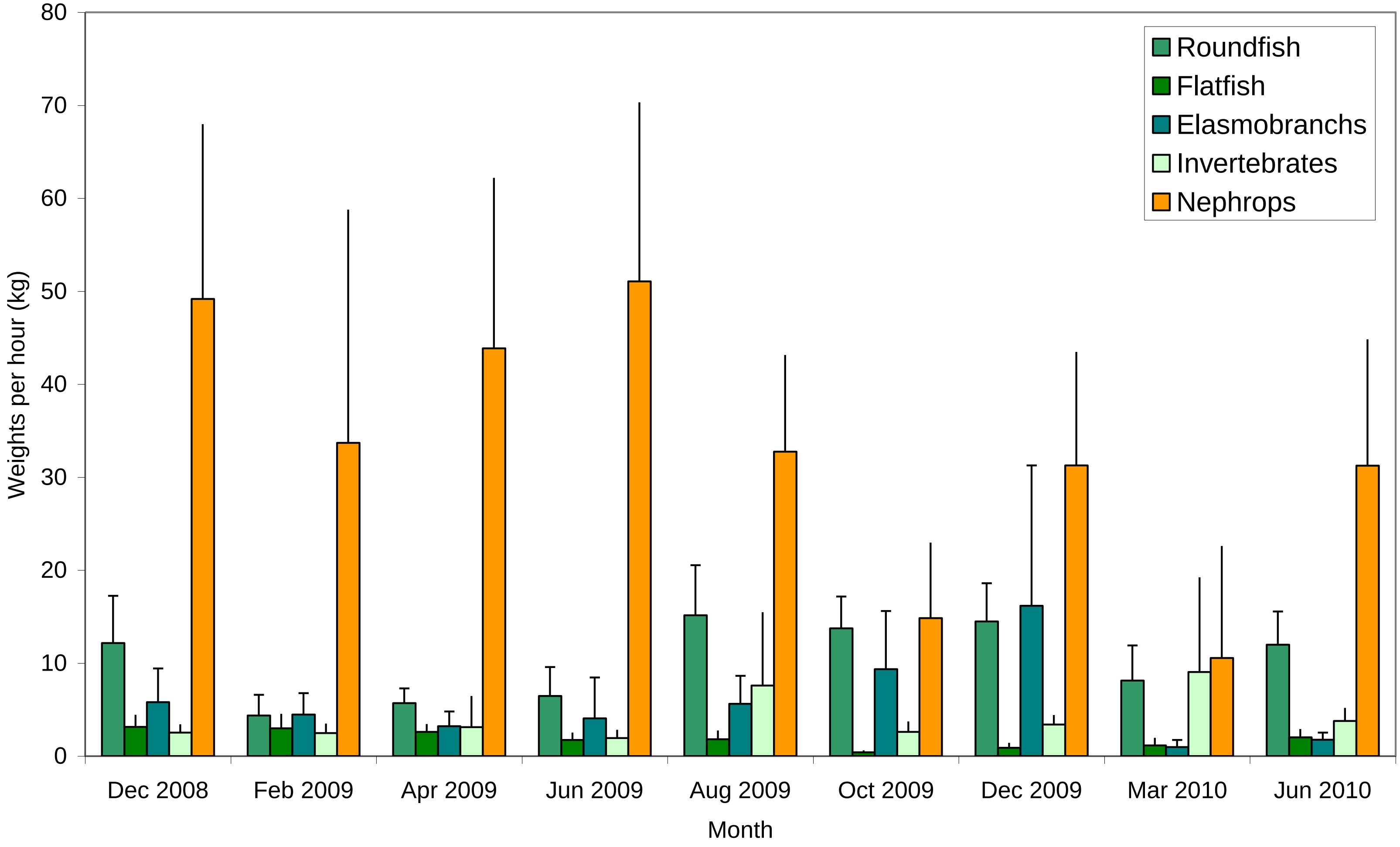


Figure 7: Mean proportion of each component of the catches by wet weight from each sampling trip. '*Nephrops*' represents the combined weights of both the landed *Nephrops* and the discarded animals and heads. Error bars show one standard deviation.

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 (ANalysis Of SIMilarity) test was carried out to determine whether any factors (such as sampling month, site (south or east), or gear type (hopper or disc net)) had a significant influence on the similarity between catches. This test showed a significant effect of both sampling month (global R = 0.827, $p < 0.001$) and site (global R = 0.395, $p < 0.005$).

SIMilarity PERcentages (SIMPER) analysis was carried out to determine which species contributed to the differences between the sites, but the results were not clear. At the south site, the 5 species contributing most to the similarity were *Nephrops,* pouts (*Trisopterus* spp.), whiting, lesser-spotted dogfish and hake (accounting for 39.8%) of the cumulative similarity. At the east site, the species were similar, with *Nephrops*, pandalid shrimp, pouts, hake and whiting accounting for 54.6% of the cumulative similarity within this region. Dissimilarity between the groups was only 30.5%, and no species accounted for more than 4.2% of the total, suggesting that the differences are quite subtle.

To visualise the relationships between the species abundance of catches, non-parametric 2D Multi-Dimensional Scaling (MDS) ordination was carried out, with the month of capture indicated in each case (Fig 8). These data generally show clustering by month, although the stress (simplistically, a measure of the error) of the 2D plot is relatively high (0.18). Better separation by month is apparent in the 3D plot, but this cannot be shown here.

BEST (BIOENV) analysis was carried out to determine whether any of the recorded environmental variables could explain the differences in composition between the catches, but none were found to be significant ($p > 0.05$). BVSTEP analysis did find that 20 species had a significant influence on the catch composition; these are shown in Table 6.

Table 6: Species identified as significant by BVSTEP analysis in explaining the relationships between catches (fourth-root transformed abundance data).

Haddock	Whiting	Four-Bearded Rockling	Plaice
Blue Whiting	Triglidae (Gurnards)	Horse Mackerel	Witch
Dab	Cuckoo Ray	Cuttlefish (Sepiolidae)	Hermit crab (*Pagurus prideaux*)
Hermit crab (*Pagurus bernhardus*)	Brown shrimp (*Crangon crangon*)	Pandalid shrimp	Glass shrimp (*Pasiphaea sivado*)
Brown crab	Squat lobster (*Munida rugosa*)	Harbour crab	Sea Mouse

The effect each species has on the relationships between the catches can be displayed as a 2D ‘bubbleplot’, which is overlaid on the 2D MDS plot and in which the size of each ‘bubble’ is proportional to the abundance of the species in question. While this was not carried out for each of the 20 species indicated, examples are shown in Figure 9, using (transformed) abundance data from haddock, whiting and pandalid shrimp.

Using Figure 8 as reference, it can be seen that there was a general increase in abundance of both haddock and whiting from left to right, which corresponds approximately with the month of capture, i.e. catches of both species increase over the survey period. Figure 9 (c) shows the opposite pattern for the pandalid shrimp, which appear to show a decline from the start of the survey through 2009, and are completely absent from catches taken in 2010.

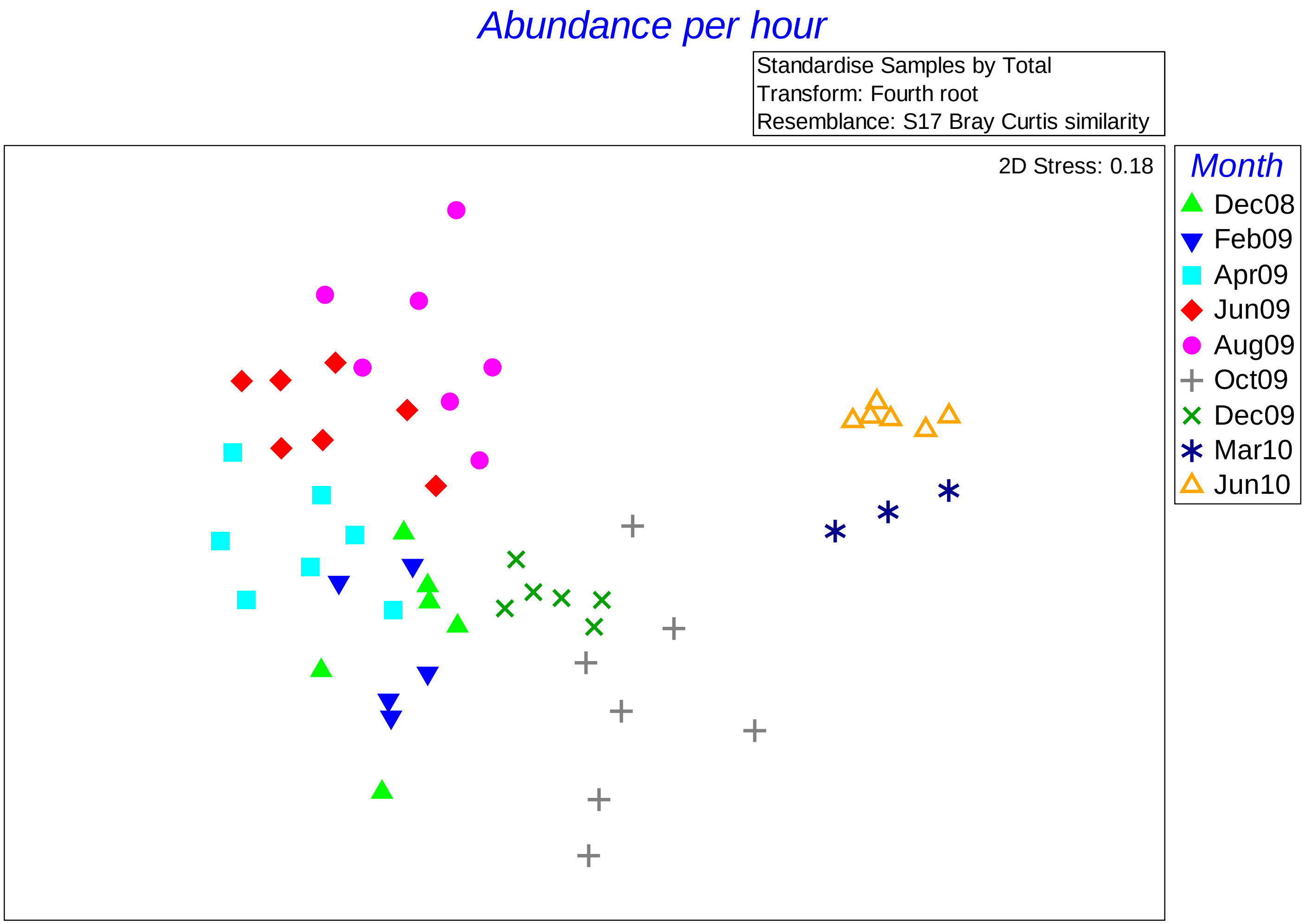


Figure 8: 2D MDS plot showing the relationships between the catches (fourth-root transformed abundance data). The sampling month is indicated for each catch (ANOSIM, Month: $p < 0.001$; Site: $p < 0.003$). Note the relatively high stress level of this plot.

