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A Review of Newfoundland and Labrador Region Research on the Effects of Mobile Fishing Gear on Benthic Habitat and Communities

Examen de la recherche menée dans la région de Terre-Neuve et du Labrador sur les effets qu'ont les engins de pêche mobiles sur l'habitat et les communautés benthiques

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ABSTRACT

Since 1990, the Department of Fisheries and Oceans (DFO) Newfoundland and Labrador (NL) and Maritimes regions have been involved in collaborative research on the impacts of Canadian mobile bottom fishing gears (MBFG) to habitat and benthic communities. This has included three fishing impact experiments on Grand Bank and the Scotian Shelf. In addition to this research there have been other studies directly and indirectly related to the impacts of MBFG that have been carried out in the NL region. In recent years one of the most important issues has been the contention by crab fishers that shrimp trawling causes excessive damage and mortality to crabs. DFO has carried out a number of studies to investigate this claim. Other research carried out by DFO in the region has included a spatial-temporal analysis of intensity and consistency of commercial trawling in the Canadian Atlantic and Pacific regions, a simulated trawl door scouring experiment and a comparison of mortality rates in Iceland scallops (*Chlamys islandica*) on a heavily fished ground (scallop dredging) and an area that had not been fished. In 2001 DFO NL region initiated a long-term deep-sea coral research program. This is largely based on corals collected as trawl by-catch in the multispecies surveys and the Observer Program. While there have been no studies examining the effects of trawling on corals in the NL region, an ever expanding database on the geographic and bathymetric distribution of corals should assist in the identification of coral ‘hotspots’ (i.e. high abundances or diversity) and the extent of commercial fishing in these sensitive habitats.

RÉSUMÉ

Depuis 1990, les Régions de Terre-Neuve et du Labrador (TNL) et des Maritimes du ministère des Pêches et des Océans (MPO) participent à une recherche concertée sur les répercussions qu'ont les engins de pêche de fond mobiles (EPFM) canadiens sur l'habitat et les communautés benthiques. Dans le cadre de cette recherche, trois études sur les impacts de la pêche ont été menées sur le Grand Banc et le plateau néo-écossais. En plus de cette recherche, d'autres études directement et indirectement liées aux impacts des EPFM ont été réalisées dans la région de TNL. Au cours des dernières années, l'un des enjeux les plus importants a été la controverse soulevée par des pêcheurs de crabe qui affirmaient que le chalutage des crevettiers causait des dommages excessifs aux crabes et entraînait leur mortalité. Le MPO a effectué un certain nombre d'études pour examiner cette question. Les autres recherches menées par le MPO dans la région incluaient une analyse spatio-temporelle de l'intensité et de la régularité du chalutage commercial pratiquée dans les régions de l'Atlantique et du Pacifique au Canada, une expérience de simulation du raclage causé par des panneaux de chalut ainsi qu'une comparaison des taux de mortalité entre les pétoncles d'Islande (*Chlamys islandica*) dans une zone fortement exploitée (dragage de pétoncles) et d'autres occupant une zone non exploitée. En 2001, la Région de TNL du MPO a lancé un programme de recherche à long terme sur les coraux des grands fonds. Cette recherche est axée en grande partie sur les coraux recueillis accidentellement dans le cadre de la pêche au chalut qui sont enregistrés dans les relevés plurispécifiques et le Programme des observateurs. Même si aucune étude porte sur les effets du chalutage dans la région de TNL, l'élaboration d'une base de données de plus en plus importante sur la répartition géographique et bathymétrique des coraux devrait nous aider à localiser les zones riches en corail de par leur abondance ou leur diversité et à déterminer l'impact de la pêche commerciale dans ces habitats sensibles.

INTRODUCTION

A dedicated research program on the environmental impacts of mobile bottom fishing gears (MBFG) carried out by the Department of Fisheries and Oceans (DFO) in the Newfoundland & Labrador (NL) region was formerly initiated in 1990. Leading up to the collapse of the Northern Cod stock, the Harris Panel made a series of recommendations intended to fill large gaps in our understanding of the ecology of cod, to provide better scientific advice and to advance the technologies used in cod research and stock assessment. This resulted in funding for 25 research projects (under the Northern Cod Science Program), one of which was an investigation of the effects of bottom trawling on an important component of cod habitat, i.e. seabed habitat. In 1990, a research partnership began between DFO Maritime (Bedford Institute of Oceanography, (BIO)) and DFO NL (Northwest Atlantic Fisheries Centre, (NAFC)) regions. The lead scientific investigators launching this new research program were Dr. Don Gordon and Mr. Terry Rowell (BIO) and Dr. Peter Schwinghamer (NAFC). Over the next 15 years, research into the environmental impacts of Canadian mobile bottom fishing gears was carried out by this inter-regional multi-disciplinary research group and included three field experiments, each three years in duration; two on the Scotian shelf (Western Bank: otter trawling; Banquereau: hydraulic clam dredging) and one on the NE Grand Bank (otter trawling). Detailed summaries of these studies can be found in (Gordon et al. in press).

While the majority of research into the impacts of MBFG off the east coast of Canada has been collaborative between the two regions, some directed research dealing with specific NL issues has been carried out in this region. It is this research that is the focus of this working paper. In particular, in recent years fishers involved in the snow crab (*Chionocetes opilio*) fishery have voiced their concern over the high numbers of crab that are caught with missing or broken legs. It is the opinion of some fishers that shrimp trawling on the same grounds as the crab fishery is the cause of this damage imposing high mortality on crabs. In order to address this issue, DFO has conducted a number of studies (see below).

In recent years the impact of trawling on deep-sea corals has gained worldwide attention. Deep-sea corals are particularly vulnerable given that they largely occur at very deep depths (e.g. >500 m), often outside the jurisdiction of neighboring states in areas that are exploited by deep-water fisheries. Deep-sea corals fall under one of the new National Science Themes: **“Understanding and describing the state of aquatic ecosystems, including identifying sensitive habitats”.** Ecological studies of deep-sea corals are a challenge given sampling/surveying logistics in very deep, offshore environments and the associated financial costs. As a first step, since 1997 DFO has been actively involved in mapping the distribution and biodiversity of deep-sea corals in both the Maritime and NL regions. In the NL region, a collaborative long-term coral research project between DFO and Memorial University was established in 2002 (see below).

MEDIA AND PUBLIC ATTENTION

- In the NL region, while there has been interest shown by the media with respect to trawling impacts, it has been sporadic and largely issue-driven. For instance, the CBC showed interest in the late 1990s after DFO's response to a newspaper commentary which stated that the department should be doing research into trawling impacts; this was after the completion of the three-year Grand Bank trawling experiment. This highlighted, at the time, DFO's shortcomings in communicating ongoing research and findings to the general public.

- Very recently, the media has shown interest in deep-sea coral research in this region, although to date interest/attention lags significantly behind that which is seen in the Maritimes region.

- Overall, the media slant has typically been in relation to the status of cod, and specifically, whether 'dragging' impacts to seabed habitat could have been at least partially responsible for the collapse of the Northern Cod stock.

There have been several workshops held in the region dealing with impacts of trawling gear and means of minimizing those impacts:

- 1999 April 19-22. ICES-FAO Working Group on Fishing Technology and Fish Behaviour Workshop held at the Marine Institute (MI), St. John's, NL.

- 1999 October 21-22. Fishing Industry Workshop on Minimizing the Sea bed Impacts of Trawl Gear: MI, Memorial University of Newfoundland.

- 2004. Industry meetings/workshops on methods to reduce seabed impacts.

- Also, in recent years there has been MI flume tank testing (and field testing) of semi-pelagic trawl doors and testing of several 'environmentally friendly' bottom trawls for Canadian and US gear manufacturers.

SPECIFIC PROJECTS

The remainder of the paper summarizes completed or ongoing research into impacts of MBFG in the NL region:

1. Impacts of shrimp trawling on snow crabs;
2. Delineating historical spatial and temporal patterns of commercial trawling activity;
3. Simulated trawl door scouring experiment;
4. Impacts of Scalloping dredging ;
5. Sensitive areas and habitats: geographic distribution and diversity of deep-sea corals.

Nb- Details of the Grand Bank trawling impact experiment can be found in (Gordon et al. in press).

1. Impacts of Shrimp Trawling on Snow Crabs (*Chionocetes opilio*)

Background

In recent years, Canadian snow crab fishers have expressed concern over the high number of crab that are caught (pot fishery) with missing or broken legs. It is the opinion of some that this is attributable to shrimp trawling where fishing grounds of the two sectors overlap. These observations were made at a time when there was also a trend of decreasing crab biomass and many in the industry attributed this to high mortality in crab due to the shrimp fishery. The NL 2000 Snow Crab Management Plan called for research to assess the impact of shrimp trawling on the crab resource. Subsequently, a two-phase study was initiated to assess the condition of crab before and after trawling had taken place. Methods used in the two phases differed.

Phase I

Locations: La Scie (original site was Hawke Channel, Labrador, however this site was abandoned due to poor fishing).
Date: November, 2000
Depths: 262-428 m.
Fishing gear: Shrimp trawl (15 cm roller balls, Bison doors).
Methods: Phase I consisted of sampling in only one location and season. Three trips, each 5 days in duration were undertaken. Trip one involved setting fleets of crab pots in an area approximately 6 km by 800 m (area to be subsequently trawled). Pots were set and hauled twice. For each crab collected, carapace width was measured and shell condition, and number and position of missing legs were assessed. All crabs were then transported a distance of 10 nm from the fishing area and discarded. A shrimp trawler then completed 10 tows within the designated fishing area, i.e. the same area where crab pots had been set. Three days later, crab pots were again set within the fishing zone (set and hauled twice) and recovered crabs examined and measured.

