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AN ACOUSTIC SURVEY OF ORANGE ROUGHY AGGREGATIONS TO THE WEST AND NORTH OF THE PORCUPINE BANK

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ABSTRACT

The survey was carried out over a 14 day period from the 5th – 20th February 2005 onboard the 65m RV *Celtic Explorer*. The main focus of this pilot survey was to acoustically survey orange roughy (*Hoplostethus atlanticus*) spawning aggregations. In total, 7 commercially fished and one "pristine" area were investigated during the survey. Of the commercially fished areas 6 were made up of seamounds or hill features and one flat seabed area. The relative abundance of orange roughy recorded for all sites combined was 19,000t with a c.v of 40%, 62% if taken as an absolute estimate of abundance. Fishing operations were carried out by the 25m stern trawler the FV *Mark Amay*. A total of 32 successful trawls were undertaken. Fishing operations yielded a total of 39 species, with orange roughy dominating catches. Other main component species by weight include baird's smoothead (*Alepocephalus baiirdi*); black scabbard (*Aphanopus carbo*) and roundnose grenadier (*Coryphaenoides rupestris*). Flat ground areas produced the highest species diversity and the greatest length range of orange roughy. Hill features yielded fewer species in greater numbers, with larger orange roughy present around hill features. The physical properties of the water column at each of the 8 survey areas were measured using a total of 34 vertical CTD casts. Conditions varied between survey areas due to local bathymetric conditions. Overall, Eastern North Atlantic Water (ENAW) dominated the first 1000m. From 1000m, a hyper-saline warm water mass of Mediterranean Sea Outflow Water (MOW), was identified in all areas to the south of 52°N and none in areas north of 54°N. A detailed investigation of two hill features (one fished and one pristine) using high-resolution multibeam, video and still imaging was carried out using the ROV *Aglantha*. ROV dives commenced at depth and advanced to the summit of the target feature. The commercially fished site was dominated by coral rubble; trawl door scars and degraded coral skeletons. At the "pristine" site species diversity was greater with coral thickets of reef forming species, soft coral bushes and little sign of anthropogenic impact. A total of 210 individual cetacean sightings were recorded (long-finned pilot whale and the bottle nosed dolphin) in addition to 12 seabird species.

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INTRODUCTION

The continental shelf to the west of Ireland represents the furthest westerly extension of the European shelf into the Atlantic. The shelf slopes off the Irish coast and is interspersed by deep-sea canyons, high reaching hill features and ridges. This area is influenced by deep oceanic drift currents in addition to surface and wind driven currents that converge at the self-break. The topographical structure of the shelf break lends itself to the formation of unique and highly localised circulation patterns and hydrographic conditions. Coldwater coral reefs are known to proliferate in deepwater areas to the west and south of the Porcupine Bank and are often associated with carbonate mounds (van Weering *et al.*, 2003). Such areas are known to support a high diversity of both vertebrate and invertebrate biota. Seamounds and hill features within this area are also known to support spawning aggregations of several deepwater fish species, including of orange roughy (*Hoplostethus atlanticus*), a highly commercial species. Orange roughy are an extremely slow growing species, with a longevity estimated at well over 100 years, reaching first maturity 23-40 years and have low fecundity relative to body weight (Branch, 2001 & Clark *et al.*, 2000). This slow growth rate coupled with the formation of local, often large, spawning and feeding aggregations make them especially vulnerable to over exploitation.

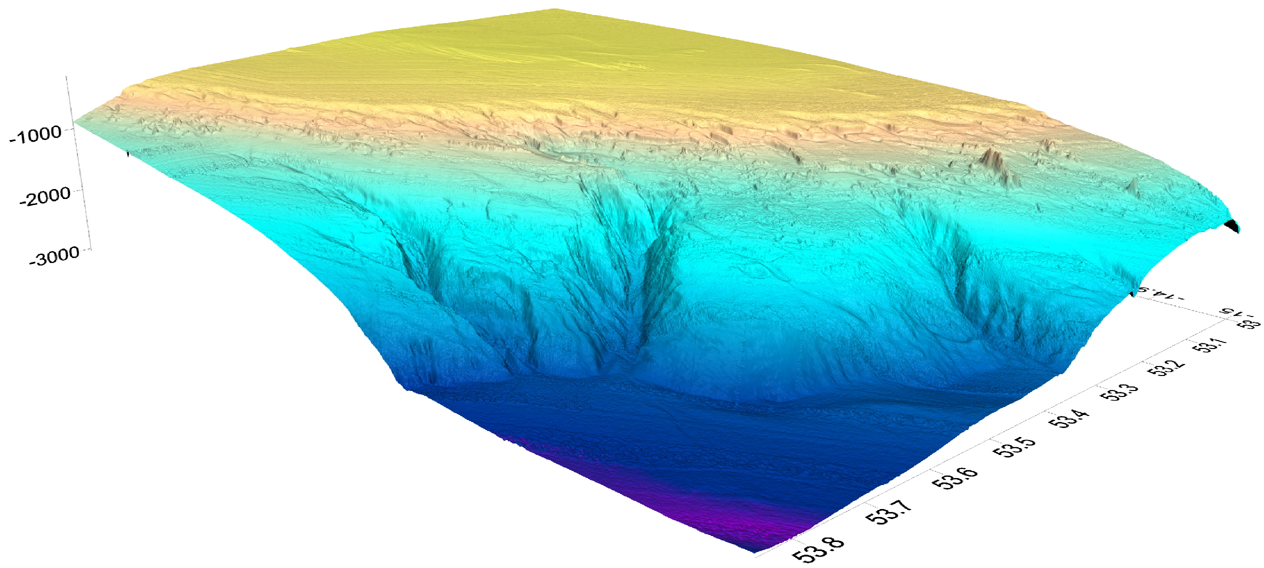


Figure 1. The bathymetry and nature of contouring occurring along the western shelf break in the Northern Porcupine Bank from 200m to over 5,000m depth. Note: deep canyons in center of image and seamound in the mid right of picture in the 1,500m depth range.(Aspect looking east.)

Orange roughy have been commercially targeted in Irish waters since the early 1990's by the French fishing fleet, although Irish participation in the fishery only began in 2001 (Boyer *et al.,* 2004). The Irish fishery rapidly developed in ICES Sub Area VII, landing an estimated 58% of the total orange roughy landed in the Northeast Atlantic for that year. The Irish landings peaked in 2002 with catches of more than 5,000t and fell by more than 75% in the following year and continued to decline (Marine Institute, 2006). In 2003, the Irish National Parks and Wildlife Service in association with the Marine Institute undertook a review to identify representative sites suitable for special protection through the EU Habitats Directive framework.

The aim of this pilot survey was to determine a snapshot estimate of relative abundance of spawning populations of orange roughy on seamounds using acoustic techniques and also, to investigate whether this is the most effective tool for abundance estimation of this species within this area. The survey was timed to coincide with the formation of pre-spawning and spawning aggregations of roughy, at pre-determined hill features and mounds. In addition, it was hoped that a more detailed picture of the biology of roughy and their local habitat may be developed by using a combination of hydrographic and habitat mapping techniques, including high resolution multibeam mapping and digital imaging.

In 2005, through the National Parks and Wildlife Service, four Irish Coral Reef Special Areas of Conservation were closed to fishing and all invasive practices. One of these areas of conservation was visited during this acoustic survey carried out in 2005. The current TAC for orange roughy in Area VII for 2007 is 174t with a further EU proposed reduction to 86t in 2008.

MATERIALS AND METHODS

Scientific Personnel

Name	**Organisation**	**Role**
Ciaran O'Donnell	Marine Institute- Fisheries Science Services	Scientist in Charge
Dr. Gavin Macauley	NIWA, New Zealand	Acoustics
Wilbert Knoll	NIWA, New Zealand	Acoustics
Dr. Sam Sheppard	UCC, Cork	Biologist
Dr. Anthony Grehan	NUIG, Galway	Deepwater corals
Margaret Wilson	NUIG, Galway	Deepwater corals
Jenny Ullgren	NUIG, Galway	Oceaonographer
Fabio Sachetti	Marine Institute- Ocean Science Services	Multibeam mapping
Mick Mackey	CMRC, Cork	Marine mammals
Asgeir Steinsland	IMR, Norway	ROV Pilot
Kjell Erik Dhal	IMR, Norway	ROV Pilot
Edin Omerdic	NUIG, Galway	PhD student
James Riordan	NUIG, Galway	PhD student

Survey Plan

Survey objectives

The primary survey objectives are listed below:

- Collect acoustic data on spawning and pre-spawning aggregations of orange roughy (*Hoplostethus atlanticus*) along the shelf break to the west and north of the Porcupine Bank (ICES divisions VIIIc and VIIk).
- Determine a snapshot estimate of the relative abundance of orange roughy within the survey area using acoustic techniques.
- Collect biological samples from trawling to determine species composition and gain length, weight, and sex and maturity data for orange roughy.
- Collect physical oceanography data from selected survey sites where orange roughy are known to aggregate.
- Collect habitat data on selected sites where orange roughy are known to aggregate, using an ROV; including colour video footage, still images and high-resolution multi-beam seabed data.
- Collect data on marine mammal and seabird abundance and distribution within the survey area.
- Determine the effectiveness of acoustic survey techniques as a means of assessing the size of orange roughy populations in Irish waters.

Area of operation

The survey was carried out from the 5th – 20th February 2005. The survey focused on the northern and western slopes of the shelf break surrounding the Porcupine Bank (Figure 2) from 54°30N in the north, south to 51°N and extending from the 11°30W to the 15°10W in the west, covering ICES Divisions VIIc and VIIk. Candidate survey sites were selected from areas identified from observer trips on commercial vessels, commercial landings data and information from Irish deepwater fishermen active in the fishery. Survey sites were further refined based on the highest commercial LPUE data (Kg hr^{-1}), practical survey logistics relating to time limitations, water depth and whether it was possible to deploy and retrieve trawl gear i.e. could directed trawling be carried out on identified fish echotraces.

In total, 9 sites were selected, of which, 8 sites are regularly targeted by commercial fishermen and one that was regarded as pristine. The depth profile of the survey area ranged between 850m to 1650m and was characterised by features including seamounds, ridges and canyons. The former features were the main area of concentration of survey effort as the preferred spawning habitat for orange roughy. The Geological Survey of Ireland (GSI) provided both high ($50m^2$) and low-resolution ($100m^2$) multibeam data of the survey sites.

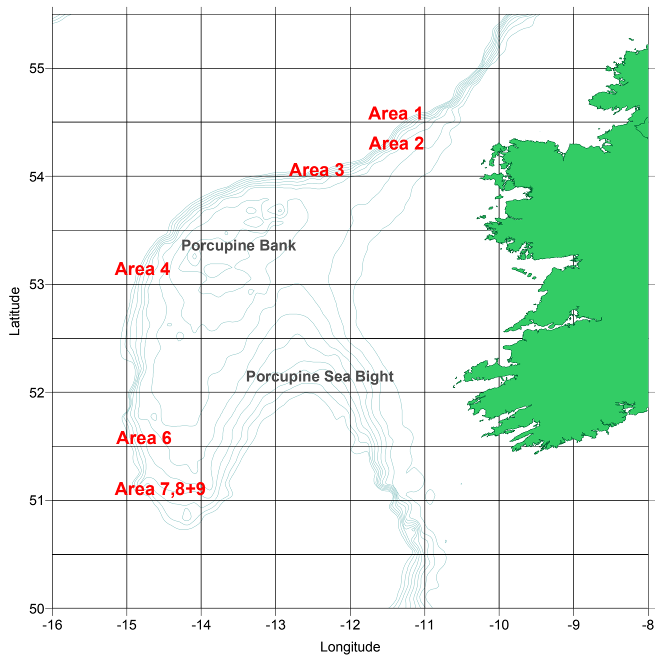


Figure 2. Location of survey areas. Depth at 100m intervals from 200-1000m.

Survey design

The acoustic survey design employed for each survey site utilised two survey methodologies. The first, a systematic parallel transect design approach was used to assess the survey site and background areas. The second approach, used a star shaped transect design with the axis centred on specific fish echotraces or bathymetric features.

Upon arrival at a site, parallel transects were initially used to survey the area. This method was used to determine the extent of the identified feature and surrounding background areas, related to GSI data and also as a means of locating fish schools for further more detailed acoustic investigation. The lay of transects was site specific and somewhat subjective. Where possible, transects were positioned in relation to shoot and haul positions, generously provided by fishermen, as this allowed for directed trawling. Trawling outside of known tow lines was outside the scope of this study. Initial surveying was carried out using both hull and deep towed body mounted transducers. Short, intensive transects were run across the feature to asses topography and also to determine the presence of fish echo traces. Coverage ranged between 5 and 23 transects, depending on size and aspect of the depth contours. Transects were positioned to run perpendicular to the depth contours where possible. Transects extended to between 1 and 4 nautical miles (nmi) from the base in order to include the flat area around the feature. Spacing of transects was set at 500 m for intensive transects. The results from the preliminary snapshots were used to determine the next step, relative to the amount of fish echo-traces encountered. If no significant echo traces were encountered, then no further surveying was undertaken at that site.

If an echo trace of sufficient acoustic density was encountered then a second higher intensity star survey was carried out. This method, developed by Doonan *et al*. (2003a) for use on orange roughy aggregations, utilises a star shaped cluster of transects centred on a specific fish school. Star surveys were made up of 3 to 4 transects, with the axis centred on the echo trace. The background flat areas surrounding a feature were initially surveyed using a broad systematic parallel transect design. However, after consultation with the catcher vessel FV *Mark Amay*, it was decided to drop the background transects and focus solely on the target features. Due to the rough nature of the background areas it was impossible to directly target insonified fish traces without serious gear damage or loss. Without biological data on species composition these data were impossible to quantify.