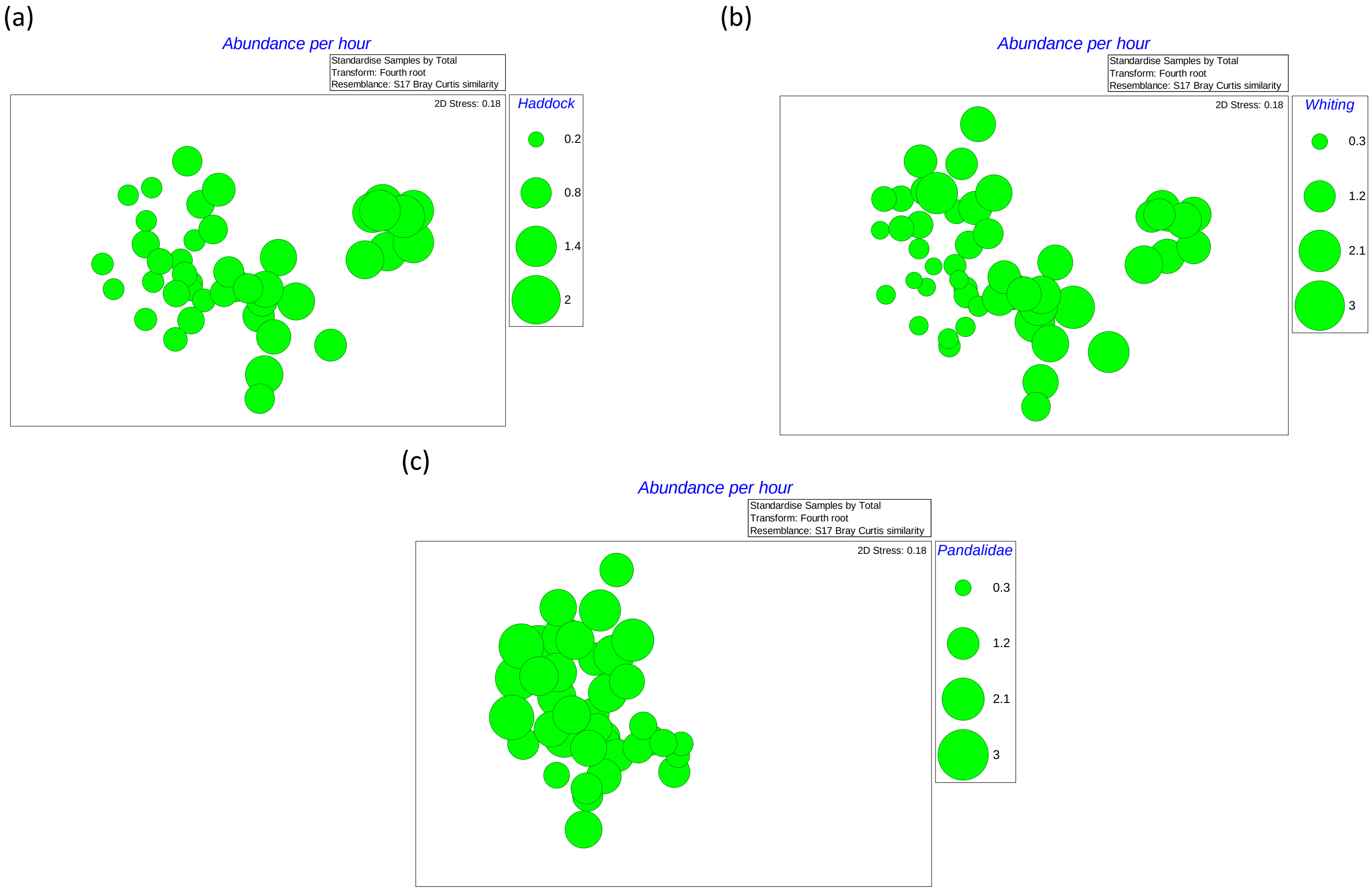


Figure 9: Bubble plots of numbers of (a) *Nephrops,* (b) *Trisopterus* spp. and (c) Pandalidae superimposed over a 2D MDS ordination of untransformed abundance data (from Fig. 8).

Relationships Between Catches: Biomass

The biomass data were standardised (to account for differences in catch volume) and fourth-root transformed prior to analysis. ANOSIM analysis showed that month and capture site were again the only significant factors to explain the similarities between the catches (Month: R = 0.652, $p < 0.001$; Site: R = 0.224, $p < 0.03$), and BEST (BIOENV) analysis again failed to find any significant effects of the environmental variables on the overall catch composition. Further testing (BVSTEP) found that 23 taxa had significant influences on the relationships between catches however, and these are shown in Table 7. A 2D MDS ordination of these data is shown in Figure 10.

Table 7: Species identified as significant by BVSTEP analysis in explaining the relationships between catches (fourth-root transformed biomass data).

Dragonet	Herring	Four-Bearded Rockling	Cod
Haddock	Whiting	Hake	Blue Whiting
Horse Mackerel	Pouts (*Trisopterus* spp.)	Long-rough dab	Witch
Dab	Lemon Sole	Plaice	‘Sharks’
Rays & Skate	Cnidaria	Mollusca	Annelida
Echinodermata	Ascideacea		

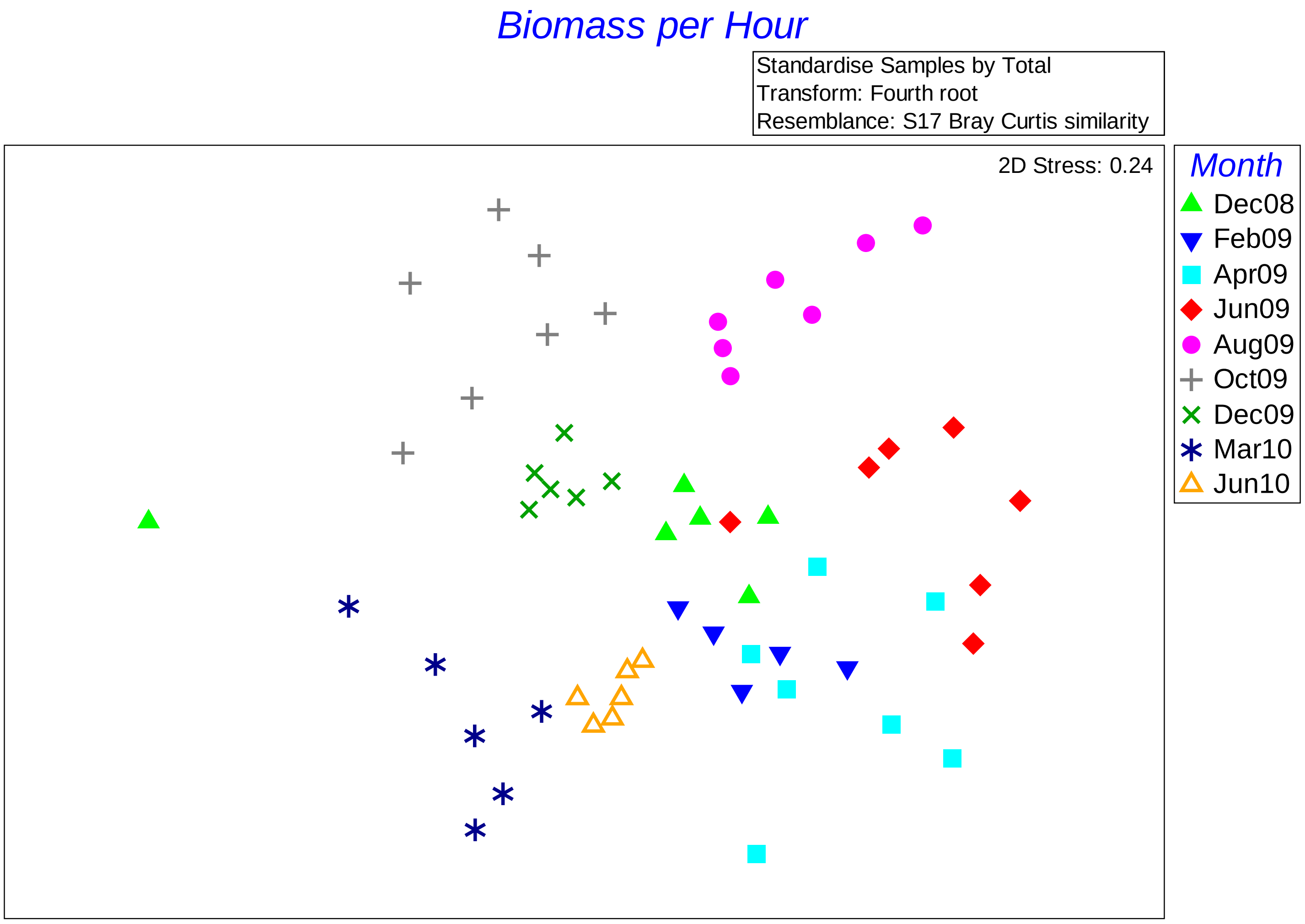


Figure 10: 2D MDS plot showing the relationships between the catches (fourth-root transformed biomass data). The sampling month is indicated for each catch (ANOSIM: $p < 0.001$).