Results/Conclusions

Shrimp trawling over a small area of crab grounds off La Scie did not result in a significant increase in damage to crabs measured as leg loss. However, it was noted that the experiment was limited in duration and spatial scale and increased damage may have been recorded if trawling had been carried out at other times of the year, particularly during soft shell periods. Additionally, the three day period between trawling and sampling may have permitted in-migration of crabs.

Phase II

Location: Off Cape St. John (outside Notre Dame Bay)
Dates: July-November, 2001
Depths: 271-293 m
Fishing gear: Shrimp trawl (30 cm rubber discs, 770 kg Bison doors).

Methods

The purpose of this phase of the study was to examine the condition of crabs that were not captured by the trawl but had been swept over by the footgear. Retainer bags were designed and tested in the flume tank at the Marine Institute, Memorial University of Newfoundland (St. John's). Three retainer bags were attached to the shrimp trawl; the headrope of each bag was attached to the trawl fishing line (i.e. the lower opening of the main trawl) such that the retainer bag footrope trailed 3 m behind the shrimp trawl footrope. Attempts were made to attach a video camera to the gear to record gear-crab interactions however these were unsuccessful. A series of tows were made during three separate trips (July, September, and November). After each tow, a minimum sample of 250 crabs was taken from each retainer bag with measurements recorded as per Phase I. After each tow crabs were taken 10 nm from the trawling area and released.

Results/Conclusions

The retainer bags towed immediately behind the heavy footgear and underneath the shrimp trawl collected large numbers of crab. It was determined that for each time period, crab populations were similar in terms of general condition, total, recent and past leg loss, average size and percentage of females present. Frequency of occurrence of recent leg loss was very low; less than 4 new leg losses per 100 crabs. It was concluded that experimental shrimp trawling did not adversely affect (in terms of damage) the large number of crab encountered.

Hawke Channel Closed Area

In 2002, DFO established a fishery closure in an area off Labrador. This box is closed to shrimp trawling but open to crab fishing. Trends in recruitment and CPUE inside vs. outside the box are being monitored.

Further Studies on the Interaction between Shrimp Trawling and the Snow Crab Resource

Background

Despite the absence of evidence to suggest that shrimp trawling was adversely affecting the snow crab resource, the controversy remained, with the crab sector maintaining that shrimp trawling was causing excessive damage and mortality to crab populations. As a result of this, DFO made a commitment to study this issue in greater detail. In addition to further work quantifying injuries to crabs encountering shrimp trawl footgear (i.e. retainer bag studies), a field trawling experiment would be carried out in which direct observations would be made of crab-footgear interactions as well as the condition of crabs remaining in the tow path.

Field Trawling Experiment

Location: St. Mary's Bay
Dates: May-June 2005
Depths: 93-183 m.
Bottom type: soft mud
Fishing gear: shrimp trawl (Yankee 36, 590 kg Brampton doors, 30 cm diam. Rockhopper discs) towed by the CCG Shamook

Methods

Experimental Design

Two trawling corridors were established in the outer and mid-bay regions of St. Mary's Bay in areas of commercial crab fishing. Suitable crab densities at these locations were verified prior to the experiment based on crab pots set by a commercial crab vessel. This information was used to position the corridors within areas of high crab densities as well as to collect baseline data on catch rates and damage/leg loss. The same vessel sampled crabs inside and outside each corridor after the trawling experiment. Each trapping period involved 4 fleets of 6 traps each. Each trawling corridor was 200 m by 500 m. A total of 10 transects, oriented perpendicular to the long axis, were spaced at 50 m intervals (Fig. 1).

Sub-surface positioning of a remotely operated vehicle (ROV) was achieved with a USBL Acoustic Positioning System, consisting of a transducer (hull-mounted boom) and a transponder attached to the ROV (actually mounted on the umbilical above the ROV due to noise interference).

Before Trawling Remotely Operated Vehicle (ROV) Surveys

A Seaeye Falcon ROV was deployed from the CCG MV Shamook for pre-trawling surveys of crabs inside the trawling corridors. The vessel would proceed to one end of a transect whereupon the ROV would be deployed and then the vessel and ROV would drift along the length of the transect. Due to combinations of wind and currents, not all transects in both corridors could be surveyed both before and after trawling. As the ROV drifted continuous digital colour video was recorded. Because the ROV was highly maneuverable, it could be moved to within cm's of individual crabs. A ruler attached to a mechanical arm permitted *in situ* measurements of carapace width of individual crabs. In subsequent postprocessing, damage to crabs, including missing legs, were recorded along with crab behaviour, e.g. degree of reaction to the ROV and position on the seabed.

Experimental Trawling

The experimental procedure for each trawling corridor consisted of pre-trawling ROV surveys followed by experimental trawling, followed by post-trawling ROV surveys. Experimental trawling required approximately one field day (~10 hrs.). This was completed in the early evening allowing fine sediments to settle overnight prior to post-trawling surveys beginning early the following morning. The design was to have the area inside the trawling corridors swept once by the footgear (wing to wing). In reality, the percent coverage was 45 % for the outer bay corridor and 58 % for the mid-bay corridor (Fig. 2 and 3). It is noted that this does not include trawl door tracks.

Post-Trawling ROV Surveys

After trawling, attempts were made to do ROV surveys along the same transects as before trawling; however, there was limited success do to variable ship drift patterns which could not be controlled due to current and wind conditions. However, all ROV surveys were within the zone of trawling disturbance. In the mid-bay corridor, three ROV surveys were done up to four days post-trawling.

Gear-Crab Interaction Observations

Two video platforms were used to record crab interactions with the trawl footgear. A remotely operated towed vehicle (ROTV) was deployed from the vessel once the trawl was on-bottom and fishing properly. The ROTV was maneuvered from the stern to various positions near the mouth of the trawl in order to record video of the footgear moving over the seabed. Approximately one hour of video was acquired showing snow crab encounters with the footgear before the ROTV malfunctioned. At the conclusion of the experiment, additional observations were made using an underwater video camera that had been attached to the trawl headline with a downward directed view. Only larger crabs could be clearly distinguished in the video. Gear-crab encounters included individuals passing between the rockhopper discs, over the discs and being swept on top of the discs in “surfing mode”.

Results/Conclusions

Analyses have been completed and presented at a RAP meeting held in St. John’s (March, 2006). Several key results are highlighted here. It should be noted that the primary focus of this research has been impacts to the resource (i.e. damage to crabs) and not habitat. However, ROV video surveys provided some insight on impacts to seabed habitat. This is particularly noteworthy since the St. Mary’s Bay experiment was the first trawling experiment on a muddy seabed in

Canada. Post-trawl ROV surveys showed that the muddy seabed had been transformed into a parallel series of furrows created by the rockhopper discs (spacing between discs varied between 18 and 30 cm). These were still visible four days after trawling. There was considerable re-suspended sediment in the water column the first day following trawling, however this had largely cleared three days post-trawling at the Mid-Bay site. At the Outer Bay site the water column had cleared one day after trawling. Most notably, all crabs observed in post-trawl surveys at both sites were active and showed no obvious signs of damage.

Sampling for Injuries

Methods

Retainer bags with independent footgear were attached to a commercial shrimp trawl to sample crabs that encountered the footgear.

The main trawl was fished in two different configurations:

(1) Commercial fishing mode: the fishing line (i.e. bottom of the trawl opening) was toggled 70 cm above the footgear. It was expected that very few crabs would be caught in the main trawl; crabs sampled in the retainer bags would have passed either over or under the footgear.

(2) Research sampling mode: the fishing line was attached directly to the footgear and the sorting grate disabled. Crabs collected in the main trawl would have passed over the footgear, whereas crabs collected in the retainer bags would have passed underneath the footgear. Both modes of sampling were conducted across the entire range of bottom types encountered in the shrimp fishery.

Sampling of crabs was done for a period of 10 days off the Labrador coast (NAFO Div. 2J, June 25-July 7, 2005) and northeastern Newfoundland (Div. 3K, July 18-28, 2005). In addition, at one location multiple tows (up to 6) were made over the same general area of seabed and crabs in successive sets were examined for injuries.

Results

Sampling done in Div. 2J was largely unsuccessful. The trawler’s doors and warps were too heavy and, as a result, the trawl did not settle properly on bottom. In contrast, sampling in Div. 3K with a different vessel was very successful. Approximately 7000 crabs were sampled from 30 sets.

Overall Conclusions

There was some evidence that trawling affected leg loss (St. Mary’s Bay trawling corridors and 3K repeat tows), however this was not supported by other data on leg loss. There is no evidence that the shrimp fishery imposes a substantial mortality on snow crab.

2. Spatial and Temporal Patterns of Trawling Activity in the Canadian Atlantic and Pacific Regions

Background

The primary objectives of this study were to delineate spatial and temporal patterns of commercial trawling, including patterns of intensity and consistency of trawling effort. In this study, the location, persistence and intensity (measured as % area of seabed swept by trawl gear annually) of trawling activity was mapped. Applications of this information include understanding the location and characteristics of traditional fishing grounds as well as areas that are not trawled and identifying potential overlap of commercial mobile bottom fishing and sensitive habitats.

