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The Gully:
A Scientific Review of its Environment and Ecosystem

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Abstract

The Gully, a large submarine canyon east of Sable Island on the eastern Scotian Shelf, is a feature which has been described as a unique ecological site and valued component of Atlantic Canadian coastal waters. Its suspected uniqueness and biological significance has attracted the attention of a wide range of government agencies, researchers, ocean resource industries and conservationists. The Department of Fisheries and Oceans (DFO) has as one of its mandates the identification of sensitive marine areas and the development of a strategy for their conservation; the Gully is one such area which DFO has been asked to evaluate. As a first step in developing a Conservation Strategy for the Gully, DFO coordinated a thorough scientific review of the region to establish the state of knowledge of its environment and ecosystem and to place that information in the context of the greater Scotian Shelf system. Thirty-two scientific experts from DFO, other federal natural resources departments, universities and other NGOs contributed to the Gully Science Review which describes what is presently known about the regions geology, oceanography, benthos, fish, seabirds and mammals. In addition to summarizing what is known about the region's environment and ecosystem, the review also identifies information gaps and outlines future research needs.

Résumé

Le Gully, un important canyon sous-marin de l'Île de Sable, dans la partie est du plateau néo-écossais, est une entité qui a été décrite comme un site écologique unique et un élément important des eaux côtières du Canada atlantique. Les caractères uniques et l'importance biologique qu'on lui attribue ont attiré l'attention d'une large gamme d'organismes gouvernementaux, de chercheurs, d'industries océaniques et de conservationistes. Le Ministère des Pêches et des Océans (MPO) a notamment pour mandat d'identifier les zones marines vulnérables et d'élaborer une stratégie pour leur conservation. Le Gully est l'une de ces zones pour lesquelles il a été demandé au MPO de procéder à une évaluation. À titre de première étape de l'élaboration d'une stratégie de conservation pour le Gully, le MPO a coordonné un examen scientifique détaillée de la région afin de définir l'état des connaissances en ce qui a trait à l'environnement et à l'écosystème de cette zone et de les situer dans le contexte du système global du plateau néo-écossais. Au total, 32 scientifiques du MPO, d'autres ministères fédéraux des ressources naturelles, d'universités et d'ONG ont participé à l'examen scientifique qui cerne nos connaissances actuelles de la géologie, de l'océanographie, du benthos, des poissons, des oiseaux de mer et des mammifères de cette région. En plus de résumer les connaissances sur l'environnement et l'écosystème, l'examen précise les lacunes en matière d'information et résume les besoins en recherche.

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SUMMARY

Background

Ocean Sciences Division, Maritimes Region, of the Department of Fisheries and Oceans (DFO) was asked in the summer of 1997 to initiate and lead a thorough scientific review of the Gully, a large submarine canyon on the eastern edge of the Scotian Shelf, in order to characterize its environment and ecosystem(s) in the context of the Scotian Shelf system as a whole. The Review Team*, consisting of some 32 government (DFO, DOE, NRCan), university (Dalhousie) and other NGO (WWF, NS Museum, Ecology Action Centre) researchers, were asked to produce a document summarizing the current state of knowledge of the Gully with respect to its geology, hydrography, oceanography, fisheries, seabirds and mammals. The individual reports produced for the Review document are organized by discipline and (1) describe the sources of available scientific information on the Gully region, (2) provide an interpretation of the data with regard to general as well as unique or special features and (3) identify information/data gaps where they exist. What follows are some of the major highlights of the Gully Science Review.

Geosciences & Hydrography

Description: This section describes the Gully's origin, bathymetric morphology, bedrock and surficial geology, sediment transport and mineral potential. The data are derived from the Geological Survey of Canada inventory and are characterized as limited and patchy. Interpretation of the history of the gully and geological processes are largely based on seismic reflection surveys.

The Gully is characterized as a large shelf-edge canyon on the eastern Scotian Shelf ***unique among canyons of the Eastern Canadian margin because of its great depth, steep slopes and extension far back onto the continental shelf (i.e. connecting the continental slope to the inner shelf)***. The Gully was formed as a result of the combination of fluvial, glacial ice and glacial meltwater erosion; the most powerful erosion took place 150K-450K years ago. The Gully is depicted as a steep-walled canyon cut into Tertiary bedrock in the deeper sections and blanketed by thick Quaternary glaciomarine sediments in the shallower parts. The floor of the Gully probably consists of sands or gravels scoured by tidally-induced currents (*e.g.* an analogue to the Laurentian fan). Recent studies of four small feeder canyons on eastern Sable Island Bank suggest that these may be sites of active sediment transport into the Gully. Based on studies in analogous regions, the slope of the Gully, its surficial geology and the grain size of the sediments are thought to strongly influence the region's benthic community structure and biodiversity.

Information Gaps:

- The geology of the Gully is based on older datasets and consequently less well known than adjacent regions (*e.g.* Grand Banks) where newer data gathering techniques have been used.
- There is little information on the geology of the deeper (>600m) areas of the Gully; <1% of that area has been surveyed.

Physical & Chemical Oceanography

Description: A detailed analysis of existing data on circulation, current variability and exchange, tides and low-frequency variability of hydrographic and chemical properties in the Gully and surrounding regions are derived largely from the DFO-BIO hydrography/nutrient database, from direct current measurements, or from finite element diagnostic and prognostic models. Patterns of circulation in the Gully suggest that it may play an important role in (1) the localized retention of material, and (2) in the larger scale transport of material onto and off of the shelf.

An analysis of the existing data on the physical oceanography of the Gully has indicated that it may feature a weak counterclockwise circulation that could contribute to the retention of particles within it. However, similar patterns are found elsewhere on the Scotian Shelf, *e.g.* the clockwise gyre around Browns Bank, the Western Bank gyre, the retention areas over Emerald and Western Banks. Low-frequency current variability in the Gully is comparable to that observed in nearby regions and for the Scotian Shelf as a whole. Barotropic tides behave regularly. There is some evidence in Batfish surveys and in the temperature variability from fixed sensors that internal tides and internal wave activity at the mouth the Gully may be enhanced. This could lead to greater vertical mixing in the Gully with implications for nutrient exchange (i.e. greater supply to surface waters) and consequently for primary productivity (i.e. increased localized productivity). However, a comparison of the long-term mean profiles of density indicates very little difference among those from the Gully and from four surrounding areas. This may indicate that either the internal wave activity seen in the Gully surveys extends into the adjacent areas, or that enhanced mixing, driven by internal wave breaking and dissipation, is highly localized within the Gully. Thus, the broad averaging of monthly density profiles may have hidden localized mixing hot spots.

There are no data on chemical contaminants within the Gully. However, extrapolation of data from adjacent areas suggest that elevated concentrations of any of the common contaminants would not be anticipated in the water, sediments, or biota of the Gully. There are adequate measurements of nutrient and oxygen concentrations in the Gully to calculate monthly mean concentrations for these variables. The general picture of monthly nutrient distributions averaged over the entire Gully is very similar to analogous descriptions for adjacent areas. However, there are not enough data for an assessment of nutrient variability on smaller time or space scales. For example, there is no indication in the dataset of localized, elevated surface nutrient levels resulting from enhanced mixing in the Gully as some of the physical oceanographic data suggest. Mixing may be no greater in the Gully than in the adjacent regions of the shelf, or it may be occurring on small time and space scales that were missed with the limited data coverage, or surface nutrients may be rapidly removed by biological uptake. Low frequency processes (caused primarily by meteorological forcing) contribute to the onshore-offshore exchange of heat and salt through the Gully. Calculations based on current meter data and source water nutrient concentrations indicate that nutrient transport through the Gully could make a significant contribution to the eastern Scotian Shelf during summer; in winter, transport from the Gulf of St. Lawrence dominates.

Information Gaps:

- There has not been a systematic array of current meter moorings or surface drifter releases in the Gully. Consequently, circulation models of the Gully are based on relatively few observational data and are therefore subject to relatively large uncertainties; oceanographic data are lacking, in particular, for the deeper areas of the Gully.
- Data on chemical contaminants (in water, sediments and organisms) in the Gully region are lacking.
- Knowledge of high frequency mixing processes occurring on small spatial scales and their importance for nutrient flux and productivity in the Gully is lacking.

Biological Oceanography - Plankton

Description: Analysis of phytoplankton, zooplankton and ichthyoplankton data from historical Scotian Shelf Ichthyoplankton Program (SSIP) surveys (1978-82), more recent research on the Scotian Shelf, acoustics backscatter and satellite ocean colour data are described.

The seasonal cycle of phytoplankton in the Gully region follows the pattern seen shelf-wide and observed in north temperate coastal waters in general; low biomass levels are observed during winter (due to light-limitation of growth) and summer (due to nutrient-limitation of growth) and biomass maxima occur in spring and fall (optimal light-nutrient conditions). Analysis of the available data does not support the suggestion that the Gully is a uniquely productive feature on the Scotian Shelf. Limited observational data do, however, suggest that high frequency events may result in localized enhancement of phytoplankton abundance in the Gully, a feature that is missed with the conventional coarse-scale sampling carried out in the past.

The zooplankton seasonal cycle in the Gully, likewise, is similar to that of the Scotian Shelf in general. The available data analyzed to date do not support the idea that mesozooplankton are especially abundant in the Gully compared with other deep water areas of the Scotian Shelf. Because it is an area of deep water, however, it does harbour overwintering populations of *C. finmarchicus* at depths of >200 m and krill, which spend the daylight hours at depths of >200 m and the night-time hours in the near surface layers. In the case of the macroplankton (krill), it is unclear whether concentrations in the Gully are generally higher than those in other Basins on the Scotian Shelf or along the Shelf break. It cannot be determined from the existing data whether the Gully is an area of intrusion of the very abundant off-shore population of *C. finmarchicus* on to the Shelf in spring, as is the case further to the south and west in the area of the Halifax section. If it is, then it may provide an important source of copepods for Sable Island and Western Banks in spring. Overall, plankton dynamics in the Gully exhibit features which are characteristic of both shelf basin and shelf break habitats.

Information Gaps:

- Existing data are neither spatially nor temporally resolved sufficiently to assess the importance of some of the mesoscale (i.e. spring and fall "blooms") and small scale processes that determine the region's plankton distribution and productivity.
- The trophic links between locally produced plankton and the benthos, fish and mammals of the Gully have not been established.

Benthos

Description: The sedimentary interface fauna (benthos) of the Scotian Shelf is poorly known and existing studies have been directed to specific regions or aspects of the benthic community rather than to broad surveys. There is no general information on the distribution of benthic organisms or benthic community structure for the Gully region. Based on a recent video survey in the region and research done in other submarine canyons on the North Atlantic continental margin, however, a general picture of the composition, structure and vertical zonation of benthic communities in the Gully region can be hypothesized. Clear from studies in analogous regions is the observation that ***the diversity of species and their abundance is generally significantly greater in submarine canyons than adjacent continental slope waters*** and that this can be related directly to the richness and variety of habitats found in regions characterized by strong horizontal gradients in bathymetry (steep slopes) and surficial geology.

An analysis has also been made of the distribution and diversity of deep sea horny and stony corals along the Scotian Shelf and within the Gully, based on data gathered from interviews with fisherman and scientists together with the study of museum collections and review of the scientific literature. From the coral survey it would appear that half of the 20 species of deep sea corals reported from Nova Scotia waters occur in the area of the Gully and the adjacent continental slope. This is a typical assemblage of species and no "rare" species occur. The corals are recognized as an important part of the benthic biota of the Gully.

Information Gaps:

- Quantitative information (distribution, abundance, community composition and structure, biology and ecology) is lacking on all components of the benthic community in the Gully and adjacent shelf and slope regions.
- Information on the fate of pelagic production and its role in supporting the Gully's benthic communities, i.e. benthic/pelagic coupling, is lacking.
- Information necessary to establish the relationship between habitat (bathymetry/surficial geology) and benthic community structure and biodiversity is lacking.

Fish and Fisheries

Description: A description of finfish and invertebrates on the Scotian Shelf is given, largely based on DFO trawl survey data from 1970-1993. Analyses compare the distribution and abundance of groundfish, pelagics and invertebrates in the Gully and surrounding Eastern Scotian Shelf and slope regions.

SSIP samples were examined to determine the importance of the Gully as a spawning area for marine fish. Twelve species of fish eggs and nearly thirty species of larvae were encountered in the Gully. Of these, silver hake was the most abundant, followed by pollock, American Plaice and cod (eggs) or sandlance, windowpane flounder and cod (larvae). Given the abundance of silver hake eggs and larvae in the region, it is reasonable to conclude that the Gully was an important spawning area for this species at the time these samples were collected (1978-82). The shelf-wide significance of the Gully as a spawning site for this and other species in more recent years, however, is not known since sample analyses were confined to only a few localized stations and were carried out more than a decade ago.

Based on these analyses, it is concluded that ***the Gully and adjacent waters are areas of relatively high demersal finfish diversity relative to the eastern Scotian Shelf as a whole***. There is no evidence for any endemic demersal species of fish, however, given the low sampling rate and the potentially low efficiency of the trawl in areas of rapid changes in bathymetry such as occur in the area, this does not rule out the possibility that such species occur.

The slope area of the Gully, as is the case for the Scotian Slope in general, is an area of faunal boundaries. The upper reaches of the slope (less than 360 m) represent the lower boundaries of distribution for the shelf dwelling species and the upper limits for those species which are truly slope dwellers. The slope itself down to depths of about 900 m has it's own ichthyofauna. Beyond these depths the demersal fish fauna changes again to represent that of the lower slope and abyssal rise. It is difficult to draw conclusions about the uniqueness of the fish occurring in the slope waters of the Gully given the relative paucity of like data from other areas suitable for comparison.

The Gully area does not appear to be important for shelf dwelling pelagic species although these do occur there as migrants. The pelagic species occurring over the shelf slope and abyssal plain adjacent to the Gully are numerous (>200). Given the broad geographic distributions of many of these species, it is unlikely that any are unique to the Gully.

The Gully is an area of high density for redfish, squid, cod, witch flounder, white hake, and longfin hake, relative to the remainder of the eastern Scotian Shelf. The top nine species of demersal fish occurring in the Gully can be split into those whose dynamics are relatively similar to those demonstrated by that species elsewhere on the eastern Scotian Shelf (redfish, squid and witch flounder) and those whose dynamics show different patterns in the Gully relative to the eastern shelf (American Plaice, haddock, cod, silver hake, white hake and pollock). The underlying causes of the different dynamics in these areas has not been investigated.

Although at present the fisheries on the Eastern Scotian Shelf are severely restricted relative to the recent past, the Gully continues to be an actively fished area. Longline effort directed at Atlantic halibut and White hake is presently the most common. In the past there has also been significant trawler effort in both the Gully and the adjacent slope waters.

Squid is the only active commercial fishery for invertebrates in the Gully trough (>200 m) but there are several other fisheries in the surrounding area (clams, scallops, snow crab, shrimp). There is potential for future expansion of existing fisheries to the Gully (*e.g.* snow crab, shrimp) as well as some new benthic fisheries (*e.g.* stone crab). There are no data that suggest the Gully is of special significance to the populations of any benthic invertebrate species, but data on shelfwide distribution of most species is currently not available.

<u>Information Gaps:</u>

- Contemporary data, particularly on ichthyoplankton distribution, is lacking.
- Information on the seasonal distribution of finfish in lacking, particularly outside the summer survey periods.
- Complete distributional data on red crab, stone crab, lobster, other crustaceans are lacking; a possible source of information is the groundfish survey database, but invertebrate species records are not complete.
- Information on the extent of movement between the Gully and the rest of the Scotian Shelf (most finfish and invertebrate species) is lacking.
- Information on the recruitment links between the Gully and the rest of the Scotian Shelf (most finfish and invertebrate species) is lacking.
- Information on interactions with other species is lacking.

Seabirds

Description: A description is given of the species making up the western Atlantic pelagic avifauna, derived principally from the PIROP database of CWS which is comprised of 25 years of observational data from ships and more recent studies.

The high variability of seabird distributional data make it difficult, with the data available, to detect small, local anomalies of distribution. Highest concentrations of pelagic birds are found along the shelf edge and in the turbulence and mixing zones where currents round major headlands: East Point in P.E.I. and Cape North in the Cabot Strait, for instance. High seabird numbers also occur predictably in the areas of mixing between Sable Island and the mainland generated by the Sable Island gyre.

The PIROP database unfortunately contains few observations made in the area of the Gully, but the few data that are available do not show any unusual enhancement of seabird numbers in the area. Researchers recently conducted a series of summertime seabird surveys in the Gully region and noted that when compared with the rest of the Scotian Shelf some species appeared less abundant, and others: Greater Shearwaters and petrels for instance, appeared to be slightly more abundant. However, the data available for comparison were taken from the PIROP database gathered more than a decade previously and interannual variations in the numbers of these southern migrants may well account for the small differences observed. Furthermore the comparison was with data for the shelf as a whole rather than the adjacent shelf edge, and pelagic seabirds are generally more abundant near the shelf edge.

Based on the poor spatial/temporal resolution of available data on pelagic seabird distributions off eastern Canada, there is not enough evidence to assess whether submarine canyons *per se* have any major effect on seabird distributions.

Information Gaps:

- There is a general lack of information on seabird distributions: (1) in the Gully region, particularly in the winter season and (2) contemporaneous with observations along the adjacent shelf edge.
- Information on the functional links between seabirds and marine mammal distributions/aggregations and other components of the marine foodweb in the Gully is lacking.

Marine Mammals

Description: A detailed account is given of existing information on the two principal orders of marine mammals (and the only two on the Scotian Shelf); whales/dolphins (cetaceans) and seals (pinnipeds). Included are descriptions of the area, data sources and a summaries for each species of habitat preference, temporal use of area, approximate numbers and significance of the Gully to the animals.

Available evidence strongly suggests that ***the Gully/Sable Island area is the most important habitat for both cetaceans and pinnipeds on the Scotian Shelf.*** The longest and most productive pinniped research programme anywhere in the world occurs in this area, as well as the only long-term study of a beaked whale species. The area is notable for (1) high diversity of cetaceans (8-13 common species), (2) a high density of cetaceans in the Gully canyon. Densities of most species of Cetacea are considerably higher in the Gully than on other parts of the eastern Scotian Shelf, and large whale density is higher in the Gully than elsewhere along the edge of the Scotian Shelf (including the entrance of the Fundian Channel), and (3) a high density of grey seals breeding on Sable Island.

In addition, the Gully/Sable area is of particular significance (within a Canadian context) for (1) Grey seals, (2) Harbour seals, (3) Northern bottlenose whales, (4) Sperm whales, (5) Striped dolphins, (6) Atlantic white-sided dolphins and (7) Short-beaked common dolphins.

The most significant marine mammal habitat within the area for pinnipeds is Sable Island and surrounding waters and for cetaceans is the deep canyon and northern basin of the Gully (>200m in depth).

Information Gaps:

- Data on at-sea distribution of pinnipeds are lacking.
- Data on cetacean distribution in the Gully outside the summer months are lacking.
- Information on how cetaceans use the Gully area is lacking.
- Data on the acoustic ambient noise within the Gully and its influence on the behavior of local marine mammal populations are lacking.

Ecosystem Classification Methods

Two ecosystem classification approaches are described. One approach is based on an objective hierarchical system of identifying enduring and recurrent oceanographic and physiographic features of the marine environment. The structure of this classification system consists of six levels leading to the delineation of marine representative units (MRUs). The second approach employs similar principles by defining submarine landscape elements using biophysical properties. This latter approach has been applied to the Scotian Shelf and is described in the recently revised edition of, *The Natural History of Nova Scotia*; the former approach is currently being tested on the Scotian Shelf.

Ecological classification is a "top-down" approach, providing a systematic and efficient means of characterizing ecosystems over a broad range of spatio-temporal scales. This approach is currently being used to describe the Gully in the context of the greater Scotian Shelf system.

General Conclusions

The Science Review has assessed the state of knowledge of the environment and ecosystems of the Gully region. With the exception of cetacean studies, the Gully has not been a region of directed research. Consequently, the available information and level of understanding of processes that characterize the Gully vary considerably. Aside from specific absence of data on certain components of the Gully environment (*e.g.* acoustic ambient noise, benthos), much of the available data lacks spatial/temporal resolution for delineating features distinctive to the Gully. Moreover, much of the biological data collection dates back a decade or longer and might not accurately represent present conditions. These deficiencies, however, are not confined to the Gully but reflect the general availability (or lack) of data and level of understanding we have for our continental shelf ecosystems. Despite these shortcomings, sufficient information exists to define the major processes and linkages which characterize the Gully and other submarine canyons.

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1.0 Geographical Setting and Conservation Efforts

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1.0.1 Geographical Setting

The Gully is the general term given to the area approximately 40 kilometres east of Sable Island (200 km off Nova Scotia), on the eastern Scotian Shelf. Fig. 1.0.1 provides a map of the eastern Scotian Shelf and the location of the Gully. A deep canyon feature with depths over 2000m, the Gully separates Banquereau Bank and Sable Bank. The Gully can be divided into two general areas: i) the trough and ii) the canyon (see Fig. 1.0.2). The *trough* is a wide (30 km x 70 km) and relatively shallow basin feature on the northern portion of the canyon, linking the feature with the inner shelf. The *canyon* section is a narrower feature (10 km x 40 km) extending into the continental slope, and is characterised by steep sides to a depth of over 2000m.

1.0.2 Conservation Efforts in the Gully

The uniqueness of a large canyon feature on the Scotian Shelf, and the suspected biological significance of the area has attracted the interest of a wide range of government agencies, researchers, and conservationists. The Gully was designated by DFO as a 'Whale Sanctuary' in 1995 in an effort to reduce ship collisions and noise disturbance with whales in the area (see Fig. 1.0.2). A Notice to Mariners outlining guidelines for vessel activity in the presence of whales has been widely distributed (DFO, 1996). Compliance with these guidelines is voluntary.

Canadian Heritage (Parks Canada) identified a large area (Fig. 1.0.2), encompassing both the Gully and the Sable Island regions, as one of three National Areas of Canadian Significance (NACS) in a study to identify a National Marine Park on the Scotian Shelf (P. Lane and Associates, 1992). The biological, physical, and historical significance of the overall region resulted in a high ranking for the area as a potential protected area. The potential user conflicts with existing and proposed oil and gas activities, shipping, fisheries, and its inability to provide any significant visitor opportunities, were identified as limitations with the site.

Environment Canada (Canadian Wildlife Service) organised a workshop on conservation issues in the Gully in 1994 (CWS, 1994). Those attending the meeting included relevant federal agencies and Dalhousie University. The workshop concluded with the following main points:

1. the Gully is biologically significant;

2. current conservation strategies are inadequate to protect the significant biological resources; and,
3. there is a need for an overall conservation strategy for the area.

A Discussion Paper outlining the main issues to be addressed in the development of a conservation strategy for the area resulted (CWS, 1995).

The Sable Offshore Energy Project (SOEP) is located to the west of the Gully (Fig. 1.0.2). The Gully was identified as a 'unique ecological site' and 'valued ecosystem component' in the SOEP Environmental Impact Statement (SOEP, 1996). The SOEP Joint Review Panel Report identified a number of concerns regarding the potential impacts of the project and future developments on the Gully area (SOEP Joint Review Panel, 1997). The Panel recommends that prior to regulatory approval, SOEP submit its Code of Practice outlining protection measures in the Gully as part of their final Environmental Protection Plan (Recommendation 11). As well, the Panel recommends that SOEP begin or contribute to research activities in the Gully that will provide the baseline data for Environmental Effects Monitoring programs (Recommendation 9). In turn, this data will assist in determining the impact of the project and further resource developments on the Gully.

The World Wildlife Fund (WWF) has identified the Gully as a potential site for a protected area as part of their Endangered Spaces Campaign (WWF, 1997). The WWF recently produced a report which details the biophysical characteristics and some of the related management issues for the area (Shackell *et. al.*, 1996).

1.0.3 Developing a Conservation Strategy for the Gully

Building upon the efforts of the Canadian Wildlife Service, a *Gully Conservation Strategy* will be developed and co-ordinated by DFO. The objective of the *Conservation Strategy* is to:

> *identify and address conservation and management issues of the Gully in an open and transparent planning process.*

The *Conservation Strategy* will provide a opportunity to review the CWS Discussion Paper, update its conclusions and recommendations, and build consensus with a broad stakeholder community on the future conservation actions. The development of the *Conservation Strategy* will coincide the efforts of other groups and studies and will to take into consideration these findings.

The *Conservation Strategy* is divided into three distinct, but interconnected phases (see flow-chart below). A staged approach will be taken with the goal of developing an information base and building consensus with stakeholders prior to moving onto further phases.

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The first phase is composed of the Gully Science Review to provide the most current knowledge on the biological and physical processes in the Gully. The Review will provide an initial indication of the key resources and related conservation issues of the area. The second phase involves developing the conservation principles and objectives for the Gully. Once identified, the range of management measures and options required to meet these objectives can be explored. The third phase involves developing and assembling the *Conservation Strategy* document. Once the *Conservation Strategy* is finalised an implementation team will be assembled to fulfil its objectives.

1.0.4 References and Additional Reading

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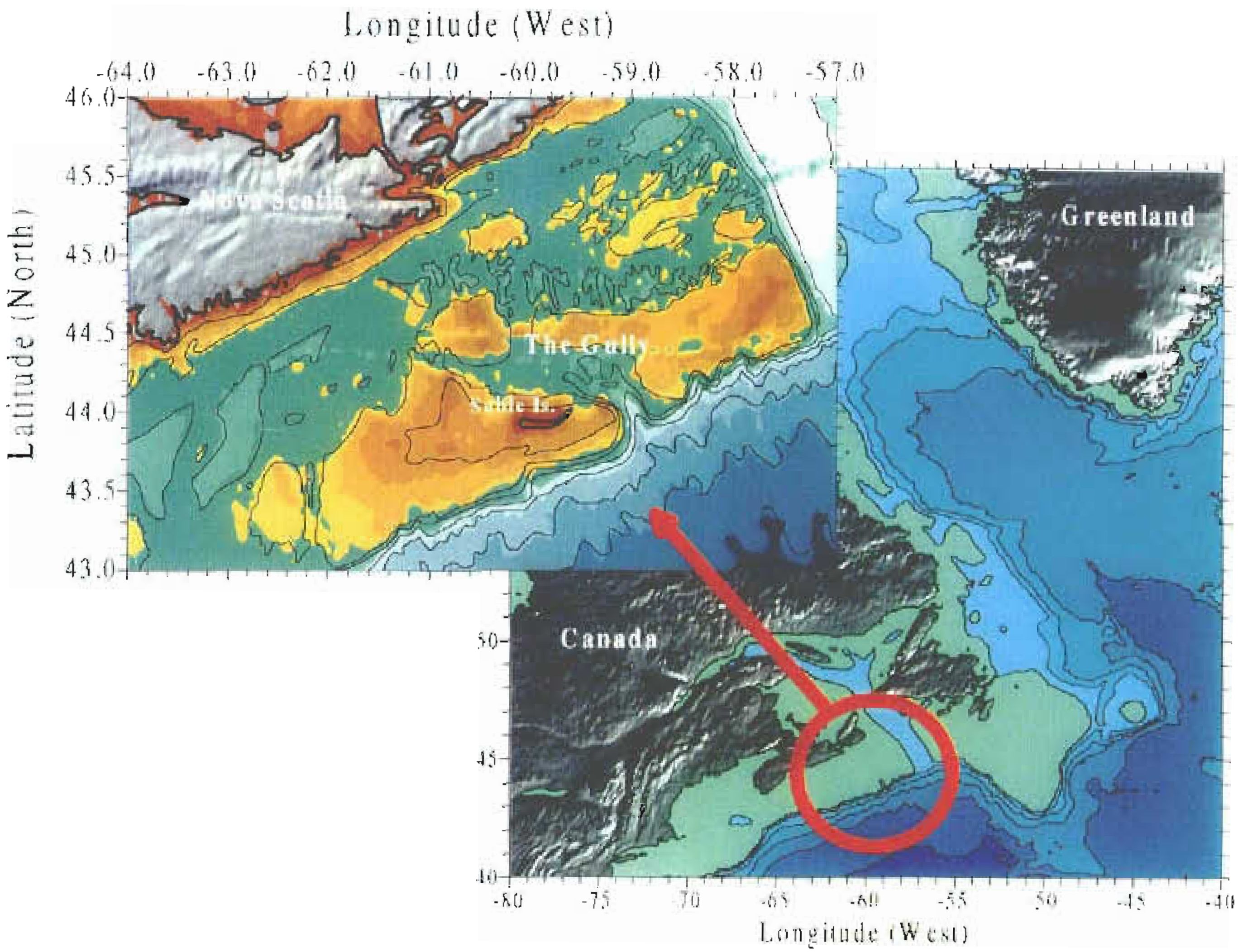

Fig. 1.0.1. The Gully: a deep submarine canyon approximately 40 kilometres east of Sable Island (200 km off Nova Scotia), on the eastern Scotian Shelf.

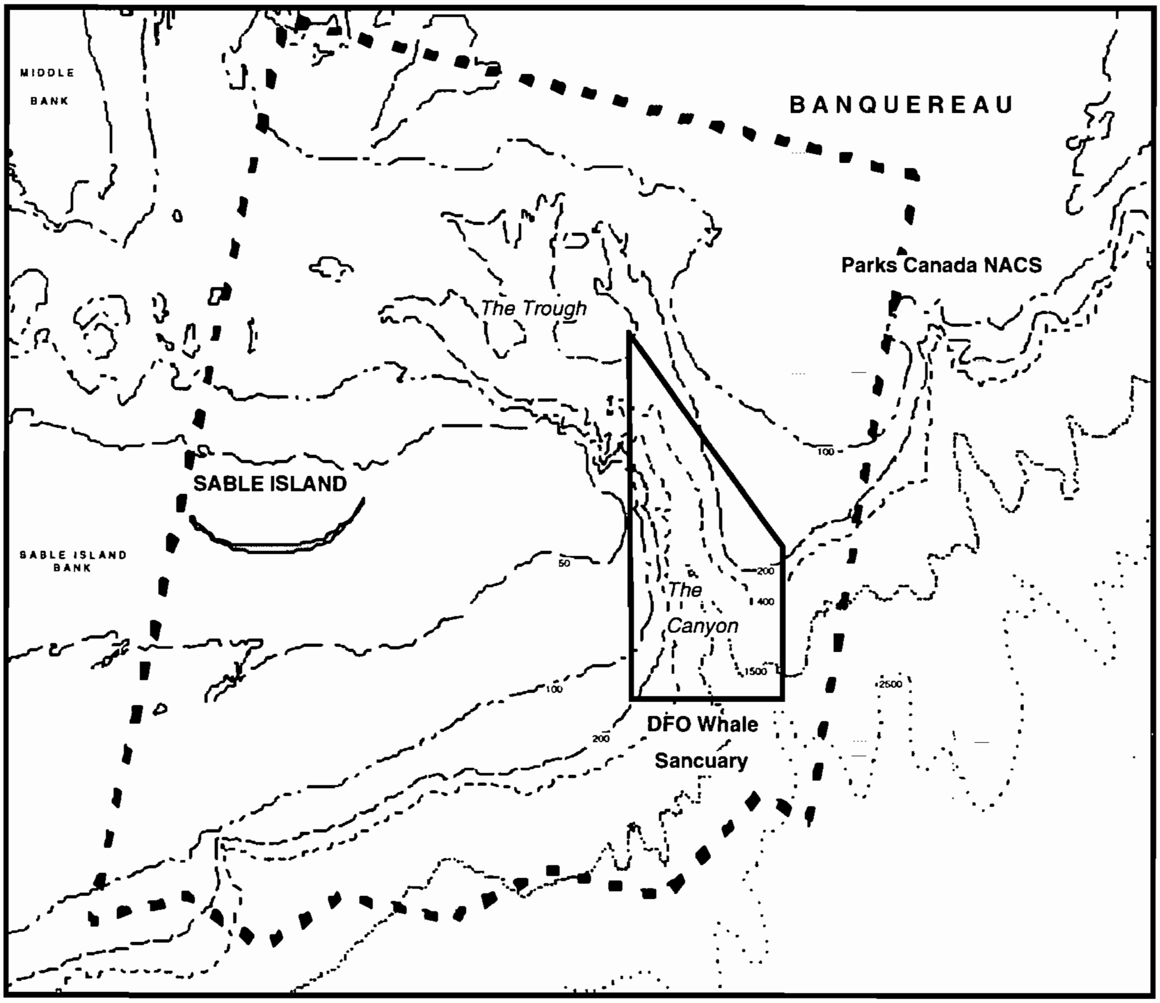

Fig. 1.0.2. The Gully. Source: Habitat Management Division, P. Lane and Associates Limited (1992), DFO (1996). The solid line depicts DFO Whale Sanctuary boundaries, dashed line depicts Parks Canada's NACS boundaries.

2.0 The Science Review

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2.0.1 Background

In May 1997, DFO Headquarters requested that Maritimes Region initiate a coordinated review of the Gully that would build upon the 1994 CWS sponsored Workshop and Discussion Paper, "Towards a Conservation Strategy for the Gully near Sable Island, N.S." (see Section 1.0). This review was to constitute a summary of the state of our knowledge of the Gully region which would be subjected to the Regional Advisory Process (RAP) and developed into a DFO Research Document. Ocean Science Division, DFO was asked to lead this review, drawing on local expertise to provide a broad and comprehensive scientific review of the region. A number of meetings were held in June from which a list of subject areas and designated experts were chosen to carry out the review (Table 2.01). The strategy chosen was to recruit a team composed of government and NGO experts since is was recognized that DFO did not have the capability to carry out such a broad review in-house.

Table 2.0.1. Gully Science Review Team Leaders.

Discipline	Team Member	Affiliation
Coordination	G. Harrsion	DFO-OSD
Conservation Strategy	D. Fenton	DFO-OACO
Geosciences	G. Fader	NRCan-GSC
Hydrography	G. Rockwell	DFO-CHS
Physical Oceanography	B. Petrie	DFO-OSD
Chemical Oceanography	P. Yeats	DFO-MESD
Biological Oceanography	E. Head	DFO-OSD
	G. Harding	DFO-MESD
Benthos	D. Wildish	DFO-MESD
	H. Breeze	Ecology Action Centre
Fish and Fisheries	K. Zwanenburg	DFO-MFD
	J. Tremblay	DFO-IFD
Seabirds	T. Lock	DOE-CWS
Marine Mammals	H. Whitehead	Dalhousie University
Ecosystem Classification	I. Milewski	WWF
	D. Davis	NS Museum

OSD (Ocean Sciences Division), OACO (Oceans Act Coordinating Office), GSC (Geological Survey of Canada), CHS (Canadian Hydrographic Service), MESD (Marine Environmental Sciences Division), MFD (Marine Fish Division), IFD (Invertebrate Fisheries Division), CWS (Canadian Wildlife Service), WWF (World Wildlife Fund).

The first meeting of the Review Team was held in July to define the scope of the review and to develop a timetable for its completion. An outline of the proposed Gully Science Review was presented shortly afterwards at a DFO-organized meeting of stakeholders (*e.g.* fisheries, petroleum industry representatives, environmental groups) where an invitation was given for broader participation in the review. Two subsequent meetings were held (September and October) to assess the status of the review components, to evaluate and discuss findings and to provide instructions for the written reports and the RAP. Final reports of all components of the review were received by early December and evaluated by external reviewers, team members and stakeholders during the 2-day RAP meetings held in February. On the basis of comments tabled during the RAP, the Gully Science Review was revised and published as a DFO Canadian Stock Assessment Secretariat Research Document. The entire process from initial planning to final document publication took nearly a year to complete.

2.0.2 Principles of the Gully Science Review

The basis for a sound conservation strategy starts with an assessment of what we know about the ecosystem and environment of the region of interest (Section 1.0). The Gully Science Review was produced to:

> ***provide a description of the environment and ecosystem(s) of the Gully and surrounding area and to frame this information in the context of the greater Scotian Shelf system.***

To address this objective, the Gully Review Team was asked to base its analysis on the following principles:

- The review will be coordinated by DFO but will include other Federal departments and experts from outside government (NGOs), using the available regional expertise.
- The review will be as comprehensive as possible (within the timeframe allocated), including an up-to-date bibliography.
- The review will incorporate unpublished research data to the extent possible.
- The review will identify knowledge gaps.
- Where no information exists, the review will draw on information from analogous (but better described) regions.

3.0 Surficial, Bedrock Geology, and Morphology

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3.0.1 Introduction

The Gully is a large shelf edge canyon on the eastern Scotian Shelf, separating Sable Island Bank from Banquereau. It is unique among canyons of the Eastern Canadian margin because of its great depth, steep slopes and extension far back on the continental shelf. From a physiographic perspective, the Gully can be divided into three regions: 1) a deep water southeastern part of the canyon incised into the continental slope to approximately 2000 m water depth; 2) a zone between Sable Island Bank and Banquereau with depths ranging between 300 m and 1600 m; and 3) a north and northwestern zone that extends for over 100 km to Middle Bank.

3.0.2 Bathymetric Morphology

An artificially shaded and depth colour-coded digital terrain model (Loncarevic *et al.* 1992, Fig. 5) provides the most graphic rendering of the bathymetry of the area. It is based on digital bathymetric data collected by the Canadian Hydrographic Service. The data covers areas of the Gully to approximately 800 m water depth and the image illustrates the morphologic relationship with the surrounding banks and connections to the north and west. The horizontal resolution of this image is approximately 400 m. Lisa Sankeralli of the University of Alberta is presently studying the origin of the morphology of the eastern Scotian Shelf, including the Gully area, as part of an M.Sc. thesis, and has reprocessed the bathymetric data (Fig. 3.0.1) for higher resolution (200 m).

3.0.3 Bedrock Geology

The regional bedrock geology of the area was first mapped by King and MacLean (1976). The Scotian Shelf Volume of the East Coast Basin Atlas Series of the Geological Survey of Canada contains a series of maps on the bedrock, surficial sediments, sediment transport, seabed and subsurface features, geotechnical sediment properties and continental slope sediments. The Gully and the outer edge of the continental shelf are underlain by Tertiary mudstones and sandstones. Within the inner part of the Gully, local salt domes rise through the sedimentary column, bringing Cretaceous sediments to the seabed in association with the diapirism (King and Maclean, 1976). Regional airgun seismic reflection profiles have been collected in the Gully and depict a steep-walled canyon cut into bedrock in the deeper sections and thick surficial materials in the shallower parts. Other V-shaped channels occur buried near the Gully and may be part of an earlier subaerial development that has shifted with time. At various places near the edge of the Scotian Shelf, including the Gully region, buried channels cut into older

Tertiary bedrock are filled with younger Tertiary sediments. Ancestral shelf edge canyons may thus be of considerable antiquity. The Gully, however, remains unique as the only canyon that is so deeply incised today.

3.0.4 The Deep Water Gully

The outer part of The Gully is a southeasterly trending, V-shaped canyon, traceable to about 2000 m water depth on the adjacent continental slope. The canyon is eroded into soft bedrock of shales and thin sandstones and limestones of Oligocene to Pliocene age, with the more resistant rocks forming terraces on the canyon walls. The canyon passes seawards into a deep-sea channel on the continental rise with prominent natural levees. These levees were formed by spillover of powerful turbidity current flows that periodically passed through and eroded the Gully in the past half million years when glacial ice extended across the continental shelf.

3.0.5 The Shallow Water Gully

The middle and inner parts of the Gully are also incised into Tertiary bedrock on the continental shelf, but in most places this bedrock is blanketed by Quaternary sediments forming a southward-thickening wedge up to several hundred metres thick. Deeply buried Quaternary sediments are known from boreholes and seismic reflection profiles on Banquereau and Sable Island Bank. There a thick sequence of alternating sands and muds was deposited, largely in proglacial deltaic environments during the Quaternary ice-ages. This sequence is cut by deeply incised channels that in places extend to 500 m below sea level. The channels are filled with Quaternary sands and gravels (Boyd *et al.*, 1988). Unfilled analogues of these channels are seen clearly in bathymetric maps of the area around Misaine Bank, north of Banquereau (Loncarevic *et al.* 1992, Fig. 1).

3.0.6 Surficial Geology

The surficial geology of the inner portion of the Gully and the surrounding banks was mapped by MacLean and King (1971), as part of a study based on echograms, airgun seismic reflection data and seabed samples. A summary of the regional surficial geology of the Scotian Shelf is provided in Fig. 3.0.2 (King and Fader, 1986). Till and glaciomarine sediments occur in the subsurface overlying Tertiary bedrock in the Gully. These sediments in turn are overlain by the thin Sambro Sand formation, a silty sand, and patches of LaHave Clay, a Holocene mud deposit. The glaciomarine Emerald Silt, a gravelly sandy mud, outcrops in several areas of the western extension of the Gully. It is widespread in the subsurface beneath thin Sambro Sand and LaHave Clay. Several terrace-like features (Fig. 3.0.1) occur at a variety of depths on both Sable Island Bank and Banquereau adjacent to the Gully. They may relate to the deposition of sediment at the position of former sea levels or may be eroded features formed at resistant geological horizons. There appears to have been little Holocene sedimentation in the inner Gully and the present seabed distribution of sediments largely relates to deposition from Wisconsinan ice and a low sea level stand that occurred at the end of the last ice age approximately 18,000 years ago at a depth of between 100 and 120 m. Amos (1989) observed terraces from a submersible dive to the seabed in these areas and interpreted their origin to a low sea level stand.

3.0.7 Sediment Transport

Bathymetric images (Fig. 3.0.1) show four small canyons on eastern Sable Island Bank, east of Sable Island, which may provide sediment pathways for material to move off the bank into the Gully. Seismic reflection profiles, however, suggest that little sediment is transferred from the adjacent banks to the inner Gully. Amos and Nadeau (1988) has suggested that an oceanographic condition termed a "hydraulic fence" occurs around the flank of Sable Island Bank, preventing the large scale transfer of sandy sediments from the bank to the adjacent basins. The hydraulic fence appears to trap sand on the tops of banks where the transport is restricted to the near bed region. Fine-grained sediments, which move in suspension, can by pass the hydraulic fence and move into deeper waters adjacent to the banks to form the LaHave Clay. Amos (1989) has also identified small slumps in the central part of the Gully suggesting recent active processes of slope failure on its flanks. The nature of the floor of the Gully is not known directly, but it probably consists of sands or gravels scoured by tidally-influenced currents, based on analogy with better known areas of the Laurentian Fan and channels near the Albatross well location. Hydraulic clam harvesting takes place on Banquereau, directly north of the Gully. This activity liquifies fine-grained sand, putting it into suspension, and making it more readily available under storm conditions for transport off the bank and into the Gully.

3.0.8 Origin of the Gully

Little has been published on the origin of the Gully and previous geoscience surveys have not been systematic. However, most marine geologists agree that it likely formed as the result of a combination of fluvial, glacial ice, and glacial meltwater erosion. The presence of the buried V-shaped channels suggests that the precursor of the Gully formed in preglacial environments as a result of fluvial erosion across an emerged early Scotian Shelf. However, repeated glaciations of the past half million years, with erosion by glaciers and subglacial meltwater, are generally interpreted to be the dominant processes which developed the complex morphology of the entire eastern Scotian Shelf including the Gully. The Gully is intimately connected with this geomorphic development and represents a shelf edge seaward outlet for drainage from both ice and water. Interpretation of deep water cores (Piper and Normark, 1989 and Piper *et al.*, 1994) suggests that the most powerful erosion took place 150,000 and 450,000 years ago.

3.0.9 Mineral Potential

The Gully is located close to the oil and gas fields of Sable Island Bank. The mineral potential of the surficial sediments of the Gully is considered to be low. Aggregate and silica sand deposits exist on the bank areas surrounding the Gully, especially on Banquereau and Middle Bank. The inner Gully has little potential for marine minerals as the sediments are largely till and glaciomarine mud, and the presence of minerals has been diluted by glacial processes of erosion and deposition (Fader and Miller, 1996).

3.0.10 Geoscience Needs

Existing geoscience information from the Gully is limited and patchy. Numerous petroleum-industry seismic reflection surveys cross the outer part of the Gully have been carried out, but high-resolution seismic reflection and sample data are sparse. Experience with modern surveying geoscience technology in other areas of the Scotian Shelf (Courtney and Fader, 1991), suggests that the collection and presentation of multibeam bathymetry from the Gully would provide a significant advance in morphological characterization, leading to a better understanding of the geological and oceanographic processes operating there. These new multibeam systems have resolutions in the order of metres to decimetres. Follow-up targeted sample, photographic, and other geophysical surveys could then focus on selected sites for both regional and detailed understanding. The unique morphology and geological conditions of the Gully suggest that benthic species may also be unique. This is the result of geological control of aspects of oceanographic currents and seabed habitat. Thus an understanding of the geoscience attributes of the Gully is an essential first step in a biological assessment.

3.0.11 References

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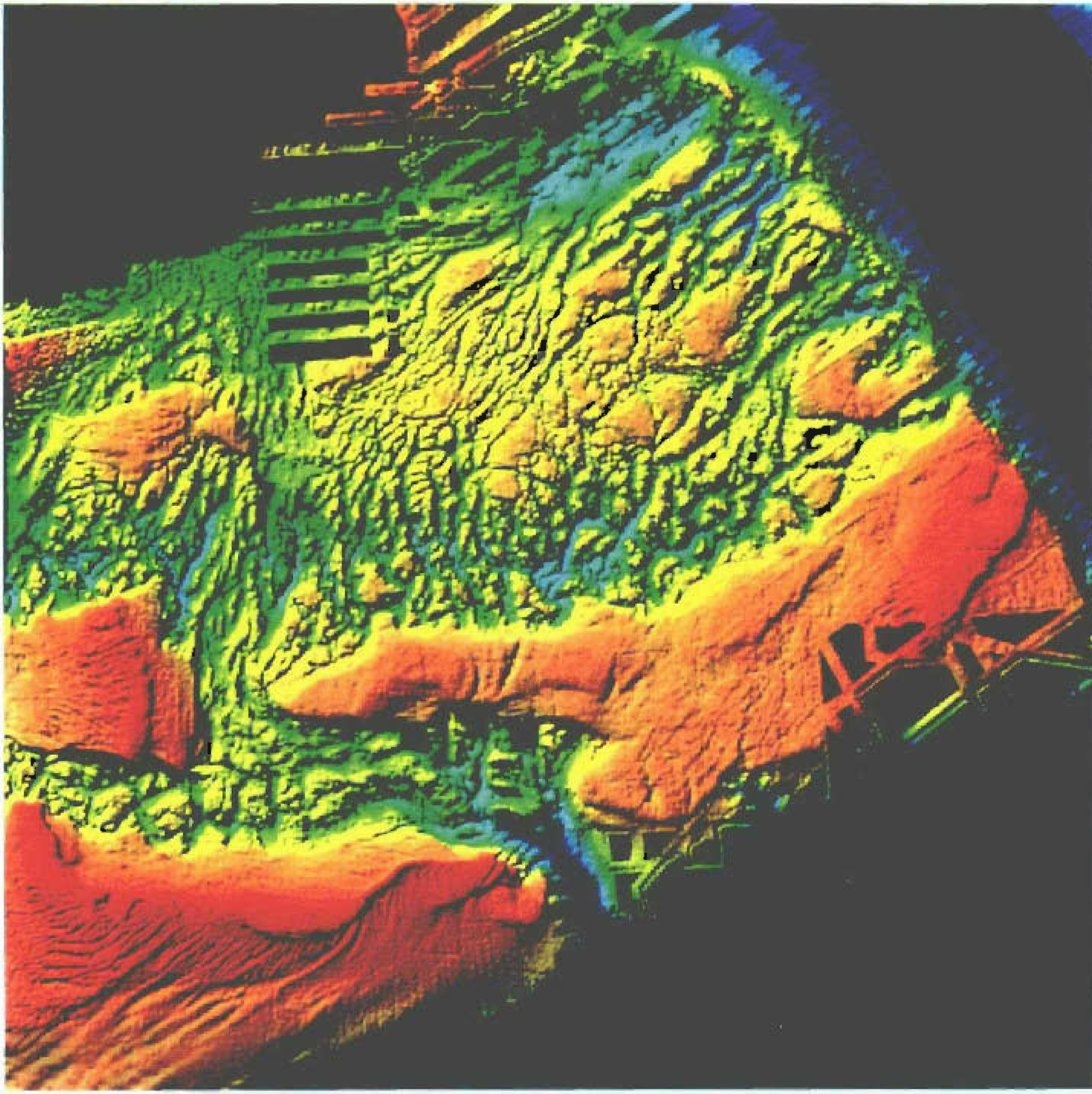

Fig. 3.0.1. A digital terrain model of the morphology of the eastern Scotian Shelf including the Gully. The image was prepared from digital bathymetric data collected by the Canadian Hydrographic Service and is a higher resolution version of a similar image published by Loncarevic et al., 1992. The image has been provided courtesy of Lisa Sankarelli, University of Alberta and the Geological Survey of Canada (Atlantic). Resolution on the image is approximately 200 m.

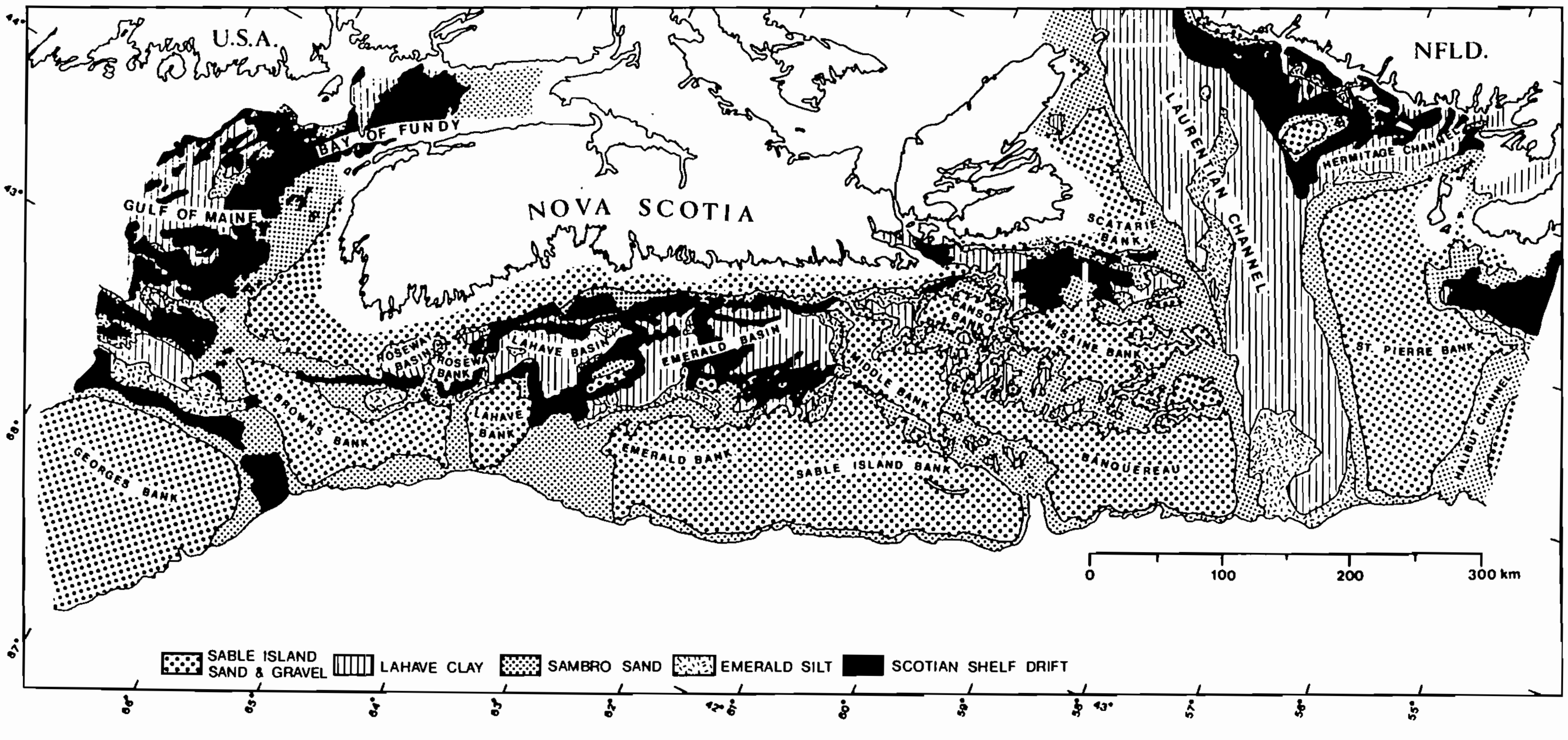

Fig. 3.0.2. The distribution of surficial sediments on the Scotian Shelf (King and Fader, 1986).

4.0 Hydrography

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4.0.1 Introduction

The bathymetric data available for the Gully area is best described as limited. It is adequate to provide basic information for the safety of Navigation but lacks the detail required for scientific study.

The Canadian Hydrographic Service (CHS) maintains a database of bathymetric information for Canadian waters. Existing bathymetry for The Gully consists of single line profiles collected over many years. This data was obtained using a variety of positioning and sounding systems and the reliability of the data is dependent on these systems. The line spacing is approximately 800 metres on the shallower inner portion of The Gully and two (2) to four (4) kilometers in other areas.

4.0.2 Geographical Boundaries

The geographic extent of The Gully is open to discussion. The area now known as "The Gully" officially received its name in 1969. Names are approved by the Advisory Committee for Under Sea and Marine Features, Canadian Permanent Committee on Geographical Names. A feature is a part of the ocean floor that has measurable relief or is delimited by relief; its bathymetric character, extent and position must be accurately established. We must be aware, however, that most oceanic toponyms are not rigorous in terms of spatial boundaries.

The current edition of the Nova Scotia (Atlantic Coast) and Bay of Fundy Sailing Directions contains the most definitive information available. On page 39, it states: "Banquereau is separated from the Sable Island Bank by 'The Gully' which is seven 7 miles wide at its narrowest part and over 500 fathoms (914m) deep at its southern most extremity between Banquereau Bank and Sable Island Bank". The Gully is the largest of the canyon features identified along the Scotian Shelf (Table 4.0.1).

4.0.3 CHS chart coverage in the Gully region

- Chart 4098, Sable Island, at a scale of 1:100k, shows the western portion of the Gully.

- Several small scale "offshore charts" (see below).

- Chart 4045 at a scale of 1:400k. This chart has a good portrayal of The Gully, highlighting the 200 metre contour.

- The area is also portrayed on the bathymetric map 801-A at a scale of 1:1,000,000. See the Atlantic Chart Catalogue, available from CHS, for specific information on charts of the Scotian Shelf.

Canadian Hydrographic Service Field Sheets are the source documents used to construct CHS charts. An index showing the locations of CHS field sheets follows (Fig. 4.0.1). The accompanying table (Table 4.0.2) gives details concerning scale, date of survey, line spacing, positioning systems and geographic extent. This data is available (at nominal cost) by contacting the CHS Hydrographic Data Centre (HDC) at The Bedford Institute of Oceanography (BIO). HDC can also conduct customized data searches.

4.0.4 Summary

The amount of bathymetric data available for The Gully is not adequate to properly study its biological and physical characteristics. This data represents a sampling of less that 1% of the total bottom area. It is now possible, using multibeam sounding systems, to achieve 100% bottom coverage. *At this time (April, 1998), CHS does not have a multi-beam system capable of data collection in depths greater than 1000 metres.*

Table 4.0.1. Approximate dimensions of the major channels and canyons along the Scotian Shelf margin as identified on CHS charts (8005, 8006, 8007, 4045).

Feature	Depth Contour (m)	Mouth (km)	Shelf Penetration (km)
Fundian Channel	200	34.2	-
Verrill Canyon	200	6.5	3.7
Dawson Canyon	200	6.5	5.6
Bonnecamps Canyon	1000	6.5	7.4
Logan Canyon	200	11.1	5.6
THE GULLY	**200**	**16.4**	**70.7**
Shortland Canyon	200	6.5	9.3
Haldimand Canyon	200	6.5	7.4
Laurentian Channel	200	61.0	-

Table 4.0.2. CHS field documents in the Gully area.

Index Colour	Field Sheet	Scale	Year	Line Spacing	Positioning System	Upper Right Corner	Lower Left Corner
Green	9127	1:100,000	1979/85	0.5 nm & 2 nm	Hyperbolic & Rho-Rho Loran-C, Bionav, GPS	45-00N 57-00W	44-00N 58-00W
Green	9132	1:100,000	1979/85	0.5 nm	Hyperbolic & Rho-Rho Loran-C, Bionav, GPS	45-00N 58-00W	44-40N 59-00W
Green	9133	1:100,000	1985	0.5 nm	Hyperbolic Loran-C, GPS	45-00N 59-00W	44-46N 59-27W
Green	9447	1:100,000	1989	1.1 nm	Rho-Rho Loran-C, GPS	43-42N 60-09W	43-17N 61-00W
Blue	4992	1:75,000	1982	0.4 nm & 2 nm	Hi-fix-6 hyperbolic	44-10N 58-56W	43-35N 60-11W
Blue	4993	1:75,000	1982	0.4 nm	Hi-fix-6 hyperbolic	44-32N 60-02W	43-40N 60-55W
Blue	9070	1:75,000	1984	0.4 nm	Hi-fix-6 hyperbolic	45-12N 60-02W	44-32N 60-53W
Blue	9072	1:75,000	1984	0.4 nm	Hi-fix-6 hyperbolic	44-46N 58-52W	44-10N 60-04W
Blue	9073	1:75,000	1985	0.4 nm	Hi-fix-6 hyperbolic	45-17N 59-00W	44-46N 60-02W
Blue	9207	1:75,000	1987	0.4 nm	Hi-fix-6 hyperbolic	44-40N 58-12W	49-09N 58-51W
Blue	9208	1:75,000	1987	0.4 nm	Hi-fix-6 hyperbolic	45-20N 58-12W	44-38N 59-00W
Orange	1000126	1:75,000	1960	2 nm	Decca	45-25N 59-29W	44-39N 60-17W
Orange	1000127	1:75,000	1960	2 nm	Decca	45-25N 58-40W	44-39N 59-28W
Orange	1000128	1:75,000	1960/61	2 nm	Decca	45-25N 57-50W	44-40N 58-39W
Orange	1000137	1:75,000	1960/61	2 nm	Decca	44-39N 59-28W	43-52N 60-15W
Orange	1000138	1:75,000	1960/61	2 nm	Decca	44-39N 58-40N	43-53N 59-27W
Orange	1000139	1:75,000	1960/61	2 nm	Decca	44-40N 57-50W	43-53N 58-39W
Orange	1000140	1:75,000	1960	2 nm	Decca	44-40N 57-00W	43-57N 57-49W
Orange	1000142	1:75,000	1961	2 nm	Decca	43-52N 59-27W	43-07N 60-12W
Orange	1000144	1:75,000	1960/61	2 nm	Decca	43-53N 58-40W	43-25N 58-25W

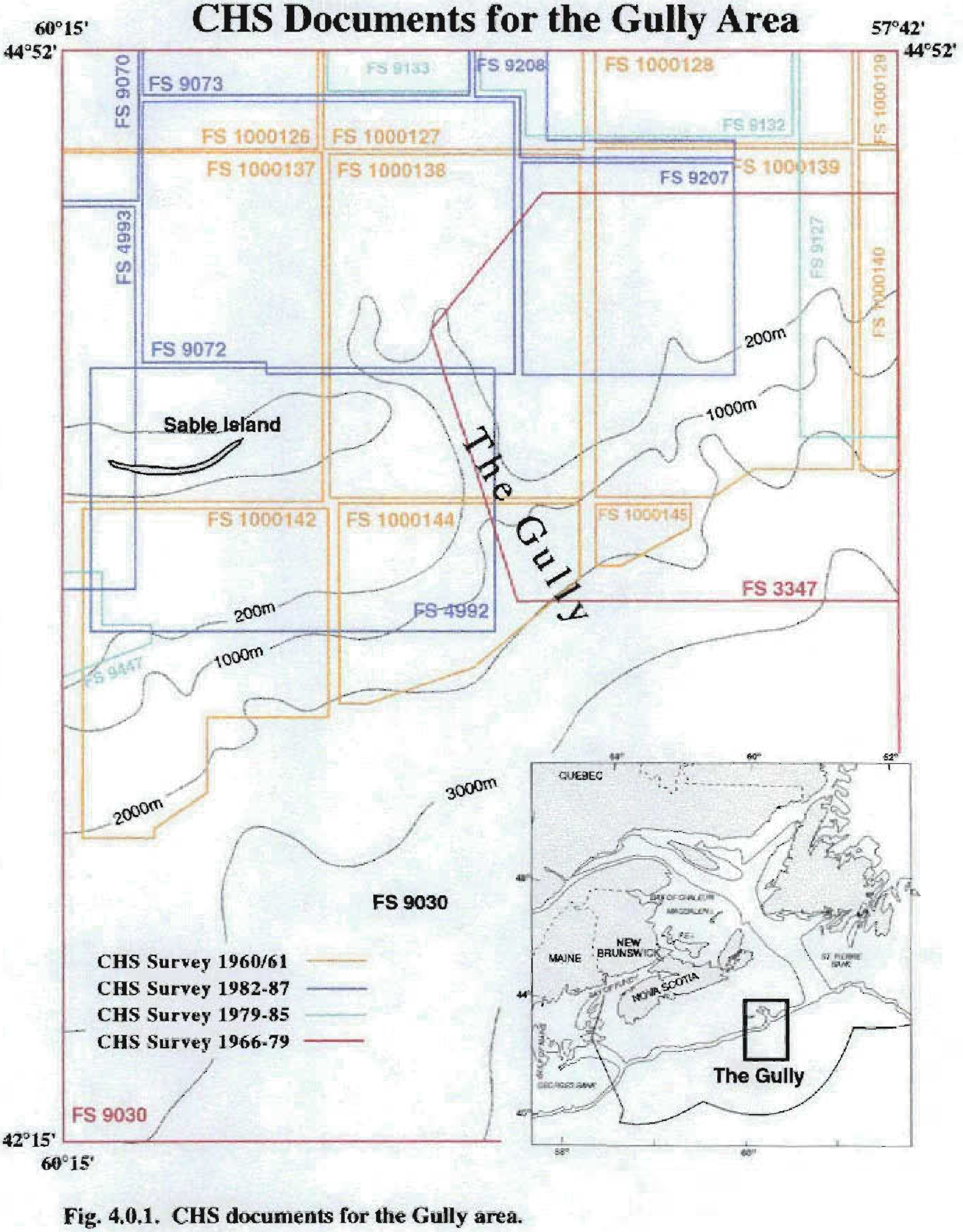

Fig. 4.0.1. CHS documents for the Gully area.