Equipment and system details and specifications

Acoustic array

Acoustic data were collected by two means. The primary collection tool was an independent deep towbody provided by the National Institute of Water and Atmosphere (NIWA). The secondary source came from drop keel mounted transducers on the vessel. Only data collected using the towbody was used for analysis. The towbody echosounder was supplied and supported by NIWA, and has been used extensively in surveys of orange roughy in New Zealand. The towed system comprised of a scientific echosounder (Crest) operating at 38 kHz, housed in a 3 m long, 0.45 m diameter torpedo shaped towbody (Figure 3). The towed system contained a 38 kHz split-beam transducer and the transmitting and receiving electronics linked to the vessel via an electro-mechanical cable. Deep towbodies allow the transducer to be positioned closer to the target area and thus reduce the shadow or acoustic "dead" or "shadow" zone encountered when working in excessive water depths and/or with steep sloped bathymetric features such as seamounds. The working depth range of the NIWA towbody during the survey was 80-150m subsurface, at towing speeds of between 4 to 8 knots (Kts).

Figure 3. NIWA's deep towbody used to acquire acoustic data on fish distribution around underwater features. Note: the transducer emits and receives echo through the perspex window on the lower surface of body.

The ships transducer array is mounted within a moveable drop keel and lowered to the working depth of 3m below the vessels hull or 8.8m below the sea surface. Moveable drop keels allow acoustic transducer arrays to be positioned below the area where hull induced turbulence may obstruct transmit or return acoustic pulses. Acoustic data were collected and viewed using a Simrad ER60 scientific echosounder. Simrad ES-38B (38 KHz) and an ES18-11 (18 KHz) split-beam transducers were used as the secondary data collection source.

Calibration of acoustic towbody

The towbody was calibrated by using a tungsten carbide sphere (38.1mm) suspended below the transducer face. The towbody was then lowered to a maximum depth of 500m in 100m intervals. Operating range for the survey was 80-150m subsurface. At each interval the towbody was held until sufficient on axis data points had been received. The mean target strength of all sphere echoes within 0.5° of the centre of the beam was calculated for each calibration depth interval and used to generate a relationship between depth and echosounder response. The vessels transducers were not calibrated during the survey itself. However, the system was last calibrated in early January 6th, 4 weeks before the start of the survey and no irregularities were observed in transducer performance.

Acoustic data acquisition

Processed incoming echoes were transferred as digital data up the tow cable to a control and storage computer onboard. At the end of each transect the data were copied to a second computer for backup. The data were collected in the proprietary Crest format, but were converted to ER 60 raw format files for reading by other software packages. Towbody pitch, roll, and depth, and vessel position, speed and heading were collected along with the acoustic data. Equipment settings for the acoustic equipment were determined at the start of the survey and were based on established settings used by NIWA on orange roughy surveys in New Zealand (Table 1). Two towbodies were available for use, but only the #2 towbody was used during the survey.

The acoustic data were processed using the NIWA ESP2 echo analysis package. For each ping, the depth at which the bottom echo was first observed was noted and stored. Pings that contained obvious signal attenuation due to excessive towbody pitch and roll and pings that contained noise were marked and removed from the analysis. Fish marks that were potentially from orange roughy were identified and stored. Acoustic data from the vessels hull mounted sounder were observed and recorded onto the hard-drive of the processing unit. The "RAW files" were logged via a continuous ethernet connection as "EK5" files to the vessels server and the ER 60 hard drive as a backup in the event of data loss. In addition, as a further backup, a copy was stored on DVD. Sonar Data's Echoview, Echolog (Version 3.2) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually over the duration of the survey.

Table 1. Equipment setting and configuration of NIWA towbody echosounder.

Parameter	Value
System number	2
Transducer model	Simrad ES38DD
Transducer serial number	28327
Nominal 3D bandwidth (deg)	7
Operating Frequancy (kHz)	38.156
Transmit interval (s)	3
Nominal pulse length (ms)	1
Filter bandwidth (kHz)	1.46
Initial sample rate (kHz)	60
Decimated sample rate (kHz)	4
TVG	20log R
Nominal absorption (dB/km)	8

Echogram scrutinisation
Two mark types were considered during the analysis; *ORANGE ROUGHY* and *BACKGROUND*. An estimate of orange roughy biomass was made for both mark-types separately. In theory, both mark types would have had their own set of biological data from separate trawls. Here, the same trawl data was applied to both mark-types, since trawls could not be unambiguously assigned to either mark-type. Trawling was carried out on positions where acoustic transects had been positioned. However, there was a time lag of up to 3 days, from when marks were acoustically observed until trawling was carried out. In addition the catcher vessel was essentially fishing acoustically blind making accurate directed trawling somewhat impossible.

For *ORANGE ROUGHY* mark-type, only the orange roughy data from the trawls were used, i.e. these mark-types were assigned as purely orange roughy. For the *BACKGROUND* mark-type, the species catch matrices were used to partition the acoustic backscatter into that for orange roughy and other species within the catch. For both, only trawls carried out within the same area were used during the analysis. The estimated error, expressed as the coefficient of variation (c.v.), i.e. standard error of the mean divided by the mean, was estimated by bootstrapping all sources of variation (Doonan *et al.,* 1999). For the *ORANGE ROUGHY* mark-type, the sources were the acoustic sampling variability, the catch variability, and the error from the estimated target strength of orange roughy. Two versions of the c.v. were estimated; the first, for an absolute biomass estimate, in which all sources were included; the second, when the estimate was treated as a relative estimate of abundance, which excludes the error due to orange roughy target strength. For the BACKGROUND mark-type, the uncertainty of mark-type assignment relating to trawl data meant that sampling variability was considered a minor part of the overall uncertainty and as a result no c.v. was reported.

Biological sampling
Biological sampling was carried out by a commercial catcher vessel. The MFV *Mark Amay* (SO 954) was built in 2000, is a 38m stern trawler of the Grand Sol design and has an operating power of 1243 Kw (Figure 4). This vessel is regarded as one of the pioneers of the Irish orange roughy fishery.

A single demersal trawl with the dimensions of 19m in length (LOA), with a door spread of 127m and a sweep length of 27m (Figure 4) was used. Mesh size in the wings was 100mm through to 30mm in the cod-end, with the inclusion of the codend liner. The vertical opening when fishing peaks was 3 to 5m and when fishing on flat grounds was 5 to 7m. Tows on the flats averaged 6 hours effective fishing time. Tows on the peaks averaged 2.5 hours from shooting to hauling, with the net spending an average of 10-15 minutes on the ground sliding down the slope of the peaks.

The vessel's fish detecting equipment includes a Furuno FCV–1200 echo sounder in combination with a Simrad ES 60, 38 KHz split beam transducer (operating at 4 Kw). The net was fished with a vertical mouth opening of approximately 3 to 7 m, which was observed using an acoustic linked Scanmar CGM-05 netsonde (50 kHz). The net was fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar system.

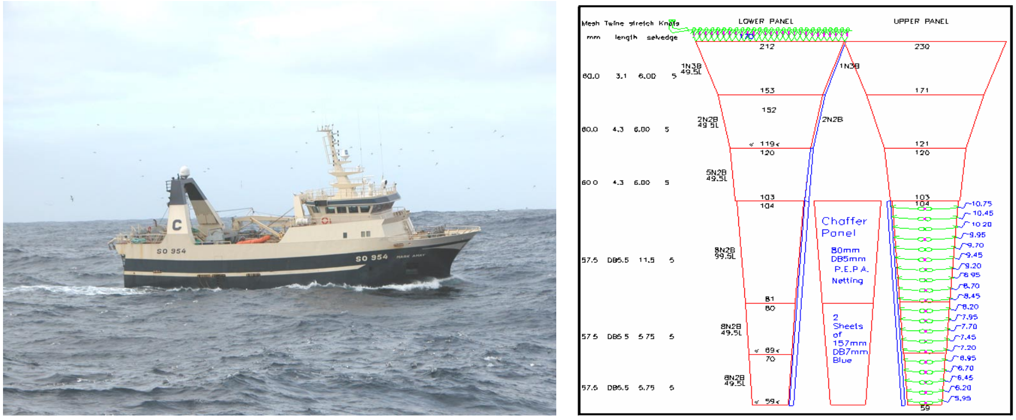


Figure 4. The FV *Mark Amay* (left image) used as the catcher vessel during the survey. Net plan of box trawl (right image) used to target orange roughy aggregations during the survey.

A systematic approach was adopted, where possible, to run acoustic transects in the same direction as safe trawl lines. The nature of the hill features does not lend itself to a random directed trawl approach and fishermen have expended a considerable amount of effort to determine how these areas are fished. All components of the catch were sorted and weighed. Fish and other taxa were identified to species level. Fish samples were divided into species composition by weight of the total catch. Length/frequency and length/weight data were collected for each component of the catch. Age, length, weight, sex and maturity data were recorded for individual roughy within a random 100 fish sample from each trawl haul. Otoliths were collected, where possible, for age analysis back in the lab. The appropriate raising factors were calculated and applied to provide length frequency compositions for bulk of each haul.

Maturity staging was carried out of orange roughy using a 6-point scale as generated from Pankhurst *et al.* (1987). Fish of maturity stages 1-2 were deemed immature, those of 3 and above were mature and capable of spawning. Positional data on notable fish echo-traces were passed onto the catcher vessel. The decision to fish on these marks was down to the discretion of the skipper in regard to the safety of the trawl.

Oceanographic data collection

Each survey area was surveyed to determine the local hydrographic conditions using a Seabird 911+ rosette sampler. This was carried out using both CTD stations and continuous collection of ADCP data from a hull mounted system (penetration to approximately 800m). CTD data was collected from depths of between 850m to 1420m during the course of the survey. Transects of approximately 2 nmi containing 5 CTD stations were carried out at each survey area. For hill features the centre point of the transect was positioned at the summit of the feature, the other 4 stations being positioned in opposition, to take in the slopes of the feature and base.

Habitat mapping

Detailed habitat mapping and visualisation was carried out using the ROV *Aglantha* (Figure 5). *Aglantha* is an electrically powered umbilical linked ROV; depth rated to 2000m and equipped recording equipment and lighting rigs. Length overall (LOA) is 2m, weight 800 Kg (in air) and payload capability of 150 Kg. Live colour viewing of seabed biota and bathymetry was possible through both analogue and digital media via an electro-mechanical umbilical to the RV *Celtic Explorer*. Analogue recordings (*s-VHS*) were used as a black box to record all dives. Special sequence digital footage of was recorded using DVC-pro media. Imaging footage of the seabed was recorded at between 1-3m off the seabed depending on location and turbidity.

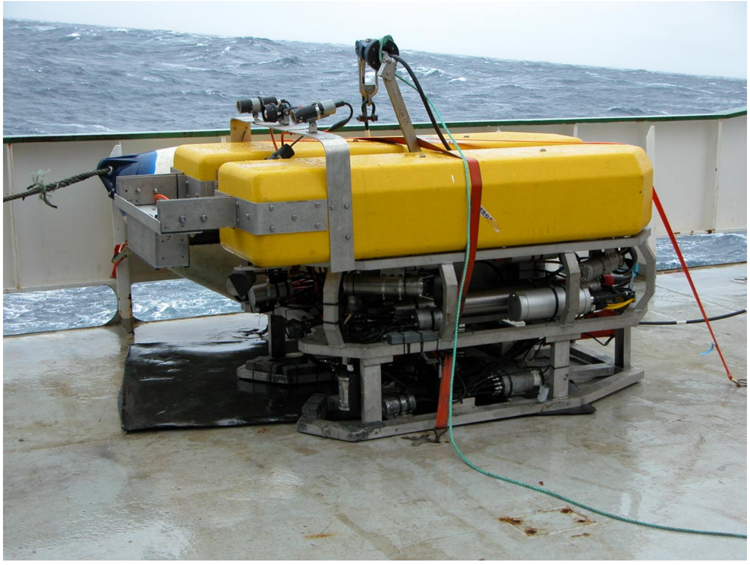


Figure 5. ROV *Aglantha* as used to recorded digital footage and high-resolution multibeam data on the sea floor.

A Reson SeaBat 8125 ultra high-resolution multibeam echo sounder system working at 455 KHz was mounted on the ROV to record seabed data. A titanium sonar head (depth rated to 1500m) was located on the front end of the ROV and linked via an oil filled fibre optic armoured umbilical for live data viewing. The high resolution of this system allowed bottom detection at up to 0.6cm with swath coverage of 120°, made up of 240 horizontal beams. Transects were run at a distance of 20 and 50m from the seabed. Substrate type and form was classified using colour image footage. Both multibeam and image viewing were carried out on predetermined transects running from the base of the feature to the summit. This method was adopted to reduce the effects of acoustic shadowing and provide the best quality footage. ROV positioning relative to the vessel and actual GPS positioning for multibeam data verification was provided through a USBL (IXSEA system) acoustic link between the RV *Celtic Explorer* and the ROV.

Marine mammal and seabird observations

Cetacean and seabird observations were carried out from the bridge (12m above sea level) during daylight hours. Watch effort focused on an area dead ahead of the vessel and 45^{o} to either side. Sightings of cetaceans in an area up to 90^{o} either side of the vessel bow to beam were recorded and used to confirm characteristics such as species, group size and behaviour. The area was constantly scanned during these hours by eye and with binoculars (*LEICA* 10x42). Ships position, course and speed and environmental conditions were recorded every 15 minutes and included, sea state; visibility; cloud cover; swell height; precipitation; wind speed and wind direction. For each cetacean sighting, the following data were recorded: time; location; species; distance; bearing; number of animals (adults, juveniles and calves) and behaviour. Relative abundance (RA) of cetaceans was calculated in terms of number of animals sighted per hour surveyed (aph). Relative abundance calculations for porpoise, dolphin species and minke whales were made using data collected in ≤ Beaufort sea state 3. Relative abundance calculations for large whale species were made using data collected in ≤ Beaufort sea state 5. For seabird counts a similar methodology was adopted. Visual scans were conducted with the naked eye in a 90° bow-to-beam sector forward of the ship, concentrating on a 300m-wide strip, from which seabird density estimates may be calculated.

