DRAFT CRUISE SUMMARY

RV SOUTHERN SURVEYOR

SS99/03

Title

Biomass of the orange roughy and study of its deep-water seamount habitat off the east coast of Tasmania.

Itinerary

Depart Hobart 00:01 hrs, Friday 16 July, 1999
Arrive Hobart 10:30 hrs, Monday 2 August, 1999

Principal Investigator

Mr. Rudy Kloser

Scientific Objectives

The orange roughy fishery remains the most valuable component of the South-East Fishery (SEF). Following a series of egg and acoustic surveys of the spawning stock off St. Helens, Tasmania from 1990-1993, and an international review in 1994, it was concluded that the fish-down of the stock had been completed and SETMAC adopted a TAC that would enable the stock to rebuild to 30% Bo by 2004. However, following data reanalysis and increasing emphasis on the combined stock hypothesis in the 1996 and the 1997 assessments, it appears that TACs would need to be further reduced to enable the stock to rebuild to 30%Bo by 2004. This would be a major loss of revenue to industry. The validity of the current estimates of stock status therefore need to be clarified.

To clarify the status of the stock a survey of St Helens hill was requested that had greater spatial and temporal coverage than in previous years. In addition, there is an ongoing need to develop deepwater acoustic assessment techniques for orange roughy stock assessment using both industry vessels and research vessels. To carry this out in a cost effective manner, information from fishing vessel sounders will be collected over a four week period in conjunction to the precise CSIRO deep-towed multi-frequency acoustic surveys over the height of the spawning period. During the intensive survey we will cross calibrate the various acoustic platforms to assess how best to use industry acoustics in the long term management of the resource.

It is not known why orange roughy spawn at St Helens Hill with such regularity and part of this study will be to establish both the water column and seabed attributes at both the St Helens and St Patricks Head grounds.

Cruise Objectives

1. To assess the biomass of orange roughy based on acoustic surveys on the Eastern Zone fishing grounds (St Helens and St Patricks) during the spawning period using industry vessel acoustics over an extended 4 week period and the CSIRO acoustic package during the anticipated peak spawning period.

2. To compare the sensitivity and precision of acoustic surveys using scientific vessel-mounted and towed-body acoustics and industry vessel-mounted acoustics at various frequencies.

3. To further develop the acoustic method by improving the multi-frequency technique for species identification: sound absorption coefficient and in-situ target strengths.

4. Map significant deep-water seabed habitats using the towed deep-water video camera and towed acoustic system and further develop the technique with experiments in shallow water.

5. Identify the composition of distinct bio-acoustic scattering layers with underway multi-frequency acoustic data and target sampling with a pelagic trawl capable of depth stratified sampling.

Cruise Track

The vessel operated in deep water 700 – 1200 m off the east coast of Tasmania on the orange roughy fishing grounds known as St Patricks Head and St Helens Hill. The attached cruise track shows the location of these grounds, Fig. 1.

Results

The primary aim of the cruise was to estimate the biomass of spawning orange roughy on the St Patrics and St Helens fishing grounds through a combined acoustic/trawl survey using both the research vessel *RV Southern Surveyor* and the industry vessel *Saxon Progress*. Both vessels were fitted with vessel mounted acoustics whilst the *Southern Surveyor* also used the MUFTI (Multiple Frequency Towed Instrument) system, a deep towed body that houses transducers of various frequencies that aid in fish species identification and determination of in-situ target strengths. The ability to remotely sense the presence/absence of orange roughy from vessel mounted acoustic records became a major component of the study. As well as obtaining a snapshot biomass assessment on the fishing grounds, we studied both the water column and seabed habitats of these grounds. A deep-water video and benthic sled was used to sample the seabed fauna and geology, the mid-water opening/closing net system (MIDOC) and MUFTI acoustics was used for nekton sampling. The physical properties of the water column were measured with a CTD both deployed vertically from the vessel, as well as being recorded by the towed (MUFTI). Table 1 outlines the operations conducted during the cruise with equipment name and start date/time and position.

Objective 1. Snapshot Biomass of Orange Roughy

The primary objective of our work was to assess the biomass of orange roughy on the two fishing grounds of St Patricks and St Helens seamount over the spawning period. The RV Southern Surveyor calibrated its acoustic sensors on the 16th July at Port Arthur and conducted acoustic and biological sampling of these grounds from the 17th of July to the 1st August. Additionally, and in conjunction with the *Southern Surveyor,* the industry vessel *Saxon Progress* conducted demersal and acoustic surveys on the grounds from the 9th July to the 11th August, Fig. 2.

Acoustic Survey Design

The acoustic survey designs for the two grounds differed due to the underlining topography and the different species that were encountered at both sites. Extensive use was made of detailed bathymetry provided by Peter Hill from AGSO to plan our surveys and to concentrate on key geographic features, Fig. 3 a and b.

At St Helens seamount we conducted three different types of surveys. The first was based on our traditional survey pattern that has been carried out since 1989: 5 North – South transects along 0.5 minute longitude lines, Fig 4. Our second survey design was effectively a star pattern that divided the hill into 6 transects of pseudo random locations. This survey design was trialed after feedback from the industry with the added advantage of optimising the turns for our deep water towed body. The third survey design that followed the depth contours (700,750, 800, 850, 900 1000 m) of the hill (loops) was required to make full use of our multi-frequency system to enable it to resolve the acoustic species at a fixed height above seabed,180-250 m, Fig. 4.

The acoustic surveys at St Patricks were designed to cross the topographic and fish distributions at right angles and hence our surveys were conducted with several East-West transects, Fig. 5. To obtain detailed information on the distribution of the orange roughy, multi-frequency tows (towed body at 700-750 m depth) were conducted along the depth contours in an approximate NNW direction. Tables 2 a, b and c outline the acoustic surveys performed with the dates and times as well as the method used and number of transects.

Acoustic Survey Summary

The overall biomass of orange roughy on the two grounds became clear after our first surveys with both the vessel and towed acoustics and detailed demersal trawling with the industry vessel (Saxon Progress).

The most striking result was the lack of identifiable acoustic marks at St Helens Hill that could be confidently attributed to orange roughy. The vessel mounted system detected many acoustic marks in the appropriate depth range (700-1000 m) but these could not be confidently attributed to orange roughy. A persistent acoustic mark that moved around the top of the hill (600 – 750 m depth range), was identified as alfonsino and or cardinal fish; based on trawling and multi-frequency acoustics. As both these species have large gas-filled swim bladders, they produced highly intense

marks when schooled tightly, but when dispersed produce marks similar to orange roughy schools; as viewed from the vessel mounted transducers. Our multi-frequency acoustic system proved to be the only method available to confidently identify the deep water marks as being from orange roughy. It showed that there were very few marks attributable to orange roughy aggregations, most were attributed to myctophid and whiptail/morid fishes. During the first survey of St Helens Hill several small orange roughy schools were found in deep water to the north and west. In later surveys distinct schools were found in the NW (800-900 m), NE (800 m)and SE (750 m). The size and intensity of these schools was greatly reduced from the previous survey in 1996.

At the St Patricks ground a large body of orange roughy was surveyed. It remained very stable over the ground for the two week survey period, although it moved locally, changing its position over hourly and daily periods. The main body of fish was located on the north eastern end of a prominent ridge, and would move on and off the ridge between surveys. This main body of fish extended along the ridge south for 3-4 nautical miles and petered out on the southern extremities, Figure 6. The school did not show any large east-west extent. Large catches of orange roughy 2-30 tonnes were obtained from tows in this region by the *Saxon Progress*.

Objective 2. Comparison of acoustic devices

Throughout our survey we logged both the vessel mounted (12, 28 and 38 kHz) and deep towed (12,38 and 120kHz) acoustics from the *RV Southern Surveyor*. We visually compared the results of both vessel and towed mounted systems for various weather conditions and species mixes. The 28kHz echosounder on the *Saxon Progress* was logged over a 5 week period whilst the vessel was on the fishing grounds. During this time we we conducted some duplicate transects on the St Patricks and St Helens grounds for direct comparison between the systems. Prior to the surveys there was uncertainty about the ability of the acoustic loggers to capture information of sufficiently high data quality from the vessels' 28kHz systems due to noise problems with the EchoListener. During this survey we tested both a modified EchoListener and a Simrad 28kHz logger. Routine checks of data quality made during the survey showed data capture was successful and was of acceptable quality, Fig. 7.

Objective 3. Absolute acoustic biomass assessment method development

During the survey we made extensive use of the multi-frequency deep water system and were able to distinguish between the orange roughy and associated bycatch species of whiptails, morids and myctophids, three groups of fishes with gas filled swimbladders. Figure 8 shows the results of mixing the multi frequency information together for a tow in deep water off St Helens seamount.

In this example, discrimination of roughy and non-roughy species was straight forward, something which is not always the case. However, the multi-frequency mixing clearly shows the different acoustic reflectors (groups of fishes) found at these depths and the advantage of the acoustic system over trawling and vessel mounted acoustics.

A detailed experiment was performed to measure the absorption of sound in seawater at 38 kHz. For absolute acoustic assessments it is important to have an understanding of this parameter (Kloser, 1996). For this experiment we turned the towed body upside down with a special rig so that the vessel and towed transducers could ping to each other. The experimental procedure required us to have a detailed knowledge of the towed transducers position whilst lowering it to 900 m depth. This was achieved by using a newly acquired Sonardyne positioning system that proved to be essential for the vessel to maneuver itself over the towed body. The experiment required great skill from the vessel operator to maneuver the vessel with thrusters against the current and 15 – 20 knots of wind. It was possible with this experimental technique to locate the towed and vessel transducers in each of the respective split beam windows of the beams from 150 to 900 m water depth. Results from the experiment will require extensive analysis to account for the movement and direction of both platforms.

Conditions for obtaining detailed target strengths of orange roughy were not available for most of the cruise due to wind, currents and fishing vessels at both grounds. At the end of the cruise, a 5 hour window of ideal conditions became available and we were able to lower the towed system whilst stationary to 850 m depth and slowly drift over the aggregation of orange roughy on the North East ridge of St Patricks Head. Several hours of simultaneous calibration and target strength information was obtained that should allow us to calculate the expected target strength of fish on this ground, Fig. 9. Given the use of multi-frequencies in the towed body we should also be able to exclude gas-bladdered targets from our estimate and produce a highly precise estimate of target strength for orange roughy. This will be a major advance in our ability to perform absolute snapshot biomass assessments.

Objective 4-5. Water column and seabed habitat

To place the acoustic biomass assessments in an ecological context we investigated the orange roughy's water column and seabed habitats at the spawning grounds. To achieve this we made extensive use of detailed bathymetry provided by Peter Hill from AGSO to plan our sampling (Fig. 3 a and b). Our habitat sampling can be divided into several parts. First we examined the overall geology of the region by making use of the deepwater video and benthic sled. On board the data was analysed and placed in context by Peter Hill from AGSO. The benthic fauna was sampled by the deep-water video and sled and summarised by Karen Gowlett-Holmes and Mark Lewis. To examine the water column nekton we used the IYGPT pelagic trawl with associated MIDOC sampler that could discretely sample 5 depth layers with associated multi-frequency acoustics over the same water column. This data was summarised on board by Alan Williams, Rudy Kloser and Tim Ryan.

Summary of deep water geological information

Volcanic rocks were recovered in benthic dredge hauls from St Helens Hill, confirming for the first time that this edifice is indeed a volcano. The rocks, of mainly basaltic composition, comprised both dense and vesicular fine-grained volcanics, scoria and dark laminated flow material. The samples were up to large pebble size (several cm across), angular to sub-angular. Fossiliferous carbonate crusts were also recovered, as were some small lumps of calcarenite (from hauls that traversed the

lower slope of the seamount). Video footage on St Helens Hill summit area indicated mainly a hard carbonate surface (crust), with patches of coarse calcareous sand and coral debris. Dark probably volcanic rock was exposed on some of the steeper and rugged parts of the summit area.

Video runs on the northern St Patricks area revealed a relatively flat bottom interspersed by mounds and pinnacles, often of high relief and rising as vertical walls many metres high. These were the local topographic highs (often 10-30 m high) seen in the swath imagery and acoustic profiles. The intervening flat areas had a relatively thin blanket of bioturbated calcareous sand, commonly with current-deposited drifts of dead coral fragments. The mounds and pinnacles were composed of a light coloured (almost white) moderately-weakly cemented sediment, fractured and blocky in places mainly massive but showing occasional bedding planes. White, freshly exposed surfaces and broken blocks were evidence of impact by trawling gear and indicted the relatively soft, friable nature of the material. Where exposed, the base to the flat-lying areas between the local highs appeared to be of the same material as that forming the mounds and pinnacles. Benthic dredge sampling brought up large quantities of this material (to boulder size). It consisted of white bryozoan sandstone (calcarenite), generally weakly cemented. This sediment would have been originally deposited on an ancient shelf, now deeply submerged as the margin subsided. Subsequent low sediment supply and differential erosion of this former shelf probably left the local highs standing as erosional remnants.

