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The Irish Whale and Dolphin Group

SSTI
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Irish Multidisciplinary Deepwater Survey 2007

SSTI Project Report

By

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Executive summary

The Marine Institute with the collaboration of the National University of Galway conducted a multidisciplinary deepwater survey along the continental slope of the Northeast Atlantic. At three selected sites northwest of Ireland and on the northern slopes of the Porcupine Bank, fishing transects were carried out at four depth strata (500m, 1000m 1500m and 1800m) during the day, while oceanographic measurements and plankton and benthic invertebrate sampling was carried out during the night. Data from CTD and ADCP measurements showed following distribution of water masses: The top 700 m was occupied by that of Eastern North Atlantic Water (ENAW) origin which is a basic feature of the upper layer hydrography in the Rockall Trough; small salinity maxima indicated the region associated with the core of the shelf edge current (SEC). At Area 6, immediately north of Porcupine Bank, a salinity maximum at a depth of 900-1000 m indicated the presence of Mediterranean Outflow Water (MOW) with the presence Labrador Sea Water (LSW) at 1800-2000 m. The SEC was identified in both CTD and ADCP transects and was characterised by a number of relatively narrow filaments evident in the salinity data.

In terms of benthic invertebrate data, a total of 104 taxa were identified with a maximum number of 33 invertebrate taxa identified per haul (these values were recorded at two 1500m hauls in 2006 and 2007, in Areas 5 and 2, respectively). Overall, no clear relationship between the number of invertebrate species and depth was apparent, however there was some indication that the number of species appears to be more variable in deeper waters. Several species occurred in very large numbers; these were the echinoderms, *Cidaris cidaris, Benthegone rosea* and *Stichopus tremulus* and the bivalve, *Pseudammusium septemradii*.

Fisheries data revealed distinct deepwater fish communities that changed with depth and to a lesser extent with area. The number of species increased with depth at all sites to reach a maximum at 1500m before decreasing again at 1800m. At 500m depth the fish community was mainly composed of rabbit fish and rattails with some shelf species present such as hake, ling and silver pout. The 1000m depth strata presented a transition of species composition. The most abundant species overall was Roundnose grenadier which had is highest abundance at 1500m in all three areas but could also be found in the 1000 and 18000m depth strata. Other species of high abundance which also had their highest number of individuals at 1500m were Baird's smoothhead and other species of grenadiers. Cluster analysis revealed that Roundnose grenadier was a distinct species grouping as was that of Baird's smoothhead. Species occurrences were similar in all three areas with some regional differences; in area 2, *Phycis blennoides*, greater forkbeard,occurred among the ten most abundant species while in area 5, species, such as Black Scabbard, *Aphanopus carbo,* and cut throat eel, *Synaphobranchus kaupi*, were being caught here in larger numbers while present in the other areas in low numbers.

Seven comparative tows were carried out with the Scottish research vessels *RV Scotia* and indicated that overall similar numbers of species and total number of fish were caught. Size distribution also compared well between the two different vessels, however for some species the numbers or size ranges of fish caught differed.

Overall it can be concluded that this survey was very successful in demonstrating how deepwater sampling can by carried out in a multidisciplinary fashion by

- joining collaborative effort of marine scientists from different disciplines;
- making effective use of time and people's resources such as 24 hour operation with fishing carried out during the day and environmental sampling during night;
- using the survey as a sample collection platform for other research groups, and requesting the analysis results in return.

This resulted in comprehensive data collection that will provide the basis for a number of scientific studies in the areas of deepsea oceanography, plankton and benthic ecology as well as fish biology. Considering that the deepwater environment is less accessible and its research requires more resources than similar studies in shelf waters, a survey programme of this type presents the best value for money and provides the data required to study the deepwater ecosystem in a holistic fashion.

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1 Introduction

1.1 Background to the survey and its approach

The deepwater environment west of Ireland harbours a complex and highly diverse ecosystem that is shaped by its unique physical and biological characteristics. Most fish species are slow growing and long living, and therefore are particular vulnerable to over fishing and any recovery will be slow. In the early nineties the Marine Institute ran a series of deepwater fisheries surveys along the shelf in order to obtain information on the distribution and abundance of deepwater fishes. Since then the fishery has drastically expanded and the deepwater commercial species as well as species taken as a bycatch have experienced severe fishing pressure with many of the stocks being depleted or close to depletion. In order to warrant its urgent protection and the development of its sustainable management, there needs to be a better understanding of the deepwater ecosystem and its human impact.

As has been highlighted by our national marine strategy in Sea Change the development of sustainable management strategies for our fish stock hinges on our adoption of the ecosystem approach to fisheries management. It is now accepted that all aspects of the ocean are inter-related and should be treated as an integrated system and the new fisheries science required will rely on the coming together of communities of marine scientists. It was envisaged that the survey presented in this report will bring together marine scientists of different disciplines (physical, chemical and biological oceanographers, fisheries scientists) to gather and integrate various datasets in order to provide a comprehensive view of the deepwater ecosystem. This survey will allow us to revisit the initial survey areas of the nineties and study its ecosystem in a multidisciplinary fashion. It is hoped to characterise all aspects of its ecosystem and to investigate the impact of the high levels of exploitation on the abundance and biological parameters of deepwater species.

The deep waters to the west of Ireland have rarely been surveyed. Since the mid 1990s only one research survey was carried out by Ireland in waters deeper than 500m. The priority of the 2007 deepwater survey was to continue the time-series begun in 2006. An expansion of the area covered was also planned. Biological, chemical, benthic and oceanographic data would be collected at various stations, based on previous coverage. Trawling at 1800m would be carried out for the first time. Oceanographic and chemical data was collected by scientists from NUIG.

1.2 Aims and objectives

The 2007 deepwater ecosystem survey aimed to characterise the different components of the slope and deepwater ecosystem at three selected sites in the north east Atlantic in a multidisciplinary fashion.

The specific objectives of the 2007 deepwater ecosystem survey can be grouped into physical and chemical characterisation, water column biology and benthic invertebrate and fish biology.

The physical and chemical characterisation of the water column entailed the following:

- To collect hydrographic data on CTD transects across the slope at the 3 target sites, to measure the water mass structure and highlight the presence of the shelf edge current (SEC) through the temperature-salinity signal.

- To assess the residual (non-tidal) current components associated with SEC and to assess connectivity or otherwise of the SEC, both along the shelf edge north/northeast of Porcupine Bank and from along the Irish Shelf Edge east of Porcupine Bank (53N) section by collecting and processing underway ADCP data.
- To collect nutrient samples in order to assess the role of the SEC in transporting and cycling nutrients along/across the shelf edge.

Work on water column biology entailed:

- To carry out vertical phytoplankton net hauls for the identification of indicator plankton species and their comparison to CPR data (see below).
- To conduct continuous plankton (CPR) tows along the shelf edge between the 3 main fishing areas with a newly purchased CPR. This was to provide (a) a field test of the equipment and (b) data on the distribution of zooplankton and Chlorophyll colour along the shelf edge. This data was to be compared to the vertical phytoplankton net hauls made at the CTD stations
- To collect data on cetacean abundance and fishing activity.

Work on the benthic invertebrate and fish biology component of the ecosystem aimed to:

- Investigate the distribution and relative abundance of shelf edge, slope and deepwater fish communities across depth transects at the three target sites in the north-east Atlantic.
- To collect biological information on the main deepwater species including length, weight, maturity, sex ratio and feeding.
- To collect benthic invertebrates and bottom sediment samples for the description of the benthic deepwater habitat.
- To continue to build an inventory of deep-water invertebrate species that will contribute important information to the development of conservation plans, develop of atlas of species of potential for biodiscovery programmes and help identify environmental indicators of the impacts of fishing activity.

2 Methods

2.1 Area of Operation

The survey was carried out in three study areas along the continental slope of the northeast Atlantic. These areas were chosen to reflect fishing areas covered during the Irish deepwater survey programme in the 1990s and corresponded to the same three areas as the 2006 deepwater fisheries survey. Two areas were located on the western continental slope (regions 2&4) and one area on the northern slope of the Porcupine Bank (region 5). In each area, a scientific sampling programme was conducted with depth stratified fishing tows carried out during day time and sampling for hydrography, water column biology and benthic ecology during night time. The overall sampling area with individual stations is shown in Figure 1. As in 2006, the 2007 deepwater survey was coordinated with the Scottish deepwater survey that covers the slope in area VIa from 55º to 58.5ºN. The *RV Scotia* fished in Areas 2 and 4 approximately 1 week after the *RV Explorer* operated in each area. Information on the *Explorer* fishing activity was sent to the *Scotia* on several occasions during the survey.

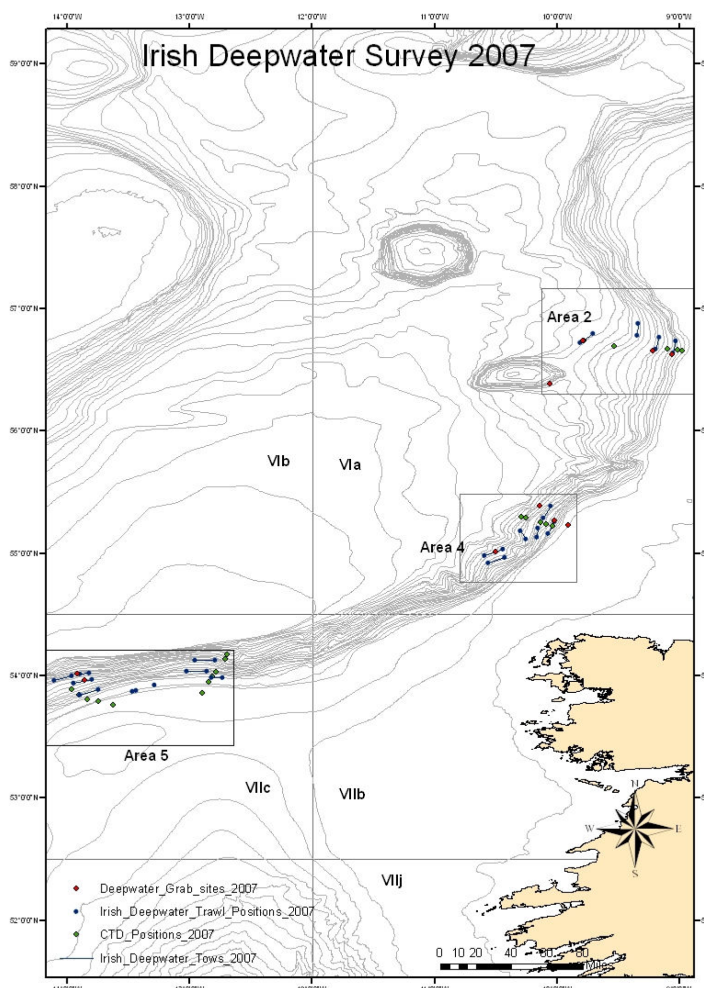


Figure1 .) Sample area and haul position of the Irish deepwater survey

2.2 Specific Operations:

2.2.1 Fish tows:

In each area trawl hauls were planned for four depths: 500m, 1000m, 1500m and 1800 meters. Trawl positions are shown in table 1. It was planned to carry out four tows in Area 2 and eight tows in Areas 4 and 5. The fishing gear used was a Jackson trawl with heavy groundgear (D-gear) and Scanmar net monitoring sensors. The doors used were Morgere ovalfoil 1700 kg doors (area 5.82 m), and the floats were 11" titanium floats. Tows were carried out along the slope. Information on possible clean fishing tows were derived from the 2006 survey, the Scottish survey and from commercial data, provided as SODENA files. Information on 1800m tows was only available for Area 2, so finding equivalent tows in Areas 4 and 5 involved surveying the areas during the night to find potentially clear areas. The effective fishing time was set at two hours and was taken from when the trawl doors settled on the bottom, to the net being hauled.

At each station the entire catch were speciated and weighed. In case of difficulties with species identification, specimens were tagged and stored for further identification. Each species was sampled in order to quantify the total weight and also the total number of each species present in the haul. For each species a random sample of the entire catch was taken for length measurements. Due to the great variety of body shapes of deep-water fish species and the fragility of their tails and fins some species are not measured to total length. The length measurements used for various fish species were agreed on with the Scottish survey and were as follows:

Sharks	total length
Skates	total length
Chimaeras	snout to base of third dorsal fin
Grenadiers	snout to base of anal fin
Bony fish	total length
Orange Roughy	total length
Black Scabbard	total length.
Smoothheads	standard length

Biological sampling (weight, sex, maturity, and age extraction) was carried out on the target species: blue ling, black scabbard, leafscale gulper shark, hake, common ling, angler fish, Portuguese shark, orange roughy, roundnose grenadier and tusk. Additional sampling of weight, sex, maturity, but not age was carried out on an ad hoc basis on a further 1193 individuals on chimeras, rat fish, cat sharks, dog fish, grenadiers spp., Baird's smoothhead, greater forkbeard and others.

2.2.2 Fish sample collection for external institutes:

Specified biological sampling was also carried out for five different institutes in Ireland, Germany, Portugal and the US:

Muscle samples of *Centrophorus squamosus* and samples from *Centroscymnus coelolepis* were collected for researchers from Portugal (IPIMAR) and the US (Virginia Institute of Marine Science) as an ongoing collaboration between these institutes and the Marine Institute. Muscle samples from 9 different species of etmopterid sharks were collected for the Natural History Museum in Munich. For a project at the Institute for Tropical Medicine in Tuebingen, skin samples and whole heads were collected to determine the possible presence of a previously unidentified sensory organ in certain species of deepwater shark, mainly of the Apristurus genus. Gill clippings from black scabbard, *Aphanopus carbo*, were collected for DNA analysis for University College, Dublin from Area 5.

2.2.3 Water sampling (CTDs)

CTD casts were carried out during night time operations along a transect in each area. Each area began at 250m and ended at 2000m and crossed at least one fishing track. Stations were 250m vertically apart. The CTD was lowered to within 10m of the bottom at each station. Water samples were collected at several points during each cast. Post processing of the data followed the standard procedure used in the Earth and Ocean Sciences. This included:

1) Conversion of SeaBird data file (.con file) to ASCII format and strip out the header information to a separation information file.
2) Input ASCII (text) raw data file into Matlab and strip out unwanted data columns to leave just Pressure, Temperature and conductivity data streams.
3) A check on the alignment of temperature and conductivity sensors to account for different time response and adjustment if required.
4) Run a median filter with a window of 121 points (equivalent to 5 seconds of data acquisition) through the data to smooth.
5) Calculate salinity from the filtered temperature, conductivity and pressure.
6) Run a median filter through the salinity data with the same window size as previously used to smooth spikes.
7) Discard data during up cast or parts of down cast when CTD is passing through a depth already obtained
8) Data average to 1 dB and 10 dB depth bins (contouring).

2.2.4 Underway ADCP

Additional data was collected using the underway ADCP. The underway ADCP system performed well during the whole survey with only one minor disruption to the data collection experienced during a period of problems with a number of shipboard electrical/navigation systems. Data was collected in 16m depth bins in bottom tracking mode (although this could not be used for the majority of the survey time). Data has been post processed by Dr. Christian Mohn of EOS using a version of the CODAS processing software. The steps taken were:

- Data averaging according to the requirements of spatial and temporal resolution (5 min ensembles).
- Rotate data from transducer to earth coordinates and verify the settings for the transducer head alignment in the Data Acquisition System. The ADCP was found to be 43° in misalignment. This mis-alignment was similar to that found during the PAP mooring maintenance survey the previous June.
- Scan and eliminate bad ADCP profiles/bins caused by bottom reflection, interference with physical objects and other occurrences affecting the measurement accuracy (only bins with a good value percentage > 20% are retained for further analysis).
- Determine the scale factors for transducer amplitude and orientation relative to the ship's gyro by using either water or bottom track calibration or both (depending on availability).
- Perform navigation calculation to obtain absolute ADCP currents in geographical coordinates and to smooth raw absolute velocities relative to a reference layer to reduce the effects of noise in the position fixes.
- Calculate absolute currents by subtracting the ship velocity relative to a reference layer (from ADCP velocities vertically averaged over a fixed depth range) from the ship velocity over the ground (from navigation).
- De-tiding of absolute velocities using an inverse tidal model and utilising the 4 main tidal components:- M2, S2, K1 and O1.