Analysis methods

Echogram partitioning and abundance estimates

The conventional acoustic approach to echo-integration was used to estimate areal backscatter of acoustic energy by fish (Burcynski, 1979 and Doonan *et al.,* 2001), this was then apportioned using a mark classification system developed onboard based on echogram comparisons and trawl catch composition. Areal backscatter that has been apportioned to different species is converted to the number of individuals by dividing by its target strength, and to biomass by multiplying the mean weight. The detailed mathematical analysis method used to calculate biomass is the same as used by Doonan *et al.* (1999).

Corrections and assumptions

There are a number of physical factors that affect the accuracy of acoustic backscatter the most important for orange roughy are the affects of shadowing, towed body motion and sound absorption through the water column. Shadowing is brought about by the physical nature of the conical beam projected by the transducer and exacerbated by depth and steep gradients, such as those encountered on seamounds or shelf break areas. Using a deep towbody allows the shadow zone to be somewhat reduced as the transducer is closer to the seabed than would be possible with a hull mounted transducer. The wave front of the beam forms a part of the surface of a sphere, so when perpendicular to the seabed the central axis of the beam strikes the sea bottom and swamps the reflections from fish close to the bottom in the periphery of the beam. The shadow zone is thus used to describe the volume of the beam not visible to the acoustic equipment. The bathymetry encountered during this survey, such as steep sided slopes of seamounds would have lead to a shadow zone in the order of 30m. In this survey the shadow zone calculation was made using methods described by Barr (in Doonan *et al.,* 1999) and assumed that orange roughy density in the shadow zone was the same as in the 10m immediately above it. Corrections were calculated for each 10-ping bin and reported as the mean for that particular survey area.

Transducer motion was monitored using a heave, pitch and role sensor mounted within the towbody. Due to transducer motion both transmit and receive pulses can result in reduced signal strength between samples. If during the receive pulse the transducer is in a different orientation than during the transmit pulse then signal strength loss can occur. The final biomass estimate was corrected for decreased signal strength loss due to transducer motion using the method of Dunford (2002).

Acoustic absorption of acoustic signal and sound speed were determined form vertical CTD casts undertaken during the survey. Corrections were made by depth for acoustic absorption (Doonan *et al.,* 2003b) and sound speed (Fofonoff & Millard, 1983). These values were then used to correct acoustic data for depths greater than 200m from nominal values.

RESULTS

Biological sampling

A total of 39 hauls were made (Table 2), 32 of which were regarded as successful. Of this, 19 hauls were carried out on peaks and seamounds and 13 were carried out on flat background areas. Fishing areas are seen in Figure 2.

Table 2. Trawling positions by survey area of catcher vessel FV *Mark Amay*.
Note: * denotes unsuccessful trawl station.

Haul	Date	Time	Shot Lat. N	Lon. W	Bottom Depth	Hauled Lat. N	Lon. W	Fishing Area	Bulk Catch (Kg)
1	09.02.05	23:00	54.03	12.41	1328	54.01	13.19	Flat	1050
2	09.02.05	07:57	00:14	13.19	1165	54.03	12.38	Flat	1470
3	10.02.05	16:15	00:43	12.33	673	54	13.2	Flat	1680
4	10.02.05	01:12	54.01	13.2	1101	54.02	12.37	Flat	1680
5	10.02.05		54.24	11.3	941	54.25	11.29	1	360
6	10.02.05	20:45	54.04	12.29	1183	54.14	12.35	3	920
7	11.02.05	23:06	54.03	12.29	1321	54.05	12.34	3	500
8	11.02.05	04:41	53.56	13.4	1212	53.43	14.11	Flat	500
9	11.02.05	17:38	53.48	14.02	1183	53.56	13.39	Flat	500
10	12.02.05	12:30	52.34	15.07	1125	52.1	15.02	Flat	4500
11	13.02.05	00:00	51.41	15.04	1082	51.16	14.57	Flat	3000
12	13.02.05	00:00	51.17	14.56	1097	51.4	15.09	Flat	2500
13	13.02.05	17:35	51.39	15.09	1200	51.21	15.02	Flat	4000
14	14.02.05	02:35	51.42	15.05	833	51.45	15.04	6	3500
15	14.02.05	04:34	51.42	15.05	1110	51.48	15.04	6	4000
16	14.02.05	06:35	51.42	15.05	831	51.45	15.04	6	1500
17	14.02.05	08:29	51.42	15.06	1114	51.45	15.02	6	750
18	14.02.05	12:12	52.11	15.04	1208	52.31	15.06	Flat	3000
19*	15.02.05	19:47	52.33	15.07	1147	52.51	14.57	Flat	0
20	15.02.05	03:39	53.04	14.55	862	5306	14.53	4	0
21	15.02.05	05:15	53.04	14.55	1200	53.08	14.57	4	1000
22	15.02.05	07:13	53.04	14.54	1200	53.09	14.54	4	400
23	15.02.05	08:51	53.05	14.51	1200	53.04	14.56	4	500
24	15.02.05	13:15	52.35	15.06	1108	52.11	15.02	Flat	4000
25	16.02.05	01:16	51.42	15.05	1060	51.46	15.04	6	50
26	16.02.05	03:08	51.42	15.05	1092	51.45	15.04	6	250
27	16.02.05	04:40	51.45	15.05	1057	51.42	15.03	6	50
28	16.02.05	06:49	51.39	15.03	1077	51.15	14.57	Flat	2500
29	16.02.05	16:33	51.01	14.57	1099	50.59	14.53	7	14000
30*	16.02.05							7	
31	16.02.05	19:45	51.03	14.5	1200	50.59	14.52	7	6000
32	16.02.05	21:52	51.07	14.52	1200	50.59	14.59	7	100
33	17.02.05	00:02	50.59	14.54	1100	51.03	14.54	7	0
34*	17.02.05				1200			7	
35	17.02.05	03:44	51	14.55	1200	50.59	15.01	7	1500
36*	17.02.05	05:51	51.01	14.53	1115	51.01	14.53	7	0
37*	17.02.05							7	
38*	17.02.05	10:00	51	14.54	1401	51.01	15.01	7	0
39*	17.02.05	12:20	51.02	14.57	1310	50.59	14.54	7	0
								Total	65760

Species composition

Species composition varied both by survey area and also by ground type (Table 3). In total, 46 species were identified from trawl samples (Appendix I). Orange roughy was the dominant species in all areas with the exception of the flat background areas.

Table 3. Percentage species composition (wet weight) by survey area.

	Area 1	Area 3	Area 4	Area 6	Area 7	Flat	Total
No. hauls (successful)	1	2	3	6	7	13	32
Orange roughy	38.5	50	70.1	94.8	57.4	6.5	47
Smoothead	46.5	41.5	10.2	0.2	15.9	31.1	19.2
B. scabbard	0	0	8.4	1.2	0.3	19	7.8
Portuguese dogfish	0	0	0	0	13.4	5.7	6.4
Leafscale gulpershark	3.8	0	0.5	0	1.3	13.2	5.1
Cardinal fish	1	1.1	0.2	0.2	9.5	0.2	3.3
Roundnose grenadier	2.7	0.7	4.6	0.5	1.1	5.6	2.9
Longnosed velvet dogfish	0.6	2.7	3.6	0.2	0.1	5.6	2.5
Others	6.8	4.1	2.4	2.9	0.9	13.1	5.8

Due to poor weather and heavy swell conditions, only one seamound in each of the areas 1-6 was fished. In area 7, three seamounds were fished. The three seamounds fished in area 7 were all in close proximity (2-4nmi) and were dominated by orange roughy from trawl catches. However, species composition of other species varied between stations (Table 4).

Table 4. Percentage species composition of 3 seamounds surveyed in area 7.

Species	Peak 1	Peak 2	Peak 3
Orange roughy	60.4	66.2	52
Smootheads	12.8	0	24.5
Portuguese dogfish	11.7	0	20.1
Cardinal fish	7.9	33.8	0
Leafscale gulpershark	0.7	0	2.3
Others	6.5	0	1.1

Orange roughy data

The total catch of orange roughy was 18,100Kg (wet weight) over the 32 valid trawls. The highest catches were recorded in areas 6 and 7 (see tables 3 and 4). Length distributions varied between areas with the broadest range observed in the flat background areas (Figure 6). Overall the mean length for orange roughy 43.7cm (SL) from all samples combined. Mean length varied between areas with the highest mean observed in area 4 (46.1cm) and the smallest in area 7 (41.7cm). All components of the catch were sampled with most emphasis on orange roughy. In total, over 5,200 length measurements and over 2,700 weight measurements were recorded from the total catch (Appendix I). Over 1,700 length measurements of orange roughy were recorded and a further 1,000 sex, weight and maturity measurements were also recorded (Table 5).

Otoliths were removed from 562 individuals for age analyses back in the laboratory at UCC (University College Cork). Maturity staging was carried out on 1,178 orange roughy gonad samples. Analysis of data reveals length at 50% maturity for females is 30-34cm (Figure 7). Sex ratios showed a slight dominance of males to females, with the former making up over 52% of the total. Females sampled revealed over 89% were mature (stages 3-6), 8% were spent, while over 70% were in a pre-spawning state. The timing of peak spawning events, as derived from gonad analysis, appears to vary between survey areas (Appendix II).

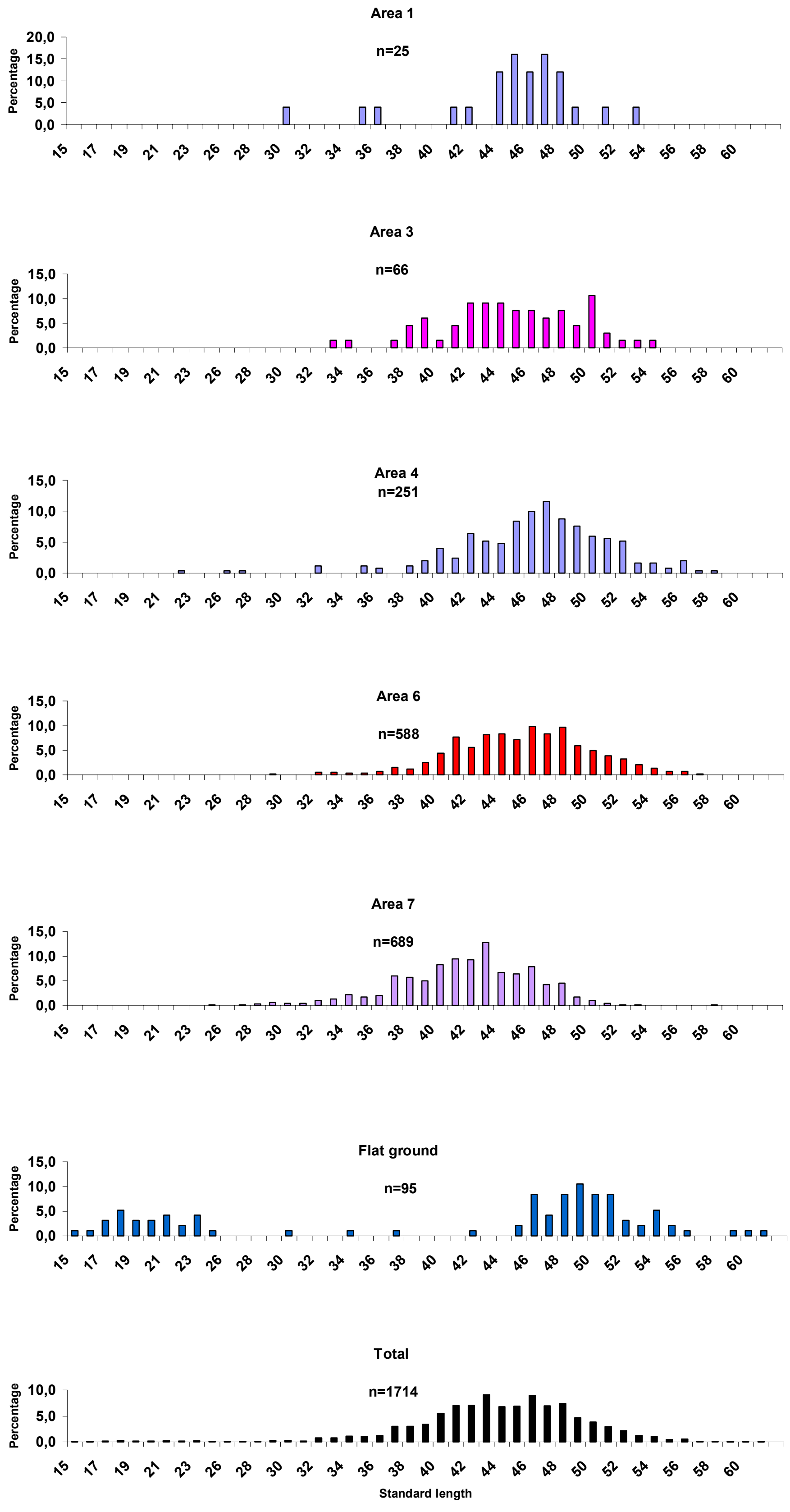


Figure 6. Length distributions of orange roughy by survey area from trawl data.