Methods

Data from the Atlantic (1980-2000) and Pacific (1994-2000) Fisheries Observer Programs, in the form of geo-referenced fishing set locations, were used to spatially delineate trawling effort. During the period 1980-1986, the Observer Program covered approximately 15% of the total trawl activity, varying by fishery (including both Canadian and non-Canadian fleets). This level of coverage increased in 1987-2000 to about 34%.

A precise quantification of the spatial extent of trawl scouring would require data for the start and end position of each tow (i.e. fishing set) including trajectory (cruise track) of the tow and the width of the foot gear for all bottom trawling activity. Such information would allow for an exact derivation of area and location of benthic habitat affected by each tow. A composite of tows would delineate patterns of varying intensity of scouring for the study area. In Canada, this level of detail currently does not exist. However, the Fisheries Observer Program provides a useful dataset for generating approximate values for these parameters. The limitation of the observer data is that the trajectory of the tow is not known and this precludes a direct measure of the overlap among sets. The point where the scour commenced is known and the dimensions of the towed area can be estimated. Thus, we can determine a distance from the start to the end of the tow but not the exact patch of sea floor trawled. Since we cannot directly measure the precise location of the trawling, this study aggregated sets occurring within an average tow length of each other and summed the area scoured for these sets to calculate the maximum area trawled for each location. This is a reasonable approach for preserving small scale integrity of the data considering that the method does not extrapolate beyond the average length of tow, about 7 km.

To account for cases where the observer data did not provide complete coverage of all fleets and therefore all sets, adjustment factors were used to scale the area towed for each set, by year, and by species. A ratio of amounts of fish and invertebrates landed compared to the retained portion of observer catch figures was used to adjust observed effort to total estimated effort. The assumption in adjusting the observer effort data using a landed/observed ratio is that the unobserved effort occurs at the same location as the observed effort. This assumption is reasonable given that fleets tend to target stocks at specific locations and do so quite consistently over time.

The geographic position of the start of the tow for each bottom trawl set was extracted to provide a geo-reference, along with the following fields: duration of tow, tow speed, width of net, (from which area towed was calculated), gear type, directed species (to adjust to landings) and date. As noted above, ideally, this work requires a geo-reference for the start and end points of the tow plus a tow vector to define the actual location of bottom trawled. As these data were not recorded, the calculated area trawled (km^2) for each tow, calculated from the duration of tow, tow speed and width of net was assigned to the geographic location for the start of the tow.

The spatial analysis was carried out using a potential mapping procedure in SPANS GIS. The technique converts geo-referenced point (fishing set) data to surfaces that describe intensity of trawling effort and is a form of spatial moving average or summation using a circle of specified radius. To bring about the transformation of point data to a continuous surface, a circle is placed around the starting position of each set and the area for all sets that fall within the circle are added. The process is repeated for each data point (set location). No output values are calculated for areas lying outside of any sampling radius, thus avoiding extrapolation.

Results

Areas that were consistently trawled over the 20 year period were identified. In the Northwest Atlantic, trawling grounds are patchy and complex, covering between 8 and 38% of the shelf area in any year although the actual area of the bottom that is trawled is much smaller (Fig. 4, 1987 and 2000 as examples). Spatial patterns of trawling changed quite dramatically over the time sequence analyzed although locations of high intensity trawling were quite similar from one year to the next. The spatial patterns were most stable during the 1980s while the greatest changes occurred during the early 1990s (Fig. 5). There were numerous persistent areas of trawling spread mainly along the shelf edge and between the banks. Except for Grand Bank and the Magdelen Shallows, the tops of the banks were largely untrawled. Thus, a substantial portion (shallow and shoreward) of the shelf was consistently not fished. The most persistently fished areas after 1990 occurred along the outer edge of the Scotian Shelf (Fig. 6 and 7) and the southwest edge of the Laurentian Channel. Trawling was moderately persistent on the central part of Grand Bank, along the shelf edge centered at latitude 49^o plus a few small areas to the north on the outer shelf (Fig. 6). In the Pacific, the trawl locations were more consistent but the observed time frame was much shorter (1994-2000). Trawl grounds comprised a string of partially joined patches along the shelf edge off Vancouver Is., three patches within the southern Queen Charlotte Sound, south and east of Queen Charlotte Is. at deeper locations and on the shelf edge north and west of Queen Charlotte Is. (Dixon Entrance).

Conclusions

This study demonstrated that the distribution of trawling disturbance on Canadian continental shelves is patchy and temporally variable. Large portions of the shelf (particularly shoreward) are seldom fished. Trawling activity was concentrated on the outer shelf and in the trenches between the banks. It is noted that certain fleets were under-represented in some years. For the Atlantic, outside of the Gulf of St Lawrence, data for vessels <150 tonnes (Tonnage Class 3) are not included in the data set up to 1994. After that, coverage levels are low resulting in an under- representation of effort near the coast. These findings suggest that over much of the shelf the seabed is either not trawled or only lightly trawled. On the other hand, the most vulnerable habitats, those with a high degree of structural complexity with an abundance of surface-dwelling fauna such as deep-sea corals and sponges, could sustain long-term damage through even limited contact with mobile bottom fishing gears (i.e. the first pass effect). The spatial and temporal history of trawling can be used to identify historical and recent trawling activity in these vulnerable locations.

3. Simulated Trawl Door Scouring Experiment

Background

The prevailing scientific opinion is that otter trawl doors inflict more damage per unit area of seabed than other gear components due to their mass and the resulting forces transmitted to the seabed. However, due to logistic constraints most field studies of trawl gear impacts have been restricted to examining aggregate impacts of gear components. In order to examine more closely the physical disturbance and biological damage caused by trawl doors, a physical trawl door model (TDM) was constructed and tested in a simulated Grand Bank sandy seabed. The primary objectives of the study were to quantify stresses transmitted to the seabed by trawl door scouring, sediment displacement and trawl door-specific damage and displacement of bivalves.

Methods

Experimental Tank, Gantry and Testbed

The trawl door simulation was conducted in, what was at the time, the ice scour research tank facility at the Faculty of Engineering and Applied Science, Memorial

University of Newfoundland. A towing gantry spanned the watertight concrete tank (14 m x 3 m x 1.1 m) and provided a base to which the TDM and a three-dimensional positioning system could be mounted and towed over the testbed. The computer linked positioning system recorded the positions of the scour path, sensors and molluscs in the test bed. The testbed was built up in 2 cm layers of compacted wet sand to a final depth of 0.5 m. With the assistance of geotechnical engineers, an attempt was made to reproduce key geotechnical properties of the seabed on the northern Grand Bank (e.g. density, grain size).

Trawl Door Model

The main component of the TDM was the shoe sections of an otter board used with the DFO Engel 145 survey trawl (Fig. 8). The TDM consisted of the shoes with a metal plate attached to the shoe to simulate the lower part of the trawl door; the plate also prevented sediment from spilling over the shoes during scouring. The shoe length in contact with the seabed (106 cm) combined with a representative angle of attack (30^o) resulted in a scour path width of 53 cm (again representative of the width of commercial trawl door furrows).The TDM assembly was bolted to the towing gantry. Various load cells were incorporated into the TDM in order to record testbed forces acting on the model during scouring while an underwater video camera, attached to the lower part of the steel plate at the leading end of the shoe, provided a close-up continual view of the entire scouring process.

Bivalve specimens

A total of 200 fixed/preserved bivalves (6 species) previously collected from the Grand Banks were arranged in the testbed in typical life positions ranging from the sediment-water interface to a depth of 20 cm. One valve of each specimen had been engraved with a unique identifier.

Testbed electronics and sediment displacement markers

Total stress cells and pore pressure transducers were used to record, respectively, sediment stress (force per unit area) and interstitial pore water pressure, during scouring. Sediment displacement markers (steel ball bearings, pliable solder strands, coloured sand) were oriented at various depths perpendicular to the scour path. These served to identify horizontal and vertical displacements of sediment and the extent of sub-surface shearing.

Test Procedure

Prior to the test, over a 12-hour period the water level was raised to a height of 20 cm above the testbed surface. The trawl door was then towed through the testbed at a scouring depth of 2 cm (representative for compacted sand) at a speed of 0.87 knots (maximum achievable speed). After draining the water from the tank the TDM was removed from the gantry and replaced with the 3-D positioning system. Post-test positions of all bivalves and displacement markers were recorded.

Results

As the trawl door scoured the testbed, it created a 2 cm furrow (pre-set depth) and an adjacent berm of displaced frontal spoil along the trailing edge of the door. Bivalves at the sediment water-interface were displaced to the berm and 58%-70% of displaced specimens (recorded in two blocks of the testbed) which were originally buried were completely or partially exposed at the testbed surface. Out of 42 specimens which had been placed in the scouring zone, two showed major damage while the remainder were not damaged. Patterns of change in sediment pore water pressure and total stress showed that infaunal organisms would have experienced maximum stress at a point approximately 50 cm from the advancing trawl door.