5.0 Acoustic Ambient Noise

5.0.1 Background

The Gully Scientific Review team did not include expertise in underwater acoustics. The review team recognized, however, that information on sources and levels of ambient noise in the region is important (see Section 9.0). Moreover, the SOEP Joint Review Panel recently recommended (Recommendation #9) that an acoustics monitoring program be implemented in the Sable Island-Gully region as part of the proposed Environmental Effects Monitoring Program of the Sable Offshore Energy Project.

We have been in contact with scientists from Defense Research Establishment Atlantic (DREA), Department of National Defence, involved in ocean acoustics research in our region, to determine what information currently exists on ambient noise in and around the Gully. Drs. I. Fraser and D. Chapman were involved in trial studies in the early 90s with one station in the Gully and, according to Dr. Fraser, that station was exceptionally quiet, particularly in the deeper reaches. He also related that the passage of a trawler during the study generated a great deal of noise and concluded that noise levels in the Gully can be as high as anywhere on the Shelf but also quieter than any other place that DREA has measured in the open ocean (at depths sufficient to cut off sound transmission from long distances). Dr. Chapman indicated that the raw data for these experiments are probably available but have not been reduced to a reportable form. He also indicated that a more recent study has been completed; a one-year cycle of ambient noise spectra at 4 eastern shallow water sites, two of which were on the Scotian Shelf, although none were in the Gully *per se*. According to Dr. Chapman, these data could provide a reference frame for future measurements in the Gully. The data were gathered in snapshots once per month, and are typical, although severely undersampled in time. The results of this study are reported in a DREA contractor report. In addition, a brief summary of the work appeared in the proceedings of the recent Oceans '97 conference (Hazen and Desharnais, 1997). Dr. Chapman also mentioned that there is another published study of ambient noise levels (based on DREA historical data) for Canadian North Atlantic coastal waters which summarizes data from 14 cruises carried out between 1972 and 1985 (Zakarauskas *et al.* 1990). The precise locations of stations, however, were not specified in the paper, only geographical averages were given.

5.0.2 References

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6.0 Oceanography

6.1 Physical Oceanography

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6.1.1 Circulation

Observed Currents

The low-frequency water circulation in the Gully region is considered, examining the monthly current maps created from all of the archived data held at Bedford Institute of Oceanography. The majority of these records were collected as a component of the offshore petrochemical exploration activity. Mean current vectors have been constructed from the data regardless of their depth or duration. In the monthly mean current maps that follow, the average duration of a record is 19.4 days with a standard deviation of 10 days. The minimum depth is 2 m, the maximum is 1500 m, the mean 43 m, and the standard deviation is 78 m.

In the northeast portion of the region, currents are generally to the southwest throughout the year with amplitudes of up to 0.15 m/s (Fig. 6.1.1a,b). An exception to this pattern is the east to east-southeast flow seen at the 50 fathom isobath on the eastern flank of the Gully from January to May. At the mouth of the Gully the current appears to be generally towards the southwest from February to August. The instruments there were at depths of 15, 22, 23, 33 and 74 m. The current records from within the Gully show a generally counterclockwise circulation pattern with current speeds generally below 0.1 m/s (see May, June and July in particular). Currents around Sable Island are quite complicated, especially off the eastern tip where the direction of flow changes markedly in a short distance (see March for example). South of Sable Island, the flow is towards the southwest just as it was northeast of the Gully.

The overall picture that emerges for the area is generally a southwestward flow with some counterclockwise circulation along the flanks of the Gully. At the mouth of the Gully there is only a weak inflow indicated by the available data. This inflow is not consistent with the stronger circulation observed within the Gully. However, since the data coverage is sparse, it is possible that, at the mouth of the Gully, a region of stronger inflow was missed.

Modelled Currents

There has been considerable effort in the Coastal Ocean Science section of Bedford Institute of Oceanography (BIO) in the development and application of finite element models (FEM) to circulation problems on the Scotian Shelf. A computational mesh for the eastern half of the Scotian Shelf demonstrates the spatial capabilities of these models, namely, high resolution in areas of rapidly changing depth and of particular concern (Fig. 6.1.2). High vertical resolution is also achieved.

Han *et al.* (1997) have used the measured density structure and the observed wind in a diagnostic FEM model.of the baroclinic circulation on the Scotian Shelf for three periods: the long-term mean January-February (winter), April-May (spring), and July-August (summer) (Fig. 6.1.3a,b,c). A diagnostic calculation is strictly constrained by the density structure that is fixed in time, and by the external forcing. Han *et al.* give a full account of the details of their model. They present the near-surface (average from 5 to 25 m) currents for three seasons. Winter near-surface flows over the Gully are generally to the southwest at about 0.1 m/s; in spring the currents show a greater tendency to form a broad scale (over the Gully and the area east of Sable Island) counterclockwise circulation with a typical current speed of about 0.05 m/s; in summer, the counterclockwise flow is confined more tightly to the Gully with characteristic velocities of about 0.1 m/s. An interesting feature crops up in the wintertime bottom circulation in the Gully, namely, a clockwise flow with a representative amplitude of 0.05 m/s.

The gyre-like surface circulation has currents on the outer edge, some 15 km from its centre, of about 0.1 m/s. In geostrophic equilibrium, there will be a surface slope of approximately 0.008 m/15 km (sea level will be lowered at the centre of the gyre) assuming a linear increase of current from the centre of the gyre (zero current) to the edge. Internal mass adjustment will cause the current to decrease to zero at some depth. This will give rise to doming of the isopycnals in a sense opposite to the sea surface (*i.e.*, the isopycnals will be shallower at the centre of the gyre). The magnitude of this effect can be estimated roughly as $(\rho/\Delta\rho)\Delta\varsigma$, where ρ is an average water column density, $\Delta\rho$ represents the vertical density difference (between 0 and 100 m for this example), and $\Delta\varsigma$ is the sea level difference across the gyre. Taking typical density differences for winter and summer, we estimate that the pycnocline would be elevated by 8 and 2 m, respectively, at the centre of the gyre.

Ongoing modelling efforts at BIO have extended the diagnostic calculations of Han *et al.* (1997) to prognostic computations (J. Shore, J. Loder, C. Hannah, pers. comm.). The newer model runs begin with a specified density distribution and external forcing that are maintained until an equilibrium has been established. The rigidly specified density field is then allowed to relax and to evolve away from the initial distribution according to the governing equations. These extended model runs generally do not change the results of Han *et al.* in a major way for the Gully region (see Fig. 6.1.4, spring 30 m currents). The detailed density and current distribution for spring across and along the Gully are shown in Fig. 6.1.5a-c. The density structure indicates that there is significant doming of the isopycnals across the Gully. The currents are asymmetrically distributed across the Gully implying that all of the inflow does not return as part of a gyre. The density slopes and the currents are generally weaker in the along-Gully section.

The model can be used to track the paths particles could take either at fixed depths or when allowed to respond to the vertical as well as the horizontal velocities (Fig. 6.1.6a-e). Particles, whose initial positions are shown in Fig. 6.1.6, are subject to the model's currents. Their positions are displayed every 5 days at 30 m (Fig. 6.1.6b, c). Particles in the western end of the Gully tend to move south of Middle Bank, towards the coast and are carried southwestward. Some particles, caught in the offshore directed flow move around Sable Island Bank and along the outer shelf. Particles whose starting positions lay near the tip of the 200 m isobath in the Gully show the greatest retention. About 11 of the 122 particles used in the calculation remain in the Gully after 40 days. The results are quite similar for the particles that can respond to vertical movement though they seem to experience greater dispersion. After 40 days there are only 4 particles remaining in the Gully.

A line of particles placed across the Scotian Shelf including the Gully shows the larger scale character of the currents in the region (Fig. 6.1.7). Currents near the coast and at the shelf break flow in the same direction for long distances approximately parallel to the bathymetry. The clockwise flow around Middle Bank and the counterclockwise circulation over the Gully indicates the influence of smaller scale topographic features.

Currents from these modelling studies have been compared to in situ current meter data. The statistic used is the sum of the squares of the vector differences between the modelled and observed currents, divided by the sum of the squares of the observed currents. A value of zero indicates perfect agreement; a value of 1 indicates that the sum of the velocities squared of the difference flow is the same as the sum for the observed flow. For spring, the values of this ratio for Western Bank and Browns Bank were 1.53 and 0.40. Both of these values, but particularly the one for Western Bank which is located just west of Sable Island, indicate that we should be cautious about over-interpreting the drifter tracks of Fig. 6.1.6 and 6.1.7.

Other modelling studies recently have shed some light upon the circulation on the eastern Scotian Shelf. Cong *et al.* (1996) modelled the 30 m circulation for an area of the Scotian Shelf defined by a line running offshore from Louisbourg at the coast, cutting Banquereau Bank just east of the Gully, then westward along the shelf break roughly at the 200 m isobath, and finally moving shoreward between Baccaro and Browns Banks to Cape Sable (Fig. 6.1.8a). The model is forced by a time-varying but spatially-uniform windstress (based on Sable Island observations) and inflows through the open boundaries. Sea-level is fixed at zero along the shelf break open boundary where outward propagating gravity waves are allowed to leave the model grid; sea level is linear along the northeastern open boundary and is inferred from Halifax observations at the coast and is zero at the outer boundary. The mean model currents are calculated from the long-term average winter density data and are used as the background flow for all runs. In summary, the circulation consists of a background flow calculated from the winter density field and held fixed, the time varying currents forced by the windstress, and the flow component resulting from the sea level variations at the northeastern open boundary.

The background winter density-forced circulation at 30 m of Cong *et al.* (1996) shows onshelf flow throughout the Gully. However, Sheng and Thompson (1996) have shown that when reasonable long-term contributions of wind and sea level are added, the total circulation features a general counterclockwise surface flow in the region, as is indicated by the current observations. However, the surface flow west of the Gully and south of Sable Island is strongly offshore in their model; moreover, while the modelled flow to the northeast of the Gully is southwestward at the shelf break like the observed currents, the modelled currents on western Banquereau Bank do not indicate the southwestward tendency shown by the observations. Thus, the modelled and observed flows have areas of agreement and disagreement.

Cong *et al.* (1996) seeded their model domain uniformly with particles at the beginning of each March and April for the period 1956 to 1993 (see Fig. 6.1.8 for an example of their model results). They then calculated the distribution of particles until the end of each month and computed retention indices over the model region. The retention index is the ratio of the number of original particles remaining in the specified area at time t, divided by the total number of particles initially in the area under consideration. The Gully was one of the regions that showed marked retention of particles. Cong *et al.* gave indices for the 15th and 30th of March and April after starting from a uniform distribution of particles on March 1 and April 1. The average (1956-1993) maximum values of the retention indices for the Gully were 0.36 (March 15), 0.17 (March 30), 0.40 (April 15), and 0.26 (April 30). These correspond to approximate e-folding times of 16 and 19 days for March and April respectively. The maximum of the retention index is generally located just north of the 200 m isobath in the inner part of the Gully.

There are a couple of caveats to bear in mind with the Cong *et al.* simulations. First, the baroclinic density-forced circulation is fixed in time. This is necessary because of the lack of sufficient observations to model this component of the circulation from year to year; however, this assumption is certainly not true. Secondly, the outer, open boundary of the model is at the outer edge of the Gully. This is also a concern in numerical modelling - usually it is better to have an open boundary far from an area of interest. However, the Cong *et al.* (1996) results do provide some useful insights into the movement of particles in the Gully region.

6.1.2 Low-Frequency Current Variability and Exchange

We have calculated the standard deviation of currents from all of the observed flows shown in Figure 6.1.1a,b. This represents 489 monthly values, with an average depth of 43 m, a standard deviation of 78 m, and a depth range of 2 to 1500 m. The variability represents all of the fluctuations that occur at periods longer than about 1 day, *i.e.*, the semidiurnal and diurnal tides, and inertial oscillations are not included. There is a seasonal variation in the standard deviation with the highest mean values in the winter (0.13 m/s in January) and the lowest values in the summer (0.07 m/s in September, see Fig. 6.1.9). We also have examined the records from within the Gully, defined by the 50 fathom isobath. The values from this more restricted area are very similar to the overall ones. These results are typical for the Scotian Shelf.

The trough between Emerald and LaHave Banks is well known as a pathway for relatively warm and fresh slope water to the inner Scotian Shelf. The Gully is a shallower trough that also connects the continental slope to the inner shelf. It also may serve as a conduit of slope water to the inner half of the shelf (Houghton *et al.* 1978). To address this question, the low frequency current, temperature and salinity from five deep current meter records (sites labelled A and B in Fig. 6.1.1b, July) from the inner part of the Gully have been examined. The current was resolved into an along-Gully component based on the direction of the mean flow over the duration of the mooring. If the Gully is a major pathway for onshelf exchange, then there should be a correlation between temperature (and salinity) and along-Gully current, which was taken as positive in the offshore direction. Temperature and salinity at 100 m increase offshore from Middle Bank to the Gully by 1.4 °C and 0.54 on average over the year (Petrie *et al.* 1996). Thus, currents out of the Gully (positive direction) should bring relatively cool and fresh shelf waters to the slope, and vice versa. In addition, given the onshore-offshore gradient of temperature and salinity, the current should lag (*i.e.*, current should reach its largest value after T or S) those variables. By correlating the current time series with the T and S series at a later time, we should get a negative correlation at one quarter period offset (assuming sinusoidal variations). The maximum negative correlations shown in the table below indicate that this is generally the case, though the values are not very large. This could be because the A and B sites are on the return side of the gyre-like circulation (see Fig. 6.1.1b, July in particular). Nonetheless, these calculations indicate that low frequency processes contribute to onshore-offshore exchange through the Gully.

Table 6.1.1. Correlations between along-Gully current, temperature and salinity from deep current meter data.

Site	Season	Depth	Correlation, series offset (d) Current, temperature	Current, salinity
A	spring	114	-0.49, 3	-0.41, 3
B	fall	138	-0.22, 0.5	-0.38, 0.5
B	winter	138	-0.60, 0.5	-0.71, 0.5
B	winter	126	-0.40, 0.5	-0.21, 0.5
B	spring	138	-0.35, 0.5	-0.29, 0.5

These current meter data can also be used to estimate the seasonal onshelf transport through the Gully. The data used are presented in detail in the chemical oceanography section (6.2). For the winter season (DJF), the estimated transport is 0.03 Sv (1 Sv=10^6 m^3/s), whereas for the summer (JJA), it is 0.07 S. These transports are very small in comparison to the estimates of outflow from the Gulf of St. Lawrence of 0.52 (El Sabh,

1977) to 1.0 Sv (Han *et al.* 1998) for winter and 0.41 to 0.8 Sv for summer. The outflow from the Gulf is the major source of water for the eastern Scotian Shelf.

6.1.3 Barotropic Tides

The principal semidiurnal and diurnal tidal species have been modelled by de Margerie and Lank (1986). A concise summary of the 3 principal tidal constituents and the residual current generated by the M2 tide, the largest constituent overall, are presented in Fig. 6.1.10 and 6.1.11. The ellipses represent the path a particle of water would take if it experienced the currents at the grid points indicated (Fig. 6.1.10). It is evident that the tidal currents are strongest where the depths are the least, *i.e.*, in the vicinity of Sable Island. Weaker tidal flows occur in the adjacent deeper area of the Gully with the weakest flows found in the adjacent deep ocean. The non-linear M2 residual flows are generally weak throughout the entire area (Fig. 6.1.11). The straight lines of Fig. 6.1.11 indicate the excursion that a water parcel would take if it experienced the mean flow in the local area for one day. The strongest M2 residual flow, 0.042 m/s, occurs just to the northwest of Sable Island.

6.1.4 Internal Waves

The outer portion and flanks of the Gully to approximately the 200 m isobath were indicated by de Margerie and Lank (1986) as regions where internal tide generation was favoured. There is some evidence that this is indeed true. Sandstrom and Elliott (1989) reported the results of extensive Batfish hydrographic surveys of the Gully. A section run on the eastern flank of the mouth of the Gully between the 100 and 200 m isobaths shows large amplitude internal waves (Fig. 6.1.12). The nature of these oscillations - very steep waveforms - indicates that they may be non-linear; that is, they are a group of cnoidal waves generated as the internal tide evolves. Quite often they are called solitary waves or solitons, though in this picture they are certainly not alone. In addition to temperature, salinity and density, the echo-sounder record is also shown Fig. 6.1.12. There were strong reflectors (Sandstrom *et al.* (1989) indicate that this is likely turbulence) at about 25 m that are associated with the density oscillations; moreover, in the shallower region, the reflectors appear to be broken up as if enhanced mixing was generated by the passing wavetrain. This may be evidence of strong vertical mixing in the region and thus could affect the overall productivity (Sandstrom and Elliott, 1984; Sandstrom and Oakey, 1995). This section is perhaps the best example in the Sandstrom-Elliott report. However, very few sites on the Scotian Shelf have received such intensive surveying. Thus, we do not have the database to compare the internal wave activity in the Gully to that elsewhere. However, de Margerie and Lank (1986) indicate that there are other areas of the Scotian Shelf and the Grand Banks that show as much potential for internal tide generation as the Gully. In this respect, the Gully is not a unique region.

From these surveys we cannot say that the activity exhibited in the Gully is average or significantly different from average for the Scotian Shelf. Of the approximately 225 sections displayed by Sandstrom and Elliott, about 40 showed marked internal wave activity. Note though, that some of these sections were very short and were obviously tracking back over the same wave repeatedly in order to determine its history and fate.

Sandstrom and Elliott placed two current meter moorings each with 2 instruments (at 15 and 67 m) on the eastern flank at the mouth of the Gully. They recorded temperature as well as currents. The shallower and deeper instruments had the first and fourth highest temperature variances for the 15 and 9 records respectively collected in the same month from the area defined by Fig. 6.1.1. This indicates that the outer Gully may be a region of enhanced internal wave activity, and thus perhaps of mixing as well.

6.1.5 Monthly Mean Temperature, Salinity and Density

Monthly mean temperature and salinity statistics from Petrie *et al.* (1996) are shown in Fig. 6.1.13 and 6.1.14 for the Gully. The temperature and salinity fields evolve much like the other regions on the Scotian Shelf. Maximum temperatures at the surface occur in the late summer (Fig. 6.1.13). The heat is mixed downward with increasing storm activity in the fall; winter cooling follows. Salinity is strongly influenced by the outflow from the Gulf of St. Lawrence which contributes to the surface minimum in October. The mean, standard deviations and extreme temperatures and salinities, shown in Fig. 6.1.14, emphasize the dominance of the annual cycle at shallow depths. Density reflects the annual variability in the temperature and salinity fields (Fig. 6.1.15).

The question of enhanced mixing in the Gully that was raised above can be addressed through an examination of the density profiles in adjacent areas. This comparison is shown in Fig. 6.1.16 for the Gully and the 4 areas surrounding it as defined by Petrie *et al.* (1996). For this comparison, we have selected only the months (March, July, August and November) that have enough data to give reasonable estimates of the mean density profiles. It is evident from these plots that there is not a marked difference among the 5 regions, except for the deeper portion of the Middle Bank profiles. This could be because Middle Bank is the region closest to the coast and is thus subject to a greater influence of nearshore waters. Hence, it does not appear that there is enhanced mixing in the Gully region.

Mean seasonal bottom salinity distributions show the tendency for saltier and thus generally warmer waters to move onto the shelf via the Gully. The winter distribution of salinity shows this pattern quite distinctly (Fig. 6.1.17). Similar intrusions are evident for the other seasons as well.

6.1.6 Interannual Variability of Temperature and Salinity

The waters of the Scotian Shelf have shown significant interannual and longer-term variability of temperature and salinity (Petrie and Drinkwater, 1993). The variability at the eastern end of the shelf was less than that in the central or western region. The interannual variability found in the Gully at the 0 and 50 m depths resembles the temporal changes Petrie and Drinkwater (1993) found for the Sydney Bight region (Fig. 6.1.18).

This indicates the strong influence of Gulf of St. Lawrence outflow. At greater depths, the long-term changes of temperature and salinity in the Gully are similar to (but with smaller amplitudes) those seen at Emerald Bank and Basin, and in the slope area to the west (see Fig. 6.1.18 and Petrie and Drinkwater, 1993).

6.1.7 Ice

The ice charts for the 30 year period from 1964-1993 prepared by the Atmospheric Environment Service have been digitized and analyzed at Bedford Institute of Oceanography (Roger Pettipas, pers. comm.). For this analysis, the ice boundary was defined as the locations where ice covered at least 10% of the ocean surface area. In the table below, we present the mean year day number of first and last appearance of ice, number of years when ice was present at some time, and average duration of ice for five 0.5° latitude by 1° longitude squares that cover the Gully. Ice cover greater than 10% in any part of a 0.5° by 1° polygon counted as an occasion when ice was present. The statistics indicate that ice is present in the Gully region for less than 30% of the years and that when present, its duration is quite short.

Table 6.1.2. Ice Statistics for the Gully for the 30 year period 1964-1993.

Latitude (°N)	Longitude (°W)	Day of 1st Appearance	Day of Last Appearance	Number of Years with Ice	Average Duration of Ice (days)
44-44.5	60-61	58	67	8	<10
44-44.5	59-60	52	66	6	<10
44-44.5	58-59	65	77	5	<10
43.5-44	58-59	79	82	2	<10
43.5-44	59-60	-	-	0	0

6.1.8 Studies of Similar Topographic Features

There have been a number of studies of North American Atlantic coast canyons that could lend some insight into the physical oceanography of the Gully. The common feature each of these canyons has with the Gully, in addition to their morphology, is that the mean flow on the adjacent shelf and slope is in the same sense, *i.e.*, from right to left as you face the canyon from the deep ocean. This external mean flow will play a major role in the determination of the circulation within the canyon.

Hotchkiss and Wunsch (1982) conducted a 15 week observation program in Hudson Canyon. Hydrographic properties, pressure and current were measured from 5 moorings with 10 current meters and 14 temperature-pressure recorders. Hudson Canyon is a steeply sloped feature cutting 30 km into the continental shelf off New York Bight. It is about 13 km wide at the mouth and 3.5 km wide at the head. In these respects, it is similar to the steep outer area of the Gully which intrudes 40 km into the shelf (approximate distance between the 2000 m and 200 m isobaths) and is about 14 km wide at the mouth. The major morphological difference between Hudson Canyon (and the other canyons discussed below) and the Gully is that, in the case of the latter, the 100 m isobath defines a shallower, broad channel-like feature that penetrates deeply onto the shelf and could be considered as part of the overall feature. In fact, the channel defined by the 100 m isobath connects the slope region to the inner Scotian Shelf. Hudson Canyon is confined to the outer shelf. The main result reported by Hotchkiss and Wunsch (1982) was the apparent amplification of the horizontal kinetic energy in the internal wave band near bottom within the canyon and towards the head of the canyon. However, the evidence was not compelling. We do not have a comparable dataset and cannot confirm if the same is true for the Gully. However, in Fig. 6.1.19, we have combined all of the data available to show the distribution of variance along the axis of the Gully, including the inner portion defined by the 50 fathom isobath. The plot indicates that the variance is largest at the mouth of the Gully and decreases shoreward. As pointed out earlier, we have reasons to suspect enhanced internal wave energy there.

Hunkins (1988) maintained 12 moorings in and adjacent to Baltimore Canyon for up to 18 months. The Canyon, defined by the 100 m and 700 m isobath is about 3 km wide at the head, 8 km wide at the shelf break, and is about 13 km long. Thus it is smaller than the Gully. The current pattern within Baltimore Canyon was quite complex making it difficult to determine a well-defined circulation. On the other hand, a number of interesting results emerged: a maximum peak current of 1.06 m/s was observed near-bottom at 275 m (this mooring had instruments at 50, 230 and 275 m); near-bottom amplification of the semidiurnal tidal flows occurred consistently throughout the mooring period. Mean currents shallower than 100 m did not appear to be affected by the canyon. Deeper instruments in the canyon were generally at 2 levels, 50 and 6 m above the bottom. These were strongly affected by the local topography; however, a well-defined circulation pattern did not emerge.

Perhaps the most intensive study of the circulation in an east coast canyon was conducted at Lydonia Canyon, off the southern flank of Georges Bank (Noble and Butman 1989). This feature cuts into the shelf by about 20 km and is about 5 km wide at the mouth. An array of fourteen moorings, three bottom tripod systems and one bottom pressure mooring was deployed for six months. Noble and Butman concluded that mean currents in the Canyon were weaker than those over the adjacent shelf and slope. In addition, the amplitude of subtidal flows was 2 to 6 times higher on the shelf and slope than in the Canyon (see Fig. 6.1.20). An analysis was carried out to determine the circulation patterns within the Canyon. The primary mode of circulation captured only 25% of the along-canyon current variability. This indicates, as was the case for Baltimore Canyon, that the circulation is quite complicated.

6.1.9 Summary

The review of the physical oceanography of the Gully has indicated that it may feature a weak, counterclockwise circulation that could contribute to the retention of particles within it. However, similar patterns are found elsewhere on the Scotian Shelf, for example, the clockwise gyre around Browns Bank, the Western Bank gyre, the retention areas over Emerald and Western Banks (Cong *et al.* 1996). Low-frequency current variability in the Gully is comparable to that observed in nearby regions and for the Scotian Shelf as a whole. Barotropic tides behave regularly. There is some evidence in Batfish surveys and in the temperature variability from fixed sensors that internal tides and internal wave activity at the mouth the Gully may be enhanced. This could lead to greater vertical mixing in the Gully with implications for nutrient exchange and consequently for primary productivity. However, a comparison of the long-term mean profiles of density indicates very little difference among those from the Gully and from four surrounding areas. This may indicate that either the internal wave activity seen in the Gully surveys extends into the adjacent areas, or that enhanced mixing, driven by internal wave breaking and dissipation, is highly localized within the Gully. Thus, our broad averaging of monthly density profiles may have hidden localized mixing hot spots.

6.1.10 Acknowledgments

Helpful suggestions of this report were provided by Peter Smith.

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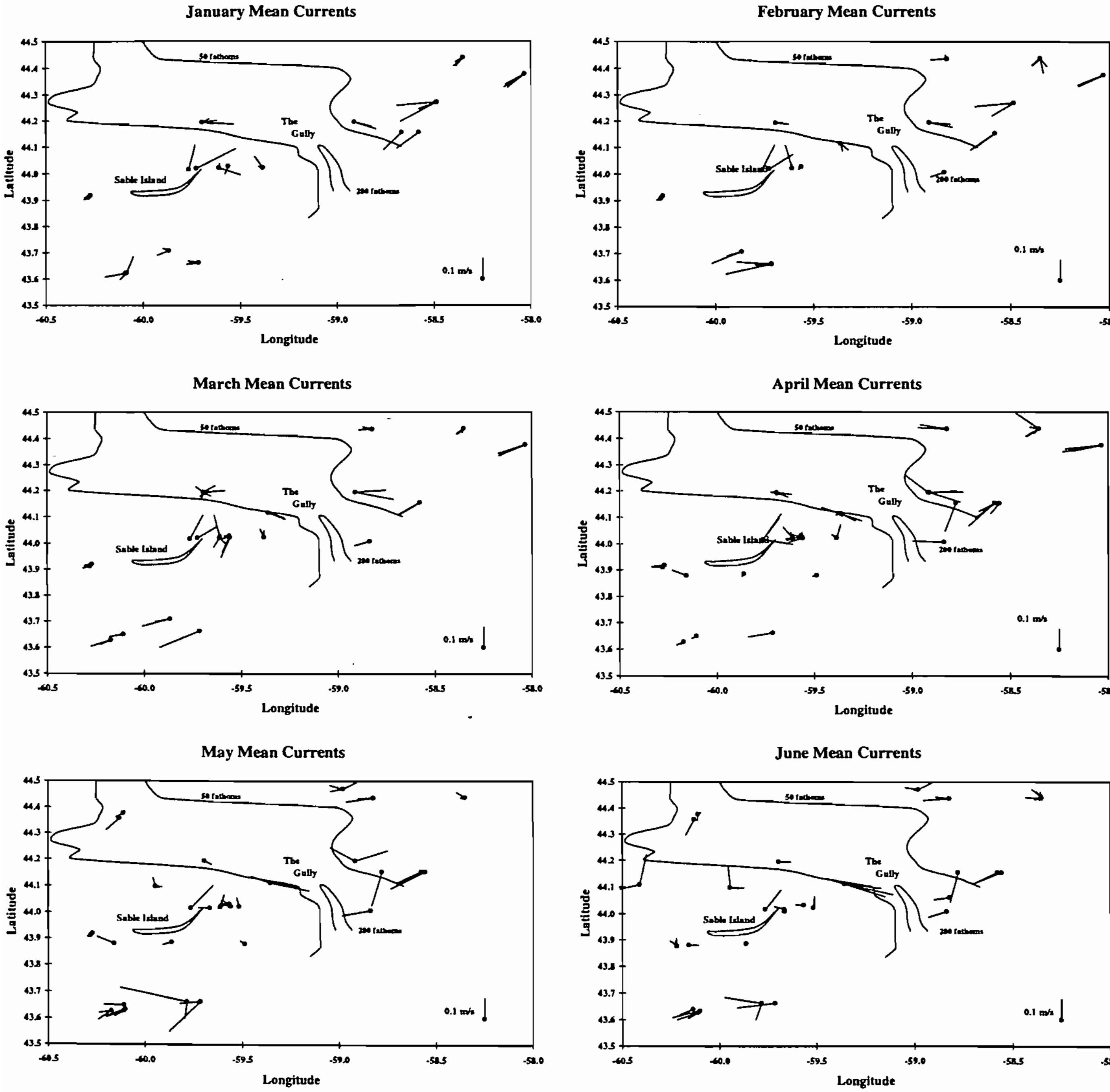


Fig. 6.1.1. Mean current vectors from the Bedford Institute oceanographic data archive for the Gully region. All vectors are plotted regardless of depth or duration (a) January-June, (b) July-December.

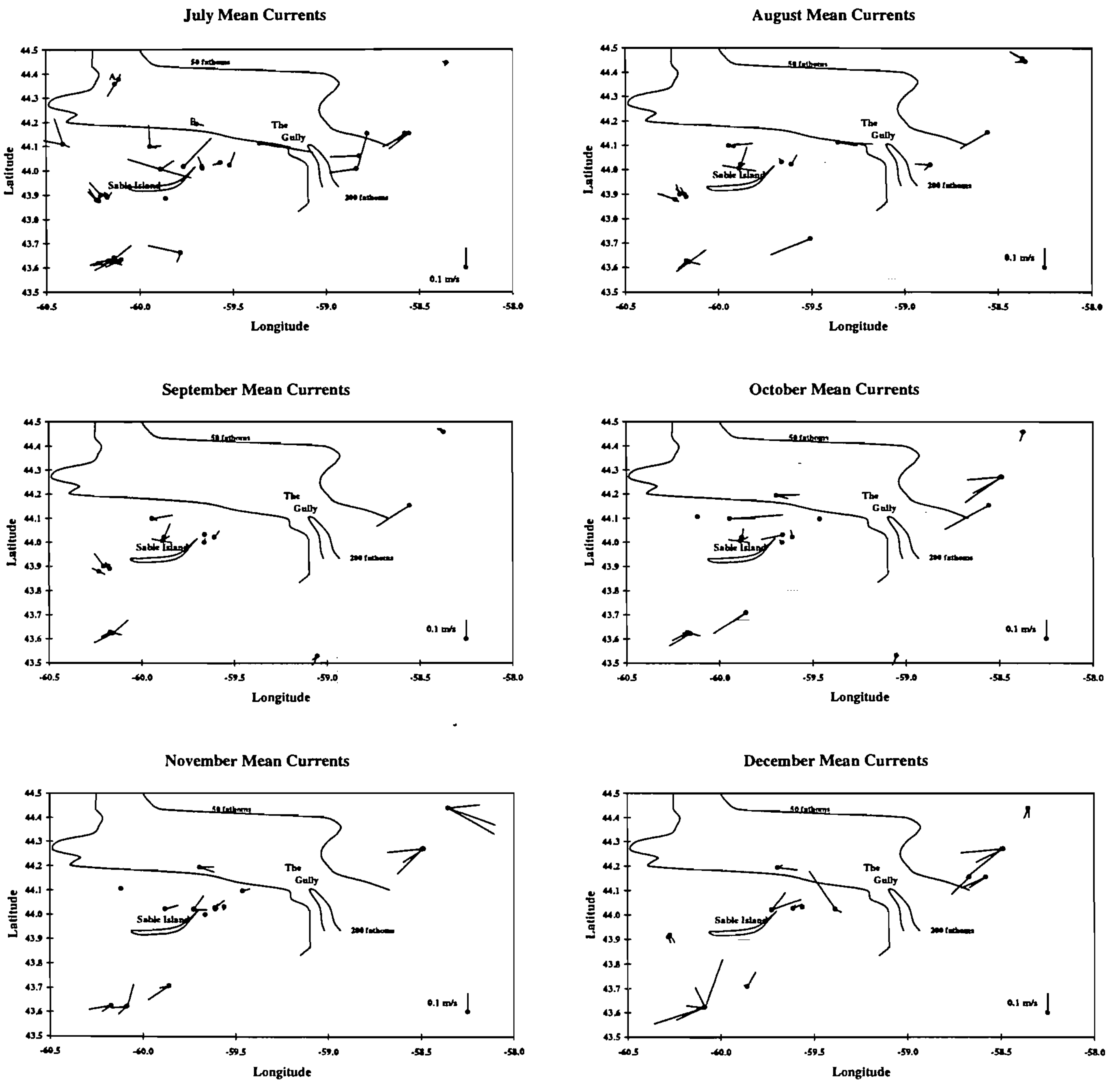


Fig. 6.1.1. (Continued)

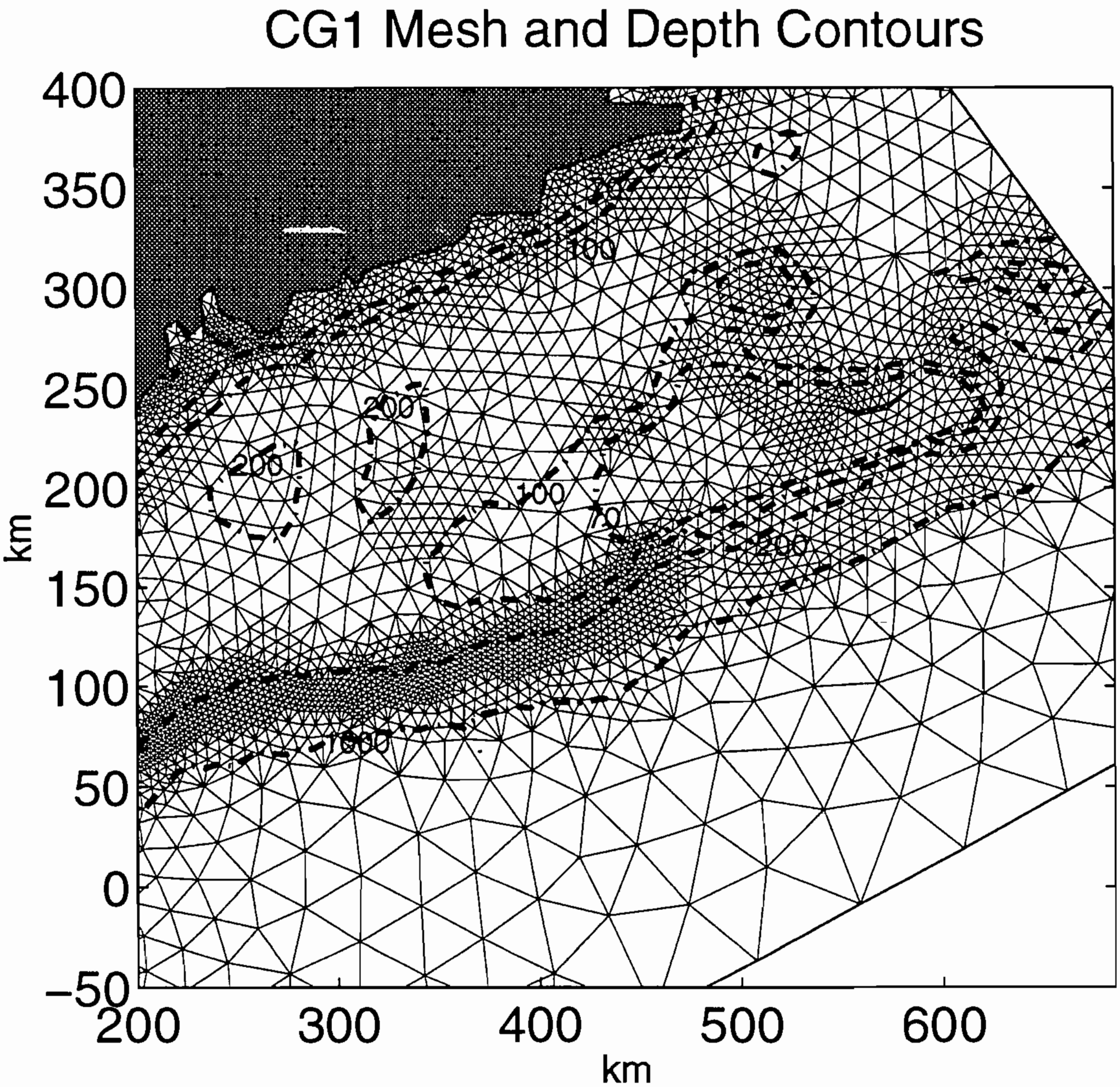


Fig. 6.1.2. Finite element model grid for the Eastern Scotian Shelf. The 100, 200 and 1000 m depth contours are shown.

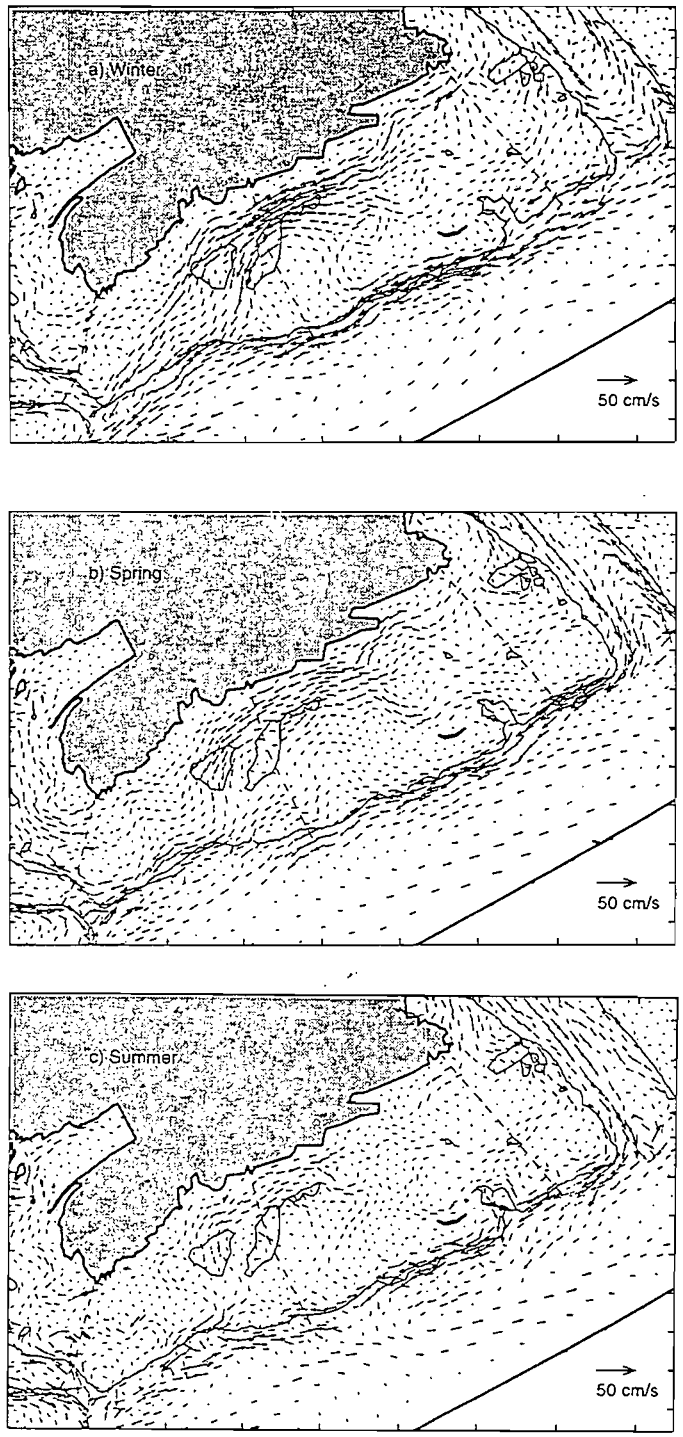


Fig. 6.1.3. Near-surface (averages between 5 and 25 m of the surface) mean currents for (a) winter, (b) spring, and (c) summer from model simulations with full forcing (From Han et al. 1996).

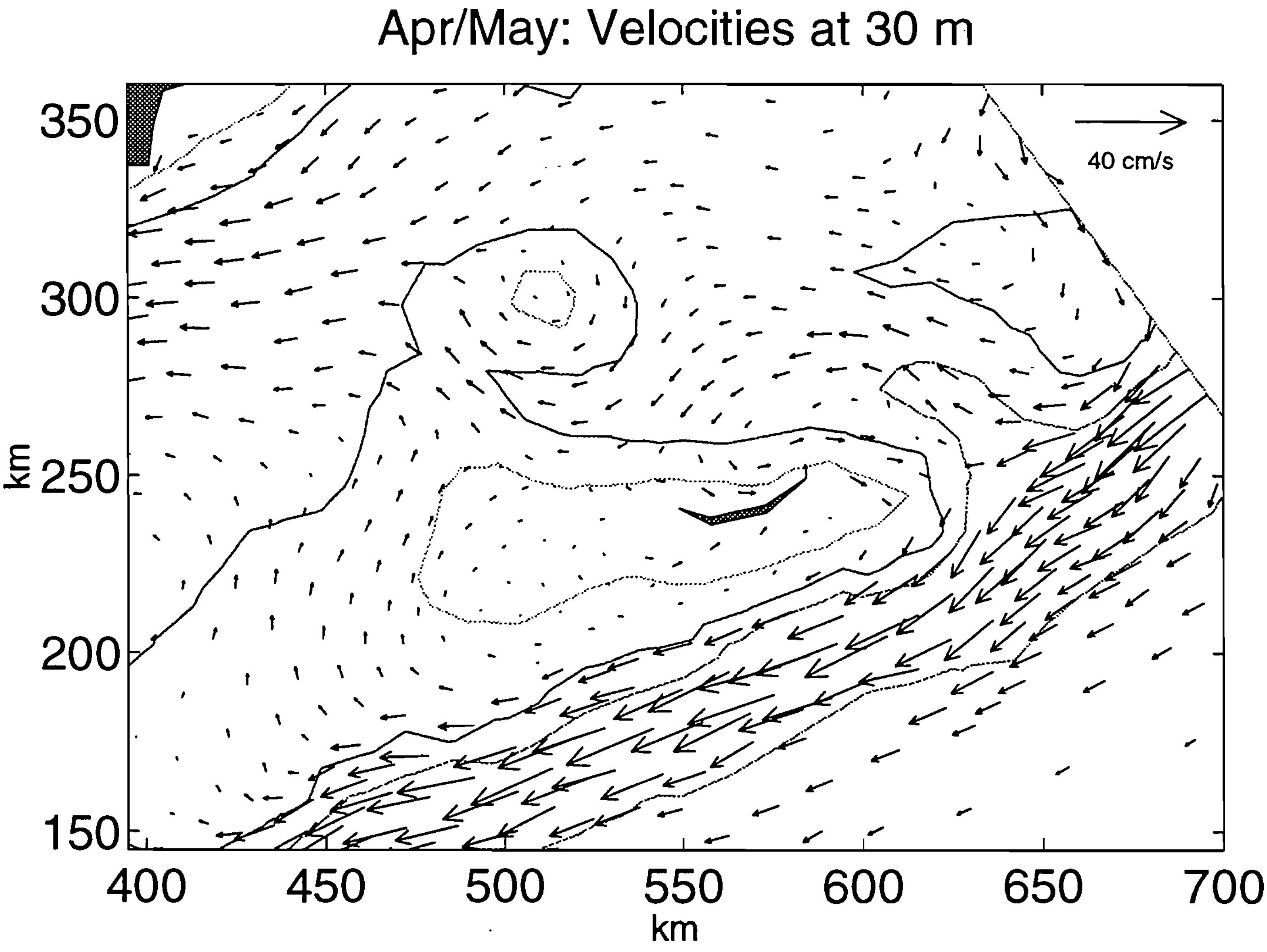


Fig. 6.1.4. Spring circulation at 30 m for the Gully region from Bedford Institute of Oceanography prognostic model.

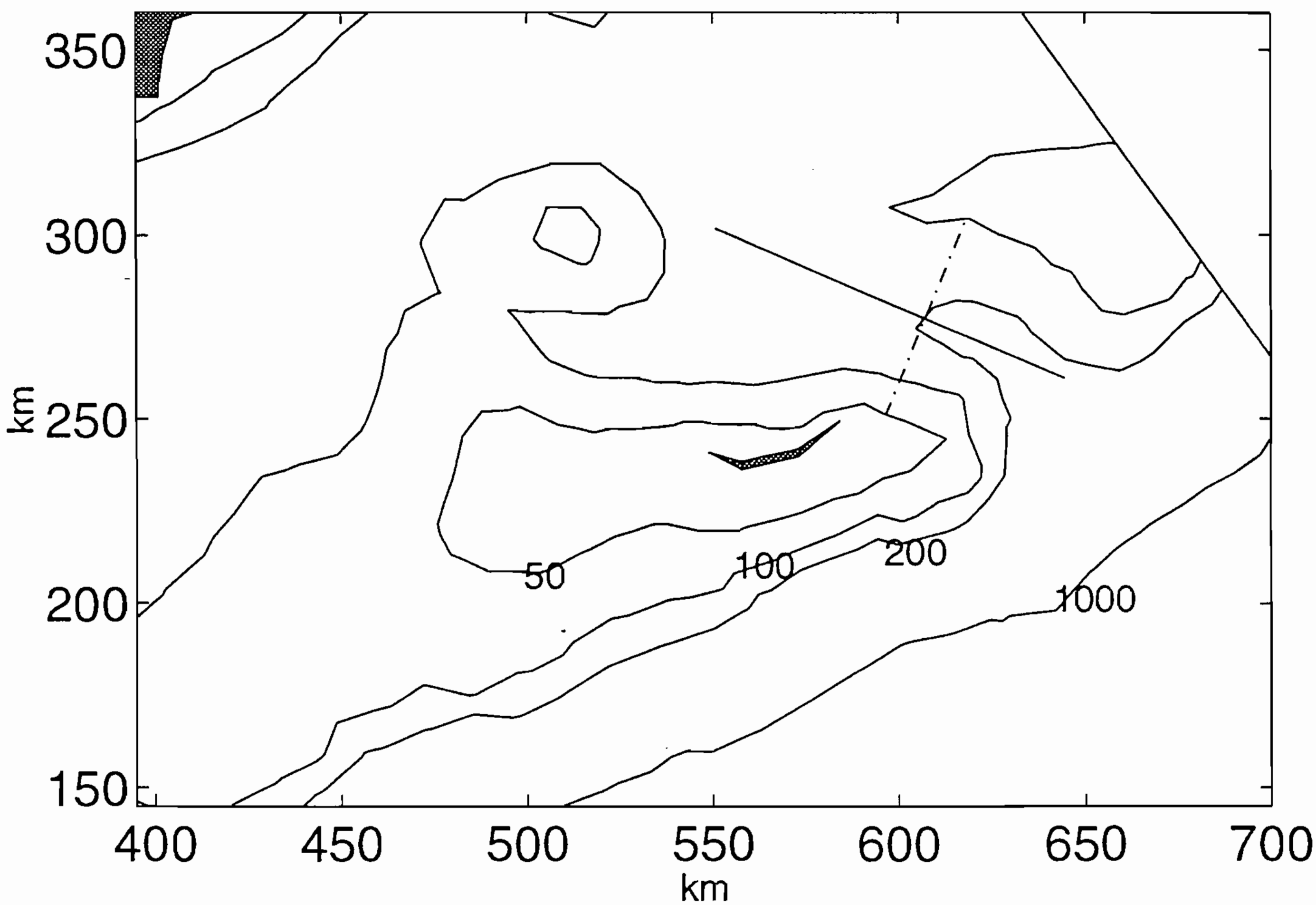


Fig. 6.1.5a. Location of density and current transects along (solid line) and across (broken line) the Gully.

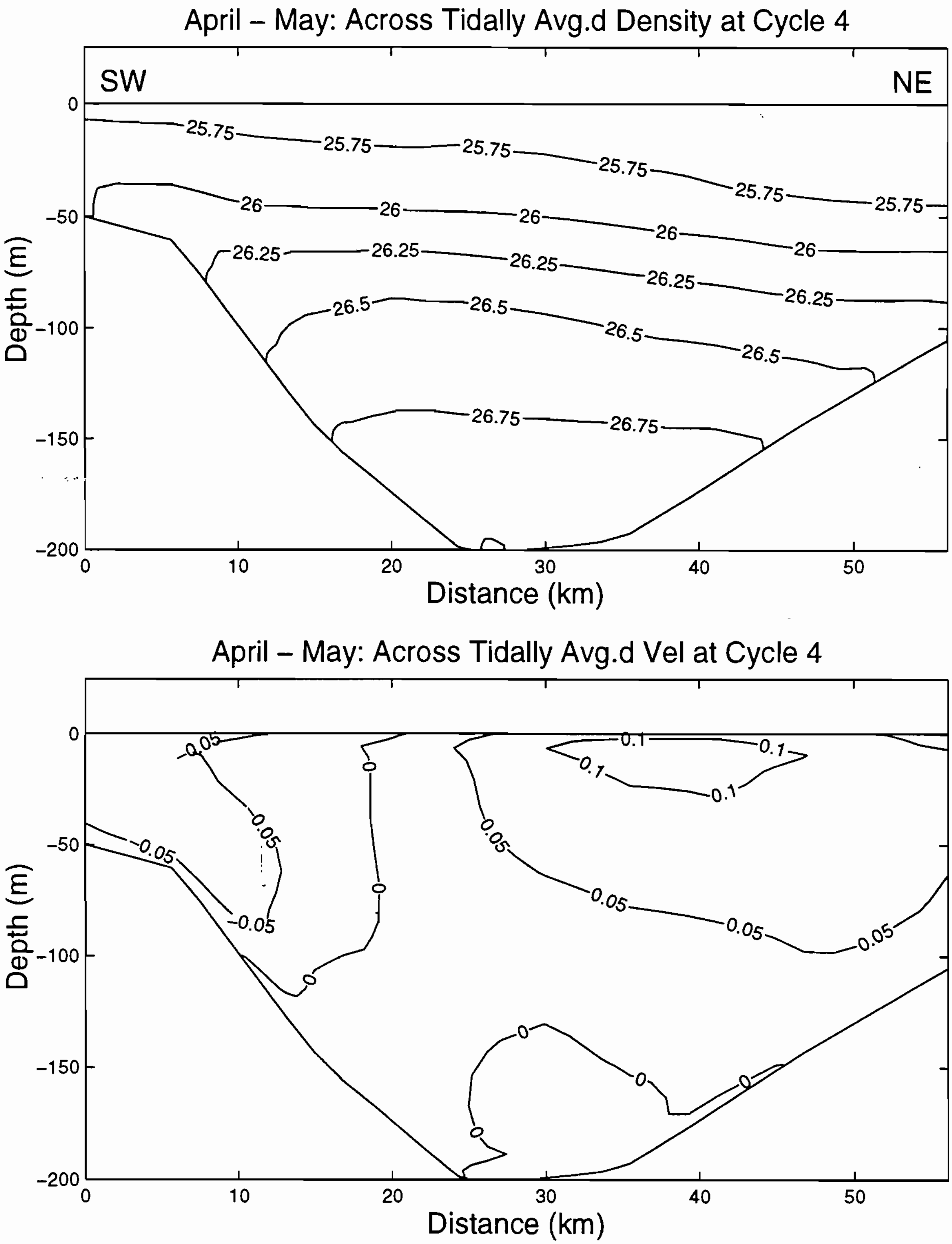


Fig. 6.1.5b. Prognostic calculation of the density and current distributions across the Gully averaged over the fourth M2 tidal cycle. Positive velocities are directed into the page.

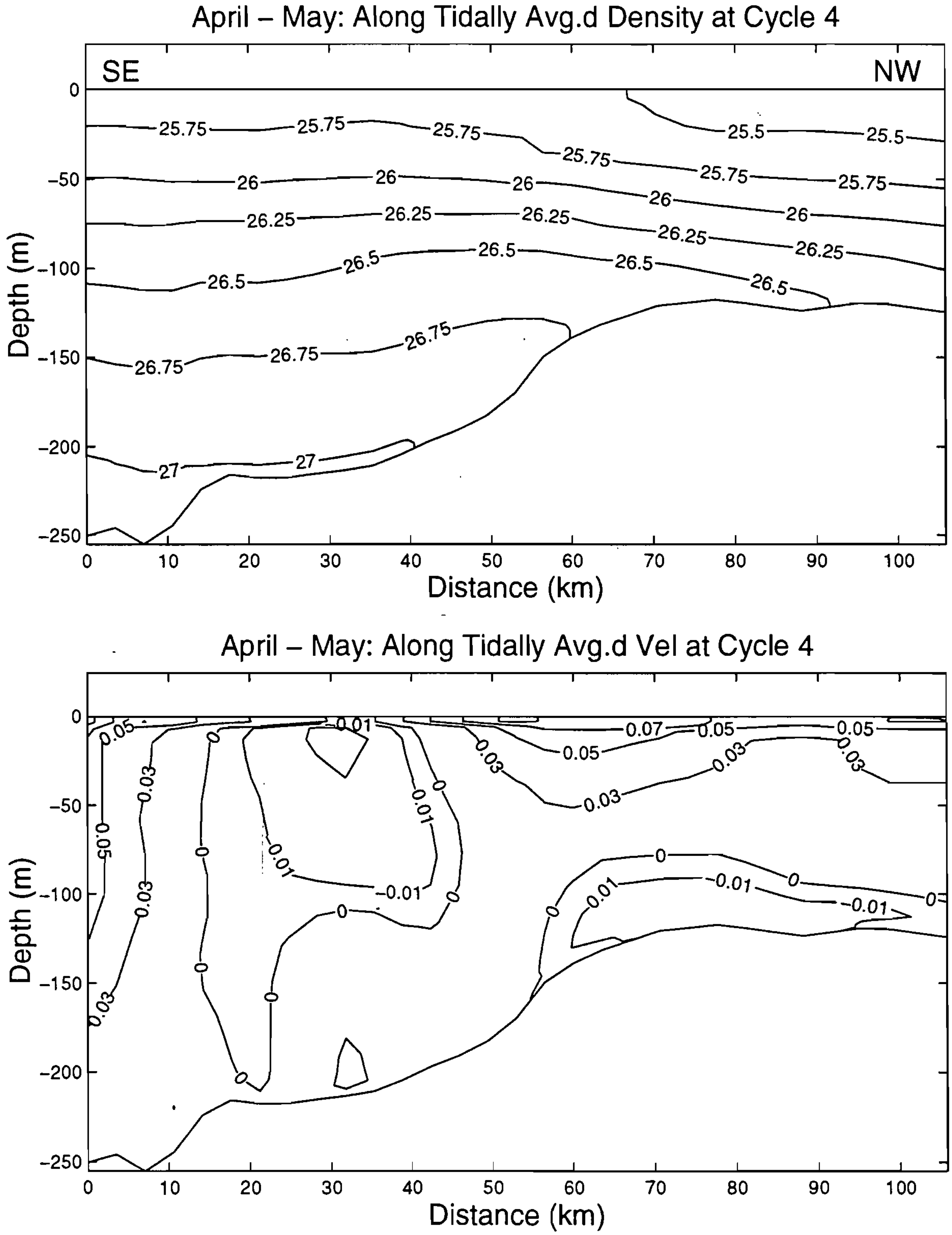


Fig. 6.1.5c. **Prognostic calculation of the density and current distributions along the Gully averaged over the fourth M_2 tidal cycle. Positive velocities are directed into the page.**

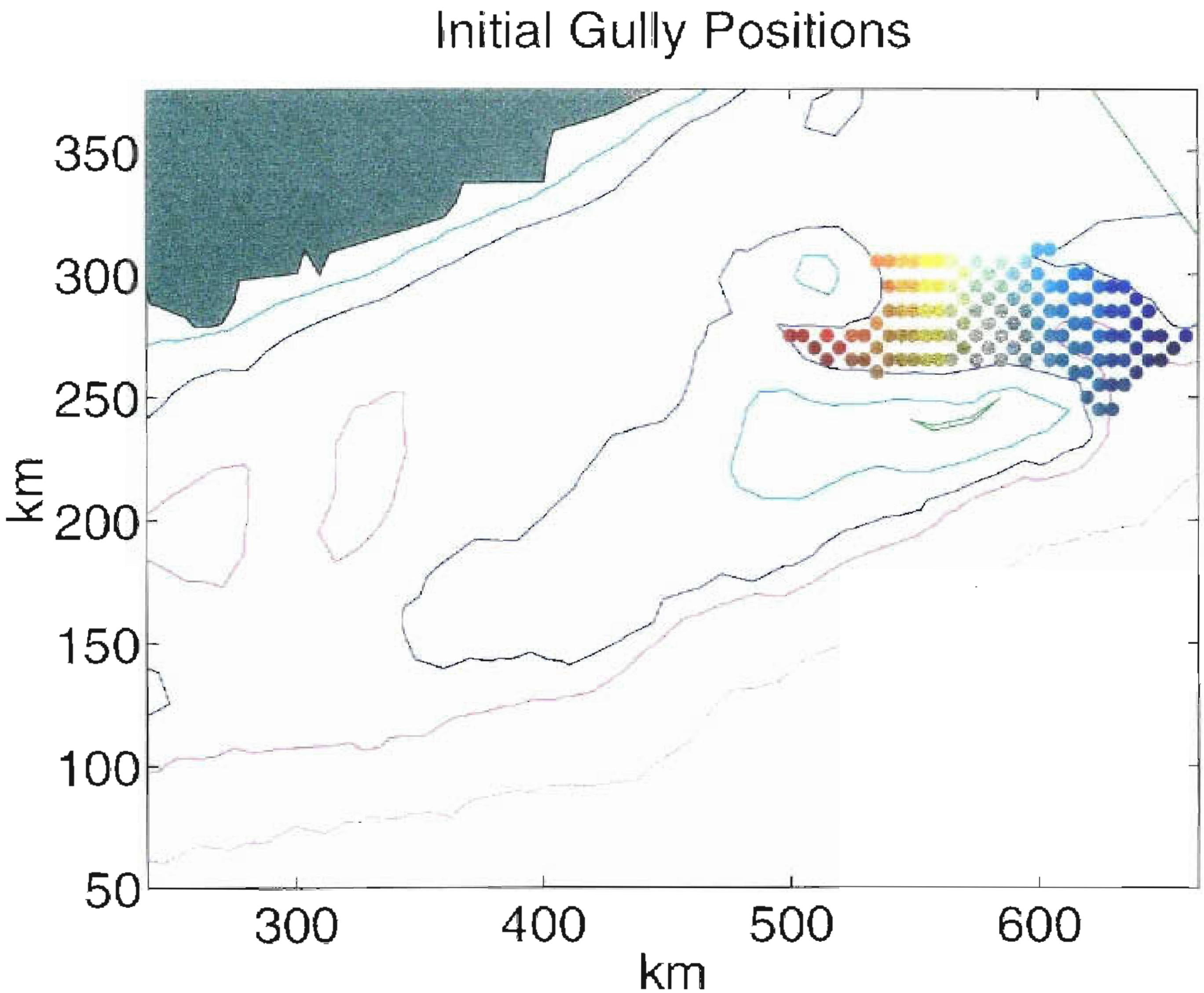


Fig. 6.1.6a. Initial distribution of particles in the Gully.

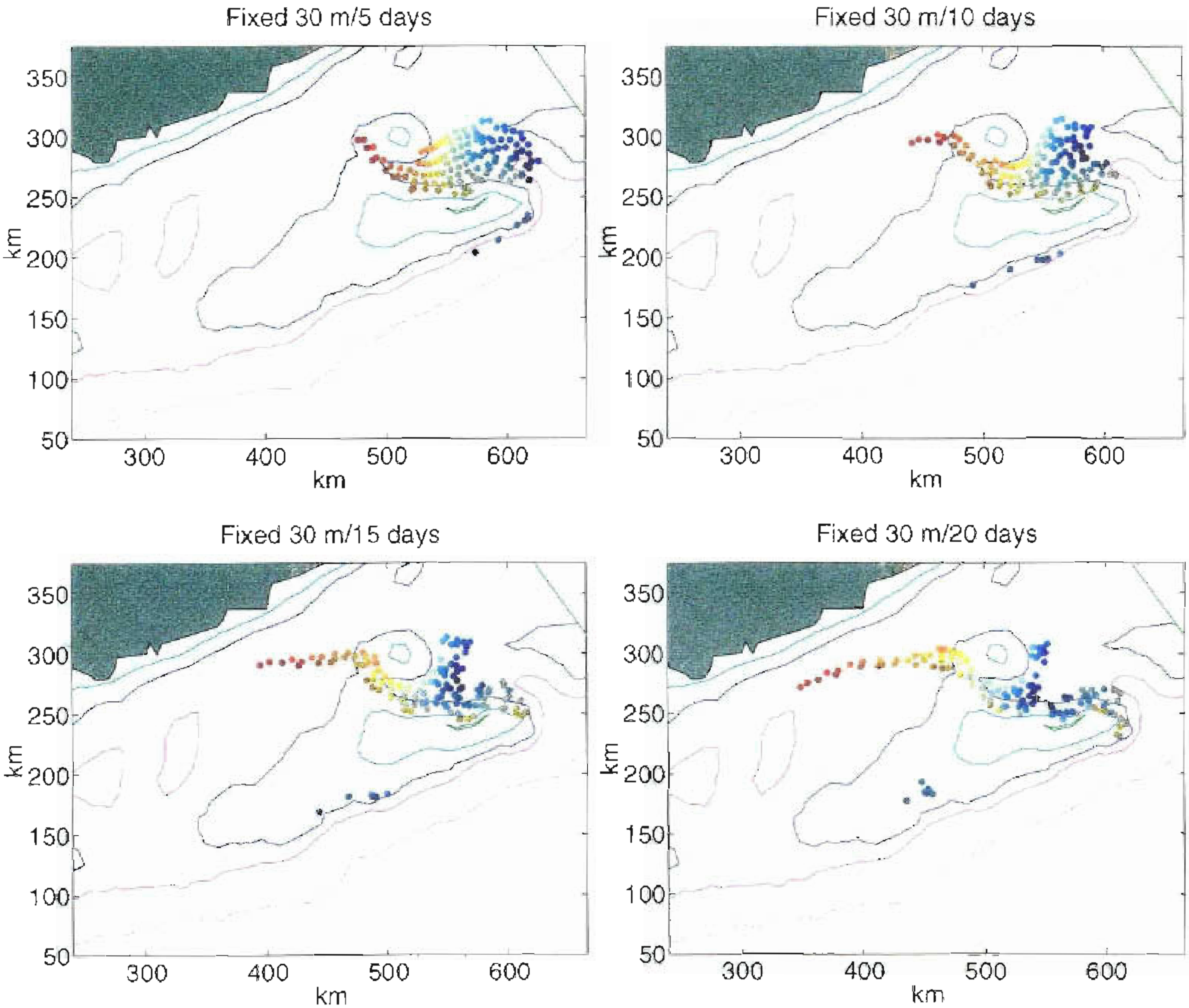


Fig. 6.1.6b. Particle positions every 5 days for days 5 to 20 at the fixed depth of 30 m.