Video runs across the steep drop-off and canyon to the northeast and east of the northern St Patricks grounds, showed a rugged rocky terrain, with many rounded boulders, and a bare rock surface on part of the canyon floor. The exposed rock appeared darker and harder than the calcarenite. A dredge haul from this area contained a 250 mm block of coarse lithic quartz sandstone, derived from local granitic basement - probably part of the onshore Devonian suite. Calcarenite is again exposed on the far side of the canyon, which lies at a lower level than the adjacent St Patricks promontory. This suggests that the escarpment and St Patricks promontory may been produced by faulting, perhaps at the time of the major phase of volcanism that created St Helens Hill and adjacent volcanic terrain.

The benthic dredge on relatively flat seafloor just WSW of East Hill recovered little in the way of volcanic rocks, probably because it was located too far off this feature. Nevertheless, bryozoan limestone was sampled, suggesting that this area, now about 1300 m deep, was formerly much shallower. It was a shelf environment, where major biogenic carbonate production was taking place. Recovery of an angular piece of meta sediment (shale/slate), perhaps early Palaeozoic Mathinna Group, suggests that basement outcrops nearby. The high foram component of the foram (nanno) silty sand recovered in the pipe dredge at this relatively deep-water site reflects the more open marine conditions here and hence higher pelagic deposition.

Summary of benthic Fauna from the deep sleds

St Patricks Head area
Two stations - #25, #26, both contained very little, very small quantities of rock and dead shell, a small colony of bushy gold coral, a pancake urchin, a stalked crinoid and a selection of gastropod molluscs.

North of St Patricks Head
One station - #38, contained over 60kg of rocks, a small colony of bamboo coral and part of a large crab, probably a homolid, both the coral and the crab had been crushed by the rocks.

St Helens Hill area
NW gutter – two stations - #62, #63, first sled near top of hill contained a large amount (50kg) of dead coral, primarily (>90%) of a species of *Enallopsammia*? (to be checked) with very small amounts of dead *Solenosmilia variabilis* (the species on the SE seamounts), and dead solitary corals, mainly *Caryophyllia diomediae*. A very small amount (a branch of a few polyps) of live *Enallopsammia*? was also collected. The coral appeared to have been dead sometime, showing some wear, possibly from transport, and some pieces were extensively bored. The few pieces of *Solenosmilia variabilis* present were very worn and fragile. The corallium of this species is often hollow from boring of sipunculan and polychaete worms, even in fresh colonies, while that of *Enallopsammia*? is never bored in this way, and is very solid. Over extended time, particularly if subject to wear and weathering, the skeleton of *Enallopsammia*? would persist longer and in a more robust state than that of *Solenosmilia variabilis*, and would skew the proportions of the species present, but I do think that this alone would account for the extremely high proportion of the former species present in these samples. The second sled collected a much smaller amount of dead coral (5kg). The proportions of the species present were very similar, although there was possibly a little more *Solenosmilia variabilis* in this sled than the last one. There were a few larger lumps of *Solenosmilia variabilis* matrix present, one of which contained the only galatheid collected. There were also a few live brachiopods present, all attached to remnants of *Solenosmilia variabilis*.

The dead shell in both sleds included dead brachiopod shells and barnacle plates, and there was a higher proportion (about 50%) of brachiopod shells in the dead shell in the second sled.

Virtually all the live animals collected were mobile fauna, predominantly scavengers/deposit feeders, e.g. gastropods, crabs, hermit crabs, sea stars, sea urchins. Even animals that are usually regarded as being fixed such as sea anemones and stalked crinoids were types that are capable of reattachment if knocked loose or moving location if required. The sea anemones collected were not firmly fixed to the substrate – they had been scraped loose with the pedal disc intact, and could easily reattach to the substrate.

SE side – two stations, #72, #73, collected samples very similar to those in the NW gutter, but in much smaller quantities. The mix of species in the dead coral was very similar, but the quantity of dead coral collected was two orders of magnitude smaller. Again, the fauna was mobile and dominated by scavengers/deposit feeders. The *Dermechinus horridus* sea urchins, while present in good numbers, were quite small compared with ones from other areas (e.g. SE seamounts, Bight) – this may indicate that they are stunted from poor food supply. A single large colony of black coral was collected, the only significant fixed filter feeder collected anywhere on the hill. While such filter feeders are obviously present (e.g. from video footage), they are not in dominance as they were on the SE seamounts.

Summary of St Helens Hill
The present living fauna is dominated with mobile scavengers/deposit feeders, most of the filter feeders present are also mobile (e.g. crinoids, brisingid seastars), resembling the situation on the summit and upper reaches of the fished seamounts of the SE seamounts. There is a marked lack of ophiuroids and galatheids, which were a major part of the communities on the SE seamounts, and the dominant species of coral in the coral rubble collected is completely different to that from the SE seamounts. No species collected so far are likely to be endemic to the area, although many are poorly known and some may be new.

The Mounds (10-40m high)
One station, #75, which came fast partway into the tow. The material collected consisted of some rocks and a quantity of dead coral, all *Solenosmilia variabilis*, mostly of a similar age, but no sign of any live polyps. There was virtually no living fauna, just an ophuroid and a crab. From the video, we know that the rocky knobs have mobile fauna present, dominated by scavengers/deposit feeders similar to that collected from the St Helens Hill, and the coral drifts, confirmed by the sled, contain little fauna.

The marked difference in the species of coral in the dead coral rubble between this sample and those from St Helens Hill cannot be explained at present. However, from the video, *Solenosmilia variabilis* is the coral present in all of the coral rubble drifts around 'The Mounds', so this sample is not aberrant in that regard.

Coral comments
On the tops of the shallower untrawled SE seamounts, even though there were huge beds of coral, very little of it was actually alive. Living coral was confined to small patches, surrounded by large areas of dead coral. The coral matrix between the living patches was, however, continuous. Further down the sides, the coral became more patchy – large clumps of mostly dead coral but intact matrix, usually with small living patches on them - often with patches of sediment between the clumps. On the lower slopes there was coral rubble, sometimes with largish lumps in it, but all dead. On the deeper seamounts, particularly those with summits below 1500m, there was dead coral, mainly rubble, with no signs of living coral.
From this we assumed that :-

- Even under good conditions the amount of living coral is small. The coral matrix is made up of dead coral still *in situ* with small patches of live, growing, coral.
- Under some conditions (but not at present), condition became good enough for coral to grow on the deeper seamounts. Under these conditions, coral growth was probably more extensive on shallower seamounts as well.
- Coral growth is probably episodic – more growth under good conditions, and small patches of live coral persisting under poorer conditions.
- Coral is very slow growing, and most growth is asexual budding in existing colonies. Rate and periodicity of sexual reproduction is unknown. Newly settled polyps, particularly on bare rock, would be subject to severe competition and predation, so successful recruitment of new colonies would be extremely rare, even during periods of good growth conditions.

The presence of large amounts of dead coral off St Helens Hill and St Patricks Head, including 'The Mounds', indicate that coral once grew readily in the area. The difference in the species present in the different areas cannot be readily explained given the current lack of knowledge of the ecology of these deepwater coral species. The lack of coral in this area explains the lack of the coral associated species such as ophiuroids and galatheids that are present on the SE seamounts. There are several possible reasons for the lack of live coral in the area at present:-

- The conditions are currently too poor for coral growth. It is possible that conditions for coral growth have been very poor in this area for some time.
- The best place for the coral to grow would be on the summit of the St Helens Hill – due to trawling, this coral has been removed. Any small patches of live coral that were persisting there during this poor period for coral growth have been removed.

Due to the extremely poor chance of recruitment of new coral, and continued trawling, it is very unlikely that the coral will recover under present conditions. Trawling at 'The Mounds' has probably not been extensive enough to remove all of the coral from the knobs to form the rubble beds. Some of this loss would have occurred due to the soft rock giving a poor attachment base for the coral, which has fallen off naturally. There has probably been no coral growth at 'The Mounds' for some time.

On the SE seamounts, coral covered seamounts summits had a fauna dominated by filter-feeding species, many of which were sessile and fixed, and coral associated species such as ophiuroids and galatheids, and included a number of endemic species. The shallower seamounts summits where the coral cover had been removed by trawling were dominated by scavenger/deposit feeding animals, mostly very mobile, and made up of species with wide distributions. The current fauna of the St Helens Hill/St Patricks Head area is very similar to the latter case.

Summary of deep –water video and camera observations

We carried out four successful camera drops. One test shot at a study site west of Maria Island, two on St Patricks Head and one on St Helens Hill. There were some initial problems with integrating the frame grabbing hardware but this was rectified for the last two deployments. Overall the camera collected over five hours of high quality footage. The trial deployment at the Maria Island site (station 9) shows a uniform seabed of carbonate sands with no ripples but a lot of bioturbation. The depth range covered was 85 to 95 meters.

The next deployment (station 30) was on St Patrick's Head and collected footage of the seafloor showing a generally flat carbonate shelf with the occasional outcrop of calcarinite inhabited by moluscs, crinoids, anemonies and fish including whiptails, cod, shark and the occasional orange roughy. The depth range covered was between 840 and 980 meters. The abundance of fish and invertebrates increased as we approached the gutter running south-east through Paddy's head. The rock became darker, more granitic and topography more dramatic. Fish and invertebrate numbers increased as the terrain changed and orange roughy became the dominant fish. The orange roughy formed quite dense schools and tended to hide close to the bottom,

sometimes swimming into the bottom or rock to escape the camera. They are fast swimmers and have a tendency to shelter between the rocks.

Station 48 finally achieved pictures of 'The Mounds'. They are not as thought in the early exploratory fishing days fish, but are outcrops of calcarinite, with very steep sides that have a covering of coral. crinoids', anemonies' and, gastropods. Fish are more abundant near The Mounds and other outcrops compared to the flat shelf. There is also good footage of trawl door tracks and bobbin tracks.

The last shot, station 71, was the most dramatic with the camera getting stuck whilst towing down the North West side of St Helens Hill. Having the frame grabs every 10 seconds enabled us to follow Deep Videos progress down the slope. Several obstacles were run over and the footage memorable. One ledge we scraped over showed an abundance of life on the deep side. An unfortunate incident occurred a few minutes later when the camera jammed into a ledge. The atmosphere was tense when successive frame grabs showed very little movement. Only the pitch and roll of the camera system changed. The screen froze, all was quite, we had lost communications, but, had we lost the camera? There were a few nervous staff members on deck during the long retrieval. It was 30 minutes or so before the distant flash of the strobes told us that all was not lost. The only damage suffered was to the roll cage and camera umbilical, the camera, pressure cases and lights were intact.

Summary of mid-water trawl sampling

Seven pelagic trawls were made with the MIDOC system. Each trawl provided six samples: four were depth-stratified and two integrated through the water column during the descent and ascent of the net to sampling depths. Trawls were targeted to provide information on the species and size compositions of fish marks in the water column.

In overview, we attempted both to characterise the primary stratified layers of micronekton in the water column and to identify particular acoustic marks close to what were believed to be orange roughy schools. Water column characterisation was done by sampling four strata of ~250 m (surface to ~900 m) during the day and night at St Patrick's ground (stations 33 and 37 respectively). Acoustic marks were targeted around the St Helens Hill in the ~700-850 m depth range in the northeastern and western sectors during the day and night (stations 61, 64 and 66). At the St Patricks ground, several depth-stratified marks were targeted in the main canyon during day and night (stations 77 and 81). Marks here were diffuse and near-bottom (in ~850 m) or clearly stratified and higher in the water column (~700-500 m and 450-350 m). Figure 10 is an example of the recorded midoc depth from a typical tow overlaid on an echogram from the 38kHz pole transducer.

The 42 catches (7 trawls x 6 samples) were generally sizeable, with an average of 74 individuals (exclusive of gelantinous zooplankton and euphausids). All catches were sorted to species or species-group and weighed and counted, and all individuals were measured (excluding gelantinous zooplankton and euphausids). Diversity was also high with 74 taxa of mainly fishes, squids and crustaceans represented; several taxa grouped more than one species (Table 3). Deep marks (>700 m) near the seabed were primarily the myctophid *Lampanyctus australis* and the macrourid *Coryphaenoides*

subserrulatus, with low numbers but relatively high biomass made up by the Johnson's cod (*Halagyreus johnsoni*) and spikey oreo (*Neocyttus rhomboidalis*). In stratified marks higher in the water column, the myctophid *Diaphus danae* and the sergestid prawn *Sergia potens* were most numerous. Large numbers of the pelagic tunicate *Pyrosoma atlanticum* were caught in shallow depths (<300 m and at the surface). Day/ night differences were due to the ascent, at night, of diel vertical migrators, particularly the myctophids. Overall, 2,590 animals were measured from pelagic catches.