Conclusions

A model was developed to explain the apparent anomaly of bivalve displacement with little associated damage based on sediment mechanics, and size and life position of infaunal bivalves living on this bottom type. The results of this experiment largely corroborated the impacts of experimental trawling on bivalves recorded in the Grand Bank experiment; small near-surface bivalves were not damaged whereas large, semi-infaunal bivalves were destroyed.

4. Impacts of Scallop dredging

Background

Two species of scallop are commercially fished in the Newfoundland & Labrador region: the sea scallop, *Placopecten magellanicus* and the Iceland scallop, *Chlamys islandica*. There has been one published study that investigated the indirect effects of scallop dredging. In this study, mortality rates (non-yield fishing mortality) of Iceland scallops in a heavily fished population were compared to those of a population that had not been fished.

Location: Strait of Belle Isle, St. Pierre Bank (new fishery), Grand Bank
Dates: 1980, 1981
Bottom type: coarse
Fishing gear: Digby dredges

Methods

Systematic sampling of Iceland scallops was conducted in each of the geographic locations. Natural mortality was computed from percent occurrence of cluckers (empty, articulated shells) (Dickie formula) while total mortality was calculated from commercial catch and effort data.

Results/Conclusions

Annual mortality in the Iceland scallop was found to be significantly higher on exploited beds than on unfished grounds. The difference between natural mortality rates in heavily fished vs. unfished populations (here estimated to be 0.047) provides an estimate of gear-induced mortality (i.e. indirect fishing mortality). Indirect fishing mortality was gear-dependent with highest mortality rates (31%) associated with the heavy, offshore New Bedford dredge compared to 17% for the inshore Digby dredge. Overall, up to 8 times as many scallops perish as a result of encounters with fishing gear than through natural causes.

5. Sensitive Areas and Habitats: Geographic Distribution and Diversity of Deep-Sea Corals.

Background

While there have been no studies of the direct impacts of bottom fishing on cold water corals in the NL region, information obtained on their geographic distribution and areas of high abundance and diversity can potentially be used in a fisheries management context (e.g. identification of candidate MPAs etc.).

In eastern Canada, the study of deep-sea corals is a relatively new area of research. DFO research in the NL region is directly linked to, and is pre-dated by, research in the Maritimes region. The following is a brief history of DFO deep-sea coral research in eastern Canada. Early stages of research can be divided into two phases (Gordon and Kenchington, 2002). Phase 1 (1997-2000) consisted largely of opportunistic coral collections and video surveys during research cruises funded through other projects. Deep-sea coral bycatch data was also collected during routine multi-species surveys. Phase 2 was initiated following the First International Symposium on Deep-Sea Corals (Halifax, 2000); DFO applied for and received funding from the Environmental Studies Research Funds (ESRF) for a three-year dedicated research program (Phase 2, 2001-2003). Two Norwegian scientists (Pal and Lene Mortensen) were recruited to work full-time on coral research at BIO. Research was expanded to include a dedicated ROPOS (a remotely operated vehicle) cruise. However, in this program, most *in situ* observations were made using the BIO-designed CAMPOD on board the CCG *Hudson.* In 2004, the dedicated deep-sea coral research program at BIO had to be scaled back to the previous opportunistic level.

Beginning in 2001, coral samples and data collected during surveys in the NL region were archived in the Maritimes region. With the arrival of coral researcher Evan Edinger at MUN and a fully operational coral collection protocol in place (multi-species surveys and Fisheries Observer Program), a long-term NL region deep-sea coral research program was initiated. This is a collaborative effort between DFO (Science and Oceans) and Memorial University (Departments of Biology, Geography and Earth Sciences). Up to 2005 this program was also opportunistic, taking advantage of coral bycatch from the multispecies surveys and Fisheries Observer Programs. The focus of this research was the mapping of coral distributions and diversity from geo-referenced fishing set locations. This research program was expanded in 2005 when three years of funding was obtained through the International Governance Program (IGP) to study deep-sea coral trophic relationships, reproductive ecology and their role as fish habitat.

Mobile bottom fishing gears are destructive to corals (Krieger, 2001; Mortensen et al., 2005). Given the groundfishery moratorium in the NL region, fishing is now concentrated outside Canada's EEZ in deep water along the shelf slope. However, this is where stands of deep-water corals are found (Fig. 9). Although there are a number of known 'hotspots' for corals in Atlantic Canada, we are still in the discovery phase in terms of mapping the distribution and diversity of deep-sea corals in eastern Canada. This information can then be used to identify candidate locations for coral conservation areas, as has been done for coral conservation areas in the Northeast Channel, the Gully and the Stone Fence (Scotian Shelf). Another objective of the NL IGP project is to collect traditional ecological knowledge (TEK) from commercial fishermen, specifically historical trends in the relative abundance of deep-sea corals estimated from trends in coral bycatch.

Results/Conclusions

The following is a brief summary of key results to date from the NL region. Currently, twenty-seven coral species have been recorded; four alcyonaceans, two antipatharians, eight gorgonians, four solitary scleractinians, and 11 pennatulaceans. Corals are primarily distributed along the edge of the continental shelf (>300 m), and are most common in submarine canyons or saddles (Fig. 9). Only nephtheid alcyonaceans (i.e. soft corals) are found on the shelf. Large, structurally robust corals include the gorgonians *Paramuricea spp.*, *Paragorgia arborea* (L.), *Primnoa resedaeformis* (Gunnerus, 1763), *Keratoisis ornata* (Verrill, 1878), and *Acanthogorgia armata* (Verrill, 1878), and two antipatharian corals. Gorgonian distributions are highly clustered, with most co-occurring with other coral species. Two date, two broad coral species richness 'hotspots' have been identified: southwest Grand Bank (16 species) and an area of the Labrador slope between Hopedale Saddle and the Funk Island Spur (14 species). Most hotspots identified in this study were suggested in earlier research based on stock assessment surveys, and Local Environmental Knowledge, with the majority from the latter (Gass and Willison, 2005). A variety of coral species may provide important habitat for fish and crustaceans, but relationships may not be obligate. Studies of the relationships between deep-sea corals and groundfish are ongoing. Currently there are no conservation measures in place to protect deep-sea corals in the NL region.

RESEARCH RECOMMENDATIONS

Gordon et al. (in press) present research recommendations intended to improve our understanding of the impacts of mobile bottom fishing gears on seabed habitat as well as to better manage commercial trawling and dredging fisheries. These recommendations are largely globally applicable and include the mapping of fishing effort and benthic habitat, and further field research including monitoring recovery of benthic communities and habitat in fishing impact experiments and further research into the identification of preferred habitat for demersal fish. In the context of benthic habitat mapping there is an urgent need to map habitat including biological communities in sensitive and frontier areas. In the NL region these include the Southeast Shoal and deep-water slope areas which have not been subjected to anthropogenic impacts, most notably fishing. In many areas of the world this is being accomplished using acoustic techniques (e.g. multibeam) combined with targeted video and grab sampling. Given that the study of these habitats is in its' infancy, there are currently no offshore conservation areas or MPAs in the region as there are on the Scotian Shelf, although Canada has tried to convince NAFO's Fisheries Commission to agree to designate the Southeast Shoal as a MPA. Research into the design of MPAs to protect sensitive habitats (e.g. deep-water corals) is needed. In the NL region, the debate over the extent of impacts of otter trawling on seabed habitat and biodiversity will continue. It is imperative that continuing research into developing fishing gears that lessen impacts to seabed habitat be supported.

REFERENCES

AquaProjects Inc. 2001. Report on the Interaction Between Shrimp Trawling and the Snow Crab Resource. Project Report: EACT-1.2001.DFO. Prepared for Fisheries Diversification Program, Environmental Awareness & Conservation Technology.

AquaProjects Inc. 2002. Report on the Interaction Between Shrimp Trawling and the Snow Crab Resource- Phase II (Revised). Project Report: EACT-4.2002.DFO (FDP 281). Prepared for Fisheries Diversification Program, Environmental Awareness & Conservation Technology.

DFO. 2001. Gear and By-catch Concerns: Interactions in the Turbot, Crab and Shrimp Fisheries in 2J3KL. Project Summary: EACT-4.2001.DFO (FDP 334). Fisheries Diversification Program, Environmental Awareness & Conservation Technology.

Edinger, E.N., Wareham V. E., and Haedrich R. L. In press. Patterns of groundfish diversity and abundance in relation to deep-sea coral distributions in Newfoundland and Labrador waters. Proceedings of the 3rd International Symposium on Deep-Sea Corals, Special Issue of the Bulletin of Marine Science.

Edinger, E.N., Wareham V. E., and Haedrich R. L. 2005. Mapping distributions of deep-sea corals in Newfoundland and Labrador waters. Contract Report to Department of Fisheries and Oceans, Oceans and Habitat Management Division, Newfoundland Region.

Gass, S.E., and Willison J.H.M.. 2005. An assessment of the distribution of deep-sea corals in Atlantic Canada by using both scientific and local forms of knowledge. *In* Cold-water corals and ecosystems. *Edited by* A. Freiwald and J.M. Roberts. Springer-Verlag, Berlin Heidelberg. Pp. 223-245.

Gilkinson, K., Paulin M., Hurley S. and Schwinghamer P. 1998. Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction. J. Exp. Mar. Biol. Ecol. 224: 291-312.

Gordon, D. and Kenchington E. 2002. Proposal: Long-term deepwater coral project. Internal DFO document, Maritimes region.