Table 5. Biological samples taken from orange roughy by survey area

Area	1	3	4	6	7	Flat	Total
Length	25	66	251	588	689	95	1714
Weight	25	66	237	339	420	91	1178
Sex	25	66	251	288	460	81	1171
Maturity	25	66	251	288	460	81	1171
Age	25	65	99	125	195	53	562
Stomack		6	14	9	3	5	37
Genetics	24	37	49	48	149	22	329

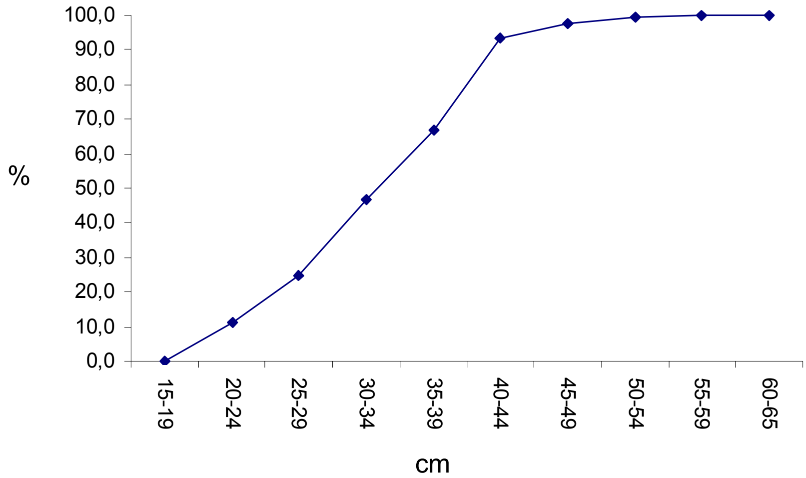


Figure 7. Maturity ogive for female orange roughy as derived from gonad analysis of trawl samples. Length at 50% maturity is 30-34cm (SL) from samples.

Acoustic data

Towbody calibration

The towbody was calibrated to the west of the Porcupine Bank (51° 01N and 14° 56W) on the 15th February between 20:48 and 23:41 UTC. Weather conditions were calm with a wind speed of less than 5 knots from the SE and a groundswell of less than 1m from the NW. The calibration sphere was suspended 20m from the transducer face. The vessel was allowed to drift during the calibration exercise. The mean and standard deviation of the calibration at each depth are given in Figure 8. There is a small difference in results between the down and up casts, particularly at 200m, but in all cases the difference is less than 1 standard deviation. Experiences with calibrations in New Zealand have indicated that the variation in calibration is due to water temperature. However, in this case the water temperature was 11.4°C down to 300m, 11.1 °C at 400m and 10.9 °C at 500m, and pressure effects appear to determine the calibration. CTD cast #29 was close in space and time to the calibration site so the data from that cast was used. For the purposes of this survey a relationship between towbody depth and 20log10(V_t) was taken as:

$$20\log_{10}(V_t) = 5.78\times10^{-9}d^3 - 8.59\times10^{-6}d^2 + 4.84\times10^{-3}d + 60.9$$

where d is the transducer depth in metres and is valid for $100 \le d \ge 500$. This relationship is the green line in Figure 8.

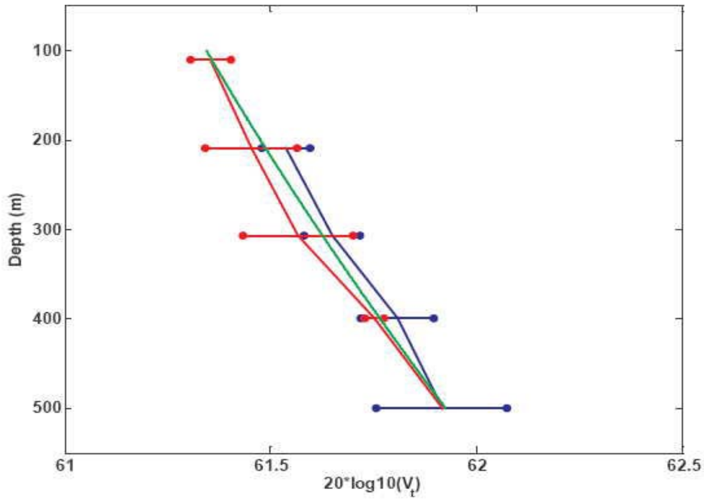


Figure 8. Calibration results for the NIWA towbody. Blue lines represent downcast, red lines upcast. Horizontal blue bars represent 1 standard deviation. Green line is an order 2 polynomial fit to the mean of both the up and downcast results. No downcast data was presented for the 100m downcast due to insufficient data points.

Echogram scrutinisation

A total of 161 acoustic data files were collected during the survey, comprising 119 from acoustic transects and the remainder collected during testing, steaming and during calibration. Data were archived in the NIWA designed acoustic database in the raw format produced by the Crest system. In the absence of timely directed trawling on acoustically identified marks, decisions regarding species composition were based on experience gained from acoustic surveys for orange roughy carried out in New Zealand. In general terms, high intensity marks that were closely associated with the seabed or pronounced changes in bathymetry were classified as the ORANGE ROUGHY mark-type (Figures 8 & 9). All other marks identified were assigned as the BACKGROUND mark-type (Figure 10).

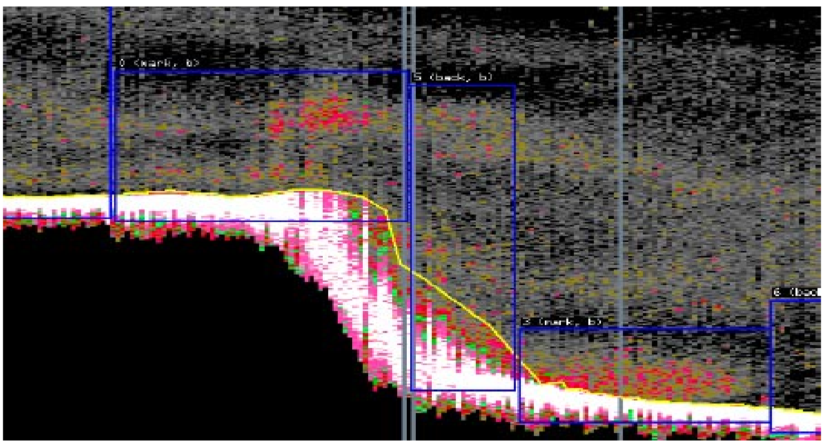


Figure 8. ORANGE ROUGHY mark-type (inside blue box), recorded on transect 19 in areas 7 and 8, snapshot 1. The mark is located close to a small seamound in approximately 1,150m depth. Vertical grey bands indicate pings removed due to excessive noise. The mark height is around 40m. Yellow line denotes boundary between echo and seabed.

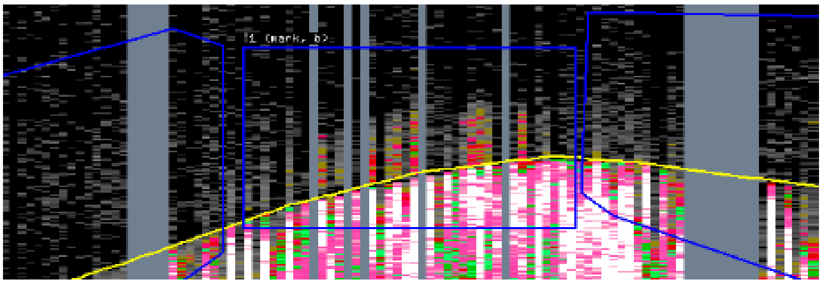


Figure 9. ORANGE ROUGHY mark-type (inside blue boxes), observed during transect 9 in areas 7 and 8, snapshot 2. Bottom depth (left side of screen) is 1,070m. Vertical height of mark on extreme right is around 40m.

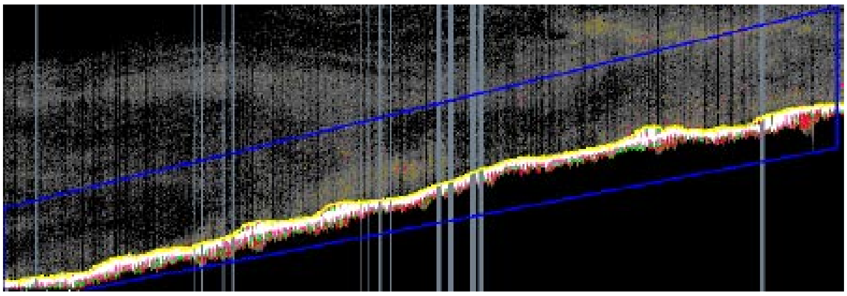


Figure 10. Typical BACKGROUND mark-type. Echoes of interest are the light grey marks lying within 10-20m of the seafloor within the blue box.

Orange roughy biomass and distribution

Echo distribution

The number of transects and their orientation relative to each target area including 3D visualisation and hydrographic conditions are shown in Figures 11-16. In total 27 echotraces were allocated as ORANGE ROUGHY mark-types on 22 transects, representing approximately 3% of the total survey track, increasing to 7% for snapshot 2 in area 1. The number of transects within an area containing orange roughy echotraces was variable, but adequate for analysis purposes since most areas had at least one allocated mark-type (Table 6). The variability in the number of transects with allocated ORANGE ROUGHY mark-types is observed in the two snapshots of area 7+8, where 9 transects yielded marks in snapshot 1, reducing to 3 in snapshot 2. The same number of transects (23) and area (52Km^2) was covered for each snapshot. In order to observe marks regularly, a high-resolution of closely spaced transects with a nominal spacing of 500m was required. For snapshot 2, transects were offset by 250m from those in snapshot 1, effectively giving a transect spacing of 250m. The average distance of the towbody from the seafloor was approximately 800m, as the beamwidth of the transducer is 7.0°. This yields a beam footprint of 98m diameter. Overall, this relates to a very high degree of seafloor coverage of approximately 51% over both snapshots in area 7+8.

Table 6. Survey area, number of transects, number of snapshots, trawl hauls and the number of orange roughy (ORH) echotraces allocated. * Indicates star survey snapshot.

		Snapshot 1			Snapshot 2		
Area	Area (Km2)	Total Transects	Transects with ORH Marks	Area (Km2)	Total Transects	Transects with ORH Marks	No. Tows
1	229	4	0	25	7	2	1
2	22	4	0	-	-	-	-
3	19	9	1	-	-	-	2
3*	30	3	1	-	-	-	-
4	65	16	5	-	-	-	3
6	30	12	1	-	-	-	4
7+8	52	23	9	52	23	3	5
Total	447	71	17	77	30	5	15

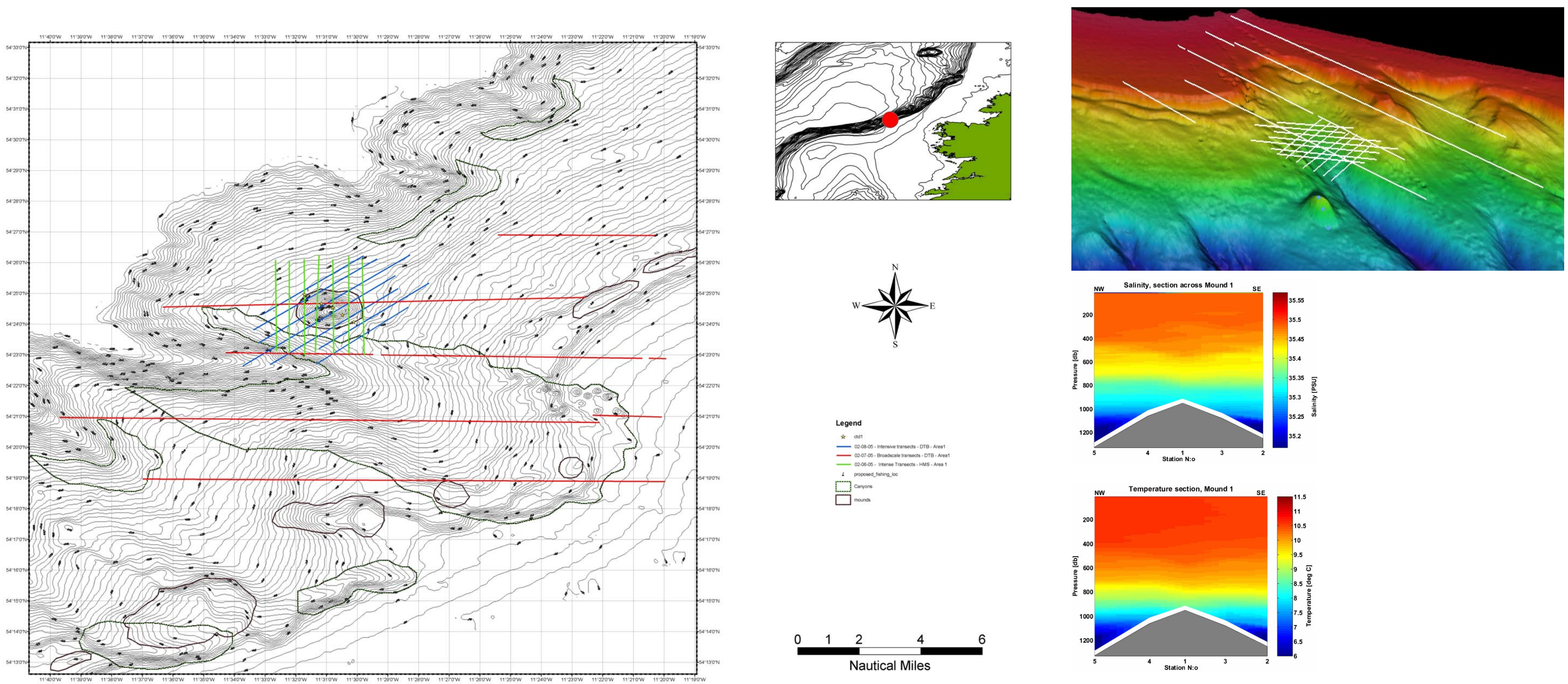


Figure 11. Area 1: Hill feature showing acoustic transects (left), 3D representation of feature with acoustic transect overlay (top right), Hydrographic conditions at the feature represented in salinity (top) and temperature (bottom right).