Swimbladder characteristics (size and gross structure) were determined for a range of important species to assess their acoustic reflectivity. Large individuals of several species were photographed, while individuals of large and small species were retained frozen for laboratory examination. The dominant water column scatterers (myctophids, and the macrourid and morid cod), as well as those making up prominent marks in the shallow reaches of St Helens Hill, the telescope cardinalfish (*Epigonus telescopus*) and alfonsino (*Beryx splendens*), have gas-filled or spongy-matrix swimbladders. They are more reflective than the wax-ester filled bladder of orangy roughy and therefore contribute strongly to acoustic backscatter.

Cruise Narrative

16.7.99
We depart Hobart 00:06 local time and headed for the EZ dump site where a CTD cast was carried out by Denise MacKay and team. On completion of the CTD drop we headed for Port Arthur at 14:00 arriving at 16:30. The Aurora Australis was just completing her calibration at this site as we arrived. Calibrations were conducted of the 38kHz hull, 38kHz pole, 28kHz hull (Furuno) vessel mounted transducers and the 38kHz towed body transducer. Additionally a beam pattern test along one axis of the 38kHz pole transducer was performed. The calibration was carried out in very calm conditions with low wind speed and swell.

17.7.99
Calibration ended at 02:00 hrs and we headed north to Maria Island for a towed body drop to carry out a seabed classification experiment. Arrived at the Maria Island site at 0630 and sounded the study site (~0.5 nm diameter area of seabed of ~100 m depth) to confirm that it was homogeneous in terms of hardness and topography. Seabed reflectance was measured at 10 m depth intervals to 75 m depth and a range of pitch angles. Two sediment samples showed that the substrate was a muddy, fine sand containing a distinct fraction of bryozoan fragments. The Smith-MacIntyre grab was lost on the third deployment when the wire parted. The towed deep video was used to film the seabed before departing north for the St Patricks Head fishing ground.

18.7.99
Followed a zig-zag acousic sounding course to St Patricks Head, passing over the historical Bicheno aggregation site. Maintained contact with two fishing vessels on the ground throughout the morning, including giving a detailed briefing of towed body work.
Conducted a survey of the ground with the vessel mounted transducer using W-E survey grid of 0.5 – 1 nm intervals. Found that the fish were aggregated along the ridge in 850 –900 m. Carried out some deep water towed body transects N-S and found extensive marks that were further identified to be orange roughy using the multi-frequency system. Individual orange roughy could be seen with the 120 kHz frequency and showed them moving to the bottom avoiding the towed body. The discrimination provided by the 120 and 38 kHz systems enabled us to separate the various species. To better clarify the extent of the mark and reduce survey variance we carried out a zig zag survey of the main fishing mark.

19.7.99
We used the first few hours to complete the east-west transects across the area of main fish aggregations at St Patricks and retrieved the towed body at 08:00 . Longer contiguous fish marks were seen on the ‘Milkrun’ in about 850-920 m, indicating an apparent change in orientation from the same time yesterday when consecutive east-west transects ‘sectioned’ an elongate mark running north-south (although note ping rate is higher). Latterly during the course of the transecting, the large marks (presumably orange roughy) moved off the bottom, and contracted northwards and slightly eastwards to form several discrete marks over the canyon edge. The positions of the schools were sounded carefully to enable a vertical towed-body drop (wind-drift) for target strength measurement. With the towed body <100 m off-bottom the

roughy appeared to go hard down as marks disappeared from the water column and appear like side-lobes in places on the bottom.

Saxon Progress sampled one background scatter mark at the southern extent of the main roughy mark, catching about 300-400 kg that was virtually clean roughy. Two additional positions for marks at the northern extents of the main marks (~41 28 305S; 148 43 900) were supplied at about 1030. The Southern Surveyor conducted a zig zag transect to ST Helens Hill to start the first acoustic survey whilst the hill was available due to a voluntary closure.

20.7.99
Completed grid-pattern acoustic survey with towed body at about 0600 and moved straight into star-pattern survey heading to the north west. Transecting progressed without incident. The primary fish features of interest were large marks on the crest and northwest sector in ~700-850 m, an elongate mark trailing from hard-down into midwater towards the northwestern base in ~950 m, and large stratified marks, meeting the bottom in places but extending into the water column and away from the hill towards the southwest in ~900-1000 m. During the late morning a large mark also formed on the northeast face in about 800-1000 m; it was hard on the bottom through this range and extended as a compact mark well into the water column. These were all consistent features from the earlier hull-mounted survey and are prime targets for sampling.

Report from Saxon Progress included details of four trawls completed during the night: three at Paddy's Head and one on the way to St Helens. Trawl overviews were: shot 20 (north of the main mark heading south at 41 26171S; 148 43 195E in 850-870 m) produced only 16 kg from a 28 minute tow on flat bottom; shot 21 (southern extension of main mark at 41 30 898S; 148 44 098E in 933-964 m) produced 1.5 tonnes of almost clean roughy from a 7 minute tow; shot 22 (shooting to the east on the southern wall at 41 31 464S; 148 45 555E in 932-945 m) produced about a tonne of clean roughy. The last shot of the morning was on flat ground a couple of miles to the south of the hill (41 17 639S; 148 44 072E in 965-988 m) for about 300+ kg of which about half was roughy and the remainder dominated by whiptails and cod.

During the afternoon we completed the acoustic survey of the Hill with the towed body with acoustic marks observed on the NW sector of the hill consistent with orange roughy. To better describe the distribution of species around the hill we conducted several deep multi-frequency depth contour tows at 800, 850, 900 and 1000 m. This effectively placed the towed body in the 720, 820, 860, and 970 m depth contours. We encountered several clumps of orange roughy during the tows mainly in the SW to NE region of the hill in 800 to 900 m water depth. The NW corner that is usually occupied with a distinct orange roughy mark was now occupied with a swim bladdered fish probably the abundant alfonsino or cardinal fish that was caught by a trawl through this depth range.

21:7:99Started the day with an unsuccessful MIDOC shot that was aimed at a mark on the side of the hill but ended up sampling the benthic fauna on top. The resulting damage included a broken foot-rope and rips throughout the length of the net, but nothing to the cod-end system. A CTD cast was completed successful in deep water to the north of the hill for a TS profile. Subsequently, a depth-stratified towed body

drop was done for water column characterisation- although some data were lost on the [12 kHz]. A problem with the outer layer of wire was noticed at this point with bunching from above the fairing down to the towed body.

22:7:99
Two sled tows at St Patricks(operations 25 & 26) appeared to have worked successfully but took only small catches: just a few individual invertebrates and fishes. Completed another acoustic grid transect over Paddy's Head (east-west transects), then headed into Binalong Bay to drop off Jeremy and pick up replacement pelagic trawl and power supply for Sonadyne. Steamed to St Patricks to perform our first video tow over the main fishing ground. Set the tow to cover both the flat ground on the west of the fish mark then drift into the fish mark and down the slope to the gutter. The vessel passed through the fish mark and the video operated well throughout.

23.7.99
Completed the deep video tow Paddy's Head at about 0300. This was a highly successful operation, generating 2 hours of footage across the northwestern flats, down into the canyon and out on to the deeper flats beyond. Many orange roughy were seen in close proximity to the bottom. Attempted a water column characterisation tow, crossed trawl doors caused the tow to be aborted. A CTD cast was completed at 0700. A daytime water column-characterisation tow with MIDOC in four depth strata (900-750 m, 750-500 m, 500-250 m and 250-0 m) along the Paddy's Head grounds was successful. Large catches identified the dominant water column scatterers at depth as myctophids, phosichthyids as well as macrourids and oreos.

24.7.99
We repeated the water column characterisation MIDOC tow at night (station 37), and obtained good samples from the corresponding strata. The same suite of dominant species was present, but with vertical migrators appearing in large numbers in the upper strata. This was followed by a sled sample (station 38) through the base of the canyon on the eastern side of the Paddy's Head ground at about 950 m. It produced good rock samples (relict carbonate and granites), and a sediment sample in the newly attached pipe dredge, but very few invertebrates. We used the remainder of the morning for a static towed body calibration drop over a large school of fish on the eastern side of the Paddy's Head area. Left for St. Helens seamount around 1015 following a zig-zag sounding route.

During the early afternoon, a star design survey using the pole transducer was used to identify marks for a MIDOC tow. An interesting mark that was hard-down and then trailed off into midwater on the NW side was targeted, however, the tow was aborted because the net hit the bottom and sustained considerable damage. We attempted to contact the vessel "Beriba" that was working on the ground without success. The remainder of the day was spent doing an acoustic survey (star/grid) with the pole in deteriorating conditions while damage assessment and repair of the net was undertaken on the back deck.

25.7.99

The first two hours of the morning were used to complete the assessment of damage to the MIDOC net: matching pieces of ripped panels were laced roughly together prior to clearing the deck. With improving conditions (moderating to <15 knots after a blow during the night with winds exceeding 35 knots) we commenced at towed body work. Two NE-SW straight-line transects were run across two large marks, respectively on the NW and N parts of the hill in 800-900 m. We continued the second transect into a clockwise loop at 900 m with the towed body set just to the south (shallower) than the vessel. Obtained good data from three marks on the eastern side of the hill before aborting the survey to avoid a fishing vessel. The details of this incident are noteworthy: Rob reported our activity and intentions, and requested acknowledgment on channels 71 and 16 at around 0530. After several unsuccessful attempts, Alan twice used channel 71 to explain the overall survey, and the details of the current operation- emphasising that we were towing an instrument 1 nm behind the vessel. The fishing vessel manoeuvred in close proximity on our starboard side without making contact. Due to the risk of crossing gears if it shot away, we aborted the loop survey at about 0600.

After altering course we headed back to the north on the eastern side of the hill. Proceeded to survey some interesting looking marks in a series of N-S transects before winching the towed body aboard. Departed survey area for Binnalong Bay at 9-15 to pick up 'Four Corners' film crew.

Steamed out to St Patricks after picking up the film crew to perform a video tow over some unique seabed features. Deployment of the gear was made difficult due to a strong southerly current of about 1.0 knots. Our first attempt appeared to miss the feature and we drifted over the eastern ledge to rough ground. We then turned the vessel with the camera out and steamed at 2.6 knots water speed, 0.6 knots ground speed, through the features. The slow scan feed from the seabed enabled us to see if the system was functioning correctly and that it was on the seabed. The video shots revealed the true nature of the seabed features that appeared to be cemented carbonated sands (calcarenite) with coral (largely dead) growths. The fish life around the features were low and this may have been due to the current.

Conducted a pole mounted survey (op ??)of the ground to assess the distribution of the fish. Needed to maneuver around the Santic Rose during the survey and also abort a TS drop at the end due to it being in the direction of the Santic Rose tow line. The fish were very dynamic, during the day one school located at S 41 29.5 E 148 44.6 in 900 m of water shifted south and up the ridge in 860 m of water. A repeat transect along the S 41 30 line over a 30 minute period mapped a school moving off the bottom into the water column.

26.7.99
Arrived on the grounds at 13:00 hrs and started to perform some Mufti towed body loop tows at 950, 900, 850, 800 and 750m bottom depths. The data showed that orange roughy were situated around the hill at various depths but they were in low numbers and associated with many other swim bladdered species. It was difficult to interpret the data as separate frequencies and it highlighted the need for a real time multi-frequency system. The hill was surrounded by a speckled cloud of swim bladdered fish from 600 –750 m. At times we had what appeared to be orange roughy marks in 680 m of water according to the multi-frequency. It will be very difficult to

interpret this data. The Saxon Progress performed the star and grid acoustic surveys during this time. From the loop data I gave two shots to the Saxon Progress one in the south west 700-750 m and the other in the NW in 1000 m.

Southern Surveyor continued survey of Paddy's Head during the early part of the morning by running two NNW-SSE transects along the flats on the western side of the canyon, roughly parallel to the canyon edge. A fairly extensive mark had been bisected during the E-W transects (~41 29.5-41-32°S) undertaken the previous night and this was seen to be an elongate mark following the topography. Overall it was very similar to the roughy mark that we'd observed during trip 2, but slightly further to the east (closer to the canyon). The large mark, that sounded strongly on 38 and 120 KHz, lifted noticeably as daylight came. Added a SW loop between transect end-points to sound a mark reported by Saxon Progress on its second transect line, but only light scatter was seen.

The morning's work was completed with a transfer of staff to and from Saxon Progress at sea (Bruce Barker/ Mark Lewis). A batch of fish was also brought over to Southern Surveyor, with the roughy processed for ovaries and otoliths, bycatch dissected and photographed for swimbladder description. The ovaries of almost all (19 of 20) roughy were spent.

Two fishing boats (Celtic Rose and Belriba) were on the hill during the voluntary closure.

Saxon Progress had joined us again for its 'trip 3' at about 0300 this morning. They commenced by doing the standard grid transect (E-W) and followed it up with a quick-fire zig-zag survey across the key area. Two shots were done: one at the southern end of the mark where it started to become less distinct (~200 kg mixed catch) and one on the way up to St Helens in the gutter about 2 miles to the south of the hill (again for a small mixed catch- about 40 kg). Data capture was modified by dropping LF's on morids and whiptails due to their consistent, tight mono-modality.

