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FIELD METHODS OF THE 2008, 2009 AND 2010 SURVEYS OF MESO- AND BATHYPELAGIC MICRONEKTON IN THE GULLY

by

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ABSTRACT

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Three midwater-trawl surveys of the nekton and micronekton at meso- and bathypelagic depths in The Gully, a submarine canyon and Marine Protected Area immediately east of Sable Island, were conducted in August / September 2008, August 2009 and March 2010 respectively. The surveys used an IYGPT net and followed a fixed-station, depth-stratified design, with replicate sampling in each of daylight and night. Additional fishing was undertaken with a fine-mesh Tucker Trawl and a large Diamond IX midwater trawl. The fishing was supplemented with CTD casts, continuous acoustic recording at 38 kHz, monitoring of marine mammals and (in 2010 only) seabirds throughout daylight hours. This report provides a detailed record of the at-sea methodology, as a foundation for publications based on the data gathered during the surveys.

RÉSUMÉ

Kenchington, T.J., R. Benjamin, M. Best, A. Cogswell, A. Cook, S. DeVaney, C. Lirette, B. MacDonald, K. MacIsaac, P. Mallam, T. McIntyre, A. McMillan, H. Moors-Murphy, G. Morton, L. Paon, S. Roach, E. Shea, D. Themelis and E.L.R. Kenchington. 2014. Field methods of the 2008, 2009 and 2010 Surveys of Meso- and Bathypelagic Micronekton in The Gully. Can. Tech. Rep. Fish. Aquat. Sci. 3076: iv+73p.

Trois relevés au chalut pélagique des espèces de necton et de micronecton des profondeurs mesopélagiques et bathypélagiques dans le Gully, un canyon sous-marin et une zone de protection marine directement à l'est de l'île de Sable, ont été menés au cours des mois d'août et de septembre 2008, d'août 2009 et de mars 2010, respectivement. Dans le cadre des relevés, on a utilisé un chalut IYGPT (pour les jeunes gadidés) et le plan de relevé comportait des stations fixes et une stratification selon la profondeur, les opérations d'échantillonnage réalisées à la lumière du jour étant répétées la nuit ou vice-versa. Des activités de pêche supplémentaires ont été menées à l'aide d'un chalut Tucker à mailles fines et d'un grand chalut pélagique Diamond IX. Les activités de pêche ont été complétées à l'aide de sondes CTD, d'enregistrements acoustiques continus (38 kHz) et de la surveillance des mammifères marins et (en 2010 seulement) des oiseaux de mer pendant les heures de clarté. Ce rapport fournit un dossier détaillé de la méthodologie en mer, à titre de base pour les publications, en fonction des données recueillies dans le cadre des relevés.

1 INTRODUCTION

The Gully (Figures 1 & 2) is both the largest submarine canyon on the eastern seaboard of North America and a Marine Protected Area (MPA). Among its signature species is the northern bottlenose whale (*Hyperoodon ampullatus*), a specialist predator of armhook squid (*Gonatus* spp.: Hooker *et al.* 2001) which dives to the lower mesopelagic and upper bathypelagic zones to feed. The presence of the whales implies a high biomass of cephalopods at great depth in the canyon (cf. Hooker *et al.* 2002). Conservation of the bottlenose whale population requires maintenance of this supply of prey but the energy source supporting the squid and the reasons for their concentration in The Gully remain unknown.

In 2007, we commenced a research program focused on understanding the ecosystems at meso- and baythypelagic depths in The Gully, both in support of MPA management and as an example of canyon systems. The first cruise (designated TEM768) was dedicated to a midwater trawl survey using an International Young Gadoid Pelagic Trawl or "IYGPT" net (Kenchington *et al.* 2009). Such a net is not expected to catch *Gonatus* spp. or other large, active squid but it can provide a first understanding of the nekton and micronekton components of the ecosystem, including the food of the prey of bottlenose whales. 2007 has, however, been shown to have been an oceanographically anomalous year on the Scotian Shelf (Harrison *et al.* 2008, Petrie *et al.* 2008). The program's second cruise (TEM832), conducted in August–September 2008, thus had a primary aim of repeating the IYGPT survey to document the degree of inter-annual change in the nekton and micronekton relative to 2007. There was also a shift in emphasis away from merely documenting diversity or community structure and towards describing the trophic ecology at meso- and bathypelagic depths within the canyon. Meanwhile, the experience of the first cruise had shown a need for improved survey protocols and gear (Kenchington *et al.* 2009) and the 2008 repetition provided a first trial of a new standardized deep-pelagic survey methodology.

While the 2008 cruise largely extended the work begun the previous year, there were three new additions: Kenchington *et al.* (2009) had observed extensive acoustic scattering by non-migrant organisms at depths greater than 400 m around the mouth of the canyon, which suggested that the scatterers might play an important role in the energy pathway supporting the bottlenose whales. Those scatterers were not, however, evident amongst the IYGPT catches and hence a fine-mesh Tucker trawl was taken on the second cruise in an attempt to sample a smaller size-fraction of the mesopelagic community. Secondly, new sampling of the IYGPT catches for stable-isotopes analysis of trophic relationships was introduced. Finally, samples were gathered for analysis of contaminants in the

Gully ecosystem, both in support of wider studies of ocean contamination and in a search for potential food-web tracers.

That second survey confirmed that there was substantial inter-annual variation in the IYGPT-vulnerable portion of the community and hence a third summer survey, conducted during August 2009 on a cruise designated NED 2009–35, was undertaken with the intention of determining which set of previous observations was the more typical. To aid comparisons among years, the methodology was largely retained unchanged from that used in 2008, except that a new and additional station was established on the open continental slope, close enough to the mouth of The Gully to allow for meaningful faunal comparisons and yet far enough away to be free of canyon influences, while the Wall Station (which had been worked in 2007 but not in 2008) was given renewed priority. The Tucker trawl was not used on NED 2009–35, for lack of a suitable winch.

The fourth cruise in the program, designated TEL-2010-900, was a survey undertaken in March 2010 and thus began an extension of the work into an examination of the seasonal cycle. That cruise was again focused on an IYGPT survey, using essentially the same methodology as in 2008 and 2009, though on a larger and more capable ship: CCGS *Teleost*. The first three surveys had, however, failed to find enough nektonic biomass at depth to sustain the bottlenose whale population two trophic levels above. Capturing the whales' prey, *Gonatus* spp., was thus of increased importance. To that end, and utilizing the higher engine power of CCGS *Teleost*, the 2010 cruise supplemented the IYGPT fishing with some trawling using a much-larger Diamond IX net.

The other addition to the established methodology in March 2010 was a dedicated seabird observer. The cruise was also charged with deployment and recovery of a seabed acoustic recorder, though the data obtained by it are not part of this research program.

Since these surveys were conducted within the Marine Protected Area and deliberately approached the endangered bottlenose whales, they required (and proceeded under the terms of) permits issued under the Oceans Act and the Species at Risk Act. Those permits imposed various conditions, among which were requirements to avoid any bottom contact with the gears deployed, to station the Chief Scientist on the bridge whenever trawling was in progress (providing a check on the vessel's operations, following a bottom-contact incident in 2007: Kenchington *et al.* 2009) and to maintain a watch for marine mammals throughout daylight hours. Trawl deployments were confined to the pre-defined fixed stations of the survey. The implications of those requirements for the methodology adopted are detailed below.

Following part of the format established by Kenchington *et al.* (2009) for the 2007 survey, the present report documents the at-sea survey methods used on, and presents cruise narratives for, TEM832, NED 2009–35 and TEL-2010-900. A subsequent report will offer overviews of the data obtained during the three cruises, excepting those derived by IYGPT and Diamond IX trawling. Together, the two reports will form a reference source for future detailed studies of those catches, matching that provided for the first survey by Kenchington *et al.* (2009).

2 METHODS

2.1 VESSELS

As in 2007, the 2008 survey was conducted aboard CCGS *Wilfred Templeman*, a 50 m metre stern trawler of 2,000 HP, while the following year the work was undertaken aboard CCGS *Alfred Needler* – a close sister ship but refitted with a more powerful, 3,500 HP, main engine.

For the March 2010 survey, the larger and more capable CCGS *Teleost* was used. She is a 63 m, 2405 GRT stern trawler with a 4,000 HP main engine.

2.2 WATCH SYSTEMS

Templeman and *Needler* each has accommodation for a scientific party of eleven, one of the berths being utilized by the required marine mammal observer, who maintained a continuous whale-watch during daylight. To ensure a fully adequate catch-processing watch in the ship's laboratory, including the required suite of taxonomic specialists, in 2008 and 2009 trawling was limited to a 15-hour period each day (0000 to 1500 UTC[1]), during which the Chief Scientist was stationed on the bridge as required by MPA permit conditions. The laboratory staff also worked 15-hour watches but offset, such that most were on watch from 0300, when the first set of the day was brought aboard, to 1800, by which time most processing of the last catch was complete. Selected individuals worked later, to finish detailed identifications of difficult taxa.

The hours from the end of trawling, at 1500, until 0000 of the next day were used for CTD casts, in 2008 for Tucker-trawl sets and in 2009 for some acoustic transects, as well as for pre-positioning the ship for the next day's trawling and

[1] All clock times presented in this report are in UTC (synonymous with GMT). While at sea, the ship's clocks were maintained on ADST (Z+3 or 3 h slow of UTC) but the computers logged data in UTC. Local Apparent Time (i.e. time relative to the Sun) in The Gully during each of the surveys was always within six minutes of being 4 h slow of UTC.

for any necessary maintenance of the trawling gear. One member of the scientific party was assigned to that work.

This system, while onerous for most members of the scientific party, worked well in 2008. In particular, it avoided many of the problems encountered in the laboratory during the 2007 survey (see Kenchington *et al.* 2009) by ensuring that the required taxonomic specialists were present whenever catches were being processed and by avoiding the need for hand-offs between watches. The 2009 survey, however, saw very high temperatures in the ship (resulting from exceptionally warm surface water), persistent good weather (meaning no breaks in the work while the ship rode out periods when the conditions prevented trawling) and exceptional diversity in the catches taken on the Deep Station. The laboratory staff became exhausted – despite efforts to alternate high- and low-diversity catches by steaming between stations. Future cruises using 15-hour watches should include enforced breaks in the laboratory work and a shortened watch every fifth day, if bad weather does not intervene to provide a break.

For the 2010 survey, the same single-watch system was maintained but budget constraints prevented the planned use of a 15-hour trawling period each day – most of the scientific staff being limited to 12-hour watches. The consequent lack of ship time made completion of the survey design both in daylight and at night doubtful. It was decided to focus on night fishing, while also completing as much trawling in daylight as opportunity allowed. The nominal trawling period was therefore set at 1830 to 0630 UTC. In practice, the relatively small catches taken in spring meant that the laboratory staff (who worked 2130 to 0930) could process the material from more than 12 hours of fishing. Thus, trawling (overseen by the Chief Scientist) typically began before 1830, the first two catches of each day being refrigerated pending the laboratory staff coming on watch[2].

Much as in the previous two surveys, in 2010 one member of the scientific party worked 0930 to 2130, with responsibility for CTD casts, pre-positioning the ship for the next trawling watch and assisting the Chief Scientist with the first fishing of the day. The marine mammal and seabird observers worked from dawn to dusk.

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[2] Animals brought aboard alive may have continued to feed while the catches were stored, though those with enough space to move within their tubs will have rapidly cooled to near-freezing temperatures, minimizing any change in the recorded catches.

2.3 IYGPT TRAWLING

2.3.1 Fishing Gear & Trawl Instrumentation

The primary sampling gear for each of the three surveys remained an IYGPT midwater trawl, as in 2007. Whereas that earlier survey had used old nets which may have deviated from the original specifications, the net used throughout the 2008 cruise was one borrowed from DFO Newfoundland Region and, following established protocols (McCallum & Walsh 1997, 2001), was in strict conformance with the design (see Appendix I). It was modified for the present program only by being fitted with fifty 8-inch “Titanium 20/3” headrope floats (rated to 2,500 m working depth), with three transducer bags on the headrope to accommodate sensors, with two ropes with looped ends sewn into the riblines of the first belly for ease of hauling the trawl up the stern ramp and with four additional lines sewn to the aft riblines for attachment of the “aquarium” codend (see below).

Two new IYGPT nets were constructed specifically for this program but were not completed until 2009. One of them was used in that year and again in 2010, the other being carried as a spare. They follow the standard IYGPT design and rigging (with the above minor modifications) except that they are made of dark green twine throughout, to minimize net avoidance at mesopelagic depths, and of 13 mm kk knotless nylon mesh for the lengthening piece and codend. The latter was adopted to reduce damage to those specimens which contact the net during capture, the lesser strength of the knotless mesh being deemed sufficient considering the small catches expected in mesopelagic trawling. The wings and belly were made of knotted webbing of braided twine, in accordance with the standard IYGPT design (save for its colour), because of limited availability of knotless webbing of appropriate mesh size.

The consequences for the recorded catches of those unavoidable changes in the nets used are unknown and will probably remain so. Conclusions drawn from analyses of the catch data must, therefore, be examined to ensure that they are not artifacts of methological variations.

In contrast to those changes in the nets, the otter boards used for all IYGPT sets made on the four surveys conducted to date were of the same design. Loaned by DFO Newfoundland Region, they were 2.45 by 1.1 m in size and weighted 450 kg each.

In 2008, the trawl was deployed with the same suite of Scanmar and Star-Oddi instrumentation that had been used in 2007 (Kenchington *et al.* 2009). The following year, those sensors were supplemented with a Seabird SBE39 temperature and depth sensor, the Star-Oddi recorders adopted in 2007 having been found unreliable and offering measurement precision that was only marginally-adequate for the needs of this program. Those recorders were dispensed with entirely in 2010, leaving only the Scanmar and SBE39 instruments on the net. While the same Scanmar sensors were used throughout, *Needler*'s signal-processing hardware, located on the ship's bridge, was more advanced than that used on the other surveys and provided substantially more reliable indications of net depth (see Section 2.10.1).

On every set during each of the three surveys, the IYGPT was fitted with an "aquarium" codend, which was designed for this survey program specifically to preserve specimens of weak-bodied pelagic species in as good condition as could be achieved (see Appendix II). That "aquarium" proved fully satisfactory in use, except that the trawl floats used to give it neutral buoyancy obstructed access to the latches which held the container closed while fishing and to their safety retaining pins. Those latches had to be secured before each set and opened after it was complete, to extract the catch, when the heavy floats were a significant impediment. In 2008, some of the catch was trapped between the net's twine codend and the "aquarium". That problem was corrected before the 2009 cruise, as explained in Appendix II. When combined with the knotless mesh of the purpose-built IYGPT, the "aquarium" was highly effective, with many specimens being taken in excellent condition, including a few mesopelagic fish and squid brought aboard alive. One consequence of that effectiveness was a likely enhancement of "net feeding" – consumption within the sampling gear of prey that the predator would not have secured without human intervention.

2.3.2 Survey Design

Throughout, the surveys followed much the same fixed-station, depth-stratified design as had been used in 2007 (Kenchington *et al.* 2009), though available ship time limited the work that could be completed. The stations (Table 1, Figures 1 & 3) comprised the same group of Offshore, Deep, Main, Wall and Head as in 2007, plus a new Slope Station, instituted in 2009, though not all were fished during any one survey. The Slope Station was intended to be representative of the continental slope near The Gully but far enough away to be independent of the direct influence of the canyon, while its exact location was chosen for having a seabed depth similar to that of the Main Station.

As in 2007, the strata nominally fished were 0–250 m, 250–750 m, 750–1250 m and 1250–1750 m, though the deepest of those was only available at the Deep and Offshore stations, while the Wall and Head stations only had the two shallowest strata. The IYGPT, however, is an open net (as are all trawls of the IYGPT's size or larger) and hence a set nominally made in the 1250–1750 m stratum, for example, actually fished the entire water column from the surface to 1750 m – or as close to the latter depth as could be achieved.

Within each stratum deeper than 250 m at each station and in each of daylight and night, the survey design called for two replicate sets following double-oblique ("V") profiles. The 0–250 m stratum was sampled by "W"-profile tows, in which the net was dropped to 250 m, recovered to 50 m depth following a double-oblique track, dropped again to 250 m and then brought to the surface as a second double-oblique track – a profile that had been developed in 2007 (Kenchington *et al.* 2009). Only one such set was required at each station in daylight (when catches in an IYGPT net towed at such depths are minimal), though the design called for two at night.

All standard IYGPT sets saw the net in the set's nominal stratum for 60 minutes. In contrast to the practice in 2007 (when attempts were made to drop the net swiftly to the upper bound of the nominal stratum and to recover it quickly from there: Kenchington *et al.* 2009), veering and hauling speeds were maintained constant throughout, such that the sets made in nominal strata below 250 m depth followed regular "V" profiles as closely as could be achieved. A set intended to reach 1750 m thus took (by design) 210 minutes, from releasing the otter boards until their return to the ship, and fished for 60 minutes in each of the 250–750 m, 750–1250 m and 1250–1750 m strata, as well as 30 minutes in the 0–250 m stratum. Such a set fished above 1250 m following the same profile as a set intended to reach that depth – as a 1250 m set fished above 750 m in the same way that a 750 m set did. That approach was intended to allow correction of the catches for the contamination inevitable as the open net passed through the shallower strata. In essence, the catches obtained in sets to 750 m can be subtracted from those taken in sets nominally deployed to the 750–1250 m stratum, on the same station and during the same diel phase, to estimate the "stratum catch" that the deeper sets took from their nominal stratum alone (and likewise for 1750 m sets).

The intent was that similar calculations could be used to estimate catches taken from the 250–750 m stratum, though they would require halving of the catch taken by 0–250 m sets before the subtraction, since the sets intended for the shallowest stratum fished for 60 minutes, whereas the deeper sets passed through that layer in 30 minutes. That intention was founded on an assumption that the IYGPT fishes so inefficiently when hauled close to the ship (the otter boards being drawn together as they approach the towing blocks) that only negligible catches would be taken above 50 m depth, making the "W"-profile of the shallow tows essentially equivalent to a pair of "V" sets. In practice, experience in analysis of the data has shown that the estimation of the 250–750 m stratum catches is problematic for some species, probably those which are concentrated at near-surface depths. Hence, future surveys should replace the 60-minute "W"-profile sets made above 250 m depth with 30-minute "V"-profile ones.

As explained above, all IYGPT trawling was confined by the watch system to between 0000 and 1500 during the 2008 and 2009 surveys or from nominally 1830 (but in practice often earlier) to 0630 during March 2010. Following the precedent set in 2007 (Kenchington *et al.* 2009), no regular survey fishing was conducted within one hour either side of sunrise or sunset to minimize the confusions resulting from sampling migratory animals while they were moving in the water column. On the dates and at the locations of the trawling, the time of sunrise varied between 0916 and 0927 during the 2008 survey and, for practical purposes, the non-fishing period was set at 0815–1030. For the 2009 cruise, the corresponding times were 0845 to 0859 and 0745–1000. Sunset fell outside the normal trawling times. However, two extra-long and extra-deep tows, made while paying away sufficient warp to allow adjustment of the winch's spooling gear, were allowed to extend into the sunset period. For the March 2010 survey, it was sunset rather than sunrise which led to the break in trawling. On the dates of that cruise and at the various stations, the time of sunset varied from 2204 to 2220. For practical purposes, the non-fishing period was set at 2100–2330.