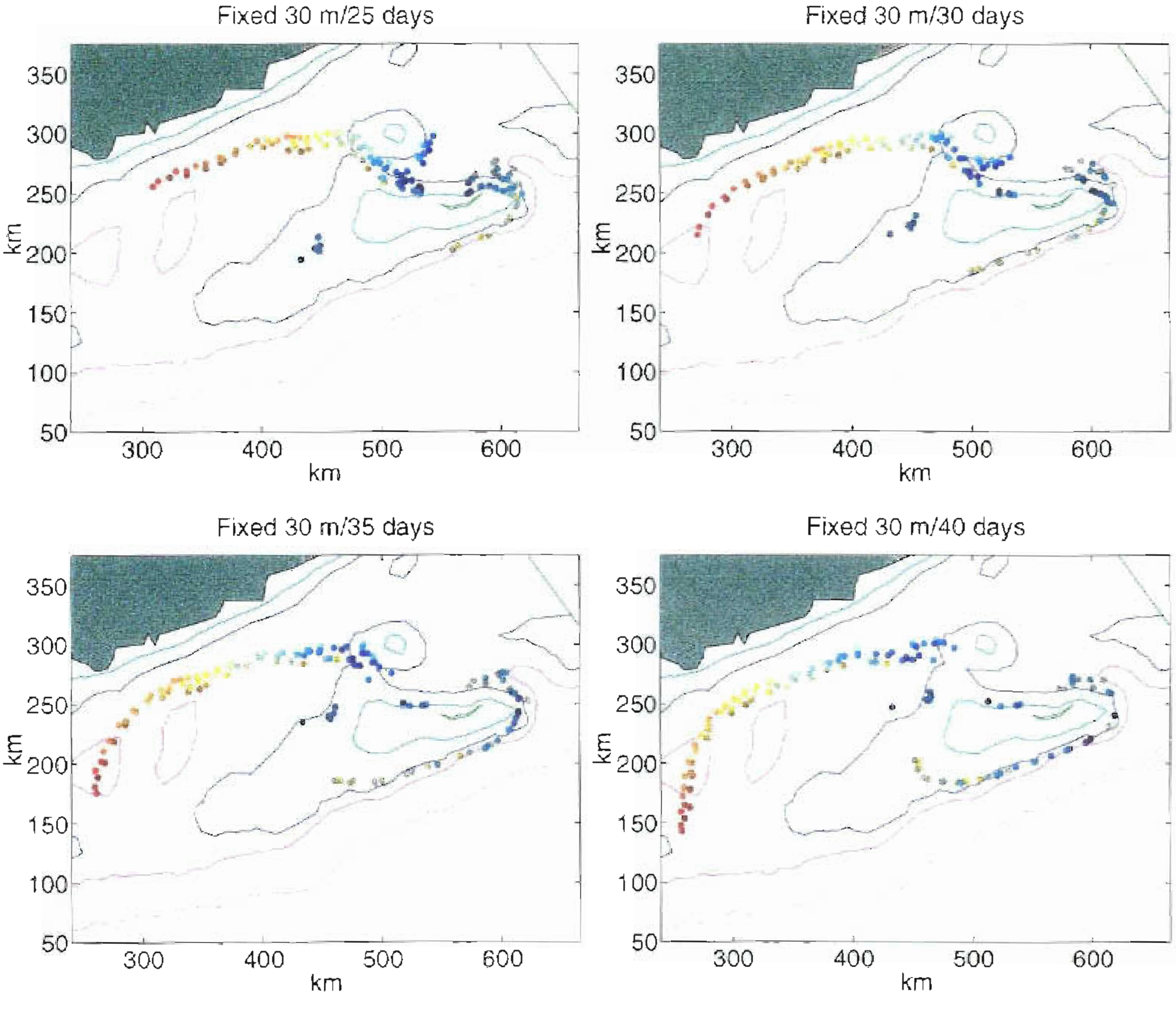


Fig. 6.1.6c. Particle positions every 5 days for days 25 to 40 at the fixed depth of 30 m.

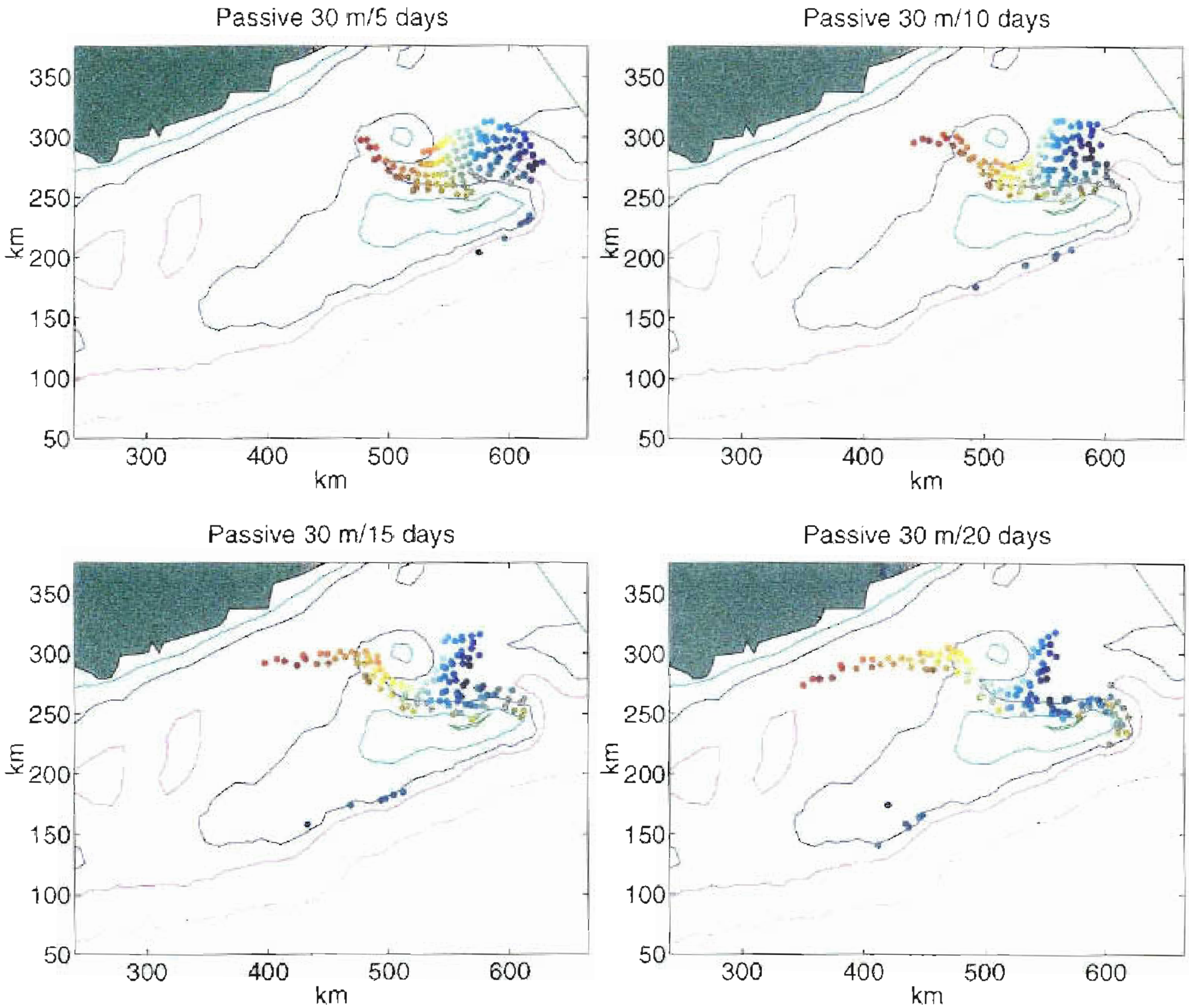


Fig. 6.1.6d. Particle positions every 5 days for days 5 to 20 when allowed to adjust to vertical velocities. Initial depth of particles was 30 m.

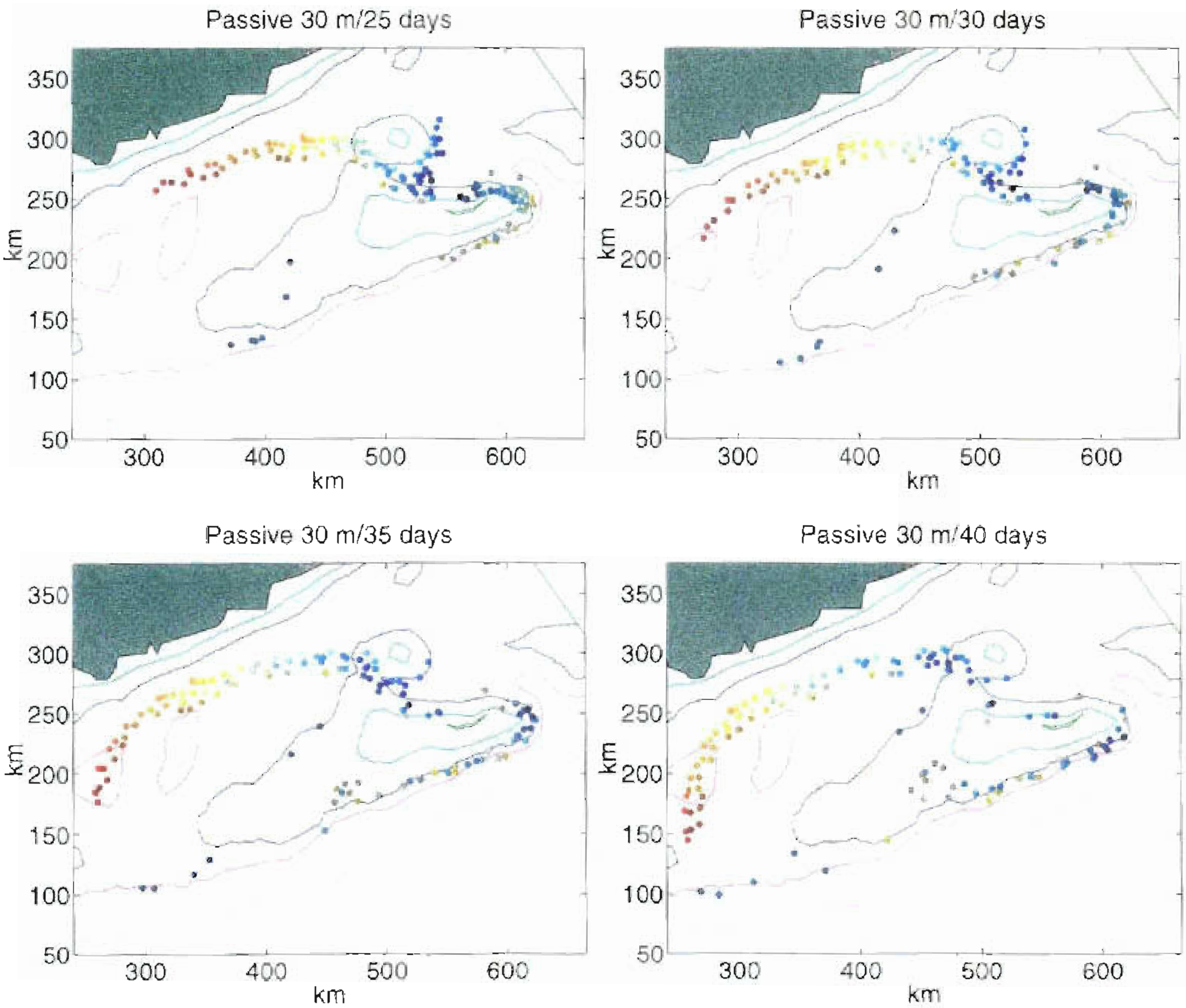


Fig.6.1.6e. Particle positions every 5 days for days 25 to 40 when allowed to adjust to vertical velocities. Initial depth of particles was 30 m.

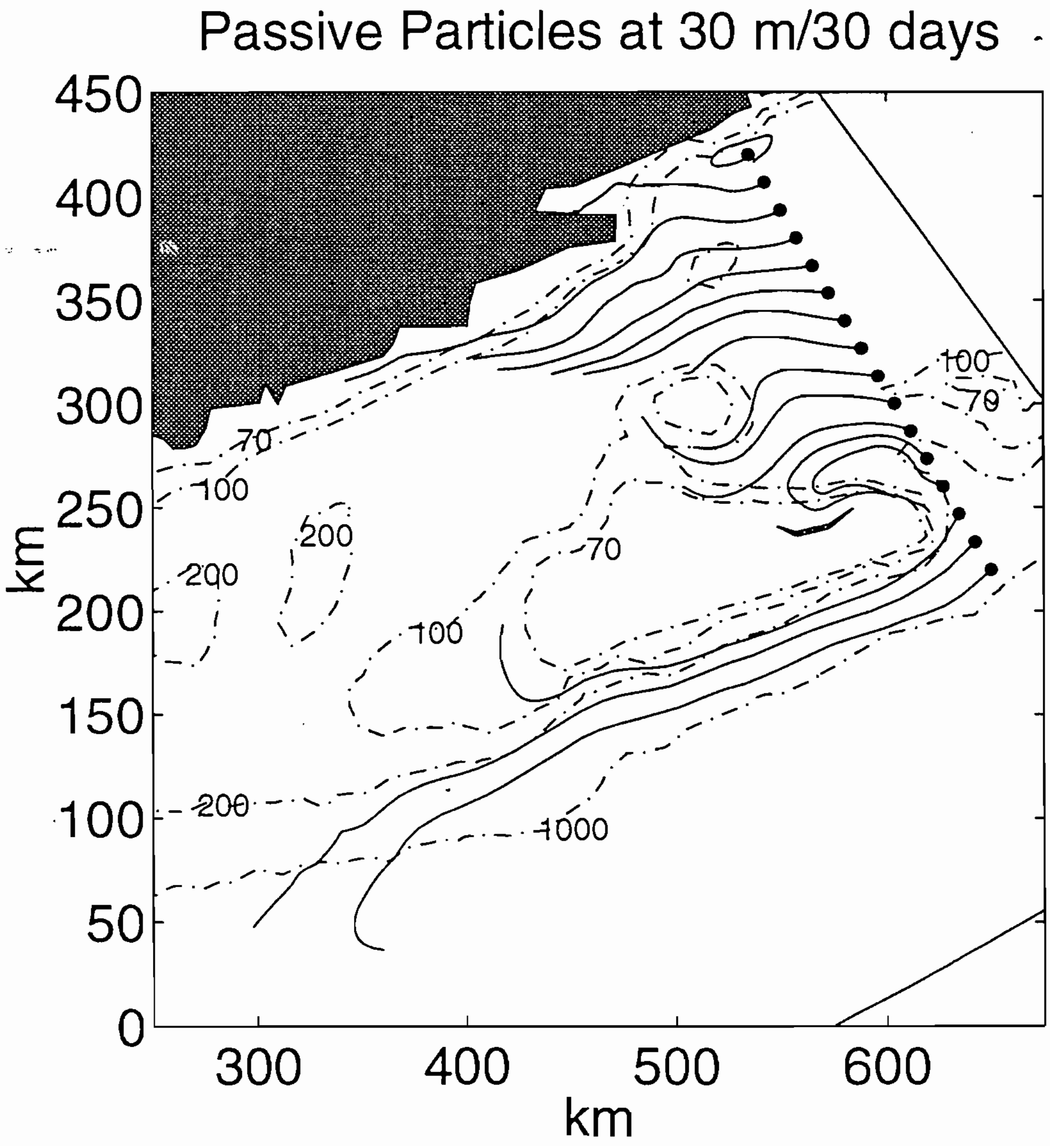


Fig. 6.1.7. Paths of a line of particles placed initially at 30 m depth across the shelf and allowed to drift for 30 days. The particles could respond to vertical velocities.

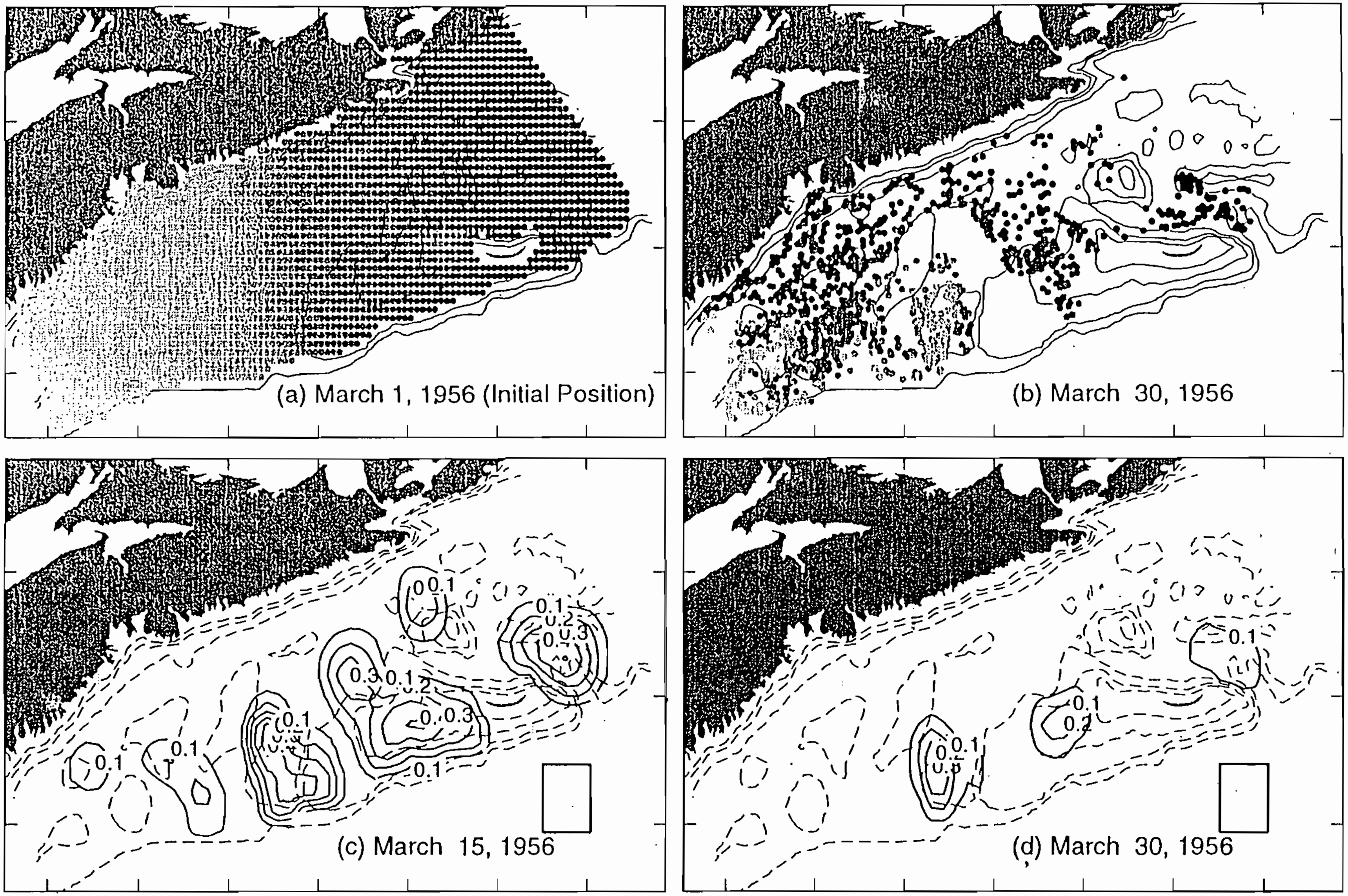


Fig. 6.1.8. (a) Initial positions of particles shaded with different intensities in gray to indicate starting positions; (b) Positions of particles after 30 days; (c) Retention index showing the proportion of particles remaining in a box of a given size (see bottom right corner) after 15 days; (d) Same as (c) but after 30 days. From Cong et al. (1996).

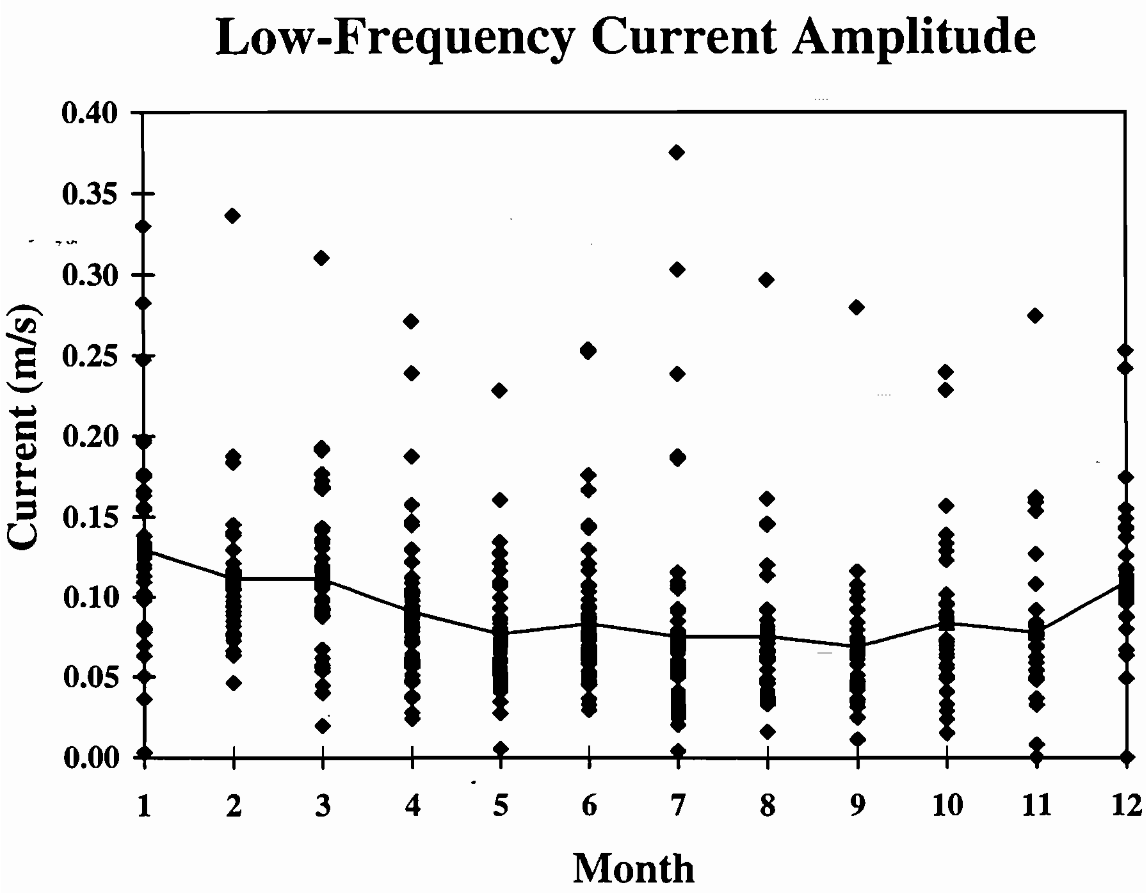


Fig. 6.1.9. Standard deviations of the low-frequency currents for the region shown in Fig. 6.1.1. The line indicates the mean value of the standard deviations.

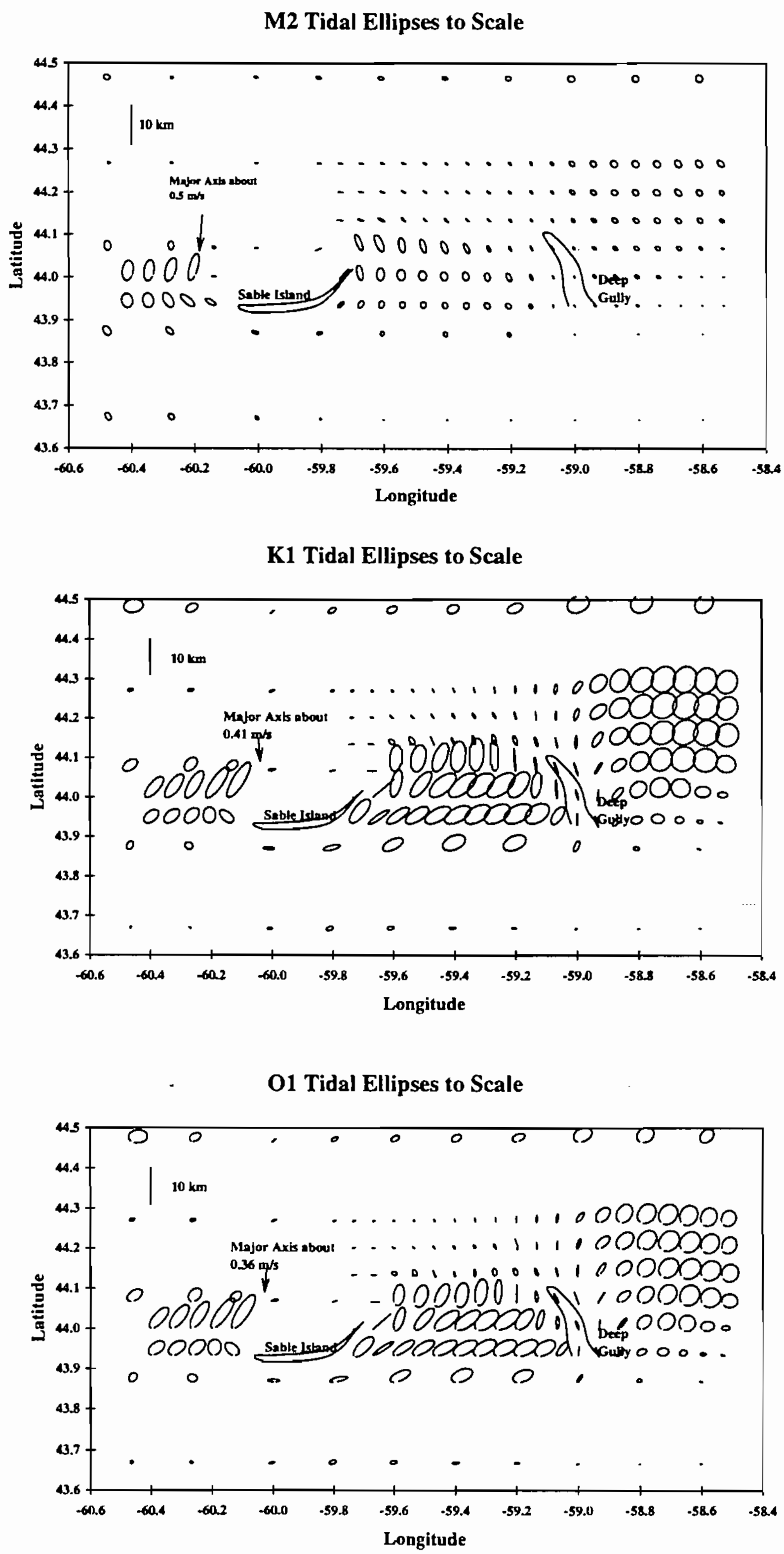


Fig. 6.1.10. Semidiurnal and diurnal tidal ellipses for the Gully-Sable Island area.

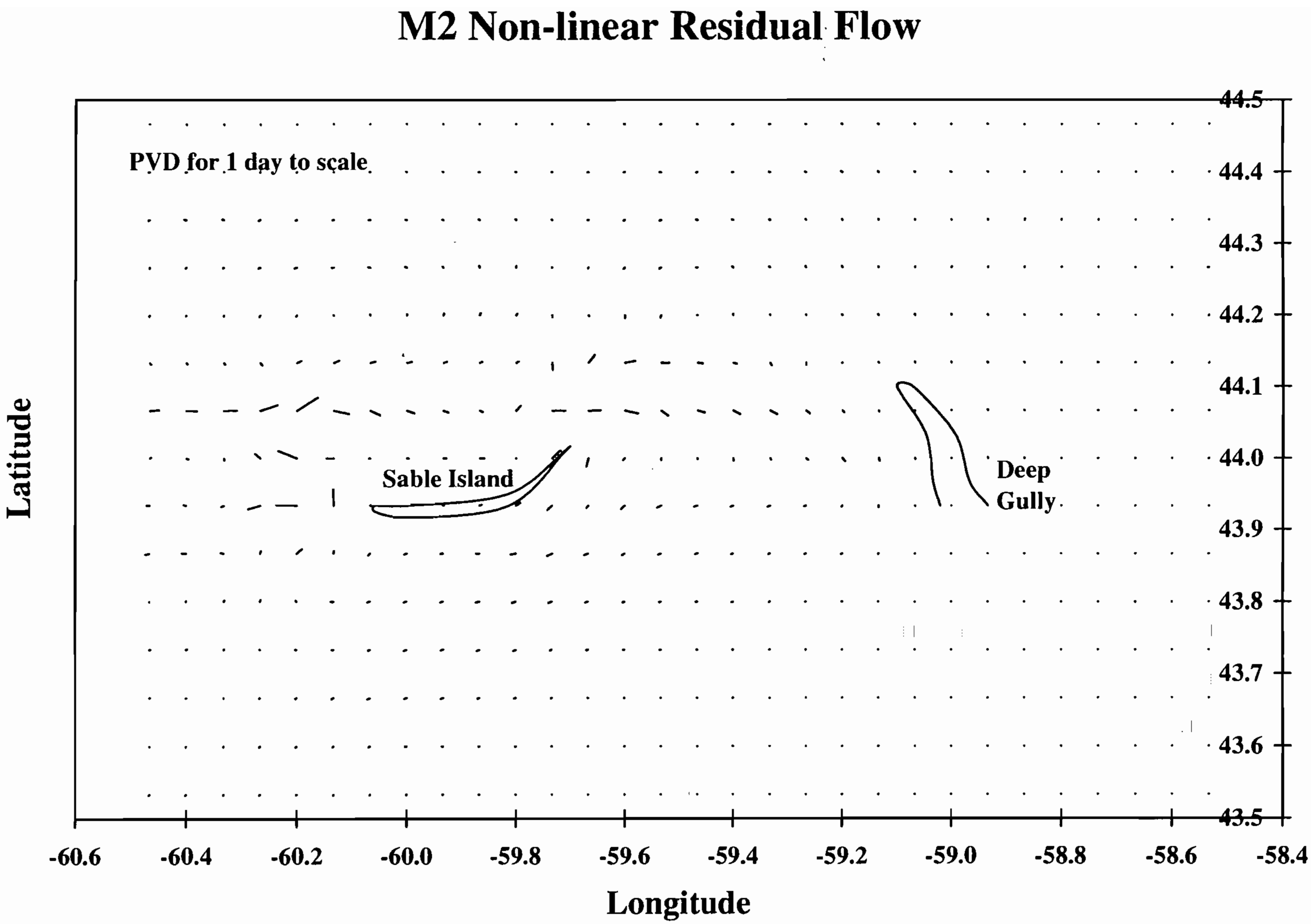


Fig. 6.1.11. Residual currents generated by non-linear interactions of the M2 tide.

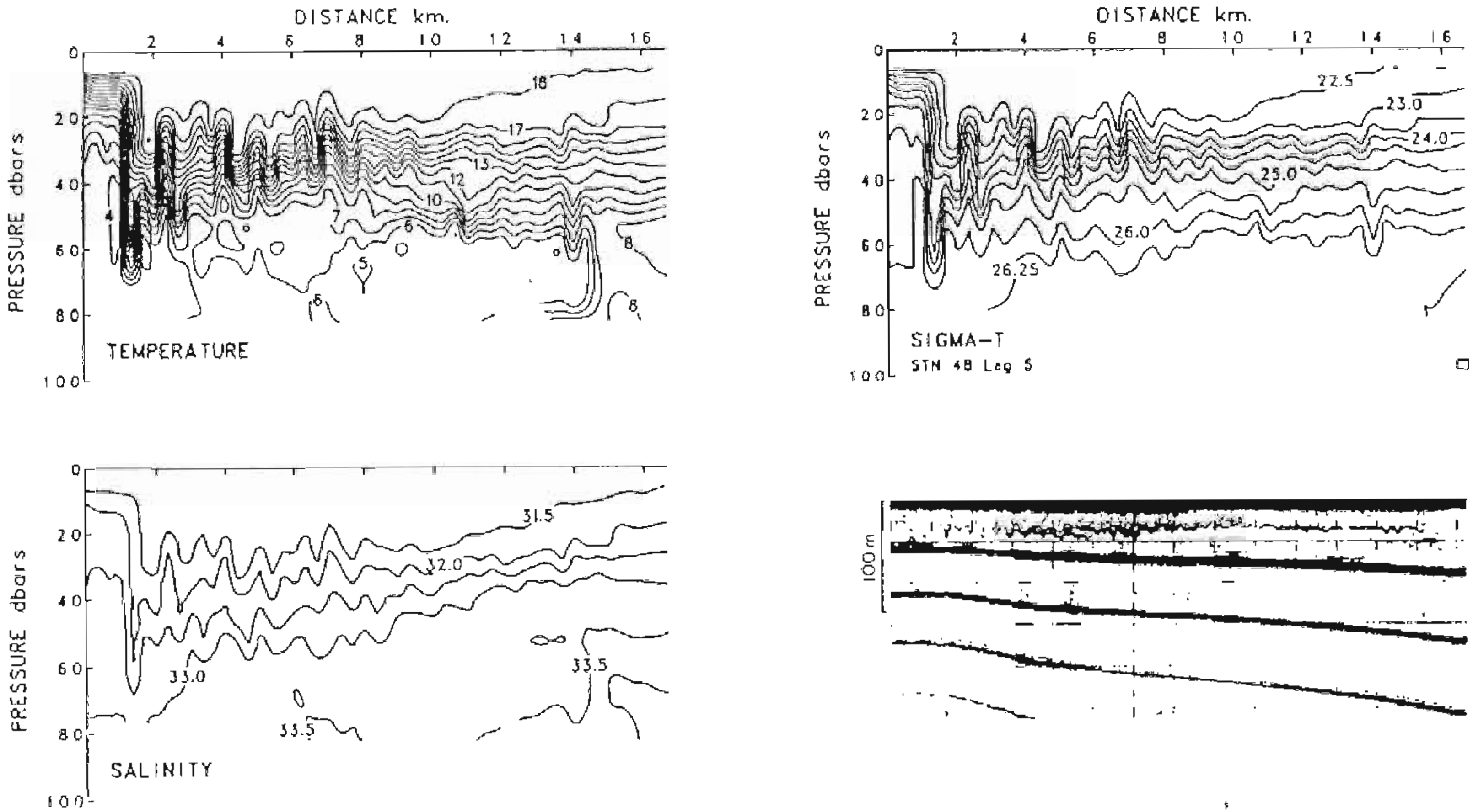


Fig. 6.1.12. Temperature, salinity, density and echo-sounder sections from the eastern flank of the mouth of the Gully (from Sandstrom and Elliot, 1989).

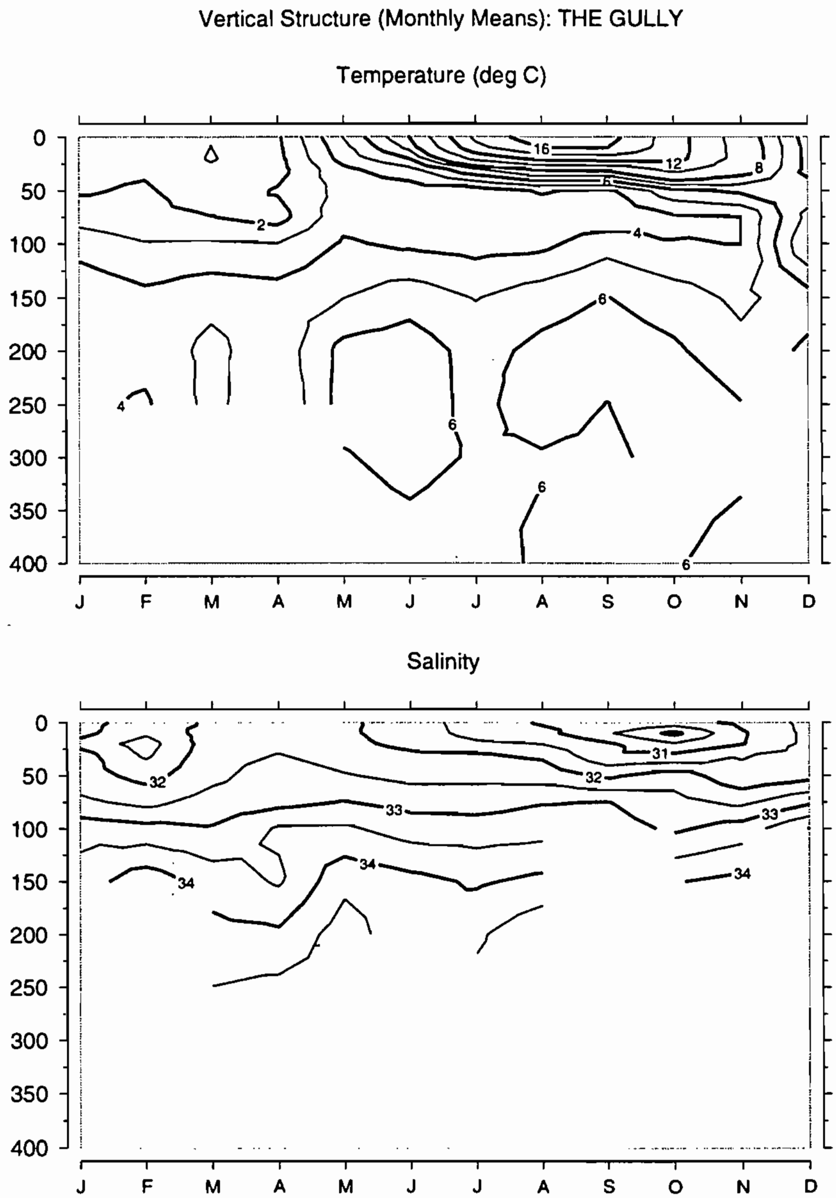


Fig. 6.1.13. Monthly average temperature and salinity for the Gully.

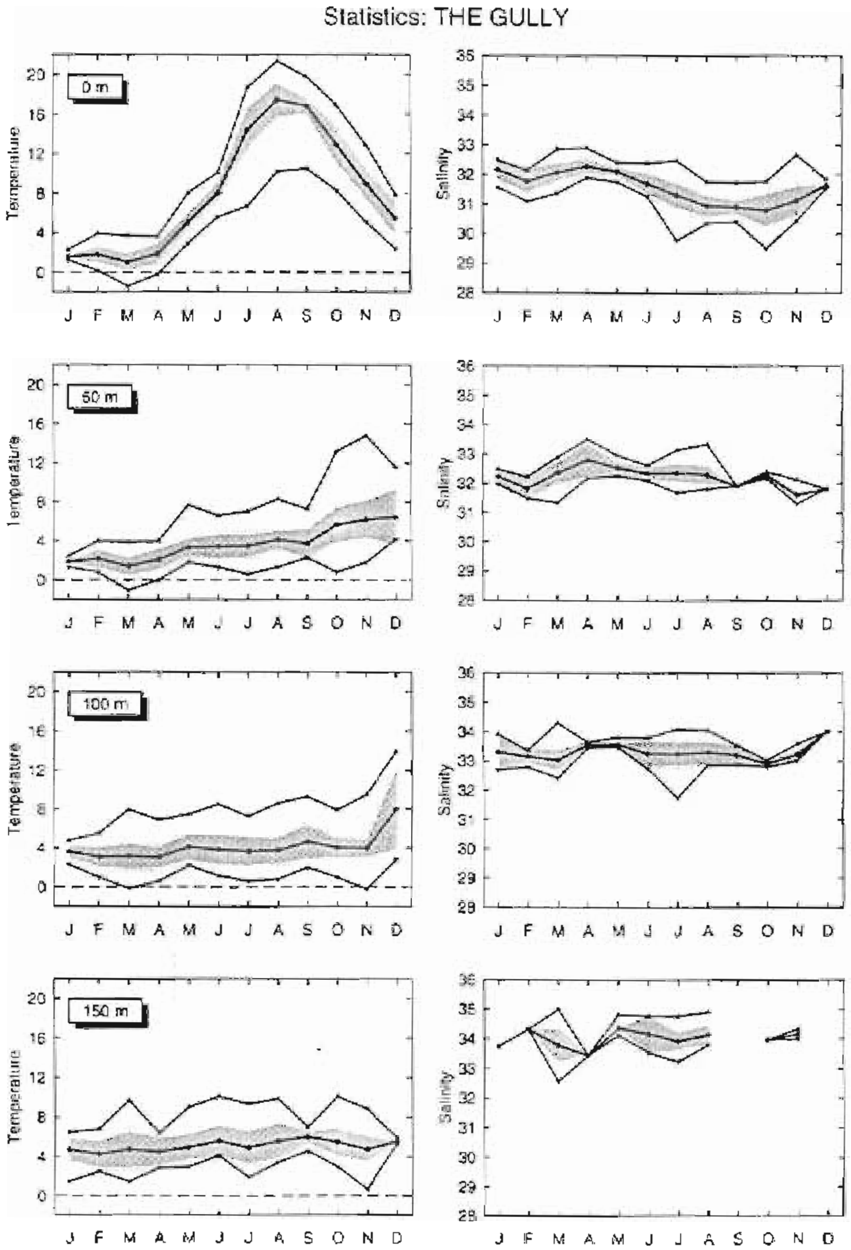


Fig. 6.1.14. Temperature and salinity statistics for selected depths in the Gully. The centre line represents the mean, the shaded ±1 standard deviation, and the outer lines represent the extremes.

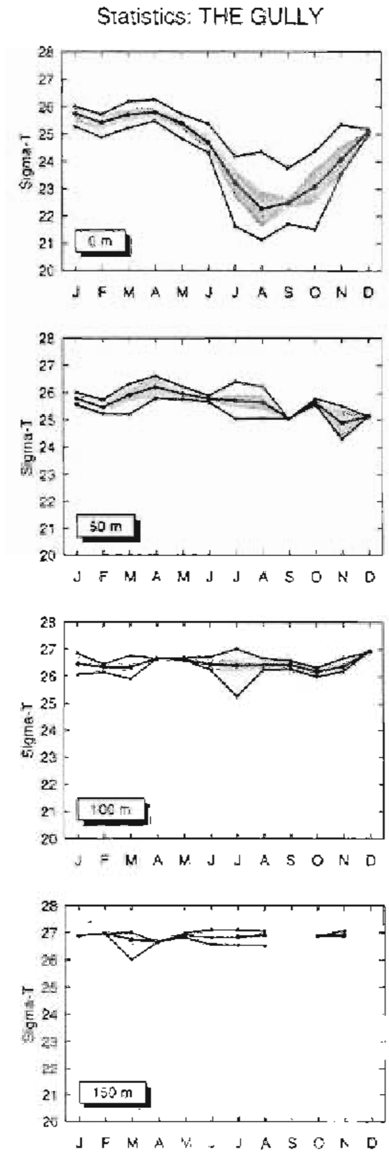


Fig. 6.1.15. Sigma-t statistics for selected depths in the Gully. The centre line represents the mean, the shaded ±1 standard deviation, and the outer lines represent the extremes.

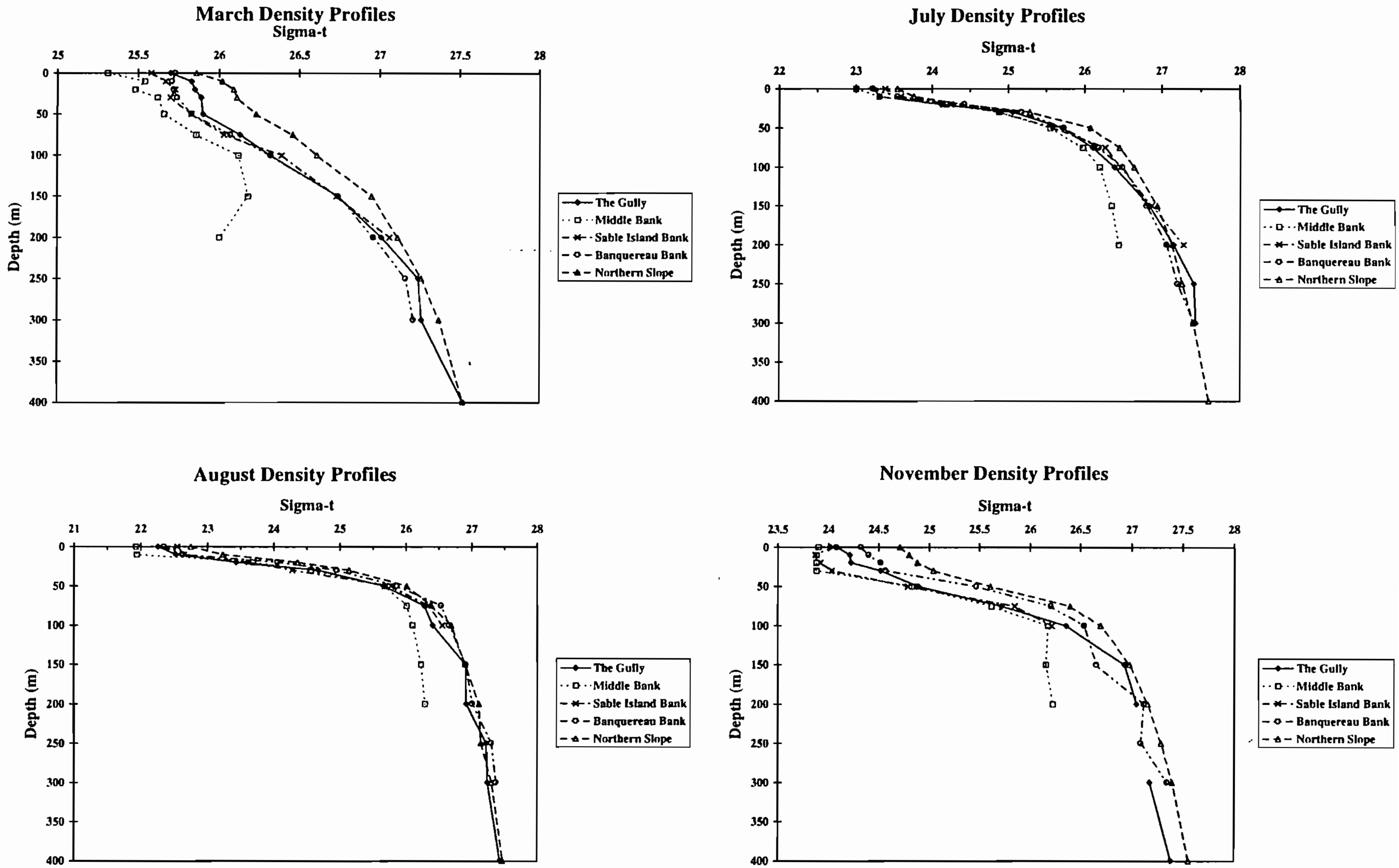


Fig. 6.1.16. Long-term average monthly density profiles from the Gully and four surrounding areas.

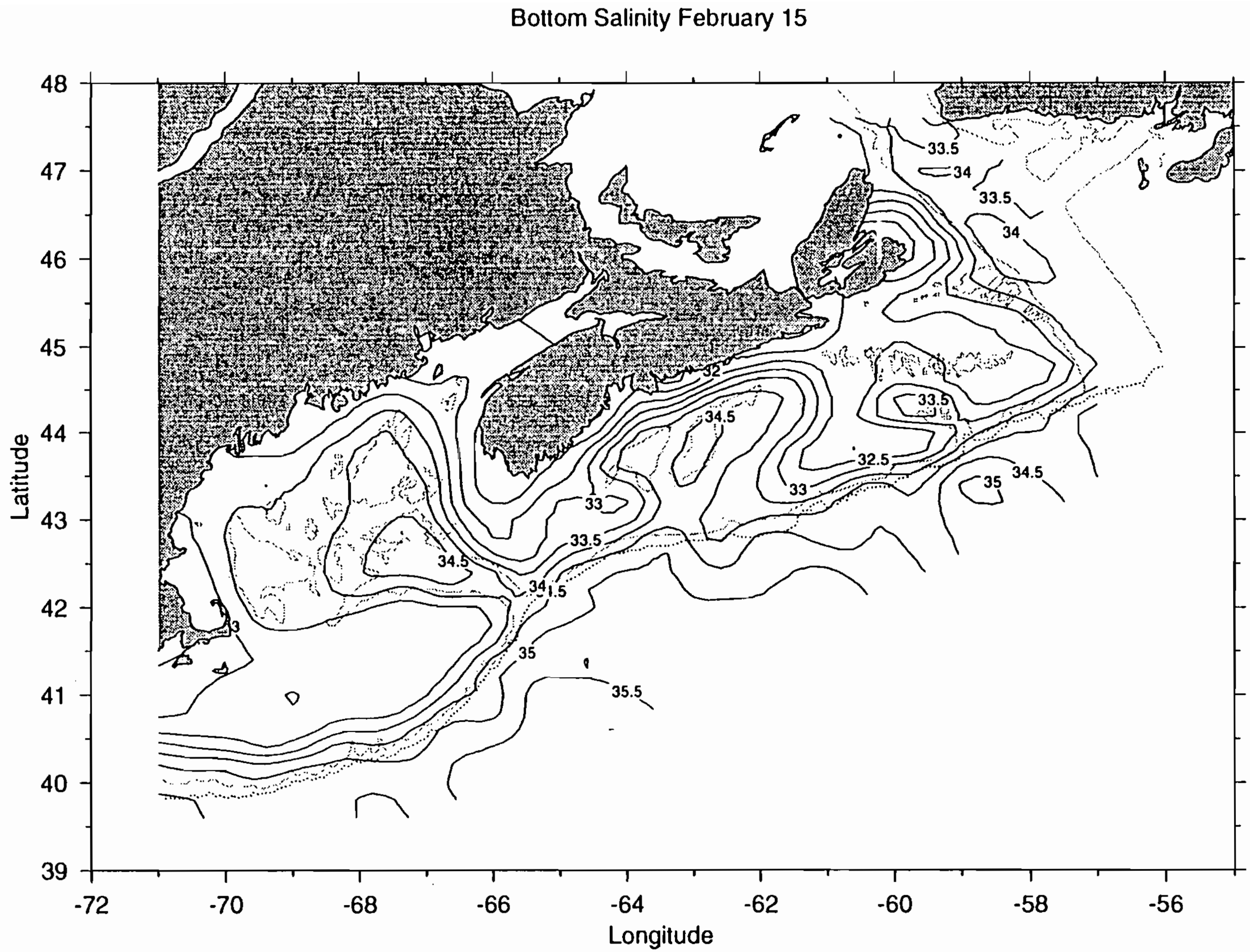


Fig. 6.1.17. Bottom salinity distribution for the Scotian Shelf (Petrie et al. 1996).

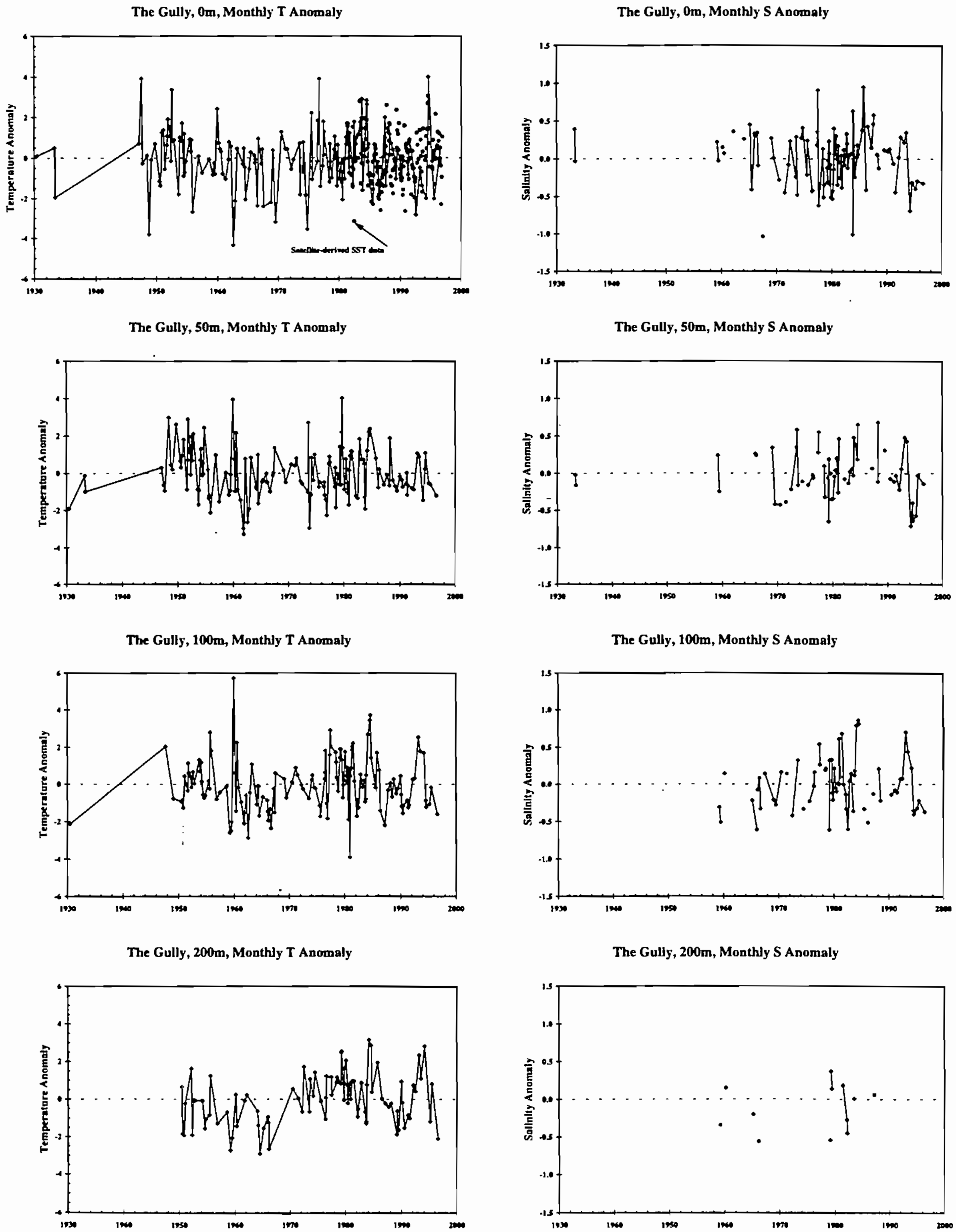
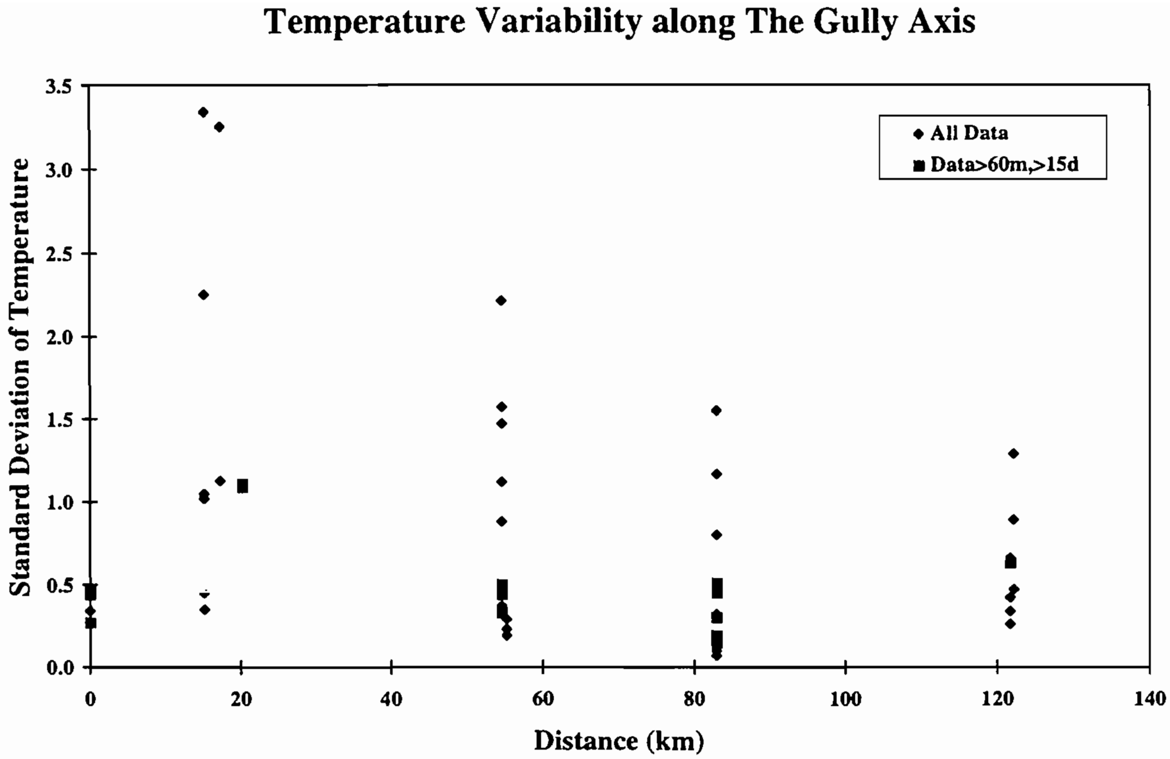


Fig. 6.1.18. Monthly temperature and salinity anomalies for the Gully.



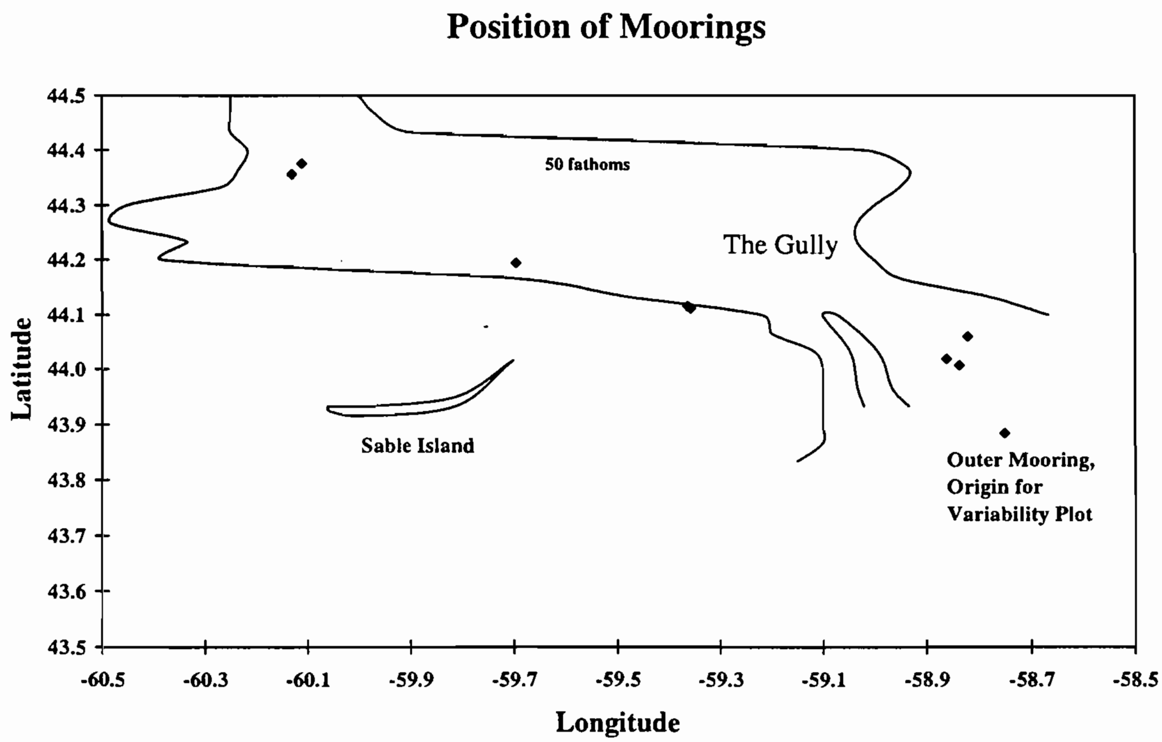
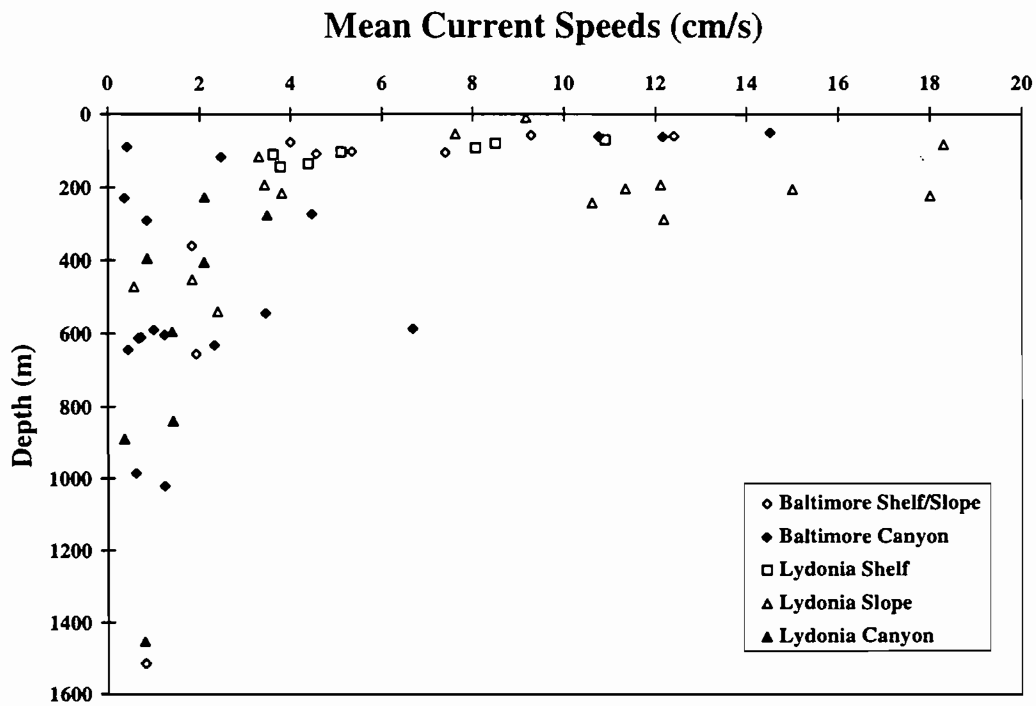


Fig. 6.1.19. (Upper panel) Standard deviation of temperature for all records in the Gully. (Lower panel) Locations of the moorings where the data were collected.