Key Species

Cod

A total of 86 cod were collected and analysed (from a total of 101) from the 60 trawls between December 2008 and June 2010. Catches of cod were low throughout the sampling period, accounting for 0.8% of all catches made by wet weight. The percentage of cod captured per month (by wet weight) is shown in Figure 11 against a 1.5% limit which represents the derogation allowing exemption from quota restrictions under the EU Cod Recovery Plan. Although catches were variable, cod accounted for more than 1.5% of catches (by wet weight) only in December 2009 and March 2010.

Sampling month, survey site or types of gear used were not found to have any effect on the length of fish captured ($p > 0.05$) and length did not vary with sex ($p > 0.05$). The average length of cod was 32.5cm (MLS = 35cm) over the entire survey period, with undersized animals comprising 64% of the total. The length-frequency distribution of captured cod is shown in Figure 12.

The CI, SCF and GSI were found to vary significantly with length ($p < 0.001$), with larger cod generally having higher index values (Figure 13). The CI was found to slightly decrease with increasing GSI, though this was only just significant at 5% ($p < 0.05$). The CI and SCF also varied with month, and typically showed higher values in the autumn months (October: 1.12 and 1.03) than in the spring (April: 0.95 and 0.86). The highest CI value occurred in December 2008, though this was not mirrored in the SCF value.

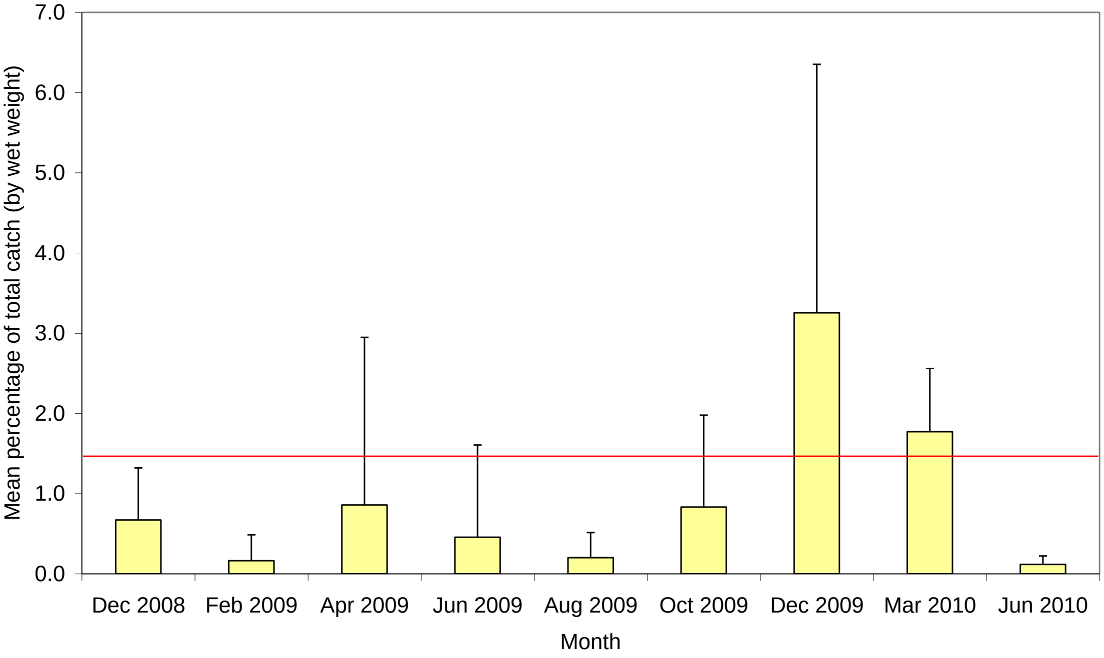


Figure 11: Mean percentage catches of cod captured during each month of the study. The 1.5% limit (indicative of the derogation limit under the EU Cod Recovery Plan) is shown in red. Error bars show one standard deviation.

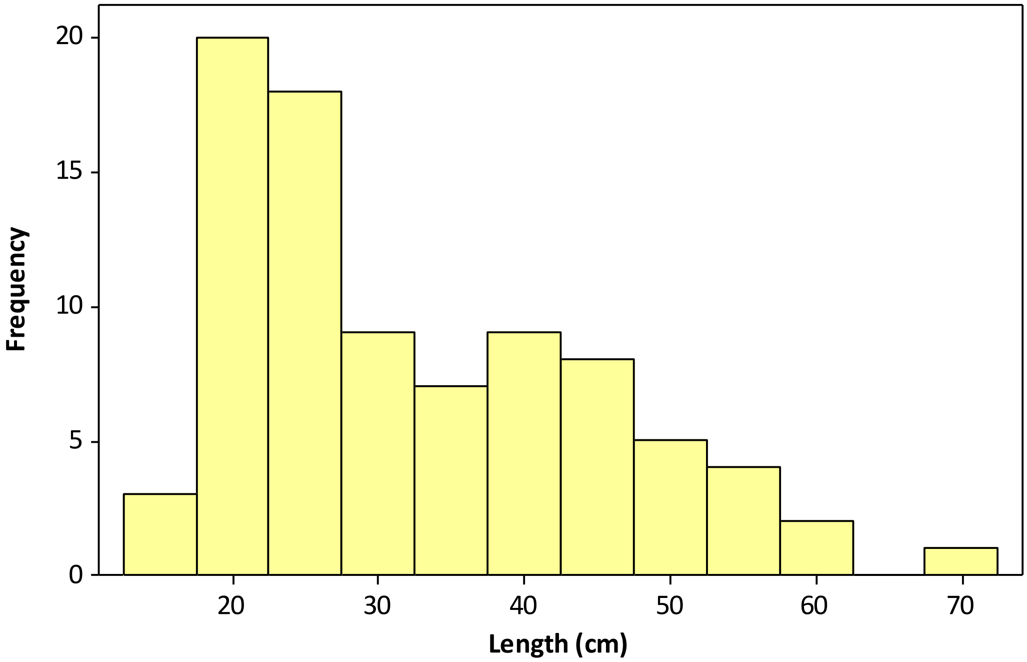


Figure 12: Length-frequency distribution of all Atlantic cod captured during the study period.

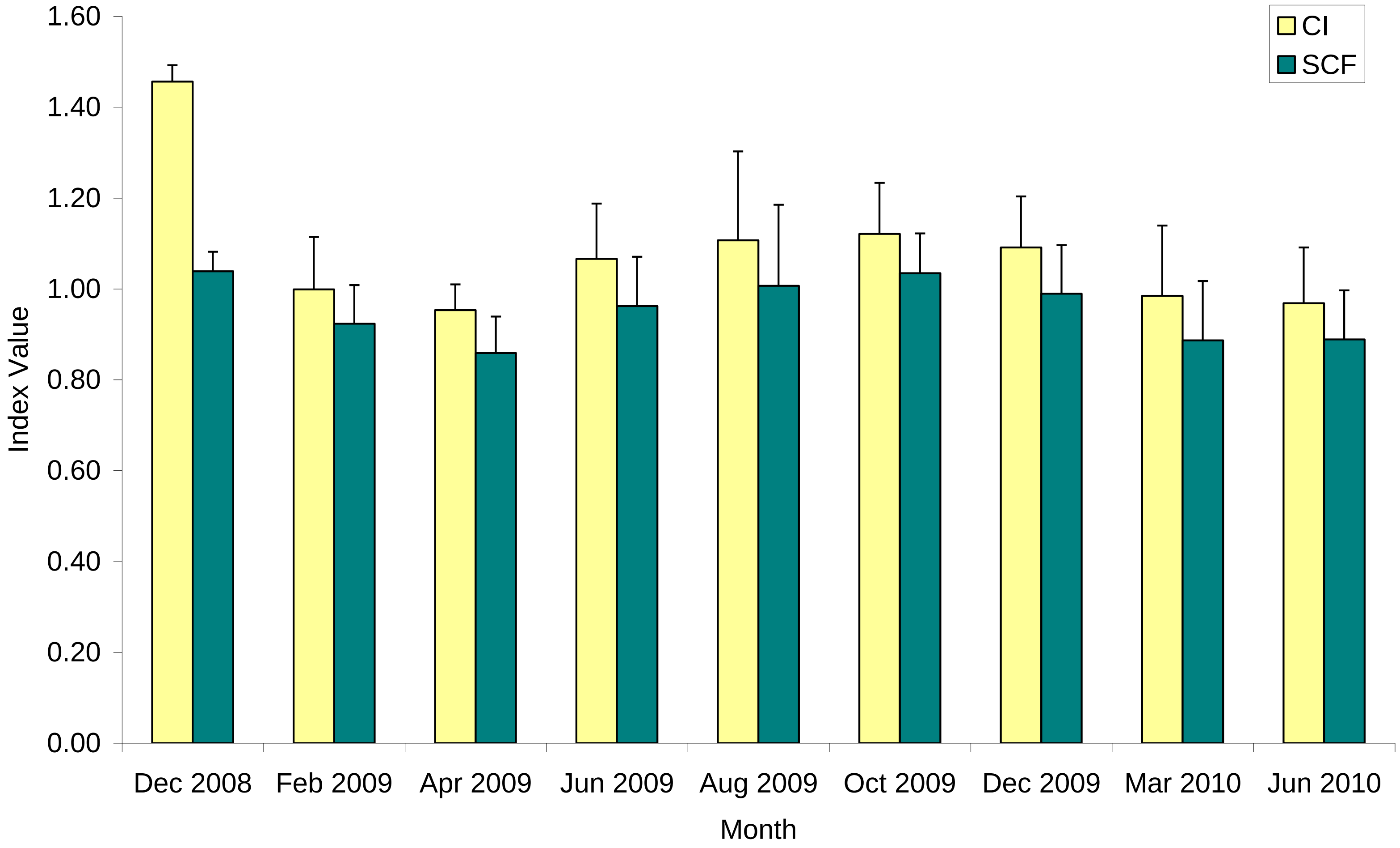


Figure 13: Mean CI and SCF values per month for Atlantic cod. Error bars show one standard deviation.