Gordon, D., Kenchington E. and Gilkinson K. 2006. A review of Maritimes Region research on the effects of mobile fishing gear on benthic habitat and communities. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/056.

Hurley, S.J., Gilkinson K.D. and Paulin M.J. 1997. Shell strength index tests on selected Grand Banks bivalves. Contract Report for Department of Fisheries and Oceans. C-CORE Publication 96-C35.

Krieger, K.J. 2001. Coral (*Primnoa*) impacted by fishing gear in the Gulf of Alaska. *In* Proceedings of the First International Symposium on Deep-Sea Corals. *Edited by* J.H.M. Willison, J. Hall, S.E Gass, E.L.R. Kenchington, M. Butler and P. Doherty. Ecology Action Centre and Nova Scotia Museum, Halifax, NS. Pp. 106-116.

Kulka, D.W. and Pitcher. D.A. 2001. Spatial and Temporal Patterns in Trawling Activity in the Canadian Atlantic and Pacific. ICES CM 2001/R:02

Mortensen, P.B., . Buhl-Mortensen L, Gordon, Jr, D.C., Fader G.B.J., McKeown D.L. and Fenton D.G. 2005. Effects of fisheries on deepwater gorgonian corals in the Northeastern Channel, Nova Scotia. Am. Fish. Soc. Symp. 41, 369-382.

Naidu, K.S. 1988. Estimating mortality rates in the Iceland scallop, *Chlamys islandica* (O.F. Müller). J. Shell. Res. 7, 61-71.

Wareham, V.E. and Edinger E.N. In press. Distribution of deep-sea coral in the Newfoundland and Labrador region, Northwest Atlantic Ocean. Proceedings of the 3rd International Symposium on Deep-Sea Corals, Special Issue of the Bulletin of Marine Science.

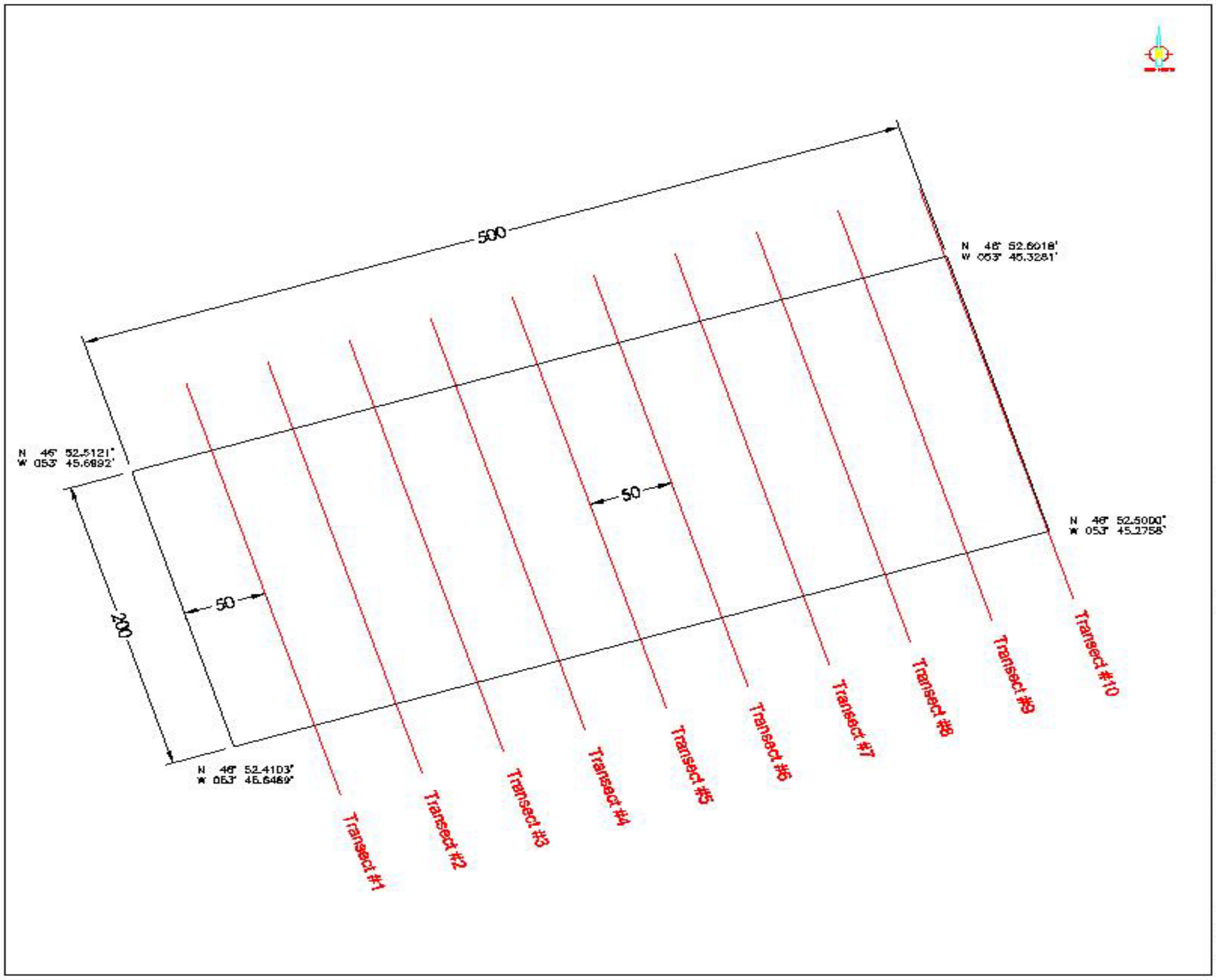


Figure 1. Layout of the St. Mary's Bay trawling corridors and ROV transects.

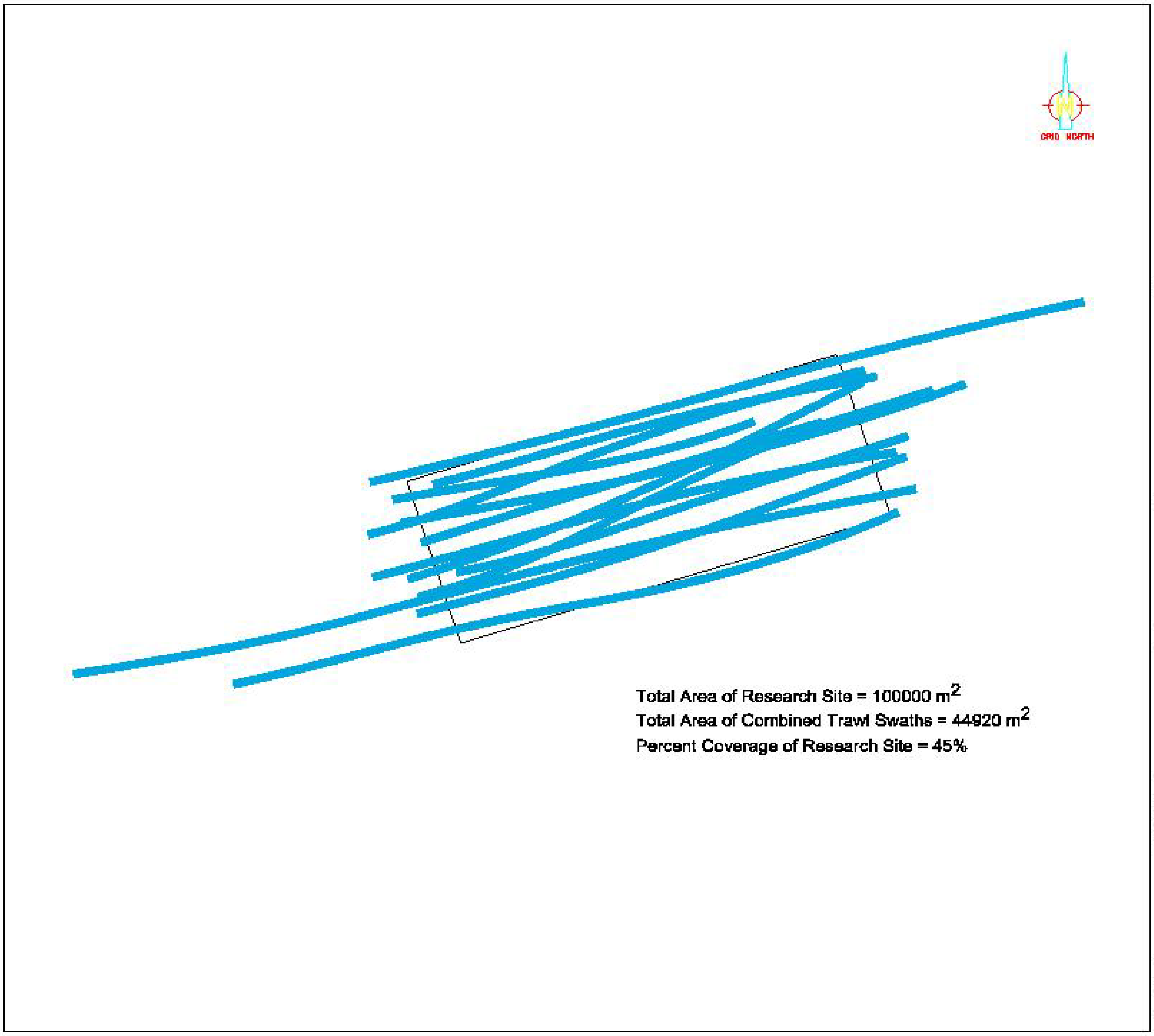


Figure 2. Outer bay trawl corridor swept area.