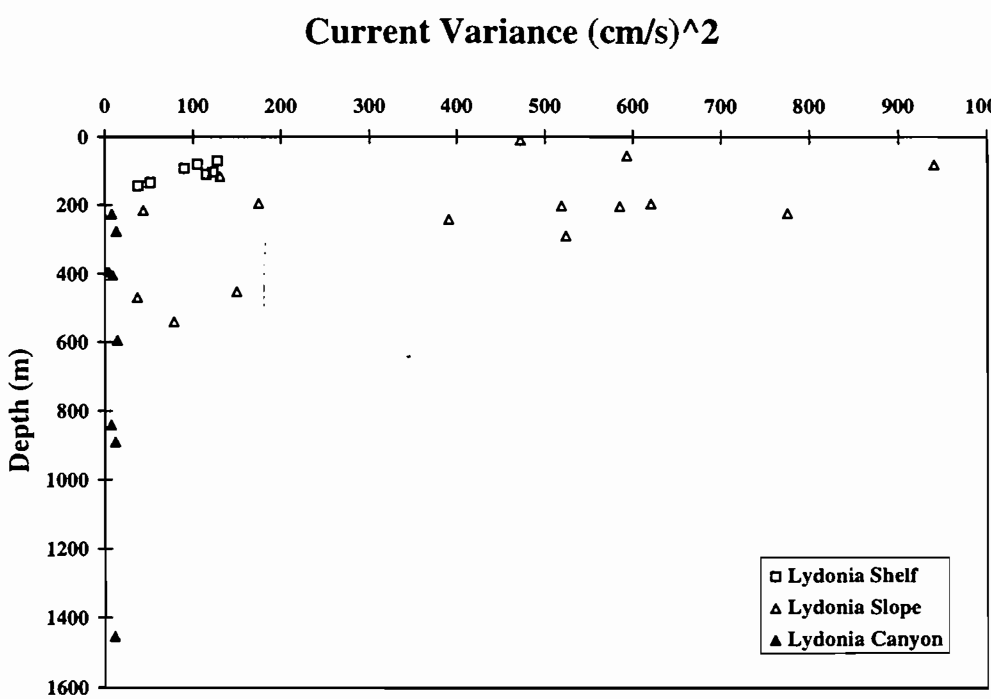


Fig. 6.1.20. Vertical profiles of the mean current speeds and current variance from Baltimore and Lydonia Canyon regions.

6.2 Chemical Oceanography

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6.2.1 Contaminants

No measurements of chemical contaminant concentrations in the Gully, either water or sediments, are available. If a broader geographic area that includes adjacent parts of Sable Island Bank, Middle Bank and Banquereau is considered, some limited measurements of contaminants are encountered, including some measurements of contaminants in biota. Some of these data were collected on BIO cruises and other field surveys, and some by the companies involved in the Sable Bank offshore energy developments. This latter body of data has recently been reviewed in the Sable Offshore Energy Project Environmental Impact Statement. Some of the BIO cruise results have been published (*e.g.* Keizer *et al.*, 1978; Dalziel, 1992; Yeats, 1993; and Addison and Stobo, 1993). Additional data are stored in the BIO node of the National Contaminants Information System, a national DFO contaminants database, and in the AGC 'open file' system. Analytes that have been considered in one or more of these studies include heavy metals, PCBs, and PAHs in water, sediments and/or biota. As would probably have been expected for an offshore area such as the Gully, no particularly elevated levels of any of these contaminants were encountered in any of these studies.

The main routes for contaminant transport to the Gully would be long range atmospheric transport and water transport in surface currents flowing out of the Gulf of St. Lawrence and across the shelf. The importance of the St. Lawrence discharge on the Gully is indicated in the assessment of monthly mean salinity statistics (Section 6.1). Some indication of the transport of heavy metals out of the Gulf of St. Lawrence in this surface water discharge is available (Yeats, 1993). No information of organic contaminant discharges from the Gulf is available. The importance of long range atmospheric transport of several organic contaminants and mercury has been identified in studies by DOE of wildlife in the Kejimkujik area of southwestern Nova Scotia. DOE data on concentrations of organic contaminants in wet precipitation in Atlantic Canada have been summarized by Brun *et. al* (1991). A potential new source for contaminant transport to the Gully is the Sable Offshore Energy Project. Contaminants could be transported in solution or as particulates, and the magnitudes of the discharges could be quite large. The work that has been done to date on the zones of impacts of drilling muds discharged from offshore developments and the current regimes in the SOEP area as part of the SOEP EIS, however, suggest that this potential source is unlikely to impact the Gully. Development of drilling sites closer to the Gully may present a far greater risk.

6.2.2 Nutrients

By far the largest chemical oceanographic data sets for the Gully area exist for nutrients and oxygen. An extensive database of nutrient and oxygen data for eastern Canadian marine waters is maintained by the Marine Chemistry Section at BIO. This database has been used to develop the following picture of the nutrient distributions in the Gully area.

For this analysis, data were extracted from the nutrient and oxygen data from a polygon that encompasses the Gully plus some of the shelf areas immediately adjacent to the Gully, and from polygons for the shelf areas to the west (eastern Sable Island Bank), north (Middle Bank), and east (Banquereau). These areas plus the locations of stations with nutrient or oxygen data are shown in Fig. 6.2.1.

A nitrate vs. depth profile for all the data from stations in the Gully polygon is shown in Fig. 6.2.2. This representation gives a picture integrated over both space and time of the nitrate distribution. The two features that are most evident from this figure are the general picture of nutrient concentrations increasing with depth and the large range in nitrate concentrations that are seen in the surface mixed layer. The general profile shows an increase from non-detectable or very low levels at the surface to approximately 15 μM at 200 m depth - a level that is comparable to those generally found in intermediate depth slope waters off the Scotian Shelf. The variability in the surface layer reflects the seasonal cycle of nutrient concentrations decreasing from high concentrations in the winter to low concentrations in the spring and through the summer into the early part of the fall. The seasonal cycle for nitrate in the surface mixed layer is shown in Fig. 6.2.3. Similar pictures, both the vertical profiles and the seasonal cycles, are seen for phosphate and silicate.

This general picture of the nitrate (or phosphate) distribution in the Gully, averaged as it is over time and space, is indistinguishable from similar pictures developed for Sable Island Bank, Middle Bank or Banquereau. A comparison of the seasonal cycle of nitrate in the surface layer for the four regions is shown in Fig. 6.2.4. This figure shows the average monthly surface layer concentrations in each region. It is clear from this figure that there are no substantive differences in the seasonal concentrations in any of these regions. For the deeper waters a comparison of the nitrate profile for all Gully stations with soundings greater than 100 m with those from similar depth stations from the Sable Island Bank and Banquereau shelf edge (Fig. 6.2.5) shows that the profiles are indistinguishable. The picture for silicate is slightly different with the seasonal surface layer distributions (Fig. 6.2.6) showing higher concentrations in winter in the Middle Bank region. The source of this signal is probably the discharge from the Gulf of St. Lawrence. Otherwise, the silicate distributions are also substantively similar in all four regions.

A major problem with the previous description is that results from all the stations are combined. Only for the seasonal cycle in the surface layer are there enough data to investigate any trends. There are insufficient data to investigate long-term trends such as the decadal scale trends in oxygen seen in Emerald Basin (Petrie *et al.*, 1994). Important features associated with specific locations such as inflows on the eastern flank of the Gully associated with a counterclockwise circulation as suggested by some of the results summarized in Section 6.1 may also be lost in the general picture. Offshore to inshore gradients or cross-Gully gradients may be important components of our understanding of nutrient supply to the Gully, but there are insufficient data to investigate these gradients. One cruise in our database does have three stations lined up more or less along the main axis of the Gully and this line (approximately 50 km long) does show significant increases in nitrate and silicate concentrations at 100 m depth from offshore to inshore. Salinity decreases slightly along this line. There are no cross-gully transects in the nutrient database that could be investigated for evidence of doming of nutrient profiles like those seen for chlorophyll a in the Gully (see Section 6.3.1) or for nutrients elsewhere (*e.g.* Shea and Broenkow, 1982).

Sources of nutrients to the Gully will include the three general sources identified above in the section on contaminants. The Gulf of St. Lawrence outflow will be an important source, particularly in the winter as the nutrient discharge from the Gulf in winter is quite large (Yeats, 1988). Atmospheric inputs for nutrients are generally considered to be fairly minor but SOEP may be a significant source because produced waters usually contain very high ammonia concentrations. The most important source of nutrients, however, will be the input from offshore. The main source of these offshore waters that mix onto the shelf will be intermediate depth slope waters, either Warm Slope Water or Labrador Slope Water (Petrie and Drinkwater, 1993). Nutrient concentrations in Warm Slope Water are high (nitrate approximately 22 μM and silicate, 15 μM), while those in the Labrador Slope Water are less well defined based on the currently available data, but somewhat lower than those in the Warm Slope Water. In either case these intermediate depth slope waters will be a major contributor of nutrients to the shelf break region including the Gully.

6.2.3 Nutrient Fluxes through the Gully

The contributions of low frequency processes to the onshore-offshore exchange of heat and salt through the Gully are described in Chapter 6.1. Moreover, Houghton *et al.* (1978) stated that there was evidence in their data of enhanced cross-shelf exchange through the Gully and the Scotian Gulf. They did not present quantitative evidence for the former but did show detailed calculations of the heat, salt and nitrate fluxes for the latter. Their nitrate fluxes were based on current meter data from a mooring located at the 250 m isobath on the shelfbreak south of the Scotian Gulf from December 1975 to April 1976 (Smith 1978) and water bottle observations of dissolved oxygen and nitrate. The current meters measured current speed and direction, temperature and salinity. Regressions between water bottle temperature and salinity with dissolved oxygen (for depths $\geq$ 50 m) were used to convert the temperature and salinity fluxes from the current meters to a dissolved oxygen flux; then, a regression between dissolved oxygen and nitrate was used to transform the oxygen flux to a nitrate flux. The nitrate flux calculated by Houghton *et al.* represents the contribution to the shelf for low frequency motions with periods of 16.5 hours to 33 days. Most of the nitrate flux is concentrated in the band from 4 to 14 d, *i.e.*, motions generally caused by meteorological forcing. Neither Houghton *et al.* (1978) nor Smith (1978) calculated the nitrate flux associated with the mean flow over the mooring period. Smith (1978) showed that the mean flow at 50 and 150 m was onshelf at 2.8 and 2.6 cm s^{-1}. Their calculations of nitrate fluxes, with a positive sign corresponding to onshelf transport, show 38.3 µmole m^{-2} s^{-1} at 50 m, -10.7 µmole m^{-2} s^{-1} at 150 m and 0 µmole m^{-2} s^{-1} at 230 m. If we take these measurements as representative of the entire Scotian Gulf and extend them to the surface, then the nitrate transport to 150 m = (Representative width*Representative depth*Flux),

$$\text{Nitrate Transport} = (50{,}000\ \text{m} * 100\ \text{m} * 38.3\ \mu\text{mole m}^{-2}\ \text{s}^{-1}) - (50{,}000*50*10.7\ \mu\text{mole m}^{-2}\ \text{s}^{-1})$$
$$= 1.7*10^{2}\ \text{moles s}^{-1}$$

In order to evaluate the importance of the Gully in terms of transport of nutrients onto the Scotian Shelf, we have calculated the nitrate transport out of the Gulf of St. Lawrence and through the Gully and Scotian Gulf. We carried out the calculations for two periods, the months of December to February, representing high nutrient levels in shallower depths, and June to August, when upper level nutrients should be depleted.

Current meter data were taken from the Bedford Institute's archives and are summarized in Table 6.2.1. We only included data between 0 and 160 m from the western half of Cabot Strait, the mouth of the Gully, and between 43-43.25° N, 63-64°W for the Scotian Gulf. The Gully was the area least sampled.

Table 6.2.1. Current Meters Records.

Location	Number of Records Months - DJF	Months - JJA	Representative Width (km)
Cabot Strait	10	43	50
Gully	1	6	10
Scotian Gulf	11	11	50

Nitrate data for these months were extracted from the MCS database for the Cabot Strait region (46-48 °N, 59-61 °W), the Gully (43.8-44.5 °N, 58.5-60.5 °W), and the Scotian Gulf (43-43.8 °N, 63-64 °W). For each region the numbers of points (DJF, JJA) were: Cabot (347, 475), Gully (55,107) and the Scotian Gulf (71,73). The nitrate transports are tabulated in Table 6.2.2.

Table 6.2.2. Nitrate Transports.

Cabot Strait						
Width=50km for outflow						
	DJF			JJA		
Depth(m)	Current(m/s)	Nitrate(μM)	Flux(moles/s)	Current(m/s)	Nitrate(μM)	Flux(moles/s)
10	0.22	6.2	2046	0.12	0.4	72
50	0.21	5.54	1891	0.01	3.35	54
75	0.2	6.73	1682	0.06	6.04	453
100	0.14	9.16	2405	0.04	8.72	654
150	0.08	12.88	1288	0.05	14.72	920
Total(moles/s)			**9312**			**2153**
Gully						
Width=10km for inflow						
	DJF			JJA		
Depth(m)	Current(m/s)	Nitrate(μM)	Flux(moles/s)	Current(m/s)	Nitrate(μM)	Flux(moles/s)
10	0.019	10.52	60	0.028	0.43	3.6
50		13.32	82		4.73	63
75		15.3	73	0.054	7.7	104
100		19.16	137		12.64	256
150		21.73	103		20.72	280
Total(moles/s)			**455**			**707**
Scotian Gulf						
Width=50km						
	DJF			JJA		
Depth(m)	Current(m/s)	Nitrate(μM)	Flux(moles/s)	Current(m/s)	Nitrate(μM)	Flux(moles/s)
10	-0.091	8.46	-1155	-0.057	0.17	-15
50	-0.025	12.88	-523	-0.036	4.1	-240
75		16.83	-358		10.21	-313
100	-0.009	18.71	-316	-0.013	11.98	-292
150	-0.004	19.08	-95	0.006	15.15	114
Total(moles/s)			**-2447**			**-746**

In the winter, the nitrate transport from the Gulf of St. Lawrence is about 4 times that through the Scotian Gulf and nearly 20 times greater than the transport through the Gully. In summer, the nitrate transport from the Gulf is 3 times that through the Gully and the Scotian Gulf. The transport through the latter two are nearly equal and but the opposite sense. Note that the transport though the Scotian Gulf is in the opposite sense for winter as well, and to that determined by Houghton *et al.* (1978). Moreover, our December-

February transport exceeds their December-April transport by a factor of nearly 15. The differences in their analysis compared to this one are that they used current data for only one period and from farther off the shelf, and they calculated the nutrient fluxes for periods of about 1 to 30 days, whereas, our calculation estimates seasonal fluxes. One earlier estimate of nitrate transport through Cabot Strait based on geostrophic calculations of the currents and BIO nutrient data collected in the 1970s (Yeats, 1988) gave an annual average of $5*10^3$ moles/s.

Our calculations are based on current meter data that were not collected at the same time as the nutrient data, assumptions about the horizontal scale that the current meter data represent *(e.g.,* half the width of the Gully at its narrowest point defined by the 100 m isobath), very few current meter observations with poor vertical resolution (particularly true for the Gully, where one winter current observation was taken as representative of the entire depth to 150 m), and in some cases few nutrient measurements from the regions (again particularly true for the Gully, where most of the data comes from the adjacent bank areas). With these weaknesses in mind, the overall indication is that the nitrate transport through the Gully could make a significant contribution to the eastern Scotian Shelf during the summer. In winter, the transport from the Gulf of St. Lawrence dominates.

6.2.4 Summary

There are no data on contaminant concentrations within the Gully. Extrapolation of data from adjacent areas would suggest that elevated concentrations of any of the common contaminants would not be anticipated in the water, sediments or biota of the Gully. Contaminant survey(s) to establish baseline levels would be worthwhile.

There are adequate measurements of nutrient and oxygen concentrations in the Gully to calculate monthly mean concentrations for these parameters. The general picture of nutrient distributions in the Gully averaged as it is over monthly time scales and Gully-wide space scales is very similar to analagous descriptions for adjacent areas. Estimates of nutrient transport through the Gully onto the Scotian Shelf based on these seasonally averaged descriptions of the distributions indicate that transport through the Gully can make a significant contribution to the nutrient pool on the eastern Scotian Shelf. There are inadequate data for an investigation of nutrient variability on smaller time or space scales. There is no indication in the available dataset of elevated nutrient levels that may have resulted from enhanced mixing or upwelling in the Gully. Mixing may be no greater in the Gully than on the adjacent regions of the shelf, it may be occurring on small time and space scales that were missed with the limited data coverage, or nutrients may be rapidly removed by biological uptake. A combined physical, chemical and biological study would be required to investigate these possibilities.

6.2.5 References

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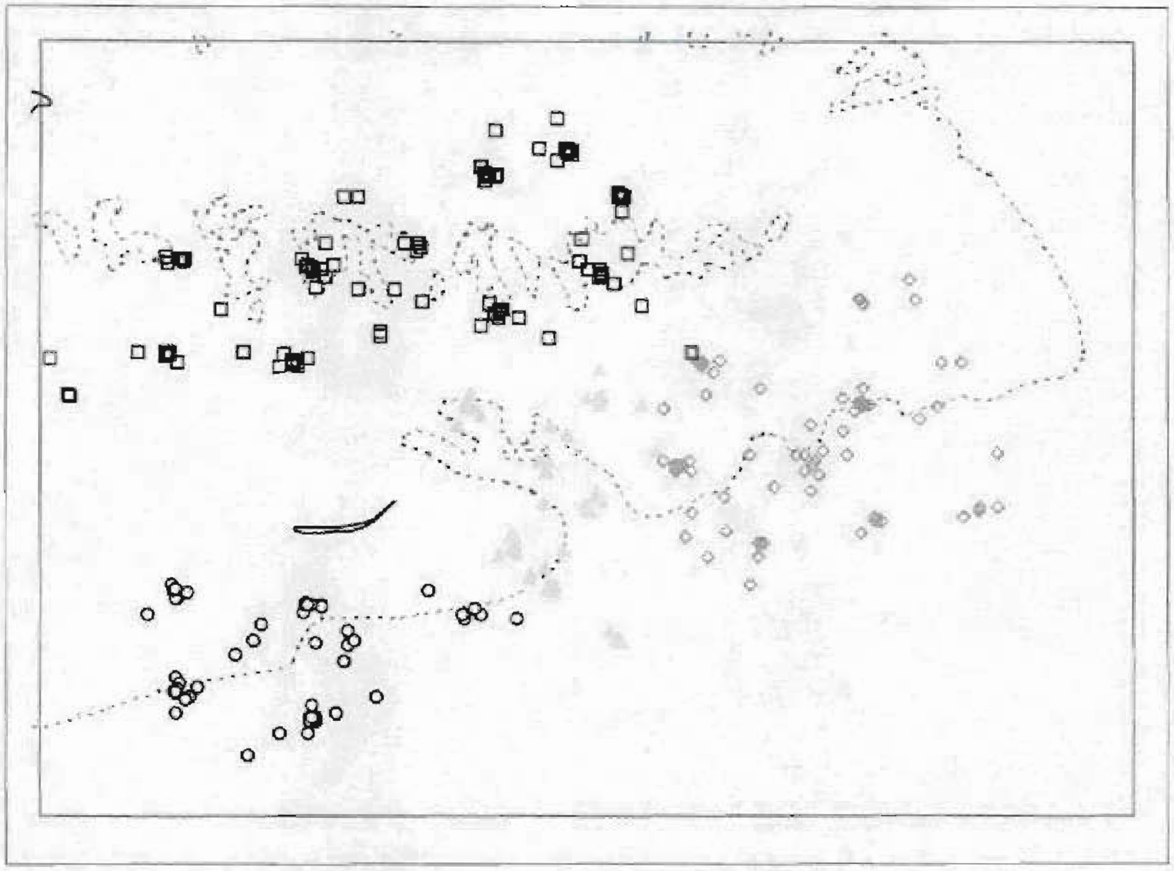

Fig 6.2.1. Locations of stations in the Marine Chemistry database with nutrient data. Triangles indicate stations from the Gully region; circles, squares and diamonds the adjacent western (Sable Island Bank), northern (Middle Bank) and eastern (Banquereau) regions.

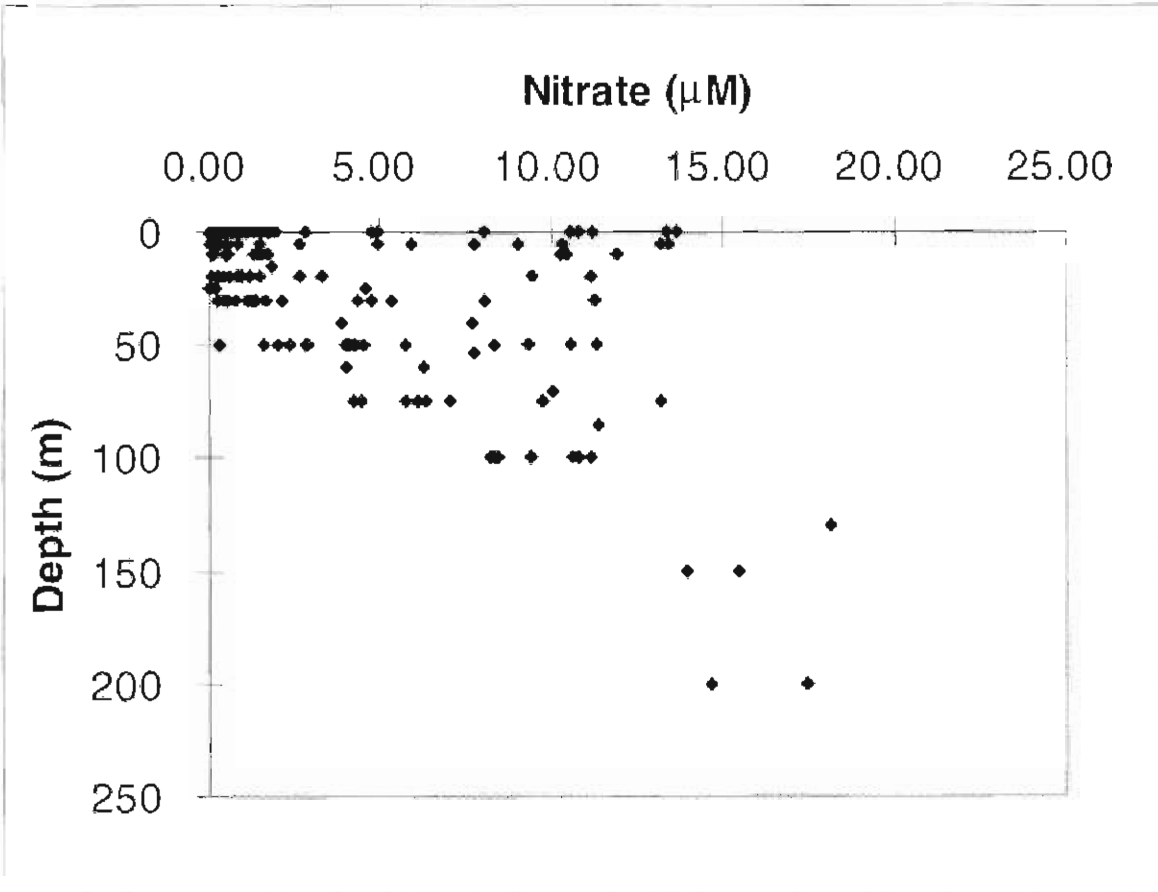

Fig 6.2.2. Nitrate versus depth for all Gully stations.

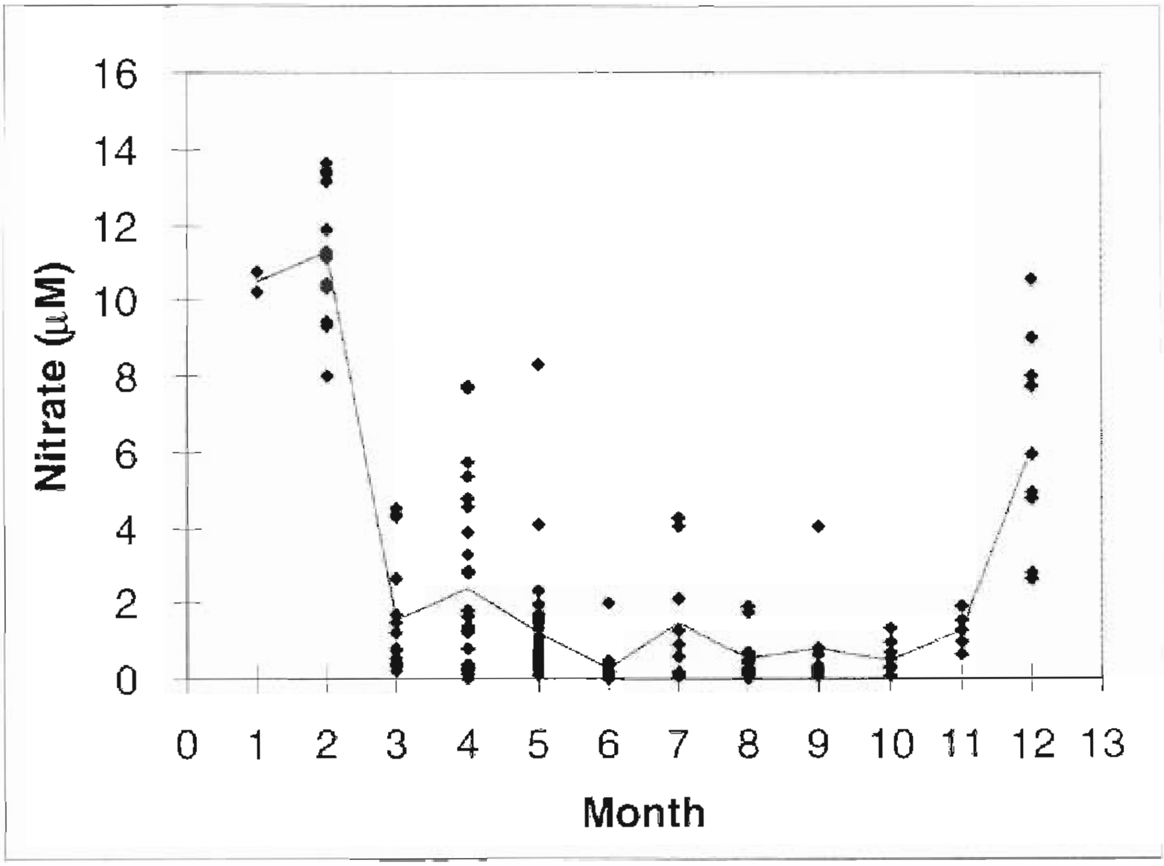

Fig 6.2.3. Gully nitrate concentrations for depths <50 m by month.

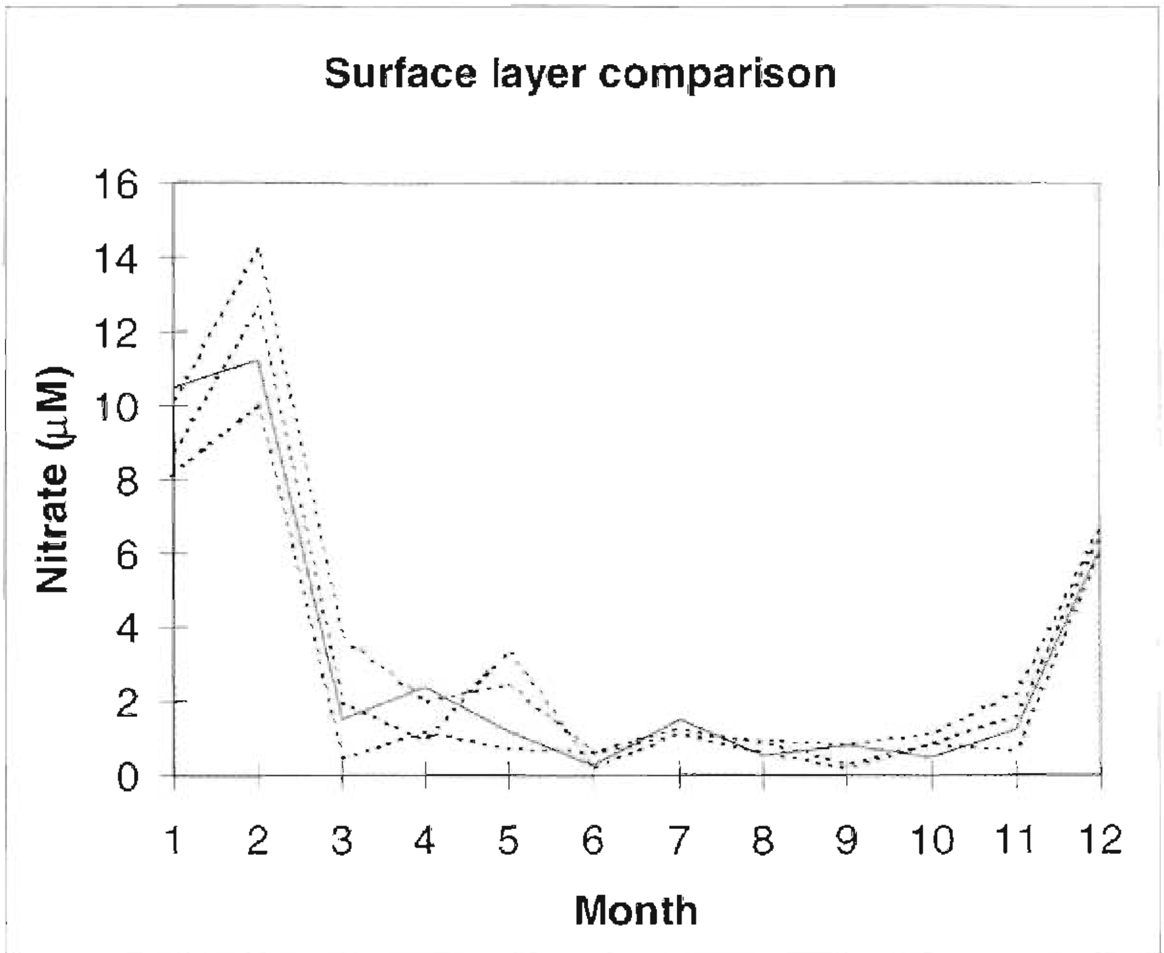

Fig 6.2.4. Average monthly nitrate concentrations for depths <50 m. Gully shown as solid line, adjacent shelf areas as broken lines.

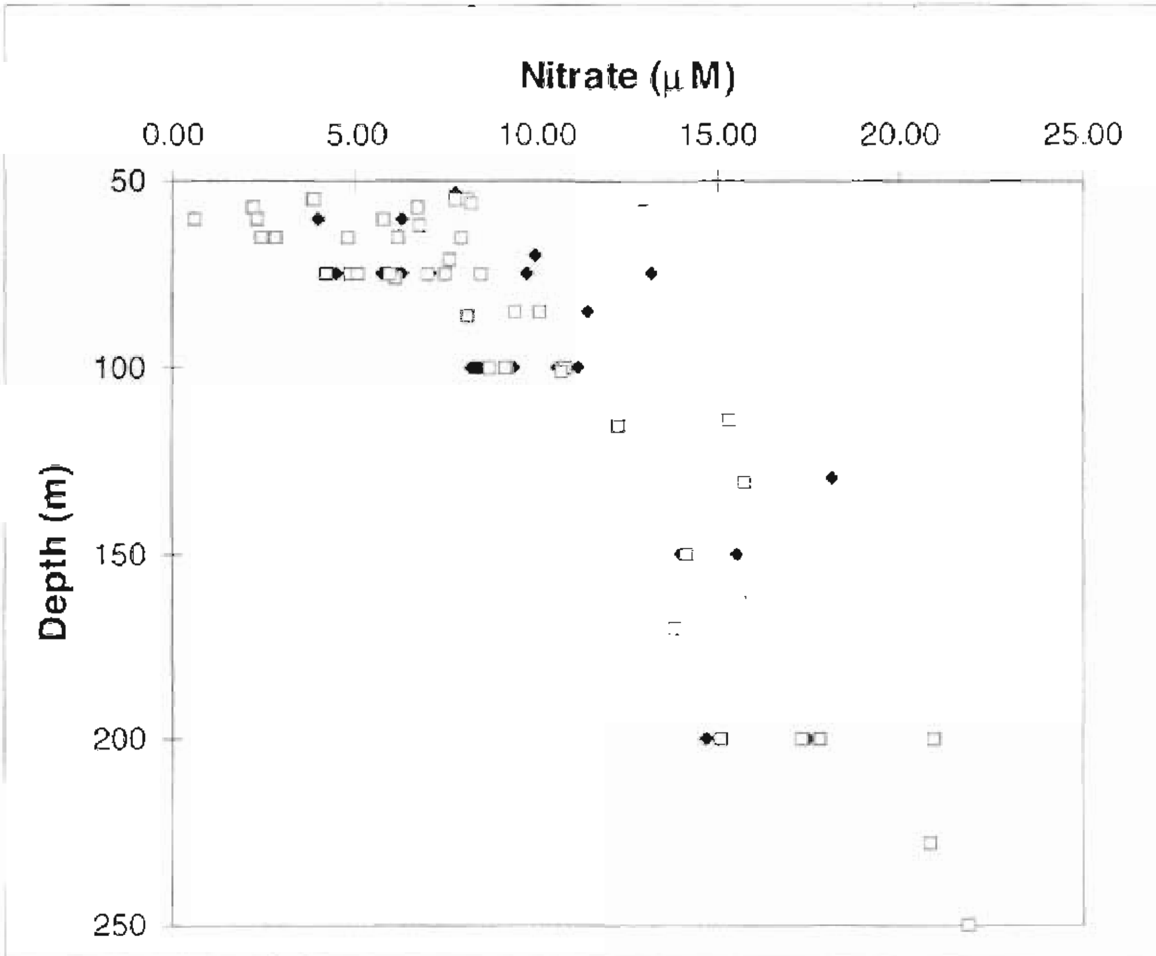

Fig 6.2.5. Nitrate versus depth (depths >50 m) for the Gully (diamonds) and adjacent shelf areas (squares).

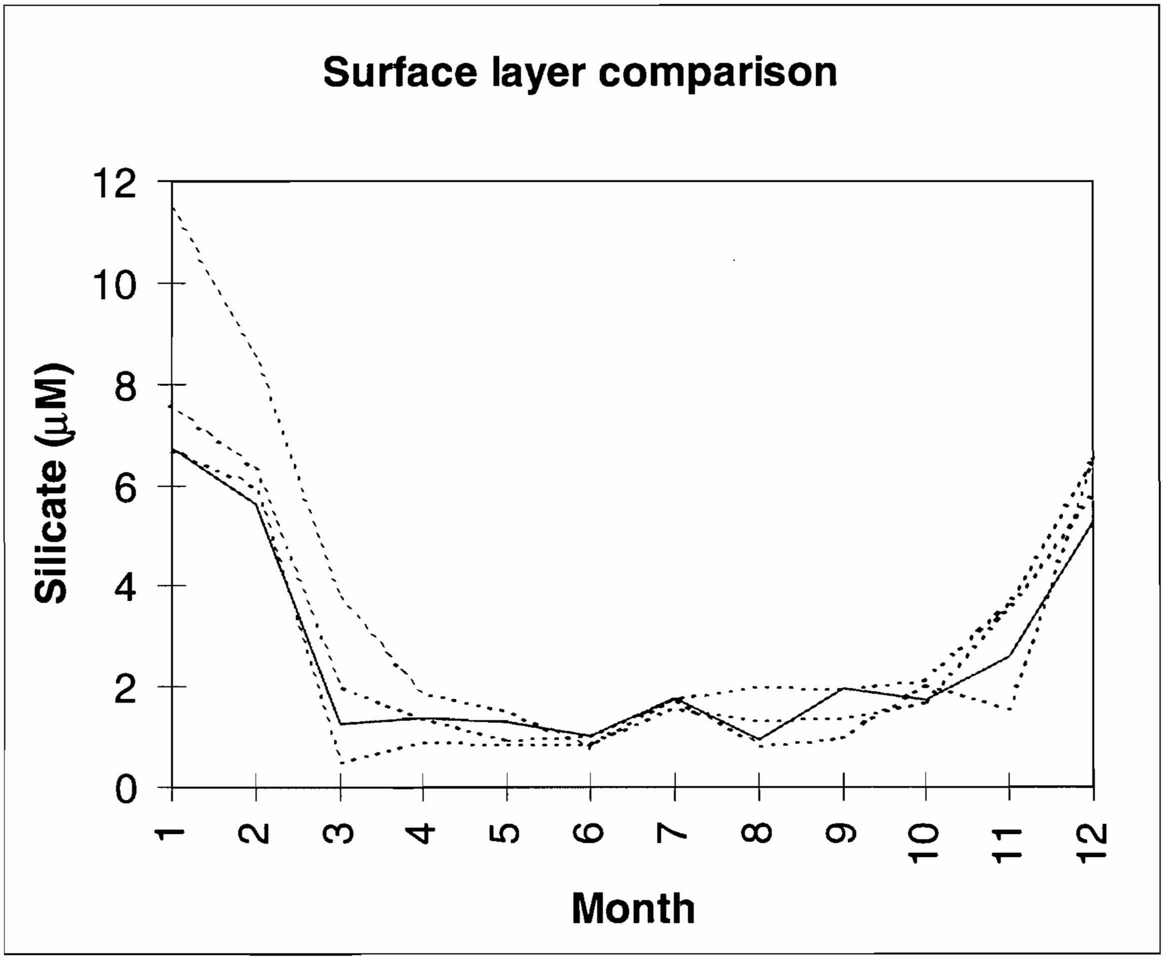

Fig 6.2.6. Average monthly silicate concentrations for depths <50 m. Gully shown as solid line, adjacent shelf areas as broken lines.

6.3 Biological Oceanography - Plankton

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6.3.1 Distribution and Seasonal Cycles of Phytoplankton

6.3.1.1 Sources of data

Five sources of data will be used in the analysis of distribution and seasonal cycles of phytoplankton. These are: (1) surface chlorophyll determinations made during the Scotian Shelf Icthyoplankton Program (SSIP), 1978-1982 (O'Boyle *et al.*, 1984), (2) surface chlorophyll maps derived from colour satellite images of the Coastal Zone Color Scanner (CZCS) which collected data from 1978-1986 (Feldman *et al.* 1989), (3) depth profiles of chlorophyll concentrations collected either in July 1993 during a training cruise run out of Wood's Hole by the Sea Education Association (Robinson *et al.*, 1993; Chief Scientist, R. Bohrer) or (4) during missions of the CSGS Hudson (July 1995, June 1996, April and October-November 1997) and CSGS Parizeau (November 1996) (Head, unpubl. data) and (5) estimates of chlorophyll concentration derived from Secchi depth observations made in July 1993 and 1994 (Simard, 1995).

<u>Winter conditions</u>

During winter, the water column over the Scotian Shelf mixes from top to bottom due to storm activity, supplying nutrients (*e.g.* nitrate) to the near-surface layers. At this time, seasonal near surface light levels are relatively low, limiting the rate at which phytoplankton can grow (photosynthesize). In addition, the deep mixing means that individual cells will spend much of their time at depths at which their metabolic requirements exceed their photosynthetic capacity, resulting in slow growth. Thus, in the winter SSIP data (February, Fig. 6.3.1), surface chlorophyll concentrations were generally low. For a few stations (including one in the Gully) chlorophyll levels were higher, but the significance of this feature cannot be ascertained from the limited data available. No usable winter data was available from the CZCS ocean colour satellite.

<u>Spring conditions</u>

During spring, the surface layer warms up as vertical mixing decreases. Solar radiation also increases and the combination of water column stability, increased light intensity and high near-surface nutrient concentrations leads to the development of a "spring bloom". On the Scotian Shelf the bloom progresses temporally from west to east, and from the shelf break to the inshore. Based on the SSIP data (1979, 1981) the spring bloom was apparent over on the shelf west of Halifax in April and persisted on the eastern shelf into

May (Fig. 6.3.1). By contrast, in April in 1997 (Fig. 6.3.2), concentrations of chlorophyll (surface and column-intergrated) were comparable in the western and eastern areas of the shelf and low levels were seen only over Emerald Basin and at stations further offshore on the Halifax Section. During April 1997, although phytoplankton concentrations (surface and integrated) were high in the Gully, they were not markedly higher than at stations on the eastern Scotian Shelf or in the Laurentian Channel. Surface and integrated chlorophyll concentrations were generally well-correlated over the shelf (Fig. 6.3.3) although distributional patterns differed along the Gully section; surface concentrations were highest offshore while integrated concentrations were highest at the inner-most station. At the inner-most station, surface chlorophyll concentration was relatively low and the subsurface chlorophyll layer was thicker (i) than at the two outer Gully stations, (ii) than at the four farthest offshore stations of the Louisbourg Line (Fig. 6.3.4), and (iii) than at most other stations of the survey (data not shown). Surface chlorophyll distributions in spring derived from CZCS satellite imagery (composites of ~25 individual images for 1979 and ~25 images for 1980) showed that high phytoplankton concentrations extended well beyond the shelf edge but highest concentrations were observed inshore; there was no evidence of enhanced surface chlorophyll concentrations in the vicinity of the Gully (Figs. 6.3.5 and 6.3.6).

Summer conditions

During summer, phytoplankton commonly exhaust surface nutrients (see Section 6.2) and their growth and biomass accumulation shifts to subsurface depths where optimal conditions of light intensity and nutrients persist (Cullen, 1982). Summer phytoplankton growth and biomass accumulation will continue in surface waters, however, in regions where nutrient supply is maintained. In the June SSIP data, the relatively high surface chlorophyll levels in the mid- and western regions of the shelf were likely a consequence of the vertical mixing of deep nutrient-rich water from upwelling along the coast or at the shelf break and tidal mixing over Brown's Bank and into the Gulf of Maine (Fig. 6.3.1). During a CSGS Hudson voyage in June 1996, surface chlorophyll concentrations were low everywhere, but integrated chlorophyll concentrations were higher on and around Banquereau Bank which was likely the result of the upwelling of slope water at the Bank's offshore margin (Fig. 6.3.7). Surface and integrated chlorophyll concentrations were not well correlated (Fig. 6.3.3); phytoplankton were generally concentrated in sharp subsurface peaks at depths of 30-40 m. Over Banquereau Bank and at its offshore margin the chlorophyll maximum depth was still at 30-40 m, but concentations were much higher than elsewhere. In the August SSIP data, surface chlorophyll concentrations were uniformly low (Fig. 6.3.1), although at this time of year they may not be representative of the total concentration of phytoplankton in the water column because of the subsurface accumulation of biomass. CZCS satellite composites for summer 1979 (based on ~22 individual images) and 1980 (based on ~24 individual images) showed that phytoplankton biomass was extremely low seaward of the shelf break with low concentrations on the central shelf and higher concentrations to the west and east. Surface concentrations were higher on the eastern shelf than during spring. No enhancement of phytoplankton biomass was apparent for the Gully region compared to the rest of the shelf (Figs. 6.3.5 & 6.3.6).

It has been proposed that deep nutrient-rich slope water is mixed to the near surface layers in the Gully which results in an enhancement of productivity there (Houghton *et al.*, 1978; Simard, 1995). It is expected that summer would be the season for which the effects of such a process would be most beneficial and most obvious. The observations of chlorophyll concentration in the SSIP data and satellite images show no enhancement of phytoplankton biomass in the surface layers of the Gully, but observations within the water column do suggest some effects. Researchers on the July 1993 cruise of the Sea Education Association ran a transect between Sable Island Bank and Banquereau Bank, near the mouth of the Gully. They observed a "doming" of the isotherms and isopycnals over the deepest region of the section. This is consistent with circulation models suggesting a cyclonic (counter-clockwise) gyre centred near the mouth of the Gully which brings deep water, if not to the surface, then to the near surface layers (see Section 6.1). Their observations of chlorophyll profiles also showed increased levels over the deep water of the Gully compared with values over the Banks, but only at depths of 20-40 m and then only to concentrations of ~1 mg l^{-1} (Fig. 6.3.8). Simard (1995) ran transects near the mouth of the Gully, across it and along its axis, during the same period (July 1993) and in July of the following year on which he determined Secchi depths (an index of water transparency). The shallowest Secchi readings and thus maximum concentration of light absorbing material (*i.e.* phytoplankton) were over the deep water near the entrance to the Gully. From his maximum attenuation coefficients in both years (*ca.* 0.14-0.16), a chlorophyll concentration of ~1-2 mg l^{-1} can be derived (Sathyendranath and Platt, 1988) which is consistent with that found in the Sea Education Association study in 1993. Although these observations suggest that there was vertical transport of nutrient-rich water towards the surface in this region of the Gully, this is not the only area of the Scotian Shelf where such processes can occur. For example, elevated chlorophyll concentrations of a similar magnitude were seen at 30-40 m at the shelf break on the Halifax Section in July 1995 (Head, unpubl. data) and, as discussed above, more significant enhancements of phytoplankton growth due to vertical mixing processes were seen in several areas in June during the SSIP survey (Fig. 6.3.1).

Fall conditions

Increasing turbulence in the water column during fall caused by intensifying seasonal winds results in water column mixing deep enough to bring nutrients to the surface, but not so deep as to mix the phytoplankton to depths where they cannot photosynthesize efficiently. The consequence of this is a "fall bloom" of phytoplankton which is often comparable to or larger in magnitude than that which occurs in the spring. In the SSIP data, increases in surface chlorophyll concentrations were seen over the Western Shelf in September and over most of the Shelf in November (Fig. 6.3.1). The CZCS colour satellite composites (1979 from ~16 individual images, 1980 from ~20 individual images) also showed clearly a shelf-wide fall bloom (1979) or one confined to the eastern shelf (1980) (Figs. 6.3.5 & 6.3.6). The surface chlorophyll concentrations in the Gully were no higher than concentrations elsewhere, however, based on SSIP and satellite data. In contrast to the data from 70s and 80s, there were low surface concentrations of chlorophyll in the falls of 1996 and 1997, suggesting that the fall blooms in these years were not important or missed (Fig. 6.3.9). Surface chlorophyll levels did appear to be reasonably representative of integrated concentrations in the fall of 1996 (Fig. 6.3.9), but the correlation was not in fact significant (Fig. 6.3.3). In the fall of 1997, at a station in the Gully, surface and integrated chlorophyll concentrations were similar to those seen elsewhere on the Scotian Shelf (Fig. 6.3.9).

6.3.2 Annual cycles of zooplankton biomass and abundance on the Scotian Shelf and in the Gully region.

6.3.2.1 Sources of data

Four sources of data will be used in the discussion concerning zooplankton. These are: (1) zooplankton abundance and biomass estimates (>333 µm) between 0 and the bottom (or 200 m), which were collected during the SSIP survey throughout the year between 1978-1982 (O'Boyle *et al.*, 1984); (2) zooplankton abundance and biomass estimates (>233 µm) made during missions of the CSGS Hudson in April, 1995, June 1996 and April, 1997 (Head, unpubl. data); (3) zooplankton abundance estimates using the BIONESS net sampling system in fall, 1989 (Sameoto, unpubl. data); and, (4) observations of macroplankton (*i.e.* krill) and small fish using acoustic backscattering in August, 1984 and April, 1997 (Cohrane, unpubl. data).

Definition of terms

Note that in this report the term zooplankton will be applied to animals > 200 µm in size. There are zooplanktonic organisms < 200 µm on the Scotian Shelf, the so-called microzooplankton, a group which includes unicellular protozoa, (*e.g.* heterotrophic dinoflagellates, ciliates) and the young life stages of some metazoans (*e.g.* invertebrate larvae, copepod nauplii). Elsewhere these are known to be very abundant at times, but information relating to their distribution and biomass on the Scotian Shelf is very limited, and for the Gully region it is non-existent, so that useful discussion is not possible.

Amongst the zooplankton 200-2000 µm in size, the so-called mesozooplankton, the most important in terms of biomass and abundance are the copepods, which are shrimp-like crustaceans which generally make up ca. 80 % of the total biomass. Although ca. 10-20 copepod species occur on the Scotian Shelf either year-round or during particular seasons, the most important in terms of biomass is *Calanus finmarchicus*. This species has as part of it life-history a requirement to overwinter at depths of >200 m, which make it particularly interesting in a discussion of the role of the Gully in the Scotian Shelf ecosystem, as will be seen below.

Another group of zooplankton, which also have particular significance for the Gully, are the euphausiids, or krill. These shrimp-like animals range in size between < 1 cm and 2 or 3 cms, depending on their age and species, and are generally referred to as macrozooplankton. They generally exhibit strong diurnal migration behaviour, spending the day at depths of > 200 m, and coming to the surface to feed on phytoplankton at night. They may also feed carnivorously on copepods, probably in the deep water during winter, and they also exhibit strong net avoidance behaviour, which means that without special precautions being taken, they will generally be underestimated in net hauls, although they are sufficiently large to be "seen" using acoustic backscattering at high frequencies.

6.3.2.2 Biomass of zooplankton on the Scotian Shelf at depths < 200 m

Winter conditions

The zooplankton net tows from the SSIP survey gave estimates of total of zooplankton biomass on the Scotian Shelf which were relatively low in the February, with levels being a little higher at stations in the east than at stations in the west (Fig. 6.3.10). The stations in or around the Gully did not show especially high values in February.

Spring conditions

The overall biomass levels of zooplankton as determined in the SSIP survey increased greatly between February and April (Fig. 6.3.10). This increase was largely due to the ascent of overwintering *C. finmarchicus* and its subsequent reproduction and growth in the near-surface layers. *C. finmarchicus* appearing on the shelf in April can derive from one of several overwintering populations. Firstly, there are populations which overwinter in the shelf basins, such as Emerald Basin. These start to ascend to the near surface layers in March and for Emerald Basin the ascent is complete by April (Herman, pers. comm.). Secondly, there is a population which overwinters in the Gulf of St. Lawrence. This population can "seed" the eastern Scotian Shelf, where its levels are higher in May than in April, and it may ascend to the near-surface layers later (*e.g.* April-May) than the Emerald Basin population. This population is carried to the Scotian Shelf in the outflow from Cabot Strait, and which runs south-east along the eastern shore of Cape Breton and then splits to form (i) the Nova Scotia Current, which flows south-west along the coastline until Halifax, and then diffuses out to the south-west over Emerald Basin and the western Scotian Shelf; and (ii) a second branch which flows along the western boundary of the Laurentian Channel and then turns at its mouth to flow south-west along the shelf break. There is a third population which overwinters in the deep water off the shelf break, which contributes to high concentrations of *C. finmarchicus* which are seen at the shelf break in April and May. According to Planque *et al.* (1997) *C. finmarchicus* overwintering in the deep water south of Newfoundland start to ascend to the surface layers in January. Given that the generation time for the species is ca. 2 months, the population occurring along the Scotian Shelf break in April and May probably includes individuals from both the previous and this year's generations. High concentrations of *C. finmarchicus* have been observed at the shelf break on Halifax Section on several occasions: April 1995 and 1997 (Fig. 6.3.11) and May 1996 (Head, unpubl. data). These animals can be advected on to the shelf in this region, so as to contribute to the biomass seen over Emerald Bank and at stations on the western Scotian Shelf.

Levels of biomass of *C. finmarchicus* at the shelf break off Banquereau Bank (eastern Scotian Shelf) in April 1995 were much higher than those seen in April 1997 (Fig. 6.3.11). By contrast, however, the biomass of another copepod species, *Calanus hyperboreus*, was somewhat higher in April 1997 compared with April 1995 (Fig. 6.3.12). *C. hyperboreus* has a life history similar to that of *C. finmarchicus*, but its overwintering period generally begins and ends earlier in the season and it may take 2 or 3 years to reach maturity, whereas *C. finmarchicus* generally produces 1 or 2 generations per year on or around the Scotian Shelf. *C. hyperboreus* is abundant in the Gulf of St. Lawrence, where it can overwinter, and in the cold surface waters of the onshore branch of the Labrador Current, which flows south and west through the deep channels of the South Newfoundland Shelf. Thus, off Banquereau Bank in 1997, compared with 1995, the zooplankton species composition suggests there may have been an increased contribution of water either from the Gulf of St. Lawrence via the Laurentian Channel, or from the inshore branch of the Labrador Current via the Newfoundland Shelf and the current at the shelf break. It appears that the second route is the most likely one, firstly because one copepod species (*Temora*) which was abundant in samples collected in western Cabot Strait (*i.e.* the Gulf outflow) in April 1997 was largely absent from samples collected at the shelf break (L. Harris, pers. comm.), and secondly, because hydrographic characteristics of water off St Pierre Bank (upstream, in the shelf break current) showed a significantly greater input of Newfoundland Shelf water in 1997 compared with 1995 (data not shown).

In the Gully in April 1997, *C. finmarchicus* biomass levels were higher than those at stations to the north and east, and *C. hyperboreus* biomass levels were lower (excluding the shallow station on Banquereau Bank) (Figs. 6.3.11 & 6.3.12). *Calanus* spp. in the surface layers of the Gully in April may derive from one or more sources: the population of the eastern Scotian Shelf, via advection in the near surface layers; the shelf break population, via intrusion of shelf break waters at depth; or a population which overwinters in the Gully itself. *C. finmarchicus* do accumulate the deep waters of the Gully in fall (see below), and it appears that the physical processes occurring there would enable them to remain there during winter, but the importance of the input from other sources cannot be assessed at this time. In terms of total zooplankton biomass, in the SSIP data (Fig. 6.3.10) and in April 1997 (Fig. 6.3.13), levels were not generally higher in the Gully than at the other nearby stations.

Summer conditions

C. finmarchicus dominated the biomass of zooplankton on the Scotian Shelf in June in the SSIP data (Fig. 6.3.10). By August most *C. finmarchicus* had left the near-surface layers and retreated to their overwintering depths, and although they remained among the most abundant copepods in the SSIP net tows, other smaller species which were becoming more abundant (*e.g. Centropages*) probably outnumbered them in the water column. This suggestion is made because a relatively large mesh net (333 mm) was used in the SSIP surveys, which would have lead to serious underestimation of the abundances of the smaller copepod species. Levels of zooplankton biomass were not especially high in the Gully in summer compared with levels at other stations.

Fall conditions

Zooplankton biomass levels remained high in September and November in the SSIP data (Fig. 6.3.10). At this time of year water temperatures, phytoplankton concentrations and primary productivity rates are high, leading to high growth rates amongst the zooplankton. The most important species at this time of year are relatively small in size (*e.g. Centropages*, *Pseudocalanus*, *Nannocalanus* etc.), and thus undersampled in the SSIP surveys, and species diversity is relatively high. *C. finmarchicus* in the surface layers at this time of year probably represent members of the second generation. Zooplankton biomass levels in the Gully in the fall at depths of < 200 m were no higher than those at other nearby stations.

6.3.2.3 Biomass of zooplankton in BIONESS tows to depths of >200 m

As has been discussed above, *C. finmarchicus* accumulate in deep water to overwinter in the fall. The Gully is one deep water area in which they accumulate and, for comparison, Emerald Basin is another. During a voyage on the CSGS Parizeau in October 1989 zooplankton tows were made in both the Gully and Emerald Basin, over series of stratified depths using the BIONESS sampling system. *C. finmarchicus* were more abundant at the deep stations in the Gully and were most concentrated at depths of 200-400 m (Fig. 6.3.14). Areal abundances at the deep stations in the Gully were ca. 6 times lower than those found in Emerald Basin, where the animals were also most concentrated at depths of >200 m (Fig. 6.3.15). That there are differences in the abundances of overwintering copepods in each location is not surprising, since their sources are different: *C. finmarchicus* overwintering in Emerald Basin probably derive from the Gulf of St. Lawrence, via the Nova Scotia Current, and from the nearby banks (Emerald and Western Banks); *C. finmarchicus* overwintering in the Gully may derive from the shelf break population or from the eastern Scotian Shelf. In addition, however, numbers of *C. finmarchicus* overwintering in Emerald Basin have varied between a high of > 300,000 m^{-2} (1986) and a low of < 35,000 m^{-2} (1996) between 1984 and 1996 (Sameoto, unpubl. data), which may be related to variations in productivity and circulation patterns. It seems likely that variations may also occur in the number of *C. finmarchicus* overwintering in the Gully, but annual variations in the two areas are not be expected to be closely linked. Thus, while the abundance of *C. finmarchicus* in Emerald Basin in 1989 was in the middle of the 12 year observed range, the same might not have been true for the population in the Gully.

Abundances of euphausiids (krill) were also determined in the BIONESS net hauls carried out in October 1989. The bulk of the population of *C. finmarchicus* in October had retreated to overwinter at depths of >200 m at both the Gully and Emerald Basin stations (Figs. 6.3.14 & 6.3.15), but krill at this time were apparently still performing their diel migrations, so that their vertical distribution was related to both time of day and water depth (Figs 6.3.16 & 6.3.17). Areal abundances of krill at stations within the Gully were very variable, but they were generally higher (up to 30 times higher) in the Gully than at the one station sampled in Emerald Basin (cf. Figs. 6.3.16 & 6.3.17). It is known that abundances of krill within Emerald Basin, which are determined quite regularly, vary considerably from year-to-year (Sameoto, pers. comm.) and the same is probably true for the Gully, although there is no reason to expect abundances in the two locations to co-vary. Thus, it cannot be ascertained from this one set of measurements whether krill abundances are generally higher in the Gully than in Emerald Basin.

6.3.3 Observations of macroplankton (krill and small fish) densities using high frequency acoustic backscattring

During the CSGS Hudson voyage in April 1997, observations of macroplankton densities were made using a hull-mounted 200 kHz acoustic system. The backscattering signal strength is proportional to the biomass of target organisms, which at this frequency includes animals of 2.5 cm and greater. The first track starts outside Halifax Harbour at a little before dusk and continues overnight into Emerald Basin. During this period euphausiids would have been either moving into, or occupying, the near surface layers (Fig. 6.3.18). The integrated acoustic backscattering signal in the 30-200 m depth range increased as the ship moved offshore, and remained high at stations in Emerald Basin until 1 or 2 h after dawn (A-F). Thereafter the signal decreased and remained low (F-J), presumably because the primary target organisms (krill) spend the daylight hours at depths of >200 m. As the ship started to move out of the Basin, a couple of hours before dusk (K-L, Fig. 6.3.18 & 6.3.19), the signal strength increased and then decreased as the ship moved into shallow water after dark (L-M). The "spikiness" in the signal between M and R was probably due to bad weather conditions, but it appears that there were higher concentrations of organisms in the deeper areas: N-O, on the outer flank of Emerald Bank; Q-R and S-T, at the shelf break (Fig. 6.3.19). After dawn the signal remained low, presumably because of vertical migration of the target organisms to depths of >200 m.

The acoustic record of ship's approach to the entrance to the Gully starts where the depth was about the 3000 m (Fig. 6.3.20, A). Between points A and D the water depth was over 2000 m. The integrated backscattering signal increased between points B and D, just before dusk. Thereafter, it decreased rapidly (C-D) and then slowly increased (D-F), until the ship reached the shelf break, where there was an abrupt increase in signal strength (ca. point G). As the ship crossed the edge of Sable Island Bank (G-H) the signal strength decreased dramatically, but it increased equally dramatically in the deep water across the entrance to the Gully (H-I). After dawn, as the ship proceeded up the Gully's axis, the signal strength remained low while the ship was over deep water (J-L). At the most northerly occupied stations where the bottom depth was ca. 200-300 m (Fig. 6.3.20, L-M; Fig. 6.3.21, M-O) the signal strength increased, even though it was still daytime. This may be because some (or all) of the target organisms were not migrating to depths of

>200 m in this area, because of the restricted depth (cf. Tows 3 & 4, Fig. 6.3.16). Thereafter, when the ship passed over shallow water (O-Q) the signal was low, but surprisingly, since it was after dusk, it did not increase much over the deep water (Q-R). Over Banquereau Bank the signal strength decreased (R-S) and at the shelf break (T) there was a sharp peak. The signal strength remained high until the ship moved into water deeper than 2000 m (T-V). After dawn the signal strength was low, with a small peak between points Z and AA as the ship was over water ca. 1000 m in depth.

The magnitude of the backscattering signal is proportional to biomass, but any organisms larger than 2.5 cm can contribute. On this voyage, a second acoustic system which measured backscattering at 12 kHz was used. The targets for this frequency are animals with air bladders, *i.e.* fish. By comparing the backscattering at the two frequencies, the relative contributions of euphausiids and small fish to the 200 kHz backscattering can be assessed. From these comparisons it was concluded that for areas at the shelf break and in the entrance of the Gully some part of the signal was due to small fish. Within Emerald Basin and the Gully, however, the signal was derived from krill alone. Thus, on the basis of the acoustic estimates it appears that concentrations of krill in some areas of the Gully were higher than those in Emerald Basin. During this voyage, net tows were made using a configuration of the BIONESS system especially designed to collect krill (*i.e.* flashing lights to prevent net avoidance) in Emerald Basin and the Gully, but the samples have not yet been analysed.