While GSI did not vary significantly with month ($p > 0.05$), it appeared that the highest index values were found in larger individuals which were over approximately 40-45cm in length. Linear regression showed the best fit to a quadratic curve ($R^2 = 47.8$, $p < 0.001$; Fig. 14). Piecewise regression may have been a more appropriate technique, but could not be conducted using the available software.

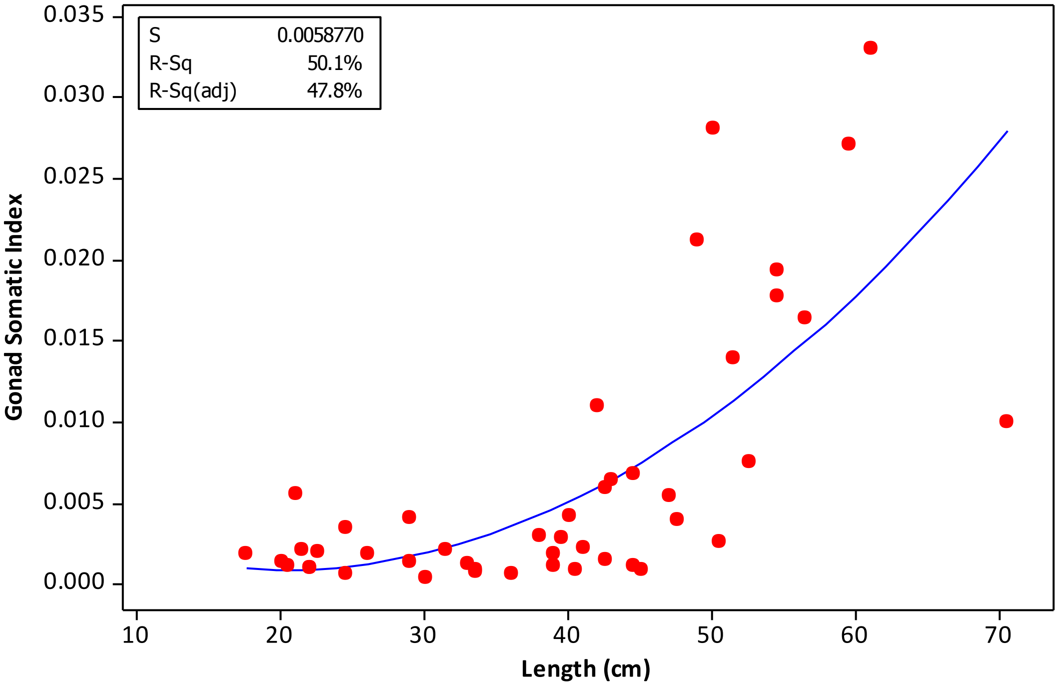


Figure 14: Linear regression showing total length (cm) against GSI values in cod. The fitted line follows a quadratic curve ($p < 0.001$).

Spurdog

A total of 100 spurdog were recovered from all trawls made between December 2008 and June 2010. The lengths and weights of the 6 animals captured in December 2008 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 8, and the length distributions for each month are shown in Figure 23.

Table 8: Numbers and mean lengths of spurdog captured between December 2008 and March 2010

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
Mar 2010	M	0	
	F	0	
Jun 2010	M	0	
	F	0	

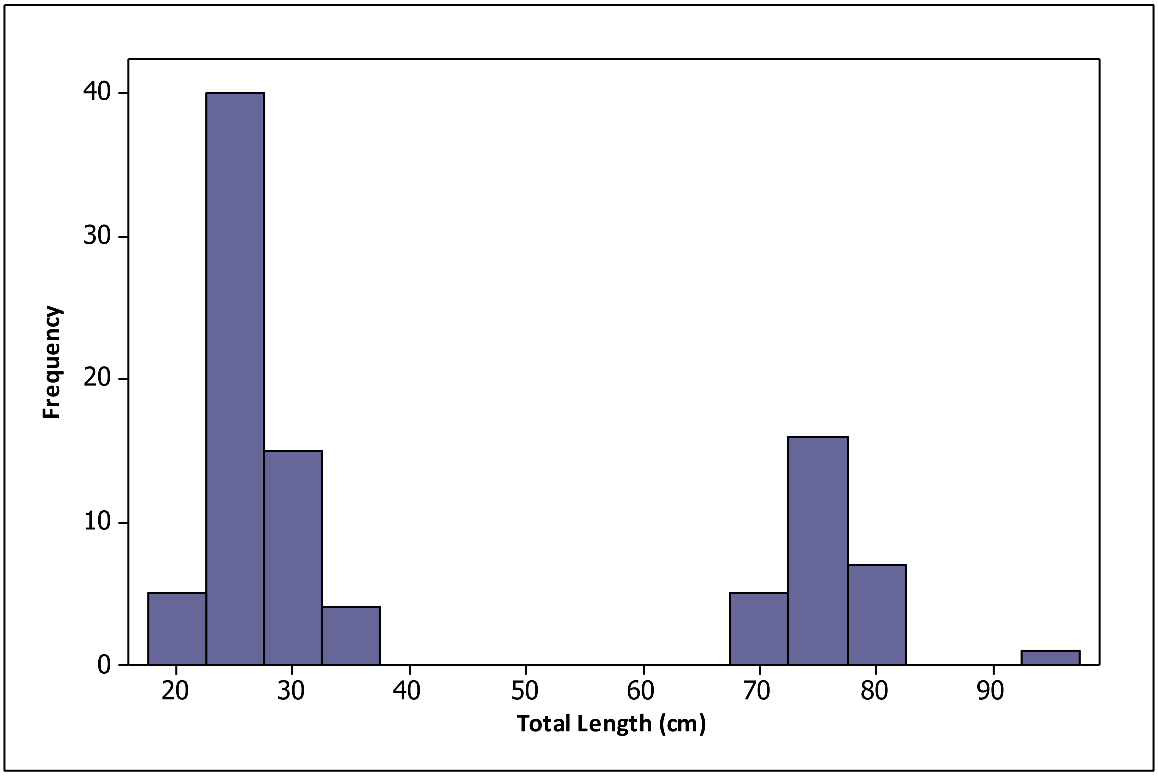
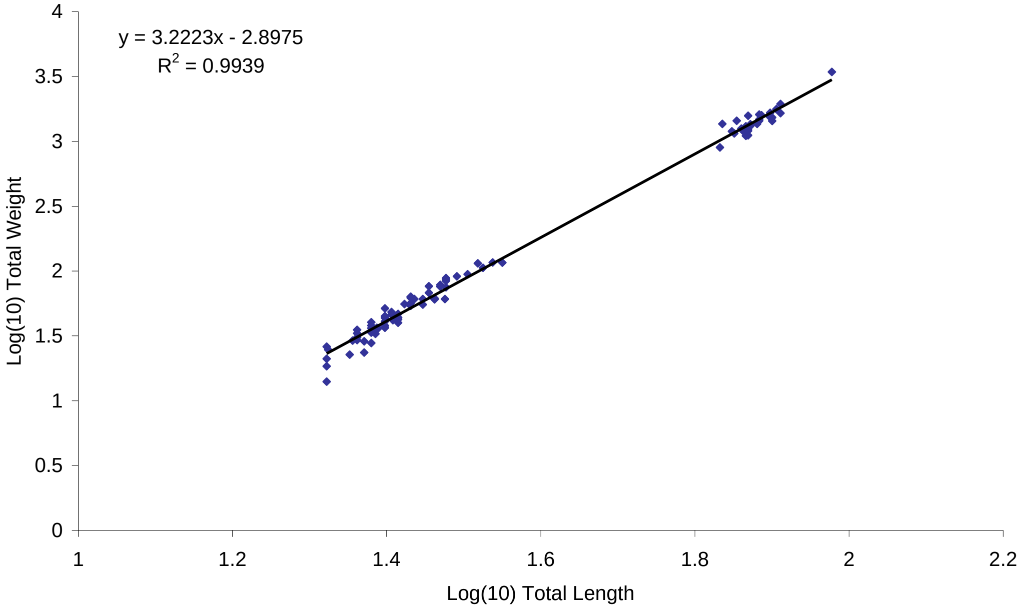


Figure 23: Length distribution of spurdog captured between December 2008 and March 2010.

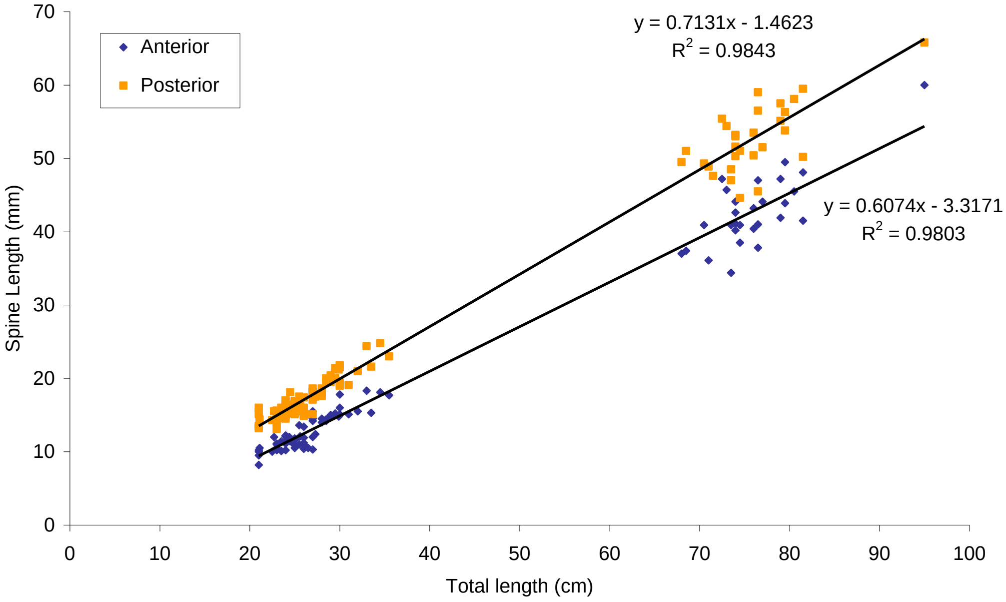
Individual spurdog were recorded as either immature or mature based on the relative length of the claspers in males or the presence of an enlarged or flaccid uterus in the females. All animals captured in June and August 2009 were immature while those captured in October and December 2009 were mature which correlated to the size of the individuals captured. Mature animals were found to be larger (mean total length = 75.9cm, $p < 0.0001$; mean total weight = 1465.1g, $p < 0.0001$) than immature animals (mean total length = 26.2cm, $p < 0.0001$; mean total weight = 51.7g, $p < 0.0001$).