A meeting was held in the operations room at 1300 hr to provide 'Four Corners' with an overview of the survey objectives and progress to date, as well as giving staff a mid-cruise de-brief.

27.7.99
Commenced a standard star-design survey at about 0100 that was completed successfully at 0900. There were some distinct patterns evident in fish marks: light scatter only in the SE sector; relatively good marks in the NE close to the hill peak (~650-800 m); extended moderately dense and irregular marks in the NW and SW that extended nearly to the base of the hill in places on the N and SSW transects (# 2 and 3 respectively).

Two marks given to the Saxon based on the prior loop-transect survey were targeted at corresponding marks in the WSW (800 m) and NNW (1000 m). The first was completed accurately, albeit over a greater depth range (670-946 m), for 3 tonnes of mostly roughy. This was interesting as it corresponded to a distinct mark seen at the same place during the night-time star survey. The second trawl shot, made to the west of position in shallower water in 800-900 m, resulted in a 36 tonne catch of roughy

and appears to be a straight-out market shot. It is nonetheless interesting in matching a relatively small area of moderately dense mark. Interestingly, Macca caught nothing on 315 directly after indicating that the schools are very small and or a lot faster than previously. Due to the long unbroken stint put in by the Saxon's crew at this stage I agreed to give them a break until late morning- leaving the NE shallow marks of perhaps greatest interest to sample by trawl.

A CTD to 1000 m with 3 water samples taken at 500 m was completed to the northeast of the hill at 1100 hr. The MIDOC was set up for a shot across the NE corner of the hill at ~700 m depth to target strong feed marks.

Completed first MIDOC with a targeted shot on the north eastern side of the hill aiming at 50 m above the 750 contour. The catches were consistent with the depth range. As John was going off shift and we were approaching the dusk period we performed too sled tows on the NW sector of the hill on the 320-340 line. The first landed shallow as indicated by the catch with two – three bins of dead coral a few rocks of fine grain basalt and calcarenit. Many specimens of benthic animals were retrieved in good condition. During the tow a SE set was experienced of 0.5 knots. Shot away the night MIDOC to retrace the day shot in the 700 m line on the NE side of the hill, nets 3 and 4 were close to the hill.

28.7.99
Two MIDOC trawls were completed successfully during the night: across the NE and W sectors in close proximity to the shallower reaches of the hill (~700 m). Catches contained appreciable numbers of all the dominant species seen previously. The last net in the trawl across the W side went close to the bottom (~10 m) and took several Johnson's cod and whiptails.

Saxon Progress sampled the strong marks at the top of the hill (~600-700 m), taking a mix including alfonsino, blue grenadier, cardinalfish and a blue eye. Brian commented that a 4-5 m high mark in the net mouth had escaped when the gear was pulled away at 700 m and thought it was probably a mix of cardinalfish and alfonsino. He had seen less life generally tonight, in the water column and on the bottom, and says this between-day variation is quite normal. There is no general correlation with tide, although he is noticing less tide tonight whereas yesterday night there was a distinct gear-set to the west. Interestingly, with the MIDOC gear, John is noticing a set to the east tonight. Saxon has sampled the deep areas to the immediate north and northeast tonight (from midnight) and will be processing until 0500-0600 hr.

Celtic Rose has been on the ground and in close proximity to us all night.

A TS towed body drop from the west to the east, meandering over the hill crest, was completed mid-morning (1030 hr) in calm conditions. A strong mark was sounded on the immediate north face of the hill top where Saxon had taken a mixed catch of the typical 'hill-top' high-reflectors (cardinalfish, alfonsino, blue grenadier and blue-eye). Following this we completed a CTD to the west of the hill (with three bottles at 500 m) before heading in to Binalong Bay to drop off the media crew and rendezvous with the Saxon Progress for a de-brief. Saxon Progress was left to sample the strong marks on top of the hill after we departed. One tow to the north gave a similar result to the first summit shot: a small catch of alfonsino, cardinal fish and blue grenadier.

Departed Binalong Bay at 21:00 hrs after a successful briefing with Brian and Ashley. It was good to catch up with the skipper and observer on Saxon Progress and discuss the events on the survey up to this point in time. Headed to the hill to perform a video tow down the NW section. After a short drift to establish that the set was 0.5 to east deployed the video at 22:00 hrs.

29.7.99
The camera became fouled after about 15 minutes on the bottom and communications were lost as it was towed clear. It was recovered with great relief at about 0130 after which we took two sled samples from the SE face of St Helens Hill. A shallow sample was taken in about 600-800 m, and although the gear eventually pinned up at 800 m, it was winched back safely. The second, deeper, tow ran smoothly and we had 20 minutes bottom time. After this, the vessel zig-zagged its way to Paddy's Head and completed a third sled tow along the 'mud hill' video transect line to the west of the canyon. We appeared to pick up some old fishing gear judging from the load on the gear as it left the bottom. Following this, we completed a set of E-W transects across the Paddy's area to identify the spatial distribution of the roughy schools. They were spread further south and more to the east than when we were here previously, but still generally followed the canyon topography from north to south.

The MIDOC was targeted on some unique mid-water features on the echogram that lay along the canyon in a NNW direction in 750-800 m of water depth as well as some layers in 700 – 500 m and 350-450 m. The resultant catch yielded high catches for the 20 minute tows and may have reflected the southerly set of about 0.5 knots. The catches at 700 m yielded mainly whiptail fishes and given their gas filled swim bladders great care will be required in interpreting the acoustic data. A deep-towed body tow repeated the MIDOC trawl and targeted the orange roughy on the ridge. Large marks were observed all along the ridge indicating that a high quantity of fish was still on the grounds. Attempted to obtain some TS data but as usual the fish reacted to the towed body well before I was able to get close to them.
Carried out a CTD in deep water off Paddy's Head and tested the new positioning system. We were finally able to get it to work after changing a few initialization settings. Conducted a repeat of the day East West transects.

30.7.99
Completed the E-W transects before deploying the MIDOC at about 0300. We repeated the tow done during the day and took good catches that were processed by about 1000. Commenced some

Finished EW Deep Tow transects to define extent of schools

Performed absorption experiment which proved to be very difficult in the weather conditions but very useful data was obtained.

Steamed to Binalong Bay for further calibration of the acoustic system but weather conditions in the Bay proved to make this very difficult.

31.7.99

Completed grid transect of St Helens Hill with extensive low scatter in all regions but no acoustic marks that could be easily attributed to roughy. Celtic Rose was on the grounds and also having difficulty located marks and catching fish.

1:8:99
Finished deep water MUFTI acoustic loop surveys on St Helens with orange roughy being found on the NW, and E sides of the hill in low quantities.
Two Benthic sled shots on the east side of hill also produced lower catches of benthic fauna than the NW side.

Steamed to St Patricks ground in near perfect weather conditions and performed a calibration and TS drop on St Patricks. Given the good weather conditions and low current we were able to position ourselves over the main aggregation on the NE of the ridge and slowly drift over the mark. The multi-frequency data was of high quality and should enable us to distinguish between orange roughy targets and other deep water fishes. Completed the operation at 16:00 hrs and commenced our steam to Hobart for a scheduled docking at 10:30 on Monday the 2nd August.

Summary

The cruise from the 16th July to 2nd of August was a resounding technical and scientific success as we were able to address all the objectives. Our ability to operate the deep-water acoustic system throughout the cruise without any technical difficulties demonstrated the advances that have been made with the reliability of this instrument. The multi-frequency system was invaluable in its ability to correctly discriminate orange roughy at St Helens Hill where vessel mounted soundings were uninterpretable.

A significant outcome of the cruise was the very low abundance of orange roughy found on the St Helens Hill ground. This is in complete contrast to the surveys of previous years. A relatively larger aggregation of orange roughy was found on the St Patricks head ground and this body of fish was found consistently throughout the two week survey. The trawl catches and acoustic surveys from the industry vessel Saxon Progress confirmed this observation.

Our ability to observe and document the habitat of orange roughy was a major success of this cruise and many breakthroughs in both video observation and geological investigations were made. We successfully videoed the seabed habitat at both St Patricks and St Helens Hill including some world class footage of swimming orange roughy, sharks and whiptail fishes. Our detailed investigations of the small mounds (20-40 m) that are numerous on the grounds confirmed their origin and composition. Of note was the collection of large amounts of coral from both grounds that were of different species and had been dead for quite some time.

Scientific Personnel

Rudy Kloser	CMR	Chief Scientist (Acoustics)
Jeremy Prince	BioSpherics	Co-Investigator (16th – 23rd days)
Alan Williams	CMR	Watch Leader (biological sampling leader)
Peter Hill	AGSO	Geologist/Swath bathymetry
Mark Lewis	CMR	Gear technologist (safety officer)
Tim Ryan	CMR	Data manager
Matt Sherlock	CMR	Electronics
Jeff Cordell	CMR	Electronics
Don Mckenzie	CMR	Vessel Operations/CTD operations
Karen Gowlett-Holmes	CMR	Benthic specialist/Photographer
Four Corners team (three off)		25th – 28th July
Denise Mackay	CMR	16th July
Jeanette Osullivan	CMR	16th July
Harry Higgins	CMR	16th July

Vessel Operations Personnel

Ian Taylor	Master
John Boyes	1st Mate
Rodney Williams	2nd Mate
Ian Murray	Chief Engineer
Simon Gould	1st Engineer
Laszlo Polgardi	Electrical engineer
Malcolm McDougall	Bosun
Drew Meincke	A.B.
Graham McDougall	A.B.
Louis Jacomos	A.B.
Tony Hearne	A.B.
Alan Brownlie	A.B.
Norman Irvine	A.B.
Howard Davies	Greaser
Ian Lock	Chief Cook
Wayne Hatton	2nd Cook
Barry Roderique	Chief Steward

Acknowledgements

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Skipper, mates and crew of Southern Surveyor and Saxon Progress
Vessel engineers for fixing the winch

Ian Helmond, Ocean Engineering, Towed system, deep video and installation of new positioning system
Workshop, Deep Video, trolley and general fit out
Lindsay and Scott, Marine Instrumentation for some unscheduled deliveries and preparation
Pavel Sakov ECHO software
Craig Macaulay Communications

Rudy Kloser,

Chief Scientist.

Tables

Figures

Table 1. Operations undertaken on the cruise with gear activity, location, start date, time and position.