2.2.5 Vertical plankton recorder

A vertical plankton sampler was deployed at each of the CTD stations, immediately after the CTD was taken on board. It was sent to a depth of 200m each time.

2.2.6 Benthic Sampling

Benthic sediment samples were collected at each of the fishing depths in each area. Grabs were usually taken at night once fishing operations had finished. It was planned to use a Box corer, with Hammon, Shipek and Day grabs aboard as backup. At least one grab was made along a fishing track in each stratum. The samples retained were archived for future analyses when resources are identified.

2.2.7 Invertebrate sampling

All invertebrates were collected from each fishing tow. These were speciated and photographs were taken for the species identification catalogue. A species list was generated and level of abundance assigned to each species. The abundance scale assigned to each category is presented in Table 1.

Abundance Category	Density per Haul
Present (P)	≤ 5 specimens
Few (F)	≤ 10 specimens
Numerous (N)	≤ 20 specimens
Abundant (A)	> 20 specimens
Very Abundant (V. A)	> 50 specimens

Table 1. Notations used to document invertebrate abundances from the hauls.

2.2.8 Continuous plankton recorder

NUIG scientists planned to collect plankton samples using a CPR. The CPR would be towed between leaving port and Area 2, while steaming between Areas, and between Area 5 and returning to port. During this cruise, the Continuous Plankton Recorder was towed for a total of 60 nm. Further tows proved impossible as the internal mechanism failed during the first tow and repair was not possible at sea. As a result of the failure of the instrument, the sampling silk was only partially stored correctly within the storage canister. However, from that tow, it was possible to retrieve 4 samples for analysis. These samples were taken to the Sir Alistair Hardy Foundation for Ocean Science in Plymouth and analysed in Dec. 2007 by Colm O'Shea. For cross-analysis purposes, the samples have been retained by SAHFOS to be analysed again by their own analysts, allowing a further check on the training obtained by Colm O'Shea earlier in 2007.

2.2.9 Cetacean studies

A single marine mammal observer was present on board during the survey and conducted watches from the 'crow's nest' located above the bridge, 18m above sea level. Observer effort focused on a 90 degree arc ahead of the ship; however sightings located up to 90 degrees to port and starboard were also included. The observer scanned the area by eye and using 7 X 50 binoculars. Bearings to sightings were measured using an angle board and distances were estimated with the aid of distance measuring stick. Environmental data were recorded every 15 minutes using Logger 2000 software (IFAW 2000). Sightings were also recorded using Logger 2000. Automated position data were obtained through a laptop computer linked to a GPS Receiver Unit.

During the cetacean survey, a lookout was kept for any fishing vessels or fishing gear operating in the area. Vessel locations and fishing activity were noted where possible.

A separate report on marine mammal and seabird activity is presented in Appendix I.

2.2.10 Acoustic sampling

The Simrad ER-60 split-beam transducer was run throughout the survey.

3 Results

3.1 Overall sampling achievements

A total of 19 fishing hauls were carried out during the survey, of which 17 were valid. In area 2, one valid tow for each depth strata (500, 1000, 1500, 1800m) was carried out: in area four there were two valid tows for the 1000m and 1500m and one for 500m and 1800m depth strata, while in area 5 there were two valid tows at 1000m, 1500m, and 1800m. There were no valid tows for 500m in area 5, so a haul was carried out at 750m instead. The hauls by strata and area are shown in table 1.

Station	Area	Hauled Depth	Depth category
1	2	975	1000
2	2	493	500
3	2	1482	1500
4	2	1836	1800
5	4	981	1000
6	4	1047	1000
7	4	490	500
8	4	1470	1500
9	4	1877	1800
10	4	1477	1500
11	5	1010	1000
12	5	1482	1500
14	5	1008	1000
15	5	1483	1500
16	5	1815	1800
18	5	750	750
19	5	1827	1800

Table 2. Details of depth and area for each station of the 2007 deepwater survey.

Seven comparative tows were carried out with the *RV Scotia*, three in Area 2 and four in Area 4. Tows at 500m in Area 5 were unsuccessful with damage to the net on both occasions. Similarly we only completed one tow at 500m and one at 1800m in Area 4

A total of 25 CTD stations were occupied, forming 4 cross slope transects, during the course of the survey. CTD data was collected from 5-6 stations per transect, between 200-1800 m water depth. At all bar 2 stations, vertical phytoplankton net hauls were performed for the upper 100 m of the water column. A summary of the stations is given in Table 3 and the station locations in Figure 1. The CTD performed reasonably well, although there was an intermittent shorting problem which caused data to stop being collected and a restart was then necessary. The source of this problem was not found.

STATIONNO	AREA	NAME	LAT	LONG	DEPTH
1	2	A2_200	56.655	-8.983	208
2	2	A2_450	56.659	-9.021	450
3	2	A2_750	56.666	-9.102	732
4	2	A2_1000		Abandoned	
5	2	A2_450	56.624	-9.068	470
6	2	A2_1800	56.735	-9.790	2000
7	2	A2_1500	56.695	-9.536	1500
8	2	A2_1000	56.651	-9.225	1035
9	4	A4_200	55.228	-9.911	200
10	4	A4_450	55.222	-10.040	450
11	4	A4_750	55.235	-10.090	750
12	4	A4_1000	55.250	-10.136	1000
13	4	A4_1500	55.290	-10.259	1500
14	4	A4_1800	55.298	-10.293	1800
15	5	A5e_1800	54.170	-12.692	1860
16	5	A5e_1500	54.134	-12.708	1503
17	5	A5e_1000	54.032	-12.782	954
18	5	A5e_750	53.990	-12.817	750
19	5	A5e_450	53.951	-12.846	495
20	5	A5_350	53.855	-12.897	363
21	5	A5w_350	53.758	-13.621	342
22	5	A5w_500	53.789	-13.743	500
23	5	A5w_750	53.804	-13.833	750
24	5	A5w_1000	53.845	-13.905	1000
25	5	A5w_1250	53.886	-13.965	1260

Table 3. Depth and positions for the CTD stations.

3.2 Oceanography

3.2.1 Water Masses

Figure 2 shows a T-S diagram for a selection of the CTD data (10 dB averages) collected at the 4 transects. The distribution of water masses was that which would be expected for this region. Surface waters, above the seasonal thermocline at 50-75 m depth, were a lot cooler and fresher in areas 2 and 5, due to their location further north and adjacent to the main continental shelf. Upper layer water from σ_t=27.1-27.4 kg m^{-3} (top 700 m) was occupied by that of Eastern North Atlantic Water (ENAW) origin. Some small salinity maxima at about σ_t~27.3 indicated the region associated with the core of the shelf edge current (SEC). At Area 5, immediately north of Porcupine Bank, a salinity maximum at about σ_t~27.5 (900-1000 m), indicated the presence of Mediterranean Outflow Water (MOW) which was not present further along the slope in areas 4 and 2. Below this level, the water mass mixing line fell between the diluted MOW and the salinity minimum associated with the Labrador Sea Water

(LSW), at 1800-2000 m, which was only reached at the deepest stations in any transect.

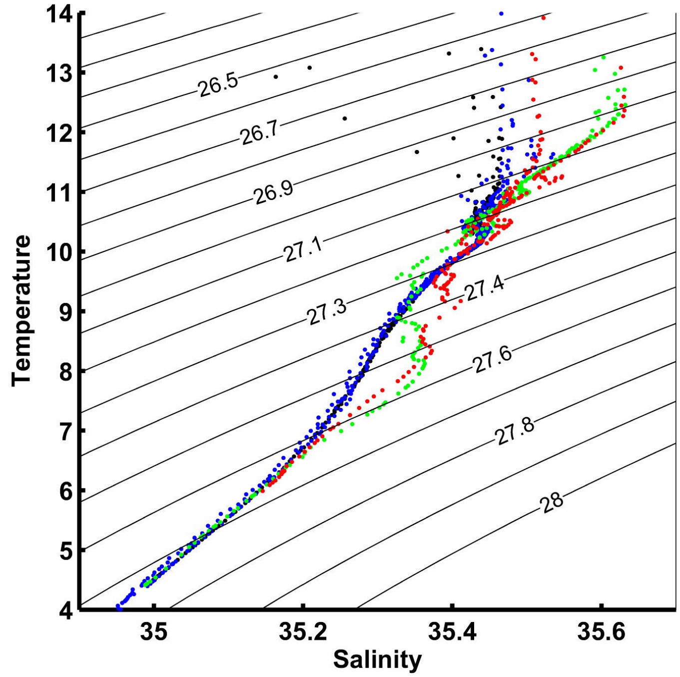


Figure 2. Temperature-Salinity diagram for a selection of CTD data for all 4 areas (black=area 2, blue=area 4, green = area 5e and red=area 5w). Lines of equal density are indicated by the thin black lines with contour interval 0.1 kg m^{-3}.

Taking just those profiles made at the 1000 m depth contour for all 4 sections (Figure 3), different Shelf Edge Current (SEC) cores may be highlighted by the small salinity maxima present between the density ranges 27.2-27.4, equivalent to a depth range of 200-600 m. These maxima were larger in absolute salinity value, as well as in amplitude at area 5 relative to areas 2 and 4. In addition, they were typically at a higher density, or at greater depth at area 5. Caution is advised however, as only those CTD profiles made at 1000 m water depth, so it may be that the core of the SEC may have been missed at some transects as it a narrow (~20 km) feature and is known to meander across slope. Maximum salinities were found just below the seasonal thermocline at area 5, which was also not apparent further along the slope. The presence of MOW at area 5, particularly at the eastern transect, was clearly apparent in the lower water adjacent to the seabed. This would be expected as MOW is found between 900-1100 m in this region and the proximity of the seabed would help steer the MOW along the slope contours. No suggestion of MOW presence was found at area 4 or 2, however, except for the minimal elevation in salinities found at this depth in profiles made in deeper water.

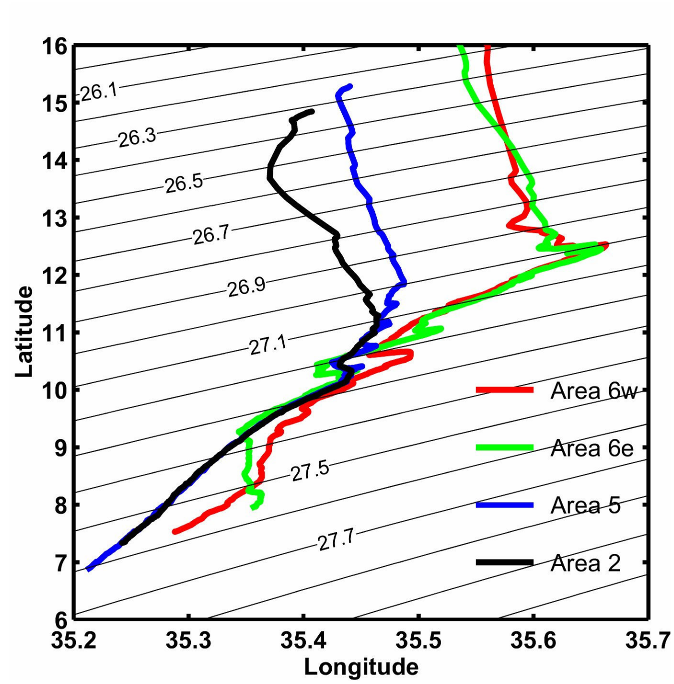


Figure 3. Temperature-Salinity (T-S) diagram for the 4 CTD profiles made at 1000 m water depth for the 4 individual transects denoted by the separate colours. Density contours are shown by the thin black lines.

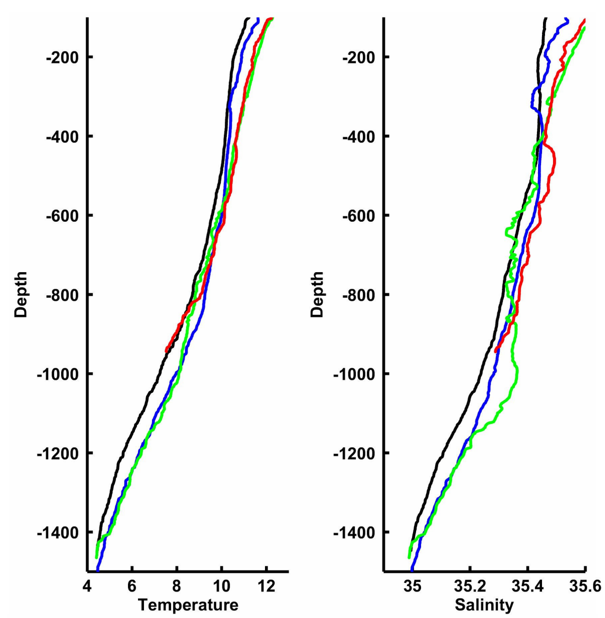


Figure 4. Vertical Profiles of (a) Temperature and (b) Salinity derived from the 1500 m water depth casts (1250 m at area 5w); (—) area 2, (—) Area 4, (—) Area 5e, (—) Area 5w.

The complexity of the salinity structure, particularly in Area 5 immediately to the north of Porcupine Bank, is apparent in Figure 4, which shows profiles of temperature and salinity derived from the 1500 m water depth profiles at each transect. The general cooling and freshening poleward along the slope for the upper layers above the permanent thermocline is readily apparent. For transects 5w and 5e, between 400-700 m, numerous salinity maxima can be observed in the vertical profiles which occur at different depths for the two transects which are only 40 nm apart.

3.2.2 Cross Slope Transects – CTD and ADCP velocities

Area 5w: At this section, made out to 1500 m water depth, the upper 600 m above the permanent thermocline was filled with warm, saline water (S>35.4) associated with ENAW (Figure 5). High salinity cores were found offslope at about 350 and 550 m depth. Adjacent to the slope a weak salinity maximum was found close to the seabed, perhaps indicating a topographically steered flow at the shelf edge. The picture is somewhat confused, perhaps suggesting interleaving or mixing of the water at this 'corner' of the Porcupine Bank might be occurring. The corresponding transect of underway ADCP data showed that the off-slope salinity cores in the upper 600 m were associated with a weak current flowing with shallow water to the right i.e. in a poleward direction (Figure 6). There was significant cross slope variation of the NE directed current component (approximately along the isobath orientation, again suggesting interleaving of water masses here. The maximum NE directed velocity core was centred at about 200-250 m and found closer to the shelf edge.

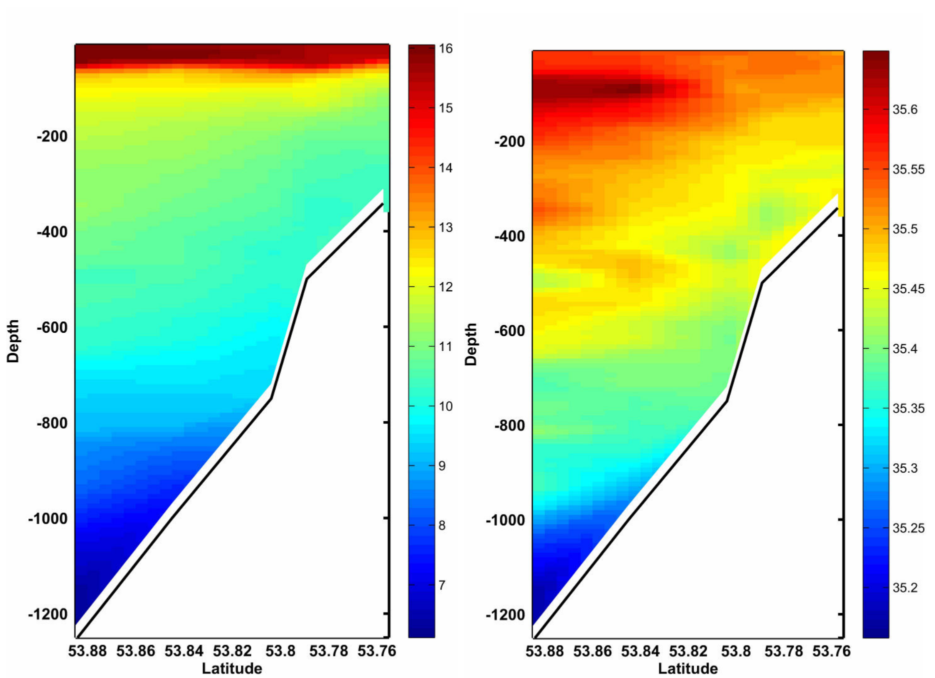


Figure 5. Cross slope section of (a) temperature and (b) salinity at transect 5w. A colour scale is given for both figures and the seabed is indicated by the black line.