Biometric measures (length, weight, anterior and posterior spine lengths) and the estimated age of each individual were strongly correlated (Figure 24), although there was evidence that the variability around the data increased in the larger (and older) individuals.

(a)


y = 3.2223x - 2.8975
R2 = 0.9939
Log(10) Total Weight
Log(10) Total Length
0
0.5
1
1.5
2
2.5
3
3.5
4
1
1.2
1.4
1.6
1.8
2
2.2

(b)


Anterior
Posterior
y = 0.7131x - 1.4623
R2 = 0.9843
y = 0.6074x - 3.3171
R2 = 0.9803
Spine Length (mm)
Total length (cm)
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
90
100

(c)

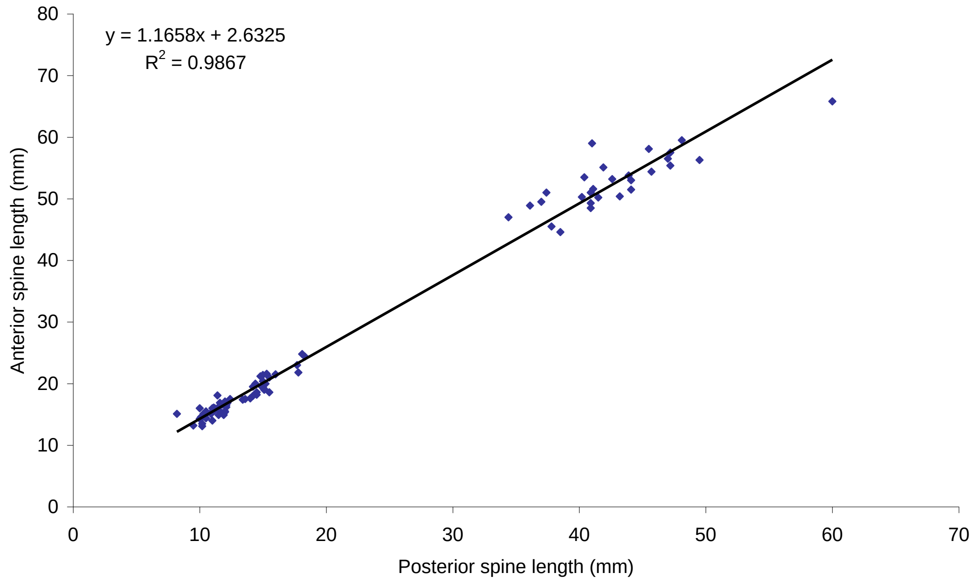


Figure 24: Morphometric relationships for spurdog: (a) Total length ($\log_{10}$ transformed) against total weight ($\log_{10}$ transformed), $R^2 = 0.99$; (b) Total length (cm) against anterior ($R^2 = 0.98$) and posterior ($R^2 = 0.98$) spine lengths (mm); (c) Anterior against posterior spine length (mm), $R^2 = 0.99$.

Age

Of the 100 total spurdog captured, 80 had spines which were considered suitable for aging. Of those 80 animals, the majority were young juveniles with estimated ages between 1 and 3 years, while the remainder were larger males with estimated ages of between 7 and 12 years. The estimated ages are shown in Figure 25 against the total length of each individual. Without expert guidance however, and with a low number of female samples in particular, it is difficult to assess how accurate these estimates are and the relatively high level of variability around each age point suggests that there is some degree of error in the data. Consequently, no attempt has been made at this stage to produce a growth curve.

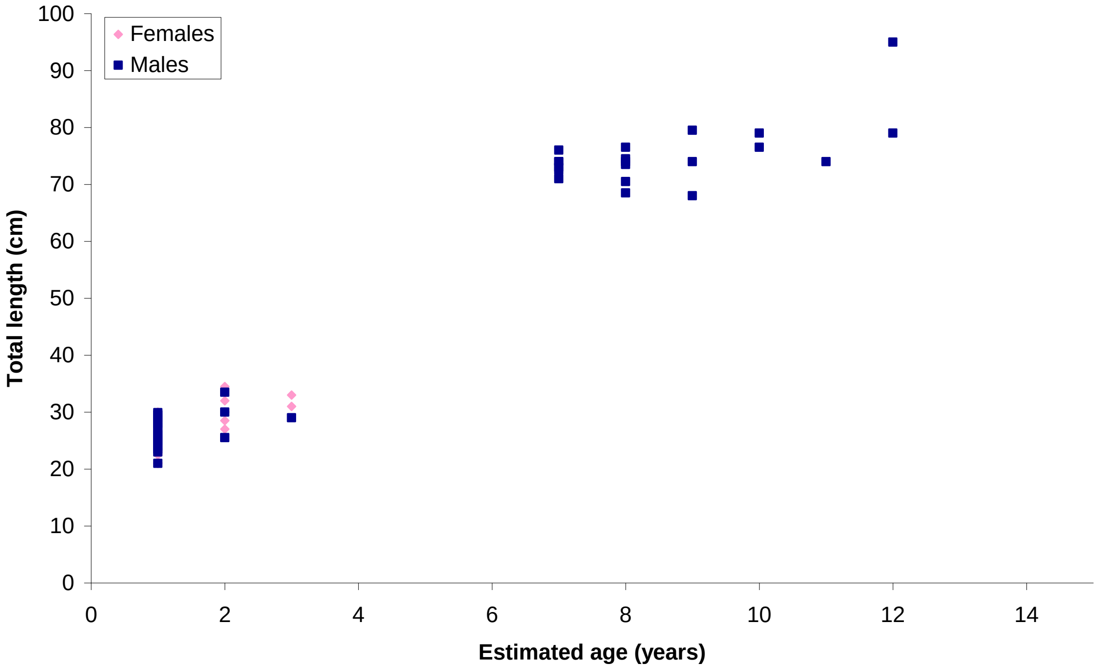


Figure 25: Age-at-length estimates for 80 individual spurdog captured between December 2008 and June 2010.

Discussion

The results show marked temporal variation in the composition of the catches over the course of this study, which is evident both in the overall abundance and biomass composition data, and also in the data for cod, spurdog haddock and whiting. This is similar to the results of other studies which have examined long-term trends in other fisheries. For example, Borges *et al.* (2005) examined the discarding practice in the Irish demersal fishing fleet between 1993 and 2002, and found that the rate of discarding and the size of discarded fish was highly variable between years. In the Irish *Nephrops* fishery, they found particularly high discards of small haddock and whiting in 2001 and 2002 which were reported to be ‘year 2’ fish between approximately 10cm and 20cm in length, which corresponds to the lengths of those species discarded in the present study.

While the total area surveyed over the period was not particularly large, broad spatial differences were also recorded within the region between the ‘south’ and ‘east’ sites although the reason for this separation is unclear. In their study of the Clyde sea area Bergmann *et al.* (2002) demonstrated that catch compositions could vary significantly over relatively small areas, as between the north and south basins. Those differences were believed to be the result of hydrodynamic and sedimentary differences between the two areas, but whether similar effects are occurring in the North Minch is not known.

However, despite the temporal and spatial variation in catch composition, the majority of the catches made were dominated by very similar species. In this study, these were found to be 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*). While the invertebrate bycatch has not been the subject of many studies, other investigations of the fish bycatch in *Nephops* fisheries in the Irish Sea, North Sea and Celtic Sea have also found whiting and pouts to be among the dominant roundfish species (Briggs, 1985, Stratoudakis *et al.*, 2001, Bergmann *et al.*, 2002, Rochet *et al.*, 2002, Catchpole *et al.*, 2005)**.**

The study by Bergmann *et al.* (2002) is the only one to describe the total catch composition including the invertebrates, but it records lower abundances of some species than were present in the North Minch. While separate grounds would not be expected to support the same communities, there were some differences of note, particularly the high abundance of the tall sea pen (*Funinculina quadrangularis*) in the North Minch compared to its absence in the Clyde sea area. This species occurs in the same mud habitats as *Nephrops* and is known to be susceptible to trawling disturbance due to its inability to withdraw into the sediment. Consequently, it is possible that this species could be used as an ecological indicator to indicate disturbance pressure between fishing grounds and 'pristine' areas, though far more data on the ecological requirements for this species and its natural distribution in Scotland are required.

Catches of cod and spurdog were very low in virtually all catches, as might be expected considering the depleted state of these species in the west of Scotland. However, this made it difficult to determine whether there were any consistent trends in the data. Spurdog are known to aggregate by sex when mature or together as juveniles which makes them susceptible to fishing pressure (Compagno, 1984), and the capture rates in this study reflect this, particularly for the juveniles. Therefore, despite apparent differences in the capture rate between the sites, it is unclear whether this result is meaningful at present, and further data on this population are required.