Op No	Start Time	Operation Type	Location	Start Lat	Start Lon
1		CTD Cast	EZ Site		
2	16-Jul 20:51	Acoustic Survey	acoustic survey 1	-42.6733	148.2417
3	16-Jul 22:30	Acoustic Transect	towed bodydrop	-42.6717	148.2433
4	15-Jul 21:13	Acoustic Transect	Calibration		
5	17-Jul 00:36	Acoustic Transect	Towed Body Test	-42.6733	148.2417
6		Sediment grab			
7	17-Jul 02:00	Sediment Grab	Sediment Grab	-42.675	148.2417
8	17-Jul 02:10	Sediment Grab	Sediment Grab Number 3	-42.6733	148.2367
9	17-Jul 07:30	Video Transect	Maria Island	-42.6733	148.265
10	17-Jul 13:00	Acoustic Transect	Zig Zag up to Patricks Head	-42.1483	148.6133
11	17-Jul 18:20	Acoustic Transect	acoustic survey2	-41.495	148.735
12	18-Jul 01:27	Acoustic Transect	towed body tow 1	-41.58	148.7233
13	19-Jul 02:19	Acoustic Transect	zig zig - st paddys - st helens	-41.5283	148.7517
14	19-Jul 07:00	Acoustic Transect	St Helens Hill pole survey	-41.2283	148.7417
15	19-Jul 09:10	Acoustic Transect	St Helens Star	-41.24	148.77
16	19-Jul 13:01	Acoustic Transect	St Helens Tow, Rectangular	-41.2017	148.7583
17	19-Jul 19:34	Acoustic Transect	Star Survey	-41.25	148.77
18	20-Jul 05:23	Acoustic Transect	St Helens loops	-41.2317	148.7417
19	20-Jul 16:09	Midoc Sampling	midoc 1	-41.2667	148.7817
20		CTD Cast	St Helens		
21	20-Jul 23:10	Acoustic Transect	Acoustic Profile	-41.205	148.7817
22	21-Jul 02:24	Acoustic Transect	sthelens to stpaddys	-41.0533	148.8083
23	21-Jul 07:10	Acoustic Transect	St Patricks grid survey	-41.45	148.75
24	21-Jul 10:00	Tow Body Transect	St Patricks	-41.455	148.7367
25	21-Jul 14:55	Benthic Dredge	St Patricks	-41.4983	148.7517
26	21-Jul 16:33	Benthic Dredge	W to E at St Pats Head	-41.505	148.7367
27	21-Jul 18:05	Acoustic Transect	towed survey stpaddys	-41.4833	148.78
28	22-Jul 04:00	Transfer	Transfer at Binalong Bay	-41.2417	148.3033
29	22-Jul 09:37	Video Transect	St Patricks Video	-41.545	148.7067
30		Video Transect	St Patricks		
31		Midoc Sampling	midoc - stpaddys		
32		CTD Cast	St Patricks Head.		
33	22-Jul 22:10	Midoc Sampling	Water column: DAY	-41.57	148.7517
34		Day Deep water TS tow	St Patricks S-N		
35	23-Jul 06:44	Deep Calibration Towed Body	TS vertical profile	-41.4967	148.7367
36	23-Jul 09:56	Night TS survey St Patricks	Night TS survey St Patricks	-41.495	148.7417
37	23-Jul 13:59	Midoc Sampling	Night Midoc	-41.4367	148.7583
38	23-Jul 18:46	Benthic Dredge		-41.49	148.7433
39	23-Jul 20:43	Acoustic Transect	towed body drop	-41.5117	148.7467
40		Acoustic Transect	St Helens starring survey		
41	24-Jul 05:17	Midoc Sampling	Sth Helens Hill	-41.2283	148.7617
42		Acoustic Transect	St Helens star grid continued		
43	24-Jul 09:28	Acoustic Transect	St Helens Hill regular grid	-41.2533	148.74
44	24-Jul 17:12	Acoustic Transect	mufti tow	-41.2017	148.7833
45	24-Jul 19:53	Acoustic Transect	muftiloop	-41.24	148.7583
46	24-Jul 21:08	Acoustic Transect	eastern side mufti transect	-41.24	148.765
47	24-Jul 22:28	Acoustic Transect	eastern side mufti transect	-41.2067	148.7667
48	25-Jul 07:01	Video Transect	St Patricks north - bumps	-41.5033	148.725
49	25-Jul 11:36	Acoustic Transect	St Patricks mark reconnaisance	-41.5233	148.7283
50	25-Jul 14:30	Acoustic Transect	along 41.3	-41.4967	148.75
51	25-Jul 17:07	Acoustic Transect	mufti tow	-41.4967	148.7317
52	25-Jul 18:52	Acoustic Transect	mufti survey of fish mark	-41.5683	148.7383
53	25-Jul 20:44	Acoustic Transect	mufti tow	-41.53	148.7467
54	26-Jul 00:00	Personel transfer – Binalong Bay	transfer at see to saxon		
56	26-Jul 03:36	Acoustic Transect	loop survey, SAt Helens Hill	-41.225	148.7433
57	26-Jul 10:22	Acoustic Transect	N-S grid, St Helens Hill	-41.21	148.74
58	26-Jul 15:56	Acoustic Transect	star grid - towed body	-41.25	148.775
59		CTD Cast #4	St Helens		
60	27-Jul 02:37	Midoc Sampling	target tow at mark	-41.1983	148.7517
61	27-Jul 04:01	Midoc Sampling	target tow at mark	-41.17	148.73
62	27-Jul 07:38	Benthic Dredge	St Helens NW gully	-41.2133	148.7517
63	27-Jul 10:36	Benthic Dredge	St Helens NW side, deep	-41.215	148.7433
64	27-Jul 12:23	Midoc Sampling	St Helens NE section	-41.175	148.73
65	27-Jul 15:53	Midoc Sampling - aborted	midoc tow	-41.175	148.7017

66	27-Jul 16:42	Midoc Sampling	midoc tow	-41.1767	148.71
67	27-Jul 20:34	Acoustic Transect	Mufti drift	-41.2283	148.7433
68	28-Jul 02:00	CTD Cast #5		-41.2283	148.73
69		Transit	transit sthelens hill to binalong		
70		Transfer	Binalong Bay		
71	28-Jul 13:53	Video Transect	St Helens Hill transect to NW	-41.225	148.755
72	28-Jul 16:47	Benthic Dredge	ST Helens Hill, SE face, shallow	-41.245	148.7717
73	28-Jul 18:58	Benthic Dredge	St Helens Hill, SE, Deep	-41.25	148.7717
74	28-Jul 19:44	Acoustic Transect	sthelens-stpaddys transit	-41.2733	148.7917
75	28-Jul 22:33	Benthic Dredge		-41.5183	148.7133
76	28-Jul 23:38	Acoustic Transect	grid survey	-41.515	148.725
77	29-Jul 03:52	Midoc Sampling	St Patricks day target	-41.5833	148.775
78	29-Jul 07:15	Acoustic Transect	St Patricks N-S following Midoc	-41.455	148.7183
79	29-Jul 10:41	CTD Cast	SE of St Patricks	-41.5867	148.8517
80	29-Jul 12:33	Acoustic Transect	St Patricks	-41.5567	148.7317
81		Midoc Sampling	st patricks night tow		
82	29-Jul 21:45	Acoustic Transect	mufti tow - stpats	-41.5	148.815
83	29-Jul 23:46	Acoustic Transect	mufti tow along stpaddys canyon	-41.4833	148.73
84		Acoustic Transect	E-W transect along 41.33		
55	26-Jul 00:36	Acoustic Transect	acoustic transit	-41.5117	148.7483
85		Acoustic Transect	Attenuation test, east of St Pats		
86	30-Jul 15:20	Acoustic Transect	transit from st paddys to binalong	-41.44	148.8217
87	30-Jul 20:29	Acoustic Transect	calibration	-41.2283	148.3133
88	30-Jul 23:11	Acoustic Transect	seafloor experiment	-41.2317	148.4517
89	31-Jul 00:56	Acoustic Transect	seabed-tb drop	-41.2433	148.445
90	31-Jul 01:47	Pipe dredge off Binalong	Pipe dredge off Binalong	-41.2283	148.445
91	31-Jul 02:00	Pipe dredge off Binalong	Pipe dredge off Binalong	-41.225	148.4433
92	31-Jul 02:13	Acoustic Transect	transit to sthelns	-41.2233	148.445
93	31-Jul 04:14	Acoustic Transect	St Helens Hill N-S grid	-41.245	148.74
94	31-Jul 10:26	Acoustic Transect	St Helens Hill loop survey	-41.24	148.7617
95	31-Jul 22:08	CTD Cast	St Helens -small hill to the East	-41.2583	148.82
96	31-Jul 23:48	Benthic Dredge	East Hill (nr St Helens)	-41.2567	148.82
97	01-Aug 01:01	Benthic Dredge	East Hill	-41.2633	148.82
98	01-Aug 03:30	Acoustic Transect	StPatricksCalibration	-41.4967	148.7383

Table 2a. Summary of Acoustic Surveys – St Patricks Head region

Op No.	Start time	end time	type of survey	mode	number of transects	comments
11	17-07 18:21	18-07 00:45	Rectangular grid	hull	8	
12	18-07 01:29	18-07 06:44	North South/South North Transects	hull/towed body	3	
	18-07 07:20	18-07 10:56	Mufti Tow	towed body	2	
	18-07 11:20	18-07 13:30	zig zag transects	towed body	3	Mufti Mode
	18-07 13:55	18-07 22:01	Rectangular grid	towed body	6	Mufti Survey
	18-07 22:28	19-07 01:13	TB drop	towed body	2	TS/Calibration work
23	21-07 19:05	22-07 01:45	Rectangular grid	towed body	5	Mufti survey
34	23-07 03:17	23-07 13:30	tb drop/tb survey	towed body	5	ops 34 to 36 inclusive
	23-07 20:26	24-07 00:19	TB drop	towed body		
39	25-07 11:36	25-07 15:56	reconnaisance survey	pole/hull	2	
50	25-07 17:06	25-07 23:26	tb mufti tows	towed body	3	50 to 53 inclusive
76	28-07 23:38	29-07 03:30	Rectangular grid	pole/hull	9	
78	29-07 07:15	29-07 10:20	tb mufti drift	towed body	1	
80	29-07 12:33	29-07 17:50	Rectangular grid	pole/hull	10	
82	29-07 21:45	30-07 06:55	tb mufti tow	towed body	4	ops 82 to 84 inclusive
85	30-07 09:18	30-07 14:15	absorption experiment		1	

Table 2b. Summary of Acoustic Surveys – Sthelens Hill

Op No.	Start time	end time	type of survey	mode	No. of transects	Comments

14	19-07 06:53	19-07 08:58	Rectangular grid	pole/hull	5	
15	19-07 09:03	19-07 12:41	Star Pattern	pole/hull	6	
16	19-07 13:00	19-07 18:59	Rectangular grid	pole/towed body	5	
17	19-07 19:34	20-07 04:34	Star Pattern	pole/towed body	6	
18	20-07 05:23	20-07 13:38	Loop	towed body	8	
40	24-07 02:00	24-07 04:14	Star Pattern	pole/hull	3	first part of survey - next a three hour gap and survey continues (see Op 42)
42	24-07 07:44	24-07 09:23	Star Pattern	pole/hull	3	second half or survey after three hour gap
43	24-07 09:29	24-07 14:46	Rectangular grid	pole/hull	8	three repeat transects along 148.45
44	24-07 16:58	24-07 23:28	loop and diagonal pass	towed body	2	Multifrequency. Not a complete formal survey
56	26-07 03:36	26-07 09:43	Loop	towed body	5	Multifrequency
57	26-07 10:00	26-07 15:24	Rectangular grid	pole/towed body	5	
58	26-07 15:56	26-07 22:32	Star Pattern	pole/towed body	6	
67	27-07 19:58	28-07 01:22	Mufti drift	towed body	1	Mufti drift – west side of St Helens Hill
93	31-07 04:15	31-07 09:28	Rectangular grid	pole/towed body	5	
94	31-07 09:43	31-07 19:57	Loop	towed body	8	
21	20-07 23:10	21-07 02:01	tb profile	towed body	1	Towed body profile - 0-900 meters

Table 2c. Summary of Habitat Experments

Op No.	Start time	end time	type of survey	mode	No. of transects	Comments
88	30-07 23:11	31-07 1:29	Star pattern	Pole	3	East Off Binalong Bay. Survey of habitat prior to towed body drop
2	16-07 20:50	16-07 21:35	Star pattern	Hull	3	Maria Island. Survey of habitat prior to towed body drop

Table 3. List of species taken by mid-water trawling using the MIDOC system

Fish Species	
Angler (black)	*Lepidorhynchus denticulatus*
Argyropelecus gigas	*Leptocephali*
Argyropelecus hemigymnus	*Leptoderma sp.*
Astronesthes sp	*Lobianchia dolfleini*
Austrophycis sp	*Malacosteus niger*
Bathylagus antarcticus	*Mauloricus mulleri*
Benthabella sp.	*Melanonus gracilis*
Caelorinchus fasciatus	*Melanostigma gelatinosum*
Centrocymnus crepidater	*Metelectrona ventralis*
Chauliodus sloani	Morid
Coryphaenoides subserrulatus	*Nemichthys sp.*
Cynomacrurus pirei	*Neocyttus rhomboidalis*
Diaphus danae	*Notacanthus sexspinnis*
Diaphus hudsoni	*Paralepididae sp*
Diastobranchus sp.	*Persparsia kopua*
Diretmus argenteus	*Photichthys argenteus*
Electrona risso	*Protomyctophum spp.*
Halagyreus johnsonii	*Rosenblattia robusta*
Halophyrne sp.	*Scopeloberyx sp.*
Hygophum hanseni	*Scopelopsis multipunctatus*
Ichthyococcus sp.	*Simenchelys parasitica*
Idiacanthus atlanticus	*Sternoptyx spp.*
Kalli sp.	*Stomias boa*
Lampadina speculigera	*Symbolophorus barnardi*
Lampanyctus (large)	*Tubbia tasmanica*
Lampanyctus (small)	*Vincigeria spp.*
Lampanyctus ater	*Winteria telescopa*
Lampanyctus australis	*Woodsia meyerwaardeni*
Lampichthys proceros	

Crustaceans	
Acanthephyra spp.	*Notostomias sp.*
Amphipoda	*Oplophorus novaezelandiae*
Euphausids	*Pasiphae (large)*
Gnathophausia ingens	*Pasiphae spp.*
Hyperiid (giant)	*Polycheiles sp.*
Lobster peruelus	*Sergia potens*

Cephalopods	
Sepiolids (cuttlefishes)	Squids

Gelatinous zooplankton	
Medusae	*Pyrosoma atlanticum*
medusae/ salps	salps
Pteropods	

Figure 1. Southern Surveyor voyage track showing areas of operation and dates of activities.