Because of the constraints of available ship time, in 2008 trawling was focused on the Deep, Main and Head stations, which are aligned along the canyon thalweg (Tables 2–4). In practice, the 1250–1750 m stratum at the Deep Station was only fished once but the survey design was otherwise completed, save for a single missing set at the Head Station. Priorities for the 2009 survey were similar, except that the work on the three principal stations was supplemented by fishing the 250–750 m stratum on the Wall Station (to determine the effects of proximity of the canyon wall) and by two sets on the newly-selected Slope Station (to provide some comparison of the biota of The Gully to that of the open continental slope: Tables 5–7). Only the 250–750 m stratum was fished on the Slope Station, since sets nominally in that stratum yield catches integrated across much of the water column, without requiring the prolonged trawling times of a set to 1250 m. Relative to the 2008 survey, additional emphasis was placed on the 1250–1750 m stratum at the Deep Station, with a minimum requirement of two regular sets there, plus two others that would serve to provide taxonomic specimens. In practice, six of the planned IYGPT tows were not completed: two at 250–750 m on the Deep Station, one each in that depth stratum at the Wall and Head stations, one at 0–250 m on the Deep Station and one at 750–1250 m on the Main Station. For the 2010 survey, the intended station coverage was the same as that attempted the previous year, except that the Wall Station was once again dropped to free time for trawling with the Diamond IX net, while it was accepted that the daylight sampling might be incomplete. In practice, only one IYGPT set was made at the Slope Station and achievement of the survey design in The Gully fell short by three daylight sets (Tables 8–10).

2.3.3 Control of Trawling

While the trawl was being towed, primary emphasis was placed on following the designed time / depth profile for the set being made. That was generally achieved with good precision, the gear spending within a few minutes (and hence a few percent) of the intended half hour or hour per depth stratum. Net depth was controlled by varying the length of warp out, the speed of hauling or veering warp, and the speed of the ship, all with reference to the read-out of the Scanmar data when those were available. In general, the warp length and winch speed were relatively standardized, while necessary adjustments were made primarily by varying ship speed. Attempts to use winch speed as the principal variable control (e.g. on Set 34 of the 2009 survey) were less successful.

Each survey had a different set of bridge personnel and hence each began with some experimentation but soon settled down to more standardized techniques for handling the trawl. Those techniques were not, however, standardized among the cruises, in part because of the different handling characteristics of the ships. In 2008 and 2009, with the near-sisters *Templeman* and *Needler*, the warp was generally veered at 1.0 $m.s^{-1}$ (range 0.8–1.1) and hauled at 0.5 $m.s^{-1}$ (0.3–0.8) – those speeds, which were the same as were used in 2007, being directly controllable from the ship's bridge. *Teleost* was equipped with automated winch controls which, whatever their merits in more normal trawling, complicated control of the gear during the "V" and "W"-profile tows required for this program. One result was more variable speeds of veering and hauling the warps, though the median rates were little different to those seen aboard the smaller trawlers: 1.0 $m.s^{-1}$ (usual range 0.4–1.2) and 0.5 $m.s^{-1}$ (usual range 0.4–0.8). On *Templeman* and *Needler*, the length of warp out (on either side) was eventually standardized at 650 m for a set intended to reach 250 m depth, 1600 m for 750 m depth, 2500 m for 1250 m depth and 3200 m (or in 2009 sometimes 3400 m) for a set intended to reach 1750 m depth. Those were only slightly greater lengths than had been selected, after initial experimentation, by the officers of *Templeman* during the 2007 survey (Kenchington *et al.* 2009). Warp lengths used aboard *Teleost* were more variable but for the deeper sets were 1700 to 2000 m for 750 m depth, 2900 to 3200 m for 1250 m depth and 3200 to 3750 m for 1750 m depth. With the automatic winch control, sets confined to the 0–250 m stratum saw the warps veered until the net reached the bottom of that stratum and then immediately hauled, without regard for the maximum length of warp used.

When the data stream from the Scanmar depth sensor was interrupted, winch and ship-speed adjustments were made based on experience accumulated during the cruise. In practice, for sets following standard profiles, the net could be well controlled without real-time depth information, though such control was deemed too uncertain for near-bottom sets within the confines of the canyon, which were aborted whenever the Scanmar depth read-out failed.

The disadvantage of the approach taken is that, while times at depth followed the survey design well, the volumes of water filtered by the trawl varied with net speed – itself influenced by ship speed. Future surveys should attempt tighter control on filtered volumes, though doing so may require a functional speed sensor on the headrope. Even if so equipped, precise standardization may not be achievable. The movements of the net can be strongly affected by vertical current sheer (between the depth of the net and the ship at the surface, with the warps potentially experiencing yet other water flows) and, in the canyon, that can vary markedly from one set to the next made to the same depth and even from minute to minute during a set, when the net passes through a pattern of internal waves.

2.3.4 Catch Processing

2.3.4.1 Bulk Catches: From Codend to Sorted Taxa: When each IYGPT set was recovered to the deck, the catch was bailed out of the "aquarium" and into buckets and tubs, which were taken below for the catch to be sorted in the ship's laboratory. Select specimens were isolated in small buckets, and often kept in water, until sorted. The twine codend was then hosed down and any residual catch retained, while the entire net was searched from wings to codend, all animals found being extracted and added to the catch. Material picked from the net, along with that washed out using the deck hose, was kept separate from the catch bailed from the "aquarium" until all specimens required for contaminants analysis had been extracted, thus minimizing opportunities for on-board contamination of the selected specimens.

The catch from each set was sorted by taxon in a multi-step process, with the finer sorting either undertaken, or at least overseen and verified by, specialists – the scientific party aboard each cruise including fish, cephalopod and crustacean taxonomists with expertise in the meso- and bathypelagic fauna of the northwest Atlantic. The final step in this process produced fish, cephalopods and decapod crustaceans sorted into individual species where possible or else into groups of similar species, the collection of each taxon including not only whole animals but also all identifiable body parts. Some non-decapod crustaceans were similarly sorted but others were only separated into coarser taxonomic groupings, such as euphausiids or hyperiids, for subsequent detailed sorting ashore. The gelatinous plankton were sorted into visually-distinguishable "types". Other invertebrates were scarce in the catches and, apart from some giant chaetognaths (which could be taken in substantial numbers in a single set), the few individuals caught only required separation from the remainder of the catch.

Catches from sets that were aborted for various reasons were almost invariably discarded without sorting or data recording, reserving laboratory-staff working time for valid sets. Some limited data were, however, recorded from selected specimens taken by a few of the aborted sets.

2.3.4.2 Weights and Counts: The catches were not weighed before sorting. Rather, the weights of each taxon in the catch of a set, here referred to as the "taxon weights", were recorded after the on-board sorting of each set was complete. Total catch weights, per set, were reconstructed ashore following data editing. The taxon weights were the combined weights of all formerly-living material found in the catch that was identified to the taxon in question. In many cases, that included substantial amounts of broken body parts – though much of the damaged material might only be identifiable to higher taxa, rather than to individual species. When more than insignificant quantities of tissue were taken that could only be identified in the most general terms, the weight of that material was recorded as, for example, "unidentified fish and remains". All weights were taken with motion-compensating electronic balances.

Meanwhile, the numbers of individuals of most (but not quite all) taxa in the catch of a set were recorded as "taxon counts". Where broken tissue was present, the taxon count was defined as the minimum number of individuals needed to explain the material in the catch, even when some of those individuals were represented only by isolated body parts. The taxon weight divided by the taxon count is not, therefore, any indication of the average live weight of individual animals.

2.3.4.3 Fish: From the catch of each set, the taxon weights of each fish taxon were determined (as wet weight, to 1 g, 0.1 g or 0.01 g precision depending on the balance used, which was selected to suit the weight being determined) and, in general, the "taxon counts" were determined by counting all individuals. If only a subsample of the fish was measured (see below), the overall taxon count (for the set) was obtained by expanding the number of individuals in the measured subsample by the ratio of the taxon weight to the weight of the subsample. No attempt was made to count the numbers of *Cyclothone* spp., which were too small for quantitative sampling by the meshes of the IYGPT net.

By intention, every individual fish caught (except *Cyclothone* spp.) was measured (standard length, in millimetres), up to a maximum of about 300 individuals per taxon per set –a limit only reached by *Benthosema glaciale*[3]– except that

[3] Kenchington (2009) reported that only *Benthosema glaciale* was subsampled before lengths were measured during the 2007 survey. Inspection of the data has since shown that the *Notoscopelus resplendens* taken by Set 12 of that survey were subsampled, though the total number caught barely exceeded 300.

specimens too damaged for reliable measurement were not measured. When greater numbers of *B. glaciale* were taken, a subsample containing about 200 measurable individuals, plus a proportionate amount of non-measurable ones, should have been extracted (with care to ensure randomness), the subsample weighed and all individuals within it counted, the lengths of the measurable ones also being taken.

Unfortunately, when the catches of a few sets of the 2008 survey were being processed, individual fish were extracted and measured until 200 lengths had been recorded, as had been done more frequently in 2007 (Kenchington *et al.* 2009). During the 2008 survey, the numbers of unmeasurable individuals picked out while preparing the length data were recorded but they were ignored in the 2009 and 2010 surveys. For some affected sets, not only will the recorded length frequencies of *B. glaciale* be biased towards larger fish (an inevitable consequence of picking individuals from a sample) but the estimated total count of the catch will be depressed, firstly by dividing the catch weight by an upward-biased estimate of average individual weight (a result of the selection of larger individuals) and by the use of an average individual weight based on whole carcasses only, when the catch included a portion of damaged individuals. The extent of those biases cannot be estimated.

Since no particular subsample was taken before commencing the measuring of lengths, the subsample weight was necessarily determined after completion of the measurements. Perhaps in consequence, no subsample weight was recorded for the *B. glaciale* taken by a few of the sets. For those, the total count of individuals caught can only be estimated by interpolation from the data from other sets.

Individual fish were not routinely weighed, except where samples were retained for specific studies (see below) and even then only if the specimen was substantially complete. Such fish weights as were taken were recorded to the same levels of precision as were used for the taxon weights (0.01, 0.1 or 1 g).

Following identification, counting, weighing and measuring, in 2008 and 2009 the first claim on fish specimens was for DNA barcoding. In the former year, as in 2007, the aim was to select one or two specimens of any fish species caught that had not previously been collected for the *Barcode of Life* project. For 2009, that requirement was increased to a total of five specimens per species (including in that count all specimens accumulated through the previous cruises). In March

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The catch of *Serrivomer beanii* taken by the Diamond IX net on Set 54 of the 2010 survey was likewise subsampled, though less than 300 were caught. Otherwise, only *B. glaciale* was subsampled during any of the four surveys.

2010 in contrast, collection of specimens for barcoding was only demanded for individuals requiring DNA evidence for their identification, though in practice some additional material was collected. Specimens selected for barcoding were measured, weighed and photographed before a muscle-tissue sample was extracted and preserved in 100% ethanol. The remainder of each specimen was then individually fixed in 10% buffered formalin. In the event, nearly 500 tissue samples were taken for DNA sequencing, including examples of 201 named taxa, according to at-sea identifications, most of which were discrete species even if not yet firmly identified beyond family or genus. Including the 300 samples gathered in 2007 (Kenchington *et al.* 2009), this program has collected barcoding samples of 235 fish taxa (by at-sea identifications). Following *Barcode of Life* protocols, DNA sequences will be prepared from the muscle-tissue samples and the remainder of the fish specimens will ultimately be archived at the Atlantic Reference Centre, St. Andrews, New Brunswick.

In 2008, from the remaining catch and whenever sufficient individuals of a taxon were available, samples of between ten and one hundred fish (per taxon per set) were selected for stomach-contents analysis, with the intent that other biological data might be taken from the same specimens at a later date. Only substantially-intact specimens were included in those samples, while an effort was made to include a range of sizes. The specimens of a particular species from each set were bagged together and frozen in brine. That sampling was repeated in 2009, except that collection of *Benthosema glaciale* was limited to one sample of 60 individuals per depth stratum at each of the Deep, Main and Head stations, all of which were to be gathered from catches made at night and were to be preserved in alcohol, after their body walls were slit – those steps being intended to improve survival of the DNA of any gut contents. Beginning in 2009, the specimens selected for stomach-contents analysis were usually (though not invariably) individually weighed before bagging.

During the 2010 survey, sampling for stomach contents followed the practice of 2009 but was further limited to 30 individuals (selected as those with full stomachs and spanning the range of available sizes) of each of seven named species (*Chauliodus sloani*, *Eurypharynx pelecanoides*, *Nemichthyes scolopaceus*, *Arctozenus risso*, *Scopelogadus beanii*, *Serrivomer beani* and *Stomias boa*), plus 30 such individuals from each of the Deep, Main and Head stations of each of *Benthosema glaciale*, *Bathylagus euryops* and *Hygophum hygomi*. For the latter three species, those samples were taken only from sets made at night and were preserved in alcohol.

In 2008 and again in 2009, additional samples, comprising (by design and from the entire cruise) ten specimens (preferably little damaged) of each of small, medium-sized and large individuals of each of eight named taxa (*Benthosema glaciale*, *Cyclothone* spp., *Stomias boa*, *Chauliodus sloani*, *Serrivomer beani*, *Ceratoscopelus maderensis*, *Myctophum punctatum* and *Arctozenus risso*) were frozen in seawater for analysis of stable isotopes. Where possible, and for *B. glaciale* as a requirement, some of the specimens of each taxon were to be gathered from each of the Deep, Main and Head stations. In March 2010, this sampling requirement was amended to include the ten species retained for stomach-contents analysis, plus *Cyclothone* spp., but no others.

During the 2008 and 2009 surveys, further samples, of seven substantially-intact individuals each, of a pre-determined range of taxa were collected and frozen in dioxin-free bags, without added water, for analyses of hydrocarbon and heavy-metal contamination. In 2008, one such sample of *Benthosema glaciale* was taken from each of the Deep, Main and Head stations, while there was also one sample from the cruise of each of *Cyclothone* spp., *Stomias boa*, *Chauliodus sloani*, *Serrivomer beani*, *Ceratoscopelus maderensis*, *Myctophum punctatum* and *Arctozenus risso*. In 2009, this sampling for contaminants analysis was confined to *Benthosema glaciale* alone. Over the duration of that cruise, three samples (of seven individuals each) were to be retained from each of the Deep, Main and Head stations and, within those, from the 0–250 m stratum fished at night and the 250–750 m or 750–1250 m strata fished by day – for a total from the cruise of 18 samples and 126 individual fish. No samples were retained for contaminants analysis during the 2010 survey. Contact between the specimens collected for contaminants analysis and oils, greases or anything containing heavy metals was carefully avoided. That required avoiding such contact between any of those contaminants and the bulk of each catch, until the required specimens were extracted.

From the remainder of the fish catch, specimens were fixed in formalin and returned to shore if they could not be identified to species or if they were specimens of rare or otherwise interesting species. Many specimens were photographed and those were usually fixed and retained. In 2010, all *Cyclothone* spp. not collected for other purposes were to be fixed in formalin for specific identification ashore. Also in 2010, various myctophids were collected for a study of maturation to be undertaken at BIO, while some additional samples were collected for studies at the Los Angeles County Museum or the Virginia Institute of Marine Science and yet others were retained for private collections, for display at BIO or for distribution to educational institutions. All other fish caught were discarded at sea. Subsequent to the cruise, all fixed specimens retained at BIO have been, or will be, re-examined to confirm and, where possible, refine their taxonomic identifications.

For efficiency in the laboratory at sea, the work flow was not as described above. Rather, the common species were swiftly sorted from the mass and, when necessary, checked for identification by a specialist. The samples for stomach analysis were picked out, weighed as a group (for subsequent summation with the weight of other fish of the same taxon from the same set), measured, individually weighed and then bagged. The remainder of the common species were then weighed, with each taxon as a unit, and the lengthy process of measuring individuals commenced. Meanwhile, less-common species were identified by a specialist, weighed and counted. During the 2008 and 2009 surveys, the first and second specimens of each taxon that were encountered during the particular cruise were handed to the "barcoding" specialist for tissue sampling.

2.3.4.4 Cephalopods: The cephalopods were handled much as the fish. All were identified at sea by a taxonomic specialist, usually to the species level. Taxon weights and counts were recorded and the dorsal mantle lengths (in millimetres) of all measurable individuals were taken.

Only a few cephalopod samples, selected for use in a DNA-based study of squid diets, were retained for DNA barcoding. However, specimens of *Gonatus* spp. and *Brachioteuthis* spp. (totalling some 20 individuals of each genus each year) were taken for DNA sequencing in support of a separate project investigating taxonomic relationships within those genera. Tissue samples were preserved in ethanol and the rest of the selected individuals were fixed in formalin.

In 2008 and 2009, further samples of *Mastigoteuthis agassizii*, *Histioteuthis reversa*, *Teuthowenia megalops*, *Taonius pavo*, *Gonatus fabricii* and *G. steenstrupi* were taken for stomach-contents analysis using barcode methods and for stable-isotopes analysis. In 2010, that sampling was amended to include *Mastigoteuthis magna*, in addition to the six species collected during the two previous surveys. In 2008 only, additional samples of those same species were retained (frozen in dioxin-free bags) for analysis of contaminants, while in 2010 samples of *Brachioteuthis beanii*, *Teuthowenia megalops* and *Taonius pavo* were taken for a study of beaks being undertaken at the University of Hawaii, the buccal masses of the squids being extracted and fixed. There was also some *ad hoc* retention of cephalopod specimens on all cruises, while many were photographed. Most cephalopod material was, however, discarded at sea after being recorded.

2.3.4.5 Crustaceans: At sea, the crustacean catch was sorted to the lowest taxonomic level possible, which was often generic in 2008 but mostly to species by 2010, with the final sorting and identification by a taxonomic specialist. For most groups, taxon weights and counts were recorded, samples of most taxa were fixed in formalin and the remaining catch, if any, was frozen (as a bagged sample of one taxon from one set) for further examination ashore. For taxa requiring special care in subsequent laboratory identification, the entire catch was fixed. Many photographs were taken of selected specimens, which were then retained in formalin.

The principal exception to that protocol concerned *Meganyctiphanes norvegica* and smaller species of euphausiid krill, decapods of the family Sergestidae (primarily *Eusergestes arcticus*) and hyperiid amphipods of the genus *Themisto* (primarily *T. gaudichaudii*), the catches of each of which were typically large, in abundance terms. Following the extraction of all other taxa, the total weight of those three groups combined was recorded for each set. A 500 to 750 ml sample of the mixture (per set) was then weighed and fixed in formalin for subsequent examination ashore. After extraction of other required specimens, the remainder of the mixture was then discarded at sea.

From the 2008 survey onwards, over 300 crustacean samples, comprising members of approximately 100 taxa, were retained for the *Bar Code of Life* program. They were handled as with similar samples of fish. In 2008, once at each of the Deep, Main and Head stations, a 100 g sample of *Meganyctiphanes norvegica* was sorted from the residue of the mixed taxa and frozen in a dioxin-free bag for analysis of organic contaminants, while a further 10 g sample was frozen for analysis of heavy metals. At each of those stations, a further 10 g sample of each of *M. norvegica*, *Themisto gaudichaudii* and *Eusergestes arcticus* was frozen for stable-isotopes analysis. The sampling for contaminants analysis was not repeated during the 2009 or 2010 surveys but samples for DNA barcoding and for stable-isotopes analysis continued to be taken.

Subsequent to the cruises, the extensive crustacean samples were examined ashore, the identifications confirmed or refined and the abundances of the taxa determined either by direct counting or by extrapolation from the weighed subsamples. Taxon weights were never taken from preserved material, except where taxa recorded at sea were subdivided after closer examination ashore, when the weights of fresh material measured at sea were divided *pro rata* to the weights of the preserved material in each taxonomic subdivision.