6.3.4 Summary

Phytoplankton

The phytoplankton data analyzed to date do not suggest that the Gully is a dictinctly productive feature on the Scotian Shelf. A statistical comparison (t-tests) of biomass levels in the proximity of the Gully with those in the surrounding Shelf waters shows no significant differences; if anything, biomass levels over the Gully are generally lower (Table 6.3.1). It should be pointed out, however, that the data summarized in this document provide information largely on the biomass at the sea surface and may not reliably assess the total phytoplankton biomass and productivity of the region *per se*. To the extent that a significant component of the biomass and growth of phytoplankton occurs below the sea surface, the data presented here and conclusions drawn from it should be considered incomplete. In order to more accurately characterize phytoplankton biomass and primary productivity in the Gully region, further study is needed.

Table 6.3.1. Surface chlorophyll concentrations (μg l^{-1}) from SSIP cruises: Mean (± S.D.). The Gully-Core is represented by the three SSIP standard stations located in the central part of the Gully as defined by the 200m contour, the Gully is represented by the Core stations plus 7 additional stations on the adjoining eastern and western SSIP lines, and the Eastern Shelf is represented by all SSIP stations east of 62W Longitude.

Season	Year	Shelf	E. Shelf	Gully	Gully-Core
Winter	80	0.43(0.24)	0.57(0.17)	0.77(0.35)	1.17(0.00)
	81	0.30(0.19)	0.28(0.22)	0.29(0.13)	0.23(0.11)
Spring	79	2.76(5.17)	3.87(6.10)	2.67(4.93)	0.31(0.11)
	80	0.40(0.37)	0.42(0.36)	0.66(0.54)	0.90(0.93)
	81	4.06(2.41)	4.14(2.26)	5.29(1.50)	4.93(0.82)
Summer	78	0.41(0.38)	0.42(0.27)	0.35(0.09)	0.41(0.09)
	79	0.56(0.85)	0.42(0.17)	0.29(0.05)	0.33(0.01)
	80	1.47(2.75)	0.95(1.21)	0.58(0.94)	0.24(0.16)
	81	0.26(0.11)	0.26(0.13)	0.20(0.03)	0.21(0.03)
Fall	79	1.00(0.68)	0.80(0.41)	0.76(0.29)	0.59(0.09)
	80	2.32(2.41)	1.96(1.87)	2.08(1.57)	2.48(1.89)
	81	0.90(0.95)	0.84(0.40)	0.74(0.39)	0.54(0.01)

Zooplankton

The zooplankton data analyzed to date do not support the idea that mesozooplankton are especially abundant in the Gully compared with other areas of the Scotian Shelf. Statistical tests (t-tests) using the SSIP data show that abundances of *C. finmarchicus* and *C. hyperboreus* and total plankton volume are no higher in the Gully-Core or Gully regions than average abundances on either the Eastern Scotian Shelf, or the entire Shelf, during any of the months for which zooplankton were collected in the Gully-Core region (Table 6.3.2). The same is true for the relative abundances of two smaller copepod species (*Centropages*, *Pseudocalanus* spp.) and indeed, concentrations of *Centropages* were actually lower (*i.e.* zero) in the Gully region than average values over the entire Scotian Shelf in May and June (Table 6.3.2). Because the Gully is an area of deep water, however, it harbours overwintering populations of *C. finmarchicus* at depths of >200 m and krill, which spend the daylight hours at depths of > 200 m and the night-time hours in the near surface layers. In the case of the macroplankton (krill) it is unclear whether concentrations in the Gully are generally higher than those in other Basins on the Scotian Shelf. Equally, from existing data it cannot be determined whether the Gully is an area of intrusion of the very abundant off-shore population of *C. finmarchicus* on to the Shelf in spring, as is the case further to the south and west in the area of the Halifax section. If it is, then it may provide an important source of copepods for Sable Island and Western Banks in spring. In order to answer these important questions more study is needed.

Table 6.3.2. Abundances of large (*Calanus finmarchicus, Calanus hyperboreus*) and relative abundances of small (*Centropages* sp., *Pseudocalanus* sp.) copepod species (#s x 1000 m^{-2}) and plankton volume (ml m^{-2}) from SSIP cruises. Region designations as in Table 6.3.1.

Calanus finmarchicus ***Calanus hyperboreus***

MONTH	Shelf	E. Shelf	Gully	Gully-Core	MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY					MAY				
Mean	43.04	63.61	150.39	126.61	Mean	5.80	8.98	9.19	16.19
Std. Dev.	67.55	74.98	132.18	74.33	Std. Dev.	8.10	8.63	7.25	7.40
No. of stns.	138	88	8	3	No. of stns.	138	88	8	3
JUNE					JUNE				
Mean	45.61	34.38	68.09	74.65	Mean	2.37	3.69	3.47	6.07
Std. Dev.	41.44	29.21	28.77	21.61	Std. Dev.	5.67	7.24	2.70	2.95
No. of stns.	153	85	7	2	No. of stns.	153	85	7	2
AUGUST					AUGUST				
Mean	12.12	10.03	13.74	50.98	Mean	0.27	0.46	0.01	0.00
Std. Dev.	14.38	11.46	19.01		Std. Dev.	1.20	1.55	0.02	
No. of stns.	38	22	5	1	No. of stns.	38	22	5	1
SEPT.					SEPT.				
Mean	12.09	16.97	21.91	7.99	Mean	0.70	1.11	0.00	0.00
Std. Dev.	13.89	16.01	13.92		Std. Dev.	2.09	2.63	0.00	
No. of stns.	88	51	2	1	No. of stns.	88	51	2	1
NOV.					NOV.				
Mean	11.50	16.95	16.59	35.08	Mean	0.93	1.43	1.52	4.48
Std. Dev.	12.61	13.92	15.17	9.39	Std. Dev.	1.99	2.26	2.43	2.14
No. of stns.	117	65	6	2	No. of stns.	117	65	6	2

Total plankton volume

MONTH	Shelf	E. Shelf	Gully	Gully-Core	MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY					SEPT.				
Mean	88.96	87.88	189.53	198.09	Mean	37.41	43.81	101.97	30.58
Std. Dev.	87.51	77.22	158.04	129.31	Std. Dev.	37.36	44.25	71.38	
No. of stns.	138	88	8	3	No. of stns.	88	51	2	1
JUNE					NOV.				
Mean	78.10	76.71	85.18	75.83	Mean	38.22	46.66	68.70	64.47
Std. Dev.	51.62	55.80	83.45	5.42	Std. Dev.	31.86	36.44	66.28	20.68
No. of stns.	153	85	7	2	No. of stns.	117	65	6	2
AUGUST									
Mean	32.16	39.56	61.75	100.61					
Std. Dev.	30.76	35.77	57.50						
No. of stns.	38	22	5	1					

Table 6.3.2. (cont'd)

Centropages **sp.**

MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY				
Mean	0.04	0.05	0.00	0.00
Std. Dev.	0.28	0.34	0.00	0.00
No. of stns.	138	88	8	3
JUNE				
Mean	0.36	0.06	0.00	0.00
Std. Dev.	1.11	0.22	0.00	0.00
No. of stns.	153	85	7	2
AUGUST				
Mean	11.69	14.51	5.24	18.78
Std. Dev.	12.97	13.88	6.97	
No. of stns.	38	22	5	1
SEPTEMBE R				
Mean	39.46	54.35	118.52	30.17
Std. Dev.	92.34	119.18	88.35	
No. of stns.	88	51	2	1
NOVEMBER				
Mean	14.52	15.00	17.14	29.08
Std. Dev.	18.00	21.59	18.71	26.74
No. of stns.	117	65	6	2

Pseudocalanus **sp.**

MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY				
Mean	8.19	11.57	15.11	22.55
Std. Dev.	12.44	12.15	10.79	9.73
No. of stns.	138	88	8	3
JUNE				
Mean	6.10	6.03	11.76	9.00
Std. Dev.	7.38	7.83	16.32	0.71
No. of stns.	153	85	7	2
AUGUST				
Mean	2.83	2.39	3.83	6.98
Std. Dev.	6.90	2.64	3.94	
No. of stns.	38	22	5	1
SEPTEMBER				
Mean	4.79	2.63	1.64	0.98
Std. Dev.	10.45	3.98	0.67	
No. of stns.	88	51	2	1
NOVEMBER				
Mean	4.66	4.64	5.27	8.61
Std. Dev.	4.69	5.24	4.18	4.64
No. of stns.	117	65	6	2

It should be noted that if all SSIP stations had been sampled on each cruise, there would have been: 3 stations in the Gully-Core; 9 in the Gully region (3 within the Gully-Core and 3 on adjacent lines); 110 on the Eastern Scotian Shelf; and *ca.* 189 over the entire survey grid.

6.3.5 General comments

Overall, the present data suggest that the Gully has some features which are characteristic of a Shelf Basin and some which are characteristic of the Shelf Break, which when put together make it a somewhat unique area of the Scotian Shelf. It does not appear to be an area of particularly high primary production, although its depth makes it an overwintering area for copepods and an area where krill congregate. The existing knowledge base is quite limited, however, and in order to gain a better understanding of the productivity of the region and its role in the ecology of the Scotian Shelf, a directed seasonal sampling programme would be needed.

6.3.6 References

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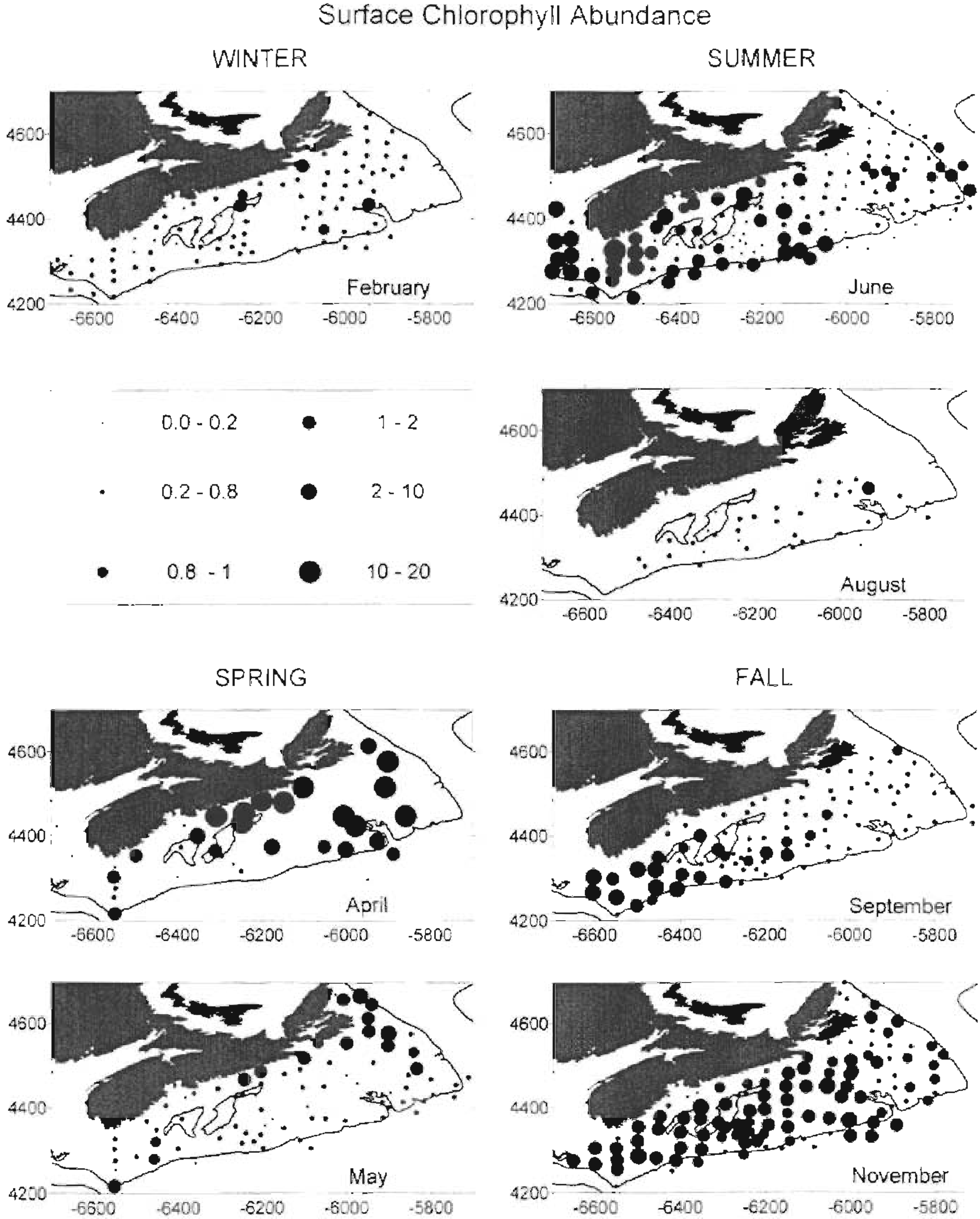
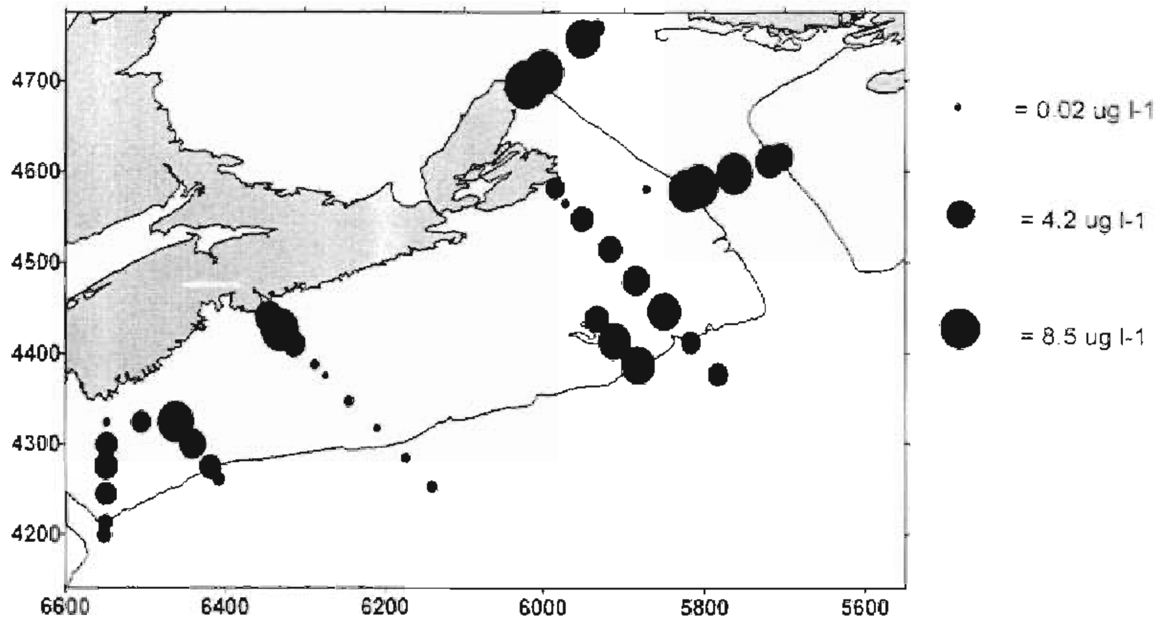


Fig. 6.3.1. Surface chlorophyll concentrations ($\mu g\ l^{-1}$) on the Scotian Shelf for cruises during the SSIP survey between 1978-1981.

SURFACE CHLOROPHYLL CONCENTRATIONS - APRIL 1997



INTEGRATED CHLOROPHYLL CONCENTRATIONS - APRIL 1997

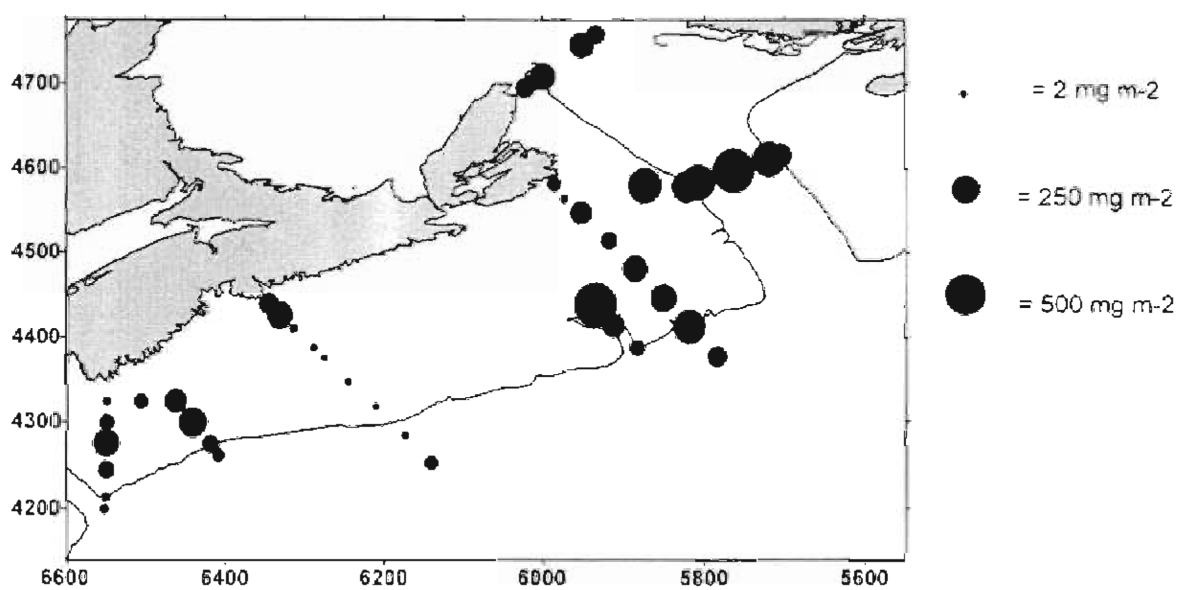


Fig. 6.3.2. Surface ($\mu g\ l^{-1}$) and integrated ($mg\ m^{-2}$) chlorophyll concentrations on the Scotian Shelf in April 1997.

Relationship between surface and integrated chlorophyll concentrations
- in spring, summer and fall

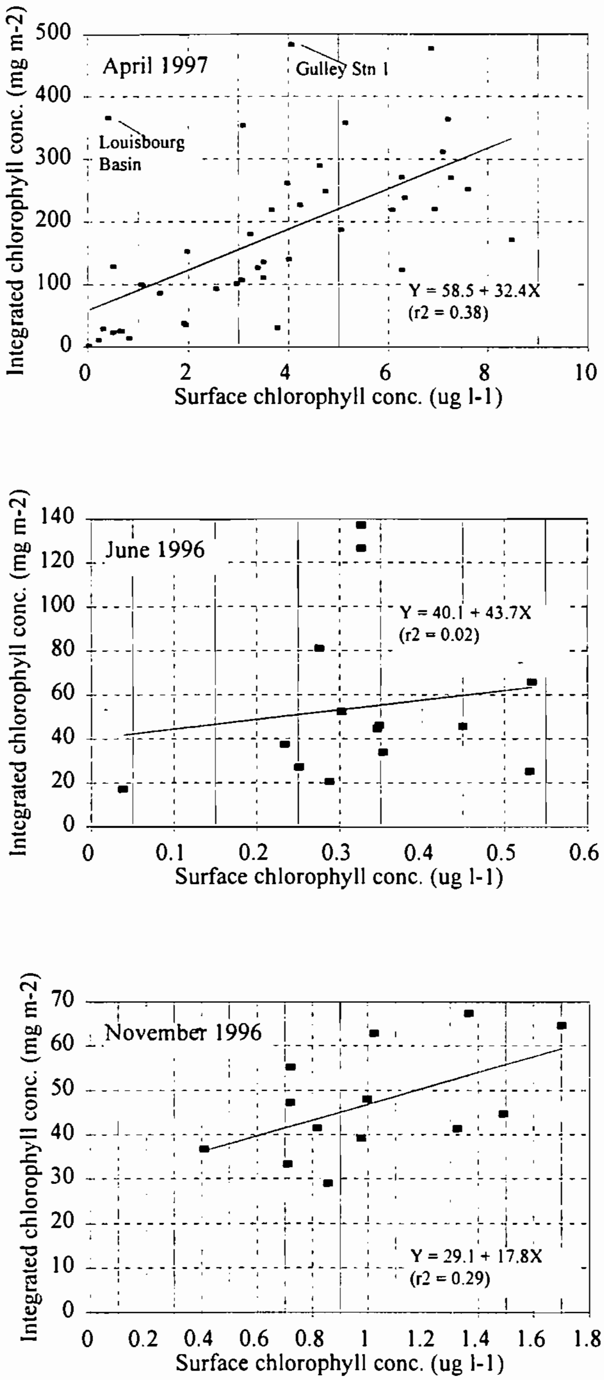


Fig. 6.3.3. Relationship between surface and integrated chlorophyll concentrations on the Scotian Shelf in April 1997, and June and November 1996.

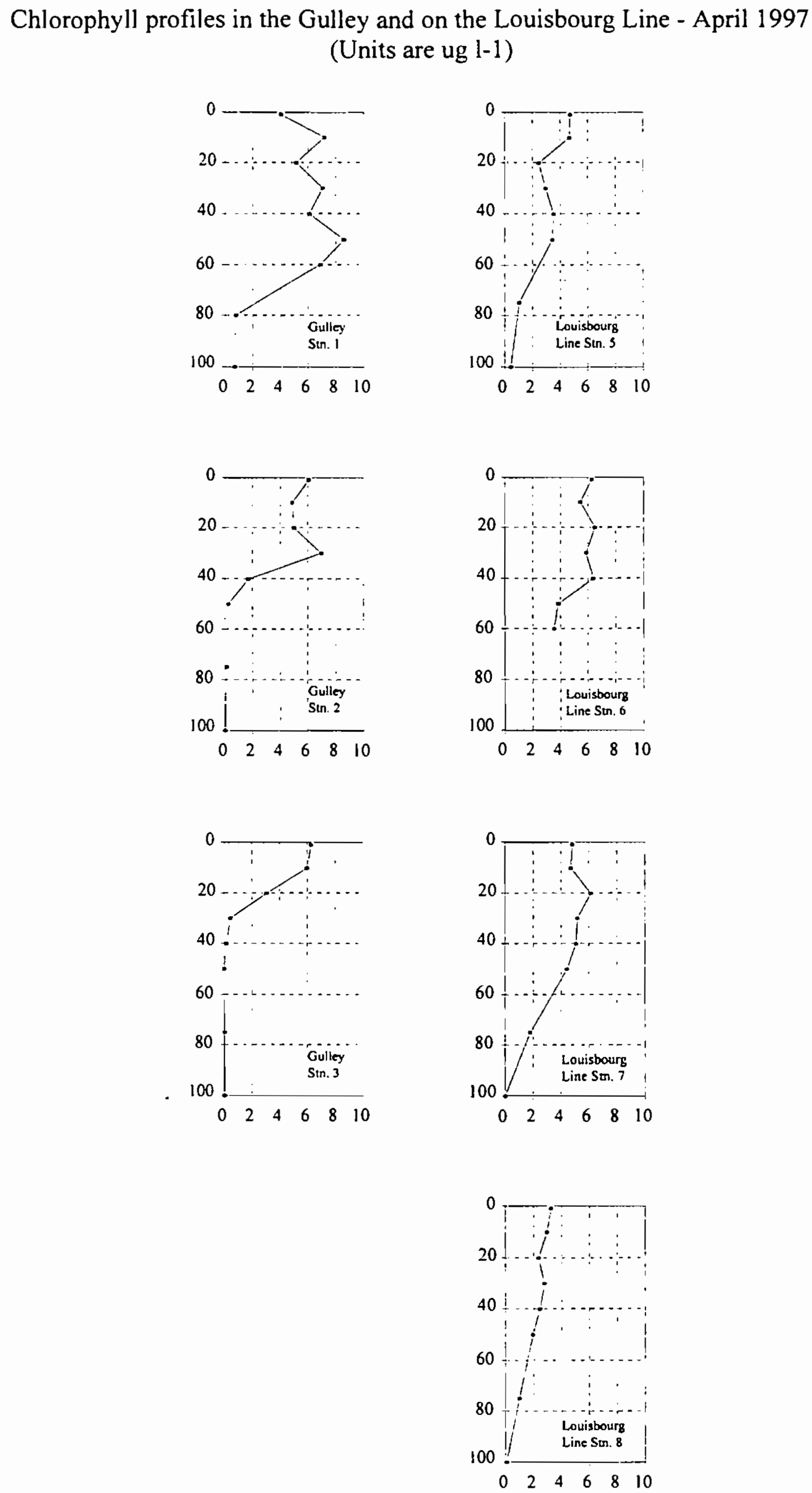


Fig. 6.3.4. Profiles of chlorophyll concentration ($\mu g\ l^{-1}$) in the Gully and on the Louisbourg Line in April 1997.

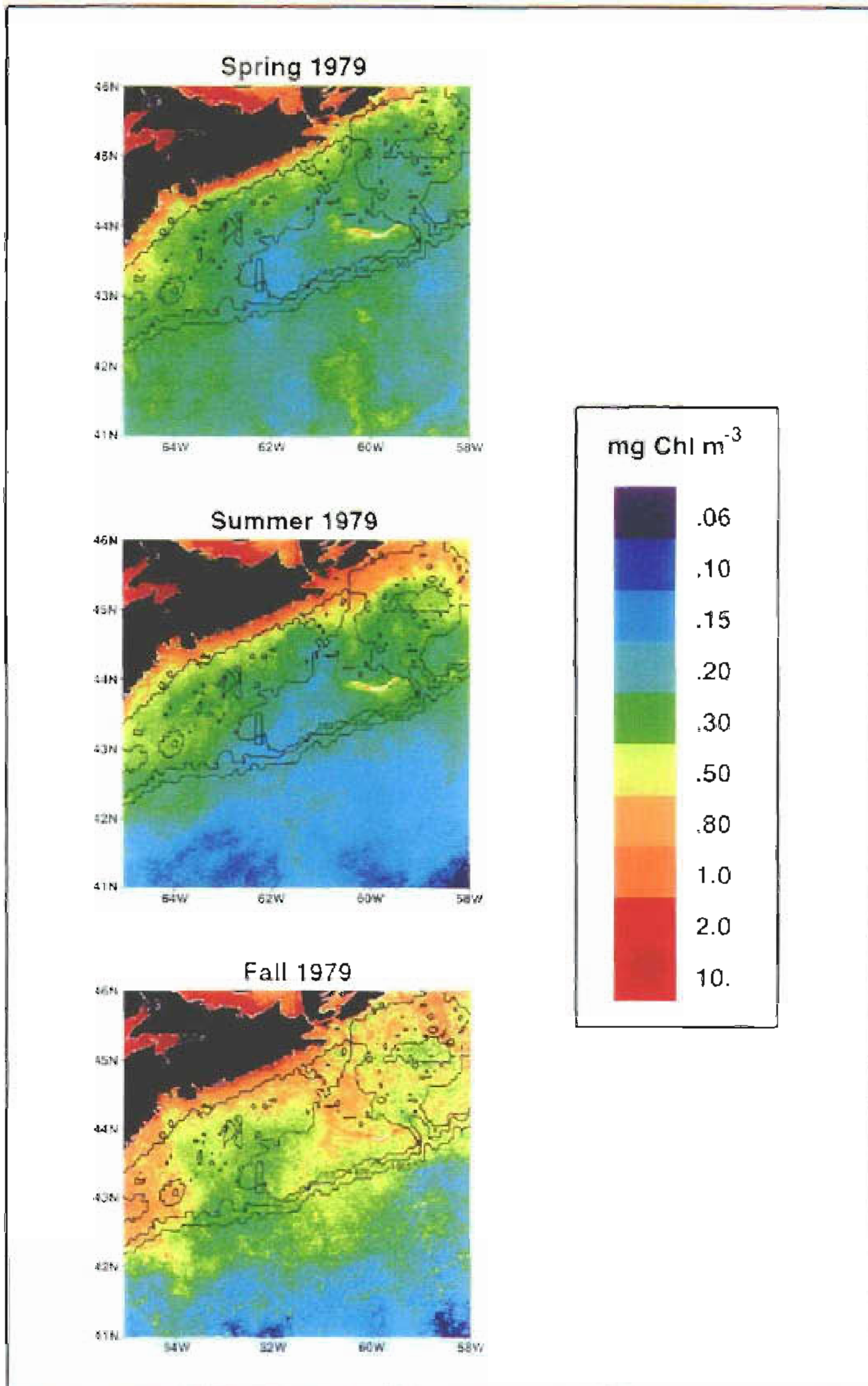


Fig. 6.3.5. Composite images of chlorophyll concentration in the near surface layers as recorded by the CZCS colour satellite during spring, summer and fall 1979.

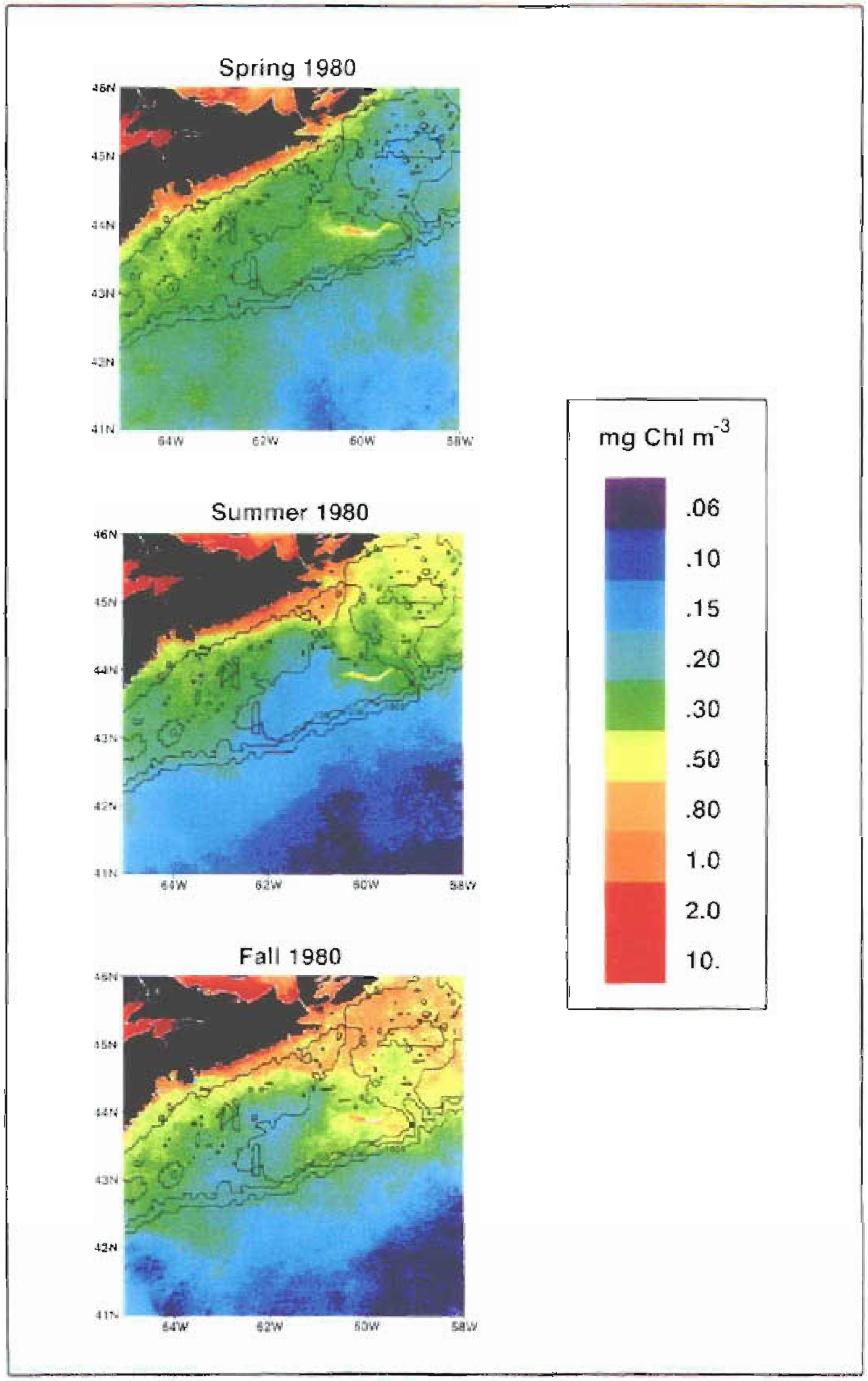
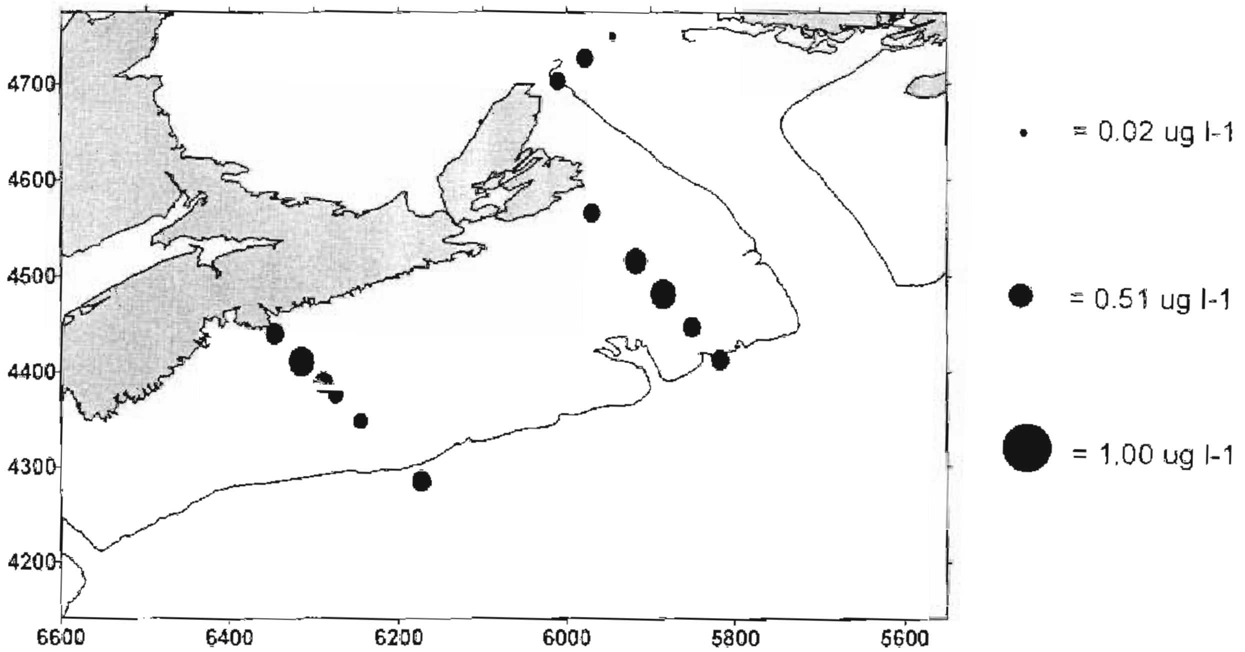


Fig. 6.3.6. Composite images of chlorophyll concentration in the near surface layers as recorded by the CZCS colour satellite during spring, summer and fall 1980.

SURFACE CHLOROPHYLL CONCENTRATIONS - JUNE 1996



INTEGRATED CHLOROPHYLL CONCENTRATIONS - JUNE 1996

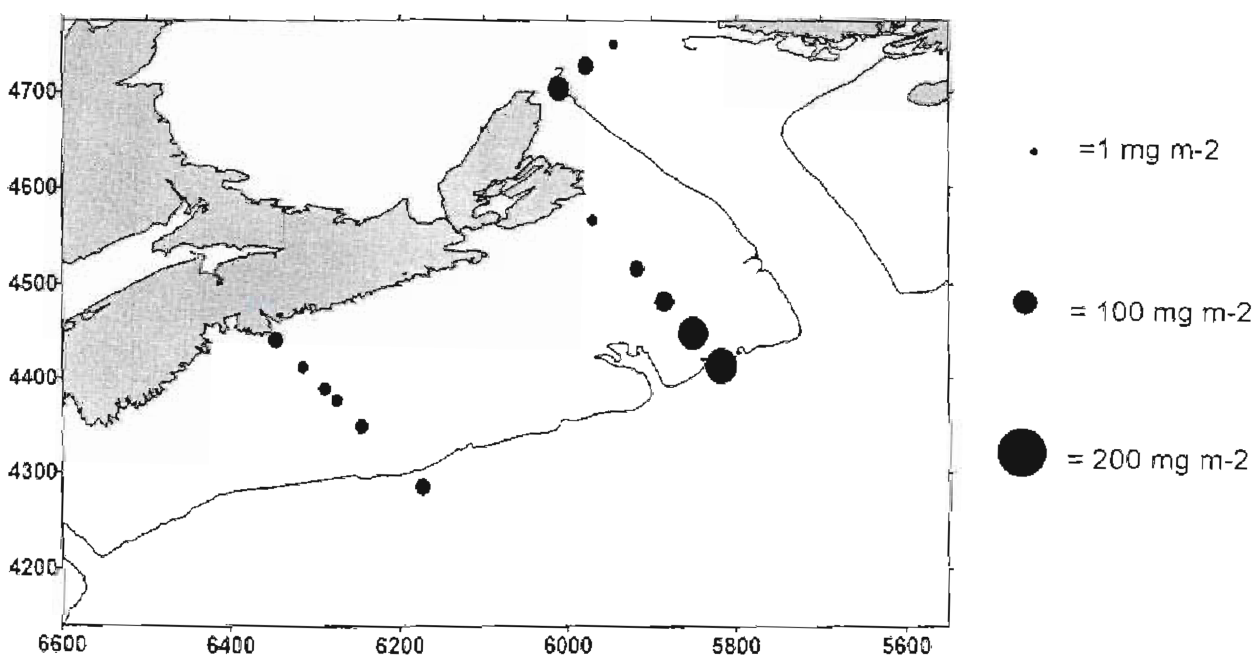


Fig. 6.3.7. Surface ($\mu g\ l^{-1}$) and integrated ($mg\ m^{-2}$) chlorophyll concentrations on the Scotian Shelf during June 1996.

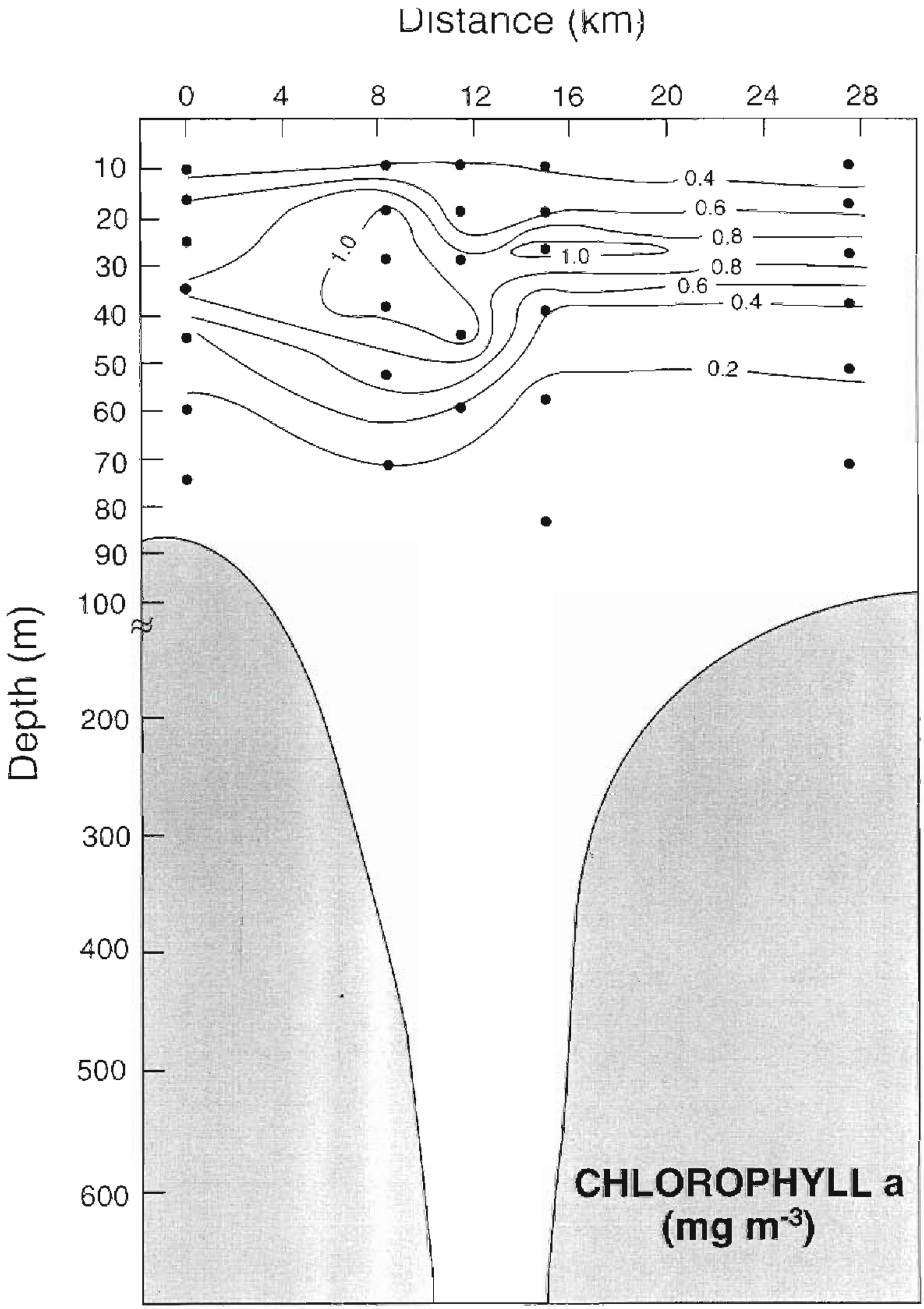


Fig. 6.3.8. Profiles of chlorophyll concentration ($\mu g\ l^{-1}$) across the Gully from Sable Island Bank to Banquereau Bank in July 1993.

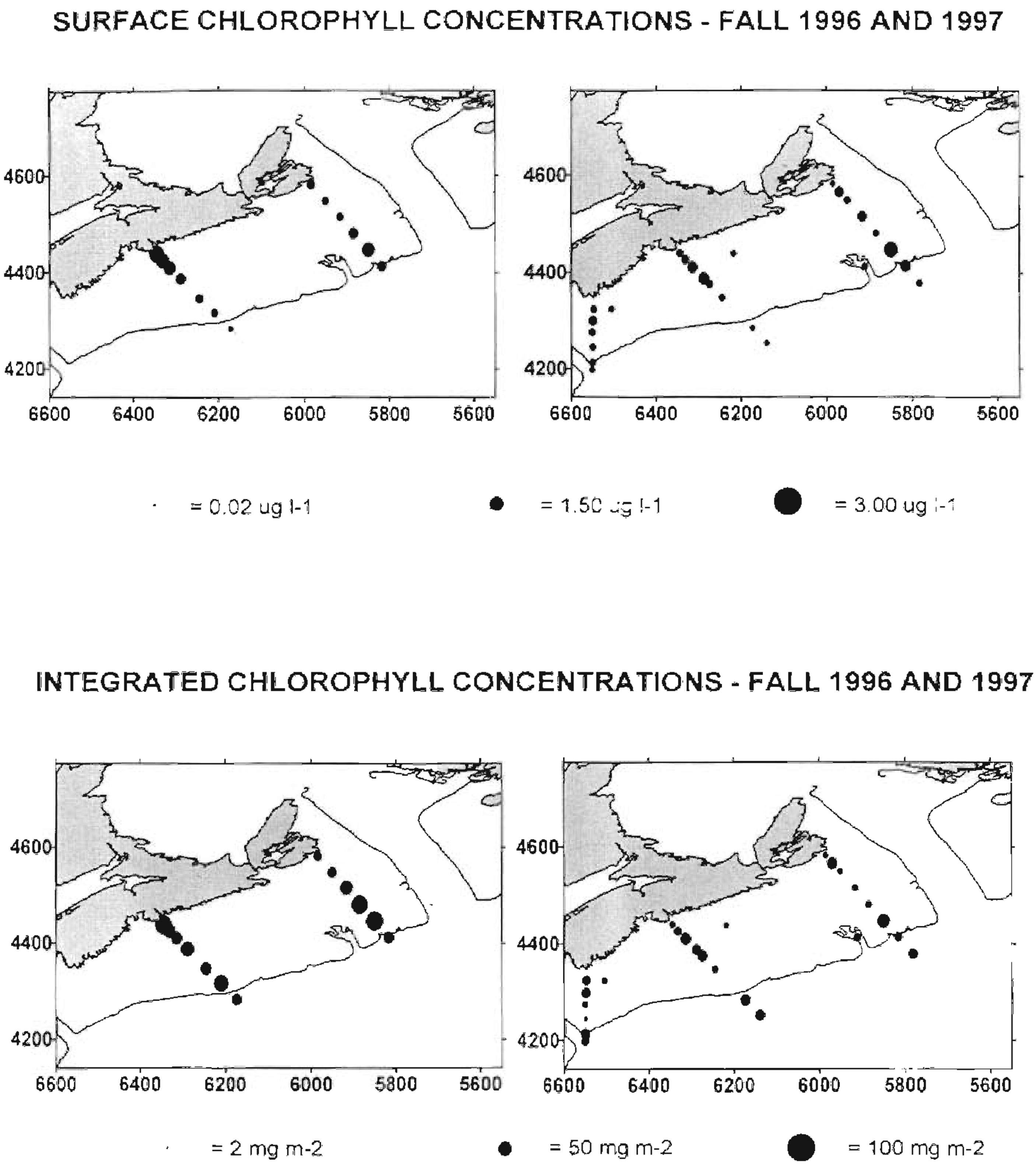


Fig. 6.3.9. Surface ($\mu g\ l^{-1}$) and integrated ($mg\ m^{-2}$) chlorophyll concentrations on the Scotian Shelf during November 1996 and October-November 1997.

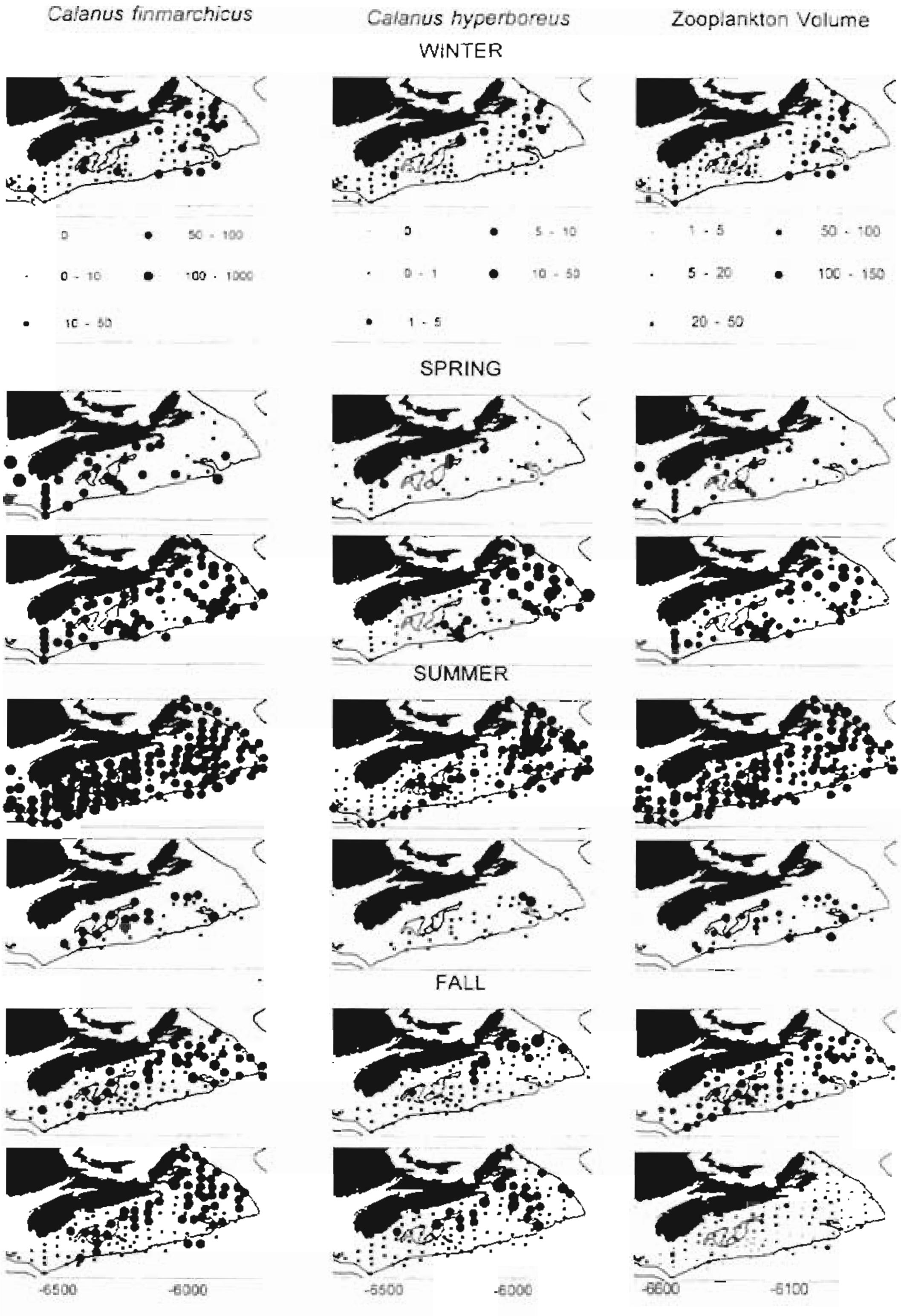


Fig. 6.3.10. Abundances (# m^{-2}; 0-200 m) of *Calanus finmarchicus* and *Calanus hyperboreus* and total zooplankton volume (ml) on the Scotian Shelf for cruises during the SSIP survey between 1978-1981. Data are for the same months as in Fig. 6.3.1.

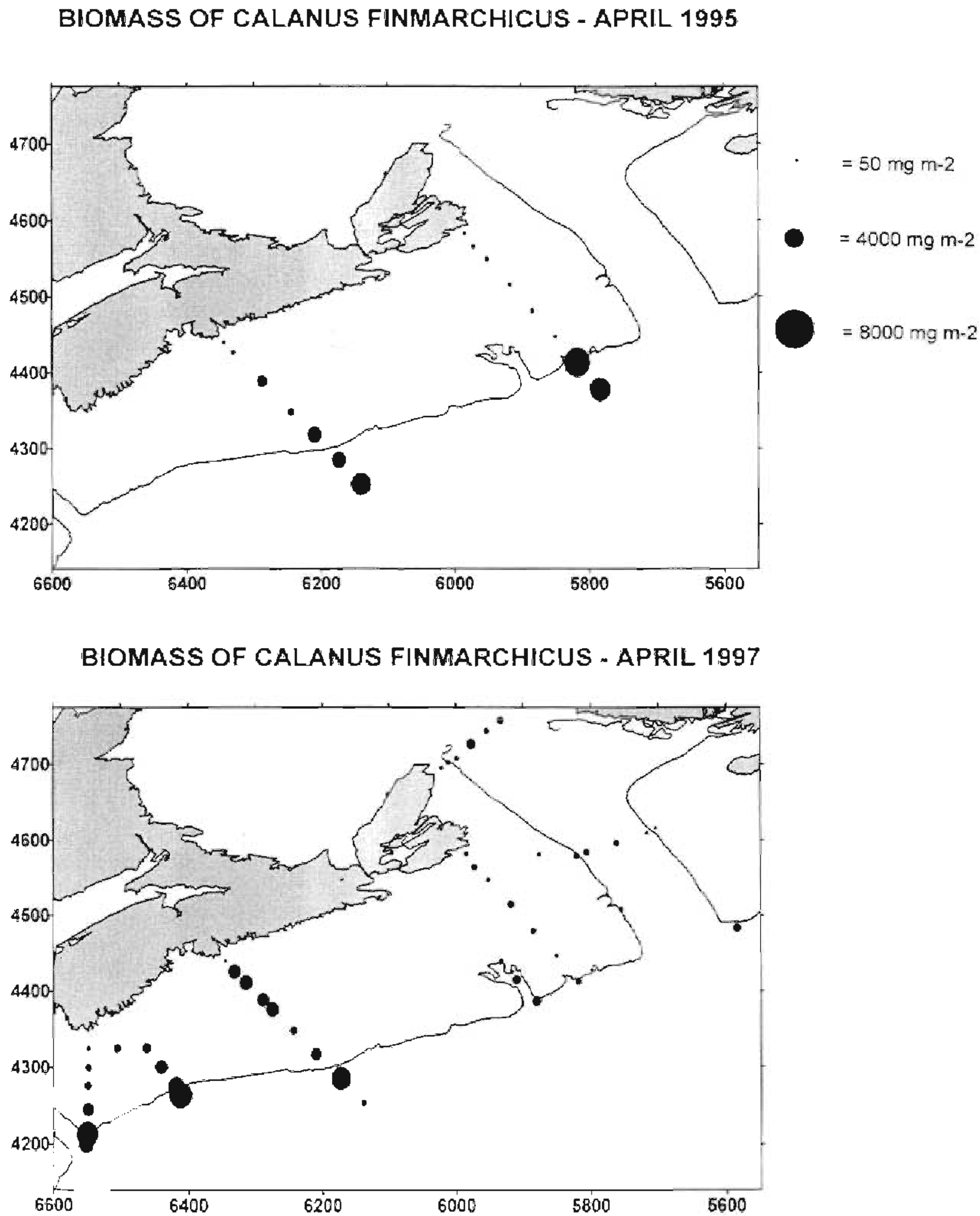
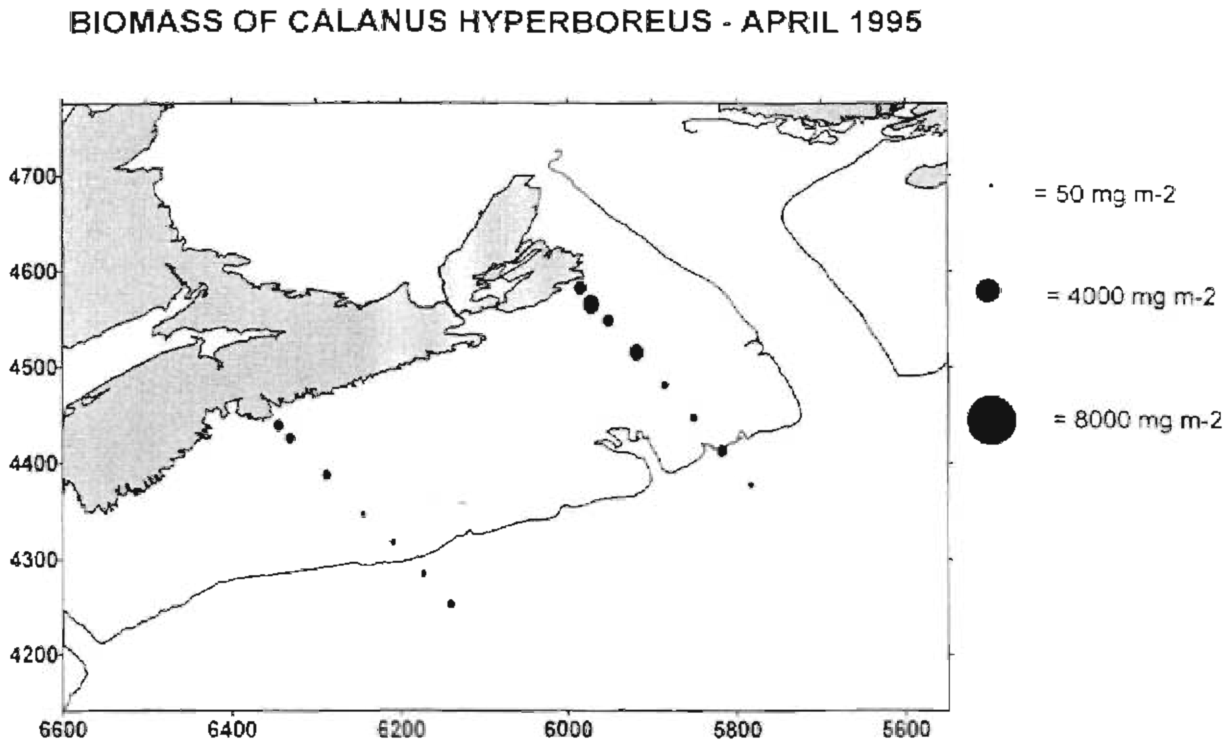


Fig. 6.3.11. *Calanus finmarchicus* biomass (gm dry wgt. m^{-2}; 0-100 m) on the Scotian Shelf in April 1995 and 1997.



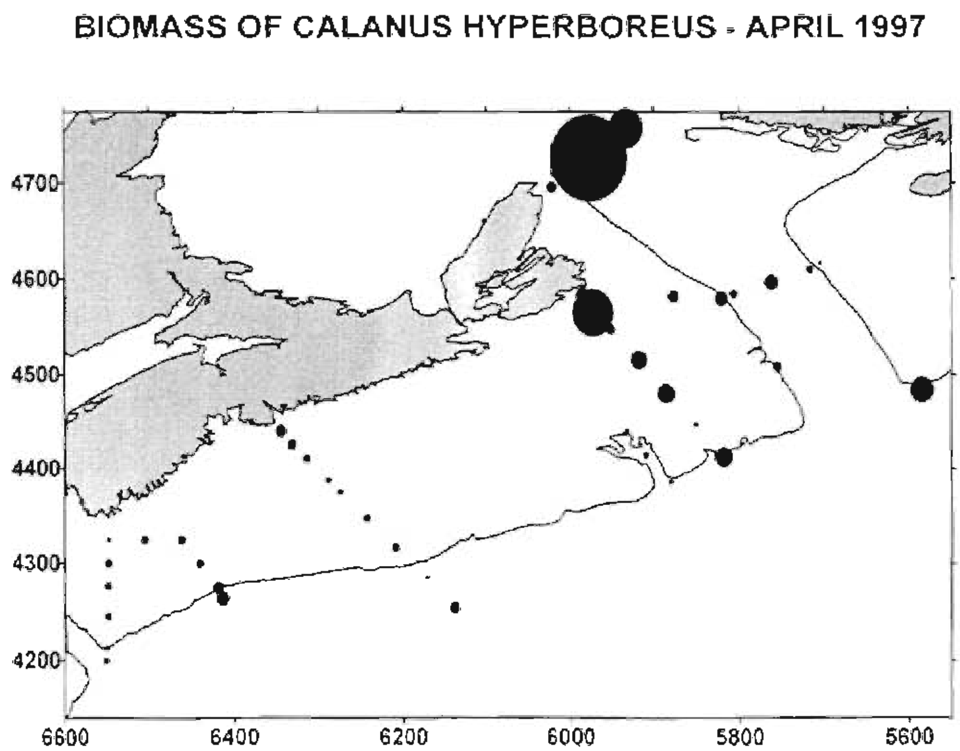
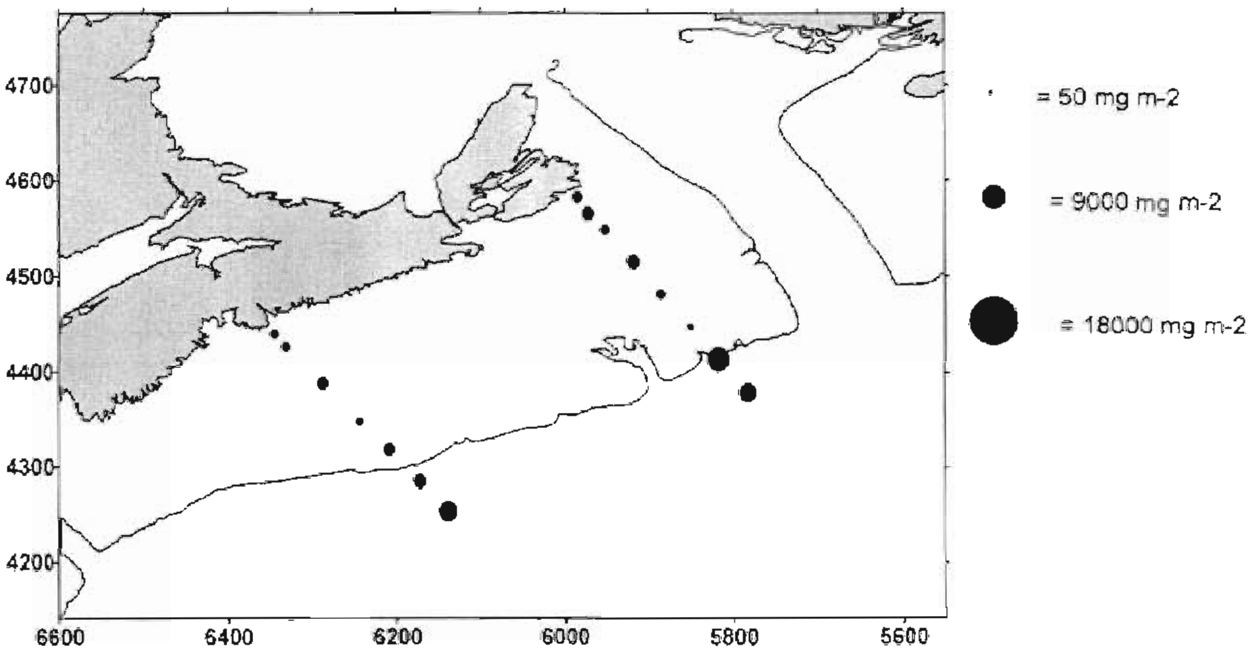


Fig. 6.3.12. *Calanus hyperboreus* biomass (gm dry wgt. m^{-2}; 0-100 m) on the Scotian Shelf in April 1995 and 1997.