Similar results were found for transect 5e (not shown). Again a number of high salinity cores were found off-slope.

(a) (b)

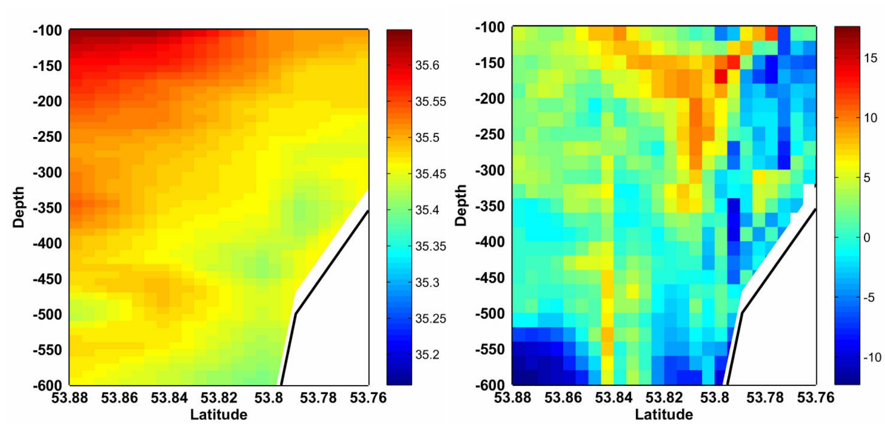


Figure 6. Cross slope transect of (a) salinity and (b) NE directed velocity (cm s-1, essentially parallel to the local isobaths) at transect 5w. A colour scale is given to the right of each figure for scale.

Area 4: At the Malin Shelf (Area 4), the upper 350 m was again filled with warm saline water (Figure 7). A deep salinity maximum at 400 m was separated from the upper layer by a salinity minimum. This deeper core was found slightly shallower at the shelf edge, at about 350 m, which is the depth of the deepest passage between the Irish shelf and Porcupine Bank west of Ireland. The deeper core, therefore, may be a result of two separate cores combining – one from the inner branch of the SEC flowing along the Irish Shelf Edge, and one derived from NW of Porcupine Bank (Area 5).

(a) (b)

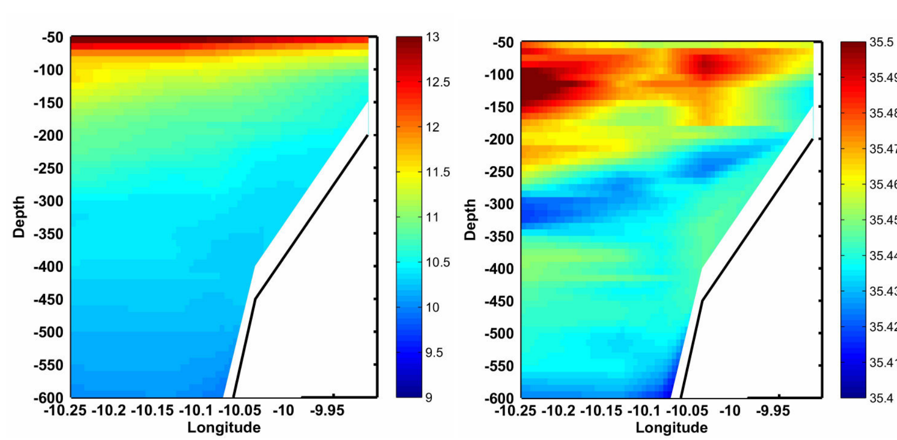


Figure 7. Cross shelf section of (a) Temperature (ºC) and (b) Salinity for the upper 600 m at Fishing Area 4 (Malin Shelf). A colour scale is given to the right of each figure.

Area 2: At area 2, the upper SEC core was manifest as a weak salinity maximum between 300-400 m, found away from the shelf edge and lying over the deeper portion of the continental slope (Figure 8). Immediately below the seasonal thermocline, the largest salinities were found between 75-100 m depth. Between temperatures of 6-8C, a very weak salinity inflexion indicated a minimal presence of elevated salinity at depths 800-1200 m. In the surface layer, the shelf edge was characterised by fresher water with a salinity front at the shelf edge separating this fresher water from the more saline oceanic waters.

The section of the northerly velocity component (i.e. the poleward along slope flow direction, Figure 9) showed that the weak salinity maximum centred at 350 m depth was perhaps surprisingly associated with a weak southward flow of less than 5 cm s^{-1}. Closer to the seabed, however, a stronger northerly (poleward directed) current up to 5 cm s^{-1} was measured, likely a result of tidal rectification at the seabed. Maximum currents were found at 550-650 m depth further off-slope. Whilst this may be a result of the ADCP being close to the limit of measurements, the strong poleward directed currents may be a result of a resonance in the tidal rectification at a depth of between 700-900 m due to the presence of strong vertical density stratification (permanent thermocline) in combination with the steep slope. The surface fresh layer at the shelf edge was associated with northerly flow, with a counter flowing flow above the seasonal thermocline further off-slope

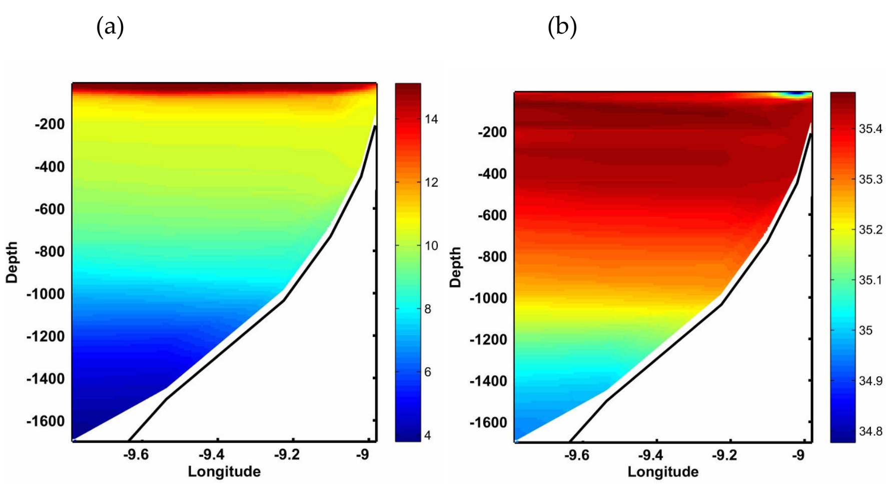


Figure 8. Cross shelf section of (a) Temperature (°C) and (b) Salinity for the upper 600 m at Fishing Area 2 (S of Hebrides Terrace). A colour scale is given to the right of each figure.

3.2.3 Hydrography Summary

Data analysis is still at an early stage. In particular the ADCP data will properly require a re-analysis of the de-tiding procedure and is presently ongoing. The water masses were essentially as might be expected for the region. The presence of ENAW in the upper layers is a basic feature of the upper layer hydrography in the Rockall Trough IT spreads northwards from its source off NW Spain and is carried in the

Eastern boundary currents close to the margin. The SEC was identified in both CTD and ADCP transects. The SEC is characterised by a number of relatively narrow filaments and this was evident in the salinity data. The course cross shelf resolution of the CTD transects probably hindered a more precise definition of the SEC current flow. This may need to be addressed in subsequent surveys. There was some tentative evidence for separation of cores at the Malin section which might suggest two separate SEC pathways for the SEC. In addition the rather 'confused' distribution of salinity across the Area 5 transects might indicate enhanced interleaving of water masses here, due to either mixing of water flowing along the western Porcupine Bank margin and water arriving in a North Atlantic Current extension from the west, or perhaps instability in the SEC as it reaches the NW corner of the Porcupine Bank. The MOW signal apparent in Area 5 was smoothed out in the two sections further north and this would have been expected at it appears MOW does not enter the northern Rockall Trough in any large or distinct volume.

The data has provided a good final year project for 1 marine Science student which has been greatly appreciated.

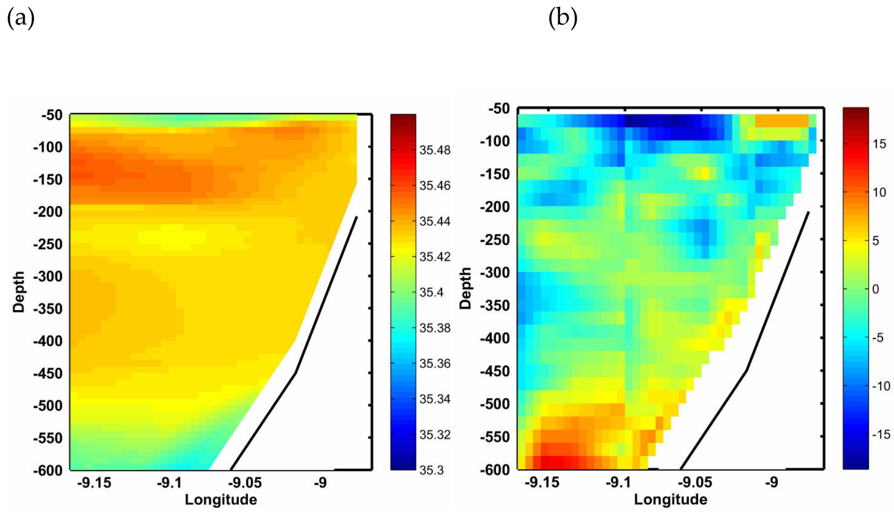


Figure 9. Cross slope transect of (a) salinity and (b) North velocity (cm s^{-1}) at transect 2. A colour scale is given to the right of each figure for scale.

3.3 Benthos

It is important to point out that the species identification presented in this report are tentative at best. Deep sea invertebrate species are relatively poorly described in the literature and there are relatively few authorities that can be consulted. The identifications were provided on-board as the samples were retrieved and were based upon keys generated from the survey conducted in 2006 and what ever literature was available to the survey team. No resources and time were available to more clearly identify the species in laboratory situations which would provide for consultation with recognised authorities- particularly for the more troublesome taxa e.g. sponges and some echinoderms. However, detailed descriptions were recorded from each taxa sampled. In addition, each were photographed and specimens were retained for future reference. Consequently caution must be advised when interpreting the species data as there could be instances where the same species are being counted more that once in term of presence. However, the figures can give some indication on the diversity and abundance of broad taxonomic group to be found in deeper waters of the Irish coast.

A total of 104 invertebrate species were identified from 18 hauls during this cruise. These consisted of 41 species of crustacea, 25 Echinoderms, 19 Molluscs, 6 coral species, 3 sponges, 4 anemones, 3 sea peas, 2 polychaetes and 1 Brachiopod. In general, fewer numbers of crustacean were noted in 2007 compared to 2006.

The species composition of the 2007 hauls was broadly similar to those of 2006, with more or less the same echinoderm, crustacean and mollusc species being recorded (Appendix 2). The additions to the previous cruise's species list were from the deeper trawls, i.e. 1500m and 1800m. *Glyphocrangon* sp., a deep sea shrimp was found at 1800m in all the Areas. The large pink holothurian, *Benthodytes cf. typica* was found at 1800m in Areas 2 and 4. While *Novodinia cf. pandina*, a large orange sea star found at 1500m and 1800m in Areas 4 and 5. Two squat lobsters and a large deep sea isopod that had not been recorded on the previous cruise occurred at 1500m depth, the former in Area 4 and the latter in Area 5. The former were found attached to coral species #3 which was only found in this haul. There were several species that occurred in very large numbers, they were the echinoderms, *Cidaris cidaris, Benthegone rosea* and *Stichopus tremulus* and the bivalve, *Pseudammusium septemradii*. Four species of parasite copepod were found. Sea pens were gathered for a Ph.D. student Emily Dolan in SOC Southampton. The starfish *Myxaster* (a new record for these waters) and the deep water shrimp (probably a new species) found on the previous survey were not found this year.

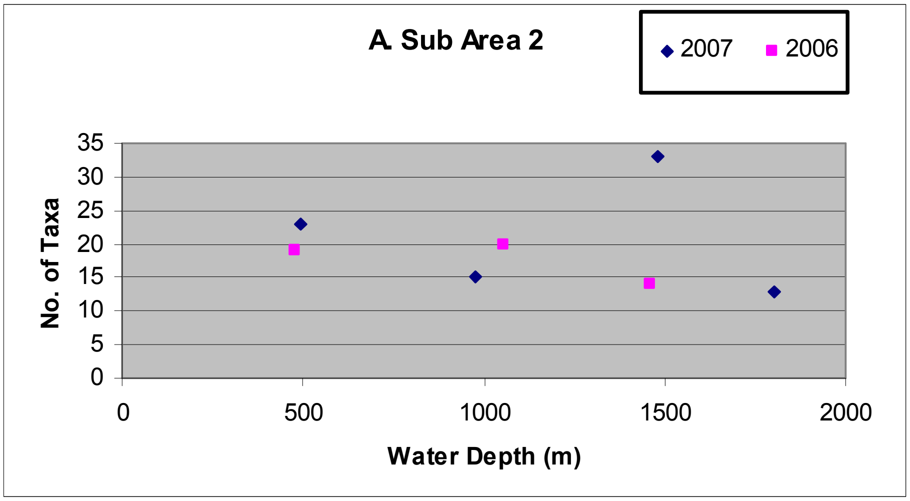
A summary of the data is provided in Table 4 whereby the number of species is presented with the haul data. The maximum number of invertebrate taxa identified from the hauls was 33 (these values were recorded at two 1500m hauls in 2006 and 2007, in Areas 5 and 2, respectively) and the minimum number of taxa retained was 3 (in 2006 at 1500m in sub-area 4). The number of species and corresponding depths were plotted against each other by year from each of the areas sampled and are presented in Figure 10. Overall, no obvious relationship between number of species and depth presents itself from the plots, although it would appear that the number of species appears to be more variable in deeper waters. From the 2006 data in Sub area 5 it also appears that there is an increase in taxa number with depth up to maximum of 1500m.

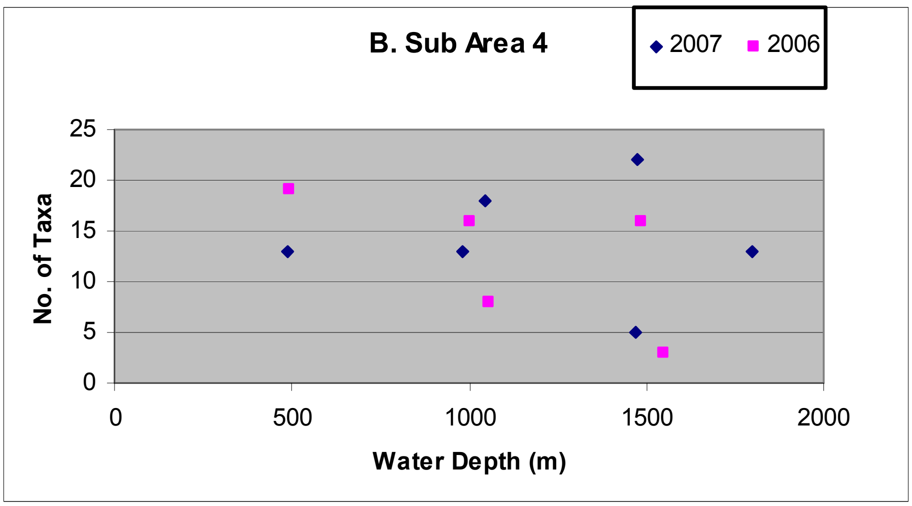
Sub Area 2							
Haul Number (2007 Coding):	*Haul 1*		*Haul 2*		*Haul 3*		*Haul 4*
Year:	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*
Depth:	975m	1053m	493m	476m	1482m	1459m	1800m
Number of Taxa:	15	20	23	19	33	14	13

Sub Area 4											
Haul Number (2007 Coding):	*Haul 5*		*Haul 6*		*Haul 7*		*Haul 8*		*Haul 9*	*Haul 10*	
Year:	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*	*2007*	*2006*
Depth:	981m	1004m	1047m	1058m	490m	493m	1470m	1488m	1800m	1477m	1550m
Number of Taxa:	13	16	18	8	13	19	5	16	13	22	3

Sub Area 5												
Haul Number (2007 Coding):	*Haul 11*		*Haul 12*		*Haul 14*		*Haul 15*		*Haul 16*	*Haul 17*		*Haul 18*
Year:	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*	*2007*	*2006*	*2007*
Depth:	1010m	998m	1482m	1496m	1008m	999m	1483m	1503m	1800m	423m	432m	750m
Number of Taxa:	14	21	20	33	25	28	16	27	8	18	15	24

Table 4. Summary statistics of hauls from 2007 with comparable ones from 2006.