<u>2.3.4.6 Gelatinous Plankton</u>: Some sorting of the gelatinous plankton was attempted during the 2007 survey (Kenchington *et al.* 2009) but the resulting catch data were subsequently edited into a single unit, aside from two cases of salps being recorded separately from the remainder. It has subsequently proven possible to reconstruct some of the original data from notes in logbooks kept while at sea. Through the surveys in 2008, 2009 and 2010, the sorting scheme was further developed and each recognizably-different kind of gelatinous plankter that was encountered was given a discrete designation which thereafter was used for that kind alone. In all, twenty "types" were noted, including fifteen of "jellyfish" (not all of them scyphozoans), two of ctenophores, one of *Pyrosoma* sp., one of salps generally and one that was recognized at sea as a siphonophore, along with a final category for unidentifiable fragments of gelatinous material – though the last was not separately recorded until the March

2010 survey. (During the earlier surveys, such fragments were added to the catches of the two principle species of scyphozoans.) As experience grew, “Jellyfish” 3 and “Jellyfish” 4 were combined. Aside from the unidentified category and the members of the latter pair, specimens were identified to their appropriate “type” with high confidence, each “type” was always recorded if present in a catch (except perhaps for “jellyfish” 6, which was small and might have been missed, if only a few were present, before if was first seen in quantity) and those “types” that were given designations more definite than “jellyfish” were determined to belong to named higher taxa. Some of the “types” may, however, have contained multiple species. In subsequent work ashore, “jellyfish” 7A and 7B were deemed to be parts of the same species, based on their repeated co-occurrence in the catches, though “jellyfish” 13A and 13B (which were seen once only, in the same set), have been proven to be very different taxa.

Representative samples of each “type” were photographed and/or fixed, while some samples were taken for DNA barcoding. Including the *Pyrosoma* sp., eleven of the “types” (including both members of the “Jellyfish” 3 and “Jellyfish” 4 pair) have subsequently been identified to genus level at least.

Weighing of gelatinous plankton is difficult, since attempts to separate them from exterior water lead to loss of water from their jelly also. Hence, the volume of each type in the catch of each set was measured and converted to weight at 1.025 kg per litre. Attempts were made to count the numbers of each “type” in the catches but very few, if any, intact specimens were taken and much of the gelatinous material caught was fragmentary. Hence, the recorded data on abundances should be treated as indicative only and the average weight of catch per counted individual (or colony, in the case of siphonphores) should not be considered as an estimate of the average live weight of those animals (or colonies).

Following the limited sampling for identification purposes, the residue of the gelatinous catch was discarded at sea.

<u>2.3.4.7 Other Invertebrate Species</u>: Such few individuals of other species as were taken were identified at sea, in so far as possible. Aside from near-ubiquitous chaetognaths (which were incompletely recorded, being difficult to separate from the gelatinous plankton), the handful of assorted specimens that were caught were preserved for study ashore. Some were sampled for DNA barcoding.

2.4 TUCKER TRAWLING

The Tucker trawl was only deployed during the 2008 survey; lack of a suitable winch precluding its use in subsequent years. The sets made with it were experimental in nature and followed no definite design. Most reached depths of 750 m or more and were made on the same stations used for IYGPT trawling but the Tucker gear twice failed to go below 500 m and was sometimes towed southwest of the Main Station in the area where the densest acoustic scattering was seen during the 2008 survey (Table 11).

The net used was much as described by Davies and Barham (1969) but had a mouth area of 2.44 by 2.14 m (8 by 7 ft) and 1.5 mm square mesh (2.1 mm maximum dimension of each pore). Although designed for use as an opening and closing trawl, the Tucker gear was fished in open mode only, on double-oblique ("V"-profile) tows. The first two sets (Sets 3 and 4 of the 2008 survey) were made with the Scanmar depth sensor from the IYGPT mounted to determine the appropriate amount of wire to veer. Subsequent Tucker sets were controlled by the length of wire and the depths achieved were recorded by Star-Oddi sensors (as used on the IYGPT) attached to the trawl. Towing speeds were generally 3 to 4 knots.

The Tucker trawl catches were only briefly examined at sea. Samples, predominantly of *Benthosema glaciale*, were removed from each catch and frozen for stable-isotopes analysis, while samples of krill (100 g per sample) were taken from the catches of three of the sets for contaminants analysis. The residue of the catch was fixed in formalin in bulk.

The filtered volume for each set was estimated as the mouth area of the net multiplied by an assumed length of each tow calculated from the straight-line distance between the ship's position when the Tucker trawl entered the water, the net depth and ship's position when the gear reached its maximum depth, and the ship's position again when the net left the water. Thus calculated, the volumes under-estimate true filtered volume (and so over-estimate the densities of the organisms caught) by ignoring curvature in the ship's track, the steeper descent of the net as it fell astern of the ship and irregularities in the depth profiles. However, they over-estimate the true volume by assuming that the mouth of the net lies perpendicular to the direction of travel, when it is designed to be somewhat oblique, and by ignoring any displacement of water flow resulting from the restriction of the mesh of the net. Additionally, densities of some organisms are under-estimated by ignoring active net avoidance. Larger but unknown errors are likely to have arisen from water flows at the depths fished, since the calculations assume that the water was static relative to the seabed. The overall effects of those errors are unknown but the resulting estimates of densities of organisms are thought to be adequate for judging whether or not the species caught are major contributors to the observed acoustic scattering, which was the primary purpose of the Tucker trawling.

Similar estimates were made of the filtered volumes within the non-migratory scattering layer noted by Kenchington *et al.* (2009) and observed again during the surveys reported here. Those were prepared in the same way as the estimates of total volumes filtered, except for substituting the ship's positions when the net passed 400 m depth on the downward and upward legs of the tow for the start and end positions of the set, while deducting that 400 m from the maximum depths reached by the Tucker gear.

2.5 DIAMOND IX TRAWLING

Following the March 2010 IYGPT survey, a Diamond IX trawl was fished on some of the same stations but only as experimental sets, not attempting to follow any particular depth profiles. The net, which was on loan from DFO Newfoundland Region and thus maintained in conformity with its design (see Appendix III), was equipped with the same Scanmar and Seabird SBE39 sensor suite as used on the IYGPT in 2010. It was also fitted with ninety 8-inch Saeplast 2080 floats (working depth 1800 m), with large concrete-block weights at the lower wings, in place of the chain clumps called for in the net design, and with the "aquarium" codend from the IYGPT net.

Winch speeds when towing the Diamond IX were little different from those used when handling the IYGPT: around 1.0 $m.s^{-1}$ veering and 0.5 $m.s^{-1}$ hauling. Ship speeds were, however, a little lower with the drag of the big net at about 3.9 knots when veering warp and 2.9 when hauling. The Diamond IX also needed much more length of warp to reach the same depths: around 3,250 m for a set made to 1,250 m depth.

The catches by the Diamond IX were sorted and processed following the same procedures as were used with those taken by the IYGPT.

2.6 PHOTOGRAPHY

As in 2007 (Kenchington *et al.* 2009), during each of the three surveys multiple camera systems were used to record the operations of the cruise and the catches. Through all four surveys, a Nikon SMZ1500 stereo microscope, equipped with an Olympus Qimaging Colour 3 digital camera hardwired to a computer, was used for photographing smaller specimens and details. For larger specimens, a macro-photographic system was developed for the 2008 survey to replace the arrangements of the previous year and, with only minor modifications, was utilized again in 2009 and 2010. That system consisted of a Nikon D300 camera mounted on a vertically adjustable copy stand, which camera was synced to two diffused electronic flashes mounted on arms radiating from the copy stand. Camera settings and image quality were adjusted as necessary using Nikon's Camera Control Pro 2, which automatically captured the images to a hard drive that was regularly backed up to a central server on the ship.

Those systems were supplemented with various hand-held still and video cameras, though more to record the work rather than the specimens.

2.7 PHYSICAL OCEANOGRAPHY

By design, CTD casts were to be made daily, outside of the trawling period but near the last station trawled, using a Sea-Bird model SBE25, bearing an oxygen sensor as well as the usual temperature, conductivity and pressure sensors. Additional casts were made during the 2009 and 2010 surveys whenever interesting features were observed, when there was an opportunity to gather data from CTD stations established by the Atlantic Zonal Monitoring Program (“AZMP”) and when there was time for multiple casts along the length of each trawling station, thus creating a fine-scale oceanographic section along the length of the canyon thalweg.

In 2008 the pressure sensor on the SBE25 instrument package proved to be defective. Only seven casts were made, of which only the first six generated any data. Fortunately, the Star-Oddi temperature / depth recorders (intended for use on the headline of the IYGPT net) had been fastened to the CTD on most casts to allow calibration of the former. The resulting data were actually used to reconstruct the defective CTD records, aided by a subsequent calibration trial in Bedford Basin, using a fully-functional CTD for comparison with the Star-Oddi recorders, and by re-calibration of those recorders by their manufacturer. Some of the resulting data appear acceptable for the purposes of biological interpretation, though likely not for physical modelling.

The SBE25 used in 2009 performed better than the one the previous year but still erratically. The processed data were eventually deemed satisfactory for oceanographic analysis on at least one leg (down or up) of each cast, though often only on one. The oxygen sensor produced data that were at times suspect. During the 2010 cruise, in contrast, the instrument performed successfully throughout.

2.8 ACOUSTICS

As in 2007 (Kenchington *et al.* 2009), the scientific sounders fitted aboard each research vessel were used to monitor scattering layers down to 1,000 m depth (by intent: continually), beginning at the ship's passage over the shelf break near the start of a cruise and until departure from The Gully when approaching its end. The focus of the cruises was, however, on trawling and only limited attempts were made to run acoustic-survey transects, the rest of the record being from ship movements dictated by other tasks.

In 2008, CCGS *Wilfred Templeman* was equipped with the same Simrad EK500 echosounder used the previous year. CCGS *Alfred Needler*, used for the 2009 survey, had a Simrad EK60, with dual 38 kHz and 120 kHz transceivers. CCGS *Teleost* was equipped with a Simrad EK500 and dual transceivers but only the 38 kHz one was active. All three had the same model of hull-mounted 38 kHz transducer and all operated at 2 kW of transmission power[4].

Through the surveys, three forms of data display were used. In each case, the sounder fed its data to a colour video display for real-time monitoring. By intent, those same data were captured digitally, using *Canadian Hydroacoustic Data Analysis Tool 1* ("*CH1*") software running on a computer linked to the sounder's output port. In 2008, the data were also routed to an inkjet printer, producing permanent paper records in case of failure of the digital capture. The following year, printouts were only made of selected echograms which showed especially-interesting features on the video display, while no hard-copy records were printed at all during the 2010 survey.

The sounder menu settings were largely left to those standard in acoustic surveys of fish biomass. In 2008, Time Varied Gain ("TVG") was consistently set at 20 Log R. Expansion of near-bottom depths was turned off, as was printing below seabed depth, while the displayed depth range was standardized at 0–1000 m. The "ping interval" was set to 4 seconds, ensuring a steady rate of printing of echograms, but it was sometimes inadvertently changed to shorter periods which, in the depths worked, caused the instrument to revert to an automatic mode which gave variable rates of generation of output display (i.e. millimetres of paper trace per minute of time). The degree to which received sound was displayed as scattering layers on printed echograms was optimized by adjusting the minimum displayed Target Strength (TS) to -70 dB and Scattering Volume (Sv) to -75 dB. Those considerations are not relevant to the digital records, the subsequent display of which can be manipulated as required.

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[4] Kenchington *et al.* (2009) incorrectly quoted *Templeman's* EK500 as operating at 4 kW and gave an erroneous source level for the sounder.

In 2008 and 2010, Sv data (corresponding to 20 Log R TVG) were captured. TS and bottom-depth data were also captured in 2009 but are not useful, the former being obscured by noise at the depths of interest while the latter were unreliable, through the sounders “white lining” on scattering layers when the bottom echo was weak.

Although acoustic data were supposed to be collected whenever the ships were over water deeper than 200 m, in 2008 problems with the computer interface caused a loss of usable paper echograms until 0425 on 31 August, while successful digital recording did not begin until 1715 that day. Thereafter, data capture was almost continuous until *Templeman* left The Gully. As in 2007, however, there were breaks in the printed record when either the paper supply or the inkjet cartridges ran out, plus some from other failures of the printing process. Moreover, much of the record (both digital and paper) was badly degraded by interference from vessel noise, while the printed version was further affected by the sounder “white lining” on the top of the scattering layers. The 2009 survey also saw a failure of digital recording at the commencement of the cruise and the problems were not resolved for some time. Only the data from the final four days in The Gully were retained in digital form, leaving the occasional, selected printed echograms as the sole record of acoustic scattering from most of the survey. In 2010, in contrast, the digital data capture worked flawlessly and proceeded without a break from 0650 on 15 March (before the ship reached the Slope Station) until 1530 on the 26th (after departure from The Gully). During that survey, noise, which was so consistent as to appear internal to the sounder, obscured the faintest echoes from depths below about 450 m but otherwise the data were usable throughout, aside from periods of bad weather.

The digital acoustic records proved considerably more detailed than the paper echograms, as well as much more easily and thoroughly analyzed. Once successfully commenced, the digital capture was also much more reliable than human monitoring of printer function.

2.9 MARINE MAMMAL & BIRD OBSERVATIONS

In contrast to the 2007 survey (Kenchington *et al.* 2009), a specialist marine mammal observer was carried on each of the cruises from 2008 to 2010 and a watch was maintained throughout daylight hours while at sea. Records of all marine mammal sightings were maintained following the standard protocols of the Whitehead cetacean-research laboratory at Dalhousie University.

During the 2008 and 2009 surveys, the modified watch system adopted to maximize trawling time precluded any attempt at the sort of casual observations of seabirds that had been made in 2007 (Kenchington *et al.* 2009). In March 2010, however, the additional accommodation for scientists aboard

CCGS *Teleost* allowed the inclusion in the scientific party of a specialist seabird observer. Records of the avifauna were therefore maintained throughout daylight hours while at sea, following Environment Canada's standard protocol (Gjerdrum *et al.* 2008, 2011).

2.10 AUTOMATED DATA RECORDING

2.10.1 Bridge Data

The ship's navigational computer (Aldebaran II on *Templeman* in 2008, Regulus in subsequent years) logged basic navigational data (date, time, position, heading, speed and usually bottom depth) every two seconds, with values for the intervening seconds being subsequently interpolated. Bottom depth was often unavailable, when the seabed was beyond the detection range of the ship's echosounder, or else was erroneous, when the instrument "white lined" on a scattering layer for want of a stronger echo. For periods when the ship was in The Gully, water depths should be determined from positions and the known bathymetry of the canyon, not from the records in the navigational database.

When trawling, the Scanmar output was recorded by another computer, under the control of the ship's watchkeeping officers. The Scanmar data will be examined in detail in a subsequent report but a caution must be offered here: the data received from the sensors, particularly the speed sensor, was often erratic and sometimes consistently wrong. Moreover, those incoming data were processed and interpreted by the control and display hardware on the bridge, with only the interpreted output being recorded. During the survey fishing, which extended beyond the system's design capabilities, it frequently preferred its own estimates to the raw values received from the sensors, sometimes smoothing the data stream but at others suppressing good data and substituting absurd information – including a tendency to record the net as flying above the sea surface. The output values generated by the more advanced instrumentation installed aboard *Needler*, and hence that used for the 2009 survey, were substantially more reliable that those available on the other ships still not without problems. Thus, while the Scanmar display was invaluable in controlling the trawling, the recorded data must only be used with great care.

Both the navigational and the Scanmar data were periodically copied to a data-management computer and were backed up daily.

One member of the scientific party was present on the bridge during all IYGPT and Diamond IX trawling operations, with the dual roles of directing the fishing (through the ship's officer of the watch) and maintaining, on hard copy, a descriptive record of events, such as shooting the net, releasing the doors, passage of the net through the upper depth limit of each stratum, application of the winch brakes and the commencement of hauling, as well as any gear damage. That was the sole record of the activity of the trawl winch, including times of starting and stopping, rates of veering and hauling, as well as lengths of warp out. The records maintained on the bridge by scientific personnel were also the primary logging of times of shooting and hauling, though they could be supplemented or confirmed from the ship's log, maintained by the bridge officers. Similar but less extensive records were maintained of CTD and Tucker trawl sets.

2.10.2 Laboratory Data

Some of the data generated in the ship's laboratory were recorded in logbooks, either physical or digital, but the bulk of those data were entered directly into a computer system running custom software developed by two of the authors (RB & AC). The 2008 survey used a prototype, based on MicroSoft Excel spreadsheets, but a finished version, written in MicroSoft Access, was used in 2009 and (in slightly upgraded form) in 2010. Experience in 2008 revealed some deficiencies in the Excel version, slowing work in the laboratory, but those were made good during preparation of the Access software, which proved fully satisfactory. Most lengths and weights were input to the database directly from electronic balances and digital callipers, though some manual entry could not be avoided. Counts of individuals in subsamples or in whole catches were necessarily manually entered.

The resulting data contained fewer errors than were encountered in 2007 (Kenchington *et al.* 2009) but have nevertheless required extensive editing before analysis.

3 CRUISE NARRATIVES

3.1 CRUISE TEM832: SUMMER 2008

For the 2008 survey, CCGS *Wilfred Templeman* departed BIO at 0130 UTC on 29 August, having been delayed by problems with the potable water supply. She proceeded towards the Deep Station, passing south of Sable Island at 2200. Set 1 was shot away, down the stern ramp, at 0400 on 30 August, in overcast weather with a 20 knot south-westerly breeze and moderate sea and swell. When Set 2 was shot, the net was torn by a sharp metal edge on the stern ramp, creating an ≈2 m^2 hole which may have affected catching efficiency on that one Set. Sets 3 and 4 were initial trials in handling the Tucker trawl, while Set 5 was the first CTD cast. Trawling then continued, in slowly-improving weather, until Set 9 – when a water leak in the main engine required that the Set be aborted after the first “V” of its intended “W” profile. Meanwhile, printing of echograms effectively commenced at 0430 on 31 August, between Sets 6 and 7, following complications arising from the dual capture of digital and hard-copy records. Set 10, the second CTD cast, had to be made using the ship’s hydro winch since the winch fitted at BIO for the purpose had developed a short to ground and could not be used subsequently. Returning to IYGPT trawling, Set 11 was completed without incident but Set 12 encountered a problem that was to recur throughout the cruise: The set was intended as a “V”-profile tow to 1750 m but the Scanmar “HC4-20/D1800” sensor (specially collected from CCGS *Teleost* for this cruise) proved unable to transmit gear depths greater than 1200 m. A decision was made to convert Set 12 into a 1250 m tow but it ended with a non-standard profile. Set 13 was lost to loose turns on the starboard winch, necessitating veering of the warps during what should have been a steady haul.

With only five of the intended fifteen IYGPT sets on the Deep Station completed, a decision was made to move to the Main Station before more time was lost. Set 14 was shot away at 1030 on 1 September, in bright sunshine and a 20-knot south-westerly that built to 25 before dropping away again. Set 16 was a Tucker trawl tow but only achieved 450 m depth, despite being given more wire than previously used in reaching 750 m. That was followed by a CTD cast that generated faulty data, leading to an immediate second cast (Sets 17 and 18). IYGPT trawling then continued without incident, aside from a jammed clutch in the trawl winch that delayed shooting of Set 21. Following that set and during the dusk period, the ship steamed a circuit around the spur that projects from the Southwest Prong of Banquereau, mapping the acoustic scattering.