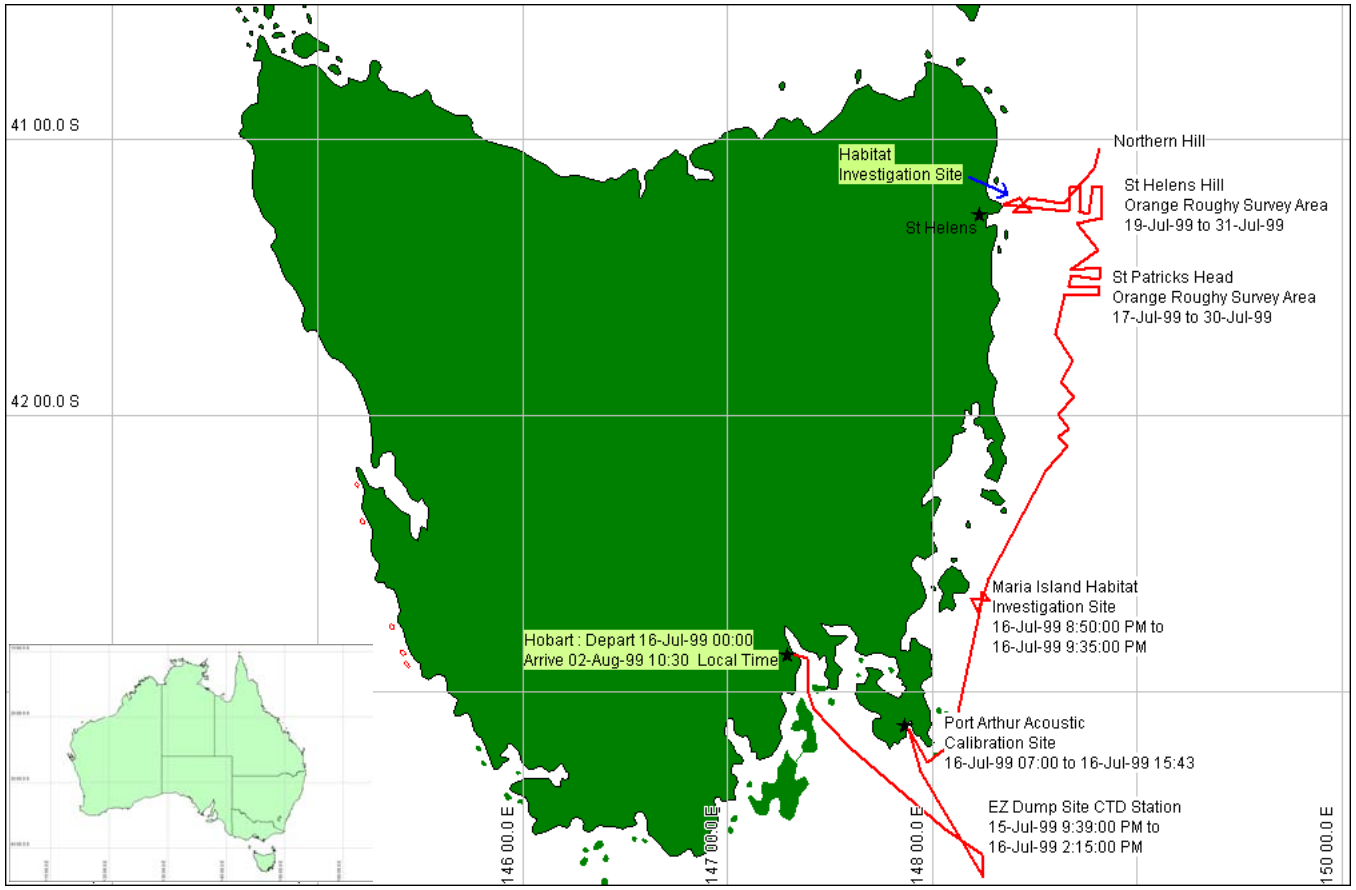


Figure 2. Saxon Progress voyage track showing areas of operation and dates of activities.