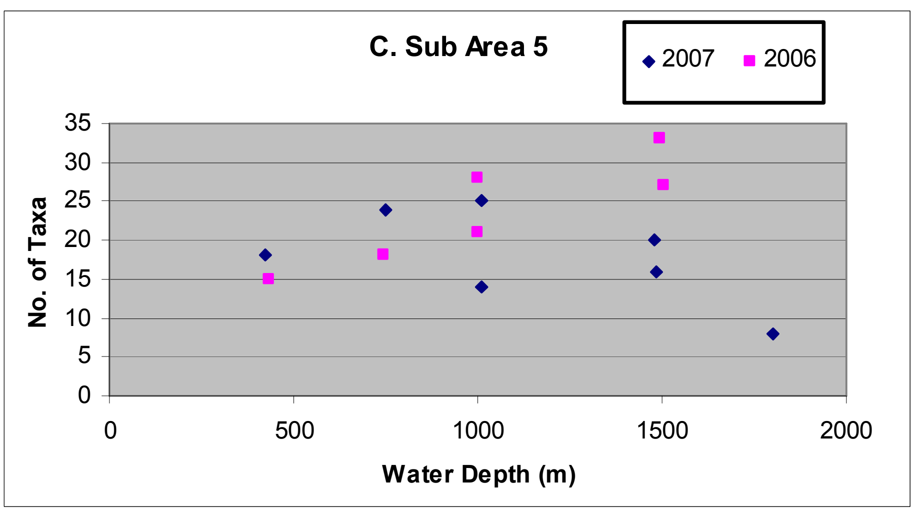


Figure 10. Plot of number of taxa versus depth fro the three sub-areas in the two years of sampling.

Infaunal benthic samples were taken in all Areas (Table 3). Due to the failure of the Box Core a Day grab was used for sampling the benthos which worked well until weather conditions deteriorated on the last few days of the cruise and efficiency decreased dramatically.

	SUB AREA 2	SUB AREA 4	SUB AREA 5
400m	*		
500m		*	
1000m	*	*	
1500m		*	*
1800m	*	*	*
		Trial Shipeck taken at 200m in this area	

Table 5. Depths of the Single Day Grab samples taken in each Subarea

3.4 Fish Communities

3.4.1 Overall fish sampling

A total of 115 fish species were identified from an estimated catch of 42,197 individuals, (22 tonnes). Of those 18,947 were measured. Biological sampling (individual weight, sex, maturity and age) was carried out on a total of 927 individuals of the target species shown in Table 6. Additional biological sampling (weight, sex, maturity, but no age) was carried out, on an ad-hoc basis, on a further 1193 individuals, Table 7.

CODE	COMMON	SCIENTIFIC	N OTO
BLI	MOLVA DYPTERYGIA	BLUE LING	57
BSF	APHANOPUS CARBO	BLACK SCABBARD FISH	244
CSQ	CENTROPHORUS SQUAMOSUS	LEAFSCALE GULPERSHARK	28
HKE	MERLUCCIUS MERLUCCIUS	EUROPEAN HAKE	62
LIN	MOLVA MOLVA	COMMON LING	24
MON	LOPHIUS PISCATORIUS	ANGLERFISH (MONK)	16
PUS	CENTROSCYMNUS COELOLEPIS	PORTUGUESE SHARK	35
RHF	HOPLOSTETHUS ATLANTICUS	ORANGE ROUGH-FISH	222
RNG	CORYPHAENOIDES RUPESTRIS	ROUNDNOSE GREN.	439
USK	BROSME BROSME	TUSK	8

Table 6. List of species on which additional biological sampling was carried out

SPECIES	SCIENTIFIC	COMMON	N BIO
RBF	CHIMAERA MONSTROSA	RABBIT FISH(RAT-TAIL)	328
NNC	Harriotta raleighana	Narrownose chimera	157
RTF	HYDROLAGUS MIRABILIS	RATFISH	143
ESP	ETMOPTERUS PRINCEPS		74
APH	Apristurus aphyodes	white catshark	71
CLA	Cataetyx laticeps		64
DCA	Deania calceus	Birdbeak dogfish	63
HAF	Hydrolagus affinis	Smalleyed rabbitfish	45
CGU	Coryphaenoides guntheri	Günther's grenadier	31
CSF	CENTROSCYLLIUM FABRICII		30
CMS	CENTROSCYMNUS CREPIDATER		30
RHA	RHINOCHIMAERA ATLANTICA		28
BSD	ALEPOCEPHALUS BAIRDII	BAIRD'S SMOOTH HEAD	25
CME	Chalinura mediterranea	Mediterranean grenadier	21
HPS	Hydrolagus pallidus		20
GFB	PHYCIS BLENNOIDES	GREATER FORKBEARD	17
MOM	MORA MORO		16
EGT	EPIGONUS TELESCOPUS		7
RDS	RAJA FYLLAE	ROUND SKATE	7
SNR	SCYMNODON RINGENS		4
BRI	Bathyraja richardsoni	Richardson's ray	2
AAF	Aldrovandia (Halosaurus) affinis		2
DGM	GALEUS MURINUS		2
CPS	NOTACANTHUS CHEMNITZII	CHEMNITZ'S SPINY-EEL	2
RKU	Raja kukujevei		1
VBY	ETMOPTERUS SPINAX	VELVET BELLY	1
HGA	HALARGYREUS AFFINIS		1
AME	Apristuris melanoasper		1

Table 7. Number of otoliths collected for the target species

Photographs were taken of 82 species and 112 fish were preserved in formaldehyde or frozen for future reference and confirmation of identification.

3.4.2 Depth distribution of fish community

One hundred and eleven fish species were recorded on the survey. The 5 most abundant species overall were Roundnose Grenadier, Baird's Smoothhead, Smooth Rattail andLepidon Eques and Murray's Rattail Their raised numbers are shown in table 8.

	SPECIES	SCIENTIFIC	COMMON	SumOfRais_Count
1	RNG	CORYPHAENOIDES RUPESTRIS	ROUNDNOSE GRENADIER	16237
2	BSD	ALEPOCEPHALUS BAIRDII	BAIRD'S SMOOTH HEAD	4365
3	SRL	NEZUMIA AEQUALIS	SMOOTH RATTAIL	3560
4	LPE	LEPIDION EQUES	LEPIDION EQUES	1779
5	MYR	TRACHYRHINCUS MURRAYI	MURRAY'S RATTAIL	1576

Table 8. The most common species by number (all hauls combined)

In all three areas it was found that the numbers of species present rose from a low number at 500m to a peak at 1500m, before dropping off at 1800m (Figure 11).

In Area 2 there was a gradual increase in species numbers from 31 at 500m to 36 at 1000m to 43 at 1500m, before dropping quickly to 25 species at 1800m. In area 4 the increase was more marked, from 15 species at 500m to 46 at 1000m and peaked at 53 at 1500m. Again a sharp decrease was noted to 28 species at 1800m. In Area 5 it proved impossible to tow at 500m, so a tow at 750m was carried out instead. 29 species were recorded. A species count of 45 at 1000m compared favourably to a similar figure in area 4. Once again the peak was encountered at 1500m with 53 species present. However the decrease in numbers at 1800m was smaller than other areas with 46 species being captured.

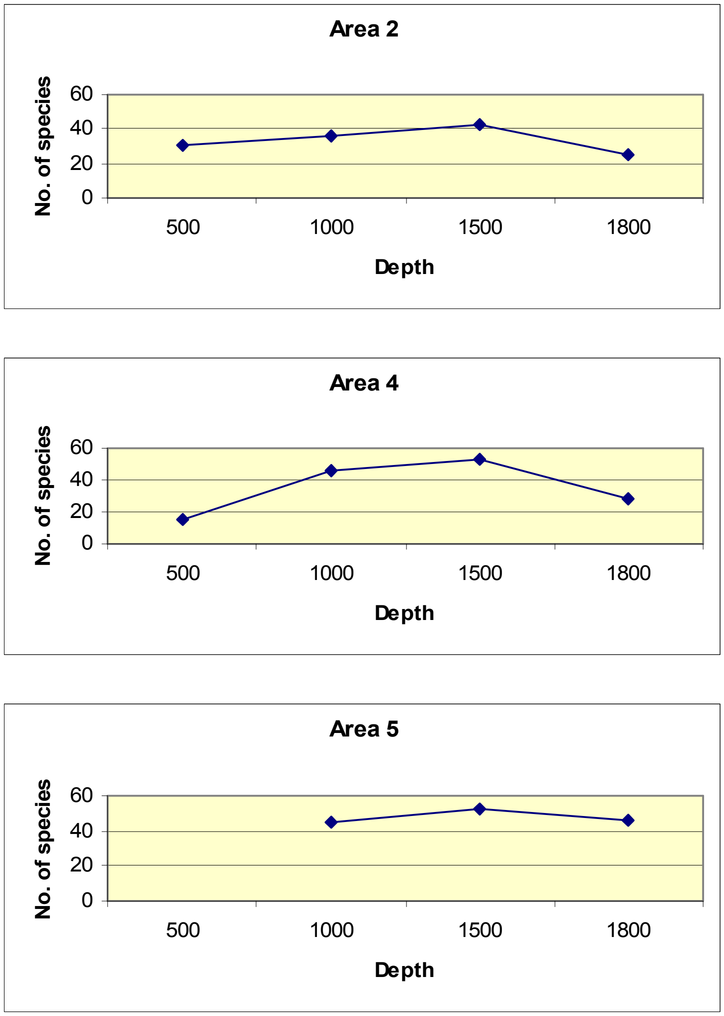
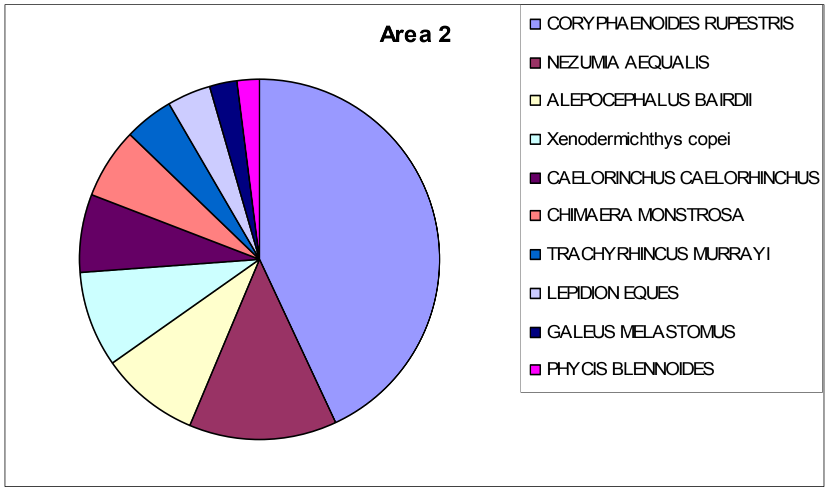
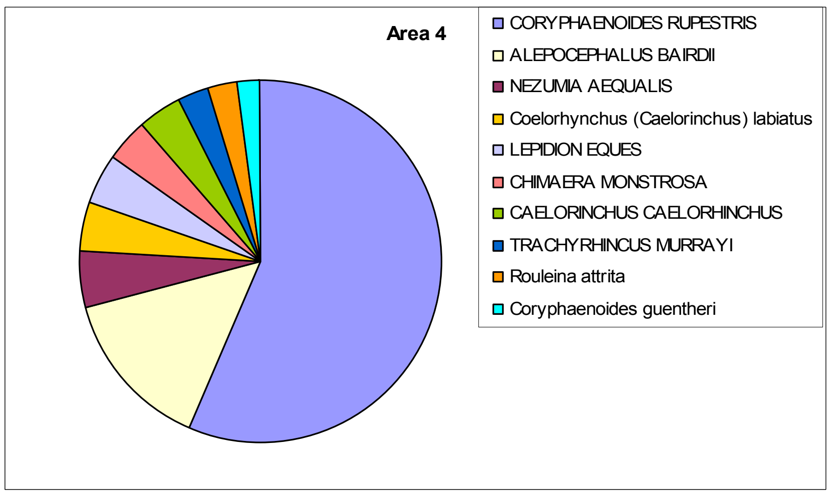


Figure 11. Numbers of species per depth per area.

Figure 12 shows pie charts with the ten most numerous species in each area. As can be seen from the charts, the most abundant species were similar in all three areas. *Coryphaenoides rupestris* was the most abundant species in each area. *Nezumia aequalis* and *Alepocephalus bairdii* were the next most common. Grenadiers provided the largest numbers of fish, but the species that produced the most biomass was *Alepocephalus bairdii*. In area 5, species, such as *Aphanopus carbo* and *Synaphobranchus kaupi*, which were present in the other areas in low numbers, were being caught here in larger numbers. In area 2, *Phycis blennoides*, greater forkbeard, is the tenth most important species, figure 12. It is hoped in future to fish a new area further south than area 5, to monitor changes in species composition.





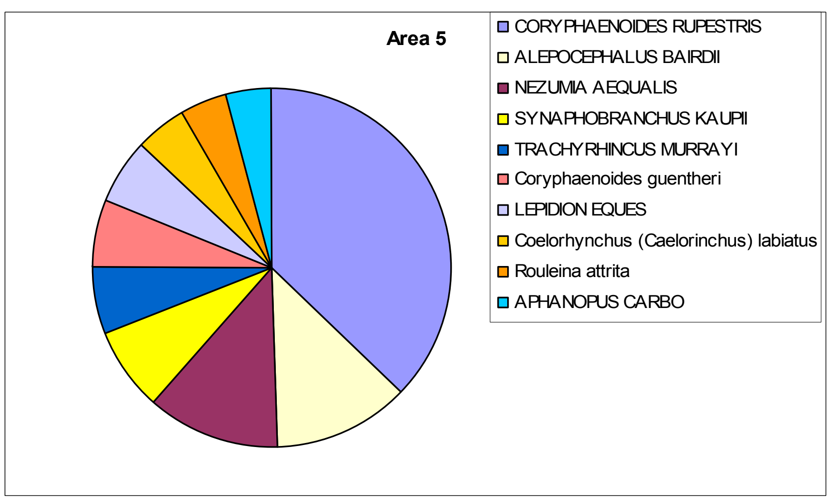


Fig. 12. Species composition of the 10 most abundant species in each study area.

Figure 13 shows a plot of the five most abundant species per depth per area. Catches are standardised per two hour tow. The largest catches occurred at 1500m in each area. In general catches per depth per area were very similar, except for 1800m in area 2. The low numbers at this site can be attributed to some gear damage. However despite this damage it can be seen from figure 13 that species numbers at 1800m in areas 2 and 4 were very similar.

In area 2 the main species at 500m were *Coelorhynchus coelorhynchus*, hollowsnout rattail, and *Chimaera monstrosa*, rabbitfish. Smaller numbers of *Merluccius merluccius*, hake, *Gadiculus argenteus*, silver pout and *Galeus melastomus*, black mouth dogfish, were also present. At 1000m *Nezumia aequalis*, smooth rat tail, was the most abundant. *Xenodermicthyes copei*, bluntnose smoothhead, *Coryphaenoides rupestris*, roundnose grenadier, *Lepidion eques* and *Aphanopus carbo*, black scabbard, were also important. *Coryphaenoides rupestris* was the main species, by numbers, at 1500m and was still present at 1800m. *Alepocephalus bairdii*, Baird's smoothhead were present in large numbers at 1500m, and provided the bulk of the biomass. Other grenadiers, *Trachyrynchus murrayi*, Murray's rattail, and *Coryphaenoides guntheri*, Günther's grenadier, were also present at 1500m along with *Synaphobranchus kaupi*, cut throat eel. Numbers caught at 1800m were quite small due to some damage to the net.