After completing Set 22 at the northern end of the Main Station, the ship continued to the Head Station and began fishing there in clear weather with moderate sea and swell, the wind dropping away to 10 knots easterly. Set 30 was aborted when the Scanmar depth sensor failed – posing too high a risk with a 750 m tow in the canyon head. After Set 32, the ship returned to the vicinity of the Main Station and commenced Tucker trawling, targeted on the major concentration of acoustic scattering immediately southwest of the Station, though the winch fitted to ship for that gear began to develop a troubling vibration. IYGPT trawling then resumed and continued without incident on the Main and Deep stations until Set 43, the wind having built by then to gusts of 30 knots from the west with moderate seas. Fishing was not interrupted, however, and the wind soon died down again. Set 45, planned for 1250 m on the Main Station, had to be aborted when the Scanmar depth sensor failed again. Set 50 had to be aborted as it was being shot, when broken strands were seen in one of the pendant wires.

Aside from the intended 1250–1750 m stratum, the planned work on the Deep Station was completed with Set 52. The ship then headed north, with one more tow required on each of the Main and Head stations. Set 53 was completed and was hauled back to the ship when a winch failure caused the starboard otter board to hit the ship so hard that the board was bent and the bracket to which the warp attached was broken off. The entire gear, including both otter boards, was left hanging from the port warp. In a display of superb seamanship, the crew successfully brought everything aboard using the gilsons but the strain was too great for *Templeman*: As the starboard otter board was finally hauled across the trawl deck, the gilson clutch exploded. With the trawl winch damaged beyond hope of repair at sea and with bad weather forecast, the final set was abandoned and the ship turned for Halifax. The catch from Set 53 was processed as normal, except that circumstances on deck did not allow the usual careful picking of the catch out of the net.

Templeman secured alongside at BIO at 1540 UTC on 7 September.

The days of trawling on Cruise TEM832 commenced immediately before a peak of spring tides, which fell on 1 September at Point Tupper, the nearest reference port. The trawling continued almost to the following nadir of neap times, which occurred on the 9th of the month. Sunrise in The Gully, specifically at 44° N 59° W (close to the Head Station), was at 0916 UTC when trawling began on 30 August and at 0926 when it ended on 6 September. Sunset was similarly at 2237 at the start of the survey and 2221 when it ended.

3.2 CRUISE NED2009-35: SUMMER 2009

CCGS *Alfred Needler* departed BIO at 1530 UTC on 12 August 2009, following a period of alongside maintenance and bound for the Slope Station south of Sable Island. In the absence of high-precision bathymetric data for that area, a final determination of the station's position could only be made after echosounding to find bottom depths similar to those on the Main Station, so that comparable catches could be taken for a test of differences between canyon and slope faunas. The sounding commenced at 1117 on 13 August, in 10–15 knot north-easterly winds, and the IYGPT was shot away two hours later for Set 1. The cruise plan called for two trawl sets to 750 m depth on the station, plus a CTD cast. Those were completed by 2100 and *Needler* headed for the Deep Station.

The early trawl sets found the IYGPT sinking very slowly, possibly due to the new nets being made of more buoyant materials than those used previously. Some of the additional floats added to support the Scanmar sensors were removed after Set 1 but otherwise the problem was cured by slowing the ship when paying out the warp. There were attempts to pay out more warp than the lengths adopted during the 2008 survey but the choices eventually evolved back to those which had proven best in previous years. The standard came to be a target of 20 and later 25 m per minute sink rate when paying out, with hauling adjusted (mainly by controlling ship speed) in an attempt to have the net spend 60 minutes within each depth stratum (except 30 m in the 0–250 m stratum for sets that went to 750 m or deeper).

Operation of the EK60 sounder was erratic, primarily because (lacking a suitable depth of water accessible from BIO) the seagoing personnel could not experiment in advance of the cruise. The transmitted power was initially set too low but that was increased to the intended 2 kW at 1523 on 13 August. Either the briefing that personnel had received on how to start digital recording of the echoes, or their understanding of that briefing, proved to have been inadequate. The commencement of recording was delayed and the full suite of intended data capture was rarely achieved.

Set 4 was shot away immediately after the dusk no-trawling period, at 0049 on 14 August, commencing the work on the Deep Station. It soon emerged that *Needler* was operating in very warm water, with surface temperatures above 25°C, which was at the limit for the main engine's cooling system. In the event, trawling operations were not curtailed but no higher temperatures could have been worked so intensively. The situation resulted from the presence of a body of Warm Slope Water that was pressed up against the continental slope. While the CTD revealed the situation to be more complex than it appeared at the time to those on board, at the sea surface the shelf / slope front cut across the Deep Station – once being visible, in the form of a drift line of *Sargassum*, and on other occasions revealed by sudden changes in the ship's movement relative to the seabed or else by observable differences in sea state and apparent wind. One consequence of those conditions was a very high diversity of mesopelagic species brought north in the Warm Slope Water, which slowed the work in the ship's laboratory. Another was difficulty in handling the trawl when it was on one side of a frontal surface and the ship was on the other, with the two water masses moving in different directions.

By intent on that on survey, every organism that was measured was to also have its individual weight recorded – on the expectation that little additional work would be involved. Once the labour of sorting high-diversity catches was realized, that requirement was necessarily dropped and individual weights were only taken from animals retained for further study, as had been the practice in 2007 and 2008. Extensive weighing of individuals was not reinstated late in the cruise, even when the ship moved to the Head Station and workloads were greatly reduced.

The Scanmar net-measurement system installed on the bridge of *Needler* proved far more effective than the older model used aboard *Templeman* for previous surveys, though its tendency to display only edited results, not raw data, caused the loss of valuable net-depth information on deeper sets. Individual sensors failed at intervals, usually because of flat batteries, some of which resulted from failures of the re-charging process and others from a failure to swap sensors before they ran out of power. For a program dependent on net measurements, greater care is needed. There was a particular problem with the net-speed sensor, which never did provide useful data on forward motion, though it seemed to be accurate in measuring the speed of transverse flows. Attempts were made to move headline floats from the area ahead of that sensor but without useful effect. Swapping the sensor was no more helpful.

The CTD's performance was also erratic, with a tendency for the recorded depth to intermittently decrease while the instrument was being lowered or *vice versa*. Set 14 showed more serious problems with the depth records apparently offset relative to the temporal sequence of a downcast followed by an upcast. From Set 15, the usual period of soaking at the surface was abandoned and the resulting traces appeared less unconventional.

Weather conditions remained favourable, with the wind rarely exceeding 15 knots and never over 20–25 knots. Through the survey, there were periods of sun, overcast, rain and even fog but no weather that affected the scientific work other than the whalewatch.

Beginning with Set 17, shot away at 0010 on 16 August, trawl sets on the Deep Station were interspersed with ones made on the Main and Wall stations, so as to keep the ship actively fishing without overloading the laboratory team.

When steaming from the end of Set 26, at the southeast end of the Deep Station, to commence Set 27 on the Main Station, the deep scattering layers over and southeast of the spur that extends the Southwest Prong suggested a massive outflow of water from the Gully. Following Set 27, therefore, trawling was suspended from 0830 on 17 August while the ship ran acoustic transects across the area and three CTD casts were made. In compensation, trawling re-commenced in daylight before the dusk period that same evening, Set 31 being shot away at 2003.

Following the sunset no-trawling period, Set 32 was made to 1750 m on the Deep Station. In paying out 3400 m of warp, the two warps came to be 30 m out of alignment due to a misadjustment of the spooling gear on the starboard winch drum. The cruise plan had called for two standard tows to 1750 m (either by night or in daylight) plus two other tows to the same depth, primarily to gather bathypelagic specimens, which sets could extend into either the dawn or dusk periods, thus minimizing the use of the trawling watch devoted to such long operations. Since the former requirement had already been satisfied by Sets 4 and 32, it was decided to make an extra-long, extra-deep tow that would allow for examination of the mechanical problem while the warp was off the winch. That became Set 38, made on the afternoon of 18 August. The process was repeated the following day, as Set 43, with the Chief Engineer adjusting the spooling gear once the winch brakes were locked with nearly 3,800 m of warp out. The Scanmar depth readout was lost when the winches stopped, which proved to be normal during the survey, but there was little concern as seabed depth was 2,300 to 2,500 m and the net had shown little inclination to sink during Set 32. However, the adjustments to the spooling gear took an hour and, when the net's headline sensors were recovered at the end of the set, the gear proved to have reached nearly 2,400 m depth. Set 43 thereby sampled the entire water column over the Deep Station.

In the meanwhile, trawling commenced on the Wall Station with Set 33. Although the cruise plan only called for 750 m tows on that station, to examine the effects of the proximity of the canyon walls, Set 33 was made to 250 m as a means of prospecting the line before risking the net too close to the seabed.

During the afternoon of 20 August, *Needler* moved north to the Head Station, fishing on the other stations being well advanced. The work on the Head Station commenced with CTD casts, followed by trawling that began with the shooting away of Set 52 at 0015 on 21 August.

Set 53 proved to be the sole case during the survey of an IYGPT set being aborted, the problem being failure of the Scanmar depth sensor, likely due to low battery power. In the confines of the canyon head, it was not safe to attempt to control net depth without the depth readout. The lack of other aborted tows, which were all too common on the previous surveys in this program, was a testament to *Needler*'s recent maintenance, to the developing experience of the survey team and to the excellent weather enjoyed on the 2009 survey.

The cruise was well on schedule to complete the work on the Head Station early on 22 August and then to proceed down the canyon, picking up the remaining four sets required by the cruise plan. Unfortunately, the approach of Hurricane Bill made it imperative that the ship be secured alongside at BIO by the end of the 22nd. Set 58 was completed at 1524 on 21 August, ending the trawling period for that day, while a delay to allow a further IYGPT set at 0000 on the 22nd would have seen *Needler* still at sea when the hurricane passed. The ship therefore completed a final CTD cast (Set 59) and then headed for Halifax, the weather continuing excellent. *Needler* secured alongside at BIO at 1338 on 22 August.

The trawling on Cruise NED2009–35 began mid-way between spring and neap tides (8 and 16 August, respectively) and continued through the period of neaps almost to the next springs (which fell on 22 August at Point Tupper). Sunrise at 44 N 59 W was at 0900 when trawling began on 13 August and at 0907 when it ended on the 21st. Sunset changed similarly from 2300 to 2251.

3.3 CRUISE TEL-2010-900: SPRING 2010

Following complications with the delayed baggage of one member of the scientific party and a change in clock time affecting crew watches, departure was set for 0600 UTC on 14 March. A problem with an exhaust temperature sensor then caused a further delay and CCGS *Teleost* departed for sea at 1100, bound for the Slope Station. The ship passed south of Sable Island at 0400 on the 15th, and prepared for the first IYGPT set on the Station an hour later. Unfortunately, an insulation fire in a UPS unit then caused sufficient further delay to prevent completion of catch processing within the working time of the laboratory watch. Thus, Set 1 became a CTD cast at 1015, completed in 20 knots of wind from the northeast, and the two planned daylight IYGPT sets on the Slope Station could not commence until after 1500. Late in the haul-back of Set 2, the doors crossed, resulting in another lost hour, while the Scanmar system failed at the start of Set 3, requiring that the tow be aborted. Repeating that set would have meant steaming on to The Gully during potential trawling time, thus losing further opportunity for the core work of the cruise. Hence, at 1955 *Teleost* left the Slope Station with only one IYGPT set completed, and headed for The Gully.

Trawling on the Deep Station commenced at 0014 on 16 March when the doors were let go for Set 4. The weather continued partly cloudy, with a 25-knot north-easterly wind and a moderate swell. The early IYGPT sets were a learning experience for the bridge personnel, which resulted in some irregularity in tow profiles (Set 6 being sufficiently affected as to raise doubts about use of the data) and also limited fishing time since the Bo's'un was required at the winch controls throughout. To make full use of the resulting extended non-trawling period, Set 7 became the deployment and testing of an Autonomous Multi-Channel Acoustic Recorder, which was placed on the seabed between the Main and Head stations. Routine IYGPT trawling finally commenced with Set 8 at 1515 on the 16th, the weather remaining unchanged. The priority for the available hours of daylight was the Main Station, while night fishing continued on the Deep Station. The early hours of the 17th saw the wind drop away to 10 knots and then turn into the west, with the sea and swell dying away.

A problem with the winch spooling gear emerged during Set 12, which caused the tow profile to be seriously non-standard and the catch was not fully processed. Repairs concluded with a gear test, Set 13, completed at 1508 on 17 March.

Set 18 concluded the required night sets on the Deep Station, aside from the very time-consuming ones to 1750 m, while Set 21 completed the planned daylight sets on the Main Station. Through that period, the wind picked up again, gusting to 30 knots by 1500 on the 18th, at the beginning of Set 21. Thereafter, the focus shifted to night fishing on the Main Station, with the daylight portion of the trawling period expended on the Head Station. That work ran through to Set 33, the wind falling away to light airs 0900 on the 19th and the weather remaining ideal thereafter.

Set 24 began a pattern of very irregular behaviour of the net or at least of the outputs of the Scanmar sensors. It was suspected at the time that this resulted from internal waves, possibly moving the net but more likely causing swift changes in echoes off the thermocline. Sets 37 and 39 were also significantly affected. Those two saw worsening weather, in the early hours of 21 March, but the wind soon dropped back to 10 knots or less.

Meanwhile, back on the Deep Station to make the required 1750 m tows, Set 35 encountered renewed problems with the winch spooling gear. The tow was prolonged while the engineers made necessary adjustments, in the process of which the warp was veered to a record total of 3760m off each drum.

Set 51, completed by 0300 on 23 March, concluded the required IYGPT tows in the MPA, with replicate tows in each stratum at each of three stations by night, plus complete coverage of the Main Station in daylight. As a bonus, work on the Head Station in daylight had been completed and two additional 1750m tows had been made on the Deep Station in daylight. Rather than continuing with the Wall Station or more daylight fishing on the Deep Station, the decision was made to change to the Diamond IX net, while there was still time to make use of its special capabilities. Once that change was undertaken, there would not be time enough to change back again.

A test set of the Diamond IX, Set 52, began at 1033 on the 23rd. It was made outside the MPA, where there was plenty of space without the constraints of permit conditions. Set 53, which commenced at 1400 the same day, saw the beginning of scientific sampling with the big net, fishing on the Deep Station and following a V profile to considerable depth, though not the same profile as with the IYGPT. The net proved workable, despite its size and complexity, but it caught little that the IYGPT did not – though the relative abundances of the species differed between the nets. Worse, little of the Diamond IX's catch reached its codend, most being hung up in the meshes, which necessitated prolonged picking of the net. Set 54 was a Diamond IX tow on the Main Station which concluded by 2330. At that time, the wind was gusting to 25 knots easterly – judged unsafe, for either the gear or the deck crew, with such a net within the confines of the canyon. Set 55 was therefore delayed until 1100 on 24 March, when fishing resumed. By the end of Set 56 at 1900, however, the wind was gusting to gale force. It eased again in time to shoot away Set 57, on the Head Station, at 2146.

While the trials with the Diamond IX had been informative, the net did not effectively sample any fraction of the ecosystem that is missed by the IYGPT. Thus, there was no value in repeated fishing on the stations within the MPA, yet there was no time to allow a change back to the smaller net and completion of more trawling. To use the remaining time effectively, *Teleost* steamed to the Offshore Station for a CTD cast (Set 58) and one Diamond IX tow (Set 59). A return to the canyon allowed recovery of the acoustic recorder as Set 60, which was successfully concluded at 1228 on 26 March.

The ship then turned for BIO, passing north of Sable Island. The weather, which had been ideal (seasonable temperatures excepted) almost consistently throughout the cruise, turned to a northerly gale with sleet and ice by 2300. *Teleost* entered Halifax at 0900 on the 27th and secured alongside at BIO by 1020.

On Cruise TEL-2010-900, the trawling began shortly before the peak of spring neap tides (which fell on 16 March at Point Tupper) and continued until shortly after the following nadir of neaps (25 March). Sunrise at 44 N 59 W was at 1009 when trawling began on 16 March and at 0946 when it ended on the 26th. Sunset changed similarly from 2202 to 2217.

4 RESULTS

Analyses of the data gathered during the three surveys will be presented elsewhere but some methodological observations are more appropriately reported here.

4.1 TRAWL PERFORMANCE

4.1.1 IYGPT Performance

During each of the surveys, ship speeds over the ground (derived from GPS position data) were logged every two seconds by computer but those data await analysis. Spot checks on speeds were recorded manually on the bridge during trawling operations with some regularity, at least when compared to their intermittent recording in 2007. An overview of those records suggests that in 2008, while the warp was being veered *Templeman* typically made about 5 knots (range: 4.4 to 5.9), contrasting with the approximately 4.5 knots (recorded range: 2.2 to 5.6) of 2007, while *Needler* went somewhat slower in 2009 (typically 3.8 to 4.0 knots, range: 1.9 to 4.8), possibly because the new nets constructed for this program were more buoyant than standard IYGPT gear and hence sank less readily. Once the winch brakes were applied, speed was cut to a median of around 2.8 knots (range: 1.3 to 4.3) in 2007, *circa* 3.7 knots (range: 3.0 to 4.0) in 2008 or *circa* 2.7 knots (range: 1.7 to 4.0) in 2009. While hauling, it was cut further to about 2.4 knots (range: 2.0 to 2.9) in 2007, about 3 knots (range: 2.4 to 3.6) in 2008 or typically 2.3 to 3.1 knots (range: 0.8 to 3.8) in 2009. In March 2010, *Teleost* made a median speed around 4.1 knots (recorded range 2.1 to 6.1) when veering warp and 3.2 knots (range: 1.2 to 4.1) after the maximum length of warp was out. She did not consistently slow down further when hauling commenced.

A more detailed analysis will be prepared in due course but, after adjustment for the speed of the winches (see Methods section above) but not for any vertical sheer in the water column, those recorded ship speeds suggest speeds of the net through the water of about 2.5 knots (1.25 $m.s^{-1}$) when the warp was veered and 3.5 knots (1.75 $m.s^{-1}$) afterwards in 2007, about 3 knots (1.5 $m.s^{-1}$) and 4 knots (2 $m.s^{-1}$) respectively in 2008, but 2 knots (1.0 $m.s^{-1}$) during veering and 3 knots (1.5 $m.s^{-1}$) during hauling in both 2009 and 2010.

A thorough analysis of net dimensions, based on the Scanmar data, is awaited. Those data do show that the nets' wingspreads and headline heights were variable. Once away from the surface, with sufficient warp out that the doors could deploy properly, wingspreads usually fell in the range 10 to 14 m in 2008, while the headline height typically lay between 4 and 6 m. On many sets, the net's mouth was about 12 by 4.5 m, or 40 to 45 m^2 (assuming an elliptical shape) when the warps were being veered and around 11 by 4 m (35 m^2) as they were hauled. Those areas were appreciably less than the approximately 55 m^2 which was typical during the 2007 survey (Kenchington *et al.* 2009) – perhaps a result of the higher towing speed, though the net used was newer, maintained in close conformance with the IYGPT design and hence may have been physically smaller. During the 2009 survey, with the purpose-built IYGPT towed by *Needler*, wingspreads tended to be somewhat higher than in the previous surveys, while the headline height was much greater, often between 4 and 9 m. Per-set average mouth areas (when the gear was below 50 m depth) were 57 to 67 m^2, with an overall average of nearly 62 m^2. When towed by *Teleost* at much the same recorded speeds during the March 2010 survey, the identical net had a smaller mouth: 36 to 60 m^2 as per-set averages and an overall average of less than 53 m^2.

Door spread could exceed 60 m, and even reached 80 m on occasion, but is of little relevance to the catches obtained: in contrast to bottom trawling, mobile animals can evade the doors and bridles in three dimensions and thus are little herded into the path of the net. Most of the animals taken during the present surveys appear unlikely to be mobile enough to be herded by doors and bridles in any case.