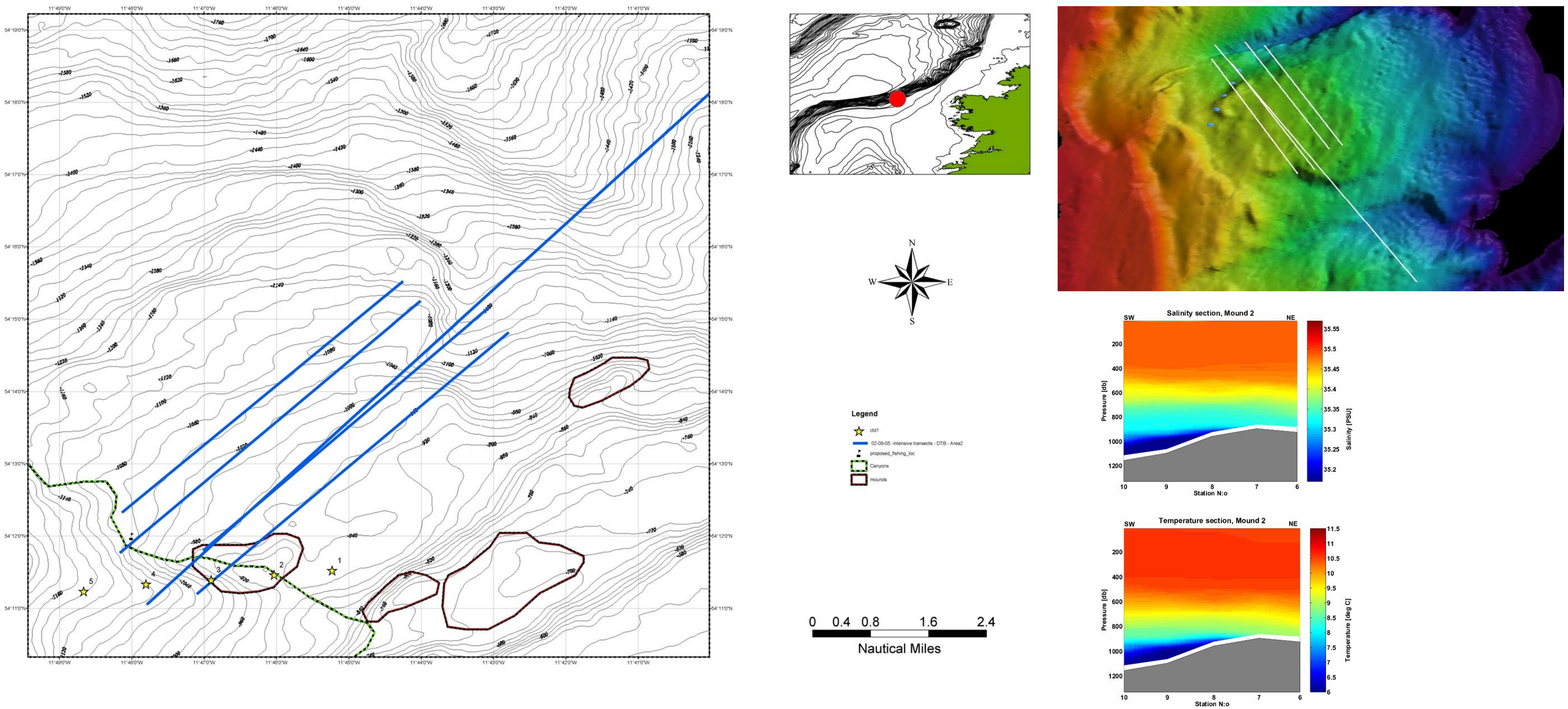


Figure 12. Area 2: Flat area showing acoustic transects (left), 3D representation of feature with acoustic transect overlay (top right), Hydrographic conditions at the feature represented in salinity (top) and temperature (bottom right).

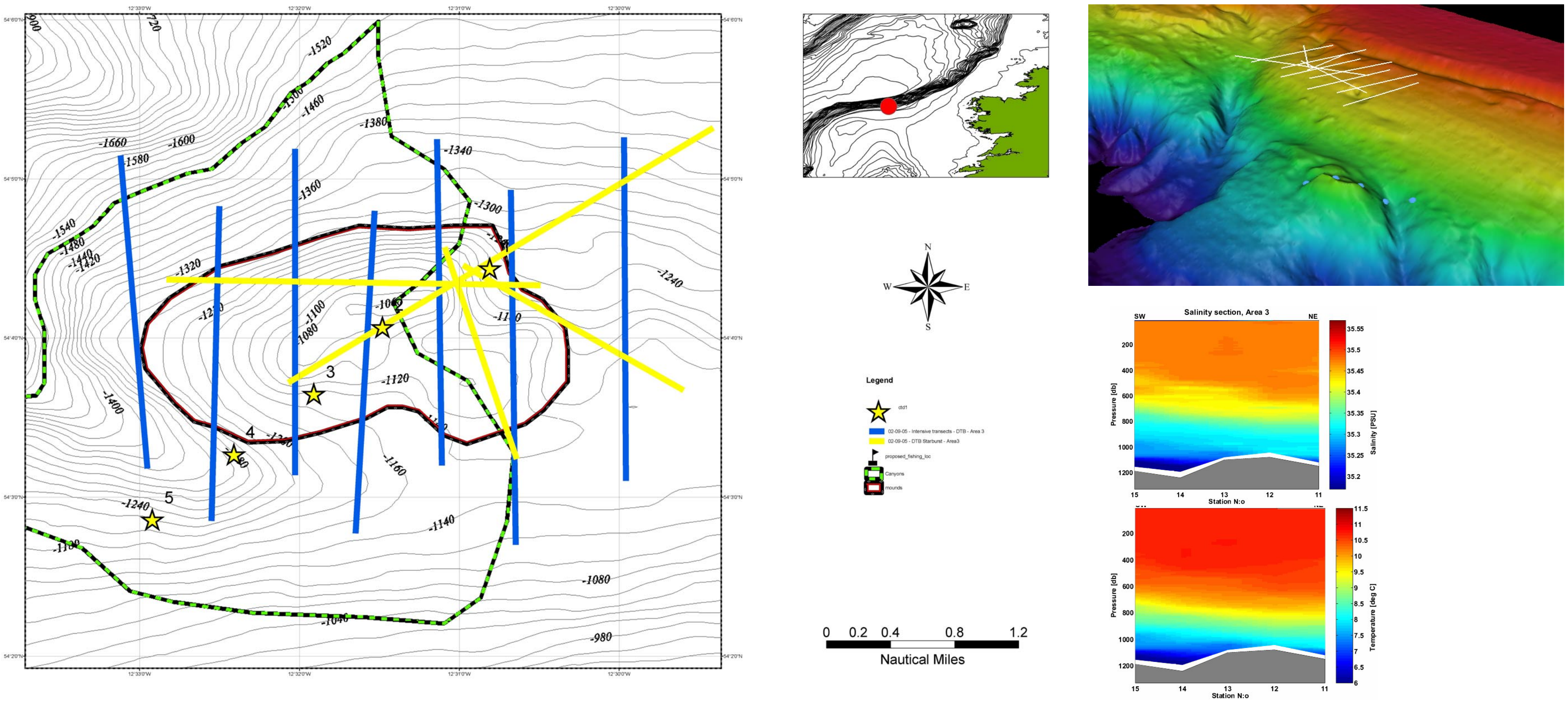


Figure 13. Area 3: Hill feature showing acoustic transects (left), 3D representation of feature with acoustic transect overlay including star survey transects (top right), Hydrographic conditions at the feature represented in salinity (top) and temperature (bottom right).

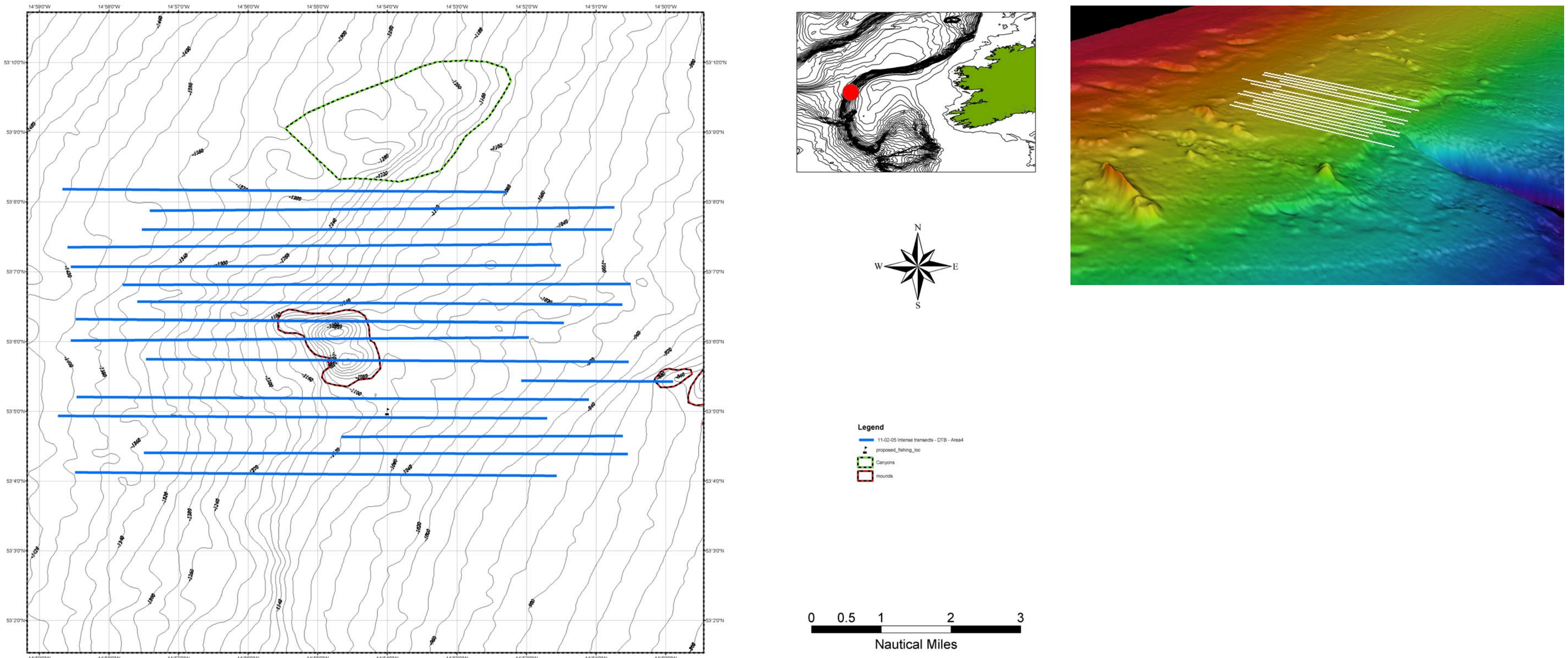


Figure 14. Area 4: Hill feature showing acoustic transects (left), 3D representation of feature with acoustic transect overlay (top right).

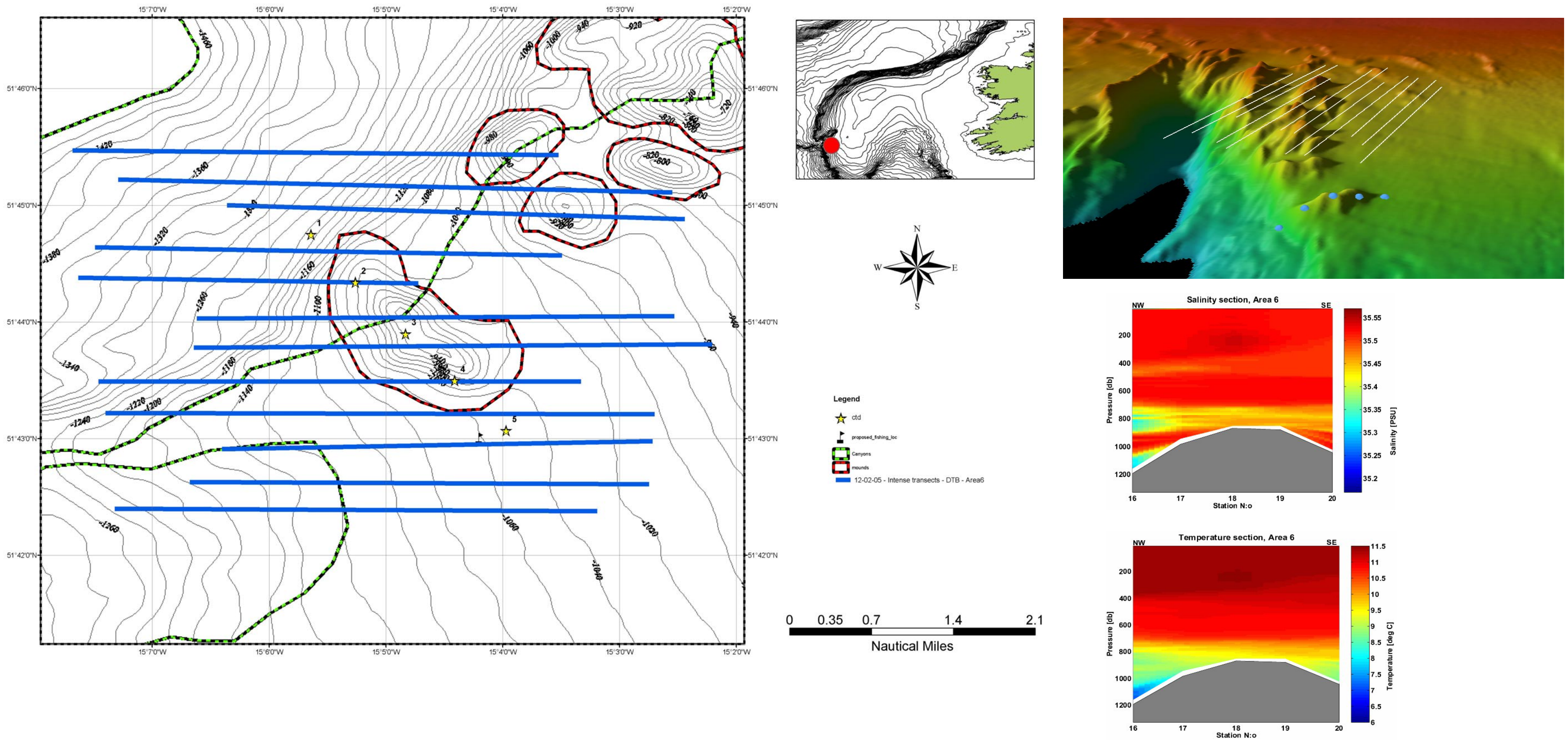


Figure 15. Area 6: Hill feature showing acoustic transects (left), 3D representation of feature with acoustic transect overlay (top right), Hydrographic conditions at the feature represented in salinity (top) and temperature (bottom right).