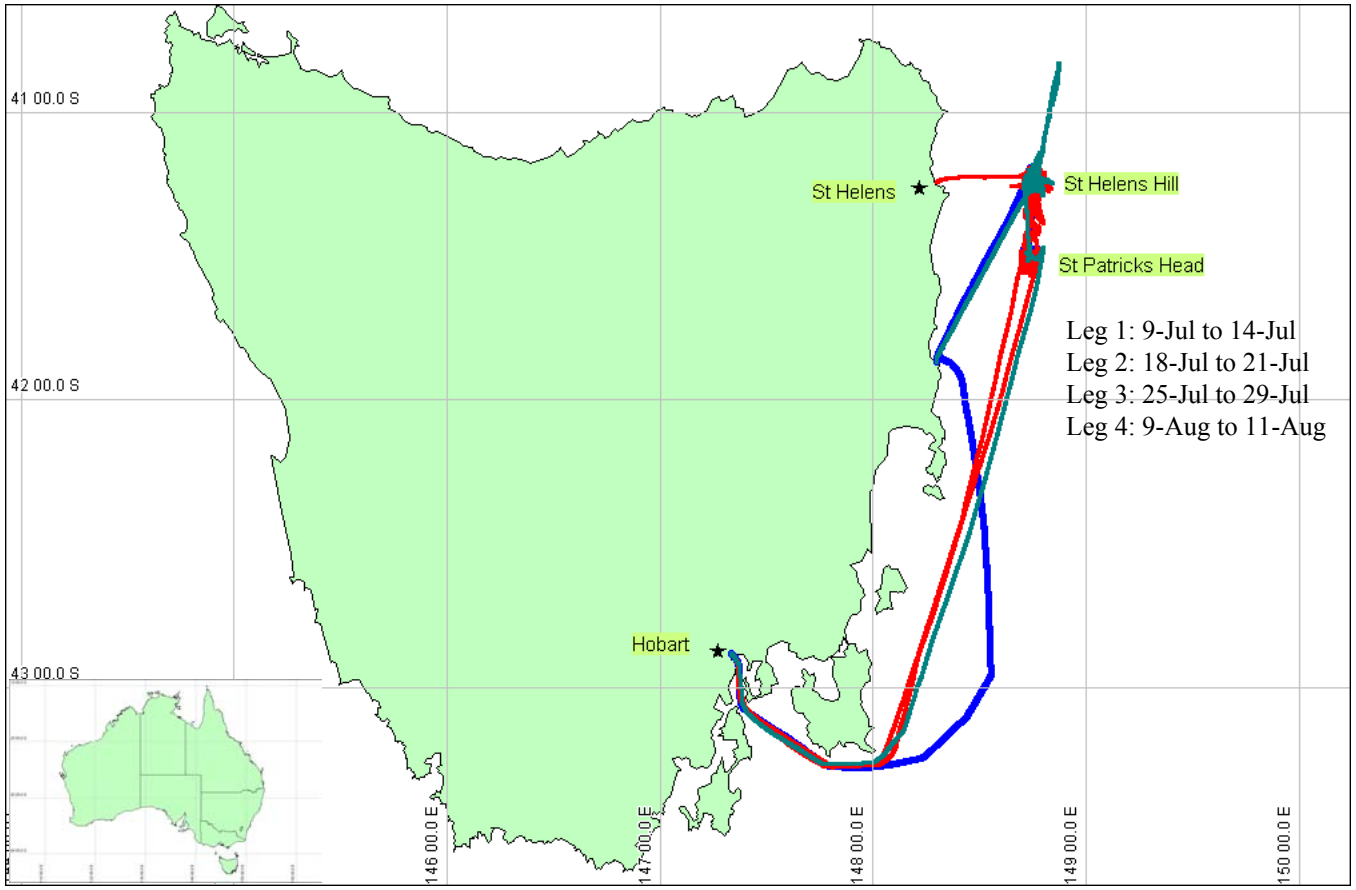


Figure 3a. 3D presentation of St Helens Hill baythmetry

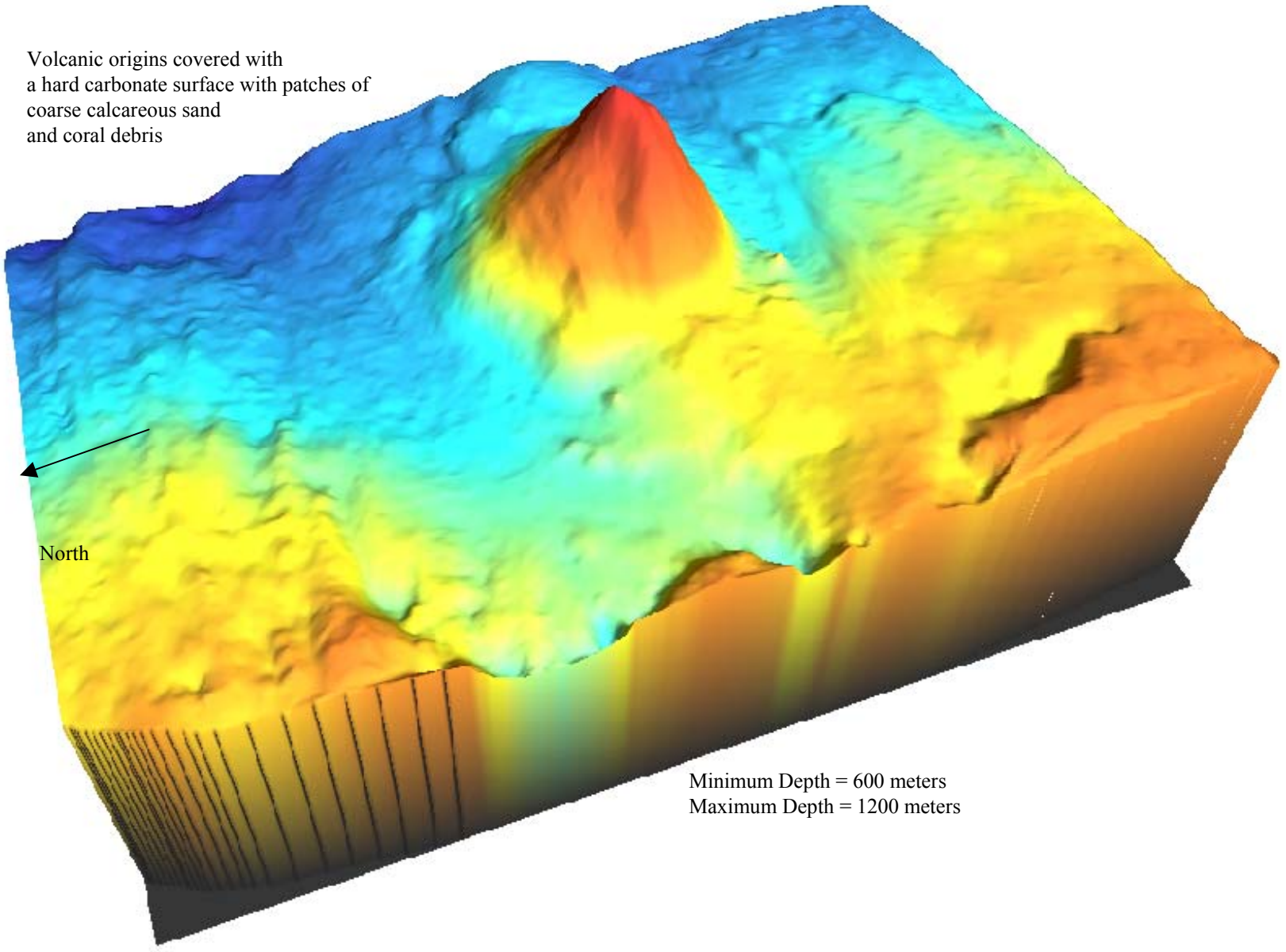


Fig. 3b 3D presentation of St Patricks Head bathymetry data

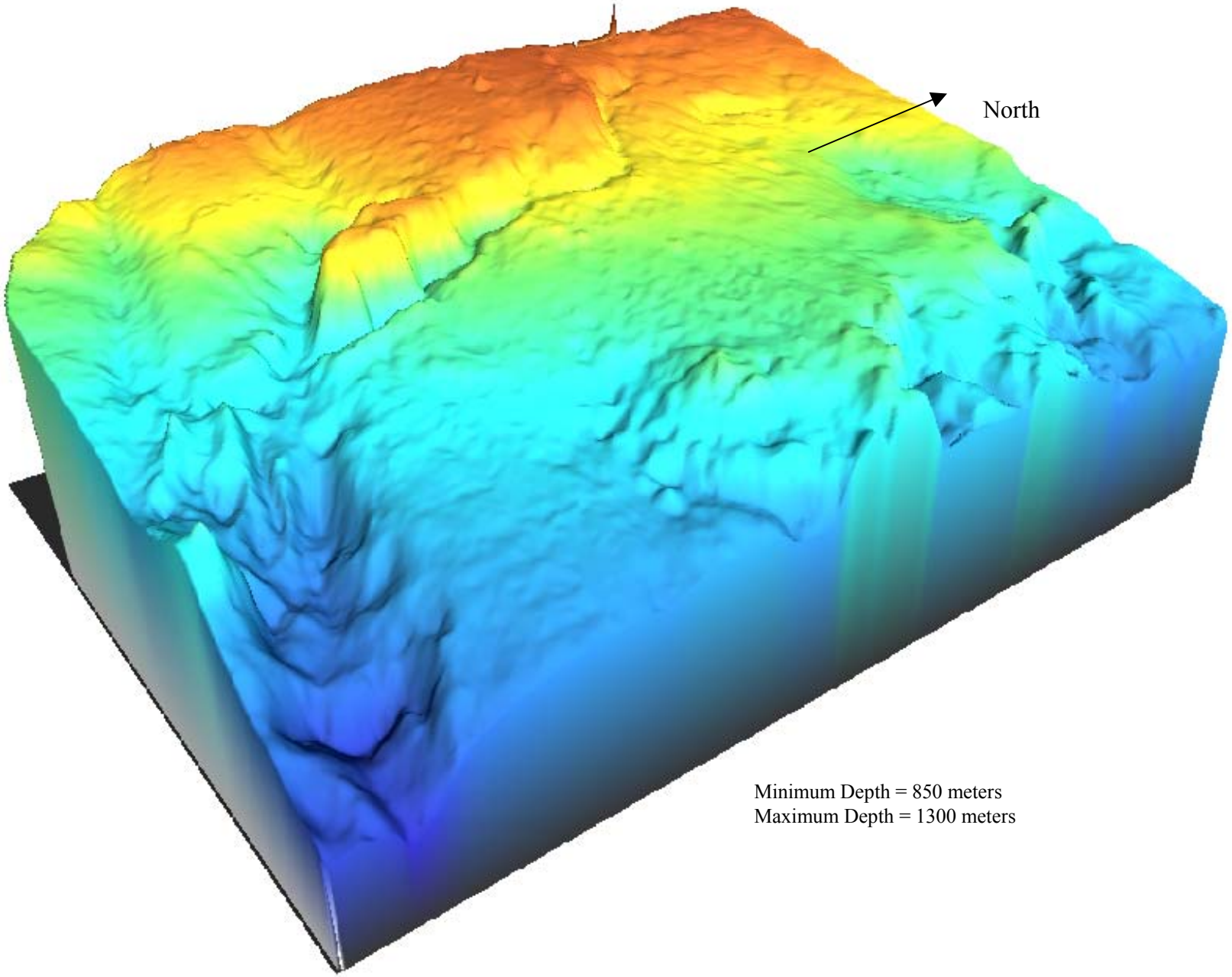


Figure 4. St Helens Hill Bathymetry with associate survey designs,
rectangular grid (A), star pattern (B) and loops (C) used trhough the voyage

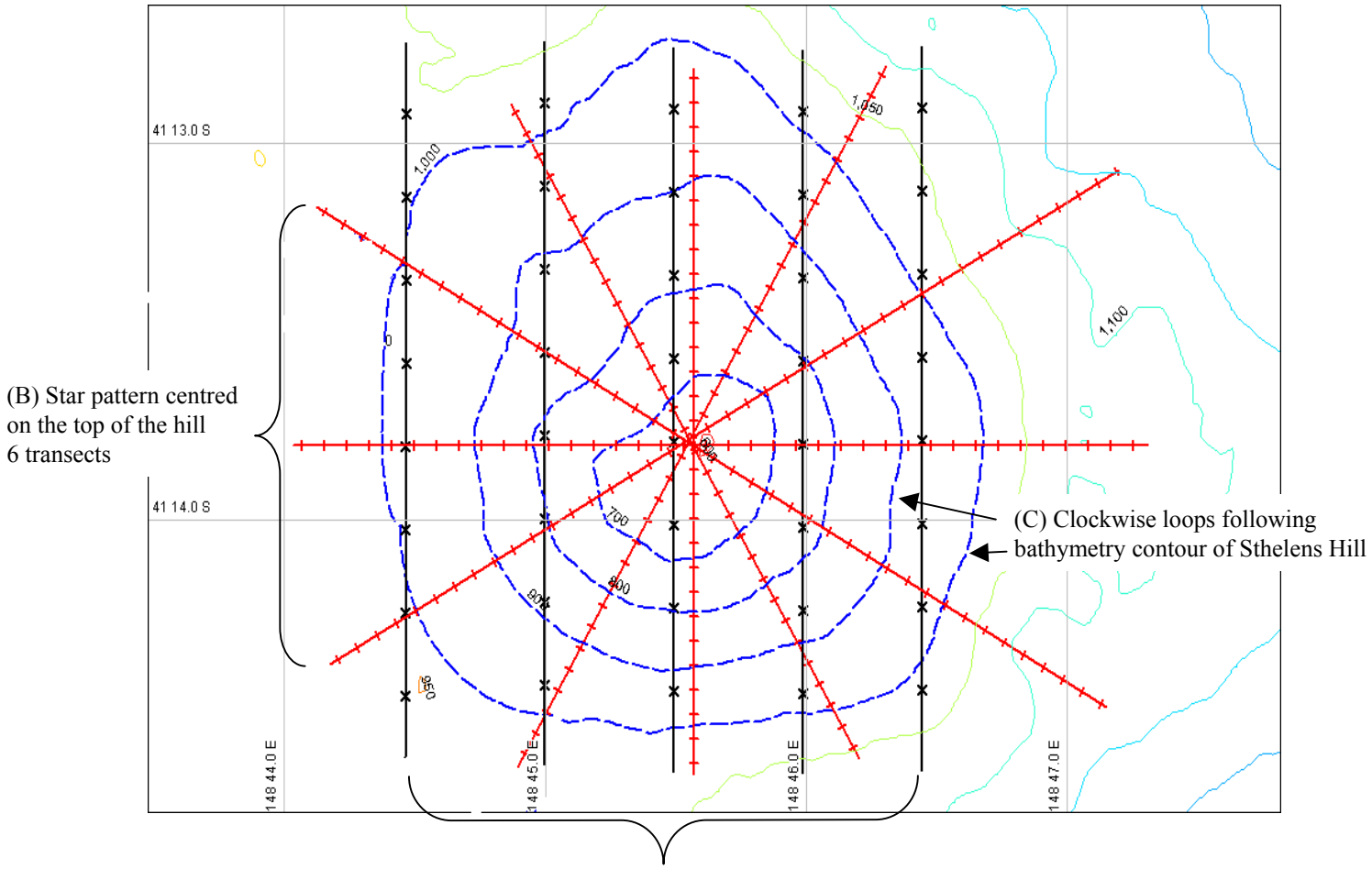


Figure 5. St Patricks Head Bathymetry with associate survey designs,
(a)East West Grid, (b)Zig Zag, (c)North South Deep Tow, (d) Following canyon ridge,
(e) Towed Body drop above fish schools

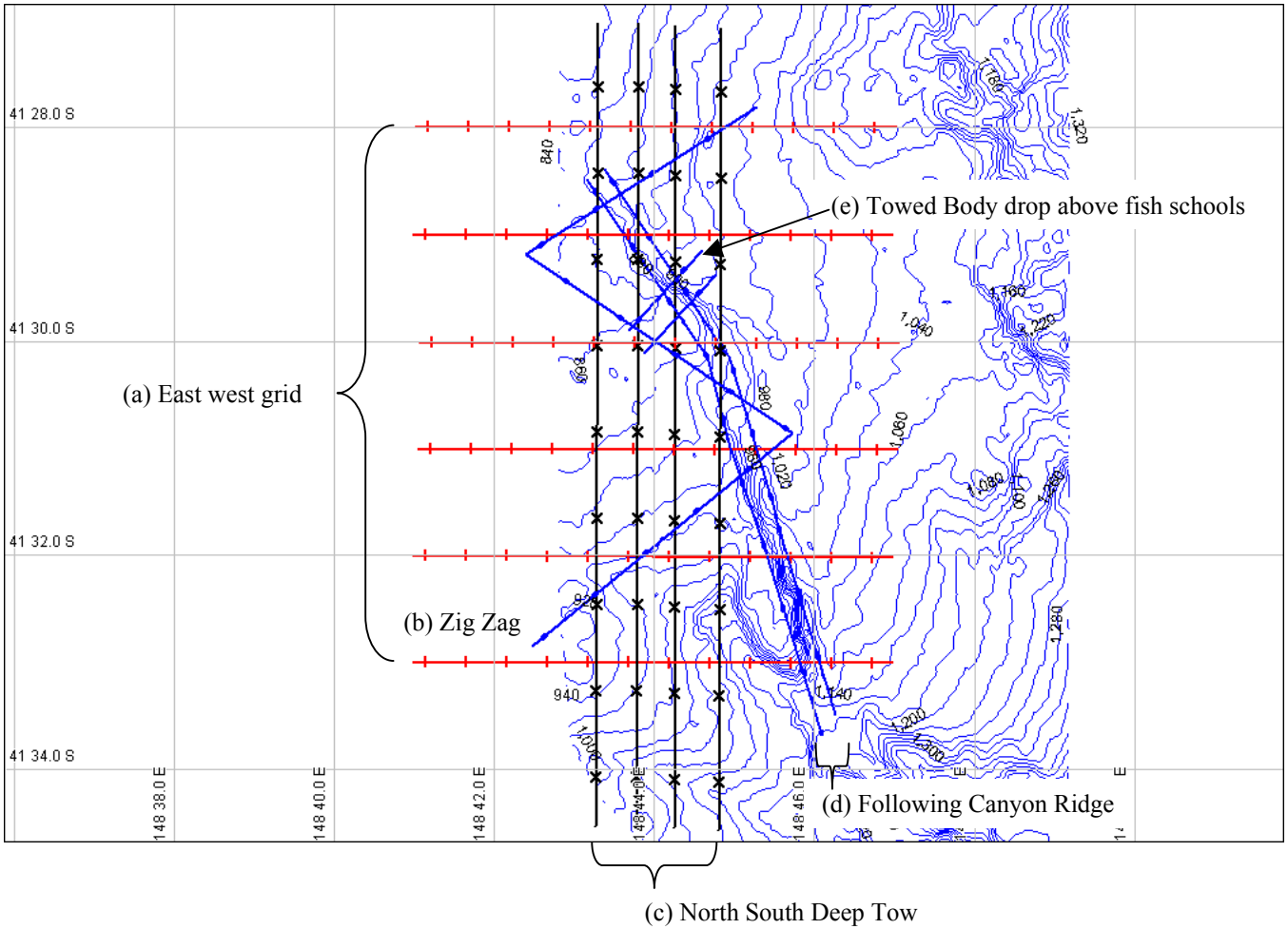


Figure 6. 38kHz pole transducer echogram from south-north transect along canyon ridge at St Patricks Head on the 29th July 19999.

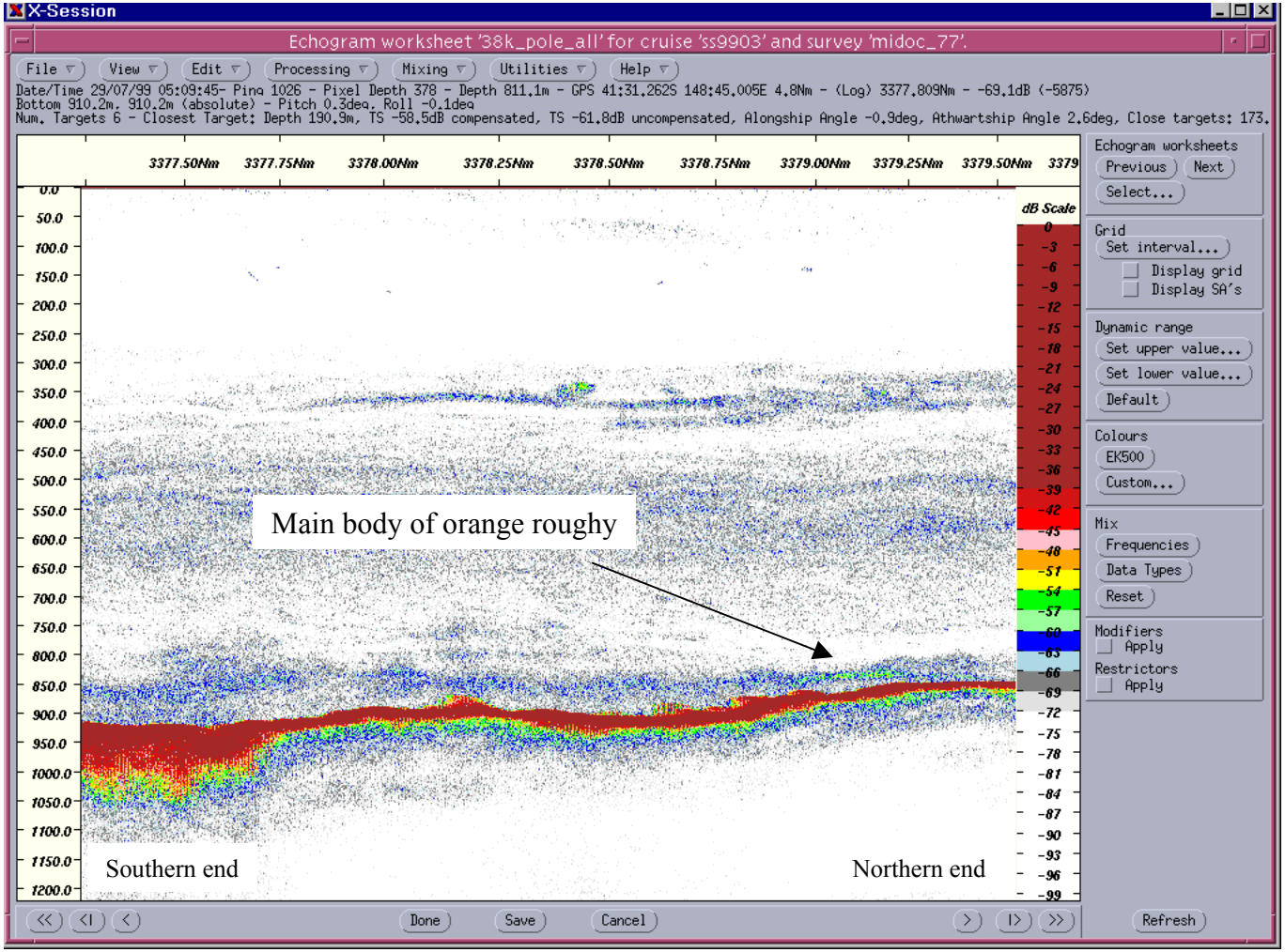


Fig. 7 Echogram of St Patricks orange roughy using the digitised information from the Saxon Progress's 28kHz Furono echosounder on the 13th July 1999.