Section 2: Self-Assessment of Bycatch & Discards

Long-term monitoring of fisheries catches requires a strong working relationship between fishermen, processors and scientists but can involve considerable monetary and time costs if vessels have to be chartered to carry out survey work or if an observer is placed on board. A self-assessment system which allows much of the survey work to be carried out directly by skippers and crew with minimal interference from scientific staff has the advantages of being relatively cheap and simple to implement and allows more vessels to be targeted than could necessarily be achieved using observers. For this study in particular, it would allow the entire fleet of ten vessels to be surveyed relatively easily, rather than continuing to focus on the single vessel used through Objective 1. Additionally, crews are free to work as normal with no extra people on board, and depending on the methods used, such a system need not significantly disrupt normal working practice.

Any self-assessment system must be reliable however as there is considerable risk of bias, particularly if fishermen are required to log data which may be detrimental to the fishery in the short-term such as high catch rates of a sensitive species for example. It is important therefore to include standardised checks to ensure that the system is not being abused and that the self-assessment records are an accurate reflection of the catches being made.

The system developed for use in the Stornoway fleet was based on existing ‘YoungsTrace’ technology designed by Young’s Seafood Inc. and based on the scientific research carried out by the scientists from Glasgow University. The skippers and crew who would be carrying out the self-assessments were also consulted and their opinions were taken into consideration during the development stages.

2.1 YoungsTrace

The YoungsTrace system, developed by Young’s Seafood Ltd., is a traceability system which was originally designed to allow *Nephrops* trawl vessels to record when and where their catches were made by inputting their vessel’s activity (e.g. trawling, hauling the gear, travelling) during the course of a fishing trip. In return for using the system, which provided valuable information on catch quality and which stocks were fished, Young’s Seafood offered a higher price for any *Nephrops* catches landed while using it. Unlike the mandatory Vessel Monitoring Systems (VMS) that are a legal requirement on vessels greater than 12m and are always switched on (Neil Campbell, *pers. comm.*), the YoungsTrace system only recorded data following input from a member of a vessel’s crew.

This original system was redesigned during 2010 to allow information on the bycatch to be recorded as well as catches of *Nephrops*, based on the methodologies developed during the 2007-08 pilot trial and in Section 1 of the present study. This has been initially limited to recording the total numbers of cod and spurdog in catches, but may be extended to include more detailed information on catches later in the study depending on its reception from the fishing fleet.

2.2 Self-Assessment Methodology

The proposed self-assessment scheme was originally based on the methods developed and used during the scientific surveys, and required crews to sort one or two trawls per calendar month into five groups:

1. *Nephrops* (target catch, to be processed as usual)
2. Invertebrates
3. Roundfish
4. Flatfish
5. Sharks, Rays & Skate

Crews were asked to count and record the total numbers of cod and spurdog in the trawl, since these species were of particular importance. To assist with the sorting and ensure that it was done accurately, a photographic ID guide was produced showing the most common bycatch species for the area and the groups that they should be assigned to.

The number of baskets of each type were then recorded (to the nearest quarter basket), and could be converted into an approximate weight or proportion of the catch as appropriate and these data could then be compared to the data from the scientific trials. It was hoped that the two survey methods would complement each other, and produce a good overall picture of discarding practice and the bycatch composition within this fishery.

Finally, to ensure accuracy, skippers were asked to provide a random sample of approximately 20kg of bulk catch from one tow per month. This was then frozen and transported to the University of Glasgow for more detailed analysis of the species composition, weights and numbers.

Paper logbooks were distributed to the skippers in the fleet in March 2010 as a temporary measure while updates to the YoungsTrace system were being made. This required GPS, date and time information to be recorded manually to ensure that each catch could be traced.

Scientific trials of these methods were carried out in March and June 2010 to determine the level of accuracy that could be expected, and to establish how the self-assessment samples would compare to the more detailed scientific analysis of the catches carried out during Section 1.

2.3 Feedback from Fishermen

In order to ensure that this system was practical for the fishermen involved to use and that logging the bycatch would not be excessively time-consuming, informal discussions were held with the fishermen to establish their views and to determine their views on the self-assessment methods after they had had an opportunity to trial them between March and June 2010. It was generally felt that sorting an entire catch required too much time, particularly during the summer months when skippers and crews were typically working exceptionally long hours anyway. As a result, no data were collected from the fleet before June 2010. The methodology was therefore adjusted so that crews were only required to record numbers of cod and spurdog and to provide a random catch sample once per month. Unfortunately however, even this has proved difficult to achieve and while some random samples have been received from Stornoway so far, they have been too small to compare with the previous work, and no logbooks have been received. This work is ongoing however, and it is hoped that these initial problems will have been overcome by the end of 2010.

2.4 Validating the Self-Assessment Methodology

To assess whether the data obtained using the self-assessment system would be comparable to the scientific data collected during Objective 1, a trial was carried out during March and June 2010 on the *MV Comrade* to compare catches sorted by a) both scientists and crew and b) crew only. The crew were considered to be 'trained' in sorting methods as they had participated in previous surveys and were familiar with the procedures they were expected to use. Twelve tows were made, all at the 'south' sampling site (Fig. 30) to minimise spatial variability and followed the same methodology as used during Objective 1.

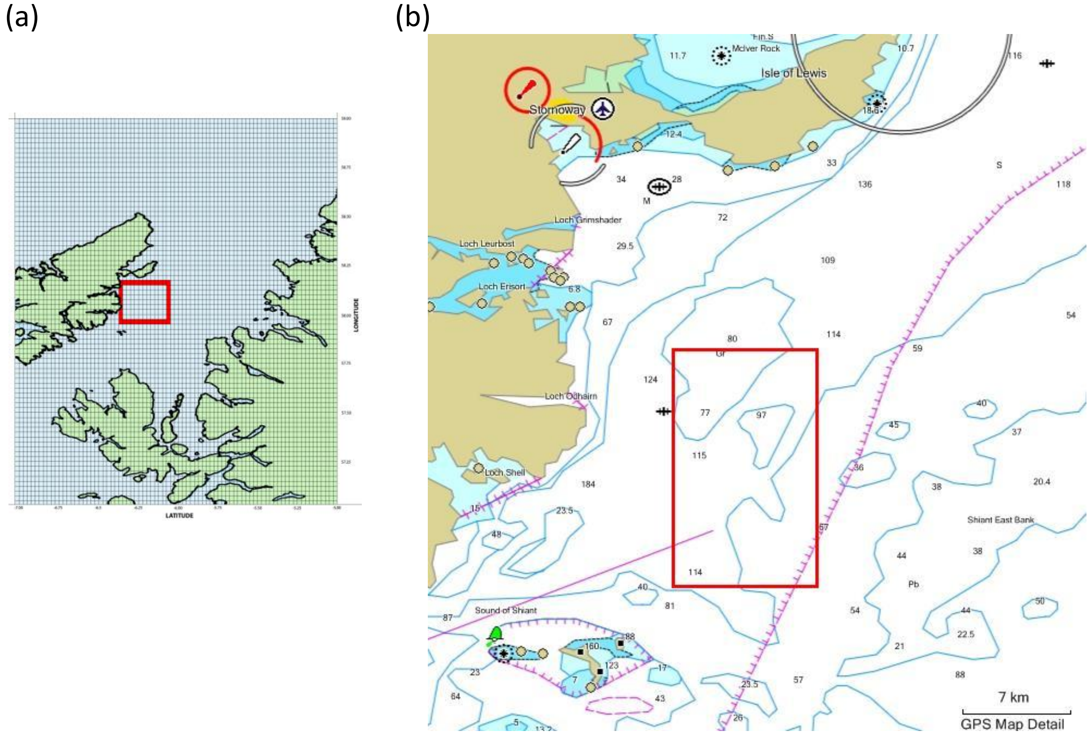


Figure 30: Maps of the study area showing (a) the limits of the sampling area (red box) and (b) detail of sampling area (tows made within red box).

As soon as each catch was recovered onto the vessel, a random sample was taken using a shovel to fill a fish basket with material directly from the hopper (prior to any sorting), and stored for analysis at the University of Glasgow.

The remainder of the catch was sorted at sea, and the individual species were identified, counted and weighed once back in the harbour. This was done using the same procedures described in Objective 1 to allow these catches to be compared to tows made during 2009. Samples of key species (cod, spurdog, haddock and whiting) were collected as before. All ‘discarded’ material (including *Nephrops* heads and animals missed during sorting) was also kept and weighed, and a subsample was taken for analysis in Glasgow University. Each catch could therefore be divided into three components: the random sample taken from the hopper, the ‘remainder’ (i.e. the bulk of the catch which was not sampled) and the discards.

The size of each random sample, and the personnel used to sort each catch is shown in Table 9. It should be noted that very poor weather and small catches in March 2010 meant that there was not always enough material to collect a random sample. Catches improved in June 2010 (and were more typical of this vessel), allowing a more complete survey.

Table 9: Data for each tow made in March and June 2010, showing the date, the personnel who sorted the catch and the size of the random sample taken (if any).

Date	Trawl ID	Sorted By	Random Sample
23/03/10	COM49	Crew & scientists	Not taken
23/03/10	COM50	Crew & scientists	Not taken
24/03/10	COM51	Crew only	¾ basket
24/03/10	COM52	Crew & scientists	¾ basket
25/03/10	COM53	Crew & scientists	¾ basket
25/03/10	COM54	Crew only	Not taken
15/06/10	COM55	Crew only	½ basket
15/06/10	COM56	Crew & scientists	¾ basket
16/06/10	COM57	Crew & scientists	¾ basket
16/06/10	COM58	Crew only	¾ basket
17/06/10	COM59	Crew & scientists	¾ basket
17/06/10	COM60	Crew only	¾ basket

On return to the University of Glasgow, the ‘discarded’ material was separated into *Nephrops* heads and whole *Nephrops* as previously described and ‘other species’. The ‘other species’ were animals that had been missed during the initial sorting and the identity and numbers of each species was recorded to allow the accuracy of the two groups of people to be compared. The random samples were analysed in the same way as the rest of the catch, and weights, numbers and the identity of each species was recorded. The compositions of the random sample and the rest of the catch were then compared in order to assess the feasibility of using random sampling as a possible self-assessment method. The data were then combined to allow the 2010 catches to be compared to those made in 2008-2009 using PRIMER.