In area 4 the same two species dominated at 500m as in area 2. Much smaller numbers of *M. merluccius*, *G. melastomus* and *Molva molva*, ling, were found. *A. bairdii* were found in large numbers at both 1000 and 1500m, but again, the main species at these depths was still *C. rupestris*. Both species were also found at 1800m, but in lower numbers. *N. aequalis* were present at 1000m along with *L. eques* and small amounts of *Centroscymnus crepidater*, Leafscale gulper shark. *Coelorhynchus labiatus*, spear snout grenadier, *T. murrayi*, Murray's rattail were found at 1500m along with *Rouleina attrita,* softskin smoothhead. Rouleina, *Chalinura mediterraneus*, mediterranean grenadier, and *C. guntheri*, Günther's grenadier, were also found at 1800m.

Fishing attempts at 500m in area 5 were unsuccessful, instead a haul was carried out at 750m. *N. aequalis* was the most numerous species, followed by *Helicolenus dactylopterus*, bluemouth, *Deania calceus*, shovelnosed shark, *A. carbo* and *L. eques*. At 1000m *Nezumia* was again the dominant. *C. rupestris* and *L. eques* were here in large numbers. Also present was *A. carbo*, and *X. copei*. *C.* r*upestris* and *A. bairdii* continued to dominate at 1500m, and were present in smaller numbers at 1800m. The 1500m hauls also contained *T. murrayi*, Murray's rattail, and *C. labiatus*, spearsnout grenadier along with *S. kaupi*, cut throat eel, which was also an important species at 1800m. At 1800m the largest species caught was *C. guntheri*. Also present in smaller amounts were *R. attrita*.

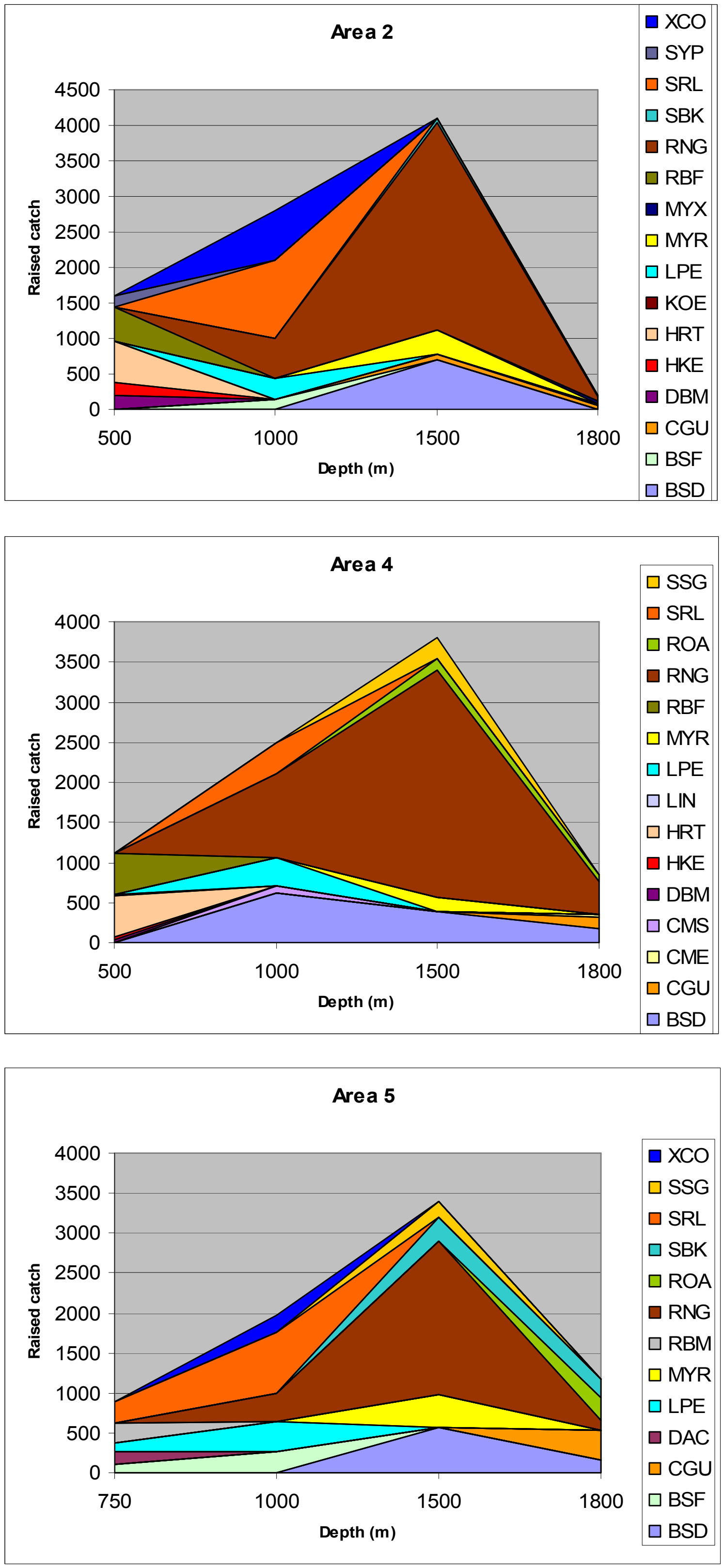


Fig. 13. Depth distribution of the five most abundant species by number per depth strata per area.

3.4.3 Cluster Analysis

Analysis

Principal Component Analysis (PCA) was run on species proportional weight within each station/haul (i.e. weight of RNG as a proportion of the total haul weight).

Station 7, 13 and 17 were discounted – invalid hauls

The main variation within the dataset on component 1 – over double that of component 2 (Fig.14)

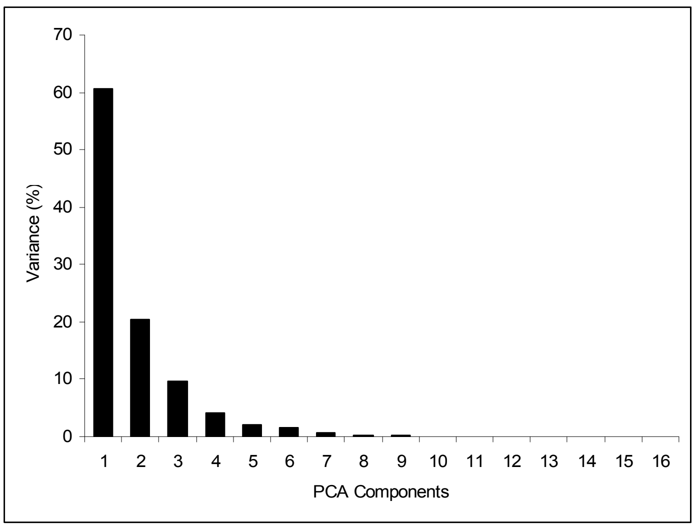


Fig.14. Percentage of the variance explained by each component from principal component analysis (PCA) of species composition by station of the deepwater survey, 2007.

The main species features within the dataset were highlighted on a bi-plot of the first two components (Fig.15). There is a clear separation of Roundnose Grenadier (*Coryphaenoides rupestris*) given by the length of the line away from the centre of the plot and the lack of any other species close by. The same is true for Baird's smoothhead (*Alepocephalus bairdii*) in the lower section of the plot. The position of these two species arrows indicate that they do occur together however, there is not a strong association between them (if it were the two species would be much closer on the plot).

Although the importance of the second, third and fourth components are far lower than the first it is worth plotting to see the influence of other species. A plot of the 2nd and 3rd components (Fig.16) again shows the separation of RNG and BSD, although here there is even less association between the two species. In addition, DAC (*Deania calcea*) and BSF (*Aphanopus carbo*) have moved away from the centre to indicate some level of importance of these species within the variation of the dataset. These species are also very close together indicating a high association between them (i.e. if one is caught it is very likely so will the other).

In the final bi-plot of the 3rd and 4th components (Fig.17) again shows the separation of DAC (*Deania calcea*) and BSF (*Aphanopus carbo*) and the association between them, in addition there is separation of Rabbitfish (*Chimaera monstrosa*) from the main, which may have some association with both Hake (*Merluccius merluccius*) and DBM (*Galeus melastomus*).

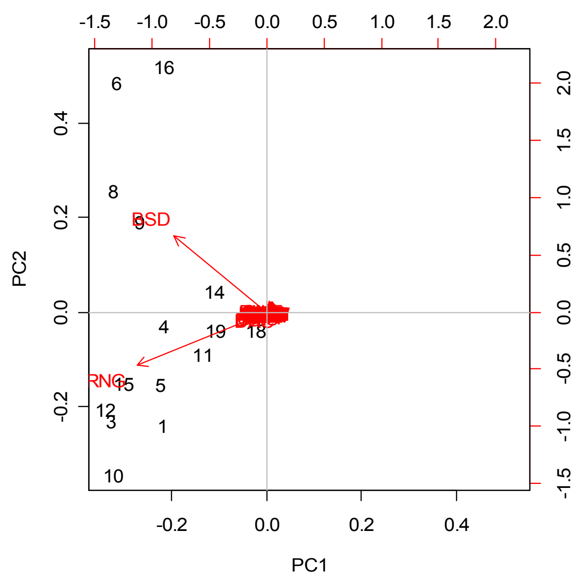


Fig.15. Bi-plot representation of the first two factorial axes from PCA of species proportions by station of the deepwater survey, 2007. Distinction between two species can be identified: 1) RNG (*Coryphaenoides rupestris*) and 2) BSD (*Alepocephalus bairdii*).

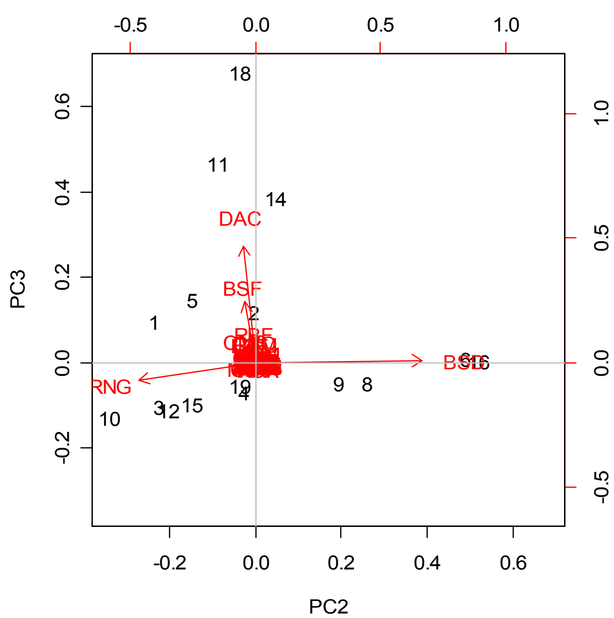


Fig.16. Bi-plot representation of the 2nd and 3rd factorial axes from PCA of species proportions by station of the deepwater survey, 2007. Distinction between three groups can be identified: 1) RNG (*Coryphaenoides rupestris*), 2) a combination of DAC (*Deania calcea*) and BSF (*Aphanopus carbo*), and 3) BSD (*Alepocephalus bairdii*).

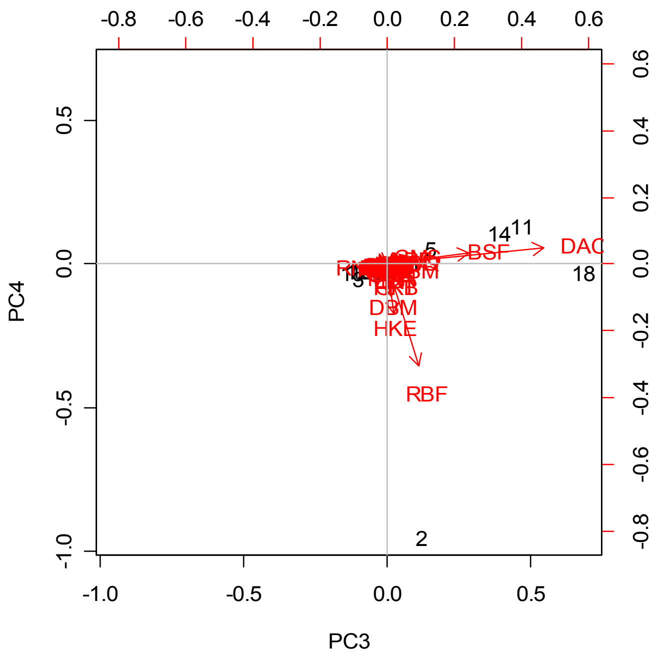


Fig.17. Bi-plot representation of the 3rd and 4th factorial axes from PCA of species proportions by station of the deepwater survey, 2007. Distinction between two groups can be identified: 1) a combination of DAC (*Deania calcea*) and BSF (*Aphanopus carbo*), and 2) separation of RBF (*Chimaera monstrosa*), which may have some association with both HKE (*Merluccius merluccius*) and DBM (*Galeus melastomus*).

Multidimensional scaling was performed on the PCA components to show how similar stations were to each other (Fig.18), the closer the stations on the plot, the more similar they are. Although the scales are small, there is some separation of stations 6,16,8 and 9 in the bottom left corner and the remainder of stations appear to show a continuation from the top of the plot to the bottom.

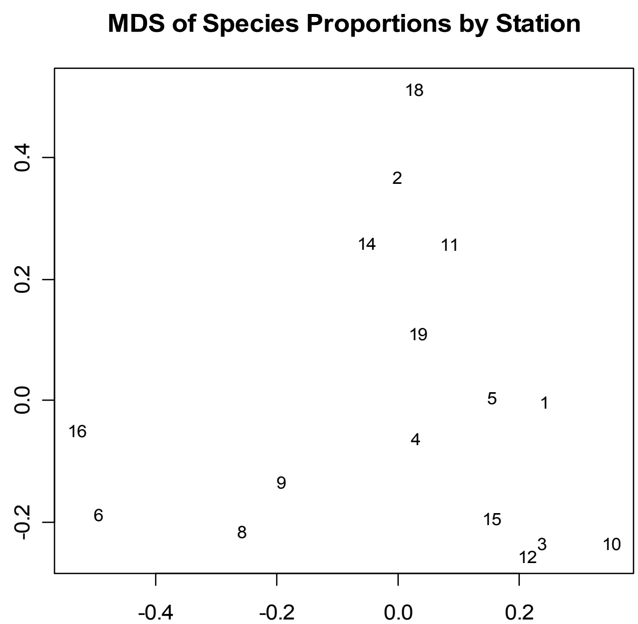


Fig.18. Multidimensional scaling of PCA components obtained from species proportions, by station of the 2007 deepwater survey.

In addition, clustering was carried out on the PCA components to show how species compositions of stations group together. The number of clusters (or groupings) was established by observing the change in variation explained by increasing the number of clusters. 5 clusters were considered appropriate, explaining 80% of the variation within the dataset. After this increasing the number of clusters resulted in less than a 5% increase in variation explained.

Figure 19 shows the results of cluster analysis where similar stations are grouped together and the height is a measure of similarity where zero represents identical stations.

The first separation divides stations 6, 8, 9, and 16 from the remainder. These stations are therefore similar to each other but dissimilar to all other stations. It is also worth noting that station 2 is grouped alone.