TOTAL ZOOPLANKTON BIOMASS - APRIL 1995



TOTAL ZOOPLANKTON BIOMASS - APRIL 1997

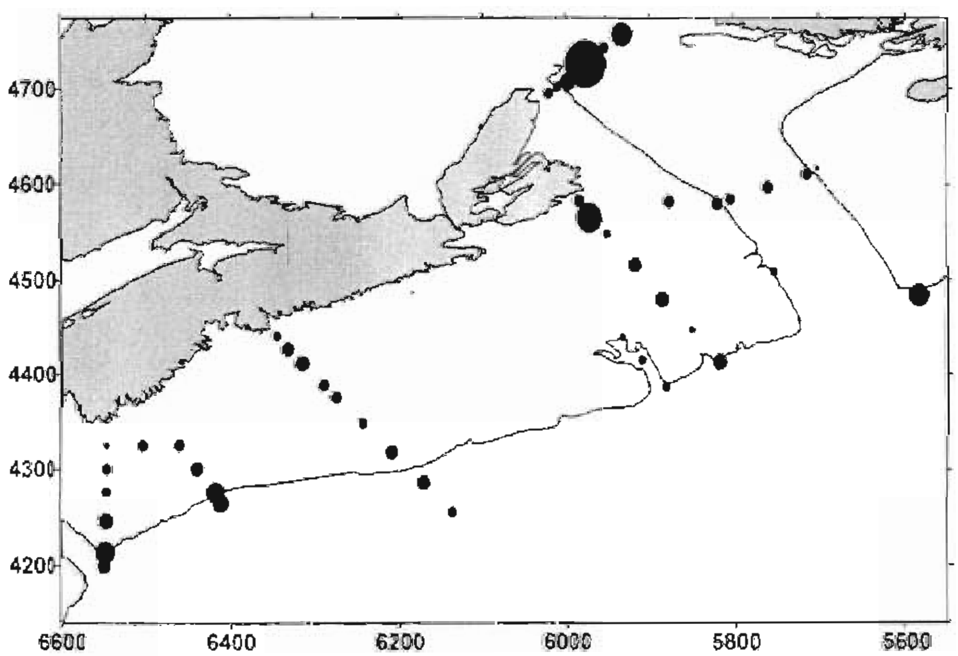
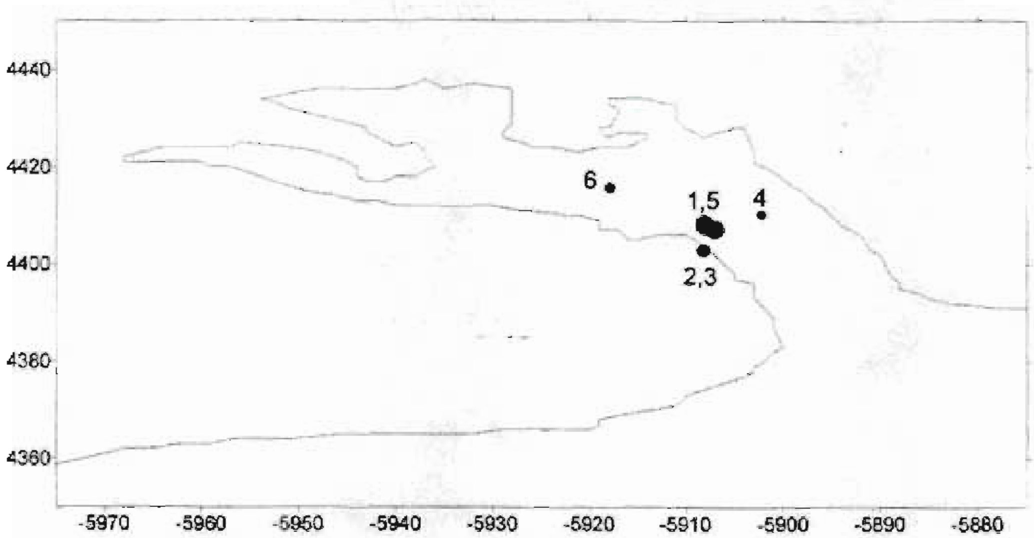


Fig. 6.3.13. Total zooplankton biomass (gm dry wgt. m^{-2}; 0-100 m) on the Scotian Shelf in April 1995 and 1997.

Abundance of Calanus finmarchicus in the Gully in October 1989



Tow	#/m2
1	15120
2	1884
3	6584
4	1090
5	16183
6	2984

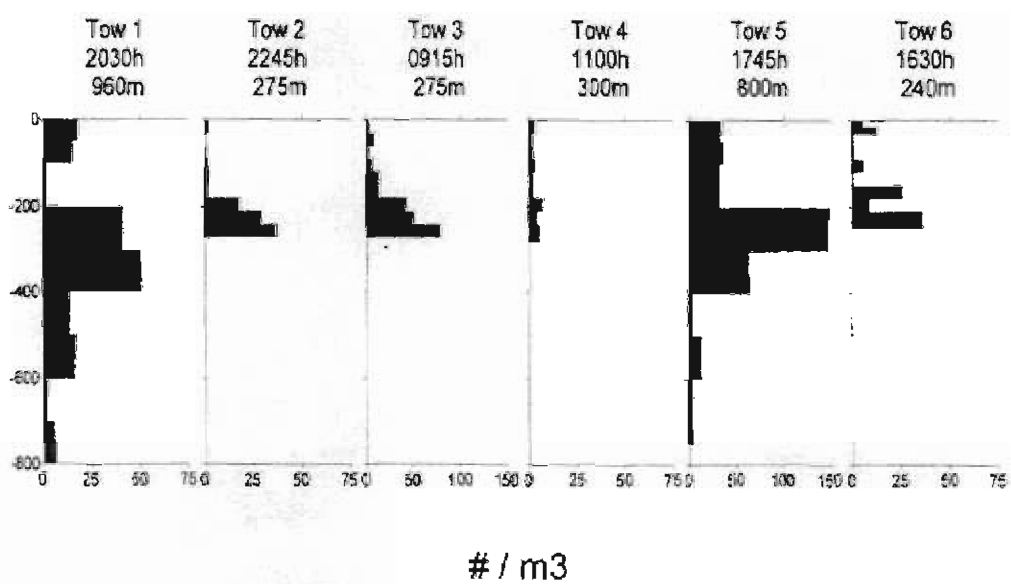


Fig. 6.3.14. Vertical distributions of *Calanus finmarchicus* at stations in the Gully in October 1989.

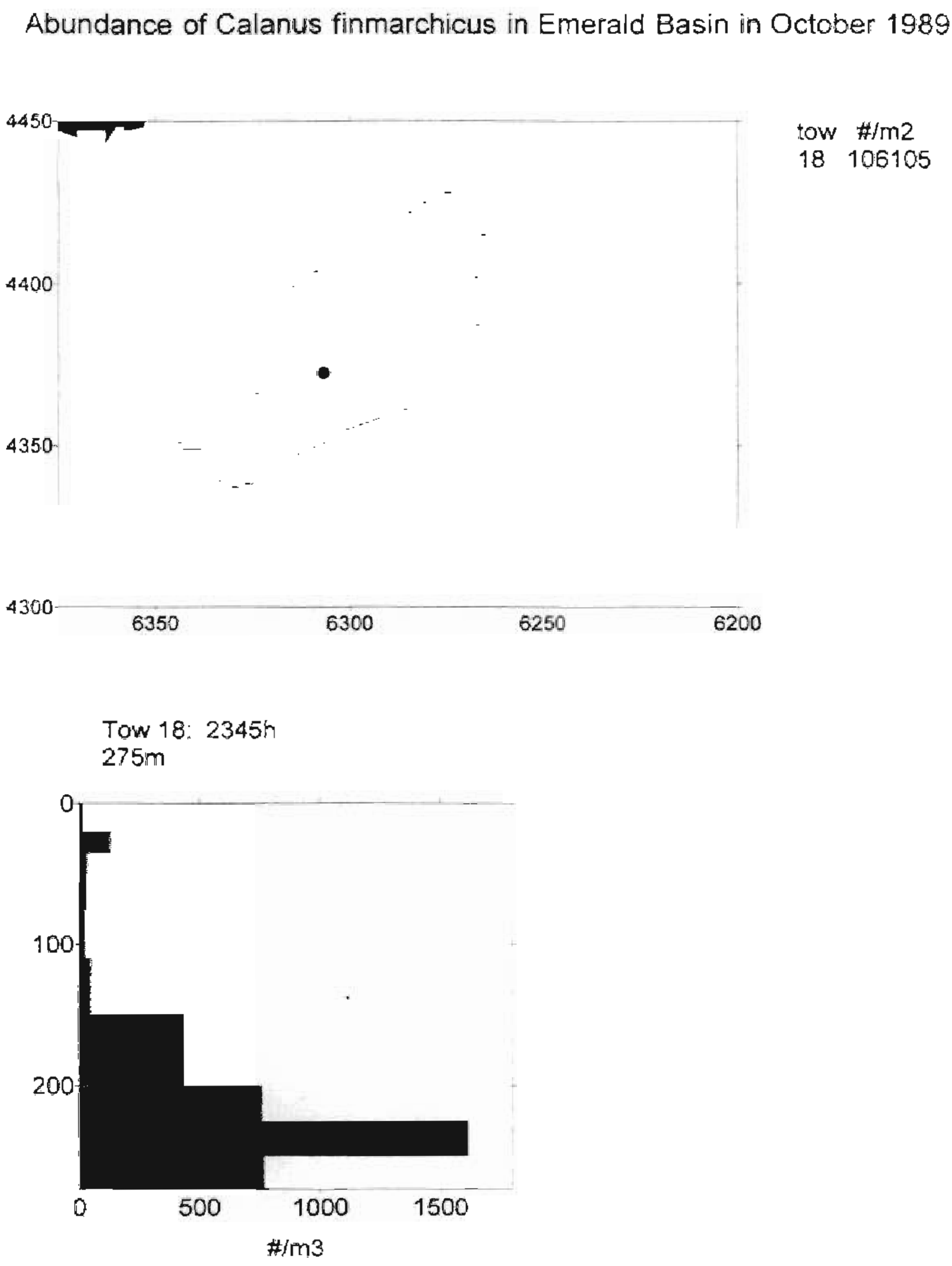


Fig. 6.3.15. Vertical distribution of *Calanus finmarchicus* at a station in Emerald Basin in October 1989.

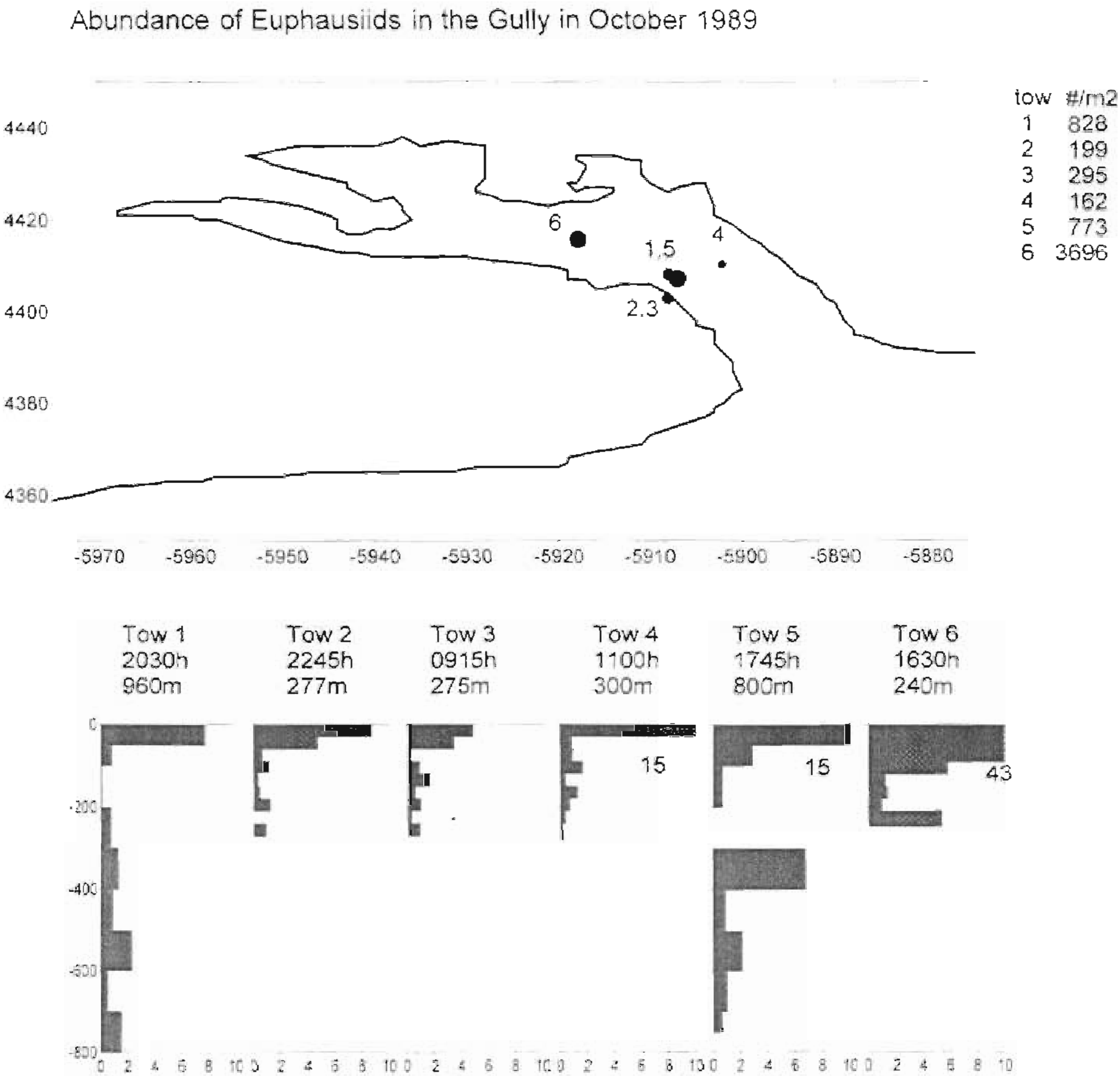
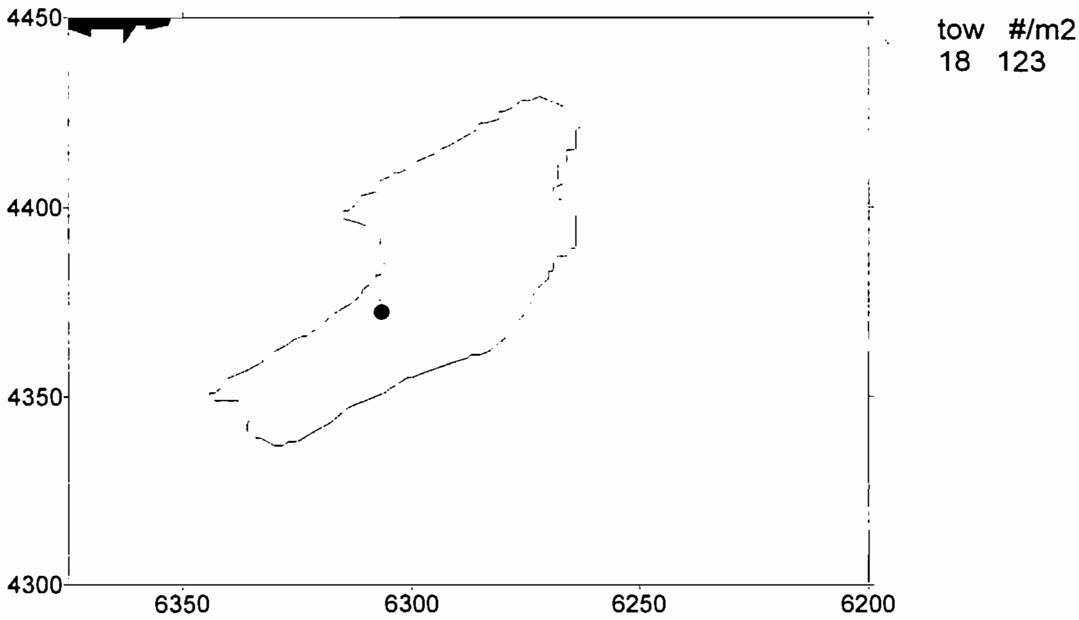


Fig. 6.3.16. Vertical distributions of krill (euphausiids) at stations in the Gully in October 1989.

Abundance of Euphausiids in Emerald Basin in October 1989



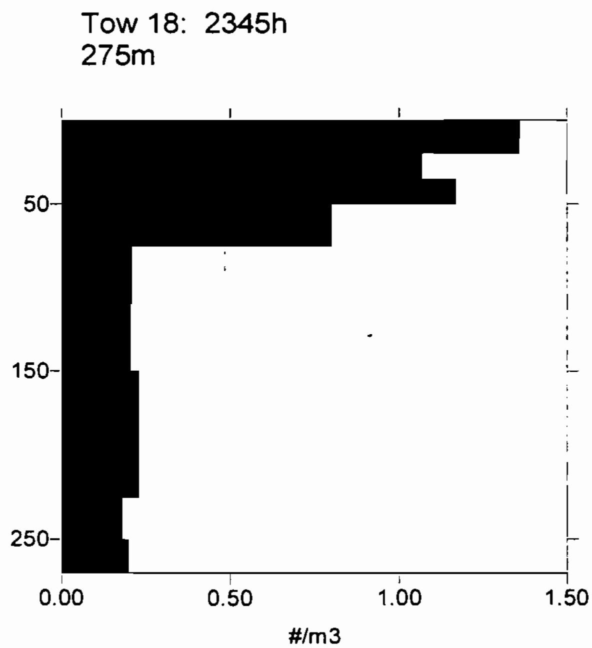


Fig. 6.3.17. Vertical distribution of krill (euphausiids) at a station in Emerald Basin in October 1989.

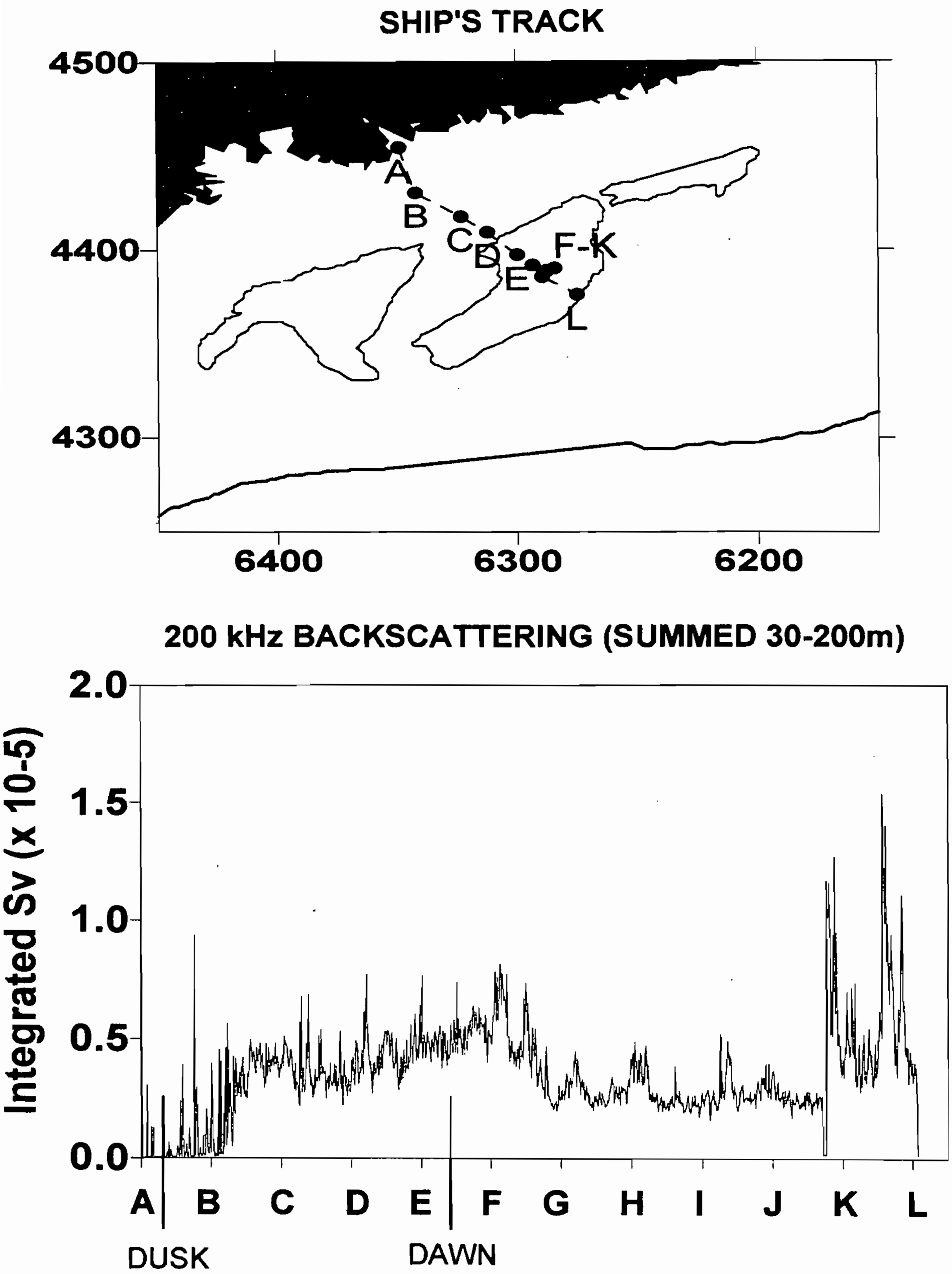


Fig. 6.3.18. Acoustic backscattering by macrozooplankton (>2.5 cm) between Halifax and Emerald Basin in April 1997.

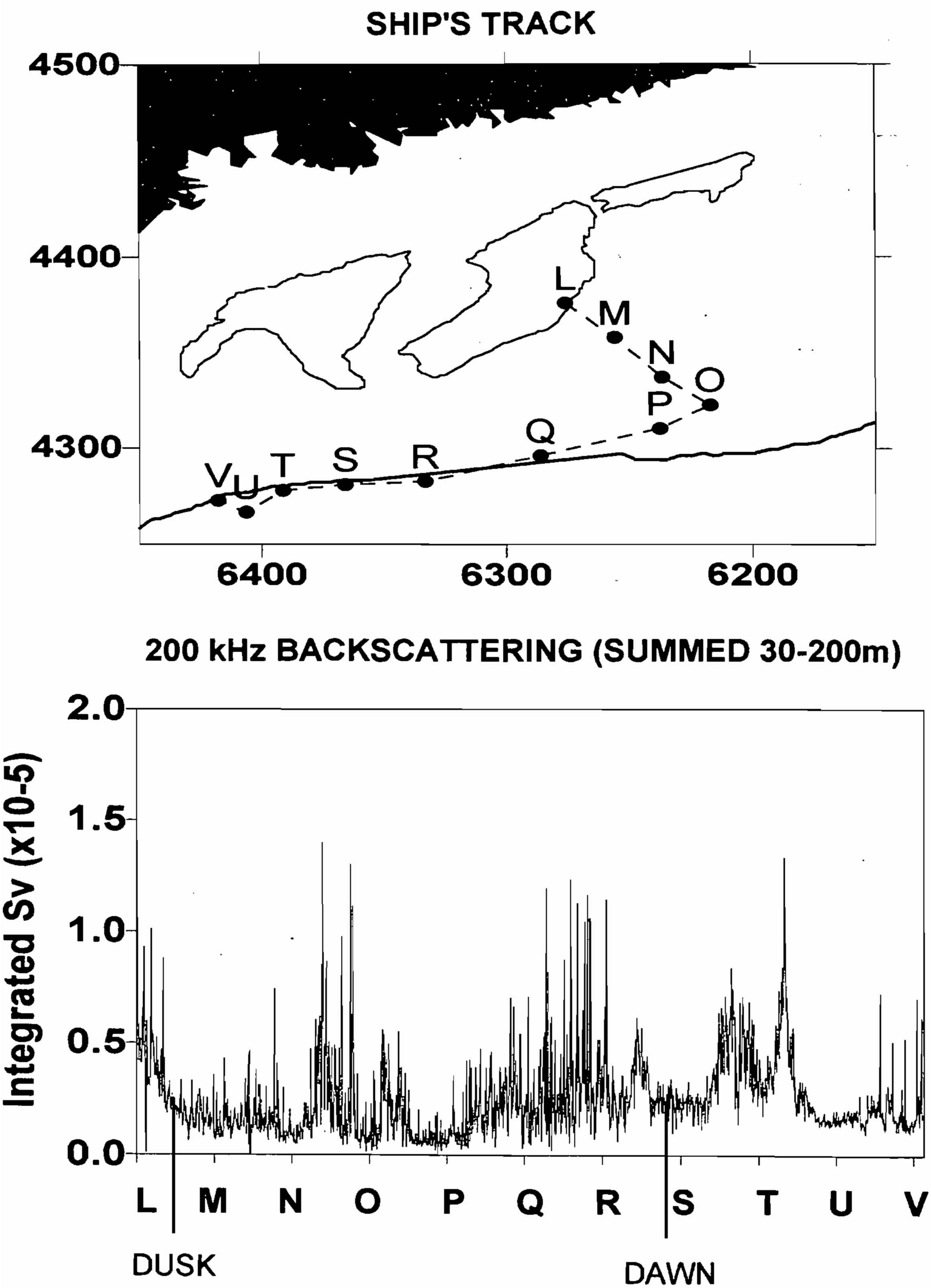


Fig. 6.3.19. Acoustic backscattering by macrozooplankton (>2.5 cm) in Emerald Basin, over Emerald Bank and westward along the shelf break in April 1997.

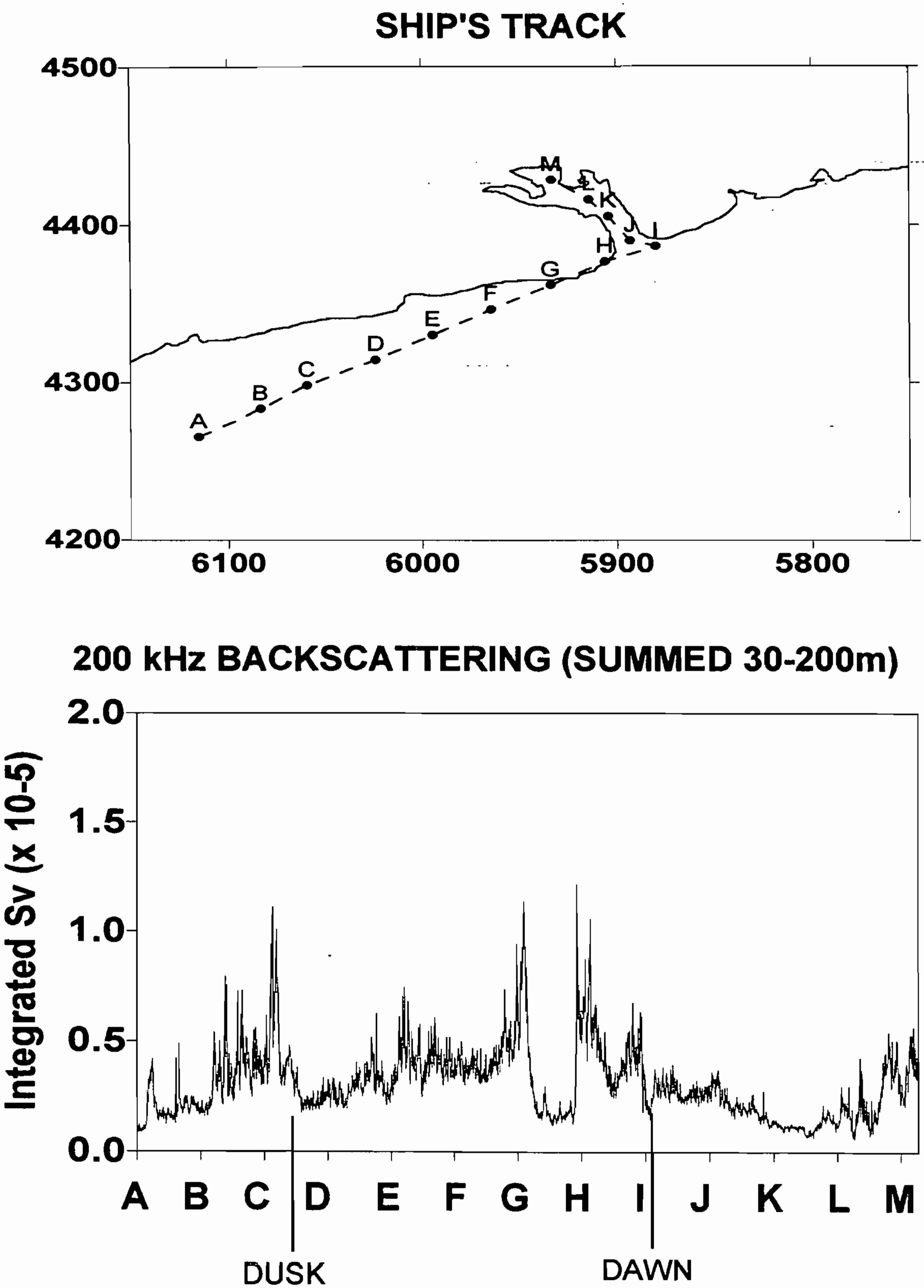


Fig. 6.3.20. Acoustic backscattering by macrozooplankton (>2.5 cm) from off Sable Island into the Gully in April 1997.

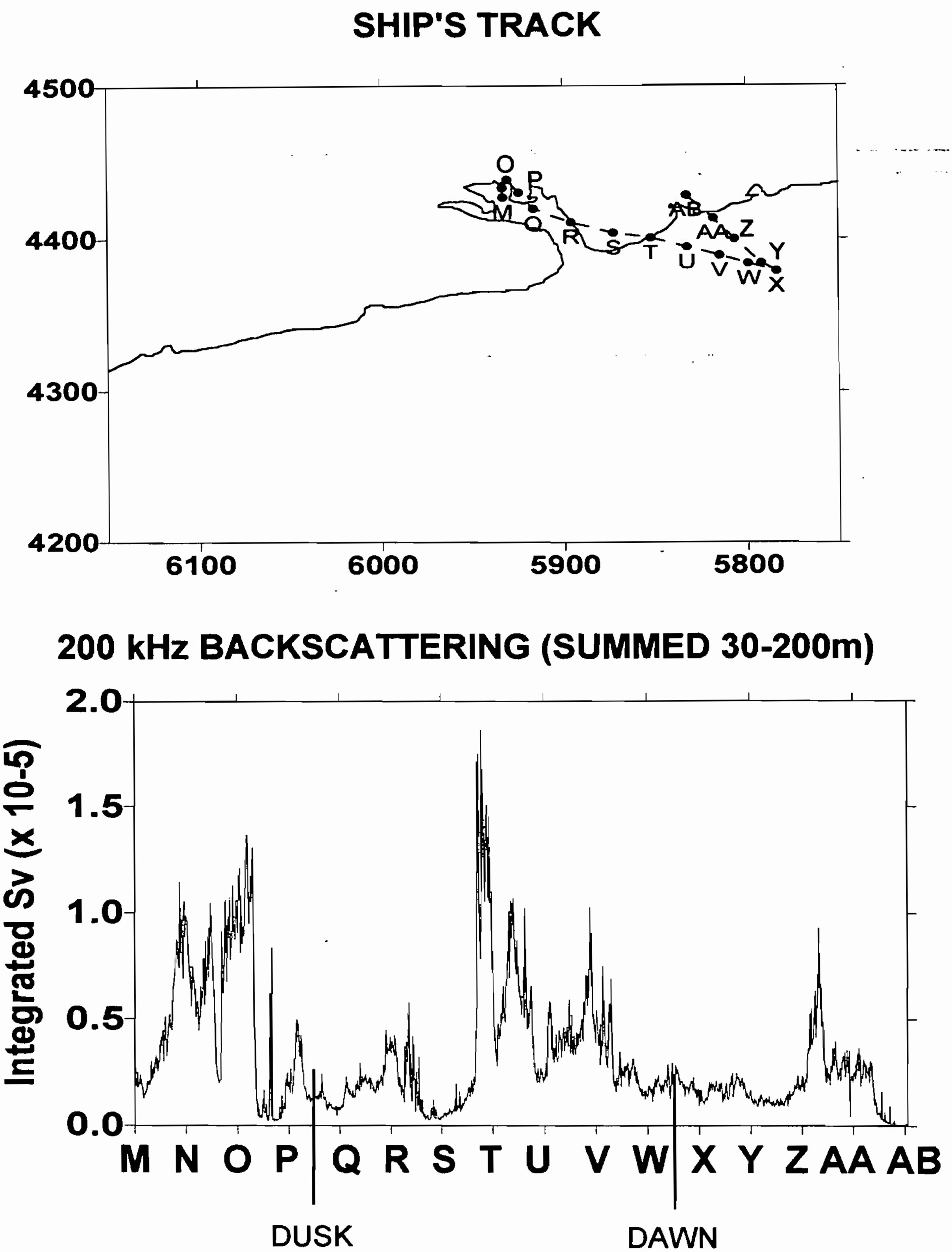


Fig. 6.3.21. Acoustic backscattering by macrozooplankton (>2.5 cm) in the Gully, over Banquereau Bank and on the Louisbourg Line in April 1997.

6.4 Submarine Canyons: Deposition Centres for Detrital Organic Matter?

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6.4.1 Background

Temperate continental shelves in general support higher primary production and consequently larger standing stocks of particulate organic matter than nearby oceanic environments. This is due in part to the close proximity of the sea floor to the euphotic zone which enables recycling of nutrients originating from benthic metabolism once the summer thermal structure of the water column is broken down by storms in the fall.

It has been known for some time that the sediments along the continental slope are enriched in organic material compared to that found on the shelves and in deeper waters (Walsh *et al.* 1981). Furthermore, it has recently been determind that the sedimentation along the continental margin is an order of magnitude greater than that measured in the deep sea at a comparable depths (Walsh *et al.* 1991). These findings were the background to two large scale studies of shelf exchange processes (SEEP I & SEEP II) to evaluate cross shelf transport and decomposition of organic matter in the Mid Atlantic Bight off New England (Walsh *et al.* 1988; Biscaye *et al.* 1994). These studies confirmed earlier findings that deposition of organics was highest in slope waters, centered at about 1000m depth, and was coincident with regions of minimum current speeds. Differences in deposition rates of up to 4x were observed between locations studied along the Mid Atlantic Bight. The export of particulates from the shelf was highly seasonal and stronly dependent on storm events. However, this seasonality was less evident at the 1000m deposition center which suggested intermediate settling and smoothing of off-shelf fluxes, possibly in continental slope canyons. The bulk of the material reaching the 1000m deposition center is refractory (Bacon *et al.* 1994; Anderson *et al.* 1994) which means that the highest biomass of benthic organisms supported by this energy source, and demersal fish feeding on these benthic organisms, should occur above this depth. Bacterialogical studies indicate that organic matter remineralization in bottom sediments and the overlying water column over the slope are approximately 3X that measured over the shelf (Kemp, 1994). This work suggests a greater supply of organic matter reaching the slope environment than revealed by the surface particle trap data, indicating the importance of a near-bottom down slope movement of organics. Kemp (1994) estimates that 7 to 15% of the primary production over the shelf in the Middle Atlantic Bight reaches the slope along or in close proximity to the bottom.

6.4.2 Implications

The implications for the Gully and other submarine canyons are obvious and may provide part of the answer to the attraction of many species of whales and other marine organisms to these regions. The physiographic and circulation characteristics of submarine canyons suggest they are sites of enhanced detrital organic matter deposition. This material will in turn support an abundant and diverse benthic community which constitutes an important food source for fish and marine mammals.

6.4.3 References

Anderson R.F., G.T. Rowe, P. Kemp, S. Trumbore & P.E. Biscaye 1994. Carbon budget for the mid-slope depocenter of the Middle Atlantic Bight. *Deep-Sea Res. II* 41: 669-703.

Bacon, M.P., R.A. Belastock, M.H. Bothner. 1994. ^{210}Pb balance and implications for particle transport on the continental shelf, U.S. Middle Atlantic Bight. *Deep-Sea Res. II* 41: 511-535.

Biscaye, P.E., C.N. Flagg & P.G. Falkowsky. 1994. The shelf edge exchange processes experiment, SEEP-II: an introduction to hypotheses, results and conclusions. *Deep-Sea Res. II* 41: 231-252.

Kemp, P.F. 1994. Microbial carbon utilization on the continental shelf and slope during the SEEP-II experiment. *Deep-Sea Res. II* 41: 563-581.

Walsh, J.J., P.E. Biscaye & G.T. Csanady. 1988. The 1983-1984 Shelf Edge Exchange Processes (SEEP)-1 experiment: hypotheses and highlights. *Cont. Shelf Res.* 8: 435-456.

Walsh J.J., D.A. Dieterle & J.R. Pribble. 1991. Organic debris on the continental margins: a simulation analysis of source and fate. *Deep-Sea Res.* 38: 805-828.

Walsh J.J., G.T. Rowe, R.L. Iverson & C.P. McRoy. 1981. Biological export of shelf carbon: a neglected sink of the global CO_2 cycle. *Nature* 291: 196-201.

6.5 Benthos

6.5.1 The Sedimentary Interface Fauna

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6.5.1.1 Introduction

The sedimentary interface is an important focus in the marine environment, where seawater and sediment meet and exchanges of materials may occur. It is delimited by the benthic boundary layer (BBL) at the bottom of the water column, and the depth of sediment, or rock, colonized by benthic animals. The latter are referred to as *infauna* in contrast to *epifauna* found on the sediment surface. Freely swimming benthic animals found within the benthic boundary layer are referred to as *BBL macrofauna* (also hyperbenthos or suprabenthos).

The fauna of the sedimentary interface zone can also be classified by their by their size. Thus:-*microfauna* <60 μm, *meiofauna* 60-1000 μm, *macrofauna* >1000 μm and *megafauna* species which cannot be adequately sampled by grab or corer (due to the distances between individuals). There is also a microflora, inclusive of fungi and bacteria, which occur in soft sediments and are functionally important in oxidizing organic matter reaching the sediment.

The sedimentary interface of the Scotian Shelf is poorly known and previous studies there have been instigated for specific reasons related to:

- groundfish feeding on benthic macrofauna, *e.g.* Mahon and Neilsen (1987)
- study to determine the spatial distribution of anthropogenic effects following benthic surveys, *e.g.* Wildish and Peer (1983)
- study of contemporary animal-sediment interactions by surficial geologists in order to better understand the stratigraphic record.

In this brief review, prior benthic work is listed relating to sedimentary interface fauna of the Scotian Shelf, some of the research findings related to submarine canyons is discussed, perhaps similar to the Gully, and some of the important benthic research needs to optimally manage the Gully are proposed.

6.5.1.2 Scotian Shelf Sedimentary Interface Surveys

Shown in Table 6.4.1.1 are the sources of information relating to the fauna of this area.

Table 6.5.1.1. Benthic Surveys on the Scotian Shelf published in the primary literature.

Geographic area	Authors
Continental shelf transect	Mills and Fournier (1979)
Lower Bay of Fundy	Wildish and Peer (1983)
Lower Bay of Fundy	Schwinghamer (1983)
General Shelf	Pocklington and Tremblay (1987)
General Shelf	Volkaert (1987)
Browns Bank	Wildish *et al.* (1989)
Browns Bank	Wildish *et al.* (1992)
Grand Banks	Hutcheson and Stewart (1994)

The paper by Schwinghamer (1983) is partly concerned with meiofauna in the Bay of Fundy and that by Wildish *et al.* (1992) with the BBL macrofauna of Browns Bank. The other papers all concern conventional studies of macrofauna collected by grab or corer. The Pocklington and Tremblay (1987) study is a review of the 50 benthic studies undertaken on the East Coast of North America between the Hudson Strait and Cape Hatteras, with respect to polychaete worms. Mills and Fournier (1979) studied a transect across Emerald Basin and Bank in which 13 stations were sampled with a single box core of 0.25 m squared. Wildish and Peer (1983) sampled 98 stations with 2 replicate grabs of 0.1 m squared, throughtout the lower Bay of Fundy. Seven box cores of 0.25 m squared were used to sample the soft sediments for polychaete worms on the central Scotian Shelf by Volckaert (1987). Wildish *et. al.* (1989) sampled at 29 stations on Browns Bank with 6 of the stations seasonally repeated over 6 cruises. As part of a baseline study of oil drilling on the Grand Banks, Hutcheson and Stewart (1994) sampled at a single station with a 0.1 m squared grab, replicated 4-5 times. All of these authors sieved their samples on mesh screen of different sizes, so the data are not strictly comparable.

As far as can be determined there is no specific information regarding the benthos of the Gully of the Scotian Shelf. However, in 1997 the Parizeau 97-053 mission made 34 deployments in the Gully using video and still photography (D.Gordon, pers.comm.). This work is still being analyzed. A video of the methods and some of the benthic communities is available at the BIO and SABS libraries.

6.5.1.3 Submarine Canyons and Pelagic-Benthic Coupling

Submarine canyons are common features of the continental slope edge and the submarine valleys may extend close to the shore. The physical oceanography of submarine canyons has been studied, *e.g.* by Cooper (1947), Schott (1971) and Roberts (1971). This work has linked upwelling of plant nutrients from deeper waters in the canyons to enhanced primary productivity.

A review of the benthic work done in canyons is presented in Cooper *et al.* (1988). Studies of the megafauna (taken to be visually observed macrofauna, *e.g.* fish, epifauna, mobile invertebrates) of continental edge gullies have been made from submersibles and underwater cameras. These studies include: Emory and Ross (1968), Rowe (1971), Haedrich *et al.* (1975), Grassle *et al.* (1975), Hecker *et al.* (1980) and Valentine *et al.* (1980). This work shows that megafauna form natural assemblages characteristic of certain depth zones within the canyon. These observations support the view that, because of the varied habitats within the canyon, faunal diversity is higher than on the continental slope. The infauna or BBL macrofauna are poorly known. The rock wall macrofauna of a deep fiord off the coast of Newfoundland has been studied from submersibles (Haedrich and Gagnon, 1991).

Off southern and central California the continental shelf is only a few km wide and deep submarine canyons are present close to the shore. Shea and Broenkow (1982) studied the physical, chemical, and biological oceanography of the Monterey Canyon, showing that two mechanisms, wind-induced upwelling and upwelling due to semiduirnal, internal tides, caused funneling up the canyon. This led to enhanced phosphate levels in surface waters and hence increased primary production.

The ecosystem linkages in the Gully between pelagos and benthos deserve further attention because it is unlikely that the classical view of coupling (see Rowe *et al.* 1975) between surface and directly underlying sediments is operational here.

6.5.1.4 Conclusions and Recommendations

The quantitative study of benthic ecology began in 1911 with the work of the Danish investigator, Petersen. His aim was to evaluate the seabed from the point of view of its worth as a feeding ground for commercially caught groundfish. Classically defined benthic macrofaunal communities originating from this work have not led to a universal system from which community types in other areas can be predicted. It is for similar reasons, therefore, that the descriptive knowledge available from other submarine canyons cannot be used in a strictly predictive sense to define the benthic communities of the Gully, beyond saying that it will have a more diverse macrofauna than adjacent Slope areas and that suspension feeders will be found on the exposed rock walls.

Since Petersen's time, single variables, *e.g.* sediment type, have been correlated with benthic macrofaunal distributions and hence give support to the suggestion that knowledge of the surficial sediment may be useful in defining the distribution and structure of benthic communities (see Section 3.0). A recent thoughtful review (Snelgrove and Butman, 1994) shows, however, that it is unlikely that single-variable correlations will be adequate. In fact, sediment distribution and macrofaunal distribution are both also correlated with seawater movements (Wildish and Kristmanson, 1997). Numerous factors have been identified as controls on community composition, biomass and production, inclusive of water movement, but the relative importance of each as a predictor of benthic macrofaunal distibution has not yet been determined.

Quantitative sampling in benthic ecology, using grabs and corers, is as limited now in its spatial coverage as it was in Petersen's day. The recent development of rapid, acoustic surveying methods of the seabed by marine geologists, in conjunction with the older methods, holds great promise for providing new tools to achieve a predictive capability in benthic ecology. In the abscence of data related to the sediment interface fauna of the Gully, it is recommended that:

- an attempt be made to spatially describe benthic communities, biomass and secondary production of the Gully.
- this be part of multidisciplinary research program to determine the pelagic-benthic coupling in the Gully.
- new methods, *e.g.* high-resolution acoustic survey tools currently under development, be employed (*e.g.* see Wildish *et al.* 1998 and Wildish and Fader, 1998).

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6.5.2 Deep Sea Corals

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6.5.2.1 Introduction

A recent study of the distribution and status of deep sea corals of Nova Scotia (Breeze, 1997) has demonstrated the diversity of horny corals (Gorgonacea) and stony corals (Scleractinia) that occur in Nova Scotia waters. The study was based on interviews with fishermen and scientists, the study of museum collections, and a review of the scientific literature which included published works by Cairns (1981), Deichmann (1936), Hecker *et al* (1989), Opresko (1980) and Zibrowius (1980). The corals found in the study area are generally typical of the continental slope of eastern North America. Some large species are well known to fishermen (as "trees") and are also reported in the scientific literature. Other, smaller, species are not especially noted by fisherman and are rarely reported in the literature. Ten species from the Order Gorgonacea are reported from the Scotian Shelf and Slope of which nine species have been confirmed for the Gully area. In addition, ten species from the Order Scleractinia are likely to occur but only three are confirmed from the Gully area.

The deep sea corals have been identified as a significant feature of the benthic fauna of the area, but relatively little is known about them or indeed many other communities of the benthos.

6.5.2.2 Distribution

Deep sea corals have a limited geographic and bathymetric distribution. With some variations the corals generally occur on the continental slope, in submarine canyons, and in gullies between fishing banks. Many have circum-North Atlantic distributions and may range north into the arctic or south into tropical waters. Most Nova Scotian corals are not found in depths less than 200 m, which roughly coincides with the shelf break. They extend at least to a depth of 2000 m and perhaps beyond. Many species occur at their most shallow depth at the northern end of their range. Distribution corresponds closely with the zone of high productivity associated with the shelf break off Nova Scotia. In the *Natural History of Nova Scotia* landscape classification (Davis and Browne, 1997), this zone is included in District 940 and Units 922 and 932 (see section 10.2). Vertical zonation of species on canyon walls has been discussed by Hecker *et. al* (1980).

6.5.2.3 Bottom Communities

Most corals require a hard substrate for attachment and are thus generally found on bedrock and gravel bottoms. The large species best known to fishermen are hard bottom species and include *Paragorgia arborea* and *Primnoa resedaeformis*. Species that are anchored in mud (*e.g., Radicipes gracilis* and *Acanella arbuscula)* have branching calcareous holdfasts for anchoring themselves. The colony generally begins attached to a small stone or shell as the planktonic planula larval stage requires a hard smooth substrate on which to settle. This is also true for the stony coral, *Lophelia pertusa* which settles on a small stone but later forms large colonies (bioherms). Dense growths of coral colonies form physical structures that provide suitable habitat for many epibenthic invertebrates and fish in what might otherwise be a relatively featureless bottom (Mortensen *et. al* 1995). Unlike the shallow water corals of the tropics, the deep water species are ahermatypic in that they do not function in symbiotic association with zooxanthellae. They feed on suspended organic particles or zooplankton.

6.5.2.4 Coral species of The Gully

Species with a North Atlantic distribution have been known to science since the middle of the eighteenth century from collections made in the eastern North Atlantic. Our knowledge of the species from the western North Atlantic only dates from the end of the nineteenth century (Whiteaves, 1901). Since the initial descriptions of species, very little new information has been published. The important Canyon Assessment Study (Hecker *et. al*, 1980) is a focal point of renewed interest in these fascinating animals.

The following species are either known from or expected to occur in the area of the Gully. The information is summarized from Breeze (1997). The known distribution of five species are shown in Fig. 6.5.2.1. Specific occurrences of seven additional species are given in the text. The "area" of the Gully used here is that shown in Figure 6.5.2.1 with the exception of two deep water stations, 800m and 1700 m, located at the south end of the Halifax Line (Sambro Bank-Western Bank) regularly sampled by Bedford Institute cruises in the 1960's and 1970's. The records come specifically from Dawson Cruise 78-006. Other records, included in Fig. 6.5.2.1 were obtained by DFO Cruise Needler 734 (1997). Several specimens from these cruises are in the collection of Nova Scotia Museum of Natural History.

6.5.2.4.1 Order Gorgonacea

Family Paragorgiidae

Paragorgia arborea (Linnaeus, 1758). A large and well known species that occurs in the North Atlantic and North Pacific as well as in the Southern Hemisphere. In the western North Atlantic it is found off Greenland and in parts of the southern Grand Banks, Nova Scotia and south to canyons off George's Bank from about 200 to 900 m depth. (Deichmann, 1936). This species is recorded from the Gully and areas of the Continental Slope to the east and west. These large "trees" are known to grow to a height of 2.5 m and larger specimens have been reported. Records from near the Gully are shown in Fig. 6.5.2.1.

Family Anthothelidae

Anthothela grandiflora (Sars, 1856). Several specimens of this small, bush-like, species collected from near Sable Island Bank and Banquereau (Haldimand Canyon) at depths of 320 to 640 m are in the collection of the Smithsonian Institution. Several specimens were also collected in the area of Haldimand Canyon, between 250 and 300 m, by DFO Cruise N734. This is a common North Atlantic species.

Family Acanthogorgiidae

Acanthogorgia armata (Verrill, 1878). A delicate, bush-like form 10-20 cm high found off Haldimand Canyon in 250-300 m depth (collected on Cruise N.734) . This species is normally attached to hard rock and boulder bottom. The Type Specimen was collected "off Nova Scotia" at about 600 m depth (Deichmann, 1936).

Family Chrysogorgiidae

Radicipes gracilis (Verrill, 1884). This is a single-stemmed, whip-like form about 80 cm long found on mud bottoms in deep water. It is considered to be rather abundant in deep water off eastern North America (Deichmann, 1936). There is one Nova Scotia record of several specimens taken in an Agassiz Trawl at a depth of 1700 m (Dawson 78-006 Stn. 9). The station is at 42°44.1' N. 61° 37.9' W, off Western Bank.

Family Isididae

Acanella arbuscula (Johnson, 1862). A small (10-15 cm) bushy species obtained near Haldimand Canyon (collected on Cruise N. 734). The collection of the Smithsonian Institution has specimens collected from near Sable Island Bank and Banquereau at between 274 and 686 m depth. This species settles on small stones and roots itself into the bottom mud as it grows. A common species from Greenland to New England in 400 to 2900 m. Also in the eastern Atlantic as far south as Madeira. (Deichmann, 1936).

Family Keratoisidae

Keratoisis ornata (Verrill, 1878). This common and distinct coral is sparsely branched, robust and grows to 1 m in height. It is found attached to rock or gravel bottoms in 400 to 600 m The species is known to occur from George's Bank to the Stone Fence. Many specimens were collected in the area of Haldimand Canyon by DFO Cruise N.734. The Type Locality is given as "Nova Scotia" (Deichmann, 1936). Records are shown in Fig. 6.5.2.1.

Family Paramuriceidae

Paramuricea grandis (Verrill, 1883). A sparsely branched, fan-like colony reaching a height of 50 cm It is found in the Northwest Atlantic from the Grand Banks to canyons off New England at 200 to 950 m depth on rock or boulder bottoms (Opresko, 1980). It occurs on the Continental Slope both east and west of The Gully at 450 to 640 m depth. Records are shown in Fig. 6.5.2.1. Little is known about the status of *P. grandis*, as few specimens have been recorded in the literature. This species may warrant special protection as it is believed to have a limited range.

Paramuricea placomus (Linnaeus, 1758). This species is smaller and has less numerous branches than *P.grandis.* Specimens were collected in 1997 (Cruise N. 734) from the area of Haldimand Canyon in about 300 m It is known from the coast of northeastern North America and Europe, including the Mediterranean (Deichmann, 1936). Records are shown in Fig. 6.5.2.1.

<u>Family Primnoidae</u>

Primnoa resedaeformis (Gunnerus, 1763). This is a very conspicuous form well known to fishermen and reported from the Gully from 1880. Dr. David Honeyman showed specimens of this species and *Paragorgia arborea* to members of the Nova Scotian Institute of Science at their meeting on March 15, 1880. They were collected by Halifax fishermen "north of Sable Island". Colonies grow to about 1 m in height, are calcified and very robust. They are usually attached to boulders from about 100 to 500 m deep (Deichmann, 1936). This species occurs in the northern North Atlantic and North Pacific. In the western North Atlantic it is found from Greenland south to the canyons off New England. Records from near The Gully are shown in Fig. 6.5.2.1.

6.5.2.4.2 Order Scleractinia

<u>Family Caryophylliidae</u>

Lophelia pertusa (Linnaeus, 1758). This is a massive much-branched stony coral that occurs in large colonies (bioherms) on areas of flat bottom. Bioherms may have heights of more than 2 m and cover an area in excess of 1,500 m (Wilson, 1979). Depth range is reported as 50 to 300 m but also down to 1000 m in the south of the range. The species occurs throughout the North Atlantic and also in the southern hemisphere. In the western North Atlantic it is known from Nova Scotia south to Brazil (Cairns, 1981). The dead specimens found in the Gully and off Sable Island probably represent the northern limit of its range in the western North Atlantic. No living specimens have been reported from the area of the Gully.

<u>Family Flabellidae</u>

Flabellum alabastrum (Moseley, 1873). A solitary coral about 6.0 cm in maximum diameter found on small stones on mud bottoms at depth of 357 to 1977 m. It is common on the Continental Slope from Georgia to the Gulf of Maine and north to Davis Strait. It also occurs in the eastern North Atlantic (Cairns, 1981). There is one record of a dead specimen from the south end of the Halifax Line, south of Western Bank in 800 m. The specimen was taken with a box core sample (Dawson 78-006, Stn.6). Specimens of this species have been saved by fisheries biologists on research cruises and fishermen have reported "mushroom" corals, which could be this species, off the southern points of Emerald Bank.

Javania cailetti (Duchassaing and Michelotti, 1864). A specimen of this species, collected near the Stone Fence (48:28 N 57.13 W) at a depth of 549 m, is in the collection of the Smithsonian Institution. The species is known from the continental slope as far south as Georgia and also from the eastern North Atlantic, South Atlantic, Indian, and Pacific Oceans.

6.5.2.5 Concluding Remarks

From this general survey it would appear that half of the 20 species of deep sea corals reported from Nova Scotia waters occur in the area of the Gully and the adjacent Continental Slope. This is a typical assemblage of species and no "rare" species occur. Although some species have been known to occur here since the late 1800's (Whiteaves, 1901) very little work has been done on the biology and ecology of these animals. They have been recognized as an important part of the biota of the Gully (Breeze, 1997).

Some effort should be made to carry out more research, especially on the status of stony corals such as *Lophelia pertusa* and *Flabellum alabastrum*. More species of stony corals, particularly *Desmophyllum cristagalli* and two other species of *Flabellum*, were expected. The former species is known from canyons on the continental slope off New England (Hecker *et al.* 1980) and has also been retrieved as fossils from Orphan Knoll, off Newfoundland (Smith *et al*, 1997). Where species such as *Acanthogorgia armata* and *Keratoisis ornata* are noted as having Nova Scotia as the Type Locality it is important to make strong efforts to conserve examples of the genetic stock.

The occurrence of corals at about 350 to 500 m depth close to Sable Island provides an exceptional opportunity for study of these poorly known animals through collection of specimens, data, and video footage and other images. Future studies might focus on the unique habitat of the coral beds in our waters and their sensitivity to environmental change and physical damage, the taxonomy of local coral species and their abundance, and the associations of animals they support.

6.5.2.6 Acknowledgments

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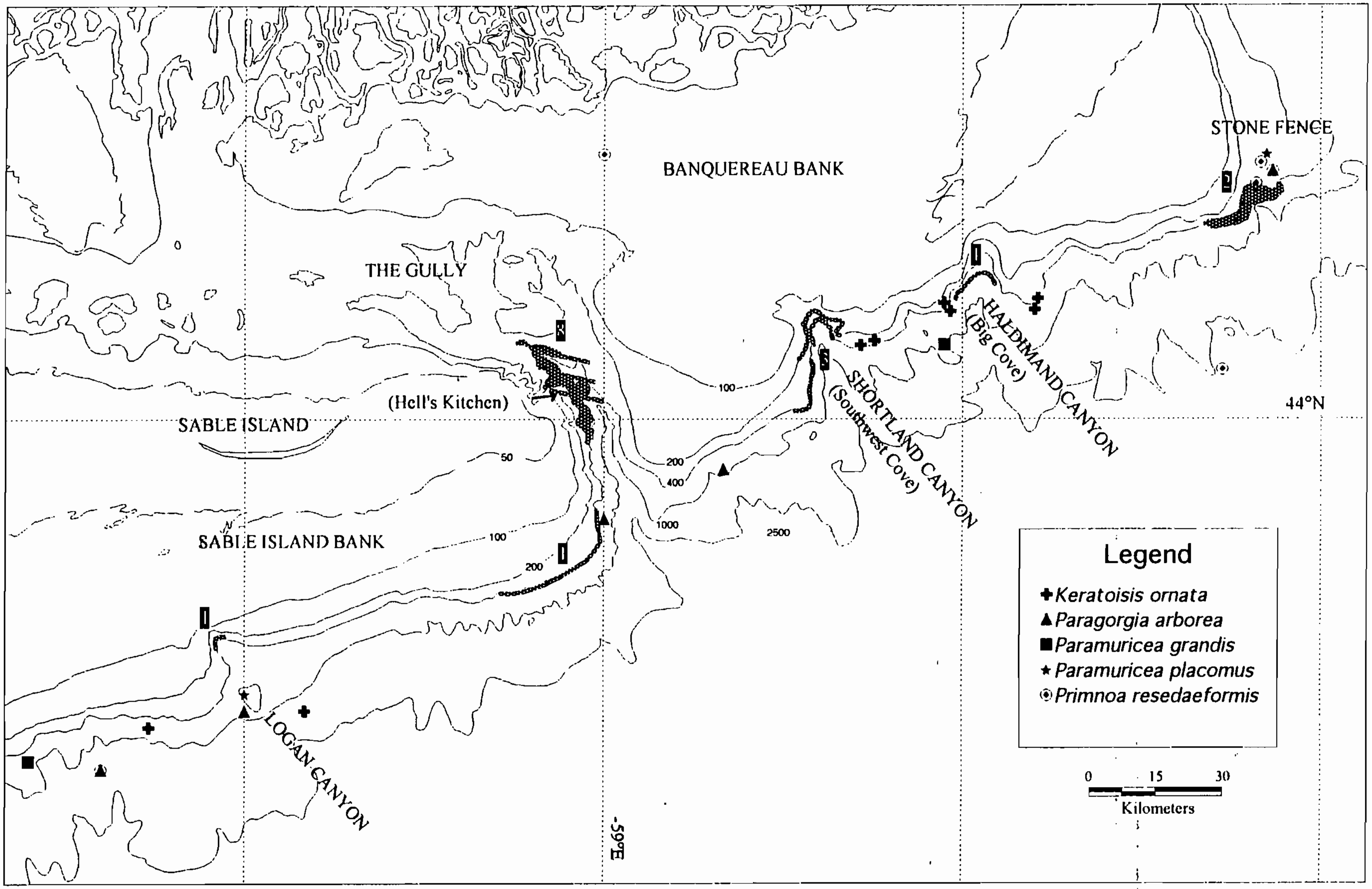

Fig 6.5.2.1. Reports of coral findings in the area of The Gully. Fishermen's reports are shaded and not distinguished by species. Numbers inside shaded areas correspond to the number of fishermen who reported coral from that area. The legend shows symbols corresponding to species from museum and scientific collections. Contours are in metres. (from Breeze, 1997).

7.0 Fish and Fisheries

7.1 Finfish and Selected Invertebrates

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7.1.1 Introduction

The purpose of this document is to describe and analyze the scientific observations on fish and fisheries occurring in the Gully and adjacent waters, and to contrast and compare these analyses to those for the eastern Scotian Shelf as a whole. The data will be presented in two major sections, the first describing the distribution, diversity and abundance of finfish and some selected invertebrate species occurring in these areas and the second describing the nature of the fisheries which occur in the area.

For purposes of this presentation we adopted the following definition of the Gully and surrounding areas. The Gully proper is considered to be defined by the 200 fathom contour of summer survey groundfish stratum 452 (Fig. 7.1.1). The Gully trough is the area of mixed depths defined by depth stratum 457 just to the north and west of the Gully proper, and the Gully slope is defined as the continental slope immediately adjacent to the Gully and extending to a depth of 5000 m. G. Fader indicated the presence of an old river bed which extends from the Gully proper down the slope and onto the upper reaches of the abyssal plain, this features should probably be considered a part of the Gully as a whole. The above features are considered to comprise the Gully and adjacent waters. In the body of the paper this area will be referred to simply as the Gully.

There are a number of recent documents which summarize, to some degree, the state of scientific knowledge of this area. The first and most comprehensive was commissioned by the World Wildlife Fund of Canada (Shackell *et al.*, 1996). This document presents a preamble outlining the form and benefits of a biophysical description of the area based on a survey of the published literature. In terms of the description of the ichthyofauna of the area these authors present a sketch of the recently published results (Simon and Comeau, 1994; Strong and Hanke, 1995). A more detailed description based on both the literature and more recent (unpublished) data was in order and to some extent prompted the present document. The second was prepared by D. Fenton (Oceans Act Coordination Office, DFO) termed *"The Gully" Overview of Biophysical Characteristics and Resource Use.* This author also reports on the results of Simon and Comeau (1994), Strong and Hanke (1995), and refers to some of the preliminary results of East Coast of North America Strategic Assessment project (published as Brown *et al.,* 1996).

7.1.2 Finfish

Descriptions of the finfish of the Scotian Shelf based mainly on the results of DFO trawl survey data include (Scott, 1976; Scott *et al.*, 1982; Mahon *et al.*, 1984; Mahon and Smith, 1989; Mahon, 1985; Brown *et al.*, 1996; and Mahon *et al.*, 1997 MS), although none of these focus on a description of the Gully itself. Strong and Hanke (1995) examine the trawl survey stratum 452 which encompasses the 100 to 200 fathom (180 to 360m) isobaths within the Gully area. The latter authors also looked at seasonal distribution of finfish in the stratum. Their results indicate the presence of some 45 species (below) over the period 1970 - 1993 with about one third of these species present all year. Information on the species composition of surrounding strata are also presented for this time period. Strata of particular interest because they represent the shallower banks which are likely ecologically connected with the Gully and approaches are 448 (Western Banquereau), 455 and 456 (Western Sable Island), and 458 (Middle Bank). Given the complicated bathymetry of the system of channels leading into the Gully proper (Fig. 7.1.1) we also examined the species composition of the mixed depth stratum 457.

Species Occurring in the 100 - 200 Fathom isobaths of the Gully (1970 - 1993, from Strong and Hanke 1995) in order of the frequency of occurrence over the time period. Note the unidentified Stomiatioid (38) and unidentified fish (42) in the table.