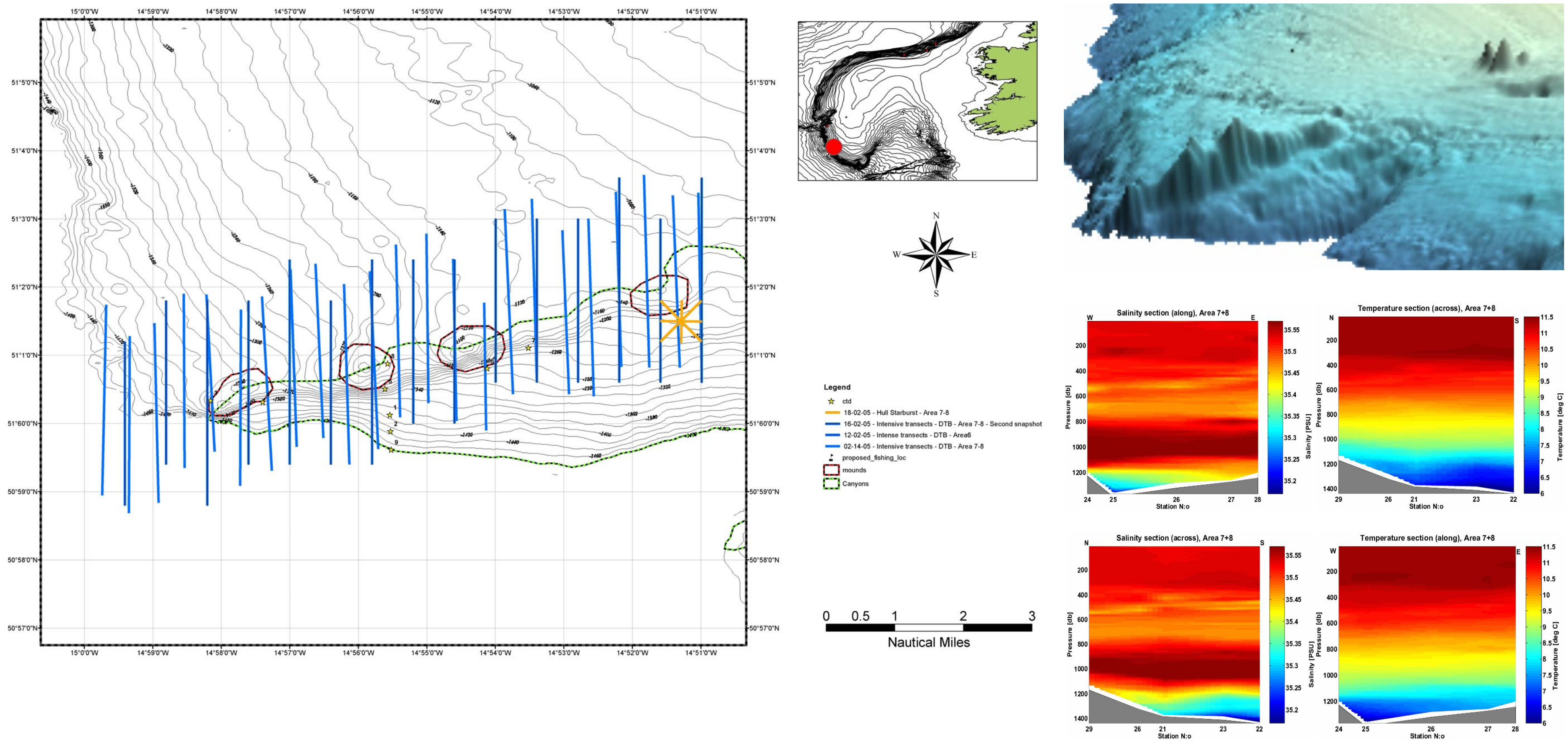


Figure 16. Areas 7+ 8: Hill features showing acoustic transects (left), 3D representation of feature (top right), Hydrographic conditions at the feature represented in salinity (top) and temperature (bottom right) respectively.

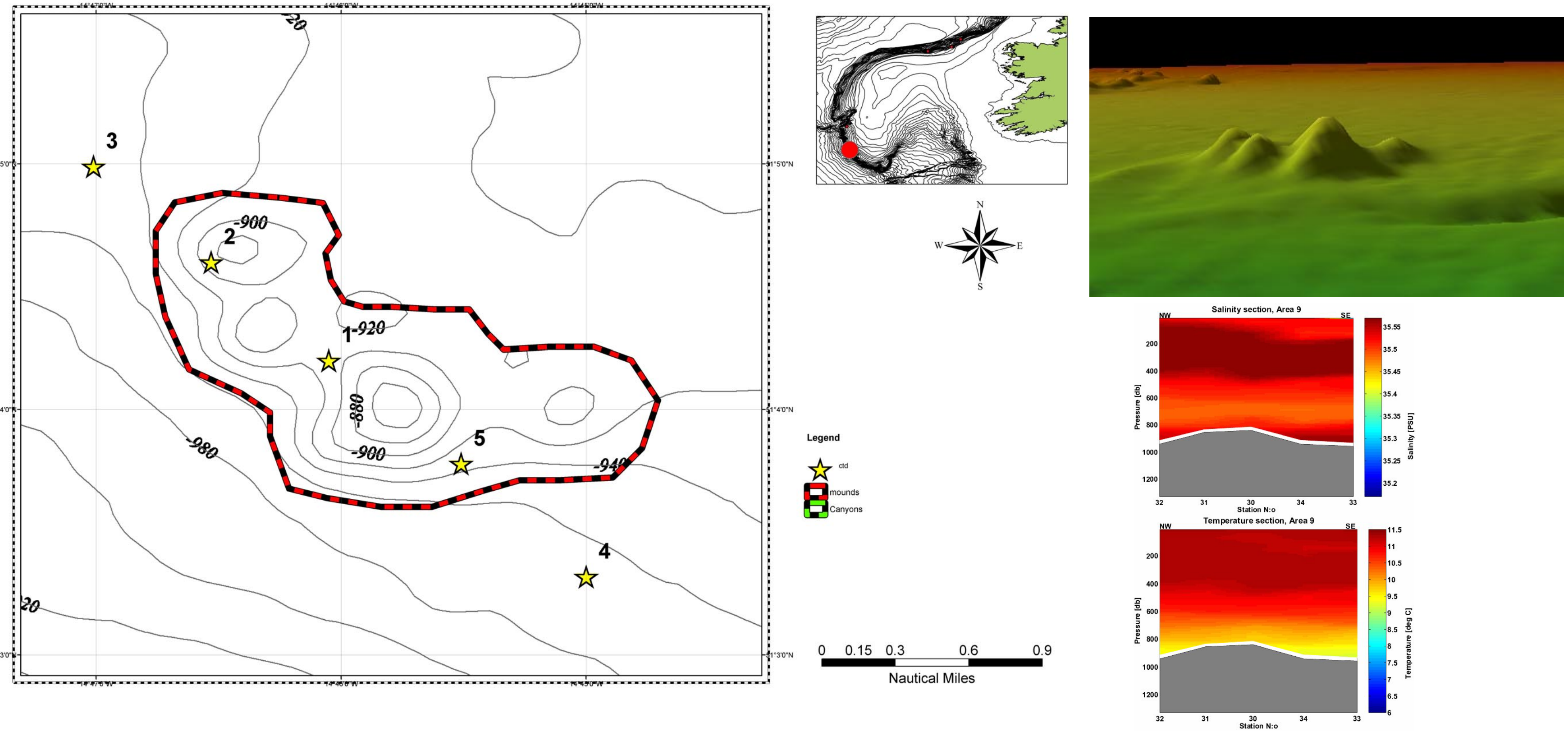


Figure 17. Area 9: Overview of the newly named "Explorer" and "Aglantha" sea mounds investigated for coral growth and habitat mapping showing CTD cast positions (1-5). 3D representation of the feature (top right), Hydrographic conditions at the feature represented in salinity (top) and temperature (bottom right).

Target strength applications

The target strength relationship for orange roughy used in this analysis is based on measurements of live fish in a tank (McClatchie *et al.,* 1999) corrected for depth (McClatchie & Ye, 2000) and combined with *in-situ* results from Barr & Coombs (2001). This relationship is the same as is routinely used for NIWA surveys. The TS (target strength) measurement used in this analysis is expressed as:

NIWA TS= 16.15 Log L –74.34 (Where L is fish length in cm)

In general, orange roughy are represented on an echogram within the -49 to -53dB range (lower end for single targets, higher end for dense aggregations). Orange roughy have a poor acoustic signature when compared to fish containing a gas filled swim bladder. The acoustic properties of orange roughy are generated through the concentration of waxy esters contained within the body mass and also the large and dense skull of the fish. This becomes apparent when roughy are found in a mixed species aggregation. Whilst echo integration works well with large single species aggregations, mixed marks create significant problems in terms of accurate estimation. Orange roughy biomass may be greatly overestimated without a trawl to determine the species composition of the mark. As air contained within a swim bladder is a much better reflector of sound energy than waxy esters, even relatively small single swim bladdered fish, such as small mychtophids may acoustically represent a number of individual orange roughy when in a dense mark.

Generic relationships were used for all other species, due to lack of species-specific target strength to length relationships. The relationship between tilt-averaged target strength <TS>, and length for the species observed in the survey are given in Table 7. The length (cm) is defined as the total length (TL) for all species except for orange roughy where it is standard length (SL) and roundnose grenadier (to pre-anal fin).

Table 7. Length-target strength relationships applied to survey data. * indicates deepwater swim bladdered species relationship as described by Doonan *et al.* 1999.

Species	Intercept (a)	Slope (b)
Orange roughy	-74.34	16.15
Smoothhead*	-79.4	20
Black scabbard*	-79.4	20
Roundnose grenadier*	-79.4	20

The length-weight relationships as determined form trawl samples and applied to acoustic data are shown in Table 8.

Table 8. Estimated length-weight relationships form biological data. Weight=a*length^b, where weight is in g and length is in cm. Where 'a' is the slope and 'b' is the intercept, 'n' is the number of fish sampled and R^2 represents the goodness of fit to the data model.

Species	a	b	R2	n=
Orange roughy	0.169055	2.56	0.77	1169
Smoothhead	0.006641	3.02	0.95	270
Black scabbard	0.000173	3.45	0.83	437
Roundnose grenadier	0.524152	2.65	0.86	201

Acoustic biomass

Acoustic biomass results include corrections for acoustic shadow zone, transducer motion, and absorption of sound by seawater. The estimated total biomass for orange roughy was 19, 000t (Table 9). This estimate was derived by summing the estimates for each of the survey areas, except for area 7+8, where the average of the two snapshots was used, and area 1 where snapshot 2 was used. The star survey in area 3 was also excluded since this was part of area 3 and its inclusion would result in double counting of allocated echoes. The c.v. for the total biomass attributed to orange roughy, considered as an absolute estimate was 60% and as a relative estimate was 29%.

Considering the three sources of variation individually gave c.v.'s of the total biomass of

- 31% for acoustic sampling variation alone
- 1% for catch data
- 44% for error in the estimation of orange roughy

The target strength variance source is due to the mean lengths of orange roughy sampled occurring outside the length range used to estimate the slope in the target strength relationship, i.e. a median if about 45cm for fish taken from trawl samples compared to a range of 27-37cm used in the regression. This is based on orange roughy samples from New Zealand, which are generally smaller than those occurring within the Irish survey area. Had the mean lengths been similar to those from New Zealand (e.g. 34cm) then the c.v. from this source would be significantly smaller at 14%. In turn this would have reduced the combined c.v. from 60% to 35% for an absolute estimate of abundance.

Table 9. Acoustic biomass (t) estimated by survey area and snapshot by mark-type. "Combined" is the estimates summed for an overall total estimate for orange roughy. Absolute c.v. includes all variance sources; relative c.v. only uses sampling variation from acoustic and catch data.

	ORANGE ROUGHY mark-type					BACKGROUND mark-type	
	Snapshot		Combined			Snapshot	
Area	1	2		Abs c.v.	Rel. c.v.	1	2
1		4420	4420	100	69	13388	2321
2						1771	
3	2884		2884	141	90	2463	
3*	892					937	
4	5085		5085	95	54	2600	
6	253		253	141	99	31888	
7+8	10059	2853	6456	62	40	2875	12529
Total			**19098**	**60**	**29**		

Estimates were also generated for BACKGROUND mark-types by area. Area 6 had a high biomass estimate for orange roughy, primarily due to the amount of roughy observed from trawl samples. However, this probably is not representative of the entire area as trawls were conducted along the same tow lines on each occasion along a known fishing line. Thus, it seems unlikely that catch data represents the background mark-type in this area, although this cannot be ruled out. Another inconsistency observed is the large difference between background estimates in area 1 between successive snapshots (1+2). This can be solely attributed to the area covered in each, 229Km^2 and 25Km^2 respectively, since the same trawl data was applied to both estimates. As trawls were restricted to where orange roughy were thought to be i.e. one trawl in the middle of area 1 and 2 trawls in area 3, these data were then applied over a wider area. Given the above, biomass estimates have not been summed over survey areas to produce a total biomass, as doing would give more credence to the total than was justified.