When initiating this survey program, it was necessary to allow the officers and bo's'uns of the research trawlers to develop techniques for achieving the required tow profiles. However, it is now clear that IYGPT nets can follow those profiles at different speeds and with different geometry. Future surveys should therefore standardize not only the profiles but also the speeds of the net (estimated, if necessary, as ship speed plus or minus winch speed), though use of different speeds with different ships may remain unavoidable.

While the above preliminary figures on net speeds and mouth areas should not be relied on, they are indicative. They suggest that a standard IYGPT set in 2007 (with the warps veered for one third of the total duration and hauled for the remainder) filtered about 310,000 m^3 per hour. Given the double-oblique, "V" tow profiles, that is equivalent to each standard set filtering the water column beneath 625 m^2 of surface and extending to the maximum depth of the set (except for the 0–250 m sets, which filtered a volume equivalent to the water column above 250 m depth under twice that area) – though the 2007 sets were non-standard, having faster veering and hauling when outside their nominal strata. In 2008, the smaller mouth area should have over-compensated for the faster trawling speed, such that the volume filtered may have been about 250,000 m^3 per hour, on average, equivalent to the water column under 500 m^2 of surface (1000 m^2 for 0–250 m sets). For the 2009 survey, the corresponding estimates approached 300,000 m^3 and 600 m^2 (1200 m^2 for 0–250 m sets), while those for March 2010 returned to approximate equality with the estimates for 2008. Hence, as an approximation to one significant figure, each standard set might be considered as having filtered the water under some 600 m^2 of surface (1200 m^2 for 0-250 m sets) but it must be recognized that any such a generalization was surrounded by considerable variation between years, between sets within a year and, indeed, between depths within a set.

If that initial estimate of the volumes filtered is used, tentatively and pending more thorough analyses of the available data on the trawling, it should be further understood that the uppermost portion of the water column was under-represented in the catches – firstly because the presence of the ship (with its noise and lights) will have led to some avoidance by the more active nektonic species, secondly because the net did not fish properly when hauled close to the ship (with the inward pull of the warps leading towards the gallows preventing the otter boards from spreading), but also because the middle portion of the "W" profiles of the sets in the 0–250 m stratum did not rise above 50 m depth, leaving those sets making only two passes through lesser depths, not the four assumed by the calculations. In 2007, all depths above the nominal stratum of each set were additionally under-represented because the tow profiles of that survey were steeper above those strata (Kenchington *et al.* 2009).

It should additionally be understood that these estimates concern only the volumes of water filtered. They make it possible to express the catches in terms of numbers or weight caught per unit volume or surface area but those figures differ from the densities of the biota by the inverse of the catchabilities of the various organisms in an IYGPT net. Not only are the catchabilities of many mesopelagic species in such a trawl expected to be very low but they will also be highly variable among species, among sizes of individuals within species and even between day and night fishing or between different depths. Hence, overall absolute biomass densities are likely to be higher (and perhaps very much higher) than densities expressed as catch per unit area, while the distribution of that biomass across species, size classes or trophic levels is almost certainly radically different from what the catch densities may suggest.

4.1.2 Diamond IX Performance

The Diamond IX proved workable aboard *Teleost*, despite its size, but shooting and recovering it was a slow, complex process. There were times when the IYGPT could have been fished but shooting and hauling the big net was deemed too dangerous for the deck crew, the large concrete weights on the lower wings being a particular concern. Worse, the Diamond IX caught little and only a minority of that catch reached the codend – most being hung up in the meshes, which necessitated prolonged picking of the net. It appeared that the angle of the water flow to the net's webbing was such that most mesopelagic species, with their limited swimming ability, tended to be swept through the meshes rather than herded towards the codend. Fish with elongated body forms were particularly vulnerable to being trapped against the knot in the trailing corner of the mesh opening as they passed through and such animals were taken in large, but unrepresentative, numbers.

Aside from an initial gear trial, only six sets were made with the big net and they did not follow any regular survey design (Table 8). No quantitative conclusions should be built from the catches recorded. For future reference, however, measured wingspread could exceed 40 m when the net was at depth but was generally less, since the inward pull of the warps constrained door spread (which could exceed 125 m) even when warp lengths reached 3000 m. Headline heights were up to 23 m.

AFTERWORD

This report will be followed in due course by one or more others presenting analyses of the data collected during the three surveys, aside from those on the IYGPT catches themselves. The background data comprise the net measurements, the Tucker Trawl and Diamond IX catches, measurements of physical and chemical conditions in the water column and of acoustic backscatter, marine mammal and seabird observations, and records of contaminants. In combination with the present report and that of Kenchington *et al.* (2009), they will provide a foundation for analyses of the IYGPT catches and studies based on the specimens taken.

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TABLES

Table 1 : Trawling Station Positions and Seabed Depths
The positions given define the nominal lines on which the trawling was undertaken, though the actual trawl tracks diverged somewhat. The positions are given as starting at the more southerly end of each line, though IYGPT sets were made in both directions. Latitudes and longitudes are presented in both decimal degrees and degrees plus decimal minutes. (In the case of any disagreements, the decimal degrees are definitive.) Depths are derived from multibeam bathymetric data, except for the Slope Station which has depths measured by echosounder.

STATION	START North Latitude	START West Longitude	START Depth (m)	END North Latitude	END West Longitude	END Depth (m)
Deep	43.7319°	58.7647°	2662	43.7675°	58.8453°	2576
	43° 43.91	58° 45.88		43° 46.05	58° 50.72	
Main	43.8470°	58.9156°	1966	43.9101°	58.9641°	1333
	43° 50.82	58° 54.94		43° 54.61	58° 57.85	
Wall	43.8832°	58.9040°	1257	43.9257°	58.9716°	1161
	43° 52.99	58° 54.24		43° 55.54	58° 58.30	
Head	44.0195°	59.0115°	1156	44.0730°	59.0678°	732
	44° 01.17	59° 00.69		44° 04.38	59° 04.07	
Slope	43.5000°	59.6667°	1370	43.5000°	59.5417°	1600
	43° 30.00	59° 40.00		43° 30.00	59° 32.50	
Offshore	43.3000°	59.0000°	2790	43.2300°	59.0000°	3000
	43° 18.0[5]	59° 00.00		43° 13.80	59° 00.00	

[5] This latitude was incorrectly stated by Kenchington *et al.* (2009).

Table 2 : 2008 List of Sets, with Set-Specific Details of Gear and of IYGPT-Catch Sampling
Dates given are those of the start of each set.

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
1	Deep	Night	750m IYGPT	30 Aug	Tow somewhat off track and profile somewhat non-standard
2	Deep	Day	750m IYGPT	30 Aug	Net torn on stern ramp when shot away. Aquarium hauled on its side
3	Deep	Day	Tucker Trawl	30 Aug	
4	Deep	Day	Tucker Trawl	30 Aug	
5	Deep	–	CTD	30 Aug	CTD data appear valid but only for downcast to 900 m depth
6	Deep	Night	1250m IYGPT	31 Aug	
7	Deep	Night	250m IYGPT	31 Aug	
8	Deep	Day	1250m IYGPT	31 Aug	
9	Deep	Day	250m IYGPT	31 Aug	**Aborted** – Main engine overheating
10	Deep	–	CTD	31 Aug	Some errors in CTD depth records in top 200 m of water column
11	Deep	Night	750m IYGPT	1 Sept	
12	Deep	Night	1250m IYGPT	1 Sept	Non-standard depth profile
13	Deep	Night	250m IYGPT	1 Sept	**Aborted** – Loose turns on winch
14	Main	Day	1250m IYGPT	1 Sept	
15	Main	Day	750m IYGPT	1 Sept	
16	Main	Day	Tucker Trawl	1 Sept	
17	Main	–	CTD	1 Sept	CTD depth records not useful. Star-Oddi depths substituted
18	Main	–	CTD	1 Sept	CTD depth records not useful
19	Main	Night	750m IYGPT	2 Sept	
20	Main	Night	1250m IYGPT	2 Sept	
21	Main	Night	250m IYGPT	2 Sept	
22	Main	Day	250m IYGPT	2 Sept	
23	Head	Day	750m IYGPT	2 Sept	
24	Head	Day	Tucker Trawl	2 Sept	
25	Head	–	CTD	2 Sept	CTD depth records not useful. Star-Oddi depths substituted
26	Head	Dusk	Tucker Trawl	2 Sept	
27	Head	Night	250m IYGPT	3 Sept	

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
28	Head	Night	750m IYGPT	3 Sept	
29	Head	Night	250m IYGPT	3 Sept	
30	Head	Night	750m IYGPT	3 Sept	**Aborted** – Scanmar depth readout lost
31	Head	Day	750m IYGPT	3 Sept	
32	Head	Day	250m IYGPT	3 Sept	
33	Main	Day	Tucker Trawl	3 Sept	
34	Main	Day	Tucker Trawl	3 Sept	
35	Main	Dusk	Tucker Trawl	3 Sept	
36	Main	Night	750m IYGPT	4 Sept	
37	Main	Night	1250m IYGPT	4 Sept	
38	Main	Night	250m IYGPT	4 Sept	
39	Main	Day	750m IYGPT	4 Sept	
40	Main	Day	Tucker Trawl	4 Sept	
41	Main	–	CTD	4 Sept	CTD depth records not useful. Star-Oddi depths substituted
42	Deep	Dusk	Tucker Trawl	4 Sept	
43	Deep	Night	750m IYGPT	5 Sept	
44	Deep	Night	250m IYGPT	5 Sept	
45	Main	Day	1250m IYGPT	5 Sept	**Aborted** – Scanmar readout lost
46	Deep	Day	750m IYGPT	5 Sept	
47	Deep	Day	250m IYGPT	5 Sept	
48	Deep	–	CTD	5 Sept	No data recorded by CTD
49	Deep	Night	1750m IYGPT	5 Sept	
50	Deep	Night	1250m IYGPT	6 Sept	**Aborted** – Pendant wire damaged
51	Deep	Night	1250m IYGPT	6 Sept	
52	Deep	Day	1250m IYGPT	6 Sept	
53	Main	Day	1250m IYGPT	6 Sept	Net not fully picked clean

Table 3 : 2008 Survey Design, showing IYGPT Sets Completed

Station	Time	Stratum	Set Numbers
Deep	Daylight	0–250 m	47
		250–750 m	2,46
		750–1250 m	8,52
		1250–1750 m	–
	Night	0–250 m	7,44
		250–750 m	1,11,43
		750–1250 m	6,51
		1250–1750 m	49
Main	Daylight	0–250 m	22
		250–750 m	15,39
		750–1250 m	14,53
	Night	0–250 m	21,38
		250–750 m	19,36
		750–1250 m	20,37
Head	Daylight	0–250 m	32
		250–750 m	23,31
	Night	0–250 m	27,29
		250–750 m	28

Table 4 : Summary of 2008 Trawling Data
For each IYGPT set, this table shows the times (in UTC, to nearest minute) of key events and the maximum length of warp veered from each drum of the trawl winch. The timed events are:

1: Release of the otter boards from the ship,
2: Net at upper depth of nominal stratum for the set,
3: Application of winch brakes after warp fully veered,
4: Net reached maximum depth and hauling commenced,
5: Net returned to upper depth of nominal stratum, and
6: Otter boards returned to ship.

"–" indicates missing data. Events not relevant to a particular set are shaded.
Data for "W"-profile sets are presented over two rows of the table, with the time of the net reaching the intermediate 50 m depth being shown in the 3rd column on the 2nd row.

Set	Time (UTC)						Maximum Warp Out (metres)
	Doors Away	Top of Stratum	Winch Stop	Start Haul	Top of Stratum	Doors Back	
1	0415	0440	0448	0512	0544	0601	1397
2	1047	1107	1116	1133	1203	1223	1600
6	0029	0108	–	0132	0208	0251	2500
7	0448		0502	0516			625
		0529	0538	0548		0604	625
8	1044	1121	1126	1148	1221	1307	2500
9	1411		1422	1429		–	650
11	0003	0017	0029	0045	0117	0134	1600
12	0229			0324		0431	2890
13	0519		0530	0539		0626	625
14	1033	–	1115	1136	–	1253	2500
15	1403	1419	1430	1444	1511	1524	1600
19	0021	0037	0047	0107	0139	0157	1600
20	0250	0340	0338	0409	0441	0517	2500
21	0634		0646	0654			625
		0706	0715	0721		0741	650
22	1040		1051	1058			650
		1114	1123	1130		1149	650
23	1308	1322	1336	1353	1425	1443	1600
27	0032		0044	0053			650
		0107	0115	0123		0144	650
28	0242	0301	0310	0333	0400	0416	1600
29	0453		0505	0511			650
		–	0534	0540		0558	650

Set	Time (UTC)						Maximum Warp Out (metres)
	Doors Away	Top of Stratum	Winch Stop	Start Haul	Top of Stratum	Doors Back	
31	1032	1047	1100	1113	1145	1202	1600
32	1255		1306	1312			650
		1328	1336	1342		1400	650
36	0022	0037	0049	0108	0139	0157	1600
37	0327	0407	0409	0440	0509	0538	2500
38	0708		0720	0725			650
		0737	0746	0753		0808	650
39	1127	1142	1154	1211	1245	1300	1600
43	0020	–	0048	0103	–	0153	1600
44	0255		0307	0315			650
		0325	0335	0342		0357	650
46	1141	1157	1210	1228	1300	1315	1600
47	1359		1411	1417			650
		1433	1442	1447		1502	650
49	2341	–	0037	0100	–	0250	3200
51	0408	0445	0447	0517	0539	0612	2500
52	1008	1047	1050	1119	1149	1223	2500
53	1321	1401	1406	1431	1502	1530	2500

Table 5 : 2009 List of Sets, with Set-Specific Details of Gear and of IYGPT-Catch Sampling
Dates given are those of the start of each set.

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
1	Slope	Day	750m IYGPT	13 Aug	
2	Slope	Day	CTD	13 Aug	
3	Slope	Day	750m IYGPT	13 Aug	
4	Deep	Night	1750m IYGPT	14 Aug	
5	Deep	Night	750m IYGPT	14 Aug	
6	Deep	Day	1250m IYGPT	14 Aug	
7	Deep	–	CTD	14 Aug	Southeast end of Deep Station
8	Deep	–	CTD	14 Aug	Centre of Deep Station
9	Deep	–	CTD	14 Aug	Northwest end of Deep Station
10	Deep	Night	250m IYGPT	15 Aug	
11	Deep	Night	1250m IYGPT	15 Aug	
12	Deep	Night	750m IYGPT	15 Aug	
13	Deep	Day	250m IYGPT	15 Aug	
14	Deep	–	CTD	15 Aug	Southeast end of Deep Station
15	Deep	–	CTD	15 Aug	Centre of Deep Station
16	Deep	–	CTD	15 Aug	Northwest end of Deep Station
17	Main	Night	250m IYGPT	16 Aug	
18	Main	Night	750m IYGPT	16 Aug	
19	Main	Night	1250m IYGPT	16 Aug	
20	Deep	Day	1250m IYGPT	16 Aug	
21	Deep	–	CTD	16 Aug	Northwest end of Deep Station
22	–	–	CTD	16 Aug	Southwest of Southwest Prong
23	Main	–	CTD	16 Aug	South end of Main Station
24	Main	–	CTD	16 Aug	Middle of Main Station
25	Main	Night	250m IYGPT	17 Aug	
26	Deep	Night	1250m IYGPT	17 Aug	

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
27	Main	Night	750m IYGPT	17 Aug	
28	–	–	CTD	17 Aug	Southeast of Southwest Prong
29	–	–	CTD	17 Aug	Northwest of Southwest Prong
30	–	–	CTD	17 Aug	Over Southwest Prong
31	Main	Day	750m IYGPT	17 Aug	
32	Deep	Night	1750m IYGPT	18 Aug	
33	Wall	Night	250m IYGPT	18 Aug	
34	Main	Day	250m IYGPT	18 Aug	Tow profile erratic
35	Main	Day	750m IYGPT	18 Aug	
36	Main	–	CTD	18 Aug	South end of Main Station
37	–	–	CTD	18 Aug	AZMP Station GULD4: 43.8095 N 58.9095 W
38	Deep	Dusk	IYGPT	18 Aug	Longer tow with maximum 3650 m warp out
39	Main	Night	1250m IYGPT	19 Aug	
40	Main	Day	750m IYGPT	19 Aug	
41	Wall	Day	750m IYGPT	19 Aug	
42	Main	–	CTD	19 Aug	South end of Main Station
43	Deep	Dusk	IYGPT	19 Aug	Prolonged tow with maximum 3767 m warp out
44	Wall	Night	750m IYGPT	20 Aug	
45	Wall	Night	750m IYGPT	20 Aug	
46	Main	Day	1250m IYGPT	20 Aug	
47	Main	–	CTD	20 Aug	South end of Main Station
48	–	–	CTD	20 Aug	AZMP Station GULD3: 44.0222 N 59.0396 W
49	Head	–	CTD	20 Aug	Centre of Head Station
50	Head	–	CTD	20 Aug	South end of Head Station
51	Head	–	CTD	20 Aug	North end of Head Station
52	Head	Night	250m IYGPT	21 Aug	
53	Head	Night	750m IYGPT	21 Aug	**Aborted** – Scanmar depth readout lost
54	Head	Night	750m IYGPT	21 Aug	
55	Head	Night	250m IYGPT	21 Aug	

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
56	Head	Day	750m IYGPT	21 Aug	
57	Head	Day	250m IYGPT	21 Aug	
58	Head	Day	750m IYGPT	21 Aug	
59	Head	–	CTD	21 Aug	South end of Head Station

Table 6 : 2009 Survey Design, showing IYGPT Sets Completed

Station	Time	Stratum	Set Numbers
Deep	Daylight	0–250 m	13
		250–750 m	–
		750–1250 m	6,20
		1250–1750 m	–
	Night	0–250 m	10
		250–750 m	5,12
		750–1250 m	11,26
		1250–1750 m	4,32
Main	Daylight	0–250 m	34
		250–750 m	31,35,40
		750–1250 m	46
	Night	0–250 m	17,25
		250–750 m	18,27
		750–1250 m	19,39
Wall	Daylight	0–250 m	–
		250–750 m	41
	Night	0–250 m	33
		250–750 m	44,45
Head	Daylight	0–250 m	57
		250–750 m	56,58
	Night	0–250 m	52,55
		250–750 m	54
Slope	Day	250–750 m	1,3

Table 7 : Summary of 2009 Trawling Data
For each IYGPT set, this table shows the times (in UTC, to nearest minute) of key events and the maximum length of warp veered from each drum of the trawl winch. The timed events are:

1: Release of the otter boards from the ship,
2: Net at upper depth of nominal stratum for the set,
3: Application of winch brakes after warp fully veered,
4: Hauling commenced, net sometimes continues sinking,
5: Net returned to upper depth of nominal stratum, and
6: Otter boards returned to ship.

"–" indicates missing data. Events not relevant to a particular set are shaded.
Data for "W"-profile sets are presented over two rows of the table, with the time of the net reaching the intermediate 50 m depth being shown in the 3rd column on the 2nd row.