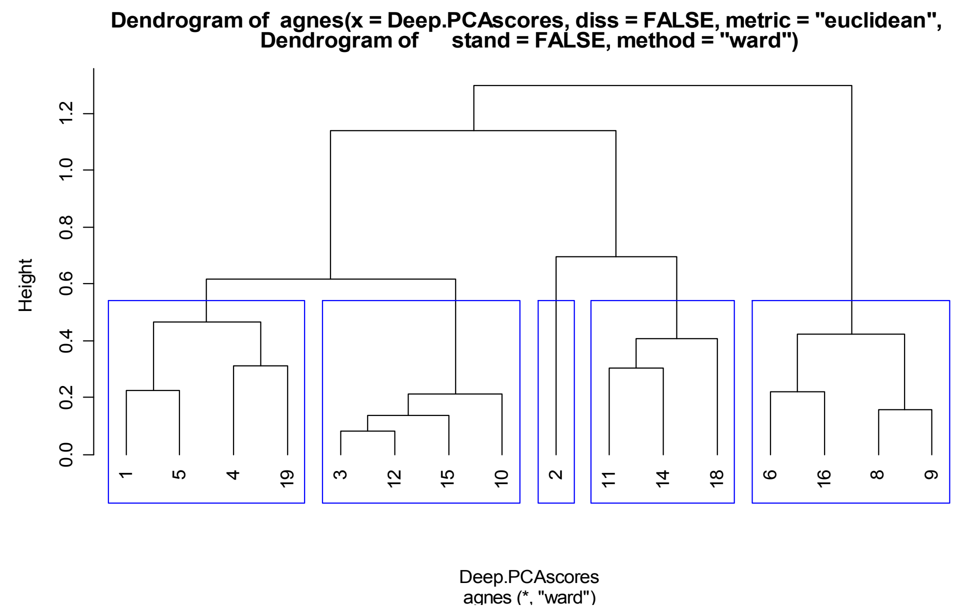


Fig.19. Clustering of PCA components obtained from species proportions, by station of the 2007 deepwater survey. The blue boxes represent the 5 groupings explaining ~80% of the variation in the dataset.

Summary and conclusion of principal component analysis

All the stations are quite similar to each other given by the low height scale on Fig.18 and Fig.19. However, species composition does vary between stations, particularly for proportions of RNG (*Coryphaenoides rupestris*) and BSD (*Alepocephalus bairdii*). Some of the variations seen in species composition appear to occur in relation to depth and, less so, area changes (depth and area details given in tab.1).

The first grouping appears to be characterised by RNG and contains stations at both 1000m and 1800m, and from each area. This would indicate that RNG has a wide depth and spatial range. Grouping 2 only contains stations at 1500m, but occur across all areas. The proportions of RNG are higher within this group than the first. Which would suggest this is the main depth for this species.

MYR (*Trachyrhincus murrayi*) is only really present (>1%) in grouping 2, similar is true for CLA (*Cataetyx laticeps*), although this also occurs in the 1500m station in grouping 5 which would indicate that CLA is restricted to around this depth.

Cluster 3 contains a single station, number 2, and shows a quite different composition to other stations. This was the only station to contain a high proportion (>30%) of RBF (*Chimaera monstrosa*), and the only one to contain quantities of HKE (*Merluccius merluccius*) and DBM (*Galeus melastomus*). In addition, this was the only valid station carried out at a depth of 500m. From the MDS plot and cluster analysis the closest stations to this are 11, 14, and 18, of which 18 is closest in terms of depth at 750m (which is also the only one at this depth). This station also contained greater quantities of RBF than remaining stations but below that of station 2. Nether of the other two species mentioned in relation to station 2 occurred at this station. This would suggest that these species are at their maximum depth range at 500m. The two remaining stations within grouping 4 both occurred at 1000m in area 5. With the exception of RBF in station 18, the three stations in grouping 4 are characterised by BSF (*Aphanopus carbo*), DAC (*Deania calcea*), and CSQ (*Centrophorus squamosus*). In addition to low levels of MOM (*Mora moro*), not present in any other stations, suggesting a preference by this species to around 1000m due west of Mayo.

The fifth grouping, which was the first to separate in the clustering is the most dissimilar from the remaining groups, this contains stations 6, 8, 9 and 16, all of which occur close to one another on the MDS plot. These stations are characterised by high proportions of BSD. Both 1000m and 1800m stations occur within this grouping indicating that this species has a wide depth range. In relation to area, grouping 5 does not contain stations from area two (the most northerly area) although BSD were caught in the area, proportions were lower far lower. This suggests that BSD are relatively less abundant, and that dominance is taken by another species in area 2.

3.5 Comparative Tows with *RV SCOTIA*

In total seven comparative tows were carried out with the *RV Scotia*, three in Area 2 and four in Area 4 (Fig 20, Table 9). The *Celtic Explorer* recorded 83 different species, totalling 18800 fish, in these hauls, while the *Scotia* recorded 107 species totalling 20700. This is mainly accounted by the *Scotia* catching only one individual of a species on nineteen occasions, whereas the *Explorer* only recorded one individual per species nine times. The *Scotia* caught four individuals, or less, of a species on thirty six occasions, whereas the *Explorer* only caught four individuals, or less, nineteen times. In Area 2 the *Explorer* caught 72 species, while the *Scotia* caught 75. In Area 4 the *Explorer* only identified 58 species while the *Scotia* had 93 species.

Table 9. Tow positions for the comparative tows

Area	IRL Haul No.	Depth haul	Scot Haul No.	Depth haul
2	1	975	393	1000
2	2	493	402	500
2	3	1482	392	1500
4	6	1047	397	1000
4	7	490	398	540
4	8	1470	396	1500
4	9	1877	395	1800

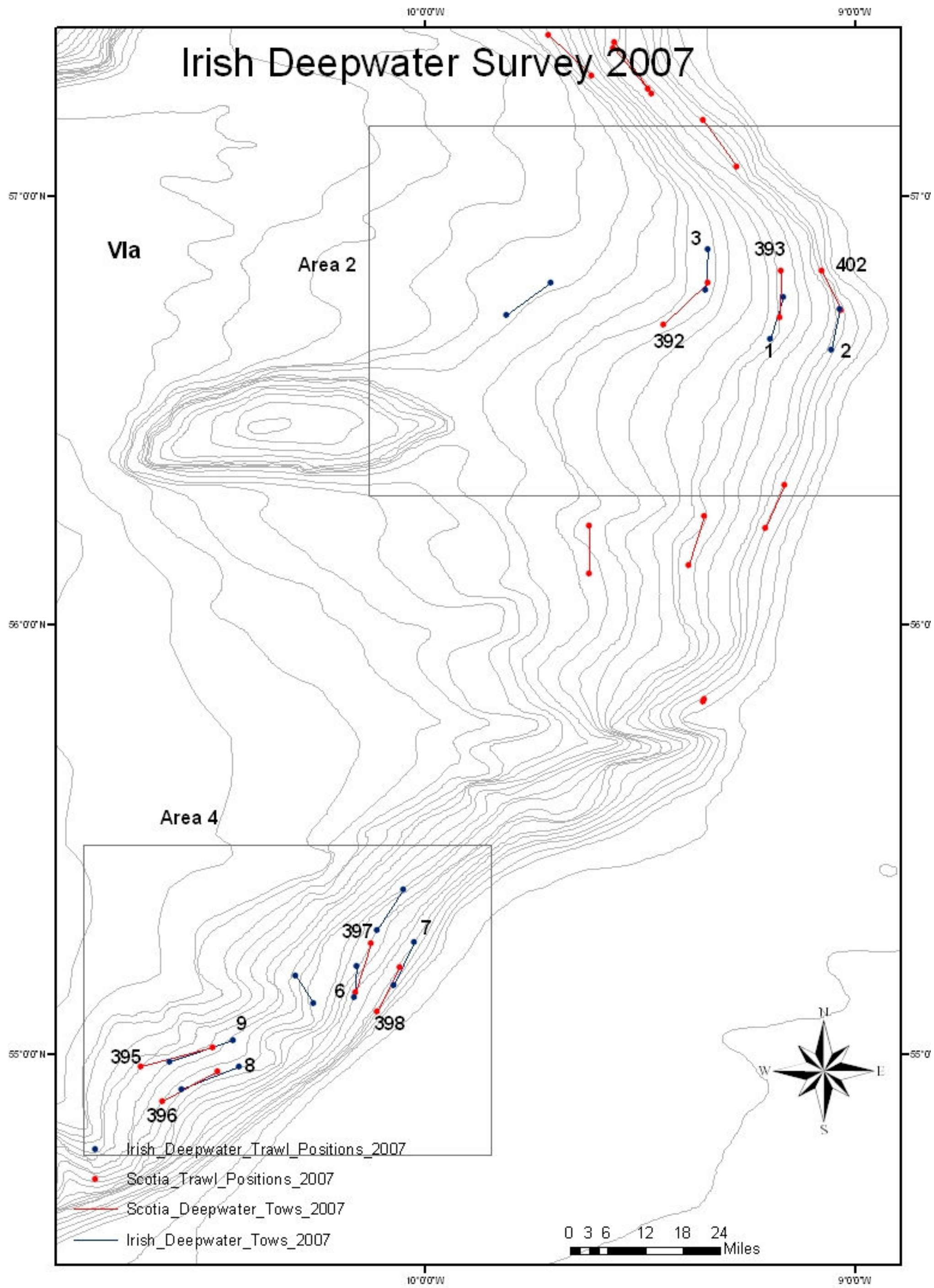


Figure 20.) Comparative tows between the *Celtic Explorer* and *Scotia* in 2007. Numbers 1 – 3 and 6 - 9, in blue, are the Irish tows.

Catches of commercial species tended to be quite small on both vessels. *Coryphaenoides rupestris*, roundnose grenadier, provided the largest catches with the *Scotia* catching 6747 fish, while the *Explorer* caught 7575. On the *Explorer Aphanopus carbo*, black scabbard, at 200 fish, and *Merluccius merluccius*, hake, at 212 fish, were the next largest catches. The *Scotia* caught 50% more scabbard, and 50% less hake than the *Explorer*. The largest catch discrepancy was found in *Argentina silus*, greater argentine. The *Explorer* caught 72 fish whereas the *Scotia* caught 1048. The average lengths of fish caught by both boats were very similar (Figure 21.(a)). Looking at the size ranges of some species in detail it can be seen that the *Scotia* was catching much smaller black scabbard, *A. carbo*, than the *Explorer*. With most other commercial species the minimum lengths caught were similar on both vessels, while the maximum size caught varied between vessels.

The sharks caught were divided up into groups, one being all *Apristurus* species, the second covering all others, (Figure 21. (b) and (c)). With the Apristurus species the numbers of each species caught were very similar, the only major difference being *Apristurus melanoasper*, black catshark, where the *Scotia* caught 21 individuals to 8 on the *Explorer*. Average lengths, as well as max. and min., were quite similar, except for *Apristurus laurussoni*. This discrepancy was due to the *Explorer* catching 4 fish whereas the *Scotia* only recorded one.

With the deepwater sharks *Centrophorus squamosus*, Leafscale gulper shark, and *Centroscymnus coelolepis*, Portuguese dogfish, both ships caught similar low numbers of both species with the *Explorer* catching a wider range of specimens than the *Scotia*. The two most abundant sharks were *Etmopterus princeps*, greater lantern shark, and *Galeus melastomus*, black mouthed dogfish. The *Scotia* caught 137 *E. princeps* to 45 on the *Explorer*, but the *Explorer* caught 233 *G. melastomus* compared with 61 for the *Scotia*. With the other sharks average lengths were quite close apart from *Scymnorhinus licha*, again due to the fact that the Explorer only recorded one fish. The maximum sizes recorded for *Centroscyllium fabricii,* Black dogfish, and *Hexanchus griseus,* Six gilled shark, were greater on the *Explorer.*

Numbers of rays and skates caught during the survey were quite low, down to one or two individuals per haul. No species were common to both vessels (Figure 21, (d)).

Grenadiers were caught in large numbers by both vessels. *Coryphaenoides rupestris,* roundnose grenadier, were the most important species in terms of numbers, with *Nezumia aequalis*, smooth rat-tail, and *Coelorhynchus coelorhynchus*, hollowsnout rat-tail, being the third and fourth most recorded species. In general the average sizes of most grenadier species, and their size ranges were similar on both ships. However the *Explorer* recorded larger average sizes for *Chalinura mediterranea*, mediterranean grenadier, and *Trachyrynchus murrayi*, Murray's rattail, whereas the *Scotia* recorded a smaller minimum size for both species, (Figure 21, (e)).

The *Scotia* recorded a greater number of species of smoothheads than the *Explorer*. However the *Explorer* caught 2639 *Alepocephalus bairdii*, Baird's smoothhead, compared to 1471 on the *Scotia*. This made it the second most important species by number on the survey. The *Explorer* also recorded a greater average length for the species, (Figure 21, (f)). Of the other three main species in common both vessels caught the same numbers of *Alepocephalus agassizi*, Agassiz's smoothhead, but the *Explorer* caught 236 *Rouleina attrita*, softskin smoothhead compared to 426 on the *Scotia*, and caught 706 *Xenodermicthyes copei*, bluntnose smoothhead, compared to 187 on the *Scotia*. The *Scotia* however caught a totally different size range of *A. agassizi* than the *Explorer* which could indicate problems with species identification.

Looking at deepwater eels both vessels caught similar species, (Figure 21, (g)). *Synaphobranchus kaupi*, cut-throat eel, produced the largest numbers. However the *Scotia* caught nearly ten times the amount as the *Explorer*, 1051 fish compared with 123. The *Scotia* also caught 81 *Polyacanthonotus rissoanus*, Risso's spiny eel, compared with one on the *Explorer*. Average lengths and size ranges tended to be similar for most species across both vessels, apart from *Notacanthus chemnitzii*, but this difference was probably due to the low numbers caught.

Both vessels recorded the same six species of rabbitfish but the *Explorer* caught more of each species, (Figure 21 (h)). The most numerous species was *Chimaera monstrosa*, rabbitfish, with the *Explorer* catching 1063 fish compared to 630 on the *Scotia*. The next most common species were *Harriotta raleighana*, Bent nose rabbitfish, and *Hydrolagus mirabilis*, large eyed rabbitfish. The average lengths and size ranges of all species were similar on both ships, apart from *C. monstrosa*. The *Scotia* recorded a much larger size range than the *Explorer*, and caught much smaller fish as well.

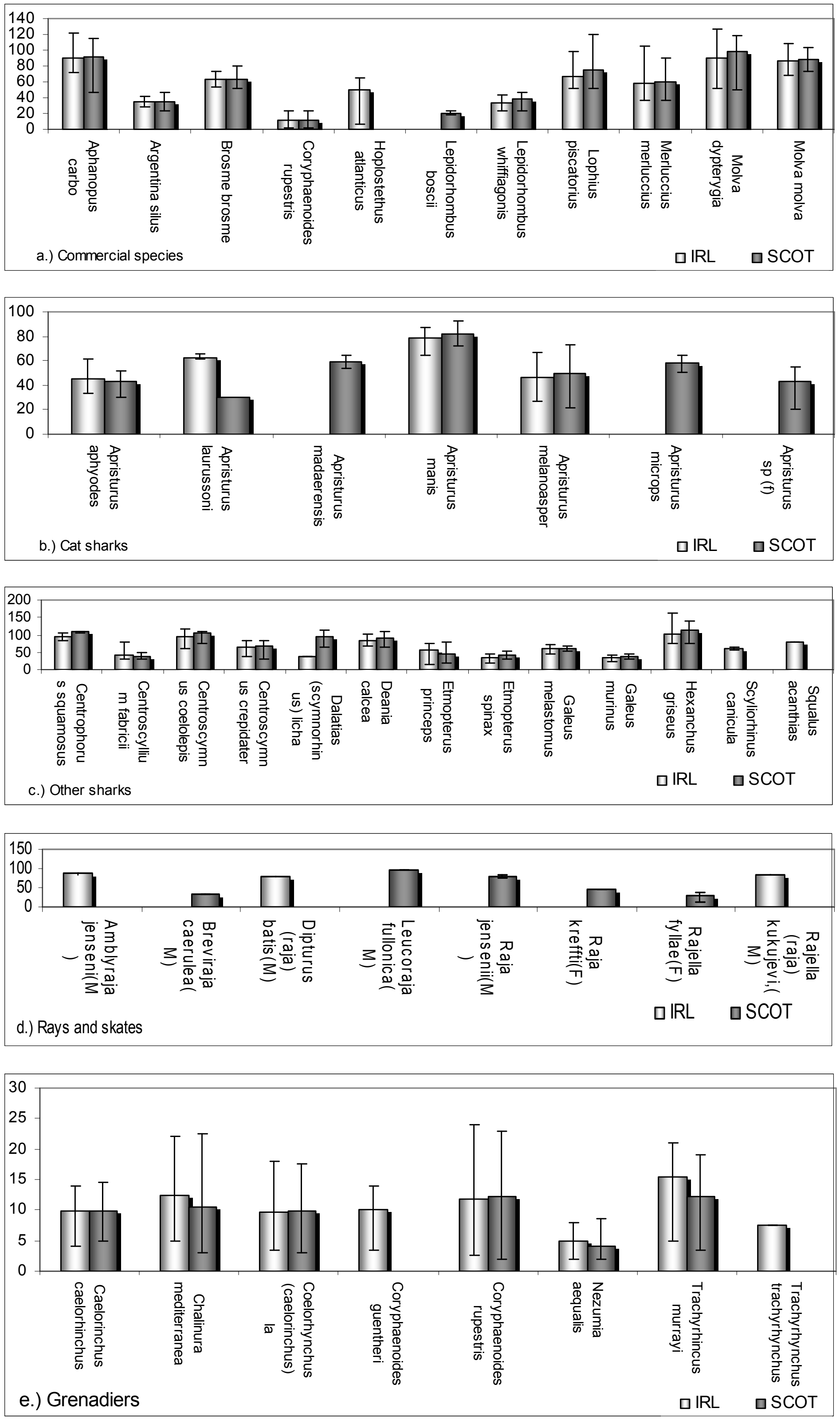
Of the other species recorded the three most common species were *Gadiculus argentus*, silver pout, *Halargyreus johnsoni*, and *Lepidion eques*. The *Scotia* caught larger numbers of all these species than the *Explorer*, in the case of *H. johnsoni* ten times as much.