1. Redfish	10. Winter Skate	19. Yellowtail Fl.	28. Ocean Pout	37. Mackerel
2. A. Plaice	11. Haddock	20. Ar. Hr Sculpin	29. N. Sand Lance	38. Unid Stomatio.
3. White Hake	12. Marlins. Gren.	21. N. Hagfish	30. Capelin	39. Rosefish
4. Witch Fl.	13. Smooth Skate	22. Cusk	31. Lanternfish	40. Arctic Eelpout
5. Thorny Skate	14. Monkfish	23. Herring	32. Rck Grenadier	41. Mailed Sculpin
6. Cod	15. Pollock	24. A. Argentine	33. Offshore Hake	42. Unid Fish
7. Silver Hake	16. Str Wolffish	25. Wrymouth	34. Spiny Dogfish	43. Shortt. Eelpout
8. Longfin Hake	17. Turbot	26. Lhrn Sculpin	35. Sea Raven	44. Ogrefish
9. A. Halibut	18. Frb Rockling	27. Red Hake	36. Little Skate	45. Rghnose Gren.

Strong and Hanke report that stratum 452 was also an area of relatively high species diversity during the period 1986-1993, the final two of six time periods. It must however be noted that this refers to stratum 452 only.

7.1.3 Ichthyoplankton

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Data from the Scotian Shelf Ichthyoplankton Program (SSIP) was examined to determine the importance of the Gully as a spawning area for marine fishes. SSIP was a fixed station survey with reasonably good seasonal coverage that was conducted from 1978-1982. Ten stations were identified as representative of the Gully area and data from oblique bongo hauls were extracted for the analysis (Fig. 7.1.2). One should bear in mind that conclusions drawn from historical data may not provide an accurate representation of the current situation and that the sampling intensity for this relatively small geographic area was low. In total, the ten stations were sampled 124 times during the conduct of SSIP.

Twelve species of fish eggs were encountered in the Gully area (Table 7.1.1). Out of these twelve species silver hake was the most abundant followed by pollock, American plaice and cod. At the earliest stages of egg development exact identification to species is not possible, therefore many categories represent groupings of two or more species types. For example, early stage cod, haddock and witch eggs cannot be discriminated from one another and are lumped together into one category. For the top four species, the temporal distribution of abundance is shown in Fig. 7.1.3. Silver hake eggs were collected in the Gully area from July to October with peak abundances evident in August and September. Pollock eggs were most abundant during November to January. American plaice eggs were encountered from March to June with peak abundance in March to May. The temporal occurrence of cod eggs in the Gully area appeared to be bi-modal with peaks in November/December and May.

Table 7.1.1. Listing of all species of fish eggs contained within the Gully and approaches with information on frequency of occurrence (n_{max}=124) and abundance (number per m3). (This information was derived from the Scotian Shelf Ichthyoplankton Program (SSIP) database. Complex[1] refers to silver hake, longfin hake, white hake, butterfish and four-bear).

common name	n	minimum	maximum	average
unidentified	16	0.0007	0.0977	0.0123
cod	16	0.0017	0.2764	0.0379
haddock	3	0.0016	0.0077	0.0047
plaice	17	0.0038	0.3629	0.0734
mackerel	2	0.0026	0.0240	0.0133
witch	1			0.0045
four-beard rockling	3	0.0045	0.0162	0.0077
yellowtail flounder	4	0.0045	0.0073	0.0056
cusk	6	0.0014	0.0073	0.0046
complex[1]	19	0.0015	0.2972	0.0266
cod/haddock	6	0.0046	0.6256	0.2799
silver hake	27	0.0015	1.1285	0.1145
cod/haddock/witch	38	0.0014	1.8434	0.1341
cusk/mackerel	6	0.0008	0.0878	0.0206
cunner/yellowtail	13	0.0019	0.3448	0.0526
offshore hake	3	0.0046	0.0207	0.0118
hake (Urophycis sp.)	6	0.0020	0.0401	0.0112
pollock	14	0.0018	1.0361	0.0980
Atlantic halibut	1			0.0017
brill/windowpane	1			0.0087

Nearly thirty fish species were collected in the Gully area at the larval stage, which is about three- fold greater than the number of species collected at the egg stage (Table 7.1.2). Part of this difference is due to the fact that certain species do not have pelagic eggs (*i.e.* sand lance) or the adults bear live young (*i.e.* redfish). The most abundant species at the larval stage was silver hake. Given that this species was also most abundant in the area at the egg stage, it is probably reasonable to conclude that silver hake spawn in the area defined as the Gully. The second most abundant species collected at the larval stage was sand lance followed by cod, windowpane flounder, redfish, witch flounder and American plaice. The temporal pattern of occurrence for four out of five of the most abundant species in shown in Fig. 7.1.4. Peak abundances of silver hake larvae occurred in August to October, offset by about one month from the peak abundance of their eggs. Sand lance larvae were collected from January to June with a peak evident in April. Cod larvae were abundant in two time periods, November/December and May/June reflecting the temporal pattern of distribution at the egg stage. Redfish larvae were encountered from March to August with a peak in abundance in April. It should be noted that pollock and American plaice, species that were relatively abundant in the Gully area during the egg stage, were encountered infrequently in the survey area during the larval stage.

Table 7.1.2. Listing of all larval fish species contained within the Gully and approaches with information on frequency of occurrence (nmax= 124) and abundance (number per m^3). (This information was derived from the Scotian Shelf Ichthyoplankton Program (SSIP) database.)

common name	n	minimum	maximum	average
Bothus sp.	1			0.0015
cod	9	0.0030	0.2172	0.0390
silver hake	29	0.0009	1.4539	0.3423
pollock	1			0.0054
redfish	23	0.0018	0.2825	0.0305
American plaice	3	0.0188	0.0225	0.0197
witch flounder	12	0.0049	0.0936	0.0242
yellowtail flounder	10	0.0017	0.0546	0.0144
Gulf Stream flounder	1			0.0026
wolffish	1			0.0033
herring	1			0.0030
mackerel	4	0.0019	0.0054	0.0031
unidentified	16	0.0020	0.1047	0.0143
four-beard rockling	5	0.0019	0.0169	0.0071
windowpane flounder	4	0.0131	0.0565	0.0312
laternfish species	10	0.0017	0.0856	0.0143
glacier laternfish	23	0.0008	0.0722	0.0145
horned laternfish	1			0.0007
spotted laternfish	1			0.0018
hake (Urophysis sp.)	14	0.0020	0.0642	0.0158
protomyctomphum	1			0.0021
Bathylagus compsus	1			0.0016
longhorn sculpin	2	0.0035	0.0054	0.0044
sculpin (Triglops sp.)	1			0.0030
sculpin (Cottidae)	1			0.0145
monkfish	3	0.0034	0.0178	0.0085
sandlance	30	0.0016	1.6499	0.1074
wrymouth	1			0.0025
coral dragonet	1			0.0007
Argyropelecus	1			0.0017
barracudina	1			0.0022
cardinalfish	1			0.0007
un i.d. gobies	1			0.0007

7.1.4 Pelagic Fish

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The distribution and abundance of these species is not well estimated by groundfish trawls which are the primary sampling tool used by DFO since the late 1940's. Although pelagic species are encountered and caught by the trawl, their overall catchability is considered to be low. The data are usually interpreted to indicate presence or absence of species or to give very general trends in abundance over long time periods. There has also been work carried out in the past which made use of commercial catch data to estimate the distribution and abundance of at least the commercially exploited pelagic species.

Small Pelagics

Kulka and Stobo (1981) report on the results of an exploratory survey for mackerel (*Scomber scombrus*) using both bottom trawl and midwater trawls (see Appendices). They found no mackerel in the Gully during the winter months. The results indicated that juvenile mackerel do stay on the shelf during the winter but that adults migrate south. During the summer these adults migrate from the south into the Gulf of St. Lawrence. The Gully is not considered an important area for mackerel feeding or spawning.

Large Pelagics

Heath Stone provided an overview of the Canadian large pelagics fisheries on the Scotian Shelf in relation to the Gully area (See Appendices). He states that a longline fisheries for swordfish does occur in the Gully and adjacent areas. Based on catch rate information the Gully does not appear to be an area of high swordfish abundance. He also reports that tuna by-catches from the swordfish fishery are low in the Gully area relative to other areas.

7.1.5 Deepwater Species I - Mesopelagics (Data provided by R. Halliday and D. Themelis)

The data on these species, which complete their life histories within the top 1000 m of the water column, were extracted from the meso-pelagic data base compiled by Ralph Halliday and Daphne Themelis. Sampling for these species was by IGYPT and Tucker trawls and ranged over bottom depths of 1000 - 4000 m at various points along the slope of the Scotian Slope (Fig. 7.1.5). The findings indicate the occurrence of more than 200 species of mesopelagic fish in the area. The Gully slope is bathed primarily by Labrador Slope water whereas further west warm slope water from the Gulf Stream is a more common occurrence. Many of the 200 species of mesopelagic fishes are southern in distribution, with quite a large number being expatriates from tropical waters. The mesopelagic ichthyofauna of the Labrador Slope water is composed mainly of Sub-arctic-Temperate species. Given this, only a small fraction of the 200 species of mesopelagic fishes (Table 7.1.3) is of common occurrence off the Gully, and none are endemic (Halliday *et al.*, 1995).

Table 7.1.3. Mesopelagic Species Composition Off the Scotian Shelf and Southern Grand Banks collected by IGYPT and Tucker trawls during the mesopelagic surveys conducted 1984 - 1989 (Data provided by R. G. Halliday and D. Themelis)

Family	Number of Species	Rank (Numerical Abundance)
Myctophidae	68	1-5,7-9,12,15-17,19,21,25
Gonostomatidae	8	6,10
Chauliodontidae	2	13
Sternotychthidae	11	14
Stomiidae	3	18
Serrivomeridae	2	20
Photichtydae	5	22,24
Nemichthyidae	3	23
Squalidae	1	>25
Derichtyidae	2	>25
Eupharyngidae	1	>25
Bathylagidae	7	
Astronesthidae	10	
Melanostomiidae	29	
Malacosteidae	6	
Idiacanthidae	1	
Scopelarchidae	3	
Paralepidae	13	
Evermanellidae	3	
Omosudidae	1	
Gadidae	1	
Melanonidae	1	
Trachipteridae	1	
Regalecidae	1	
Stylephoridae	1	
Diretmidae	1	
Anoplogasteridae	1	
Melamphaeidae	11	
Rondeletiidae	1	
Zeniontidae	1	
Zeidae	1	
Grammicolepidae	1	
Caproidae	1	
Liparidae	1	
Apogonidae	2	
Perchichthyidae	3	
Bramiidae	1	
Caristiidae	1	
Chiasmodontidae	2	
Scombrolabracidae	1	
Gempylidae	5	
Trichiuridae	2	
Stromateidae	7	
Total	227	

These results show clearly that myctophids (lanternfish) dominate the mesopelagic ichthyofauna of this area. This large family also contains the largest number of species (68) making up about 30% of the 227 species encountered.

7.1.6 Deepwater Species II - Epipelagic and Bathypelagic Species (Data provided by R. Halliday and D. Themelis)

Species composition and a general idea of relative abundance of the epipelagic (life history completed in the upper 100 meters of the water column over oceanic depths), bathypelagic (life history completed deeper than 1000 m but not on the bottom) and neritic (those species which generally reside on the shallower waters of the shelves), are presented below (Table 7.1.4). These data were also gathered during the IGYPT and Tucker trawl surveys reported for the mesopelagic species above, and give only a general impression of the composition of the ichthyofauna at these depths in these regions.

Table 7.1.4. Epipelagic, bathypelagic, and neritic species caught during the IGYPT, and Tucker Trawl mesopelagic trawl surveys conducted adjacent to the Scotian Shelf and Southern Grand Banks 1984 - 1989. ** The indicated species occur only in the mesopelagic data set, while those which are not marked occur both in the mesopelagic data set and the summer survey results conducted in waters < 360 m.

Species	Unique**	Frequency	Total
Acanthurus sp	*	14	41
Ahlia egmontis	*	7	21
Ahliesaurus berryi	*	4	5
Albula vulpes	*	1	1
Aldrovandia phalacra	*	1	1
Alepocephalus sp	*	2	2
Aleposaurus ferox	*	6	7
Anguilla rostrata	*	17	41
Antennarius sp	*	3	3
Anthias sp	*	11	22
Ariosoma balearicum	*	1	1
Ariosoma sp	*	16	49
Beryx Dedecadactylus	*	2	2
Beryx splendens	*	2	2
Bothus sp		48	121
Bregmaceros sp	*	50	83
Callionymid sp		2	3
Callionymus agassizi		5	5
Caranx hippos	*	1	1
Caranx sp	*	3	5
Carapid sp	*	8	11
Chaetodon sp	*	6	7
Citharhicthys arctifrons		8	11
Congrid sp	*	134	723
Cookeolus boops	*	1	1
Cryptopsaras couesi	*	55	80
Cryptopsaras sp	*	1	1
Danaphryne nigrifilis	*	1	1
Decapterus sp	*	2	2
Dibranchus atlanticus		3	3
Echiodon dawsoni	*	6	6
Ectreposebastes imus	*	2	3
Edriolychnus schmidti	*	5	5
Eineria edentula	*	1	1
Engraulis eurystole	*	3	3
Epinephelus sp	*	7	14
Etmopterus princeps		4	4
Etremeus teres	*	1	45
Etropus microstomus	*	1	1
Facciolella sp.	*	5	5
Fistularia tabacaria	*	5	5
Gadus morhua		2	2
Glossanodon sp	*	8	10
Glyptocephalus cynoglossus		2	3
Gonioplectrus sp	*	1	1
Gymnothorax sp	*	4	4
Halosaurid sp.	*	1	1
Helicolenus dactylopterus		20	42
Hildebrandia sp	*	1	2
Himantolophus sp	*	5	5
Hippocampus erectus	*	5	6
Histrio histrio	*	2	2
Holocanthus sp	*	13	26
Holtbyrnia anomala	*	3	3
Hoplunnis sp.	*	5	6
Labrid sp	*	5	5
Laemonema barbatula	*	5	7
Lasiognathus beebei	*	1	1
Linophryne brevibarbis	*	1	1
Linophryne coronata	*	1	1
Linophryne macrodon	*	1	1
Linophryne sp	*	1	1
Linophrynid sp	*	2	3
Lophodolus acanthognathus	*	2	2
Lopholatilus chamaeleonticeps	*	1	1
Macrorhamphosus scolopax	*	1	1
Macrourid sp		10	12
Melanocetus johnsoni	*	5	5
Melanocetus murrayi	*	2	2
Melanostigma atlanticaum		1	5
Monolene sessilicauda		1	1
Morid sp	*	6	9
Mugil cephalus	*	1	1
Mugil curema	*	1	1
Muraenid sp.	*	1	1
Myrophis punctatus	*	3	8
Naucrates ductor	*	1	1
Nettastoma sp	*	1	1
Nezumia bairdi		3	3
Normichthys operosus	*	13	24
Notacanthid sp.	*	1	1
Oneirodes sp	*	1	1
Oneirodid sp	*	4	6
Ophichthus cruentifer	*	5	8
Paraxenomystax sp	*	18	27
Peprilus triacanthus		5	8
Percoid sp		49	252
Petromyzon marinus	*	3	3
Photostylus pycnopterus	*	2	2
Phycis chesteri		29	63
Polymmixia lowei		5	6
Priacanthus arenatus	*	6	12
Roulenia maderensis	*	1	1
Rypticus sp	*	2	2
Scombresox saurus		7	10
Scopelosaurus argenteus	*	1	1
Scopelosaurus lepidus	*	33	53
Scopelosaurus mauli	*	1	2
Scopelosaurus smithii	*	5	11
Scorpaenid sp		4	5
Searsia koefoedi	*	4	4
Sebastes mentella		1	1
Sebastes sp		18	69
Selar boops	*	1	1
Selar crumenophtalmus	*	1	1
Selene vomer	*	9	14
Serranid sp	*	2	3
Serranus sp	*	1	1
Sphoeroides maculatus		3	3
Stephanolepis hispidus	*	15	19
Svetovidovia sp	*	19	59
Symphurus sp		2	2
Symphysanodon sp	*	2	3
Synodontid sp	*	5	103
Taractes asper	*	1	1
Taractes sp	*	1	1

Species	Unique**	Frequency	Total	Species	Unique**	Frequency	Total
Taractichthys longipinnis	*	2	2	Uroconger sp	*	1	5
Tetragonurus atlanticus	*	3	3	Urophycis sp		1	2
Trachinocephalus myops	*	6	8	Urophyics tenuis		6	10
Trichopsetta sp	*	3	4	Xenodermichthys copei	*	1	1

These data show that some 75 species of epipelagic and neritic fauna occur in the Scotian Slope and adjacent abyssal plain fauna. They also indicate a relatively low degree of overlap between the neritic fauna (shallow species as characterized by the results of the summer trawl surveys) and the bathypelagic and epipelagic fauna. Of 125 species encountered only 25 occur in both data sets. The data indicate that these fauna are dominated numerically by conger eels. It is likely that this fauna is composed of a mixture of resident species, migrants and vagrants from more southerly or oceanic populations. The spatial and temporal resolution of these data do not allow us to draw conclusions about whether or not particular species are restricted to the Gully.

7.1.7 Demersal Fish

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7.1.7.1 Scotian Slope

Species composition for the lower reaches of the slopes of the Gully (below) 300 m is presently not well defined. Some previous publications of the species composition of these deep waters include: Marckle and Musick (1974), Marckle *et al.* (1988), and Pohle *et al.* (1992).

A series of redfish directed trawl surveys were carried out annually from 1982 to 1987 and extended to depths of 500 fm (900 m). The observations made along the shelf edge between 58 and 60 W were used to characterize the slope ichthyofauna for the shelf slope portions of the Gully. Preliminary analyses indicate the presence of 63 species of fish caught by the bottom trawl in depths ranging from 100 to 900 meters (Table 7.1.5). The numerically most abundant at depths less than 180m was Winter Skate, while at depths greater than 180m redfish was most numerous.

Table 7.1.5. Species composition by depth zone as estiamted by bottom trawl surveys of the Scotian Slope between 58 and 60W. Species are shown as the percentage of the total numbers of fish caught in that depth zone (each column sums to 100%).

Species	*Depth Zone*				
	<180m	*180-360m*	*360-540m*	*540-720m*	*720-900m*
AMERICAN LOBSTER	0.012	0.054	0.000	0.000	0.000
AMERICAN PLAICE	3.092	0.836	0.065	0.023	0.239
AMERICAN STRAPTAIL GRENADIER	0.000	0.000	0.003	0.000	0.000
APRISTURUS LAURUSSONI	0.000	0.000	0.006	0.000	0.000
ARCTIC EELPOUT	0.000	0.000	0.003	0.000	0.000
ARGENTINE(ATLANTIC)	0.004	0.109	0.145	0.051	0.000
BACKFIN TAPIRFISH	0.000	0.000	0.027	0.000	0.000

Species	Depth Zone				
	<180m	*180-360m*	*360-540m*	*540-720m*	*720-900m*
BARNDOOR SKATE	0.000	0.000	0.063	0.000	0.000
BLACK DOGFISH	0.000	0.000	0.174	1.871	9.988
BLUE ANTIMORA/HAKE	0.000	0.000	0.000	0.059	0.246
BOA DRAGONFISH	0.000	0.000	0.000	0.000	0.123
COD(ATLANTIC)	18.999	6.310	0.360	0.000	0.000
CUSK	0.000	0.242	0.233	0.000	0.000
DEEPSEA CAT SHARK	0.000	0.000	0.000	0.000	0.123
EELPOUTS(NS)	0.000	0.004	0.000	0.032	0.000
FRECKLED SKATE	0.000	0.004	0.000	0.000	0.000
GRAY'S CUTTHROAT EEL	0.000	0.000	0.000	0.059	0.000
HADDOCK	12.329	5.362	0.090	0.000	0.000
HALIBUT(ATLANTIC)	0.959	1.498	0.357	0.237	13.212
HERRING(ATLANTIC)	0.500	0.221	0.000	0.000	0.000
JENSEN'S SKATE	0.000	0.000	0.000	0.028	0.000
KNIFENOSE CHIMERA	0.000	0.000	0.000	0.063	0.000
LANTERNFISH (NS)	0.000	0.000	0.002	0.000	0.000
LITTLE SKATE	0.004	0.007	0.000	0.000	0.000
LONGFIN HAKE	0.073	0.715	1.138	1.754	1.176
LONGHORN SCULPIN	0.038	0.007	0.000	0.000	0.000
LONGNOSE CHIMERA	0.000	0.000	0.000	0.078	0.233
LONGNOSE GRENADIER	0.000	0.000	0.000	0.028	0.000
LUMPFISH	0.369	0.000	0.000	0.000	0.000
MACKEREL(ATLANTIC)	0.080	0.000	0.000	0.000	0.000
MARLIN-SPIKE GRENADIER	0.000	0.035	0.044	0.238	0.726
MONKFISH,GOOSEFISH,ANGLER	0.201	1.188	0.934	0.118	0.000
NORTHERN HAGFISH	0.008	0.014	0.004	0.000	0.000
NORTHERN STONE	0.011	0.052	0.025	0.054	0.000
NORTHERN WOLFFISH	0.029	0.032	0.033	0.703	0.000
OCEAN POUT(COMMON)	0.000	0.004	0.000	0.000	0.000
OFF-SHORE HAKE	0.008	0.051	0.570	0.854	0.349
PANDALUS SP.	0.000	0.000	0.000	0.032	0.000
POLLOCK	18.513	17.584	0.102	0.000	0.000
REDFISH UNSEPARATED	1.875	**36.842**	**93.405**	**88.338**	**67.618**
ROCK GRENADIER(ROUNDNOSE)	0.000	0.000	0.012	0.028	0.116
ROUGHHEAD GRENADIER	0.000	0.000	0.005	0.028	2.210
ROUGHNOSE GRENADIER	0.000	0.000	0.010	0.000	0.000
ROUND SKATE	0.000	0.000	0.004	0.000	0.000
SEA RAVEN	0.051	0.000	0.000	0.000	0.000
SHORT-FIN SQUID	0.000	0.015	0.003	0.000	0.000
SHORTSPINE TAPIRFISH	0.000	0.000	0.000	0.028	0.000
SILVER HAKE	6.253	8.440	0.219	0.061	0.000
SMOOTH SKATE	0.353	0.160	0.003	0.000	0.000
SNOW CRAB (QUEEN)	0.008	0.027	0.000	0.000	0.000
SNUBNOSE SLIME EEL	0.000	0.000	0.003	0.000	0.000
SPIDER CRAB (NS)	0.000	0.010	0.014	0.000	0.000
SPIDER/(QUEEN,SNOW)UNID	0.008	0.035	0.004	0.032	0.000
SPINY DOGFISH	0.071	0.151	0.013	0.000	0.000
SPINY EEL	0.000	0.000	0.063	0.123	0.131
SPINY EELS (NS)	0.000	0.004	0.000	0.000	0.000
SPINY SPIDER CRAB	0.013	0.069	0.003	0.000	0.000
SPINYTAIL SKATE	0.000	0.000	0.000	1.276	0.000
SPOTTED WOLFFISH	0.040	0.046	0.050	0.028	0.000
SQUID (NS)	0.022	0.102	0.000	0.000	0.110
SQUIRREL OR RED HAKE	0.005	0.036	0.013	0.000	0.000
STRIPED ATLANTIC WOLFFISH	1.405	0.572	0.087	0.000	0.349
THORNY SKATE	4.124	1.705	0.209	0.158	0.000
TRUNKFISH	0.000	0.000	0.016	0.000	0.000
TURBOT,GREENLAND HALIBUT	0.021	0.021	0.177	2.266	2.583
WHITE HAKE	2.426	12.316	1.060	1.055	0.349
WINTER SKATE	**27.025**	2.112	0.137	0.000	0.000
WITCH FLOUNDER	0.903	2.974	0.107	0.297	0.116
WRYMOUTH	0.017	0.000	0.003	0.000	0.000
YELLOWTAIL FLOUNDER	0.153	0.036	0.003	0.000	0.000

An analysis of species abundance by depth zone of the slope waters in and adjacent to the Gully, showed that the continental slope represents distributional boundaries for a large number of the demersal species. Over the range of depth sampled (100 - 900 m) some species are 1) shallow water inhabitants in that their abundance is highest in the shallows depths, some are 2) upper slope dwellers with numbers declining abruptly with depth, some are 3) true slope dwellers with the highest numbers at the mid range depths and declining abundance in either deeper or shallower waters, and some 4) deepwater species whose increasing abundance at the lower limits of the survey indicates that they may be most abundant at depths beyond 900 m (Fig. 7.1.6). The table below groups species into these categories and shows their relative abundance within each of the depth zones examined. For each species we list the total numbers caught in the depth zone by the surveys.

<u>Shallow Water Species (Decreasing abundance beyond 180 m)</u>

	LT180	**LT360**	**LT540**	**LT 720**	**LT900**
AMERICAN PLAICE	778.24	242.93	23.93	0.92	2.00
COD(ATLANTIC)	4781.17	1833.4	133.34	0.00	0.00
HADDOCK	3102.76	1558.1	33.52	0.00	0.00
LONGHORN SCULPIN	9.48	2.12	0.00	0.00	0.00
LUMPFISH	92.96	0.00	0.00	0.00	0.00
MACKEREL(ATLANTIC)	20.20	0.00	0.00	0.00	0.00
SEA RAVEN	12.93	0.00	0.00	0.00	0.00
SMOOTH SKATE	88.79	46.37	0.97	0.00	0.00
STRIPED ATLANTIC WOLFFISH	353.55	166.29	32.39	0.00	2.92
THORNY SKATE	1037.75	495.45	77.44	6.25	0.00
WINTER SKATE	6801.12	613.79	50.85	0.00	0.00
YELLOWTAIL FLOUNDER	38.45	10.51	1.09	0.00	0.00

This group contains 12 species and most of the presently commercially exploited species The results indicate that the summer surveys used to monitor their abundance, and which fish only to 360 m, sample the largest portion of their depth ranges. These survey results do however indicated that some of these species do occur in small numbers to depths of up to 720 m.

<u>Upper Slope (Decreasing abundance beyond 360 m)</u>

	LT180	**LT360**	**LT540**	**LT 720**	**LT900**
FRECKLED SKATE	0.00	1.03	0.00	0.00	0.00
LITTLE SKATE	0.97	2.12	0.00	0.00	0.00
MONKFISH,GOOSEFISH,ANGLER	50.53	345.07	346.12	4.67	0.00
NORTHERN HAGFISH	2.09	3.95	1.59	0.00	0.00
OCEAN POUT(COMMON)	0.00	1.03	0.00	0.00	0.00
POLLOCK	4659.01	5109.73	37.75	0.00	0.00
SHORT-FIN SQUID	0.00	4.25	1.09	0.00	0.00

	LT180	LT360	LT540	LT 720	LT900
SILVER HAKE	1573.69	2452.44	81.04	2.42	0.00
SPINY DOGFISH	17.94	43.79	4.67	0.00	0.00
SPINY EELS (NS)	0.00	1.03	0.00	0.00	0.00
SQUIRREL OR RED HAKE	1.17	10.50	5.00	0.00	0.00
WHITE HAKE	610.43	3578.83	393.00	41.59	2.92
WITCH FLOUNDER	227.17	864.27	39.60	11.73	0.97
WRYMOUTH	4.18	0.00	0.97	0.00	0.00

This group contains 14 species of which are half are presently commercially exploited. The results show that significant numbers of monkfish, white hake, and witch flounder occur beyond the limits of our regular summer groundfish surveys.

Slope (most abundant >360 <900)

	LT180	LT360	LT540	LT 720	LT900
AMERICAN STRAPTAIL GRENADIER	0.00	0.00	1.09	0.00	0.00
APRISTURUS LAURUSSONI	0.00	0.00	2.33	0.00	0.00
ARCTIC EELPOUT	0.00	0.00	1.09	0.00	0.00
ARGENTINE(ATLANTIC)	0.92	31.65	53.70	2.01	0.00
BACKFIN TAPIRFISH	0.00	0.00	9.99	0.00	0.00
BARNDOOR SKATE	0.00	0.00	23.33	0.00	0.00
CUSK	0.00	70.40	86.34	0.00	0.00
EELPOUTS(NS)	0.00	1.03	0.00	1.25	0.00
GRAY'S CUTTHROAT EEL	0.00	0.00	0.00	2.34	0.00
HALIBUT(ATLANTIC)	241.27	435.29	132.43	9.36	110.42
JENSEN'S SKATE	0.00	0.00	0.00	1.09	0.00
KNIFENOSE CHIMERA	0.00	0.00	0.00	2.50	0.00
LANTERNFISH (NS)	0.00	0.00	0.80	0.00	0.00
LONGFIN HAKE	18.34	207.88	421.79	69.16	9.83
LONGNOSE GRENADIER	0.00	0.00	0.00	1.09	0.00
MARLIN-SPIKE GRENADIER	0.00	10.09	16.34	9.38	6.07
NORTHERN WOLFFISH	7.37	9.26	12.27	27.73	0.00
OFF-SHORE HAKE	1.93	14.82	211.32	33.67	2.92
REDFISH UNSEPARATED	471.81	10705.77	34622.05	3483.81	565.13
ROCK GRENADIER (ROUNDNOSE)	0.00	0.00	4.37	1.09	0.97
ROUGHNOSE GRENADIER	0.00	0.00	3.67	0.00	0.00
ROUND SKATE	0.00	0.00	1.59	0.00	0.00
SHORTSPINE TAPIRFISH	0.00	0.00	0.00	1.09	0.00
SNUBNOSE SLIME EEL	0.00	0.00	1.17	0.00	0.00
SPINY EEL	0.00	0.00	23.25	4.84	1.09
SPINYTAIL SKATE	0.00	0.00	0.00	50.31	0.00
SPOTTED WOLFFISH	10.07	13.38	18.57	1.09	0.00
TRUNKFISH	0.00	0.00	5.83	0.00	0.00
TURBOT,GREENLAND HALIBUT	5.25	6.18	65.56	89.36	21.59

We found 29 species which were at their highest abundance over this range of depths. The overall most abundant was redfish (*Sebastes* sp) with significant numbers occurring to depths of over 700 m. Atlantic halibut (*Hippoglossus hippoglossus*) which do not appear to be very effectively sampled by trawls, occur in significant numbers to depths of 900 m.

Deep Slope (most abundant at or beyond 900)

	LT180	LT360	LT540	LT 720	LT900
ROUGHHEAD GRENADIER	0.00	0.00	2.01	1.09	18.47
LONGNOSE CHIMERA	0.00	0.00	0.00	3.09	1.94
DEEPSEA CAT SHARK	0.00	0.00	0.00	0.00	1.03
BOA DRAGONFISH	0.00	0.00	0.00	0.00	1.03
BLUE ANTIMORA/HAKE	0.00	0.00	0.00	2.34	2.06
BLACK DOGFISH	0.00	0.00	64.45	73.79	83.48

The abundance of these species increased to the limits of the surveyed depths likely indicating that the center of their distribution lies deeper. The most abundant of these are black dogfish (*Centroscylliun fabricii*).

It is unlikely that the species composition of the shelf slope in the Gully is unique. The Gully represent only a small portion of the slope of the Scotian Shelf and it is likely that this composition is indistinguishable from the species composition from adjacent areas of the slope. The unique bathymetric features of the Gully (rapid changes in bathymetry analogous to terrestrial cliff walls hundreds of meters high) may attract certain of the species observed. Redfish appear to prefer areas of rapid changes in bathymetry at depths >360 m and are therefore relatively abundant in the Gully relative to adjacent areas. Halibut (*Hippoglossus hippoglossus*) also appear to be relatively abundant in the Gully relative to adjacent areas. There are active fisheries for both these species in the area.

Beyond 900 m

The data in the Table 7.1.6 below augments the data presented for the deepwater redfish surveys above in that it describes the species composition of demersal fish inhabiting depths of 900 - 2700 m. It is noteworthy that these data are relatively consistent with the depth distributions for the species encountered in the redfish surveys. Black dogfish (*Centroscyllium fabricii*), Portuguese shark (*Centroscymus coelolepis*) Roughhead grenadier (*Macrourus berglax*), Longnose chimeara (Harriotta raleighana), Blue hake (*Antimora rostrata*) were all reported from the redfish surveys as having distributions with maximum numbers occurring at or beyond 900 m. Greenland Halibut (*Rheinhardtius hippoglossoides*), Deepwater chimaera (*Hydrolagus affinis*), Atlantic halibut (*Hippoglossus hippoglosoides*), Jensen's skate, snubnosed eels, and spinytale skates all had maximum abundances between 360 and 720 m. These data show that for depths from 900 to 1800 m, black dogfish are most numerous near bottom dwelling fish followed by roughhead grenadier and Portuguese shark. Beyond 1800 m Deepwater Chimaera become most abundant followed by Blue hake and Portuguese shark.

Table 7.1.6. Species Ranking for the slope off Emerald Bank, and the Gully for two depth zones

Species	Common Name	E	G1	G2
Centroscyllium fabricii	black dogfish	1	1	-
Centroscymnus coelolepis	Portuguese shark	2	3	3
Hydrolagus affinis	deepwater chimaera	3	5	1
Etmopterus princeps	rough sagre	4	+	-
Reinhardtius hippoglossoides	Greenland halibut	5	4	5
Antimora rostrata	blue hake	+	+	2
Macrourus berglax	roughhead grenadier	+	2	4
Urophycis tenuis	white hake	+	-	-
Harriotta raleighana	longnose chimaera	+	+	-
Hippoglossus hippoglossus	Atlantic halibut	+	-	-
Raja jenseni	Jensen's skate	+	+	+
Alepocephalus sp.	slickhead	+	-	-
Simenchelys parasiticus	snubnose eel	+	-	-
Raja spinicaudata	spinytail skate	-	-	+
E = Off Emerald Bank				
G1 = Gully 900 - 1800 m				
G2 = Gully 1800 - 2700 m				

7.1.7.2 Eastern Scotian Shelf

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Simon and Comeau (1994) report on the results of summer trawl survey results for the period 1970-1992. These authors show trends in abundance for the top 90% of the species caught. Although these authors did not examine data for the Gully specifically, their results indicate that this area appears to represent a preferred area of distribution for a number of species as evidenced by their relative concentration in this area relative to that observed in adjacent waters. These species include American Plaice, Atlantic Halibut, Atlantic Cod, Haddock, Herring (late 1980's and early 1990's), Longfin Hake, Monkfish, Pollock (mid to late 1980's), Redfish, Smooth Skate, White Hake (especially 1982 - 1992), Winter Skate, and Witch. Their results also indicate the presence of a number of the species in the Gully area which are caught at relatively low frequency (less that 10% of tows) by the trawl survey in general.

Based on the results of summer groundfish surveys conducted between 1970 and 1997, species composition and abundance for the Gully and Gully trough and for the Eastern Scotian Shelf excluding these two areas were compared. The Eastern Scotian Shelf was sampled over depths ranging from 50 - 200 fathoms (100 - 400 m). For the time series examined this area has had a relatively low sampling rates with less than 100 observations falling within the bounds of the Gully and Gully trough. For the period 1970 - 1997 a total of 140 species of fish were encountered (Table 7.1.7). Results indicate that the fish fauna of this area is numerically dominated by redfish. Overall mean catch rate for this species is about 160 fish per tow. The top 20 species (numerically) for this period were redfish, silver hake, squid, haddock, halibut, cod, yellowtail, capelin, sand lance, herring, white hake, longfin hake, thorny skate, pollock, witch flounder, longhorn sculpin, argentine, mackerel, red hake, and dogfish with catch rates ranging from about 50 to less than 1 individual per tow (Fig. 7.1.7).

The Gully and Gully trough are also dominated numerically by redfish (Fig. 7.1.8) with mean catch per tow values for this species about three times higher in the Gully than in the Gully trough. Excluding redfish (Fig. 7.1.9) the top 10 species in the Gully were white hake, witch flounder, squid, longfin hake, halibut, silver hake, haddock, cod, pollock, and herring over the period 1970-1997. For the Gully trough (Fig. 7.1.9) the top ten species over the same period were squid, cod, halibut, haddock, silver hake, herring, yellowtail, thorny skate, witch flounder, and capelin.

Summer surveys have captured a total of 55 species of fish in the Gully and Gully trough over the period 1970 - 1997 (Table 7.1.8). Only the ogrefish (*Anoplogaster cornuta*) was caught in the Gully and not elsewhere on the eastern Scotian Shelf. This is a deepwater species which has been encountered elsewhere on the Scotian Slope as reported from the mesopelagic survey results above.

Table 7.1.7. Fish species (including squid) caught on the Eastern Scotian during summer groundfish surveys conducted between 1970 and 1996

AGONIDAE F.	GAIDROPSARUS ENSIS
AGONUS DECAGONUS	GAIDROPSARUS SP.
ALOSA PSEUDOHARENGUS	GLYPTOCEPHALUS CYNOGLOSSUS
ALOSA SAPIDISSIMA	GONOSTOMA ELONGATUM
AMMODYTES DUBIUS	GYMNELIS VIRIDIS
AMMODYTES SP.	HAKE UNID.
ANARHICHAS DENTICULATUS	HELICOLENUS DACTYLOPTERUS
ANARHICHAS LUPUS	HEMITRIPTERUS AMERICANUS
ANARHICHAS MINOR	HIPPOGLOSSOIDES PLATESSOIDES
ARGENTINA SILUS	HIPPOGLOSSUS HIPPOGLOSSUS
ARGYROPELECUS ACULEATUS	HYPEROGLYPHE PERCIFORMIS
ARTEDIELLUS ATLANTIC	ICELUS BICORNIS
ARTEDIELLUS UNCINATUS	ICELUS SPATULA
ASPIDOPHOROIDES MONOPTERYGIUS	ILLEX ILLECEBROSUS
ASPIDOPHOROIDES OLRIKI	LIMANDA FERRUGINEA
BLENNIOIDEI S.O.	LIPARIS ATLANTICUS
BLENNIOIDEI S.O.-OBS	LIPARIS COHENI
BOTHIDAE F.	LIPARIS FABRICII
BROSME BROSME	LIPARIS GIBBUS
CALLIONYMUS AGASSIZI	LIPARIS INQUILINUS
CAREPROCTUS LONGIPINNIS	LIPARIS LIPARIS
CAREPROCTUS REINHARDTI	LIPARIS SP.
CENTROSCYLLIUM FABRICII	LOPHIUS AMERICANUS
CERATOSCOPELUS MADER	LUMPENIDAE F.
CHAULIODUS SLOANI	LUMPENUS FABRICII
CHLOROPHTHALMUS AGASSSIZI	LUMPENUS LUMPRETAEFORMES
CITHARICHTHYS ARCTIFRONS	LUMPENUS MACULATUS
CLUPEA HARENGUS	LYCENCHELYS PAXILLUS
CORYPHAENOIDES RUPESTRIS	LYCENCHELYS VERRILLI
COTTIDAE F.	LYCODES ESMARKI
COTTUNCULUS MICROPS	LYCODES LAVALAEI
COTTUNCULUS THOMPSON	LYCODES RETICULATUS
CRYPTACANTHODES MACULATUS	LYCODES SP.
CYCLOPTERUS LUMPUS	LYCODES TERRAENOVA
CYTTUS ROSEUS	LYCODES VAHLII
DIBRANCHUS ATLANTICUS	MACROURIDAE F.
ENCHELYOPUS CIMBRIUS	MACROZOARCES AMERICANUS
ETMOPTERUS PRINCEPS	MALACOCEPHALUS OCCIDENTALIS
EUMESOGRAMMUS PRAECISUS	MALLOTUS VILLOSUS
EUMICROTREMUS SPINOSUS	MAUROLICUS MUELLERI
GADUS MORHUA	MELANOGRAMMUS AEGLEFINUS
GADUS OGAC	MELANOSTIGMA ATLANTICUS

MERLUCCIUS ALBIDUS
MERLUCCIUS BILINEARIS
MICROMESISTIUS POUTASSOU
MONOLENE SESSILICAUDA
MYCTOPHIDAE
MYCTOPHUM PUNCTATUM
MYCTOPHUM SP.
MYOXOCEPHALUS AENEUS
MYOXOCEPHALUS OCTODEDECMSPINOSUS
MYOXOCEPHALUS SCORPIDUS
MYOXOCEPHALUS SCORPIOIDES
MYXINE GLUTINOSA
NEMICHTHYS SCOLOPACEUS
NEZUMIA BAIRDI
NOTOLEPIS RISSOI
NOTOLEPIS RISSOI KROYERI
OGCOCEPHALIDAE F.
OSMERUS MORDAX
PARALEPIDIDAE F.
PARALEPIS ATLANTICA
PARALICHTHYS DENTATUTUS
PARALICHTHYS OBLONGUS
PARASUDIS TRUCULENTA
PEPRILUS TRIACANTHUS
PHOLIS GUNNELLUS
PHYCIS CHESTERI
POLLACHIUS VIRENS
POLYMIXIA LOWEI
POLYMIXIA NOBILIS
PRIONOTUS CAROLINUS
PSEUDOPLEURONECTES AMERICANUS
RAJA ERINACEA
RAJA LAEVIS
RAJA OCELLATA
RAJA RADIATA
RAJA SENTA
RAJA SPINICAUDA
REINHARDTIUS HIPPOGLOSSOIDES
SCOMBER SCOMBRUS
SCOMBERESOX SAURUS
SCOPHTHALMUS AQUOSUS
SEBASTES SP.
SPHOEROIDES MACULATUS
SQUALUS ACANTHIAS
STERNOPTYCHIDAE F.
STOMIAS BOA FEROX
STOMIATIDAE
SYMPHURUS SP.
SYNAPHOBRANCHUS KAUPII
TAUTOGOLABRUS ADSPER
TRACHYRHYNCHUS MURRAYI
TRIGLOPS MURRAYI
UROPHYCIS CHUSS
UROPHYCIS REGIUS
UROPHYCIS TENUIS
ZENOPSIS OCELLATA

Table 7.1.8. Fish Species (including squid) caught in the Gully (strata 452 and 457) during summer groundfish surveys conducted between 1970 and 1997 (indicates species not caught on the remainder of the eastern Scotian Shelf).**

AGONIDAE F.
AGONUS DECAGONUS
AMMODYTES DUBIUS
ANARHICHAS LUPUS
ANOPLOGASTER CORNUTA **
ARGENTINA SILUS
ARTEDIELLUS ATLANTICUS
ARTEDIELLUS UNCINATUS
ASPIDOPHOROIDES MONOPTERYGIUS
BROSME BROSME
CLUPEA HARENGUS
CORYPHAENOIDES RUPESTRIS
CRYPTACANTHODES MACULATUS
ENCHELYOPUS CIMBRIUS
EUMICROTREMUS SPINOSUS
GADUS MORHUA
GLYPTOCEPHALUS CYNOGLOSSUS
HELICOLENUS DACTYLOPTERUS
HEMITRIPTERUS AMERICANUS
HIPPOGLOSSOIDES PLATESSOIDES
HIPPOGLOSSUS HIPPOGLOSSUS
ILLEX ILLECEBROSUS
LIMANDA FERRUGINEA
LOPHIUS AMERICANUS
LUMPENUS LUMPRETAEFORMIS
LUMPENUS MACULATUS
LYCODES RETICULATUS
LYCODES SP.
LYCODES TERRAENOVA
LYCODES VAHLII
MACROZOARCES AMERICANUS
MALLOTUS VILLOSUS
MELANOGRAMMUS AEGLEFINUS
MERLUCCIUS ALBIDUS
MERLUCCIUS BILINEARIS
MYCTOPHIDAE
MYOXOCEPHALUS OCTODECEMSPINOSUS
MYXINE GLUTINOSA
NEZUMIA BAIRDI
PHYCIS CHESTERI
POLLACHIUS VIRENS
PSEUDOPLEURONECTES AMERICANUS
RAJA ERINACEA
RAJA OCELLATA
RAJA RADIATA
RAJA SENTA
REINHARDTIUS HIPPOGLOSSOIDES
SCOMBER SCOMBRUS
SEBASTES SP.
SQUALUS ACANTHIAS
STOMIATIDAE
TRACHYRHYNCHUS MURRAYI
TRIGLOPS MURRAYI
UROPHYCIS CHUSS
UROPHYCIS TENUIS

Trends in Abundance

A comparison of the density distribution of the ten most abundant fish species in the Gully to those in the Gully trough and the eastern Scotian Shelf as a whole (Fig. 7.1.10) showed some intriguing patterns: Squid (*Illex illecebrosus*), American Plaice

(*Hippoglossus platessoides*), Silver Hake (*Merlucius bilinearis*), Haddock, (*Melanogrammus aeglefinus*), and pollock (*Pollachius virens*) all occurred in highest overall density (mean numbers per standard survey tow) in areas of the eastern Scotian Shelf outside the Gully. Redfish (Sebastes spp.), Witch flounder (*Glyptocephalus cynoglossus*), Cod (*Gadus morhua*), White Hake (*Urophycis tenuis*), and Longfin Hake (*Urophycis chesteri*) occurred at their highest densities in the Gully

Trends abundance for redfish (*Sebastes spp*) are broadly similar in all areas (Fig. 7.1.10). For squid (*Illex Illecebrosus*) the dynamics are again roughly similar except for the most recent years where they have increased in the Gully and continue to decline elsewhere. Dynamics of American plaice (*Hippoglossus platessoides*) show declines for both the eastern shelf and Gully trough but an variable increase for the Gully proper.

There are a group of species who's dynamics show a significant similarity for the eastern shelf in general but whose dynamics in the Gully differ from this overall pattern. The pattern for the shelf is characterized by a relatively rapid increase until the mid 1980's followed by a decline. For some the decline continues to the present (Haddock, Cod, and Longfin Hake) while for Silver and White Hake abundance increases again after 1992. Except for White Hake in the Gully proper, the dynamics of these species in the Gully do not show the period of increase to the mid 1980'

7.1.8 Fisheries

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The Gully and adjacent waters have had a long history as an important fishing area. During the previous 5 years, with the closure or severe restrictions of many of the fisheries on the Scotian Shelf, the Gully has been increasingly fished, both for traditional species and for non-traditional species. A report commissioned by the WWF (Milewski 1996) reports on both the fishing activities and other stakeholders in the area.

DFO has a wealth of both catch and effort information available from which to describe the fishing history of the Scotian Shelf. Unfortunately, the spatial resolution of much of these data is low relative to the dimensions of the Gully and adjacent waters. The finest resolution of catch and effort data is found in the Observer Program database. This data set consists of geo-referenced set by set information on catch composition, and trawling effort spanning the period 1978 to present. For the domestic Canadian fleet this represents only a small fraction of the total effort (<20% per year?). However, all of the foreign fisheries effort operating inside the 200 mile economic zone are represented in this data set. These data should be carefully examined to determine both the history of the fishery in this area (at least during the last 20 or so years), and to augment the descriptions of species compositions of these shelf slope areas, particularly from the catches realized by Cuban and former Soviet vessels fishing for silver hake and Japanese vessels fishing for redfish and large pelagic species.

The difficulties associated with trawling in much of the area both in the steep sided canyons of the Gully and the adjacent deep waters (> 300m seaward, and stratum 457 landward) have likely contributed to the relatively low sampling rate for the area. However, this area has been important to the fishing industry (both mobile gear and fixed gear) over an extended period. The detailed catch and effort information gathered by the members of the Fishermen and Scientists Research Society would be an additional source of information, however we must appreciate the potential sensitivities associated with these data if they are to be used in what could be viewed by members of the industry, as an argument to restrict fishing activities in the area.

We examined the general catch and effort data collected by DFO for the past three years (1995 - 1997) to get an indication of present fishing effort in the Gully and adjacent waters. The resolution of these recent data is by geo-referenced location of each set. Prior to 1992, the highest level of resolution was to unit area. Since the Gully is bisected by the boundaries of two NAFO unit areas, it is difficult to use these earlier data to gain an understanding of fishing effort in the area. There is a complicating factor to these analyses in that the major fisheries in this area have been essentially closed since 1993 with the declaration of a moratorium on the Eastern Scotian Shelf cod stock.

Fig. 7.1.11 shows that since 1995 the bulk of trawler effort has moved progressively eastward in the past three years. It is likely that this trawler effort was mainly directed at redfish, especially the effort along the edge of the continental shelf and along the slopes of the deep holes on the shelf proper. In 1995 we observe that there were several hundred sets in the mouth of the Gully and the waters immediately adjacent and to the east.

Shrimp trawls (Fig. 7.1.12) were active on the eastern Scotian Shelf during the period 1995 - 1997, but concentrated their efforts in the mixed depth areas to the north and east of the Gully. Only a very few sets were made in the Gully trough in the past two years. Effort by Danish Seiners (Fig. 7.1.13) has been more or less restricted to the shallowest portion of Banquereau Bank and none has been expended in the Gully.

Longline effort (Fig. 7.1.14) represents by far the most significant portion of all the fishing effort in the area. This effort is focused to a large extent on Atlantic halibut (*Hippoglossus hippoglossus*) and White hake (*Urophycis tenuis*). Over the past three years this effort has amounted to hundreds of sets annually.

These preliminary analyses indicate that the Gully presently represents an area of significant longline effort but that trawler effort is presently low. Indication from industry representatives are that the Gully has in the past been an area of significant trawler activity and that the current lack of activity is due to the moratorium in effect.

7.1.9 Conclusions

Based on the analyses presented above we conclude that the Gully and adjacent waters, as defined above, is an area of relatively high demersal finfish diversity relative to the eastern Scotian Shelf as a whole. There is no evidence for any endemic demersal species of fish, however, given the low sampling rate and the potentially low efficiency of the trawl in areas of rapid changes in bathymetry such as occur in the area, this does not rule out the possibility that such species occur.

The slope waters of the Gully, as is the case for the Scotian Slope in general, is an area of faunal boundaries. The upper reaches of the slope (less than 360 m) represent the lower boundaries of distribution for the shelf dwelling species and the upper limits for those species which are truly slope dwellers. The slope itself down to depths of about 900 m has it's own ichthyofauna. Beyond these depths the demersal fish fauna changes again to represent that of the lower slope and abyssal rise. It is difficult to draw conclusions about the uniqueness of the fish occurring in the slope waters of the Gully given the relative paucity of like data from other areas suitable for comparison. A more exhaustive survey of the literature on this subject is warranted before drawing firm conclusions.

The area does not appear to be important for shelf dwelling pelagic species although these do occur there as migrants.

The pelagic species occurring over the shelf slope and abyssal plain adjacent to the Gully are numerous (> 200). Given the broad geographic distributions of many of these species it is unlikely that any are unique to the Gully. A more detailed examination of the existing data by sampling location may help to resolve this issue.

The Gully is an area of high density for redfish, squid, cod, witch flounder, white hake, and longfin hake, relative to the remainder of the eastern Scotian Shelf.

The top nine species of demersal fish occurring in the Gully can be split into those whose dynamics are relatively similar to that demonstrated by that species elsewhere on the eastern Scotian Shelf (redfish, squid and witch flounder) and those whose dynamics show different patterns in the Gully relative to the eastern shelf (American Plaice, haddock, cod, silver hake, white hake and pollock). The underlying causes of the different dynamic in theses areas has not been investigated.

Although at present the fisheries on the Eastern Scotian Shelf are severely restricted relative to the recent past, the Gully continues to be an actively fished area. Longline effort directed at Atlantic halibut and White hake is presently the most common. In the past there has also been significant trawler effort in both the Gully and the adjacent slope waters.

7.1.10 References

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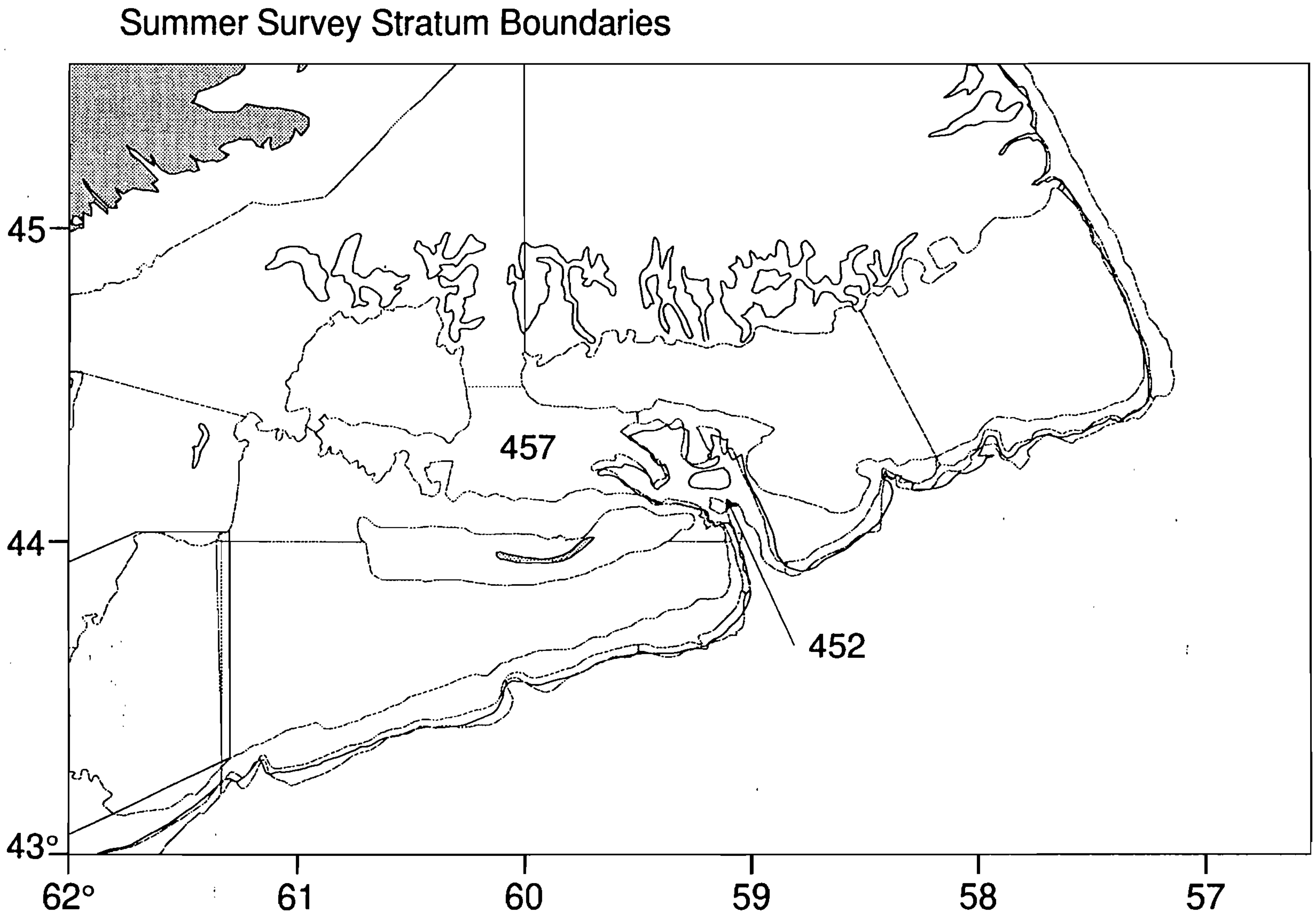


Fig. 7.1.1. Map of the Eastern Scotian shelf showing both the 100 m and 200 m isobaths and the boundary of summer survey stratas 452 and 457, as discussed in the paper.

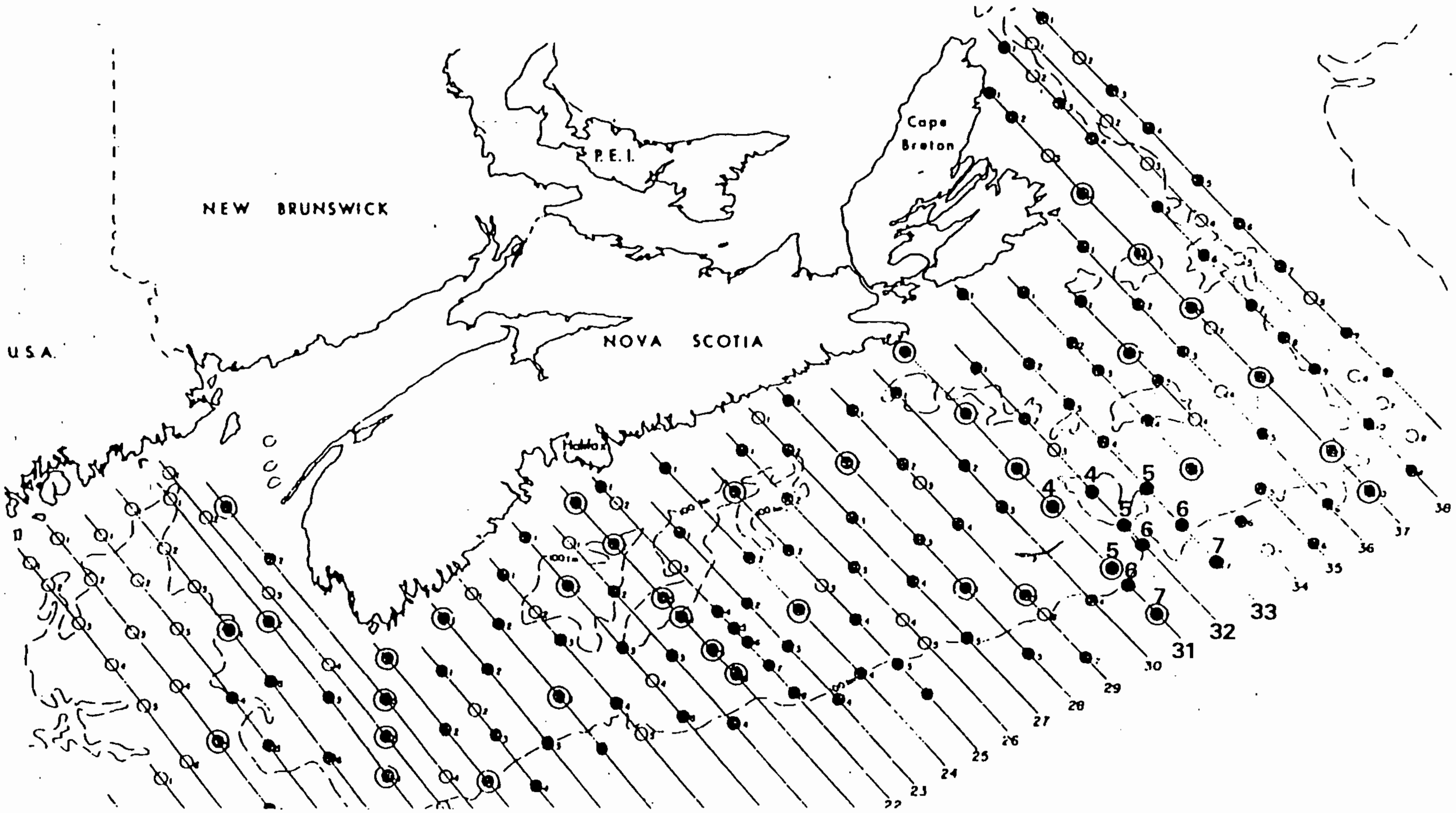


Fig. 7.1.2. Sampling grid used for the Scotian Shelf Ichthyoplankton Program (SSIP). Highlighted are the lines and stations in the area defined as the Gully adjacent to Sable island. Egg and larval fish data were extracted from ten line/station combinations (line 31 stations 4, 5, 6, and 7; line 32 stations 4, 5, and 6; line 33 stations 5, 6, and 7) from the SSIP database to address the question of the importance of this area for spawning.

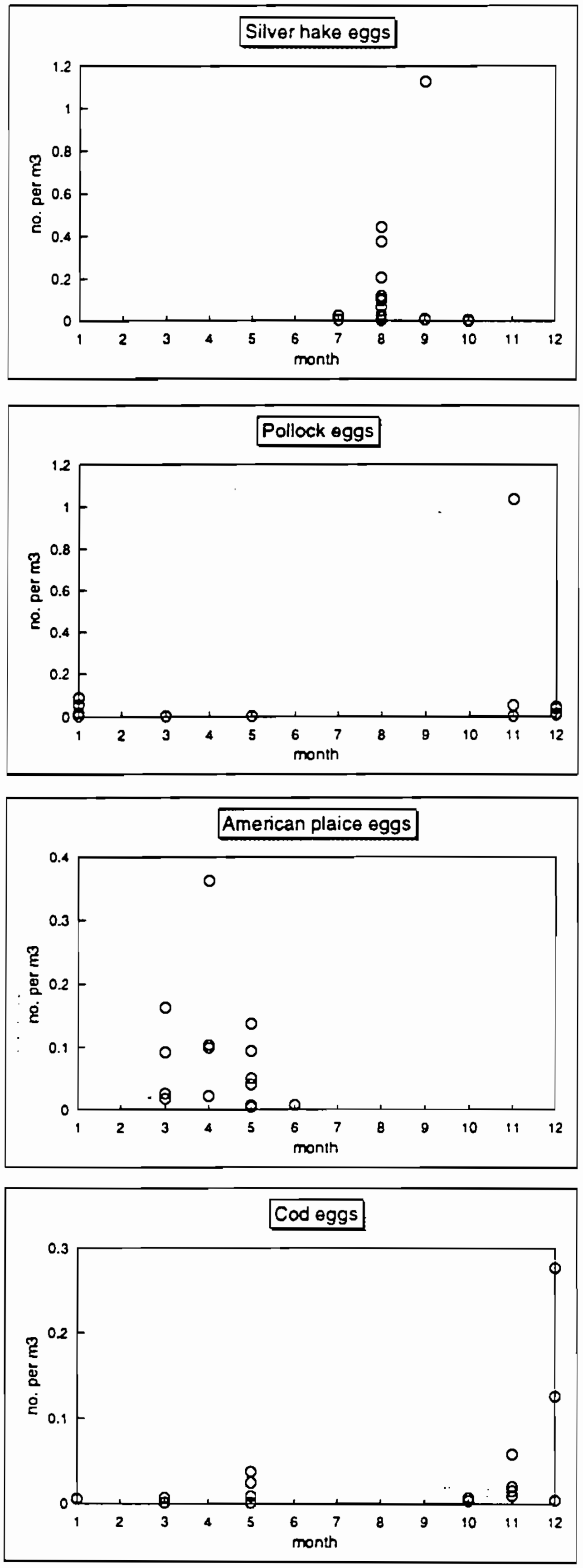


Fig. 7.1.3. Temporal pattern of abundance of the most abundant fish egg types encountered in the Gully area.