Physical oceanography
In total, 34 CTD casts were carried out in depths between 850m to 1,420m (Figures 11-17). One of the hydrographic transects (Area 4) was cancelled due to the bad weather, but all the other stations were carried out as planned. The water contained within the first 1,000m over the survey area was dominated by Eastern North Atlantic Water (ENAW). Salinity and temperature within ENAW varies due to local air-sea interaction and the influence of adjacent water masses. A mixed winter layer was evident down to about 400m. However, even this relatively well mixed layer contained variations, the largest of which were induced by the shelf edge current that brings highly saline and warm water northwards along the continental slope. It appeared as a salinity maximum at about 200-350m depth, which was very pronounced in the southernmost transects, and seemed to be present if less obvious in some of the northern ones. At about 1,000m depth, a hyper-saline, warm water mass of Mediterranean Sea Outflow Water (MOW) is known to spread northwards. We found a clear MOW presence, identified by its salinity maximum of near 35.6ppt, in all transects south of 52°N (Area 6, 7+8 and 9) and in none of the transects north of 54°N (Area 1, 2 and 3), as could be expected - MOW normally becomes diffuse north of about 52.5°N.

The small-scale spatial variations observed are hard to draw conclusions from with any certainty. The hydrographical variations within any transect are of course generally smaller than between different areas. Still, there are some temperature and salinity differences between stations only 0.44km apart. The question is whether these variations are significant on the spatial scale that we are looking at, i.e. whether they are small-scale features that would be better resolved with denser station spacing, or parts of a larger pattern. One notable small-scale feature is in the along-canyon section of area 7 & 8 (see Figure 16). In the inner (eastern) part of the canyon, at stations 27 and 28, the salinity structure at depth was distinctly different from the stations further out. The first three stations on that transect, 24, 25 and 26, all have a clear MOW salinity maximum centred at about 1,000m. In contrast, the two easternmost stations both have two salinity peaks, one around 1,000m and another at about 800m. Furthermore, the salinity at the 1,000m maximum is slightly higher at these stations than at the stations further west. Further assessment is required here to track any temporal variations that may occur. Finally it should be noted that due to the rough weather and the lack of any kind of bottom proximity sensor on the CTD rosette (except the echo sounder image), we had to put safety first and often stopped about 30m from the bottom, so there are no hydrographical data from the layer closest to the seabed.

Habitat mapping
Poor weather in week one combined with technical difficulties which resulted from damage to the ROV umbilical resulted in a curtailed work programme with ROV deployments only in Area 7, 8 and 9. Nevertheless, seafloor mapping using the IMR, Bergen ROV 'Aglantha' was a resounding success where deployment was achieved. All major objectives were achieved:

- High resolution video transects over target mounds documenting seabed facies type, biotope, biodiversity and impacts of orange roughy fishing.
- Multibeam calibration and mapping at Explorer Mound.
- First operational use of new GAPS (USBL) navigation system.

ROV Dive Summary- Area 7+8
Dives 1 and 2 took place on adjacent mounds situated on the northern edge of a canyon in Area 7 and 8 (Figure 18). Both dives began on the canyon floor and worked there way north to the mound summits. Dive 3 on a shallower three mound cluster in Area 9 began at the base of the southern flank of the largest 'Explorer' mound, moved up to the summit, where multibeam calibration and short survey was performed, before transecting across to the adjacent 'Aglantha' mound peak.

The first dive was carried out in near perfect weather conditions (wind SE at 4Kts, long-period swell of 1m height from the NW). The area in question was within Area 8 (51°01N and 14°56W). The dive was approached from a N-S aspect starting in the deep canyon (1,400m) and rising to the summit of the hill (1,160m), travelling a total vertical distance of 260m and a total linear distance of approx 1,500m. The dive took 6 hrs in total (including 1 hr each way decent/accent time). The strong 3 Kt current (E-W) hindered progress somewhat during the dive and was found to be the strongest on the canyon floor and also approaching the peak. No mulitbeam data was collected. The ROV speed was maintained at approx 0.3 knots with an altitude of around 1m from the sea floor. From 1,400m depth (transect start point) the bottom was characterised as muddy sand with occasional small boulders, small dropstones and biogenic mounds, pits and lebenspurren, interspersed with coral rubble and trawl door furrows (Figure 19a). On the mud, a large herd of *Amperima rosea* (Holothuroidea) was encountered actively feeding on detritus from the sediment surface. A number of individuals could be seen in the water column 'hang-gliding' within the immediate area. As the depth decreased to 1,300-1,250m a large, uniform field of dead coral, composed of varying colours (browns and whites) was encountered in an area before the hill started to rise. Degradation of coral skeletons is known to follows a sequence, which is reflected by its colour. Recently dead coral is a translucent white and occurs near the outer living edge of a coral bush. Below this the skeleton takes on a brownish colour as it is colonised by bacteria, which secrete a biofilm. Beneath this layer, corals that have been buried become white and smooth, as diagenic processes take hold. This indicates that the level and mixed nature of the field of relatively large coral chunks may have resulted from disturbance and active displacement due to trawling activity. From 1,250 to 1,160m the substrate was composed of coral rubble and interspersed with small patches of living soft and hard corals with associated epi-fauna, much of which showed some level of disturbance. A large (8m tall) vertical rock wall containing soft corals was the main feature at 1,200m. The summit of the feature was dominated by dead coral rubble, trawl door and gear impact scars. Small pockets of untouched growth existed in dips and hollows. This is consistent with information from the fleet, which attain large orange roughy catches from this hill during the spawning season.

Dive 2 took place on the hill to the east of Dive 1 (Area 7/8). The ROV began it's video transect on the canyon floor (1,350m) which was similar to that of Dive 1, characterised as muddy sand with occasional small boulders, small dropstones and biogenic mounds, pits and lebenspurren. Small boulders were typically sponge encrusted and hosted stylasterids, tubiculous polychaetes, *Psolus* sp. and ophiuroids. Stalked globular glass sponges were visible above sediment surface (Figure 19b). Linear gouge marks consistent with the passage of trawl door tracks and a large overturned boulder (epifauna upside down) indicated that these areas have been fished. Moving upslope on a northerly heading, fragments of dead coral (predominantly *Lophelia pertusa*) became more plentiful and larger in size. An area of relatively intact dead coral framework encountered at 1,206m provided a good contrast with an adjacent fished area that contained only fine coral rubble. A steep coral covered slope (c. 45°) was encountered at 1,200m giving way to gentler sparsely covered terrain. At 1,180m dense coral rubble was again a feature. An orange roughy was seen close to a massive triangular shaped rock outcrop at the 1,167m mark. The area above the rock outcrop, c.1,140 m, had been heavily impacted by trawling as evidenced by trawl door gouge marks, coral debris and displaced soft corals. The terrain close to the summit was dominated by dips and hollows. A large monkfish (*Lophius* sp.) was stationed near at the top of the mound, c.981m. The most visibly abundant fish at this location were *Lepidion eques* and *Neocyttus* sp. At the summit, the ROV took an easterly heading and proceeded down the slope gradient. The dive end point was located close to at a position where a trawl was reportedly lost from a commercial vessel. However, the ROV did not reach this point, as planned, due to the strong northerly current running between the peaks.

ROV Dive summary- Area 9

The dive began at the base of the so named "Explorer" Mound in 950m of water. Coral thickets made up of *Lophelia pertusa* and *Madrepora oculata* were immediately encountered as well as large antipatharian (soft coral) bushes. A striking feature was the presence of abundant tall erect vase-like fragile glass sponge (Hexactinellidae) of an unknown species together with lesser densities of the *Aphrocallistes* sp (Figure 20a). As the ROV progressed up slope the reef framework, composed predominantly of dead coral stands with occasional live colonies, became denser. The associated biodiversity encountered was high and compares well with pristine coral sites mapped in detail in the Porcupine Seabight and Rockall Trough. Several *Paramola* sp. (decapods) protecting their carapace with large pieces of *Aphrocallistes* sp. were seen (Figure 20b). Close to the summit coral cover reached 100%.

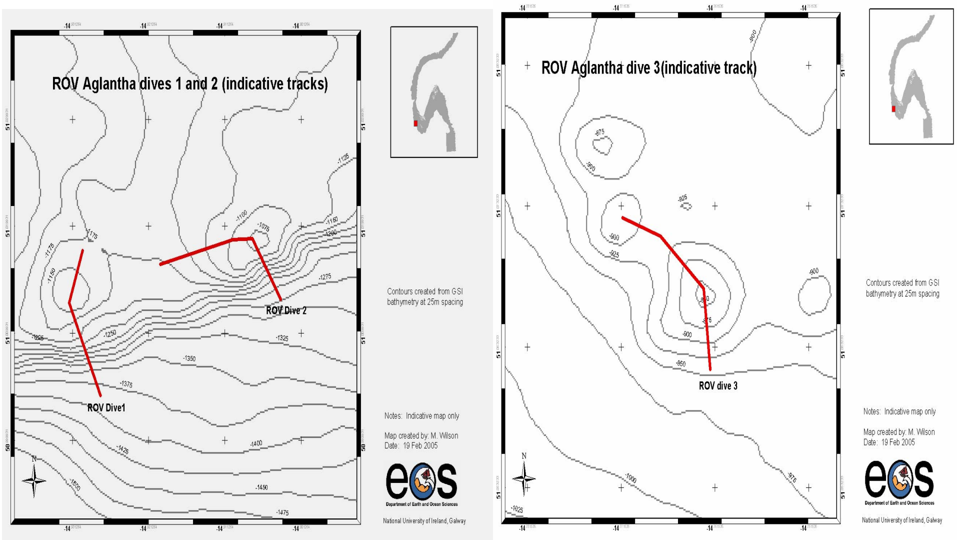
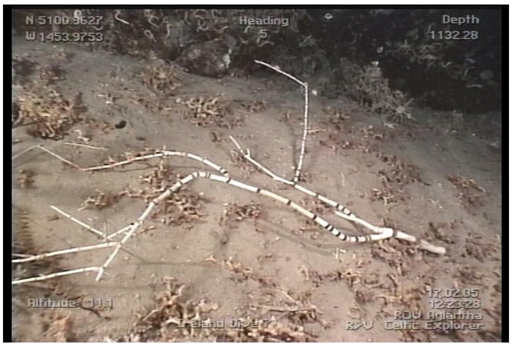


Figure 18. ROV "*Aglatha*" video and mulitbean transects in Areas 7+8 and Area 9.

At the summit, the ROV moved to an altitude of 20m above bottom and began a multibeam calibration exercise consisting of 2 passes over the same area in opposite directions to calculate offsets resulted from sensor bias. The ROV first moved east for 200m and then repeated the transect in a westerly direction. The ROV then moved to 50m above the summit and covered the same transect to compare feature resolution at the different heights. Following completion of the multibeam tests, the ROV dropped down to 1m above bottom and recommenced video survey. Several steep coral covered slopes were encountered together with coral covered sediment ridges and areas of dense coral stands. Between mounds there was little ground cover with some evidence, in the form of a displaced gorgonian, suggesting this area has been trawled.

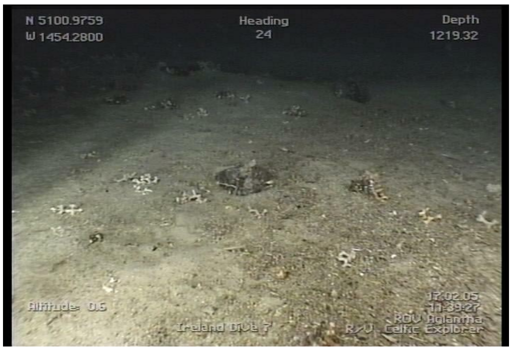
First impressions are that these mounds are relatively intact and have not been impacted heavily by fishing as borne out by the abundance of large fragile sponge and coral stands. Reef forming corals at this location, on first view, do not appear to be thriving, although in the past they must have done so, given the extensive sub-fossil reef still present. The dead reef nevertheless, forms an important habitat for small fish and other fauna including soft corals (gorgonians, antipatharians and octocorals), echinoderms (crinoids, ophiuroids and echinoids in particular), fan-worms (sabellids and serpulids), decapods (including squat lobsters, red crab) and sponge (erect and encrusting). All of these animals combine to form spectacular 'coral gardens', full of colour and vitality.

A



B

C



D

E

F

G

H

Figure19. ROV "*Aglantha*" still images taken during dives in Area 7 (plates A-H).