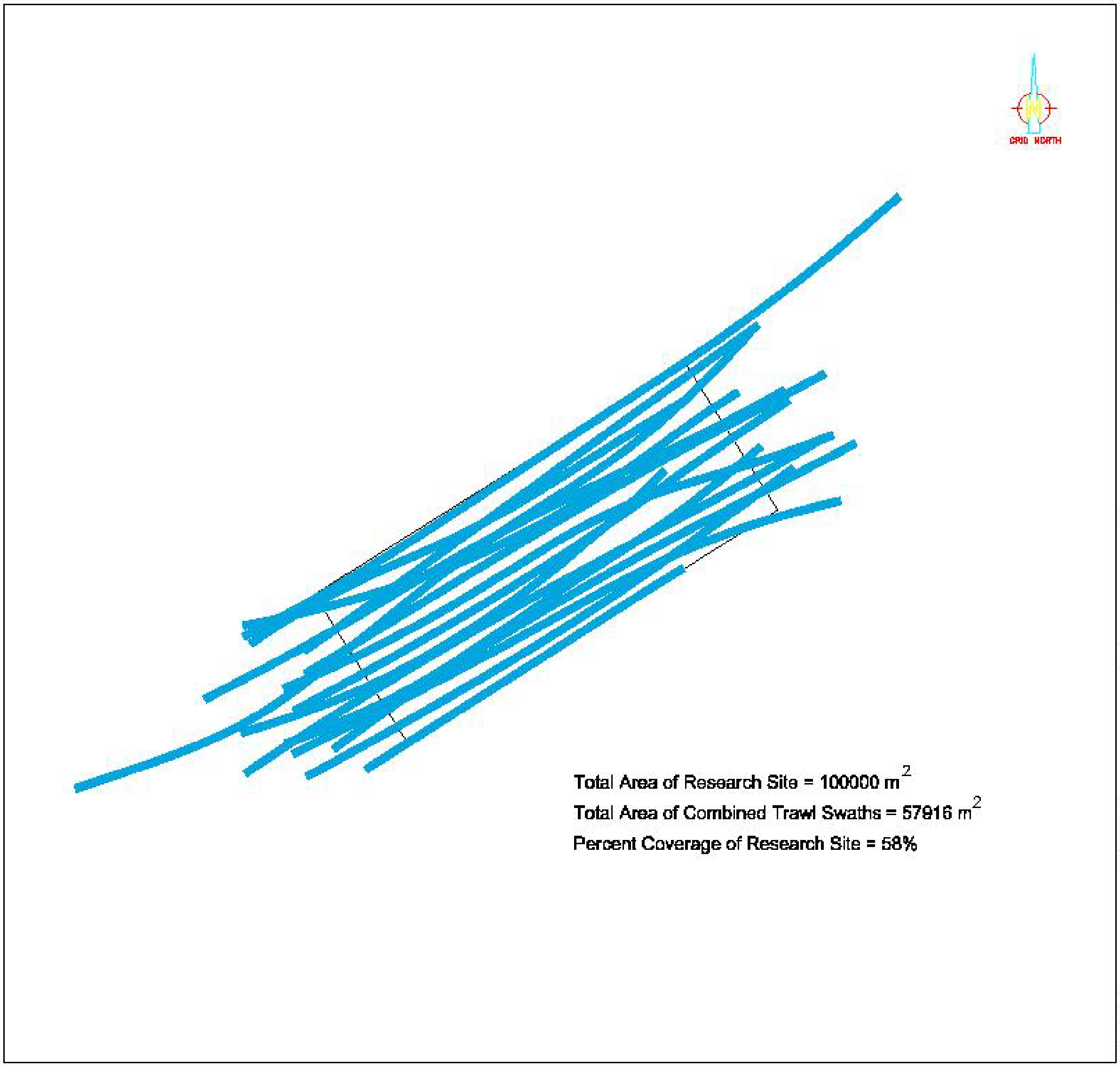


Figure 3. Mid-bay trawl corridor swept area.

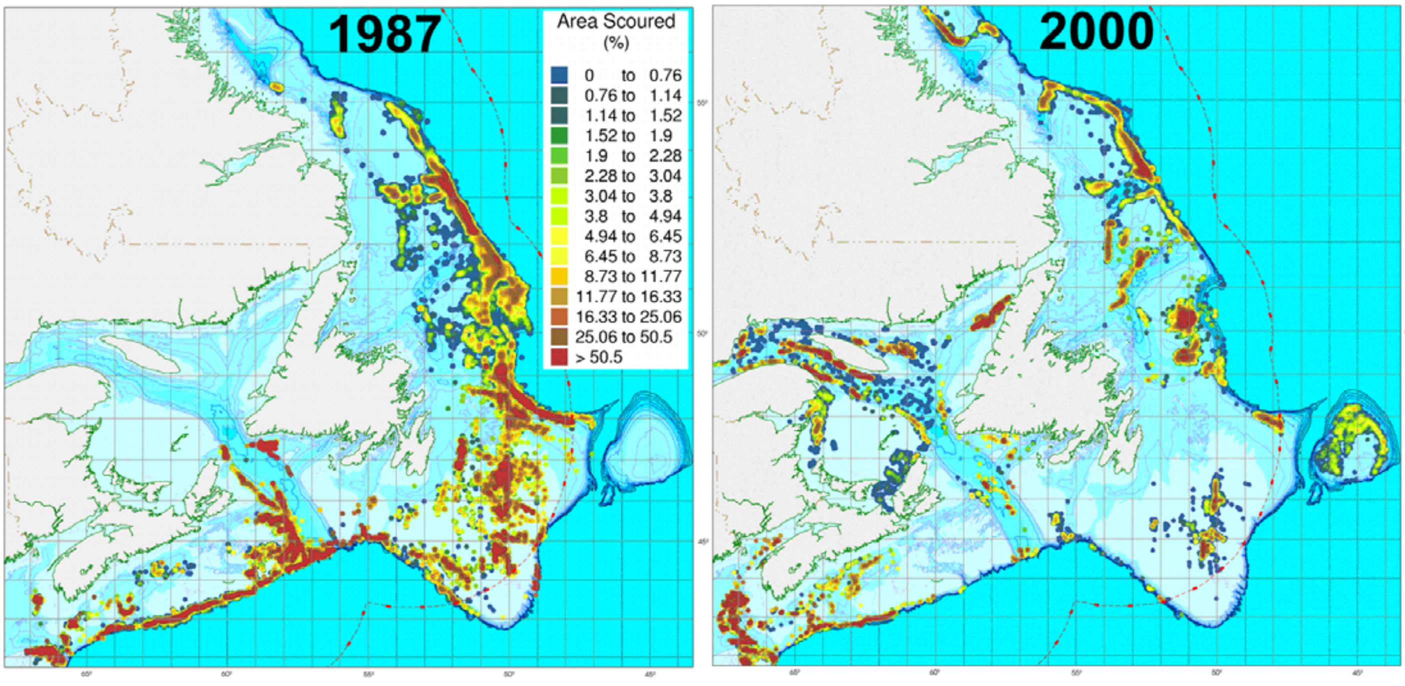


Figure 4. Distribution of trawling effort in Atlantic Canadian waters in 1987 and 2000. Images are based on fishery observer fishing locations of bottom trawl activity adjusted to total effort for vessels in tonnage category 3 (<150 t).