Overall both surveys were tracking one another quite well. The analysis of the catches showed good agreement on the size structure of the fish between both vessels. Similar species were also being caught by both vessels.

Comparative Hauls- summary and conclusions

It is important to continue the cooperation between both surveys. This includes carrying out comparative tows to make sure that the nets are both fishing in the same manner. In a number of species, *A. bairdii, T. murrayi* and *N. aequalis*, the *Scotia* tended to catch smaller fish and the *Explorer* larger ones. There were regular differences in the numbers of fish caught during a haul, but neither vessel consistently outperformed the other. The *Scotia*, for instance, caught a large number of small *H.johnsoni*. One solution for this may be differences in the height of the headlines. Attention needs to be constantly paid to the gear parameters. It is intended to monitor these parameters in future surveys between the vessels.

Another important area to monitor is ensuring scientists on both vessels are identifying problem fish in the same way. This may account for some of the discrepancies in the number of species recorded by both vessels. In order to address this issue the two countries intend to hold annual ID workshops with other, outside, taxonomists. This will ensure that scientists can discuss difficulties with new species. It is important to retain examples of problem fish for examination at these workshops. It is also important to upgrade keys, and test them on surveys, and also take photographs of unusual fish wherever possible.


140
120
100
80
60
40
20
0
Aphanopus carbo
Argentina silus
Brosme brosme
Coryphaenoides rupestris
Hoplostethus atlanticus
Lepidorhombus boscii
Lepidorhombus whiffiagonis
Lophius piscatorius
Merluccius merluccius
Molva dypterygia
Molva molva
a.) Commercial species
IRL
SCOT
100
80
60
40
20
0
Apristurus aphyodes
Apristurus laurussoni
Apristurus madaerensis
Apristurus manis
Apristurus melanoasper
Apristurus microps
Apristurus sp (f)
b.) Cat sharks
IRL
SCOT
200
150
100
50
0
Centrophorus squamosus
Centroscyllium fabricii
Centroscymnus coelolepis
Centroscymnus crepidater
Dalatias (scymnorhinus) licha
Deania calcea
Etmopterus princeps
Etmopterus spinax
Galeus melastomus
Galeus murinus
Hexanchus griseus
Scyliorhinus canicula
Squalus acanthias
c.) Other sharks
IRL
SCOT
150
100
50
0
Amblyraja jenseni(M)
Breviraja caerulea(M)
Dipturus (raja) batis(M)
Leucoraja fullonica(M)
Raja jensenii(M)
Raja krefftii(F)
Rajella fyllae(F)
Rajella (raja) kukujevi,(M)
d.) Rays and skates
IRL
SCOT
30
25
20
15
10
5
0
Caelorinchus caelorhinchus
Chalinura mediterranea
Coelorhynchus (caelorinchus) la
Coryphaenoides guentheri
Coryphaenoides rupestris
Nezumia aequalis
Trachyrhincus murrayi
Trachyrhynchus trachyrhynchus
e.) Grenadiers
IRL
SCOT

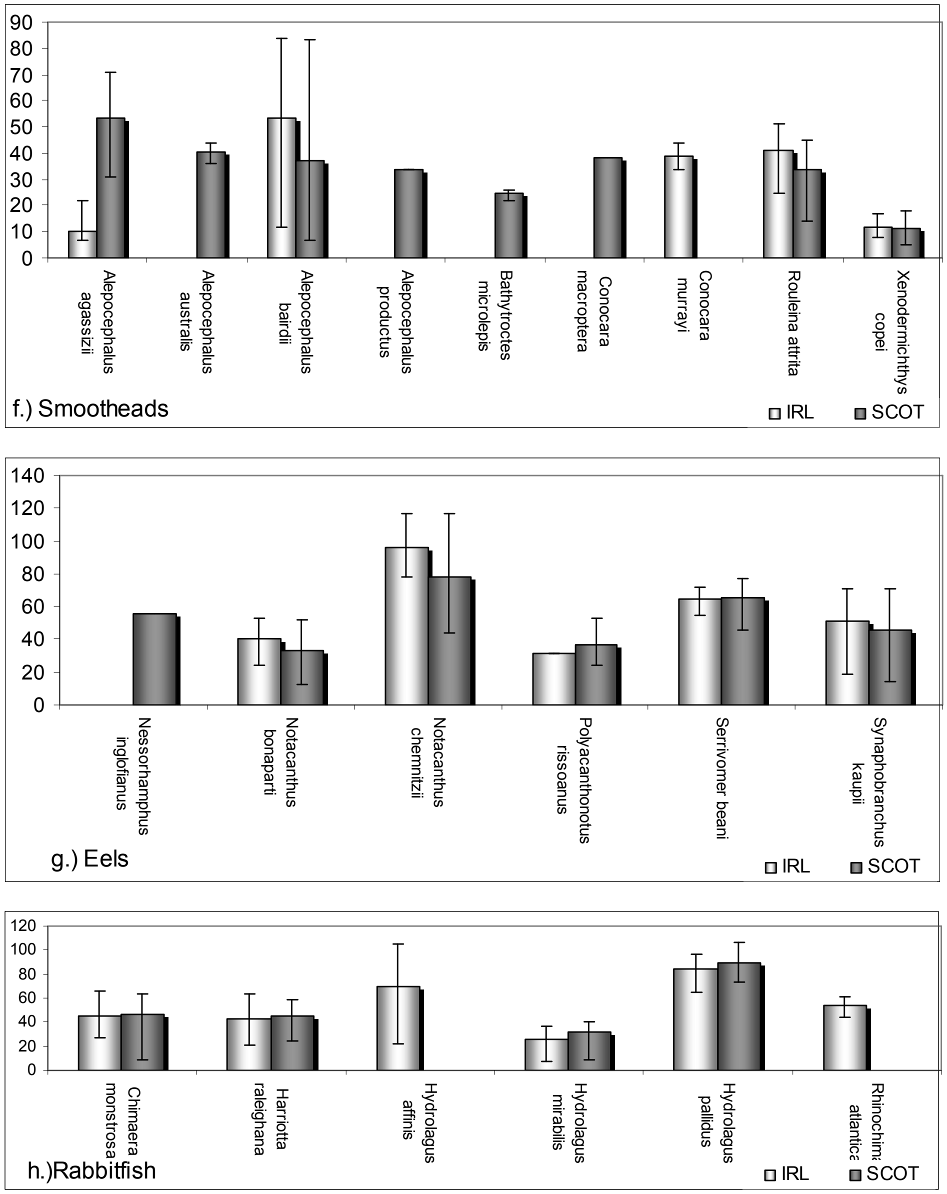


Fig. 21. Comparison of fish mean, maximum and minimum length caught during the comparative tows on the Irish and Scottish surveys. Solid bars show mean length, while lines give the minimum and maximum length, light grey bars: Ireland, dark grey bars: Scotland.

3.6 Distribution of Sea Mammals and seabirds

3.6.1 Environmental Conditions

Environmental data was collected at 296 stations. Survey conditions were generally poor, with sea state ≤ 3 at only 20.9% of environmental stations, while one full day and two half days were lost to bad weather (conditions unsafe for survey in crow's nest). Visibility was good (>5km) at 66.9% of stations, moderate (1–5km) at 29.7% of stations and poor (<1km) at 3.4% of stations. A heavy swell (2m+) was recorded at 45.3% of stations. Rainfall was recorded at 11.1% of stations and fog/mist was recorded at 18.2% of stations (fig. 22).

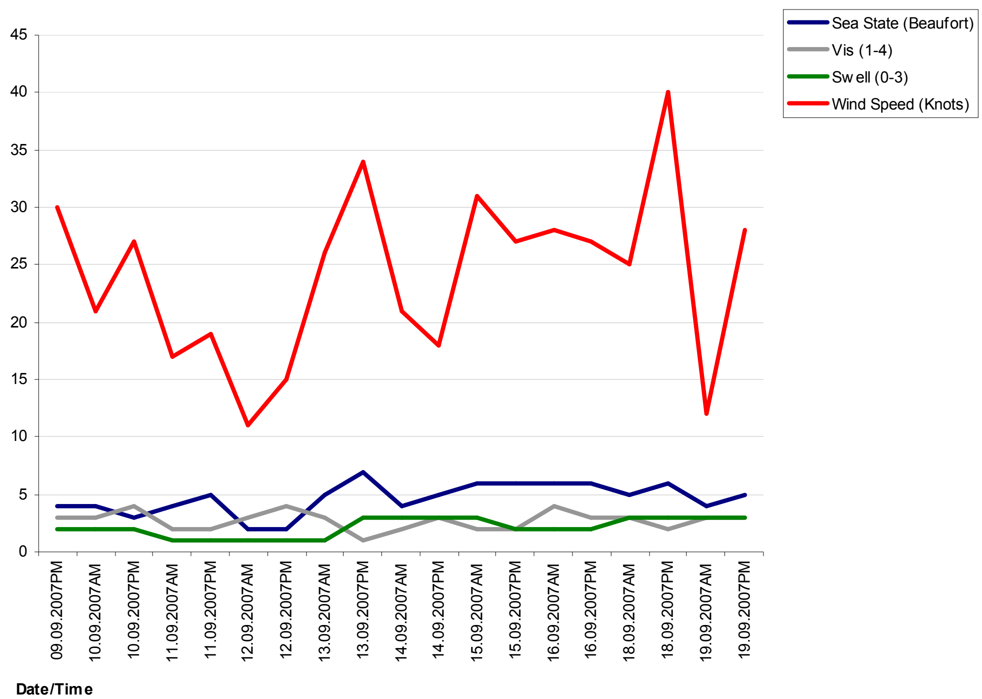


Fig. 22. Sea state, swell conditions and wind speed recorded twice daily during the survey.

3.6.2 Cetacean Survey Results

68 hours of survey time were logged with 40.2% (27.3hrs) of this at ≤ Beaufort sea state three. Eighteen sightings of at least four cetacean species, totalling 665 individuals were recorded (fig. 23).

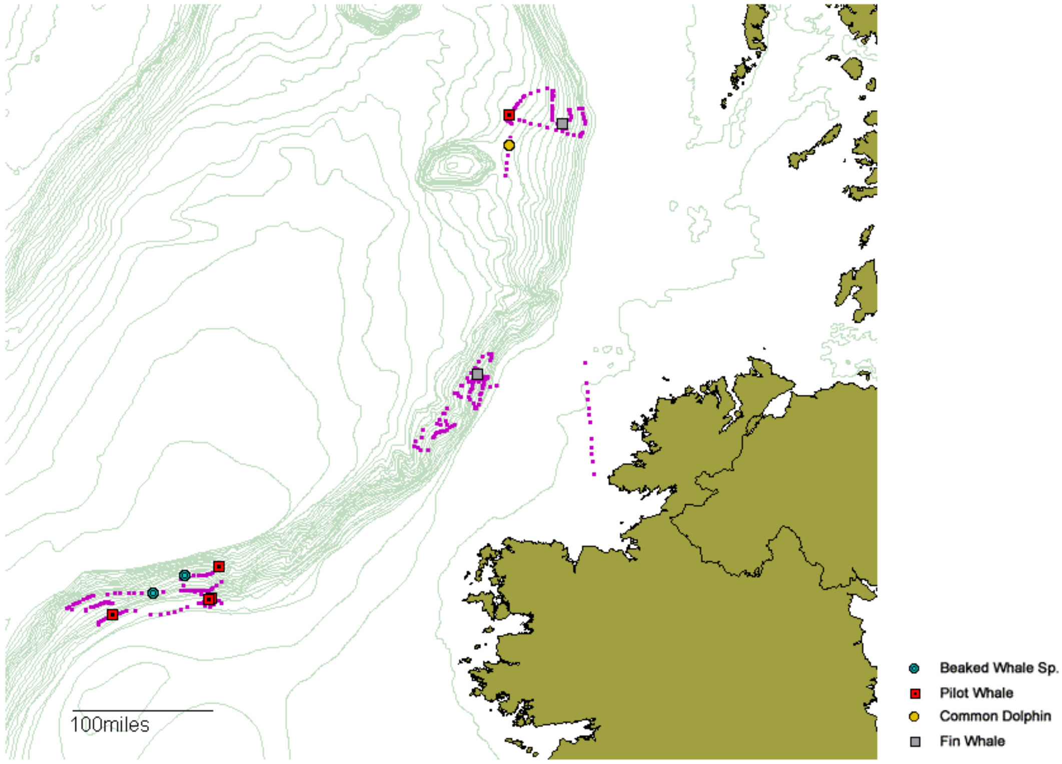


Fig 23. Distribution of cetacean sightings recorded during the current survey.

Identified cetacean species were common dolphin (*Delphinus delphis*), pilot whale (*Globicephala melas*) and fin whale (*Balaenoptera physalus*). Two sightings of unidentified beaked whale species were also made. Both beaked whale sightings were thought to involve one of the *Mesoplodon* species; Sowerby's beaked whale (*Mesoplodon bidens*), Gervais' beaked whale (*Mesoplodon europaeus*) or True's beaked whale (*Mesplodon mirus*).

In common with the results of the 2006 Deep Water Survey, pilot whales were the most commonly encountered species along the continental shelf slopes while common dolphins were only encountered once during this survey. Also in common with the 2006 survey the distribution of beaked whale sightings appears to correlate well with the presence of deep-water canyons along the shelf slopes (fig. 24), which are known to be their preferred habitat (MacLeod 2005). The two fin whales sighted occurred along the shelf slopes off the northwest coast. It is hoped to conduct further cetacean survey effort, both acoustic and visual, in these canyon systems over the next three years.