Results

The catch data was interpreted using PRIMER 6 software, and was standardised and fourth-root transformed prior to analysis. MDS ordination and subsequent ANOSIM analysis showed significant differences in species composition between all three sections of the catch as shown in figure 31 ($R = 0.715$, $p < 0.001$). The month of capture also had a significant effect ($R = 0.502$, $p < 0.001$).

When the species composition random samples were compared to the remainder of each catch only, a significant difference was found between the catch sections ($R = 0.439$, $p < 0.001$) and between sample months ($R = 0.688$, $p < 0.001$) which can be seen in Figure 32.

The discarded sections were examined separately to determine how accurately each catch had been sorted by different personnel (i.e. whether one group was more likely to miss certain animals compared to the other). ANOSIM analysis showed that there was no significant difference between the discards whether they were sorted by the scientists and crew, or by crew alone ($R = -0.375$, $p > 0.05$) as shown in Figure 33. There was no significant effect of sampling month on these data either ($R = -0.25$, $p > 0.05$).

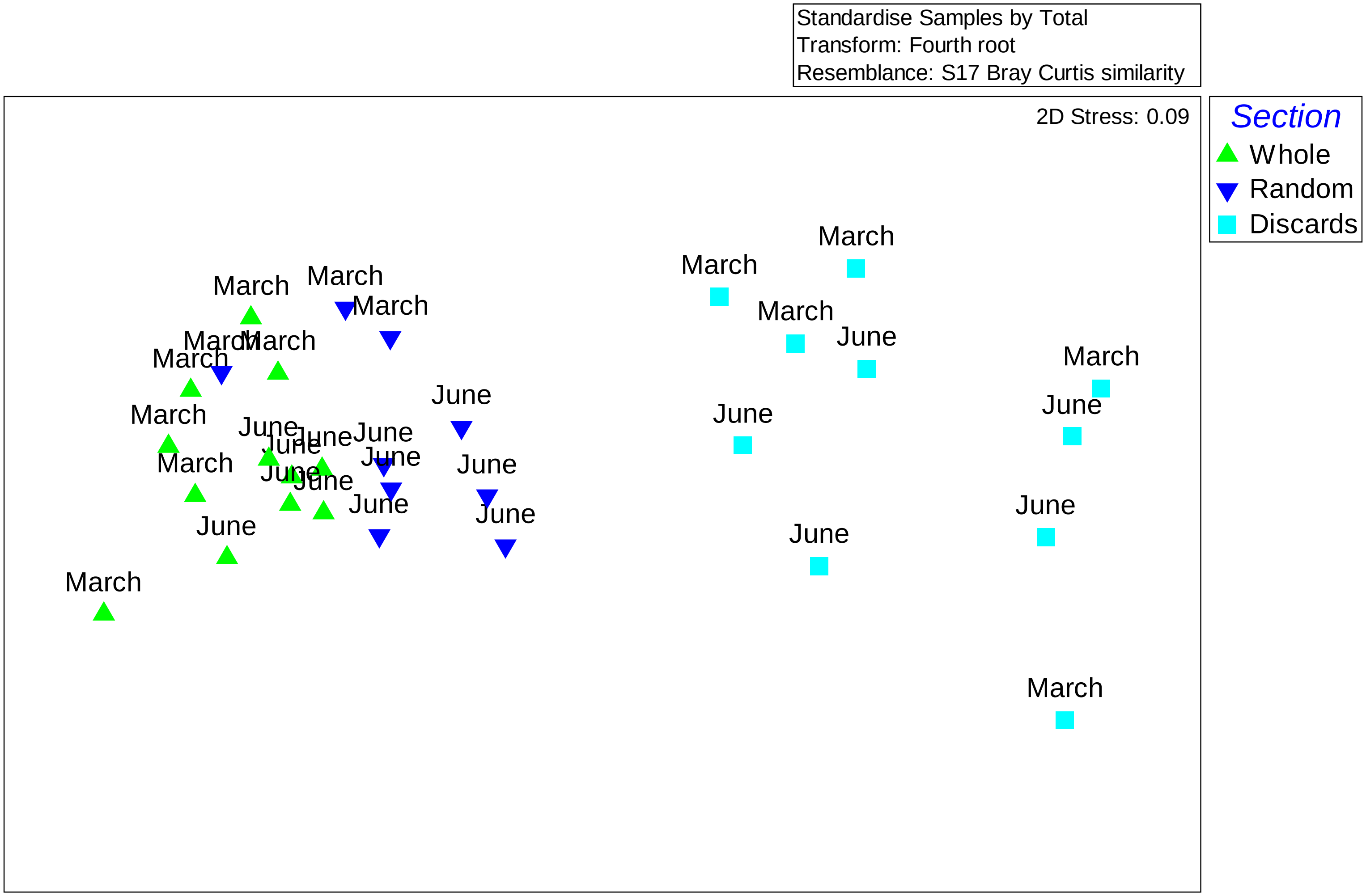


Figure 31: 2D MDS ordination showing the separation between the discarded (cyan), remainder (green) and random sample (blue) sections of each catch, and the sampling month is also indicated. ANOSIM: $p < 0.002$.

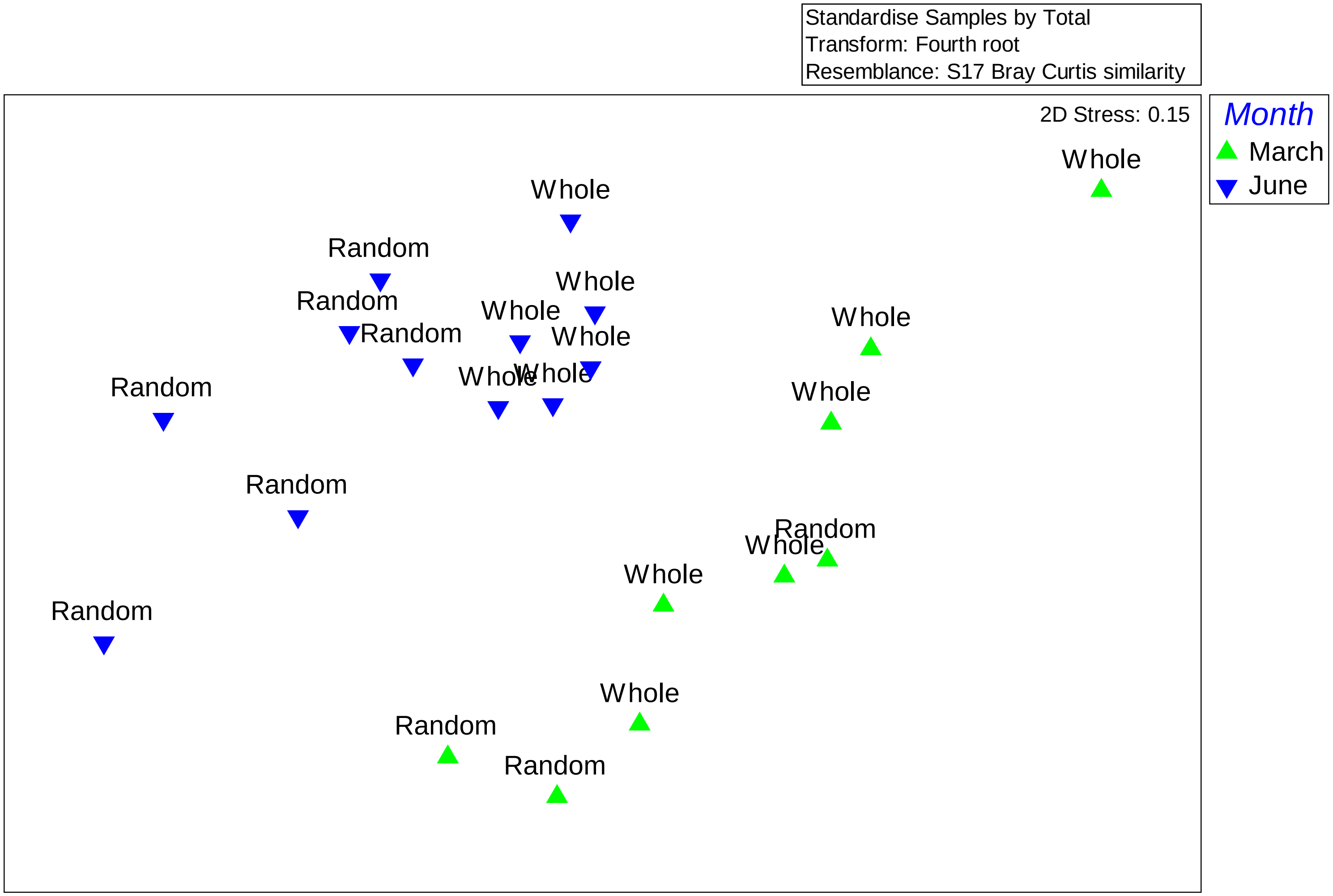


Figure 32: 2D MDS ordination showing the separation between the catch sections (labelled) and between sampling months. ANOSIM: $p < 0.001$. Note the relatively high stress of this plot.