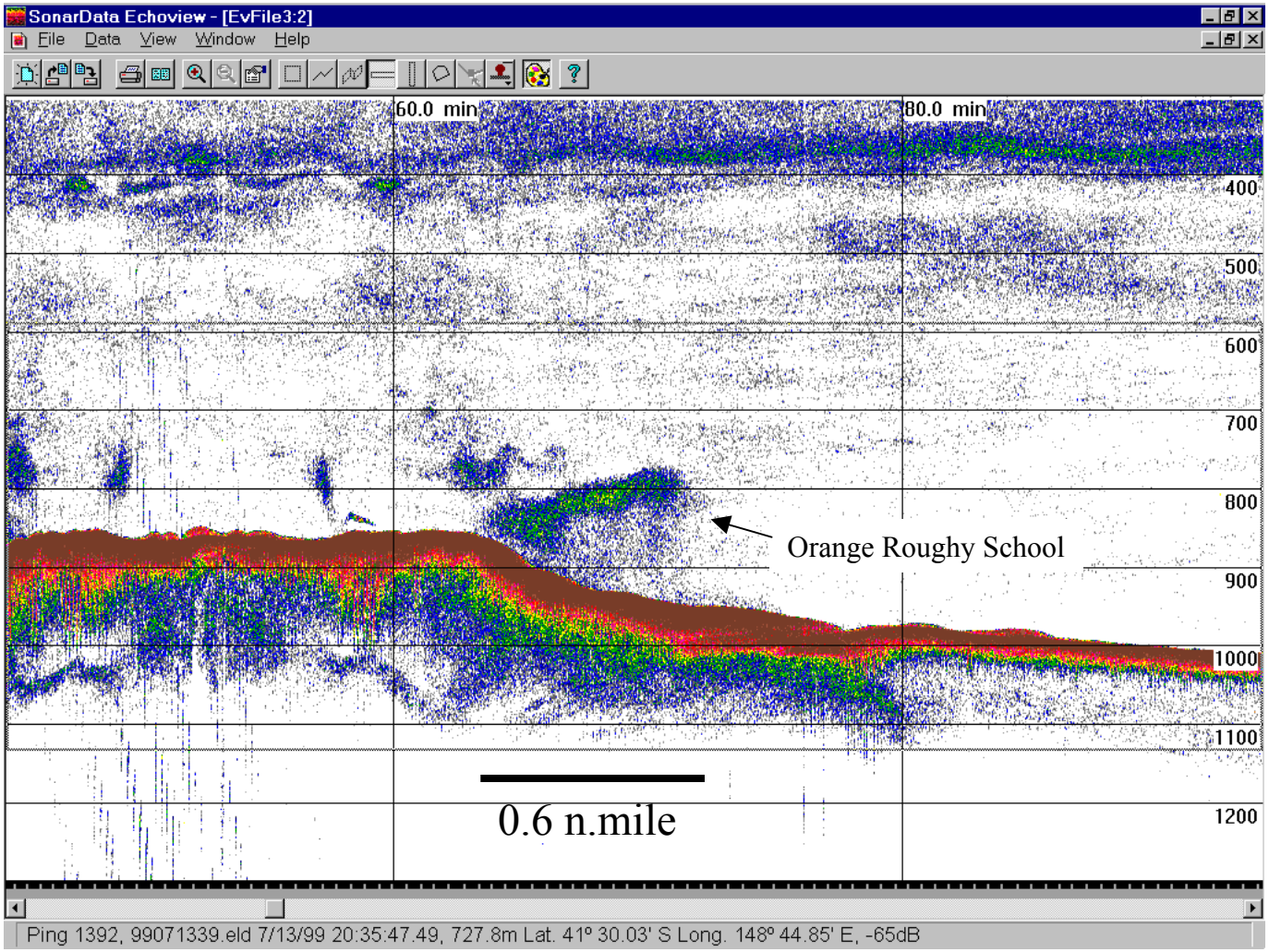
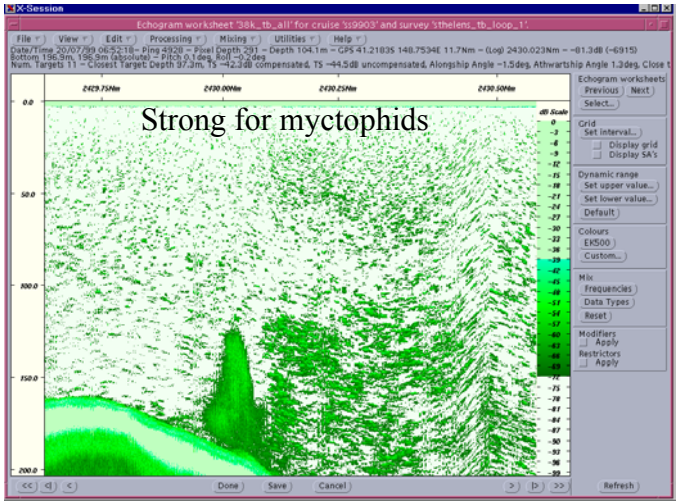


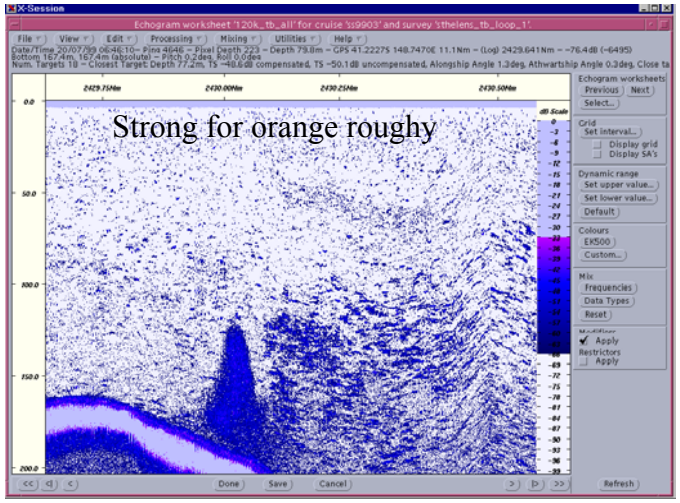
Figure 8. Frequency mixing for identification of acoustic species at St Helens Hill. The red is associated to 12 kHz and is dominated by large gas bladdered species, green is associated to 38kHz and is dominated by small gas bladdered myctophid species, blue is associated to 120 kHz and is relatively strong for orange roughy. The combined frequency echogram clearly shows the difference between the frequencies and the school of orange roughy blue/green and the distribution of large and small gas bladdered fishes.

12 kHz

38 kHz



120 kHz



Mix of 12,38 and 120 kHz

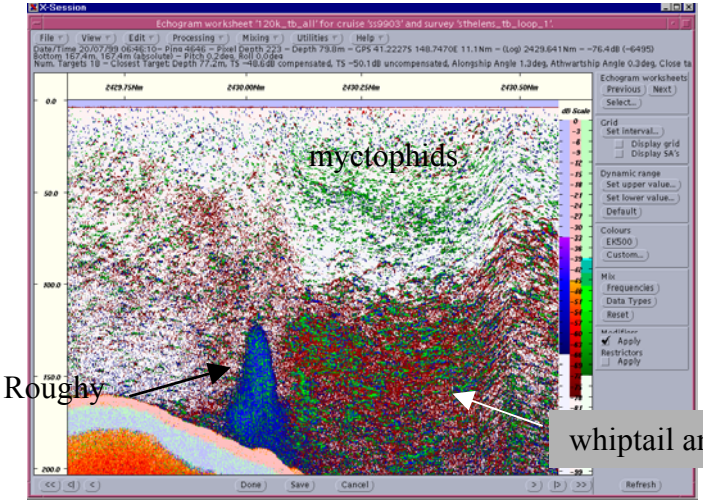


Figure 9. Example of insitu target strength information with associated calibration for orange roughy on St Patricks Head.

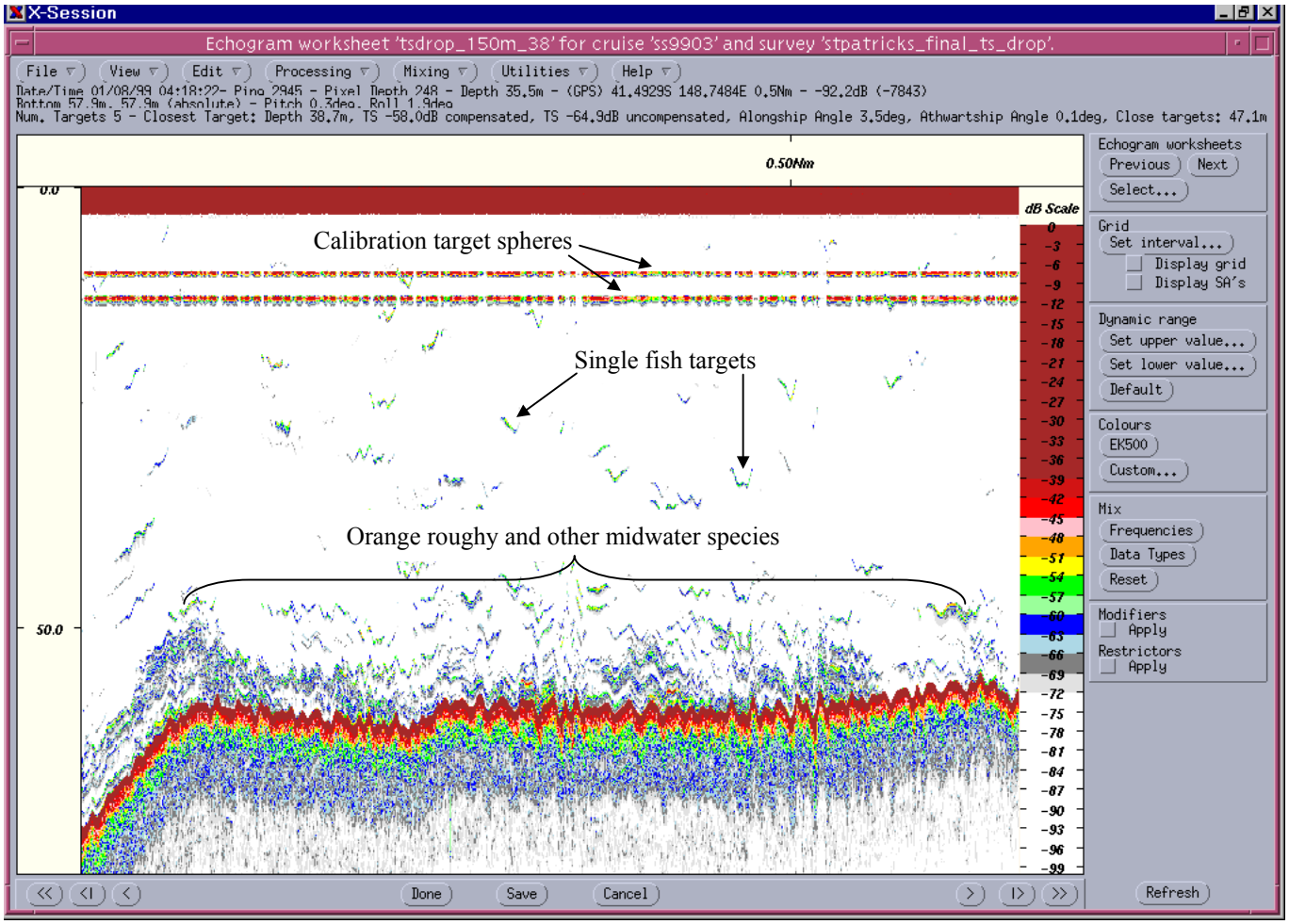


Fig 10. Midoc 77 Depth Profile Overlaid on Echogram from 38kHz Pole Mounted Transdcuer - St Patricks Head.