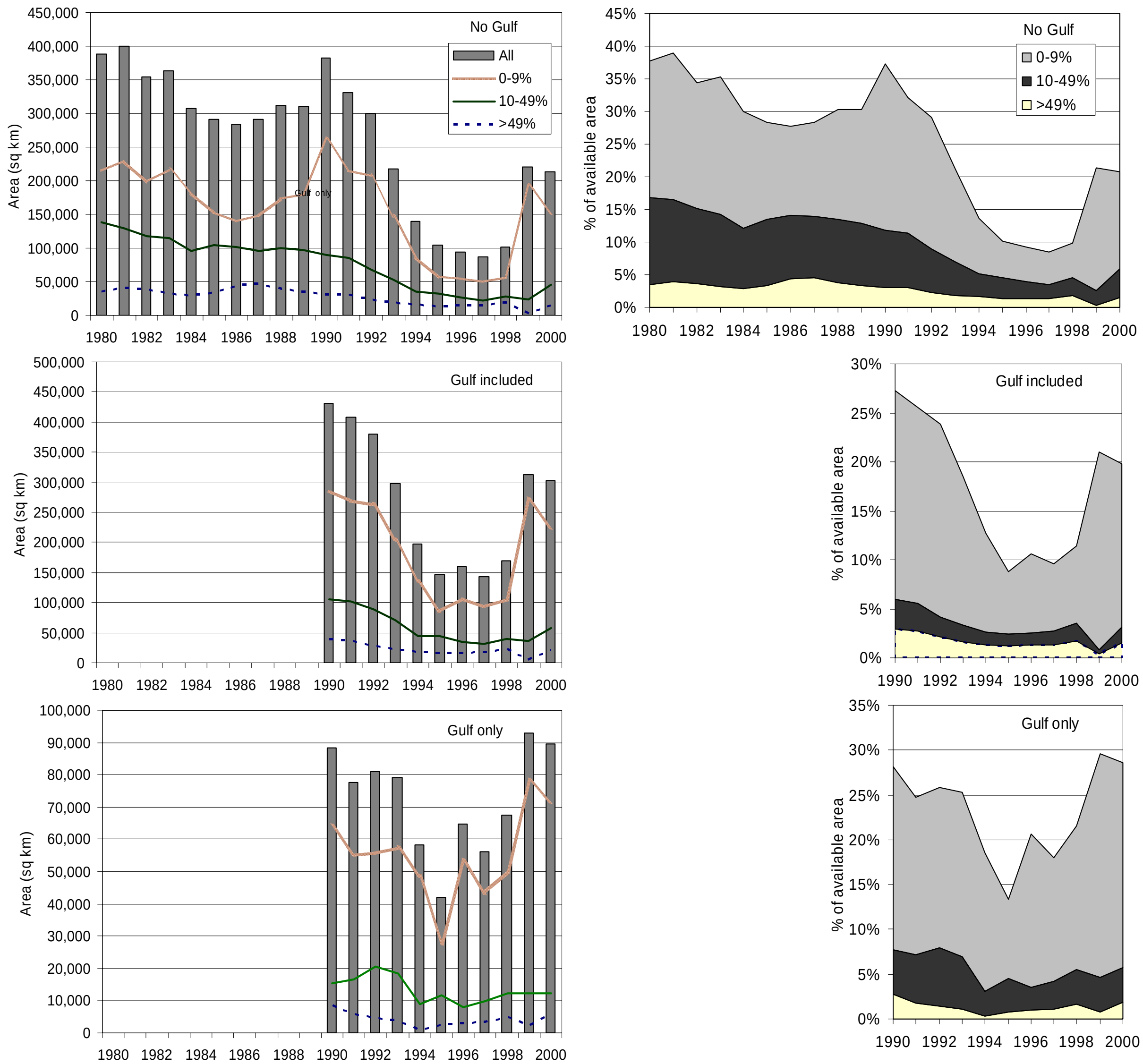


Figure 5. Spatial extent of trawling in the NW Atlantic, 1980-2000. Left panel shows extent of trawling in km^2 by year. The right panel shows same in terms of percent of total area of the shelf.

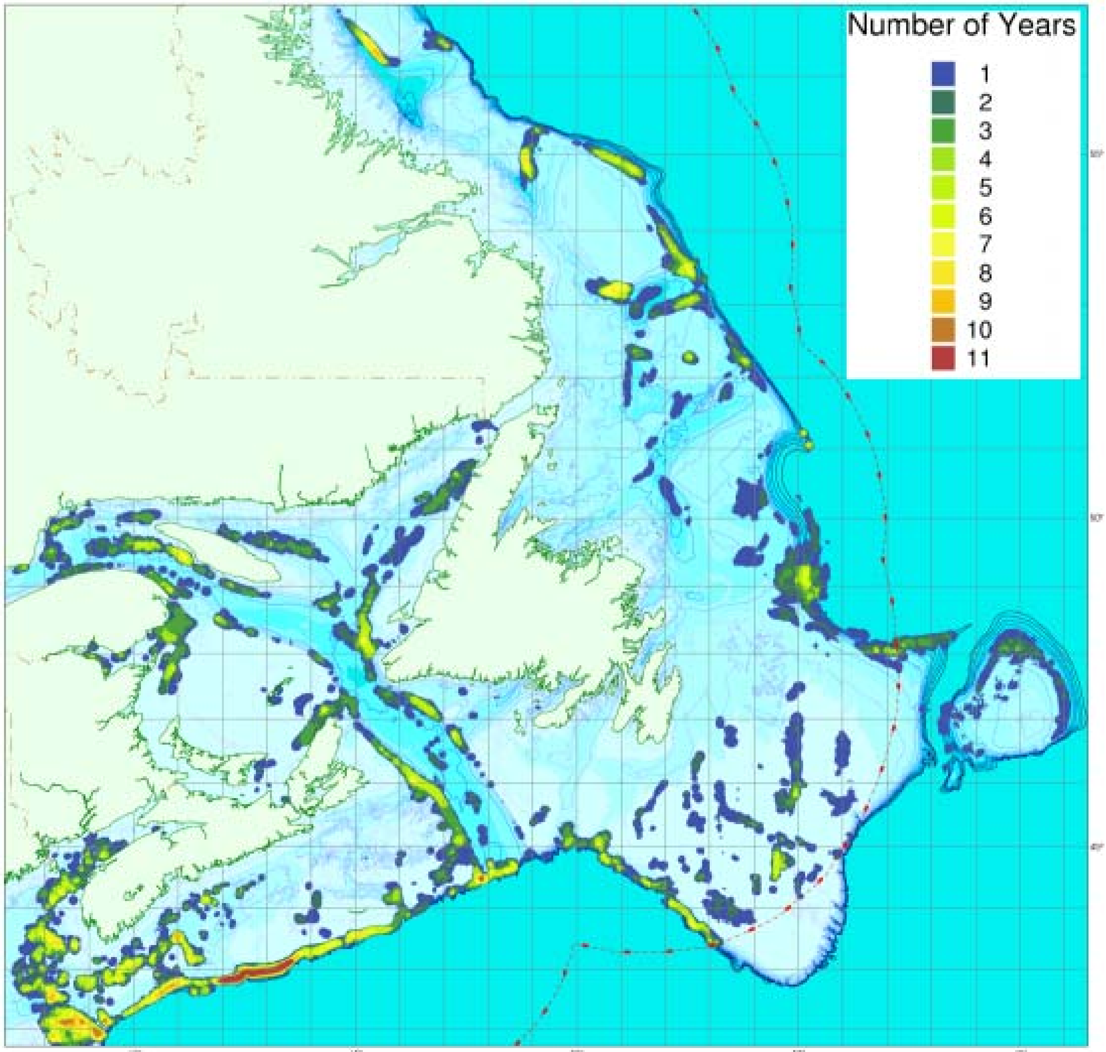


Figure 6. Maps depicting persistent areas of high intensity trawling in the Atlantic (areas where >50% of the bottom was scoured in a given year) over the period 1990-2000, Gulf of St. Lawrence included. Red locations depict where >50% of the bottom was trawled in all years between 1990 and 2000.