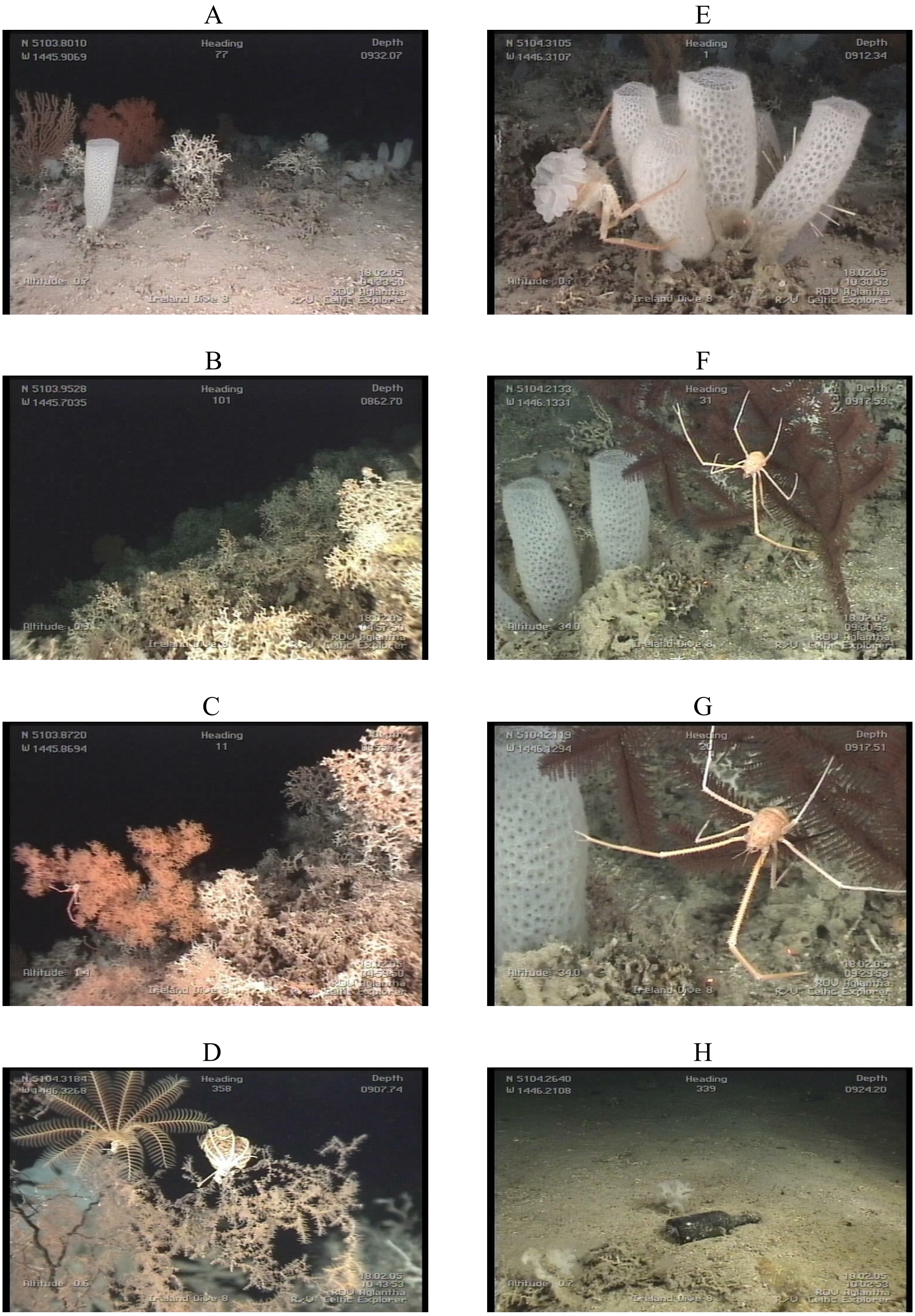


Figure 20. ROV "*Aglantha*" still images taken in Area 9 (plates A-H).

Marine mammal and seabird survey

Only two cetacean species of were positively identified during the two-week survey – the long-finned pilot whale (*Globicephala melas*) and the bottlenose dolphin (*Tursiops truncatus*). The blows of a single large whale and the splashes of small to moderate–sized cetaceans were also observed. However, these animals could not be positively identified. A total of 210 individual cetaceans were observed. The most frequently encountered and numerous species was the long-finned pilot whale. Approximately 140 individuals were observed during 12 separate encounters. Although group sizes ranged from one to 50 animals, most groups consisted of between 8-15 animals. Family groups composed of adults, immature individuals and calves were regularly observed, indicating the survey area may be a nursery/breeding area during the month of February. Long-finned pilot whales were observed in close proximity to the stern of the F.V. *Mark Amy* on three separate occasions. The same groups were then observed to subsequently devote their close attention to the activities of the R.V. *Celtic Explorer*. One such encountered lasted over five hours. Family groups of bottlenose dolphins were also noted over the southwest slope of the Porcupine Bank during the latter stages of the survey (*indicated by yellow circles in* Figure 21). The sighting of very small calves indicated the southwest slope of the Porcupine Bank may be a potential breeding site for bottlenose dolphins during February. Group sizes of this familiar dolphin species ranged between four and 35 animals. One mixed-species encounter involving approximately 50 long-finned pilot whales and 20 bottlenose dolphins was observed while the ROV was in operation.

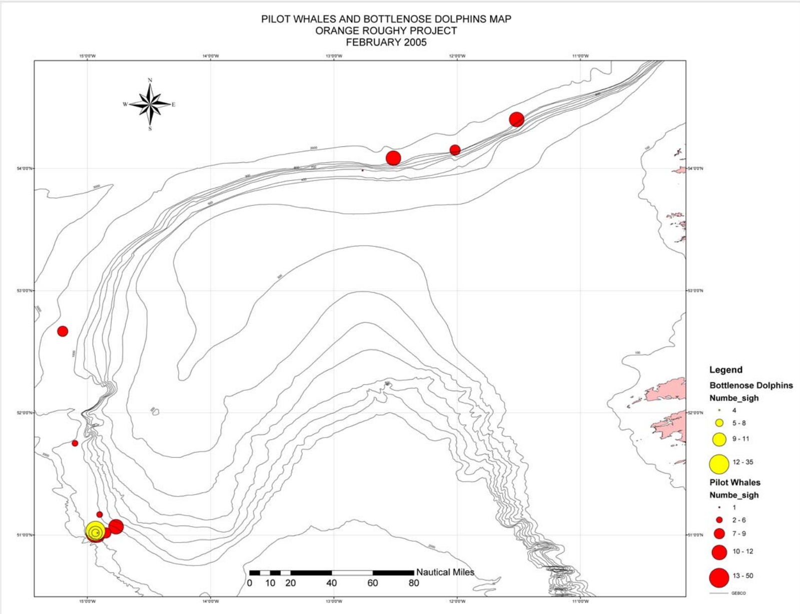


Figure 21. Sighting locations indicating approximate group sizes of long-finned pilot whales and bottlenose dolphins.

Only twelve seabird species were recorded during the 14-day survey. By far the most frequently encountered seabird species were the black-legged kittiwake and the northern fulmar, which were constant companions throughout the survey period. The highest concentrations of both species were recorded in close association with the survey vessels (i.e. R.V. *Celtic Explorer* and M.F.V. *Mark Amy*). Over 2,000 black-legged kittiwakes were observed on one occasion circling the M.F.V. *Mark Amy* during a haul. Other species to be recorded along the slope included the northern gannet, great skua, glaucous gull, Manx shearwater, Atlantic puffin and a single European storm-petrel that landed on the survey vessel's stern. The sightings of herring gulls, great black-backed gulls, common guillemots and razorbills were restricted to coastal waters as the ship headed out and returned from the offshore survey area.

DISCUSSION AND CONCLUSIONS

Discussion

In general, the survey was deemed a success in all aspects with survey aims achieved as planned. Heavy swells and poor weather conditions dominated the start of the survey and as a result 36 hours were lost in downtime. However, weather conditions in the last four days were exceptional and the downtime was partly made up.

The biomass estimate generated for orange roughy is modestly reliable when considered as a relative estimate but, not as an absolute estimate. The target strength relationship applied to data collected here in Ireland is too uncertain in relation to the size of fish encountered. The orange roughy encountered during the survey are larger than those on which the target strength relationship was originally based, mean lengths of 45cm as compared to 34cm in New Zealand. As a result mean lengths of orange roughy were outside of the length range used to estimate the slope in the target strength relationship.

As a relative estimate of abundance this is not considered a robust result and has low precision. In addition to target strength differences, the lack of directed trawling on acoustic marks, whether due to poor ground or weather conditions, meant not all areas were fished and so biological data had to be applied to marks that had not been positively identified. It was assumed therefore that marks attributed to orange roughy were indeed orange roughy. The biomass estimate generated for background mark types are not considered reliable or robust estimate. In all areas fishing was carried out on known fishing lines only, any marks encountered outside of these lines had to be attributed to the closest trawl station, whether this was representative of what the mark actually contained remains unknown. In all cases limited and highly localised trawl station data was applied over a wider geographical area to determine abundance. This level of precision leads to large uncertainties in the estimate.

The time lag between acoustically surveying an area and actual trawl sampling led to further uncertainties in the data as a time lag of up to a maximum of 3 days was recorded. This time lag would need to be significantly reduced in future surveys to ensure the integrity of the data. This is of particular importance for acoustic surveys where fishing operations are the sole means of mark identification of target species for the analysis. The timing of the survey, as determined from maturity stage sampling of orange roughy, indicated that the bulk of fish sampled had yet to spawn. The skipper of the catcher vessel and a feasibility study carried out by Boyer *et al.,* (2004) agreed that the survey might have been carried out a month too early and as a result the bulk of fish had yet to aggregate on the spawning grounds.

Important physical oceanographic data was collected during the survey, this allowed for detailed local conditions to be determined on specific features. When combined with ROV video transects this allowed for a very detailed examination of specific areas, both fished and un-fished area. Holistically, the multidisciplinary nature of the survey has provided some of the most detailed examinations carried out in this area to date.

Conclusions

Future surveys should consider using the main survey vessel as both survey and fishing platform, so as to reduce time lags and timing issues encountered mobilising two vessels. Fishing expertise could be accommodated onboard the survey platform to advise during trawling. The use of a separate catcher vessel should be employed on a basis that allows for direct control of fishing operations, so as to make best use of the vessel in regards to survey objectives.

High-density mono-specific orange roughy marks, as observed in New Zealand, were not seen during the survey and the biomass estimate is based on a scattering of light marks, a situation far from ideal for robust acoustic survey and biomass estimates. The large flat area over which roughy can be found in commercial quantities and the numerous seamounds and peaks, low catch rates and lack of large spawning aggregations, suggests a stratified bottom trawl survey may be a feasible alternative to a dedicated acoustic survey. However, it should be noted the lack of large aggregations might be a consequence of survey timing.

The current state of the orange roughy stock in Sub Area VII in 2007, remains uncertain. Current advice recommends no directed fishing and by-catch from mixed fisheries should be limited as far as possible. Closed areas have been in place since 2005 and a further recommended reduction in TAC to less than 90t in 2008 is advised.

Many questions remain unanswered from this pilot study, variability in the timing of peak spawning events and residence time on spawning mounds both pre and post-spawning need to be further investigated. If large aggregations are encountered, then the possibility of a combined trawl and acoustic survey may be realised as has been successfully carried out in New Zealand for a number of years.

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APPENDIX I

Total number of species encountered from trawl samples and level of sampling carried out.

Scientific name	Common name	Length	Weight	Sex	Mat.	Age	Stomach	Genetics
Hoplostethus atlanticus	Orange roughy	1714	1178	1171	1171	562	37	329
Aphanopus carbo	Black scabbard	800	437	332	332	154		11
Alepocephalus baiirdi	smoothead	726	272	118	118			
Coryphaenoides rupestris	Roundnose	687	202	47	47	25		
Lepidion eques		297	75	30	30			
Epigonus telescopus	Cardinal fish	223	192	74	74	50		
Centroscymnus crepidater	Long nosed velvet	135	57	121	31			
	Spearsnout gren	101	6	3	3			
Centrophorus squamosus	Leafscale	90	79	87	78			
Deania calceus	Shovelnose	78	29	74	24			
Centroscymnus. Coelolepis	Portuguese	60	25	59	59			
Hydrolgus mirabilis	Large-eyed	56	20	21	1			
Neuzumia aequalis	Smooth grenadier	44	1					
Molva dypterigya	Blue ling	40	34	26	26			
Etmopterus princeps	Lantern shark	31	30	23	10			
Mora moro	Mora	26	12	5	5			
Coryphaenoides guentheri	Gunther's	23	2	2	2			
	possible blue	19	8	1	1			
Galeus. murinus	Mouse catshark	15	6	14	5			
	Squid	12	4					
	Blue whiting	10	5	1	1			
Neocyttus helgae	False boarfish	10	7	1	1			
Chimaera. monstrosa	Rabbitfish	8	6	3	1			
Spectrumculus grandis		8	7	7	7			
Lophius piscatoris	Monkfish	6	6	4	4			
	Scorpion fish	5	3					
Chalinura sp.		4	1	1	1			
Notacanthus chemnitzii	Spiny eel	4	3					
Schedophilus medusophages	Black fish	3						
Cottonculus thomsonii	Pallid sculpin	3	1	1	1			
Benthodesmus elongatus	Frostfish	2	2					
Congridae spp.		2	2	2	2			
Caechion affinis	Deepwater crab	2	2					
Hariota releighana	Bentnose	2	1	1				
Raja fyllae	Round ray	2	1	1				
Agyropelicus oflersi		1	1					
Anaplogaster cornuta		1						
Beryx decadactylus	Beryx	1	1					
Pseudotrikais microdon	False cat shark	1		1	1			
Rhinochimaera atlantica		1	1	1				
	Octopus	1						
Syngnathidae spp.	Pipefish	1						
Stomidae spp	scaly dragon fish	1	1					
Serrivomer beani	Bean´s sawtooht	1	1					
Raja oxyrinchus	Longnosed skate		1					
Total		5257	2722	2232	2036	791	37	340

APPENDIX II

Maturity stages of female orange roughy by area as determined from trawl samples.

Area		1	3	4	6	7	7	7	7	Flat	Total
						Peak 1	Peak 2	Peak 3	Total		
Stage	**1**			1			1		1	6	1.4
	2	44.4	9.1	2.2	5.9	25	14.7	9.3	15.1	4.4	8.8
	3	11.1	13.6	2.9	6.5	22.2	27.5	7.4	20.8	2.2	10.5
	4	22.2	45.5	20.9	19.6	16.7	22.5	31.5	24	55.6	25.4
	5	0	18.2	64.7	57.5	25	27.5	50	33.3	15.6	45.2
	6	22.2	13.6	8.6	10.5	11.1	6.9	1.9	6.3	8.9	8.8
Total		100	100	100	100	100	100	100	100	100	100
n=#		9	22	139	153	36	102	54	192	45	560