	Time (UTC)						
Set	**Doors Away**	**Top of Stratum**	**Winch Stop**	**Start Haul**	**Top of Stratum**	**Doors Back**	**Maximum Warp Out (metres)**
1	1300	1316	1327	1402	1426	1440	1600
3	1916	1938	1947	1957	2037	2056	1800
4	0058	0149	0205	0214	–	0402	3400
5	0548	0607	0617	0638	0700	0728	1600
6	1026	1100	1110	1132	1203	1253	2500
10	0022		0035	0036			700
		0053	0102	0103		0127	700
11	0236	0311	0318	0334	0404	0457	2500
12	0603	0616	0631	0641	0720	0737	1600
13	1251		1302	1309			650
		1322	1327	1334		1352	650
17	0021		0032	0035			650
		0050	0058	0100		0122	650
18	0210	0232	0237	0244	0321	0342	1600
19	0452	0523	0541	0542	0618	0657	2500
20	1019	1051	1111	1121	1155	1305	2500
25	0013		0025	0025			650
		0040	0049	0049		0111	650
26	0224	0254	0309	0316	0349	0441	2500
27	0637	0651	0706	0710	0749	0811	1600
31	2009	2020	2037	2037	2115	2129	1600
32	0024	0111	0126	0134	0213	0338	3400
33	0618		0631	0636			650
		0654	0704	0704		0724	650

	Time (UTC)						
Set	**Doors Away**	**Top of Stratum**	**Winch Stop**	**Start Haul**	**Top of Stratum**	**Doors Back**	**Maximum Warp Out (metres)**
34	1019		1031	1032			570
		1051	1103	–		1126	650
35	1222	1237	1250	1301	1339	1407	1600
38	2203	2256	2305	2315	2354	0111	3650
39	0312	0344	0405	0412	0444	0550	2500
40	1034	1047	1102	1114	1149	1210	1600
41	1348	1402	1415	1425	1458	1517	1600
43	2031	–	2140	2244	–	0035	3767
44	0243	0258	0312	0318	0355	0413	1600
45	0617	0632	0648	0653	0731	0749	1600
46	1006	1040	1049	–	1137	1245	2500
52	0021		0038	0038			650
		0054	0103	0108		0125	650
54	0314	0330	0345	0349	0428	0449	1600
55	0538		0550	0552			650
		0612	0621	0622		0642	650
56	1007	1019	1033	1038	1120	1138	1600
57	1213		1226	1228			650
		1243	1252	1256		1315	650
58	1351	1406	1418	1432	1505	1524	1600

Table 8 : 2010 List of Sets, with Set-Specific Details of Gear and of IYGPT-Catch Sampling
Dates given are those of the start of each set.

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
1	Slope	Day	CTD	15 Mar	
2	Slope	Day	750m IYGPT	15 Mar	Doors crossed at end of haulback
3	Slope	Day	750m IYGPT	15 Mar	**Aborted**: No Scanmar data
4	Deep	Night	250m IYGPT	16 Mar	
5	Deep	Night	750m IYGPT	16 Mar	
6	Deep	Night	250m IYGPT	16 Mar	Tow profile very irregular: **Use caution when analyzing data**
7	–	–	–	16 Mar	Deployment of acoustic recorder
8	Main	Day	750m IYGPT	16 Mar	
9	Main	Day	250m IYGPT	16 Mar	
10	Main	Day	750m IYGPT	16 Mar	
11	Deep	Night	1250m IYGPT	16 Mar	
12	Deep	Night	750m IYGPT	17 Mar	**Aborted**: Spooling gear failure
13	–	Day	–	17 Mar	Trial deployment of IYGPT to test repaired winch
14	Main	Day	1250m IYGPT	17 Mar	
15	Main	Day	CTD	17 Mar	
16	Deep	Night	750m IYGPT	17 Mar	
17	Deep	Night	250m IYGPT	18 Mar	
18	Deep	Night	1250m IYGPT	18 Mar	
19	Deep	Day	CTD	18 Mar	
20		Day	CTD	18 Mar	AZMP Station GULD4: 43.8095 N 58.9095 W
21	Main	Day	1250m IYGPT	18 Mar	
22	Head	Day	250m IYGPT	18 Mar	Deficiencies with Scanmar records
23	Main	Night	250m IYGPT	18 Mar	
24	Main	Night	750m IYGPT	19 Mar	Net behaved badly during haul back
25	Main	Night	1250m IYGPT	19 Mar	
26	Main	Day	CTD	19 Mar	
27	Head	Day	CTD	19 Mar	

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
28	Head	Day	750m IYGPT	19 Mar	**Aborted**: Scanmar depth sensor failed
29	Head	Day	750m IYGPT	19 Mar	
30	Head	Day	750m IYGPT	19 Mar	
31	Main	Night	750m IYGPT	19 Mar	
32	Main	Night	250m IYGPT	20 Mar	
33	Main	Night	1250m IYGPT	20 Mar	
34	Main	Day	CTD	20 Mar	
35	Deep	Day	IYGPT	20 Mar	Spooling gear failed. Set extended into an extra-deep, long tow
36	Head	Night	750m IYGPT	20 Mar	
37	Head	Night	250m IYGPT	21 Mar	Net and Scanmar performed badly: **Do not use data**
38	Head	Night	750m IYGPT	21 Mar	**Aborted**: Commercial fishing vessel in ship's track
39	Head	Night	250m IYGPT	21 Mar	Net performed badly at 185m depth when first shot away
40	Head	Night	750m IYGPT	21 Mar	
41	Head	Day	CTD	21 Mar	
42		Day	CTD	21 Mar	AZMP Station GULD3: 44.0222 N 59.0396 W
43	Deep	Day	1750m IYGPT	21 Mar	
44	Deep	Day	750m IYGPT	21 Mar	
45	Deep	Night	1750m IYGPT	21 Mar	
46	Head	Night	250m IYGPT	22 Mar	
47	Deep	Day	CTD	22 Mar	
48		Day	CTD	22 Mar	AZMP Station SG 23: 43.8687 N 58.7381 W
49		Day	CTD	22 Mar	AZMP Station SG 28: 43.7114 N 59.0119 W
50	Deep	Day	1750m IYGPT	22 Mar	
51	Deep	Night	1750m IYGPT	22 Mar	
52	Outside MPA	–	–	23 Mar	Gear Trial with Diamond IX net
53	Deep	Day	Diamond IX	23 Mar	196 minutes (doors away to doors back), max. depth 1,589 m[6]
54	Main	–	Diamond IX	23 Mar	202 minutes (doors away to doors back), max. depth 1,285 m

[6] Maximum depths of Diamond IX sets were taken from the Seabird SBE39 headline recorder.

Set	Station	Light	Set Type	Date	Set-Specific Details and Deviations from Standard Protocols
55	Main	Day	Diamond IX	24 Mar	142 minutes (doors away to doors back), max. depth 1,337 m
56	Deep	Day	Diamond IX	24 Mar	133 minutes (doors away to doors back), max. depth 1,435 m
57	Head	–	Diamond IX	24 Mar	118 minutes (doors away to doors back), max. depth 458 m
58	Offshore	Day	CTD	25 Mar	
59	Offshore	Night	Diamond IX	26 Mar	179 minutes (doors away to doors back), max. depth 1,657 m
60	–	–	–	26 Mar	Recovery of acoustic recorder

Table 9 : 2010 Survey Design, showing IYGPT sets completed

Station	Time	Stratum	Set Numbers
Deep	Daylight	0–250 m	–
		250–750 m	44
		750–1250 m	–
		1250–1750 m	43,50
	Night	0–250 m	4,17
		250–750 m	5,16
		750–1250 m	11,18
		1250–1750 m	45,51
Main	Daylight	0–250 m	9
		250–750 m	8,10
		750–1250 m	14,21
	Night	0–250 m	23,32
		250–750 m	24,31
		750–1250 m	25,33
Head	Daylight	0–250 m	22
		250–750 m	29,30
	Night	0–250 m	39,46
		250–750 m	36,40
Slope	Daylight	250–750 m	2

Table 10 : Summary of 2010 Trawling Data

For each IYGPT or Diamond IX set, this table shows the times (in UTC, to nearest minute) of key events, the maximum net depth achieved and the maximum length of warp paid out off each drum of the trawl winch. The timed events are:

1: Release of the otter boards from the ship,
2: Net at upper depth of nominal stratum for the set (50 m for 0–250 m sets),
3: Application of winch brakes after warp fully played out,
4: Hauling commenced,
5: Net returned to upper depth of nominal stratum (50 m for 0–250 m sets), and
6: Otter boards returned to ship.

"–" indicates missing data. Events not relevant to a particular set are shaded.
Data for "W"-profile sets are presented over two rows of the table.

	Time (UTC)							
Set	**Doors Away**	**Top of Stratum**	**Winch Stop**	**Start Haul**	**Top of Stratum**	**Doors Back**	**Max. Depth (m)**	**Max. Warp (m)**
2	1529	1546	1559	1614	1650	1745	765	1950
4	0014	0019	0025	0025	0040		170	650
		0040	0058	0058	0113	0120	250	730
5	0225	0239	0256	0357	–	0402	728	2025
6	0548	–	0558	0558	0611		289	–
		0611	–	0623	–	0634	245	–
8	1521	1535	1556	1556	1628	1654	757	1950
9	1752	–	1805	1808	1821		245	755
		1821	1835	1835	–	1853	253	755
10	1940	1955	–	–	2046	2104	770	1950
11	2334	0013	0034	–	0113	0204	1252	3200
12	0304	0319	–	–	0413	–	736	–
14	1551	1626	1641	1649	1721	1812	1235	3200
16	2327	2340	2357	2359	0034	0105	746	1950
17	0155	0158	0205	0205	0221		208	650
		0221	–	0234	–	0255	–	700
18	0334	0405	0423	0423	0457	0544	1265	2900
21	1512	1549	1601	1613	1642	1754	1245	2900
22	1923	1928	1941	1941	1950		245	750
		1951	1957	1957	–	2029	245	–
23	2332	2335	2345	2347	0000		251	750
		0001	0009	0010	0026	0033	260	800
24	0114	–	–	0143	–	0240	751	–

Set	Time (UTC)						Max. Depth (m)	Max. Warp (m)
	Doors Away	Top of Stratum	Winch Stop	Start Haul	Top of Stratum	Doors Back		
25	0331	0406	0425	0431	0456	0604	1247	3000
29	1558	1613	1638	1641	1709	1735	753	2050
30	1823	1840	–	1904	1936	1957	752	–
31	2315	2329	2347	2347	0026	0055	763	1810
32	0141	0145	0152	0152	0209		264	700
		0209	0216	0218	0237	0247	257	700
33	0325	0400	0413	0420	0444	0525	1249	3000
35	1323	1413	–	1610	1648	1803	>1960	3760
36	2324	2336	2355	2359	0030	0051	764	2000
37	0127	0130	0134	0143	0155		239	665
		0155	0204	0205	–	0224	–	800
39	0438	0444	0451	0457	0509		236	750
		0509	0522	0522	–	0544	253	–
40	0618	0633	–	0651	0719	0735	741	–
43	1538	1625	–	1641	1701	1806	1740	3450
44	1854	1911	1929	1930	2004	2028	742	1735
45	2310	0014	–	0044	0113	0229	–	3450
46	0500	0507	0522	0522	0538		245	650
		0538	0551	0551	0607	0612	256	–
50	1544	1709	1738	–	1809	1922	1752	3200
51	2317	0039	0107	0113	0137	0253	1747	3500
53	1410		1525	1600		1731	>1507	3600
54	2102		2154	2210		2324	>1294	3250
55	1156		1246	1310		1418	≈1150	3240
56	1647		1743	1805		1900	>1267	3600
57	2159		–	2322		2357	≈450	–
59	0149		–	0355		0448	–	3600

Table 11 : Summary of Tucker Trawl Sets

Set	Start Latitude	Start Longitude	End Latitude	End Longitude	Start Time	Start Haul Time	End Time	Maximum Depth
3	43° 43.1' N	58° 43.4' W	43° 43.9' N	58° 45.6' W	1600	1617	1640	774
4	43° 44.2' N	58° 45.6' W	43° 45.1' N	58° 48.2' W	1705	1720	1741	744
16	43° 50.7' N	58° 54.9' W	43° 53.1' N	58° 55.6' W	1557	1614	1645	461
24	44° 03.7' N	59° 03.4' W	44° 02.2' N	59° 02.8' W	1630	1646	1706	874
26	44° 03.5' N	59° 03.3' W	44° 01.9' N	59° 02.7' W	2138	2153	2215	818
33	43° 50.3' N	58° 54.6' W	43° 49.1' N	58° 55.7' W	1712	1725	1746	746
34	43° 49.1' N	58° 56.0' W	43° 50.7' N	58° 55.1' W	1841	1855	1912	490
35	43° 51.4' N	58° 54.0' W	43° 50.0' N	58° 54.9' W	2238	2252	2312	811
40	43° 50.2' N	58° 53.6' W	43° 49.5' N	58° 54.4' W	1605	1618	1634	916
42	43° 41.6' N	58° 41.4' W	43° 40.9' N	58° 40.5' W	2233	2246	2302	781

FIGURES

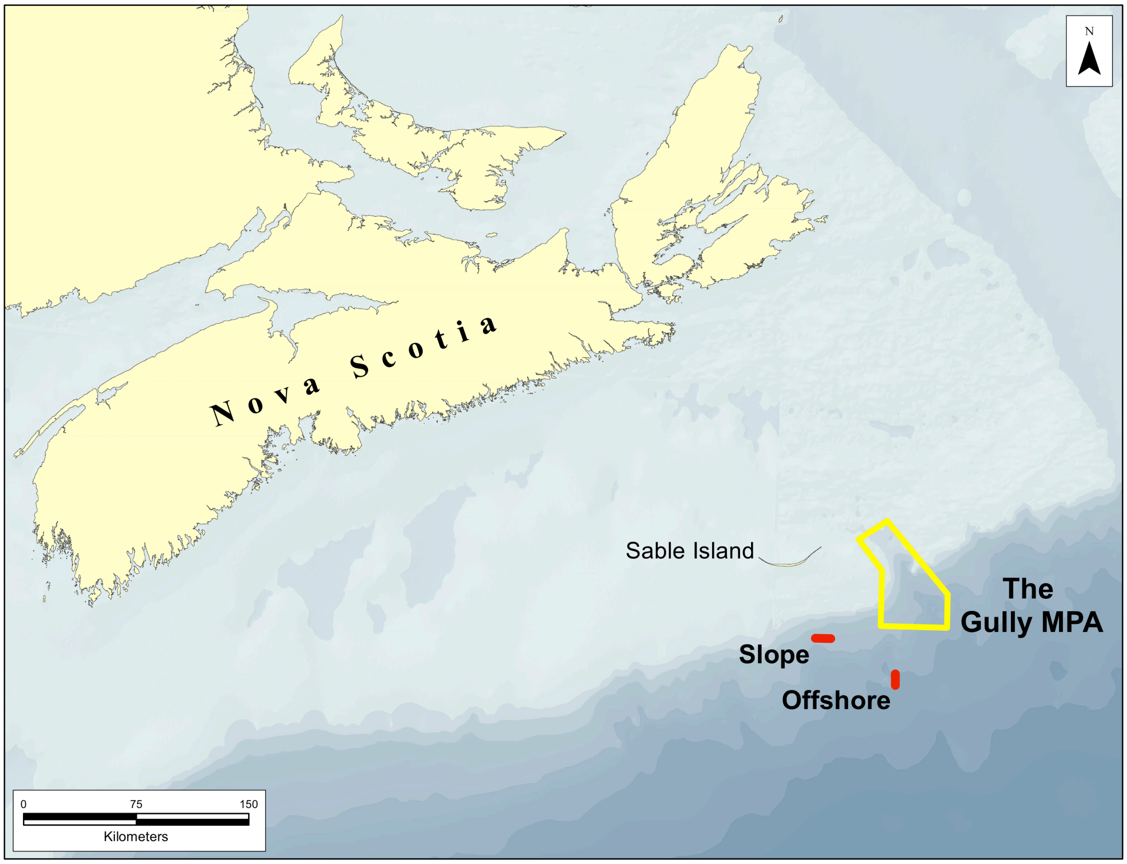


Figure 1 : Location of The Gully and those of the Offshore and Slope stations

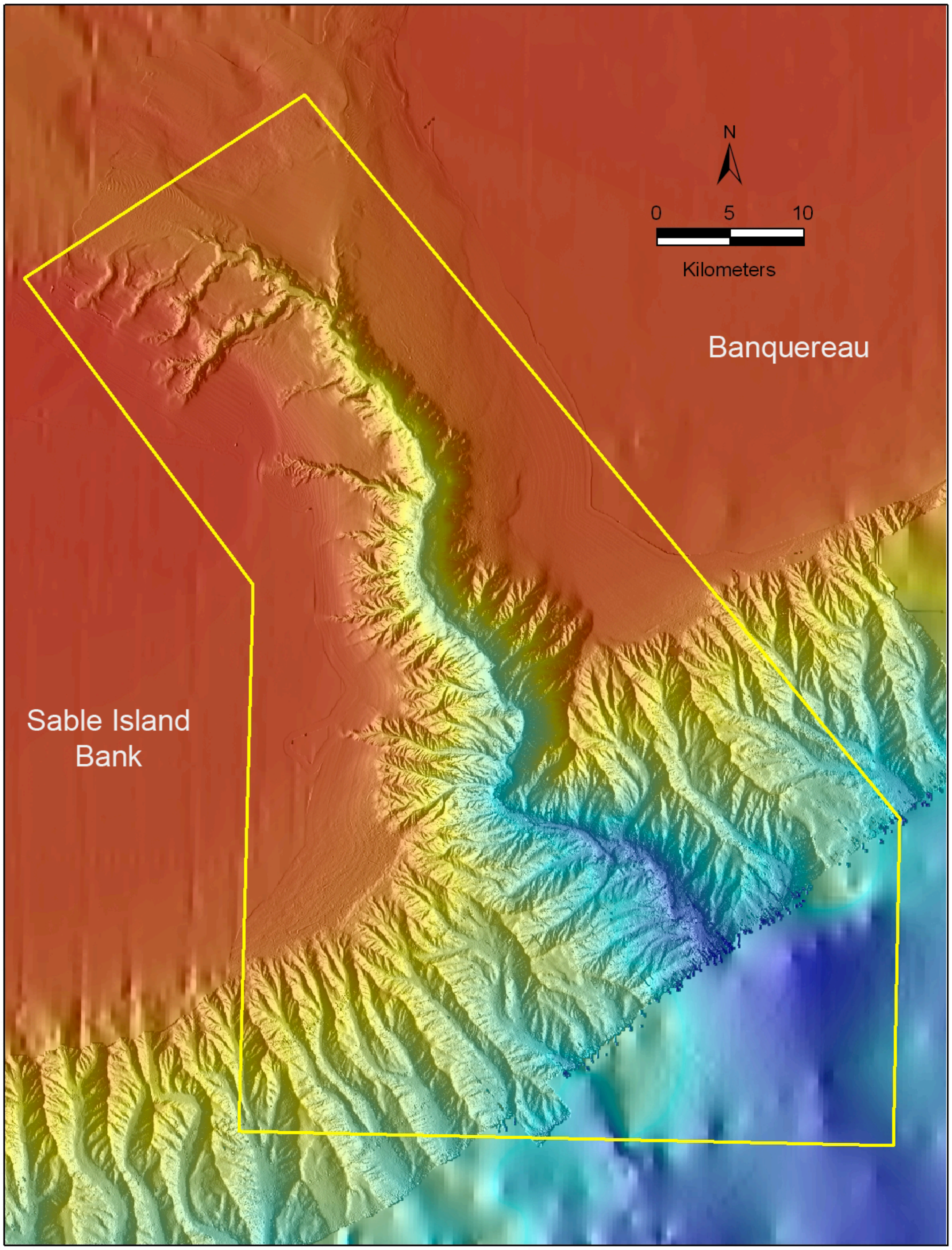


Figure 2 : Bathymetry of The Gully
Boundaries of the Marine Protected Area are shown. Note that the bathymetry of the deeper waters to the southeast has not been surveyed to the same accuracy