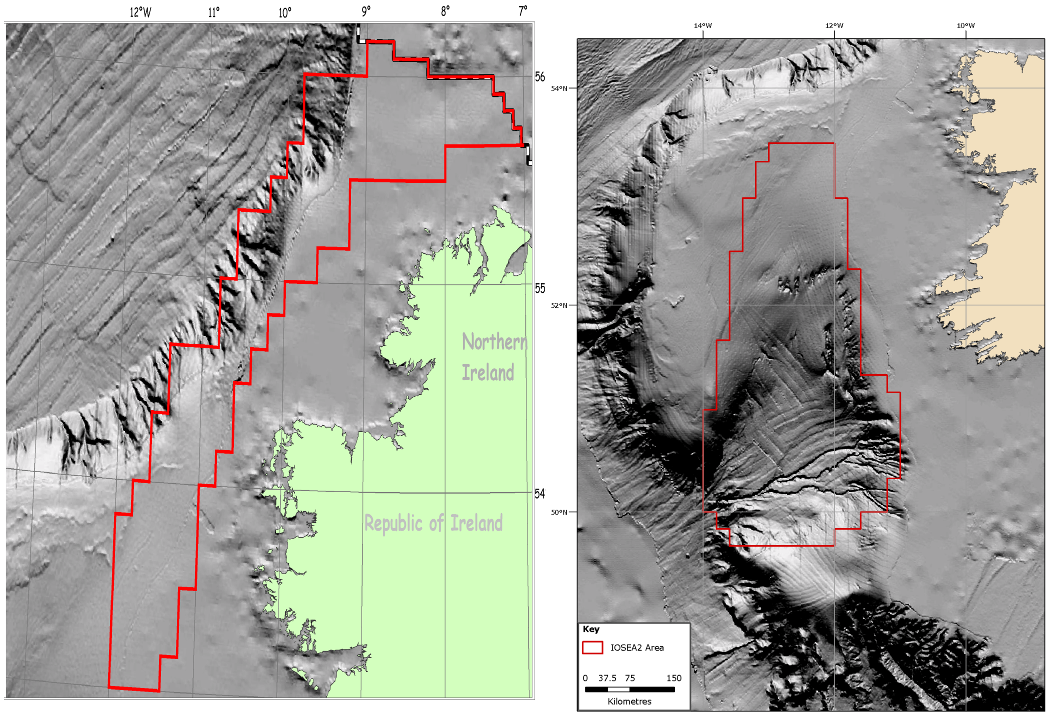


Fig. 24. Location of deep-water canyon systems along the continental shelf slopes, west of Ireland. (**source:** **IOSEA1 & IOSEA 2 Final Reports, Petroleum Affairs Division, 2006 & 2007)**

3.6.3 Bird Activity

Species lists were made of all bird species seen around the survey vessel each day (Fig.25). 13 bird species were recorded during the survey: lesser black backed gull (*Larus fuscus*), great black-backed gull (*Larus marinus*), great skua (*Stercorarius skua*), Pomerine skua (*Stercorarius pomarinus*), parasitic skua (*Stercorarius parasiticus*), gannet (*Morus bassanus*), fulmar (*Fulmarus glacialis*), great shearwater (*Puffinus gravis*), sooty shearwater (*Puffinus griseus*), Manx shearwater (*Puffinus puffinus*), kittiwake (*Rissa tridactyla*), Arctic tern (*Sterna paradisaea*) and storm petrel (*Hydrobates pelagicus*). A whimbrel (*Numenius phaeopus*) approached the vessel on one occasion but did not land, while a turnstone (*Arenaria interpres*) was noted on deck for several days.

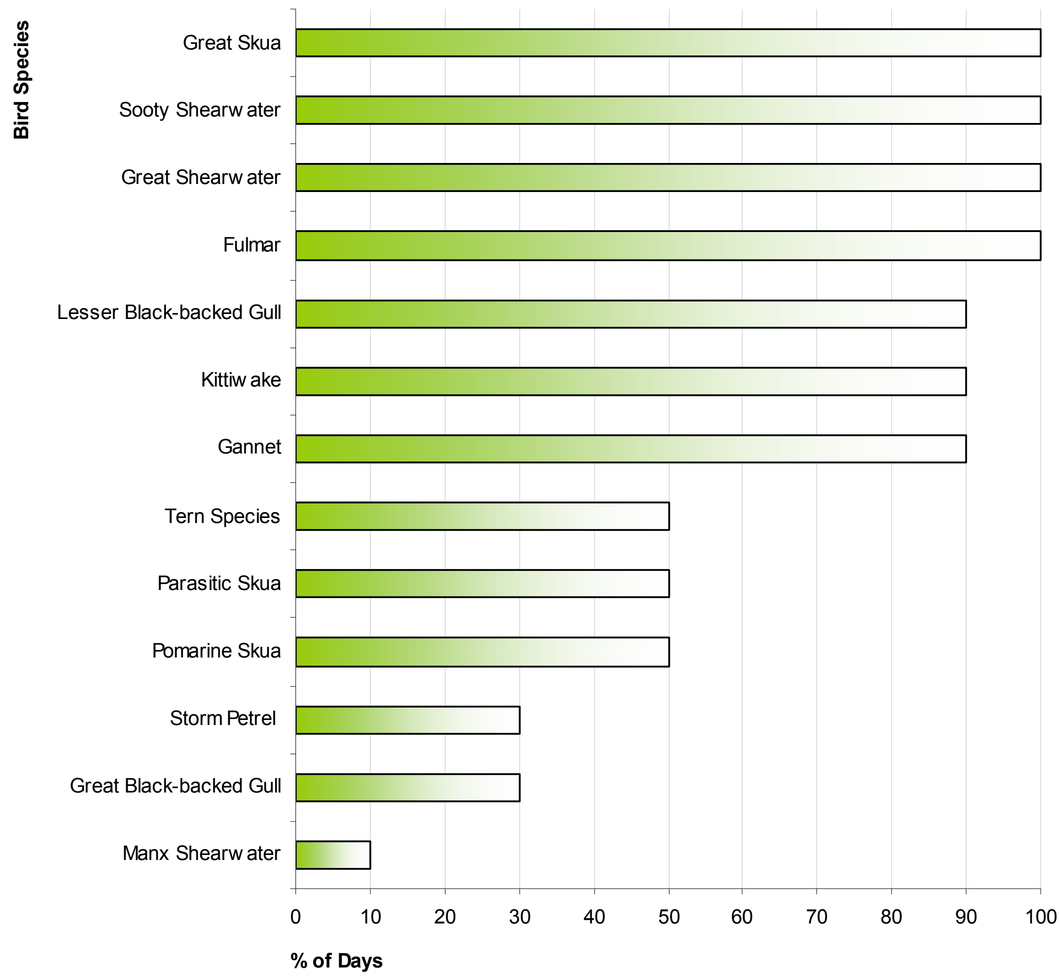


Fig. 25. The percentage of days on which 13 seabird species were recorded during 10 survey days.

Annex 1: List of participants

3.7 Scientific Personnel:

NAME	ORGANISATION	ROLE
Graham Johnston	Marine Institute	Chief Scientist
Brendan O'Hea	Marine Institute	Fishing/Wet lab.
Hans Gerritsen	Marine Institute	Deckmaster - Wet Lab.
Sarah Davie	Marine Institute	Fishing/Wet lab.
Sean O'Connor	Marine Institute	Fishing/Wet lab.
Mairead Sullivan	Marine Institute	Fishing/Wet lab.
Nils-Roar Hareide	Runde Environmental Centre	Fishing/Wet lab.
Yvonne Leahy	Marine Institute	Benthic Ecologist - Wet Lab.
Edward McCormack	Marine Institute	Benthic Ecologist - Wet Lab.
Martin White	NUIG	Senior Scientist - Oceanography
Momo Kochen	NUIG	Oceanography/CTD/Grabs
Deirdre Duggan	NUIG	Oceanography/CTD/Grabs
Naomi Foley	NUIG	Fishing/Wet lab.
Dave Wall	IWDG	Marine Mammal Observer
Hugh Boyle	MI Contractor	Technical specialist

Annex 2: Invertebrate taxa records from 2007 Survey and equivalent tows in 2006.

Sub Area			Area 2				
Haul Number (2007 Coding)	**Haul 1**		**Haul 2**		**Haul 3**		**Haul 4**
Depth	**975m**	**1053m**	**493m**	**476m**	**1482m**	**1459m**	**1800m**
Year	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Number of Taxa	**15**	**20**	**23**	**19**	**33**	**14**	**13**
Taxa							
Acanthephyra purpurea	V.A				N		
Actinauge richardii	P	P					
Adamsia carciniopados				F			
Anapagurus laevis			P		P		
Anemone sp#1					F		P
Anthozoa sp#3						P	
Ascidian sp				P			
Barnacle sp#1	P						
Bathynectes maravignae			P				
Benthoctopus sp (same as 2006)			P				
Benthodytes cf. typica							N
Benthogone rosea					P		
Brachiopod sp#1			P				
Calveriosoma hystrix		P					
Cephalopod sp#1	P						
Cephalopod sp.3					P		
Cephalopod sp2					P		
Chaecon affinis			P				
Chondraster grandis						P	
Cidaris cidaris		A	P	N			
Crangonid sp.1 (Glyphocrangon)							P
Crangonidae sp#1						P	
Dichelopandalus bonnieri			N	V.A.			
Earred octopus sp#1		P					
Ephyrina hoskynii		V.A.			P	F	
Epizoanthus incrustatus + hermit crab						P	
Geryon trispinosus	P		P				
Gnathophausia zoea		N			P		P
Gonatus (gonatus) cf. onyx		P					
Gracilechinus elegans	A	N	P	F			
Graneledone verrucosa		P				P	
Holothurian sp#3						P	
Hygrosoma petersii		P		P	F	F	
Laetmogone violacea	N	N					P
Loligo vulgaris		P					
Munida tenuimana	P	P					
Nematocarcinus ensifer					N		
Neolithodes grimaldi						P	
Nephrops norvegicus			P	P			
Nephropsis atlantica	F	F					
Nereidae				P			
Octopodid sp#1			P				
Pagurus prideaux				F			
Palaemon sp#1						N	
Paramola cuvieri			P	P			
Pasiphaea multidentata		P	P				
Pasiphaea sivado			P	P			
Pasiphaea sivado				P			
Pasiphaea tarda	N						P
Phoromosoma placenta	F						F
Plutonaster bifrons		P		P			P
Polybius henslowii			P				
Polycheles nanus					P		
Polycheles sculptus	P				P		
Polycheles typhlops	P			P			
Pontophilus norvegicus	P	F					
Porania pulvillus pulvillus			P	F			
Poraniomorpha (Culcitopsis) borealis				P			
Prawn fragments			N		P		
Pseudammusium septemradii			V.A.		P		
Pseudoarchaster parelii				P		P	
Psilaster andromeda andromeda							P
Sabinea cf. hystrix					P		
Sea pen sp#2						P	
Sea pen sp#3		P					
Sepiolidae sp#2		P					
Sergia robusta	A	V.A.	P		P	F	P

Annex 2. cont.

Sub Area					Area 4					
Haul Number (2007 Coding)	**Haul 5**		**Haul 6**		**Haul 7**		**Haul 8**		**Haul 9**	**Hau**
Depth	**981m**	**1004m**	**1047m**	**1058m**	**490m**	**493m**	**1470m**	**1488m**	**1800m**	**1477m**
Year	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**		**2007**
Number of Taxa	**13**	**16**	**18**	**8**	**13**	**19**	**5**	**16**	**13**	**22**
Taxa:										
Acanthephyra purpurea	V.A.		F							
Actinauge richardii	P		P		P	P	P			
Amphipoda		P								
Ancistrocheirid sp.1			P							
Anthozoa sp#2						P				
Araeosoma fenestratum					P				P	
Bathynectes maravignae					P	P				
Benthoctopus sp.2			P		P					
Benthoctopus sp.3			P							
Benthodytes cf. typica	P								P	P
Benthogone rosea									P	N
Calveriosoma hystrix			N	N						
Cancer bellianus						P				
Cephalopod fragments				P						
Chaecon affinis						P				
Chondraster grandis										P
Cidaris cidaris		P	P		V.A.	V.A.	P			
Copepod parasites on Alepocdephalous bairdii (Smooth heads)									P	
Coral sp#1									P	
Coral sp#2										P
Coral sp#3										P
Coral sp#4										P
Coral sp#5										P
Coral sp#6									P	P
Crangonid sp.1 (Glyphocrangon)	P									
Dichelopandalus bonnieri					P	P				
Diplopteraster multipes			P							
Echinus cf. acutus		P								
Ephyrina hoskynii		V.A.		A						
Epizoanthus incrustatus + hermit crab		F		A						
Epizooanthus paguriphilus & Parapagurus pilosimanus	P		P							F
Eunicid polychaete										P
Gastroptychus formosus (on orange coral sp#3)										P
Geryon trispinosa						P				
Gnathophausia zoea	N		P	P						
Gonatus (gonatus) cf. onyx		P		P		P				
Gracilechinus elegans	V.A.	A	P							P
Holothurian sp.1	P									
Hygrosoma petersii			P						P	P
Laetmogone violacea		P								
Majid crab sp#1						P				
Monodaeus couchii						P				
Munida tenuimana					P					
Neolithodes grimaldi										P
Nephrops norvegicus					P					
Novodinia cf. pandina										P
Octopodid sp#3					P					
Octopodid sp#4							P			
Octopodid sp.2					F					
Ophiocominid sp#1		F								
Ophiuroid sp.1	F									
Ophiuroidea spp		P								
Pasiphaea multidentata		A		F						
Pasiphaea sivado	P					P				
Pasiphaea sivado						P				
Pasiphaea tarda	N		P				F		F	N
Phoromosoma placenta		P	P						P	
Plesiopenaeus edwardsianus						P				
Plutonaster bifrons			P							P
Polycheles nanus									P	
Polynoidae sp.#1		P								
Pontocaris lacazei	P									
Porania pulvillus pulvillus					P	P				
PRAWN BITS	N		N							
Prawn bits		P								
Sea Pen sp#A										P
Sergia robusta	N	A	F	A						

Annex 2. cont.

Sub Area							**Area 5**				
Haul Number (2007 Coding)	**Haul 11**		**Haul 12**		**Haul 14**		**Haul 15**		**Haul 16**	**Haul 17**	
Depth	**1010m**	**998m**	**1482m**	**1496m**	**1008m**	**999m**	**1483m**	**1503m**	**1800m**	**423m**	**432m**
Year	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2007**	**2006**
Number of Taxa	**14**	**21**	**20**	**33**	**25**	**28**	**16**	**27**	**8**	**18**	**15**
Taxa:											
Acanthephyra purpurea	P	VA	P		N		P			P	
Actinauge richardii	P			P	P	A	P	P			
Amphinomidae											P
Anemone sp#1					P						
Anemone sp#2 or sp#3			P							P	
Araeosoma fenestratum										N	
Ascidian sp#1											
Asterina sp#2				F							
Balanus hameri											
Bathynectes maravignae										P	
Benthoctopus sp (same as 2006)					P						
Benthoctopus sp#1									P		
Benthogone rosea						V.A.	A		P		
Calveriosoma hystrix										P	
CEPHALOPOD BITS	P				P						
Cephalopod bits						P					
Cephalopod sp.											
Cidaris cidaris										V.A	P
Colossendeis colossea		P									
Colossendeis macerrima		P									
Colossendeis sp#1											
Copepod parasite (not attached)											
Copepod parasites on Macrourus berglax (rough head grenadier)											
Copepoda parasite on Nezumia aegualis								P			
coral								P			
coral branched						P					
coral soft						P					
Cranchia scabra						P					
Crangonid sp#2								P			
Crangonid sp.1 (Glyphocrangon)									P		
Crangonidae sp#1						P					
cup coral		P									
cup coral purple				F							
Dichelopandalus bonnieri											F
Diplopteraster multipes				P							
Earred octopus sp#1				P		P					
Earred octopus sp#2						P					
Echinasterid sp#1					P						
Echinus esculentus											P
Ephyrina hoskynii		A		P		P		P			
Epizoanthus incrustatus + hermit crab		V.A.		A		V.A.		V.A.			
Epizooanthus paguriphilus & Parapagurus pilosimanus	V.A		A		P		P		P		
Geryon sp#1											
Geryon trispinosa		P				P					
Glypocrancrangon sp.											
Gnathophausia zoea		P	P	P	P		P	P		P	
Gonatus (gonatus) cf. onyx		P		P							
Gracilechinus elegans	P	F	P	P	P	N					P
Graneledone verrucosa		P		P		P		P			
Hesianidae											P
Histeoteutis sp#1										P	
Histioteuthis bonellii bonellii								P			
Holothurian sp#3				P							
Holothurian sp.1 or 2									P		
Hygrosoma petersii	P	P	P	V.A.	P		P	P			P
Hymenaster pellucidus				P							
Isopoda sp#1							P				
Laetmogone violacea	P	P		P	F	P		V.A.			
Lepadid barnacle on Neolithodes							N				
Loligo vulgaris											P
Luidia bits (other than species#1)										P	
Luidia sp#1										P	
Majid crab sp#1											P
Majid crab sp#2											P
Meningodora mollis						F					
Myxaster perrieri				P							
Nematocarcinus ensifer							P				