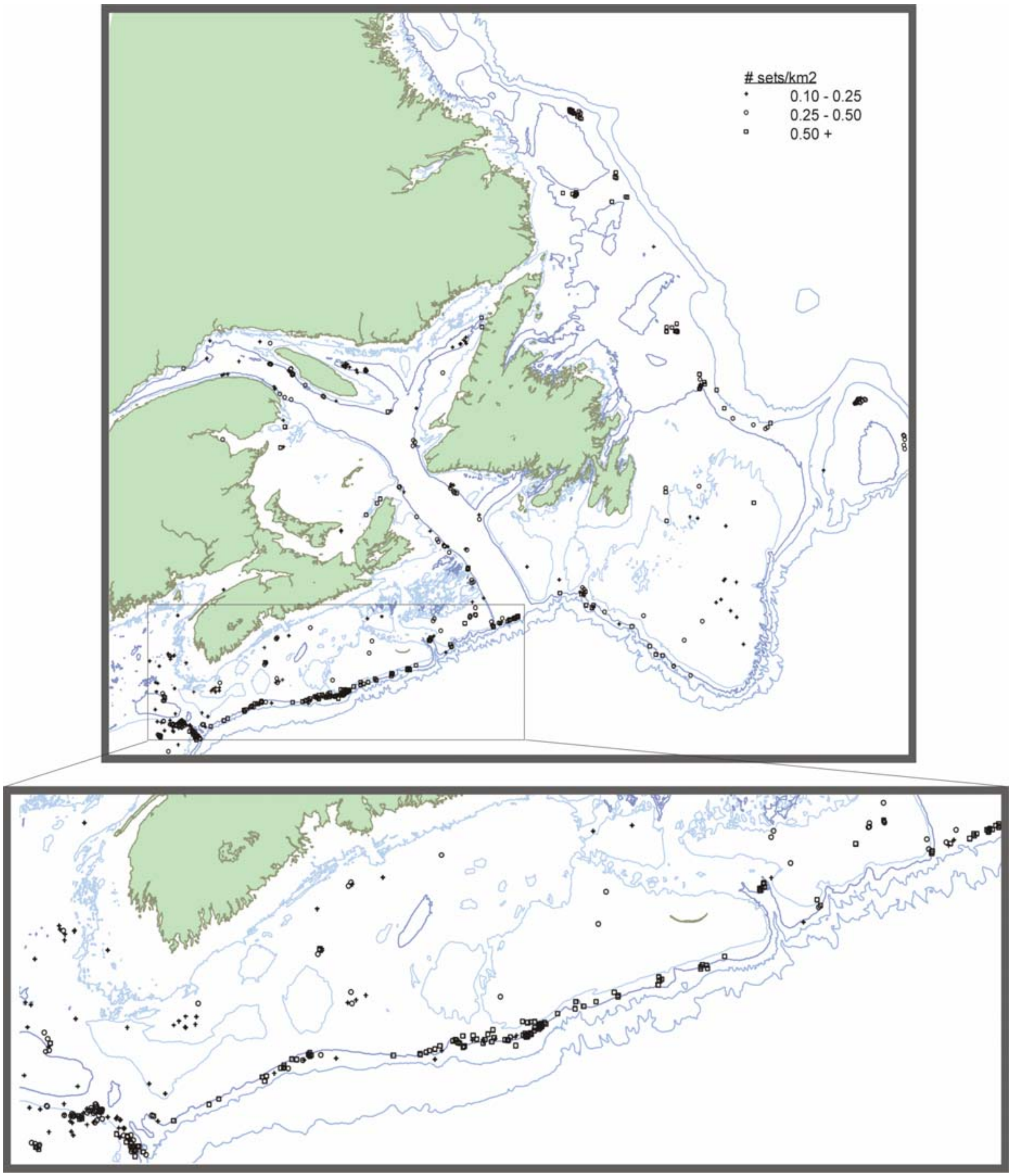
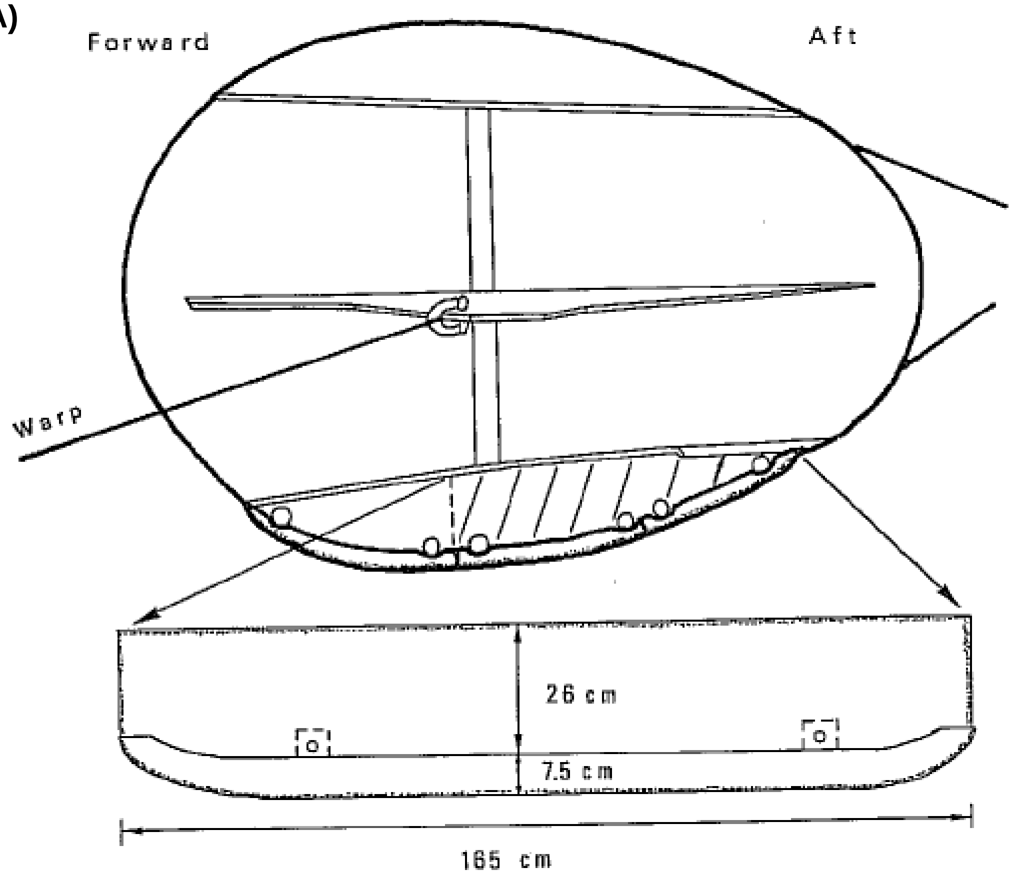


Figure 7. Locations where >100% of the area was trawled in the Atlantic in any year (centroids of areas where total area trawled exceeded extent of the area).

A)



B)

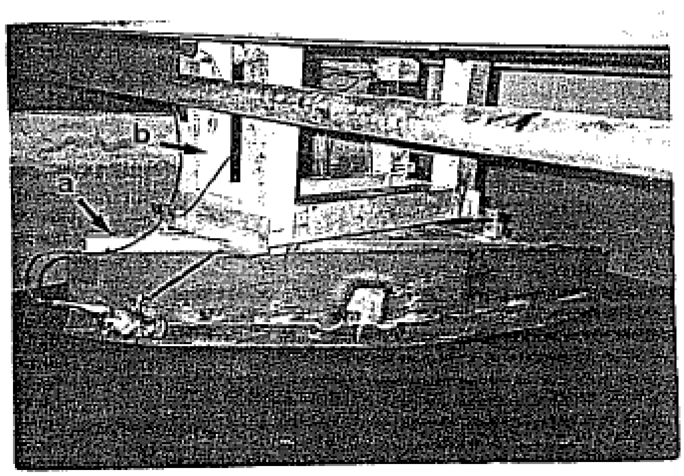


Figure 8. A. Portion of trawl door that formed the main part of the TDM, consisting of the welded center and aft shoe sections and plate. B. Assembled TDM attached to the towing gantry.

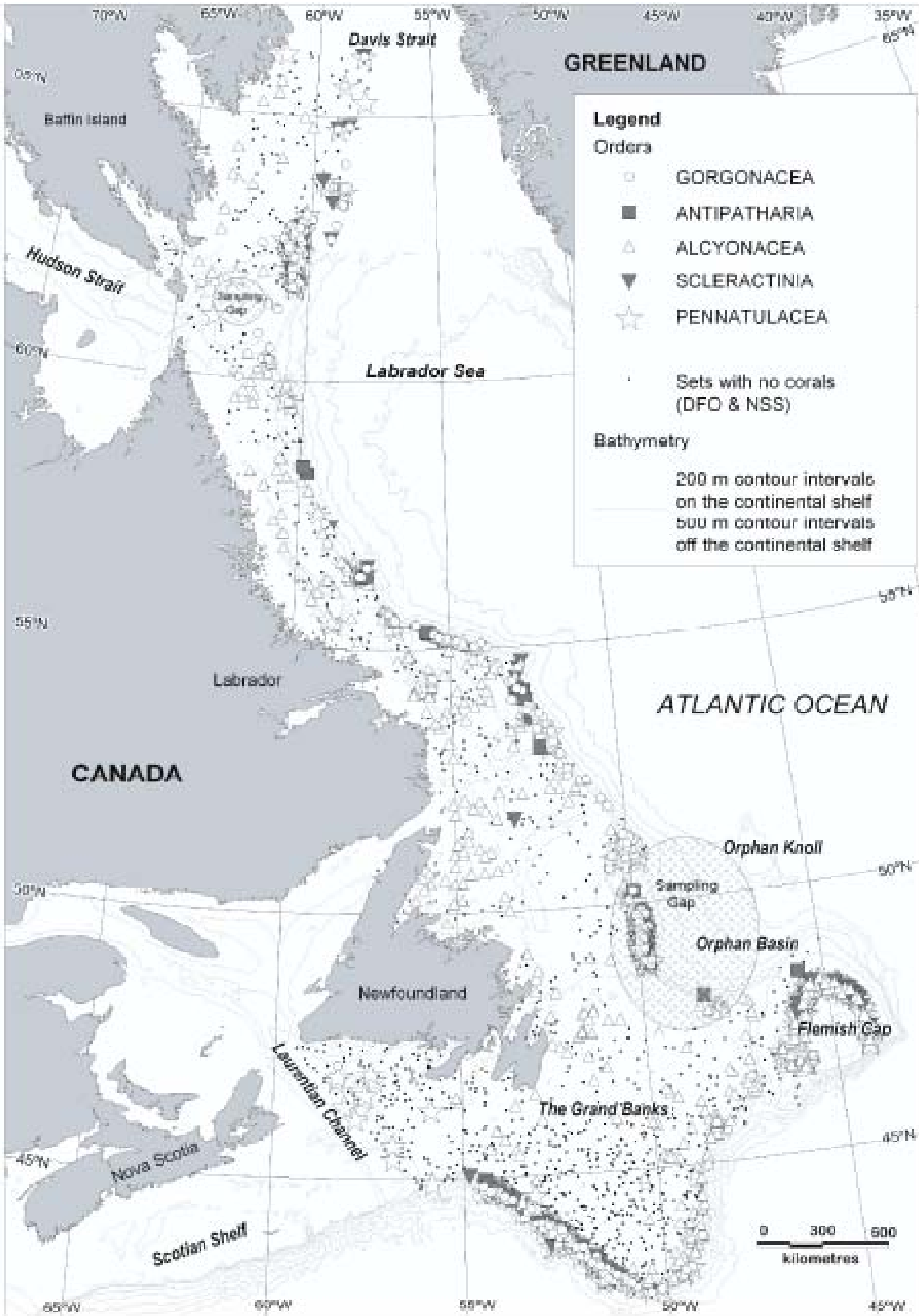


Figure 9. Distribution of deep-sea coral collections by Orders from trawl bycatch (DFO multispecies surveys, 2003-2005, the Northern Shrimp Stock Assesment Surveys, 2005, and Fisheries Observer Program, 2004-2005) from Wareham and Edinger, in press.