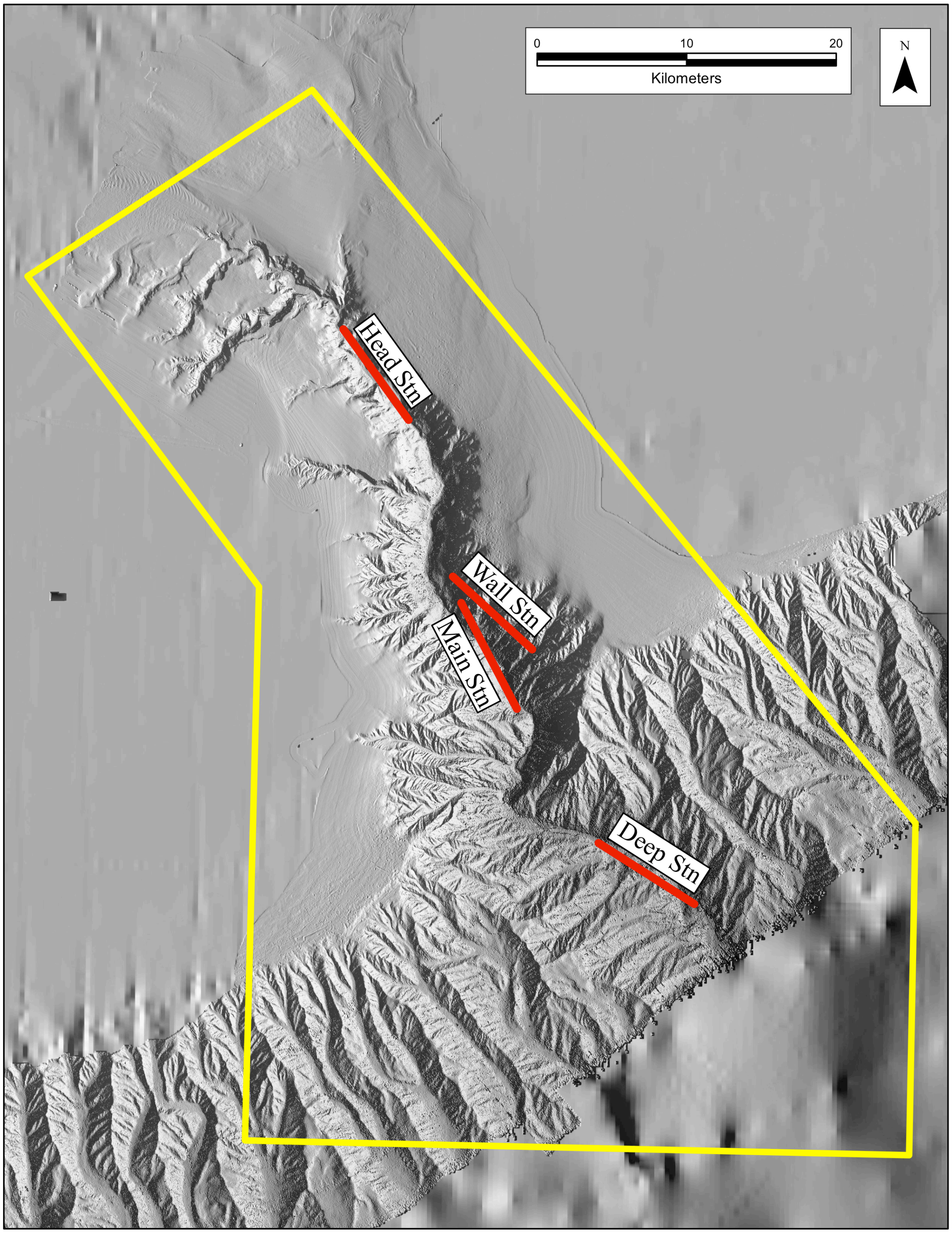


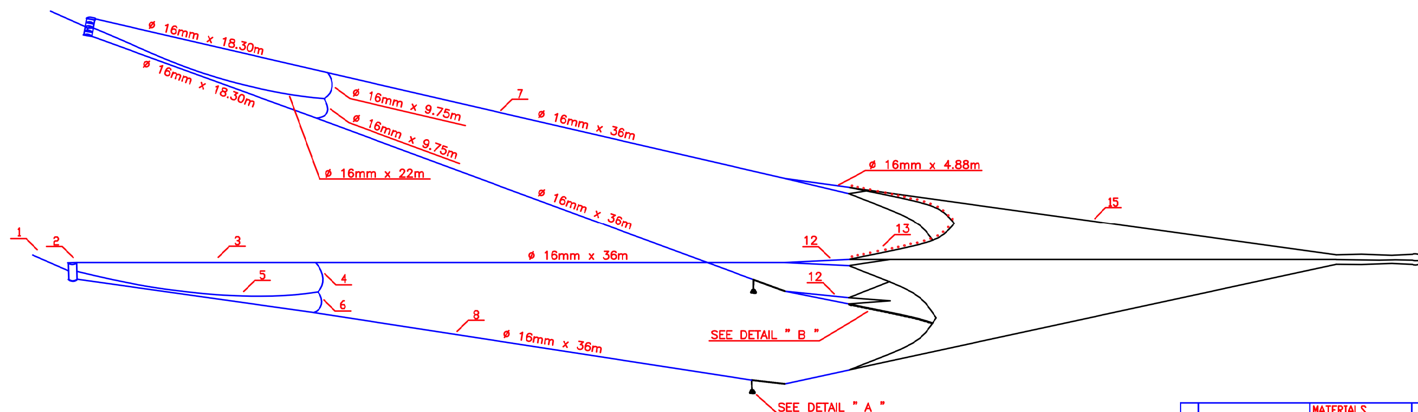
Figure 3 : Locations of the named trawling stations within the Marine Protected Area that were worked during the 2008 to 2010 surveys

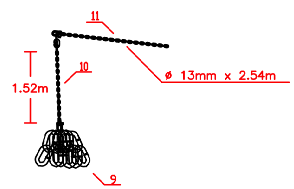
APPENDIX I

DESIGN AND SPECIFICATIONS OF THE INTERNATIONAL YOUNG GADOID PELAGIC TRAWL (IYGPT)

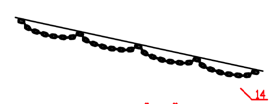
These are the specifications for a standard IYGPT net, as used during the 2008 survey. The net used subsequently was designed for mesopelagic sampling. It had knotless mesh for the lengthening piece and codend, while being coloured dark green throughout.

Extracted from a set of drawings prepared by the Marine Institute for Fisheries and Oceans Canada





DETAIL " A "



DETAIL " B "

#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Warp	Wire 6 x 19	2	1	IY01
2	4.0 sqm Trawl Doors	431 Kg Suberkrub	2	1	IY02
3	Door Legs	Wire 6 x 19	4	1	IY03
4	Upper Pennant	Wire 6 x 19	2	1	IY04
5	Middle Pennant	Wire 6 x 19	2	1	IY05
6	Lower Pennant	Wire 6 x 19	2	1	IY06
7	Upper Bridle	Wire 6 x 19	2	1	IY07
8	Lower Bridle	Wire 6 x 19	2	1	IY08
9	Wingend Weight	Chain 60 KG	2	1	IY09
10	Weight Dropchain	Chain 13mm ø	2	1	IY10
11	Setback	Chain 13mm ø	2	1	IY11
12	Wing Bridles	Wire 6 x 19	8	1	IY12
13	Floats (203mm) Pl.	(2x20) + 10	50	1	IY13
14	Footrope Chain	Chain 13mm ø	23.20m	1&7	IY14
15	Trawl Body	PA Netting		1	

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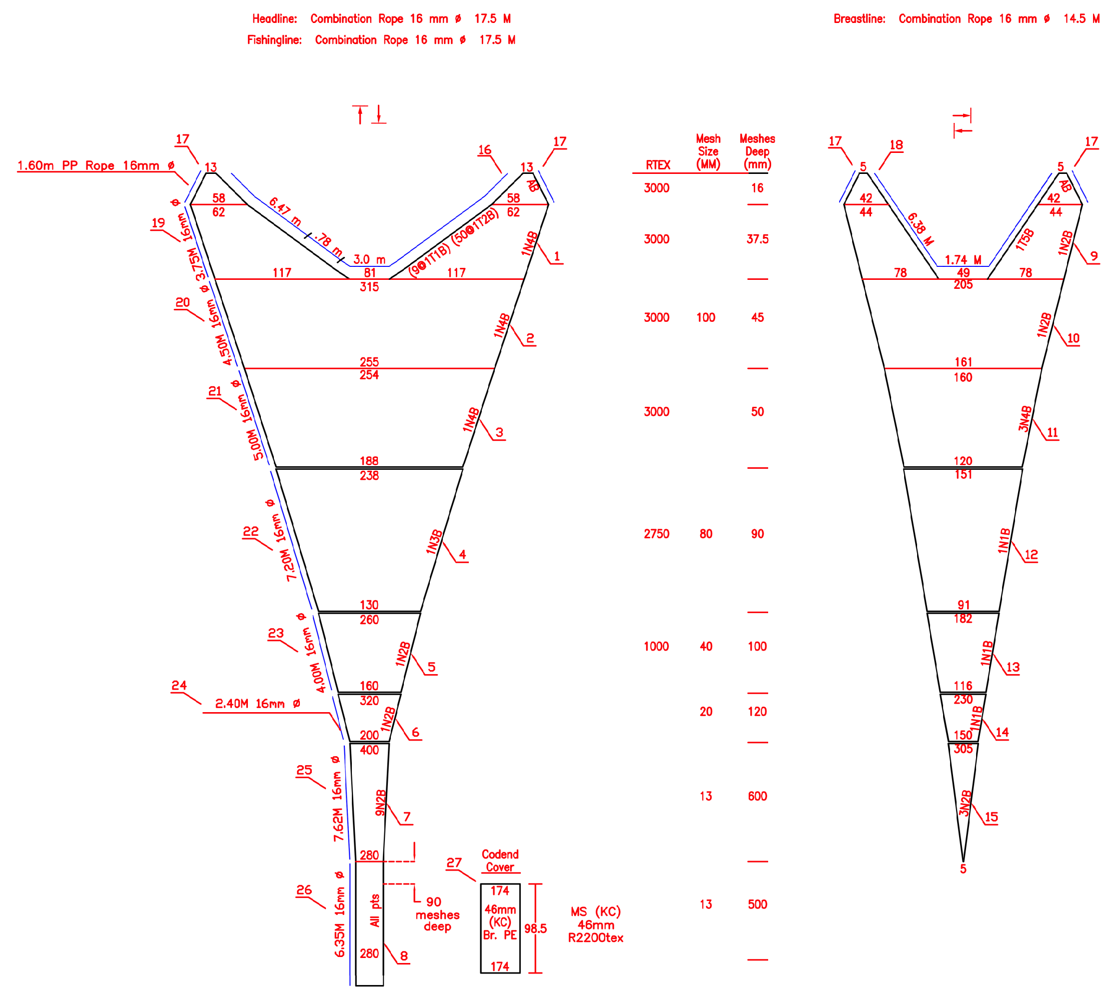
IYGPT SURVEY TRAWL

RIGGING PROFILE

DATE DRAWN:	DWG NO.:		REV.	SCALE:
24/03/95	IYG*1.0	PG 1 OF 7 PG		NTS

DRAWN BY:

MARINE INSTITUTE
FISHING TECHNOLOGY UNIT
ST.JOHN'S NEWFOUNDLAND



#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Upper & Lower Wings	PA Netting	4	2,3	IY15
2	1st Upper & Lower Belly	PA Netting	2	2	IY16
3	2nd Upper & Lower Belly	PA Netting	2	2	IY17
4	3rd Upper & Lower Belly	PA Netting	2	2	IY18
5	4th Upper & Lower Belly	PA Netting	2	2	IY19
6	5th Upper & Lower Belly	PA Netting	2	2	IY20
7	Upper & Lower Extension	PA Netting	2	2	IY21
8	Cod End	PA Netting	2	2	IY22
9	Side Wings	PA Netting	4	2,4	IY23
10	1st Side Belly	PA Netting	2	2	IY24
11	2nd Side Belly	PA Netting	2	2	IY25
12	3rd Side Belly	PA Netting	2	2	IY26
13	4th Side Belly	PA Netting	2	2	IY27
14	5th Side Belly	PA Netting	2	2	IY28
15	Side Extension	PA Netting	2	2	IY29
16	Headline and Fishingline	Comb. Rope	2	2,5,7	IY30
17	Wingline	TW. P.P. Rope	8	2	IY31
18	Breastline	Comb. Rope	2	2,6	IY32
19	Wing Ribline	P.P. Rope	4	2	IY33
20	1st Belly Ribline	P.P. Rope	4	2	IY34
21	2nd Belly Ribline	P.P. Rope	4	2	IY35
22	3rd Belly Ribline	P.P. Rope	4	2	IY36
23	4th Belly Ribline	P.P. Rope	4	2	IY37
24	5th Belly Ribline	P.P. Rope	4	2	IY38
25	Extension Ribline	P.P. Rope	4	2	IY39
26	Codend Ribline	P.P. Rope	2	2	IY40
27	Codend Cover	P.E. Netting	1	2	IY41

REMARKS

- PANEL DEPTH DOES NOT INCLUDE JOINING ROUNDS
- PANEL WIDTHS INCLUDE SELVEDGE MESHES
- MESH SIZES ARE KNOT CENTER MEASUREMENTS

DOUBLE NETTING
JOINING ROUND
SINGLE NETTING
FRAMELINE & RIBLINE
UPPER & LOWER PANELS
SIDE PANELS
DOUBLE MESH
DIAMETER
MS MESH SIZE
MD MESHES DEEP
PE POLYETHYLENE
PP POLYPROPYLENE
PA POLYAMIDE (NYLON)

DENIER	RTEX	DIAMETER
210/108	3000	2.80
210/96	2750	2.50
210/36	1000	1.90
	2200	2.00

FISHERIES and OCEANS   PECHES et OCEANS

IYGPT SURVEY TRAWL

NET PLAN

DATE DRAWN: 24/03/95 | DWG NO.: IYG*2.0 | PG 2 OF 7 PG | REV. | SCALE: NTS

DRAWN BY: MARINE INSTITUTE
FISHING TECHNOLOGY UNIT
ST.JOHN'S NEWFOUNDLAND

APPENDIX II

DESIGN OF THE “AQUARIUM” CODEND

Rigid “aquarium” codends for trawl nets appear to have first been used with surface trawls to catch live and undamaged salmonids for tagging (e.g. Holst and McDonald 2000; Lacroix and Knox 2005; Sheehan *et al.* 2011). A variety of designs have been developed for that purpose, at least one of which has subsequently been used in sub-surface midwater trawling to catch herring, also for tagging (Kanwit and Libby 2009), as well as in mesopelagic sampling (Dr. M. Fogarty, North East Fisheries Science Centre, Woods Hole, *pers.comm.*). Meanwhile, a distinct design was developed in Norway specifically for the latter purpose (Dr. O.-A. Bergstad, Institute of Marine Research, Flødevigen, *pers.comm.*). For the 2007 survey of The Gully, an old “aquarium” codend, originally constructed for a salmonid-tagging program, was modified for use at depth and deployed on a few trial sets (Kenchington *et al.* 2009). While that prototype proved useful, further improvement seemed possible and so a new unit was designed by three of the authors (TK, GM & SR), specifically for mesopelagic sampling. It was constructed in 2008 and used on all IYGPT and Diamond IX sets during the four surveys reported here. This Appendix outlines the design of that “aquarium” and explains the rationale behind it.

All “aquarium” codends are essentially rigid tanks, into which the catch is guided after passing through the tube formed by the trawl’s mesh codend. The tanks are typically fitted with some form of baffle that isolates the catch from the flow of water through the gear, while they provide for both the escape of that water and the retention of the catch. The particular requirements of the 2008 design were: that the tank should hold catches from the longest trawl sets made by this program without undue crowding; that the size and weight of the water-filled “aquarium” should neither distort the IYGPT net when fishing nor be difficult or dangerous to handle on deck; that the baffles and mesh should cause the least possible damage to any catch which contacted them; that the “aquarium” should ride up the trawler’s stern ramp as the net was hauled aboard, without damage and in the worst sea states in which the program’s fishing could continue; that the catch in the tank should be readily accessible from above, so that specimens could be bailed out without further damage; and that clearing, cleaning and re-assembling the equipment after each set should not be unduly onerous. Information for design guidance was available from the 2007 trials, a trio of prototype “aquaria” built for salmonid tagging in Atlantic Canadian waters and images of the units used in midwater trawling by research institutes in New England and in Norway.

The 2008 design took the form of a rectangular, open-topped tank, of 1.83 m length, 0.53 m width and 0.91 m height, made from grade 6061 aluminium (Figure II–1). The front face was sloped, to allow it to ride up onto the stern ramp, while the base was fitted with runners of ultra-high molecular weight plastic, in aluminium channels, to reduce friction. It would be ideal for the catch to pass into the “aquarium” unhindered but that would require the connection between the rigid and mesh codends to be placed above the rim of the tank and hence the “aquarium” would be pulled through the water from points displaced from its centre of drag. Worse, the tank would encounter the stern ramp while hanging below the meshes that transmit the force of the winches, with a risk that the “aquarium” would not ride up onto the ramp. Thus, the entry to the “aquarium” was placed at the mid-height of its forward end. That entry led directly to a smoothly-contoured ramp which lifted the catch, and the flow of water through the net, above the rim of the tank. Directly above the ramp, the body of the “aquarium” was shaped into a forward cowl. Internally, that mirrored the curves of the ramp, thus maintaining the cross-sectional area available for water flow within the unit and so preventing a pressure wave from forming. Externally, the cowl provided a robust structure where the net was attached, while there was a small free-flooding space between the inner and outer surfaces. The rear end of the “aquarium” had a second and smaller cowl.

In use, the open top of the tank was closed by a cover which incorporated a flat, aluminium deck (extending back from the top of the ramp and forming a lid to the tank) and a large area of mesh to discharge the water flowing in from the net, the mesh extending from forward to rear cowls. The mesh combined an outer aluminium layer for rigidity and an inner textile lining for fine filtration – the later made from the same material as the liner of the net’s codend. The extent of the filtering area was substantially larger than the cross-sectional area of the entry point, thus reducing water-flow velocities through the meshes, minimizing trapping of catch against that surface. The aluminium deck ended by the rear cowl, leaving a slot through which the catch could drop into the tank, the cowl being shaped to smoothly guide animals into the latter, after they had passed between the cover’s deck and its mesh top. The cover was held in place by clips, that were in turn secured by locking pins, but it could be swiftly released and removed to give unfettered access to the catch in the tank.

All internal surfaces of the “aquarium”, including its cover, were made as smooth and gently contoured as could be achieved, to minimize damage to specimens that struck metal *en route* to the tank (Figure II–2).

The “aquarium” was fitted with external lugs that allowed towing, lifting and the securing of sufficient trawl floats to provide the unit with neutral buoyancy. The rear wall of the tank had a drain, to facilitate emptying and cleaning the equipment, though the great majority of the catch was bailed out of the open top of the tank. Near its forward end, each side wall had an array of small holes (smaller than the pore size of the mesh top), covered by a cowling which opened to the rear – the combination being intended to encourage a slow water flow through the tank, from the rear slot forwards, thus maintaining the catch in oxygenated water.