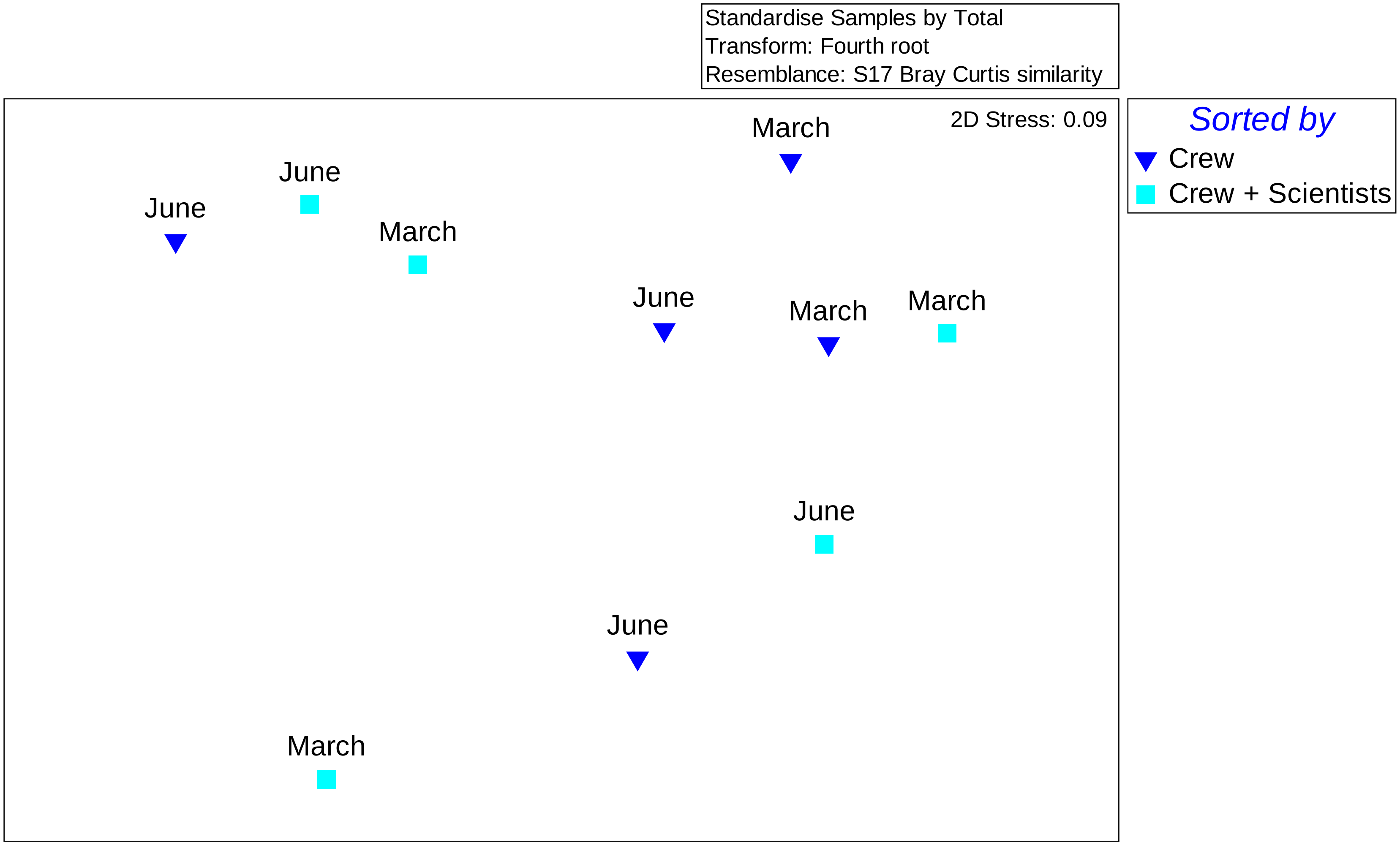


Figure 33: 2D MDS ordination showing the separation between the catch sections (labelled) and between sampling months. ANOSIM: $p > 0.05$.

SIMPER analysis was carried out to determine which species contributed most on average to the differences between the random and remainder sections of the catches. This test determined that 30 species contributed to 90% of the difference, with no single species contributing to more than 7% of the difference. Of the key species of interest, it was apparent that cod, whiting and haddock were more abundant on average in the remainder section than in the random samples, suggesting that this method of collecting a random sample leaves these species relatively under-sampled. By contrast, a higher average abundance of both *Nephrops* and pandalid shrimps were found in the random samples. The SIMPER data for these species is given in Table 10.

Table 10: Average dissimilarity data for key species between the random and remainder sections of the catches.

Species	Average Abundance		Average dissimilarity	Contribution (%)
	Remainder	Random		
Whiting	1.58	1.18	0.82	2.81
Haddock	1.48	1.10	0.81	2.75
Cod	0.51	0.15	0.63	2.15
Nephrops	2.70	2.90	0.43	1.47
Pandalid shrimp	0.97	1.06	0.83	2.82

However, when the proportional abundance of the major taxa within each catch section was examined, no differences were found between the remainder and random samples ($p > 0.05$) with the exception of the flatfish ($H = 17.24$, $df = 2$, $p < 0.03$) which were apparently undersampled in the random section. For all other groups (roundfish, elasmobranchs, invertebrates and *Nephrops*), there were significant differences between the discards and the other samples ($p < 0.05$), with fewer bycatch animals and more *Nephrops* being found in the discards. Similarly, the proportional wet weights of each major taxon only showed a significant difference in the weights of roundfish ($H = 18.33$, $df = 2$, $p < 0.04$), with a greater relative biomass occurring in the remainder than in either the random or discard samples. The proportional abundance and biomass for each major taxon are shown in figure 34.

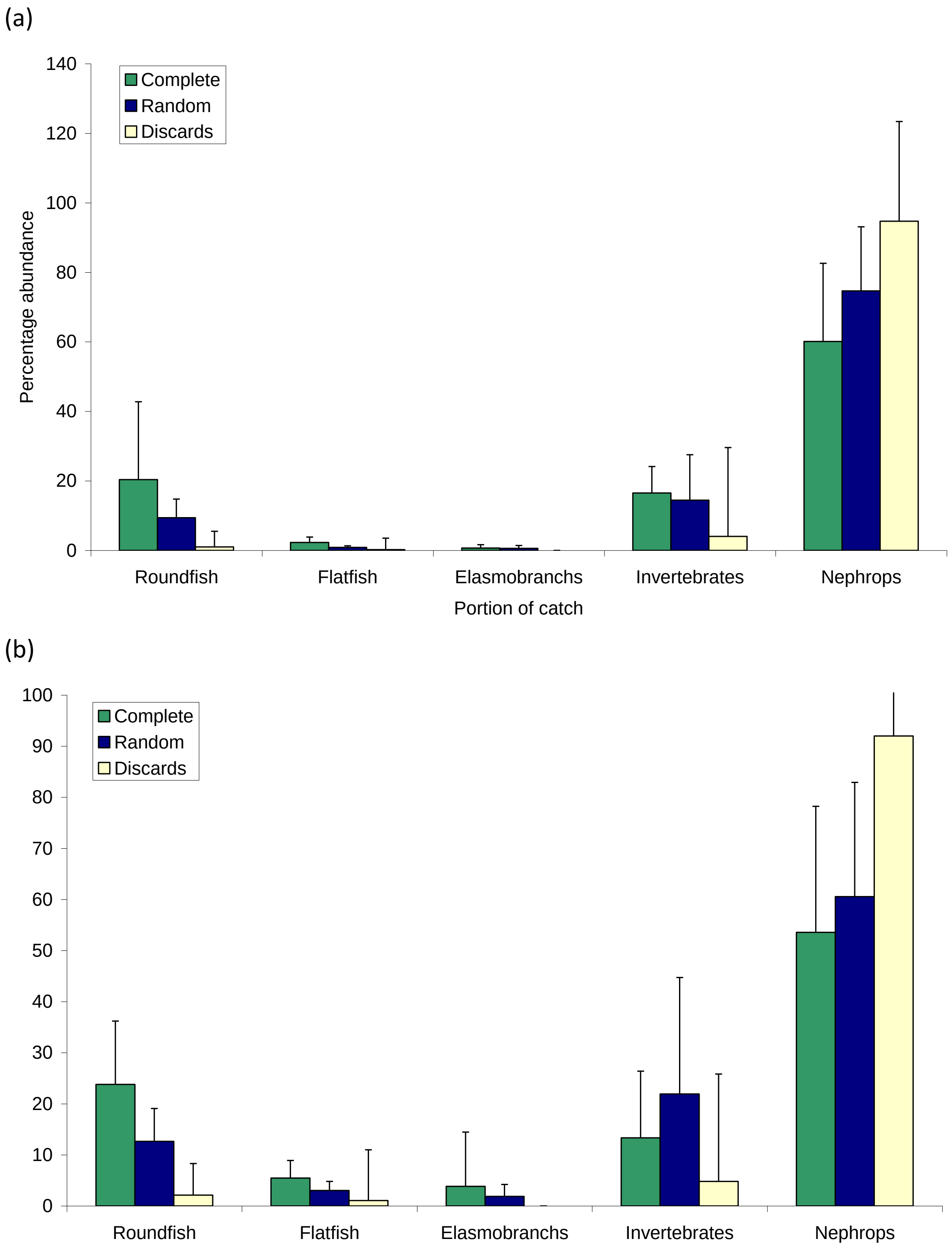


Figure 34: Proportional (a) abundance and (b) biomass of the major taxa occurring in each section of the catch samples. Error bars show one standard deviation.

The discarded portions of each catch were dominated by *Nephrops* (94.7% by number and 92% by wet weight), with the remaining composition typically comprising small roundfish (such as *Trisopterus* spp**.**) and invertebrates (dominated by pandalid shrimp, *Munida rugosa* and *Funiculina quadrangularis*). Small long-rough dab were also occasionally recovered.

Discussion

The results of this short trial show that a commercial fishing crew, once properly trained, are able to sort their catches into each of the major taxa described in section 1 as effectively as when a scientific team is working alongside. This is an encouraging result as it suggests that it may be possible to introduce wider self-assessment procedures in the future without loss of data quality (compared to a scientific assessment).

A number of challenges still remain however which would each need to be overcome before such a procedure could be introduced, including convincing the fishermen of the value of the work. This is likely to take time, but the procedures are now in place to ensure that the work continues across the fleet.

Small, random samples taken from a complete catch will not contain the full range of species present due, and some rarer species may be missed. However, the random samples have been shown to correspond well to the composition of the rest of the catch and showed similar distinction between the sampling months. As a result, this should be able to provide adequate baseline data on the overall catch compositions, while logbooks detailing the numbers of cod and spurdog captured at periodic intervals should provide suitable data on those species. Intermittent scientific observation will be required to ensure that the scheme operates as intended.

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