The entry point was surrounded by a flange, around which the net’s mesh codend was clamped, using a standard cargo strap. As built in 2008, the entry was rectangular, simply for practicality of construction (Figure II–1). Thus configured, the cargo strap did not exert sufficient inward force along the straight edges of the rectangle and water flow caused the mesh to bulge, forming pockets into which a small part of the catch was lost. For the 2009 survey, therefore, the outside of the entry and its accompanying flange were re-shaped into an oval. Clamping around that exerted enough inward force to cure the problem.

The force required to draw the “aquarium” unit through the water was not transmitted to it via the codend meshes of the net but rather by four lines sewn to the latter’s aft riblines and shackled to the towing lugs on the “aquarium” (Figure II–3).

The “aquarium” was fitted with sufficient trawl headline floats to provide neutral buoyancy (Figure II–4). Since the gear had to be deployed to great depth and the floats thus had to withstand very high pressure, each was heavy and yet contributed little buoyancy. In consequence, large numbers of floats were required and they made handling of the “aquarium” somewhat awkward. Rigidly-mounted floatation would have been preferable but could not be readily added without obstructing access to the catch in the tank.

Apart from the deficiency in the initial flange design, the awkwardness of the floatation and some chafing of the net when the “aquarium” contacted the stern ramp, the performance of the unit was entirely satisfactory (Figure II–5).

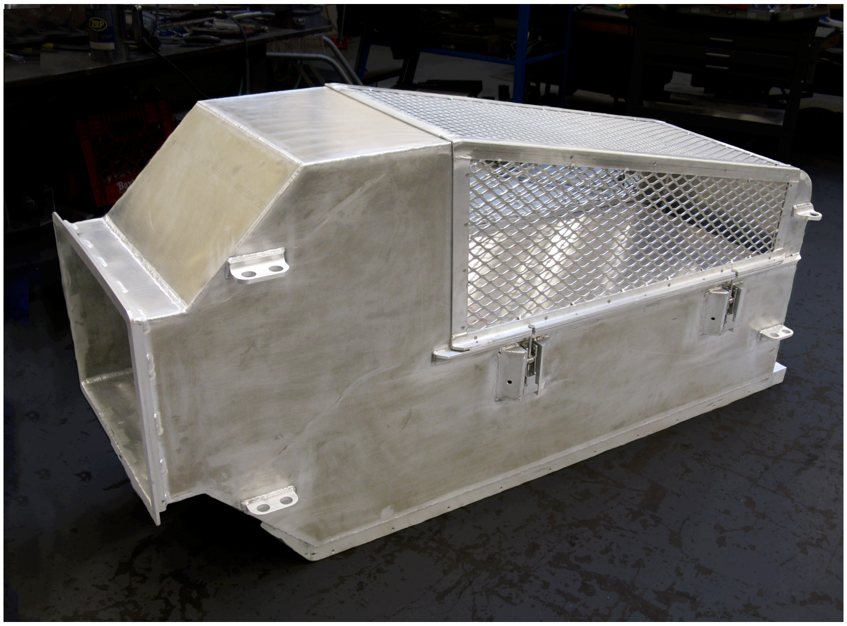


Figure II–1 : General view of "aquarium" codend during construction, with cover in place. Note slot (seen through mesh of cover, beyond rear end of deck) through which the catch drops into the tank. The shape of the ramp, leading from the entry to the deck, can be traced by the welding mark. When this photograph was taken, the vent holes had yet to be drilled.

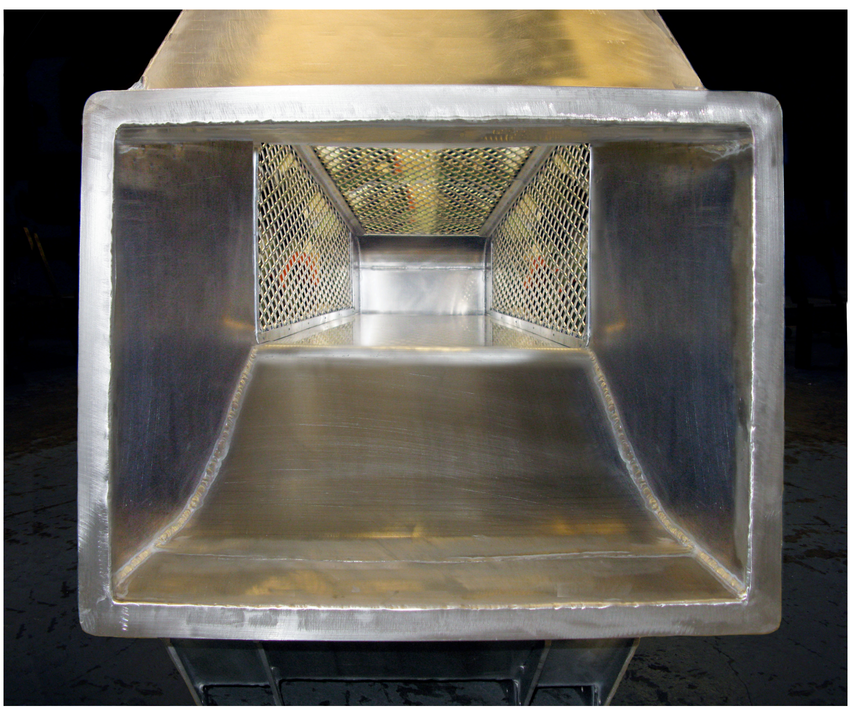


Figure II–2 : View into entry of "aquarium" codend and towards rear cowl, showing contoured ramp. The cover is in place, with its aluminium-mesh top and its deck visible. The slot through which the catch drops into the tank is under the rear cowl.

Figure II–3 : "Aquarium" codend attached to net, ready for deployment

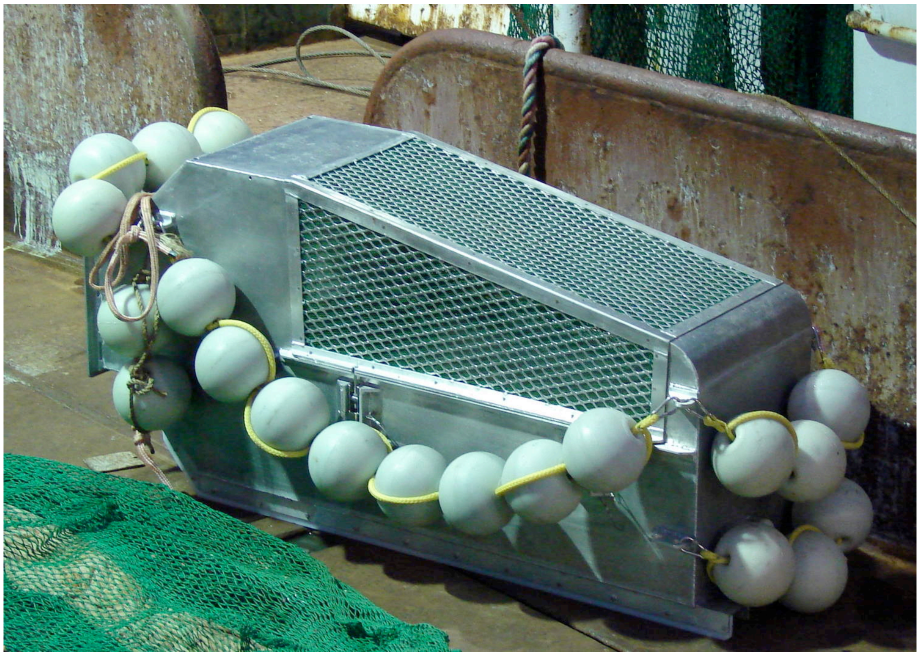


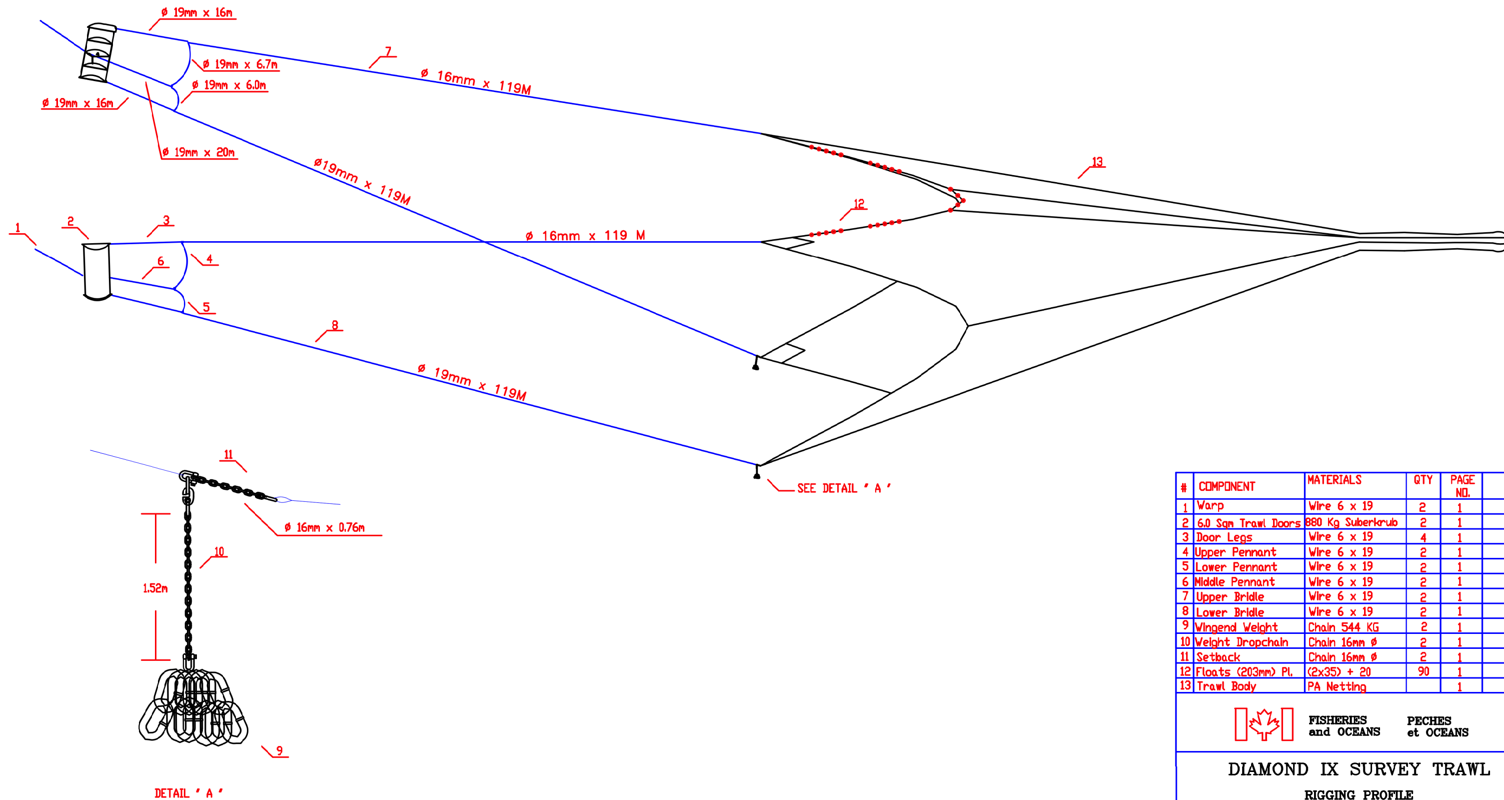
Figure II–4 : "Aquarium" codend ready for attachment to net, showing array of trawl floats used during the 2008 survey. For the subsequent surveys, only minor modifications were made to the arrangement of floats.

Figure II–5 : Recovering catch from the "aquarium" codend after removal of its cover

APPENDIX III

DESIGN AND SPECIFICATIONS OF THE DIAMOND IX MIDWATER TRAWL

Extracted from *Survey Trawl Reference Manual: Diamond IX*
prepared by the Marine Institute for Fisheries and Oceans Canada



#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Warp	Wire 6 x 19	2	1	DI01
2	6.0 Sqm Trawl Doors	880 Kg Suberkrub	2	1	DI02
3	Door Legs	Wire 6 x 19	4	1	DI03
4	Upper Pennant	Wire 6 x 19	2	1	DI04
5	Lower Pennant	Wire 6 x 19	2	1	DI05
6	Middle Pennant	Wire 6 x 19	2	1	DI06
7	Upper Bridle	Wire 6 x 19	2	1	DI07
8	Lower Bridle	Wire 6 x 19	2	1	DI08
9	Wingend Weight	Chain 544 KG	2	1	DI09
10	Weight Dropchain	Chain 16mm ø	2	1	DI10
11	Setback	Chain 16mm ø	2	1	DI11
12	Floats (203mm) Pl.	(2x35) + 20	90	1	DI12
13	Trawl Body	PA Netting		1	

FISHERIES and OCEANS — PECHES et OCEANS

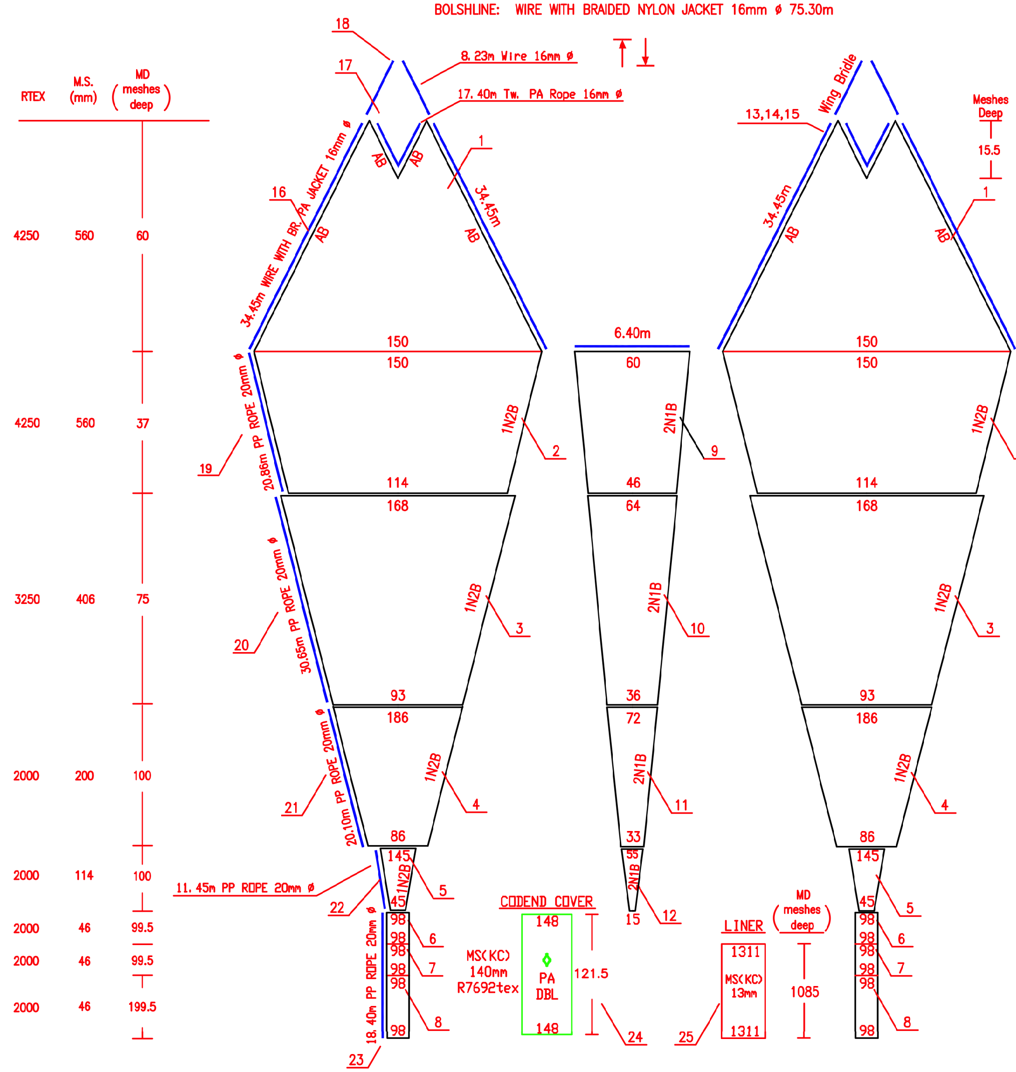
DIAMOND IX SURVEY TRAWL

RIGGING PROFILE

DATE DRAWN:	DWG NO.:		REV.	SCALE:
24/03/95	DIA*1.0	PG 1 OF 5 PG		NTS

DRAWN BY: MARINE INSTITUTE
FISHING TECHNOLOGY UNIT
ST.JOHN'S NEWFOUNDLAND

HEADLINE: WIRE WITH BRAIDED NYLON JACKET 16mm ø 75.30m
FISHINGLINE: LEAD WITH BRAIDED NYLON JACKET 16mm ø 75.30m
BOLSHLINE: WIRE WITH BRAIDED NYLON JACKET 16mm ø 75.30m



#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Wings	PA Netting	4	2,3	DI17
2	1st Belly	PA Netting	4	2	DI18
3	2nd Belly	PA Netting	4	2	DI19
4	3rd Belly	PA Netting	4	2	DI20
5	4th Belly	PA Netting	4	2	DI21
6	1st Lengthening Piece	PA Netting	4	2	DI22
7	2nd Lengthening Piece	PA Netting	4	2	DI23
8	Codend	PA Netting	4	2	DI24
9	1st Wedge	PA Netting	2	2	DI25
10	2nd Wedge	PA Netting	2	2	DI26
11	3rd Wedge	PA Netting	2	2	DI27
12	4th Wedge	PA Netting	2	2	DI28
13	Headline	Wire, PA Jckt.	3	4	DI29
14	Fishingline	Lead, PA Jckt	3	5	DI30
15	Bolshline	Wire, PA Jckt.	3	5	DI31
16	Wingline	Wire, PA Jckt.	4	2	DI32
17	Veeline	Tw. PA Rope	4	2	DI33
18	Wing Bridles	Wire 6 x 19	8	2	DI34
19	1st Belly Ribline	Tw. PP Rope	6	2	DI35
20	2nd Belly Ribline	Tw. PP Rope	6	2	DI36
21	3rd Belly Ribline	Tw. PP Rope	6	2	DI37
22	4th Belly Ribline	Tw. PP Rope	6	2	DI38
23	Aft Ribline	Tw. PP Rope	4	2	DI39
24	Codend Cover	Braided Nylon	1	2	DI40
25	Liner	PA Netting	1	2	DI41

REMARKS

- WING FRAMEROPE DETAILS CAN BE SEEN ON THE FOLLOWING PAGE NO.'S :
  - HEADLINE – PAGE 4 OF 5
  - FISHINGLINE – PAGE 5 OF 5
  - BOLSHLINE – PAGE 5 OF 5
- PANEL DEPTH DOES NOT INCLUDE JOINING ROUNDS
- PANEL WIDTHS INCLUDE SELVEDGE MESHES
- MESH SIZES ARE KNOT CENTER MEASUREMENTS

(green line)	DOUBLE NETTING
(red line)	JOINING ROUND
(black line)	SINGLE NETTING
(blue line)	FRAMELINE & RIBLINE
↑ ↓	UPPER & LOWER PANELS
◊	DOUBLE MESH
ϕ	DIAMETER
TW	TWISTED
MS	MESH SIZE
PA	POLYAMIDE
PP	POLYPROPYLENE

FISHERIES and OCEANS — PECHES et OCEANS

DENIER	RTEX	DIAMETER
210/156	4250	3.00
210/120	3250	2.50
210/72	2000	2.00
	7692	4.00

DIAMOND IX SURVEY TRAWL

NET PLAN

DATE DRAWN:	DWG NO.:		REV.	SCALE:
24/03/95	DIA#2.0	PG 2 OF 5 PG		NTS

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