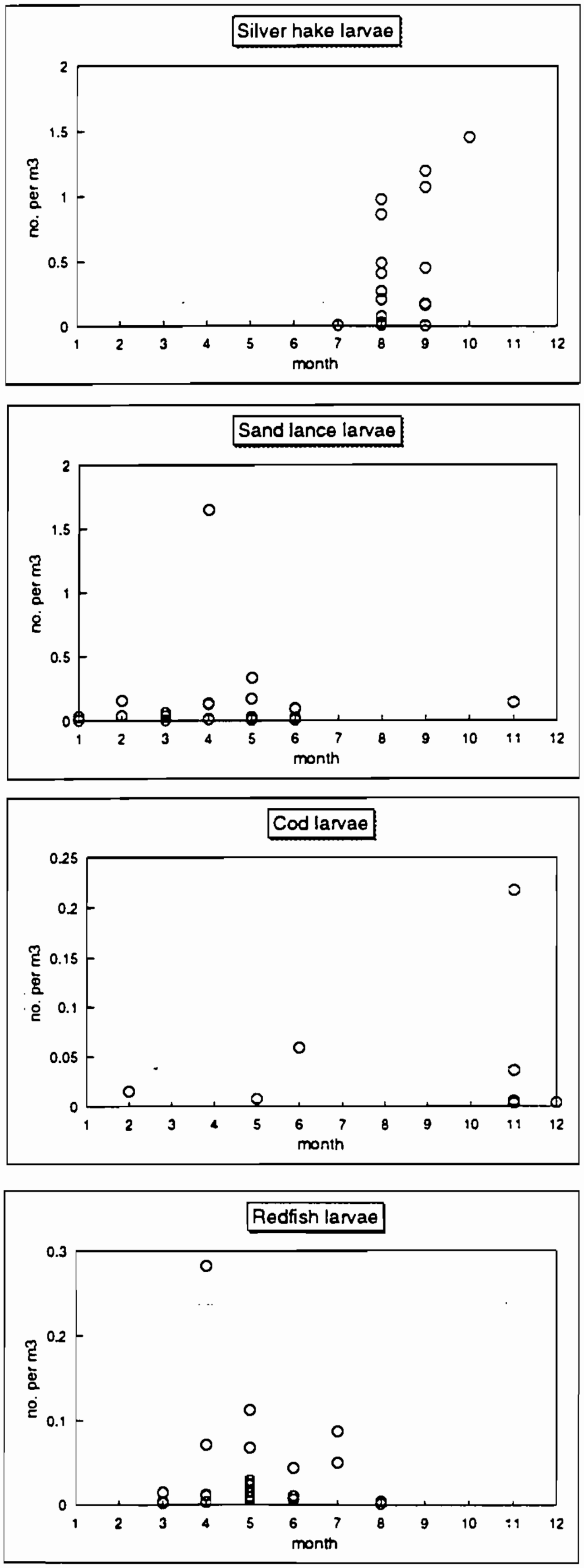


Fig. 7.1.4. Temporal pattern of abundance of the most abundant fish types encountered in the Gully area.

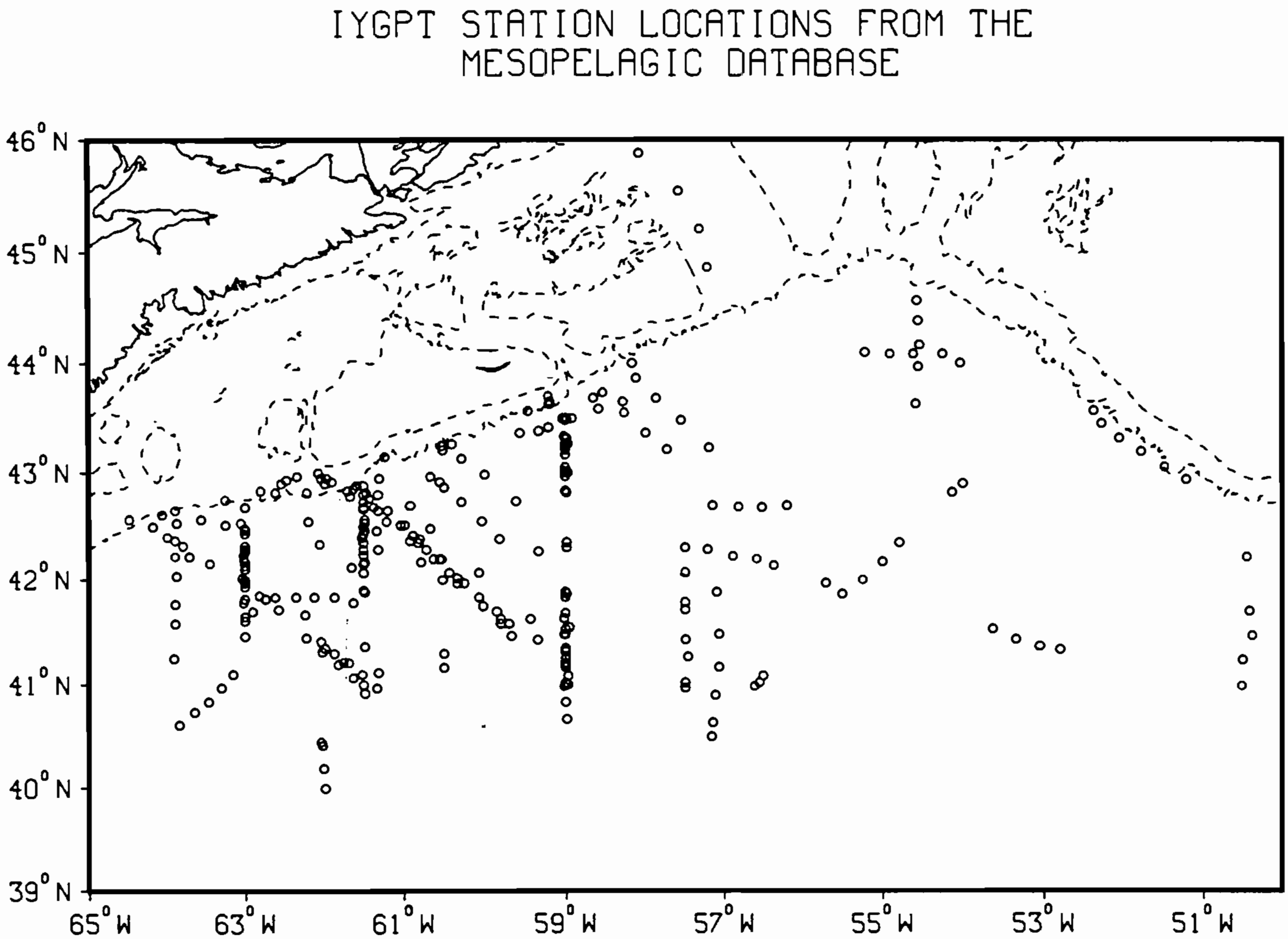


Fig. 7.1.5. Location of the stations at which sets were made to sample mesopelagic fishes along the Scotian Shelf and southern Grand Banks. All tows were made using an IGYPT trawl (International Young Gadoid Pelagic Trawl).

Depth Distruibution of Species along the Shelf Edge (58 - 60 W, to 1000 m)

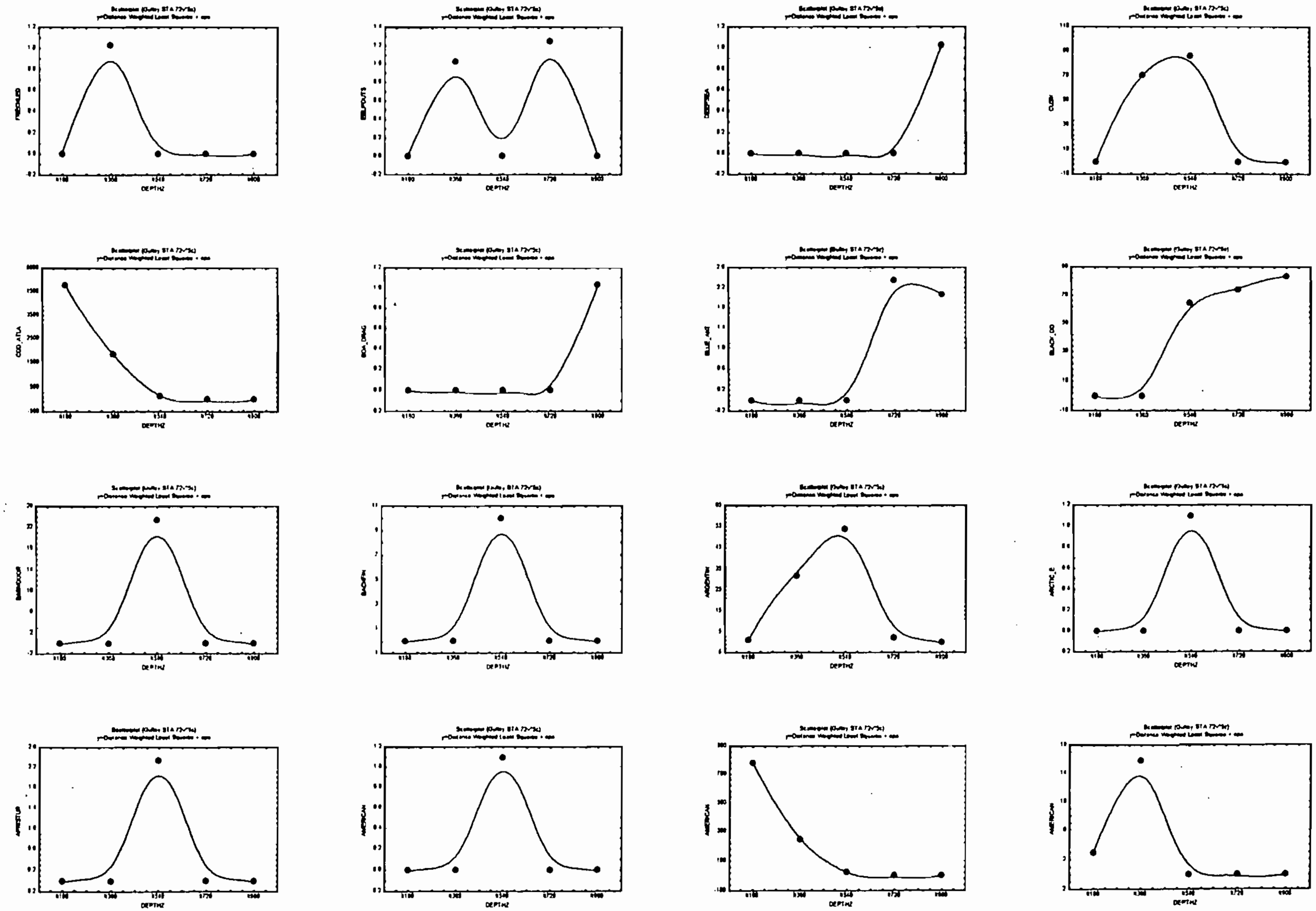


Fig. 7.1.6. **Depth distribution of species caught by redfish directed surveys conducted along the Scotian Shelf between 58 and 60W. The data plotted are the total numbers caught by depth zone, the line for each plot is the distance weighted least square line.**

Depth Distruibution of Species along the Shelf Edge (58 - 60 W, to 1000 m)

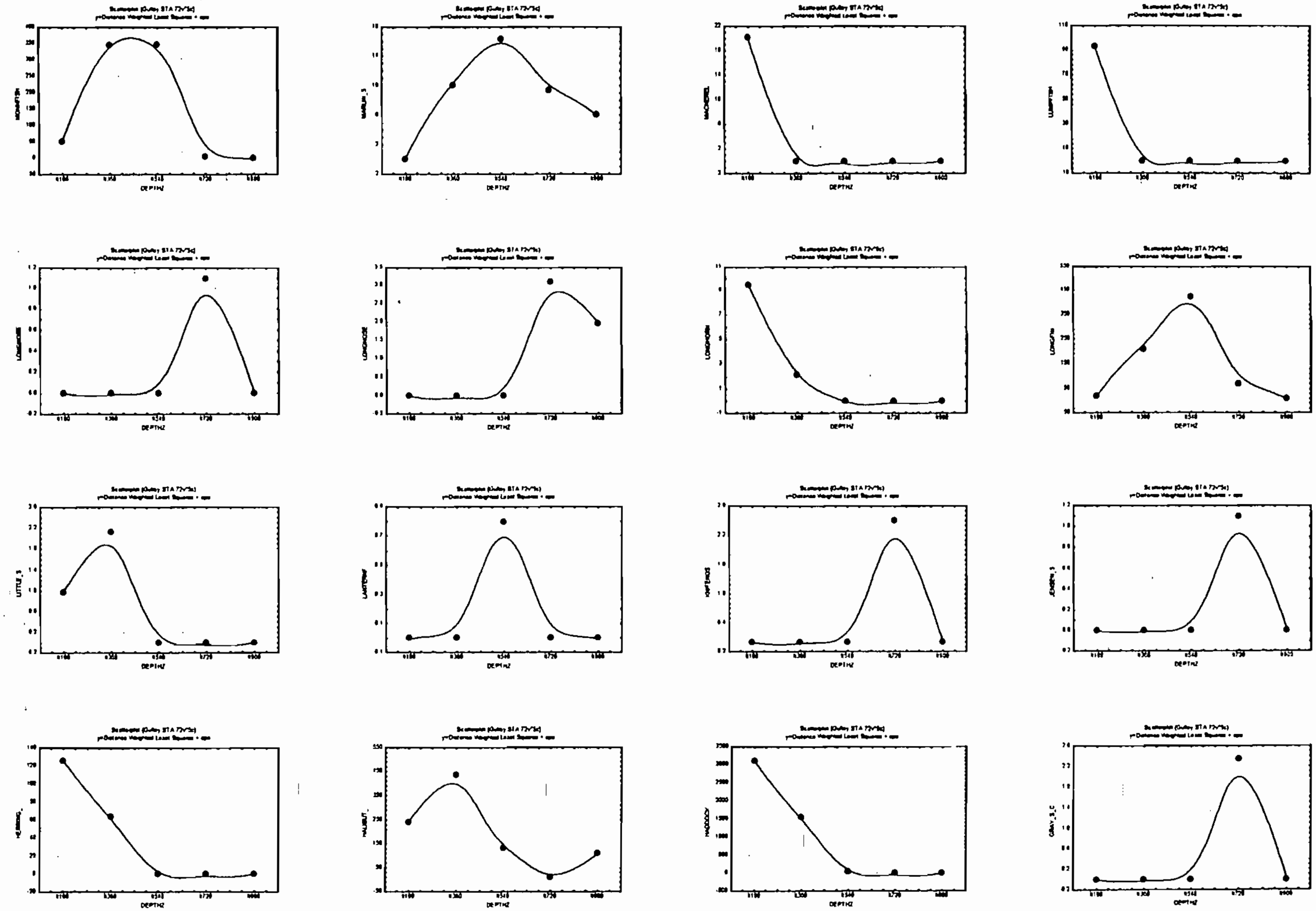
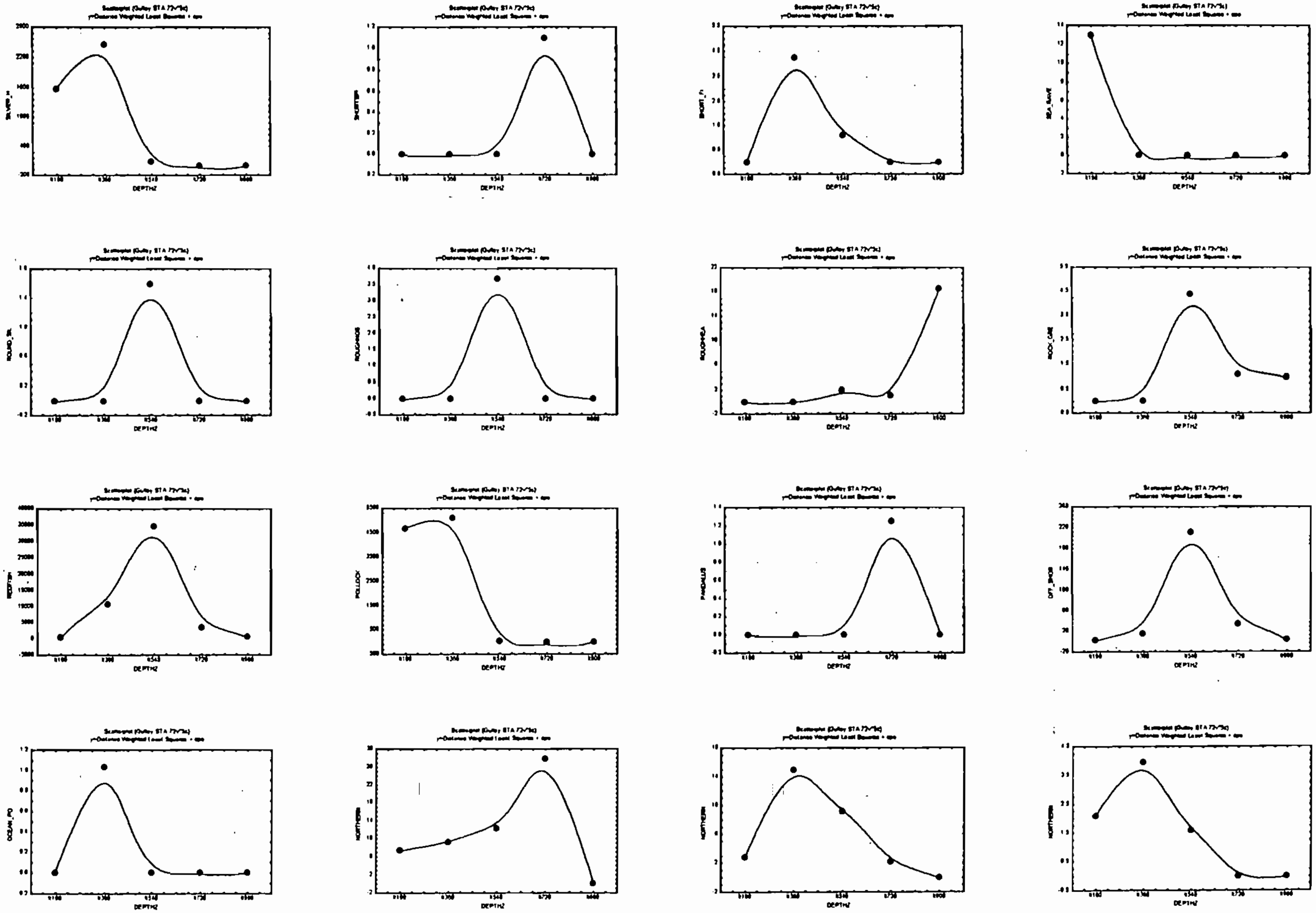


Fig. 7.1.6. (Continued)

Depth Distruibution of Species along the Shelf Edge (58 - 60 W, to 1000 m)



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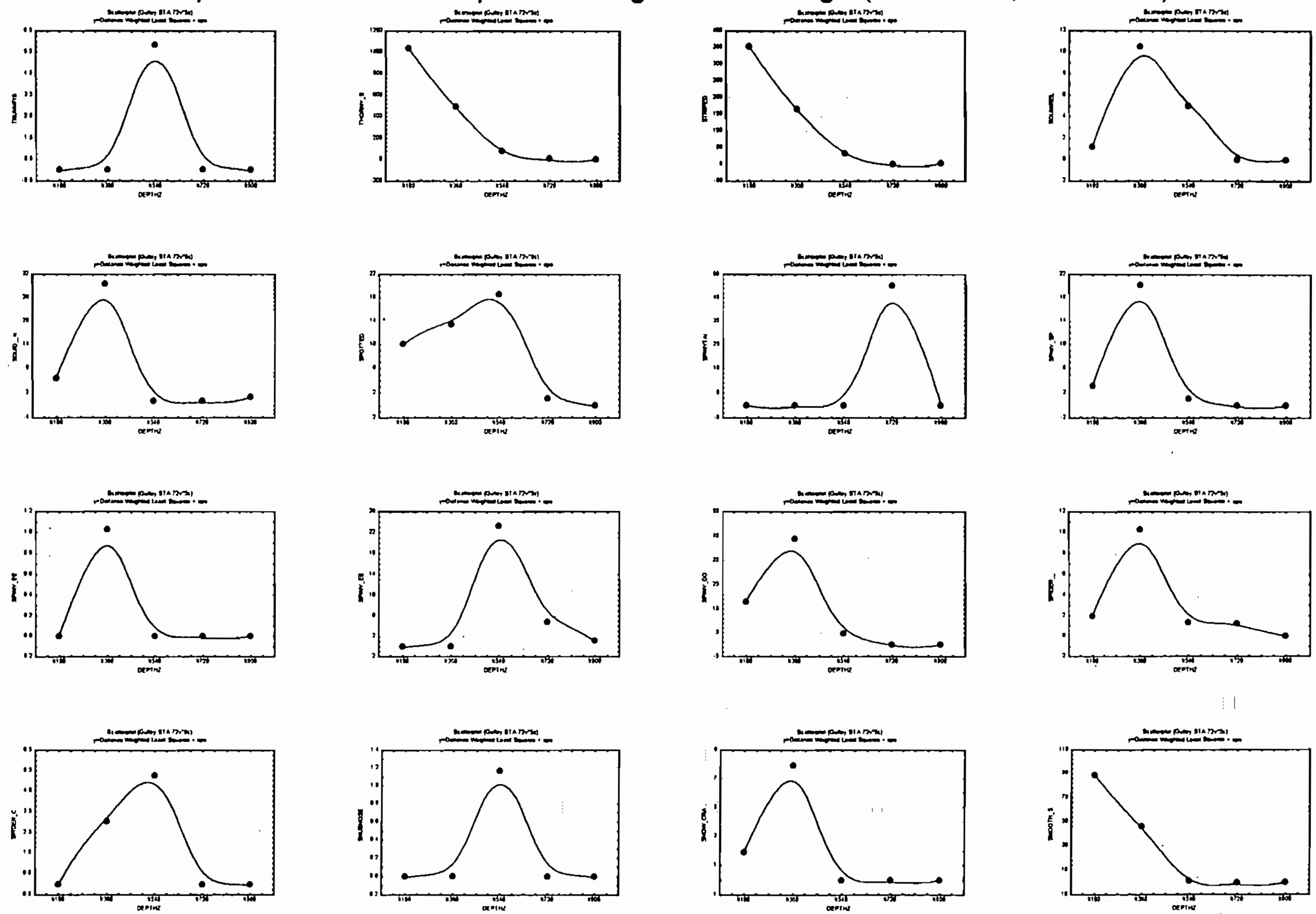
Depth Distruibution of Species along the Shelf Edge (58 - 60 W, to 1000 m)



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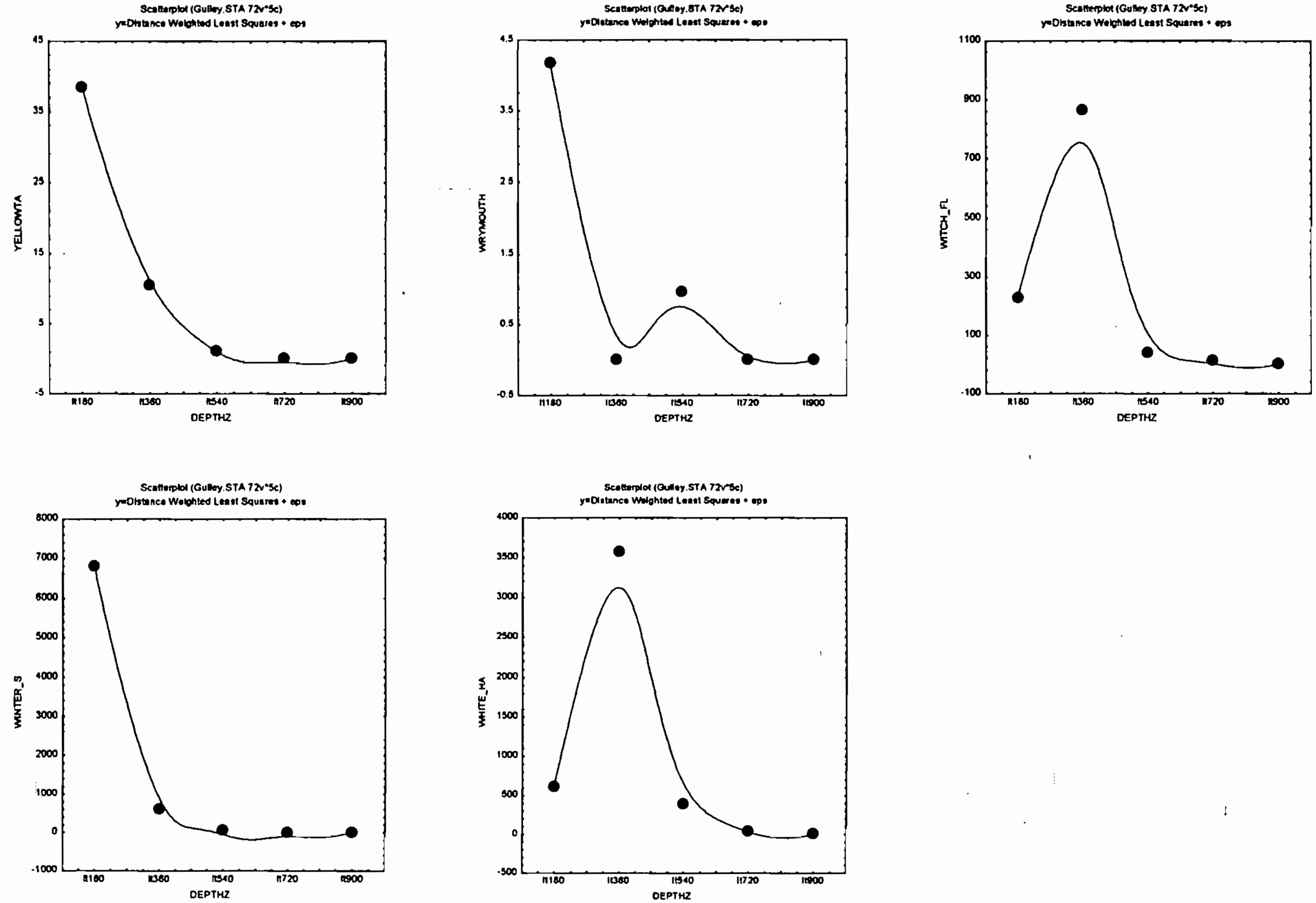
Depth Distruibution of Species along the Shelf Edge (58 - 60 W, to 1000 m)



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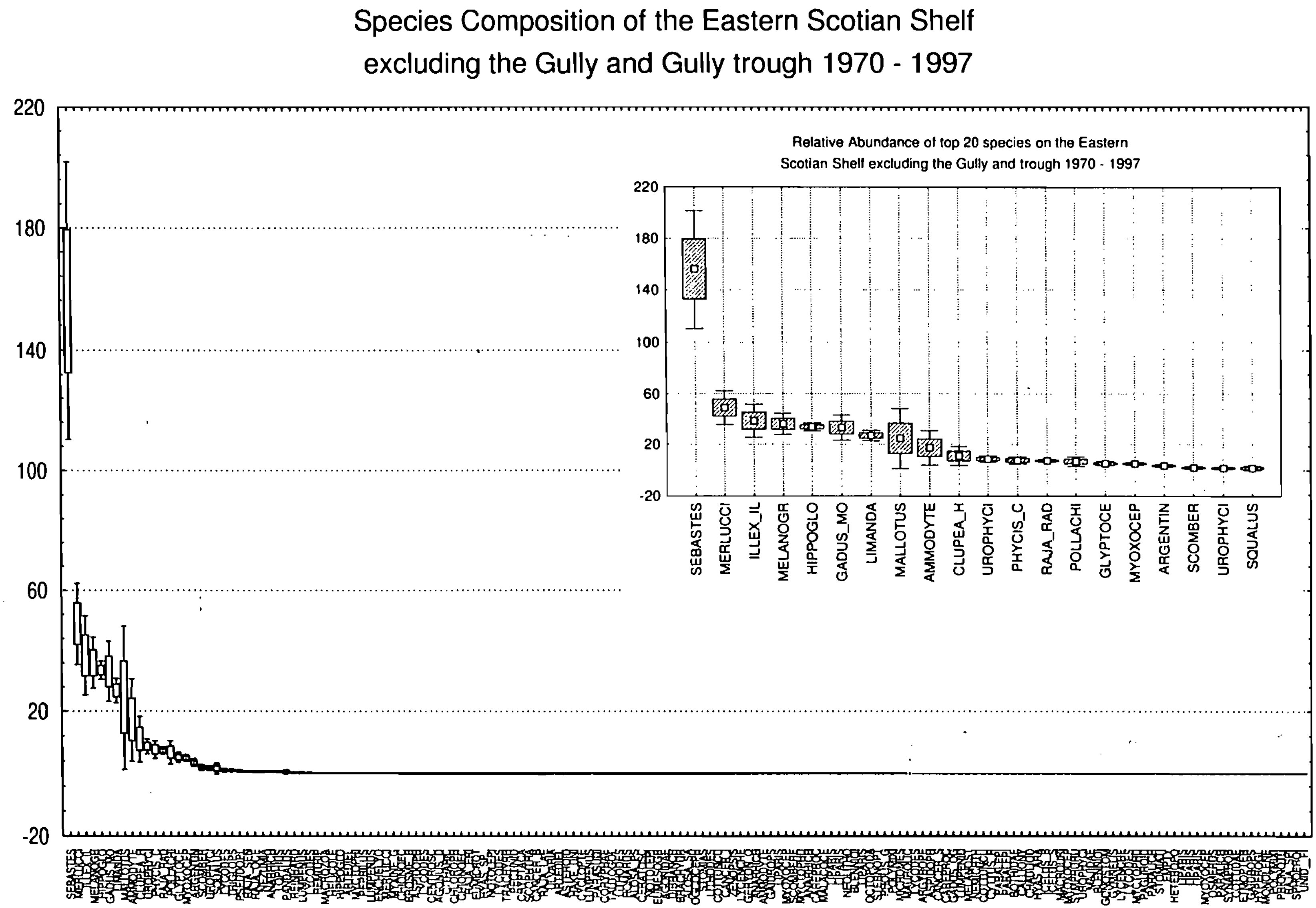
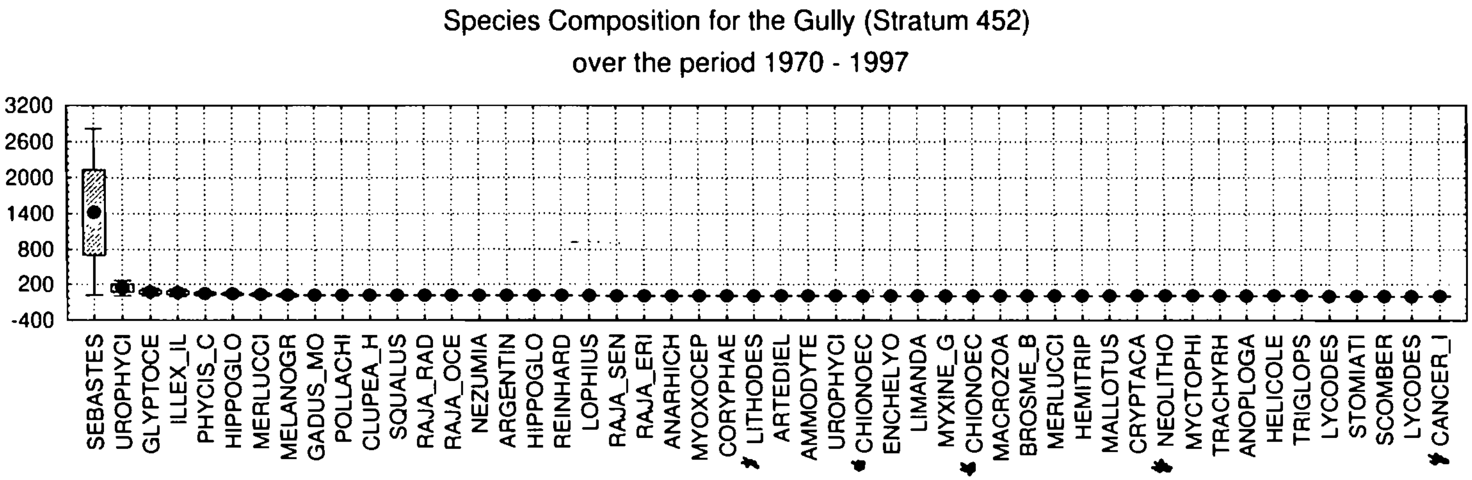


Fig. 7.1.7. Species composition of the Eastern Scotian Shelf excluding the Gully and the Gully trough for the period 1970-1996. The inserted box and whisker plot shows an expanded section of the overall plot for the top 20 species.



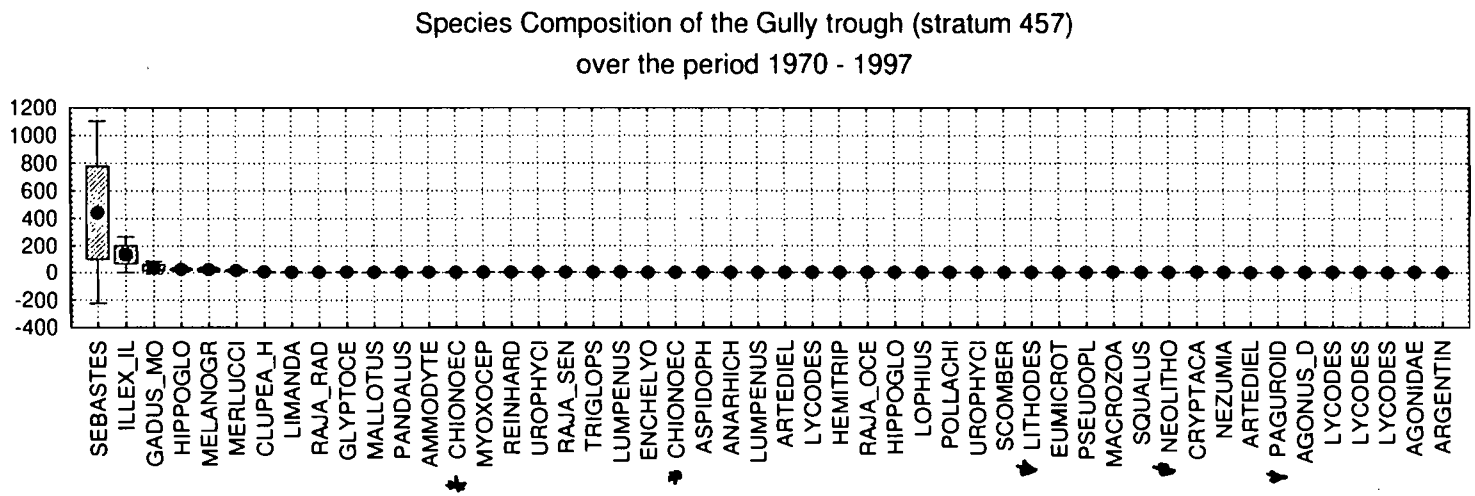
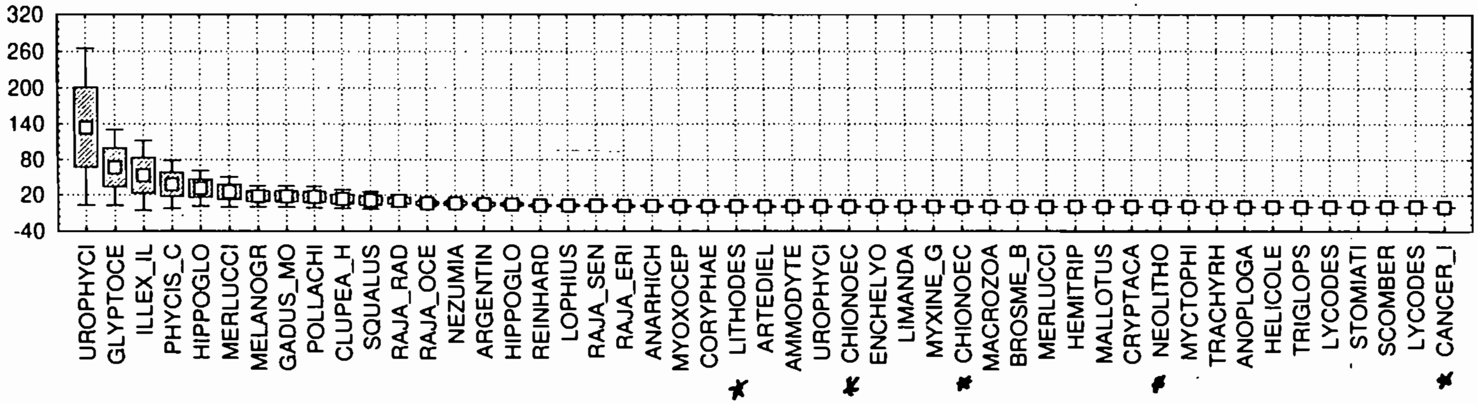


Fig. 7.1.8. Species composition of the Gully an Gully trough for the period 1970-1996. Those species indicated with an "*" are invertebrate species.

* INVERTERATES

Species Composition for the Gully (Stratum 452) excluding redfish for the period 1970 - 1997



Species Composition of the Gully trough (stratum 457) excluding redfish for the period 1970 - 1997

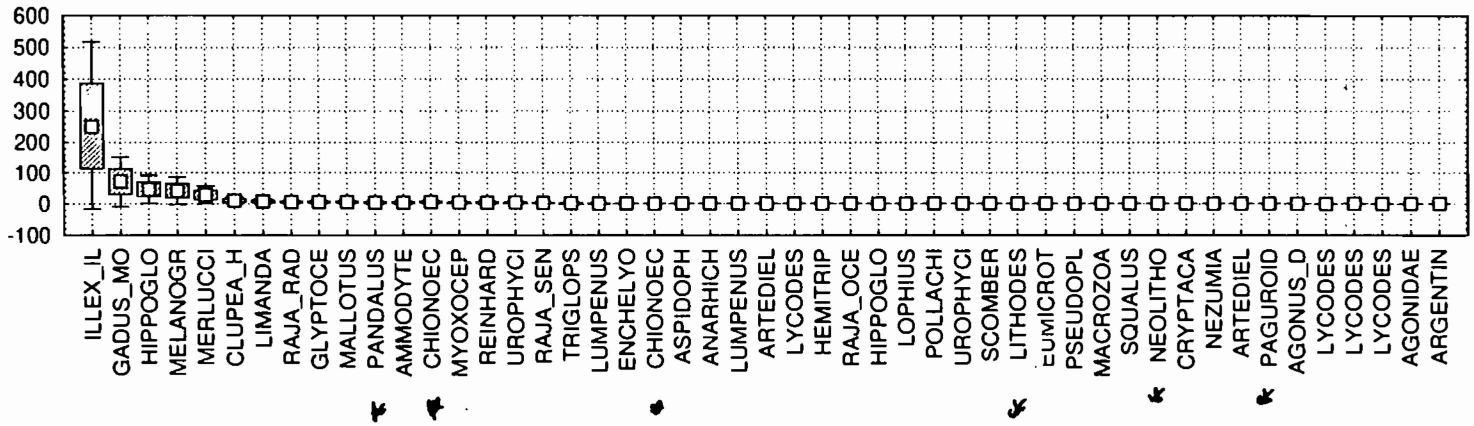


Fig. 7.1.9. Species composition of the Gully and Gully trough for the period 1970-1996, excluding redfish. Those species indicated with an "*" are invertebrate species.

* INVERTEBRATES

Trends in abundance of *Sebastes sp* and *Illex illicebrosus*

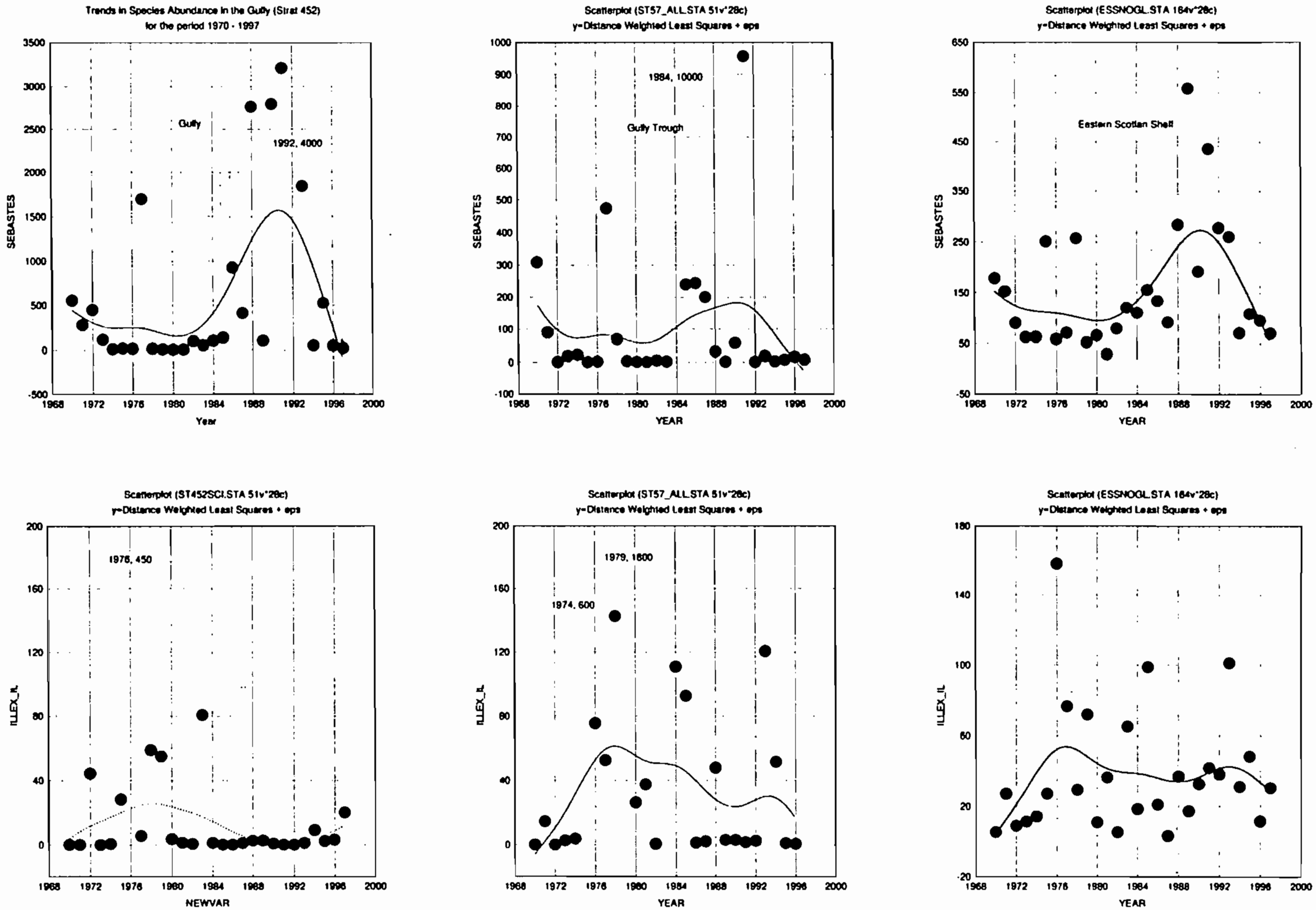


Fig. 7.1.10. Trends in abundance of the 20 most abundant species in the Gully relative to the trends in these species for the Gully trough and the Eastern Scotian Shelf excluding these areas. The data plotted are the stratified mean numbers caught per standard research tow for the year indicated. The line through the points is the distanced weighted least square estimated line.

Trends in abundance of *Hippoglossus platessoides* and *Merlucius bilinearis*

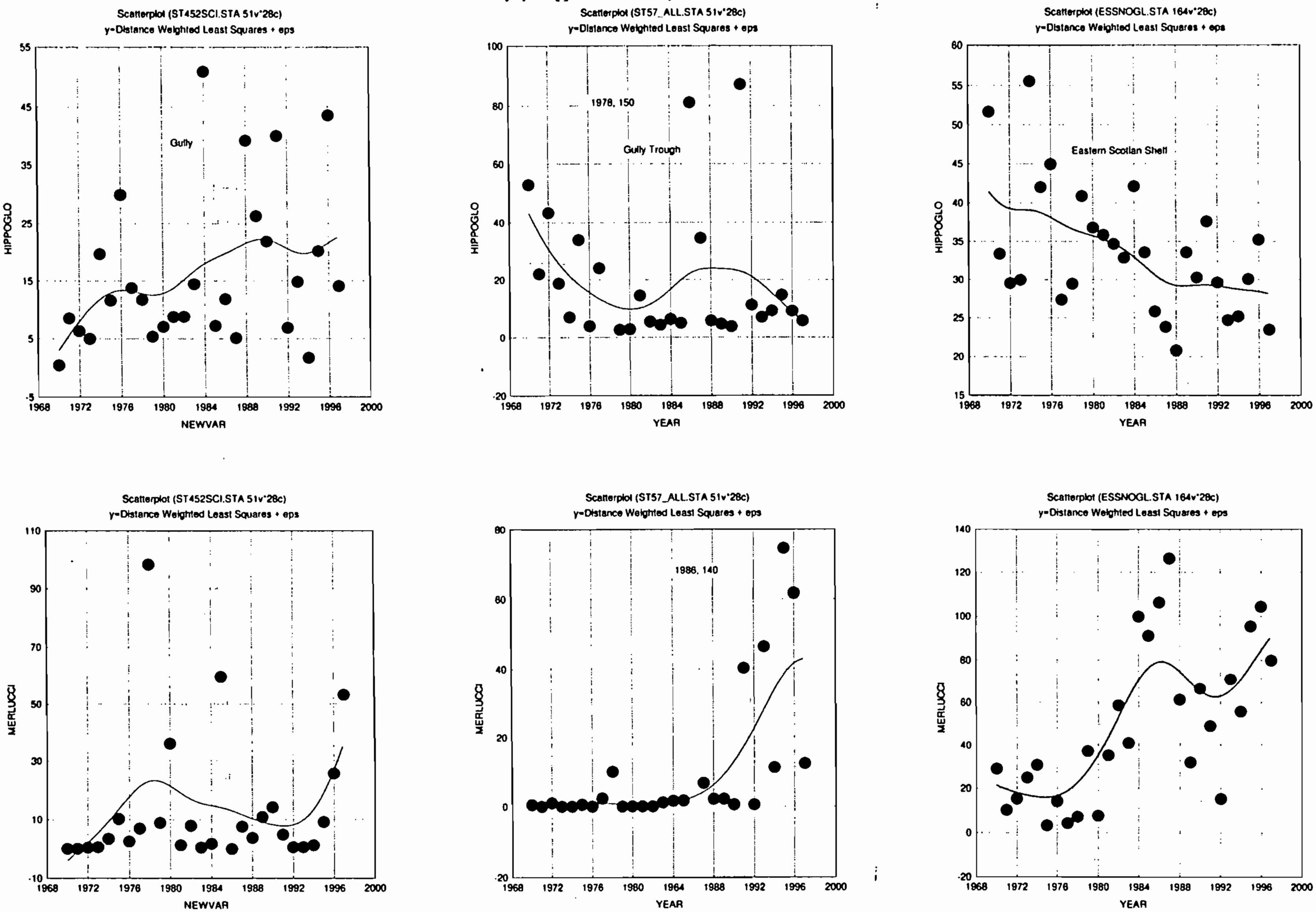


Fig. 7.1.10. (Continued)

Abundance of *Melanogrammus aeglefinnus* and *Glyptocepahalus cynoglossus*

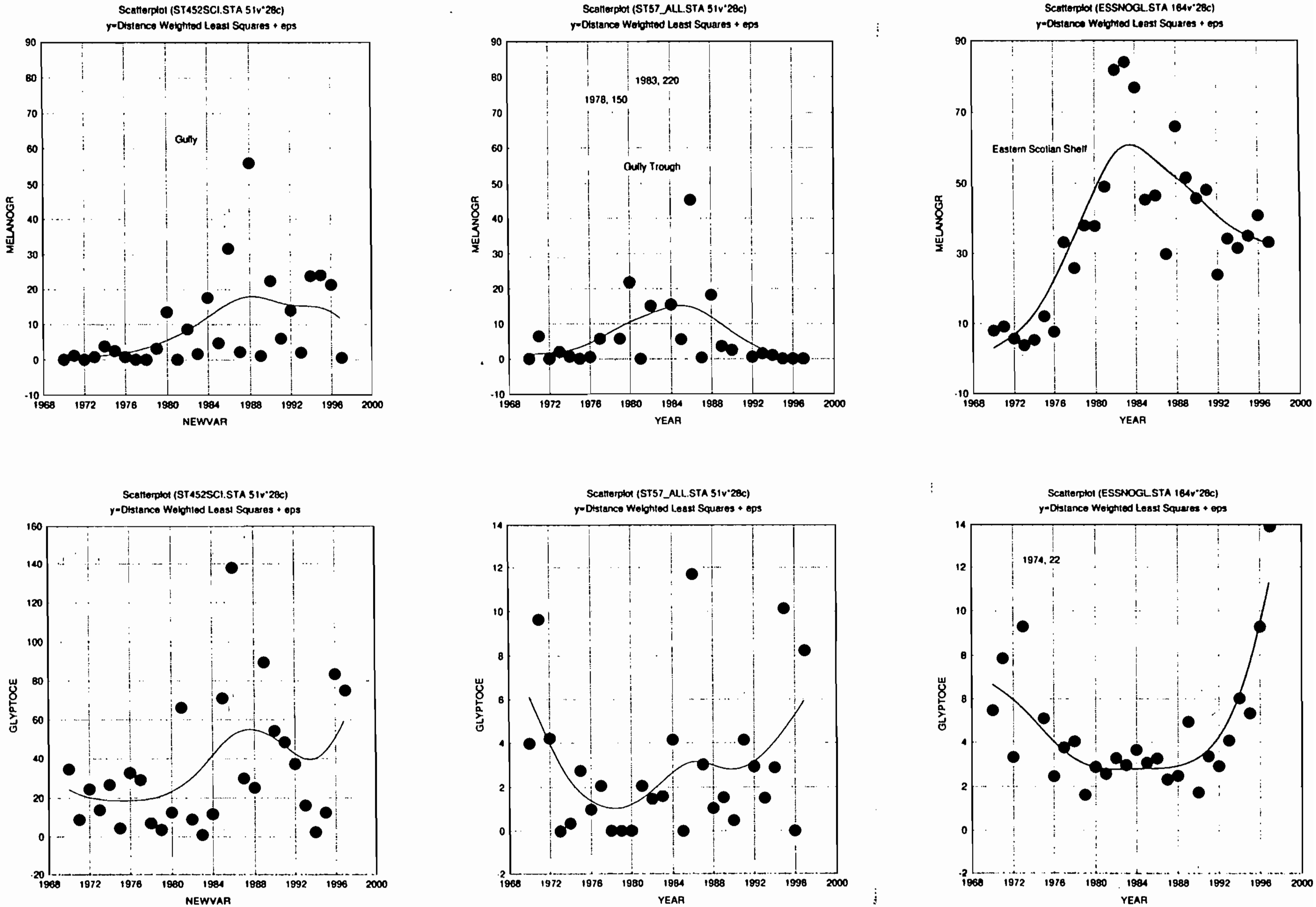


Fig. 7.1.10. (Continued)

Trends in abundance of *Gadus morhua* and *Urophycis tenuis*

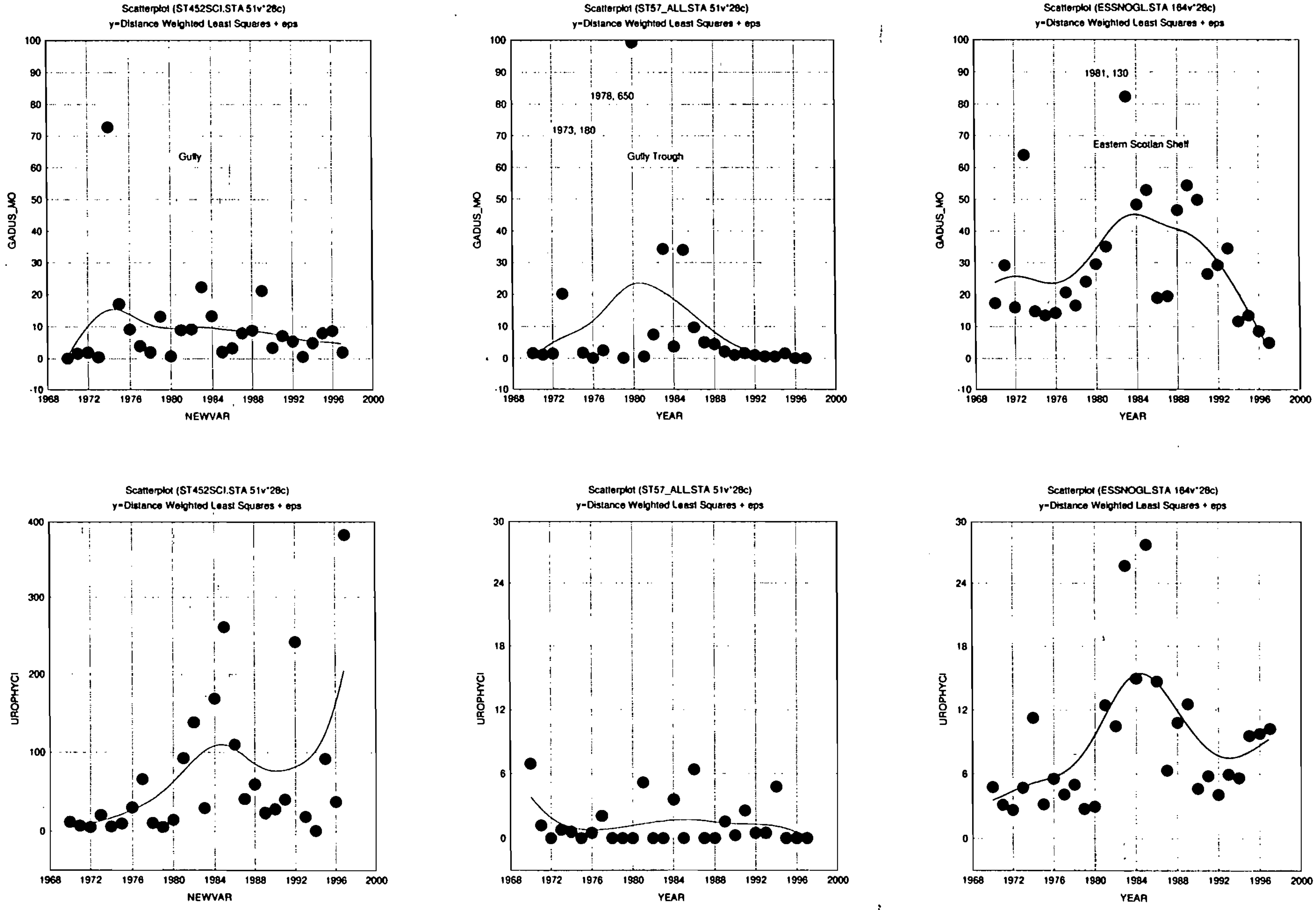
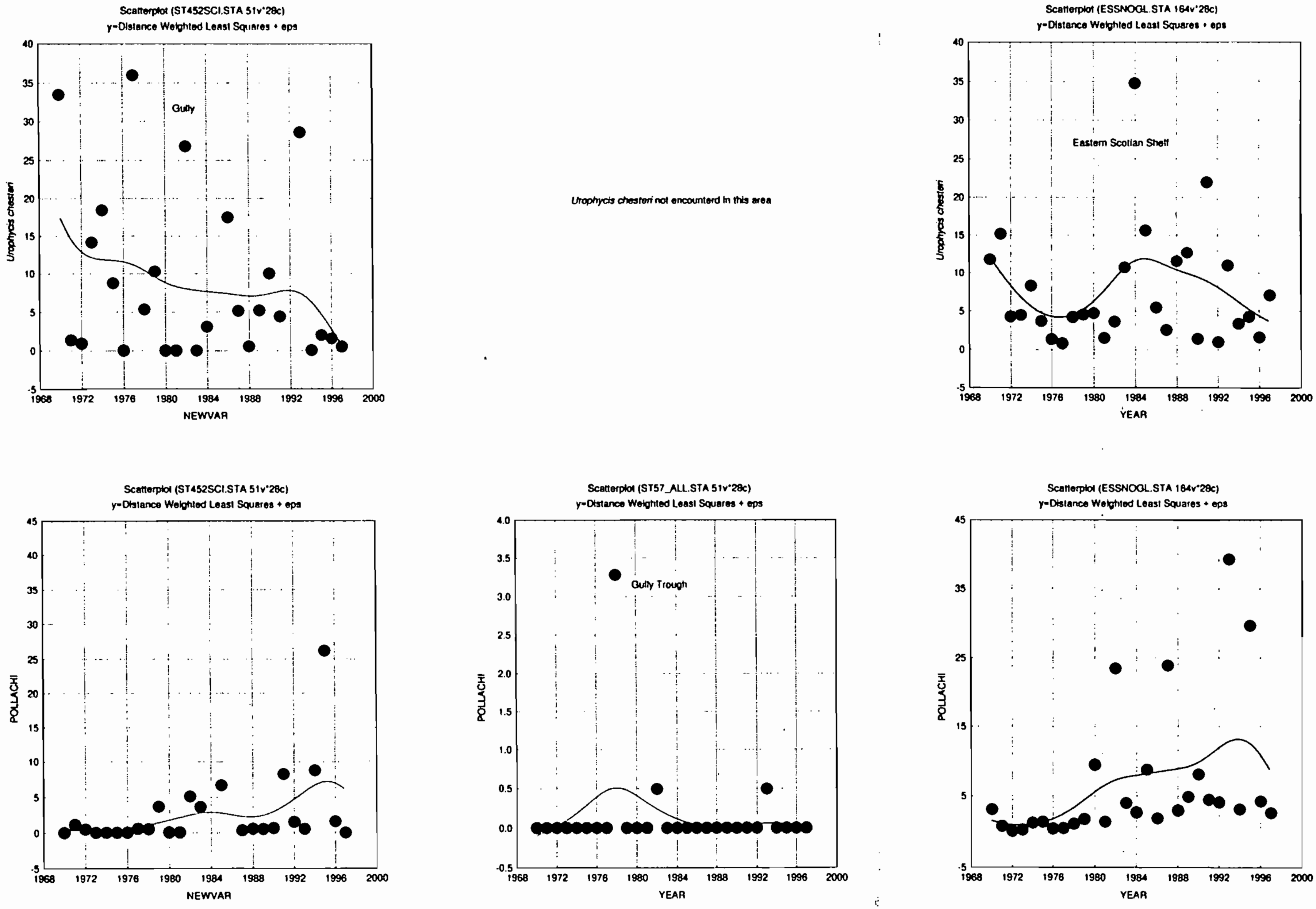


Fig. 7.1.10. (Continued)

Trends in Abundance of *Urophycis chesteri* and *Pollachius virens*



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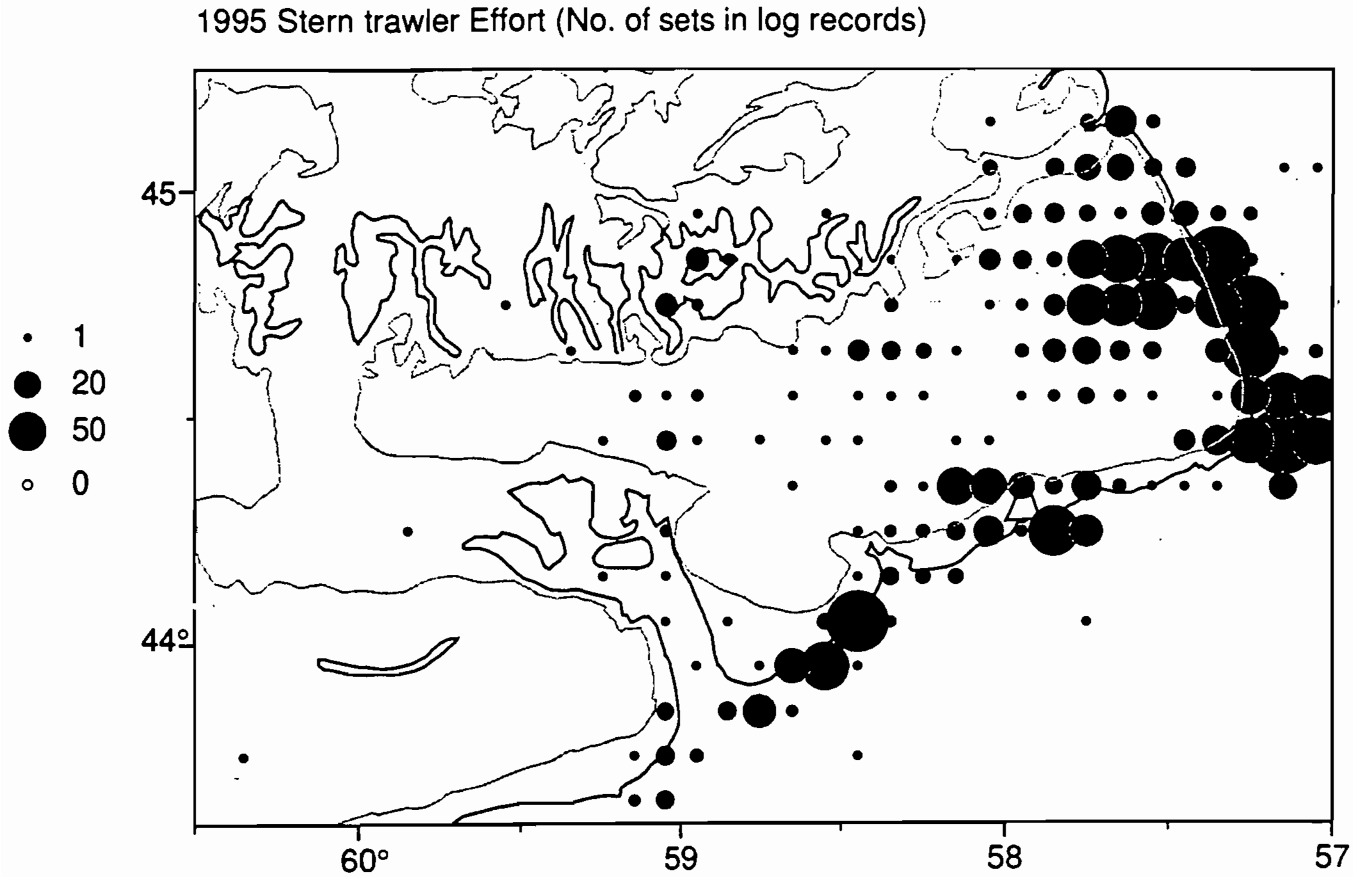


Fig. 7.1.11. Stern trawler effort distribution shown as the total number of sets recorded by 10 min square for the years 1995-1997.

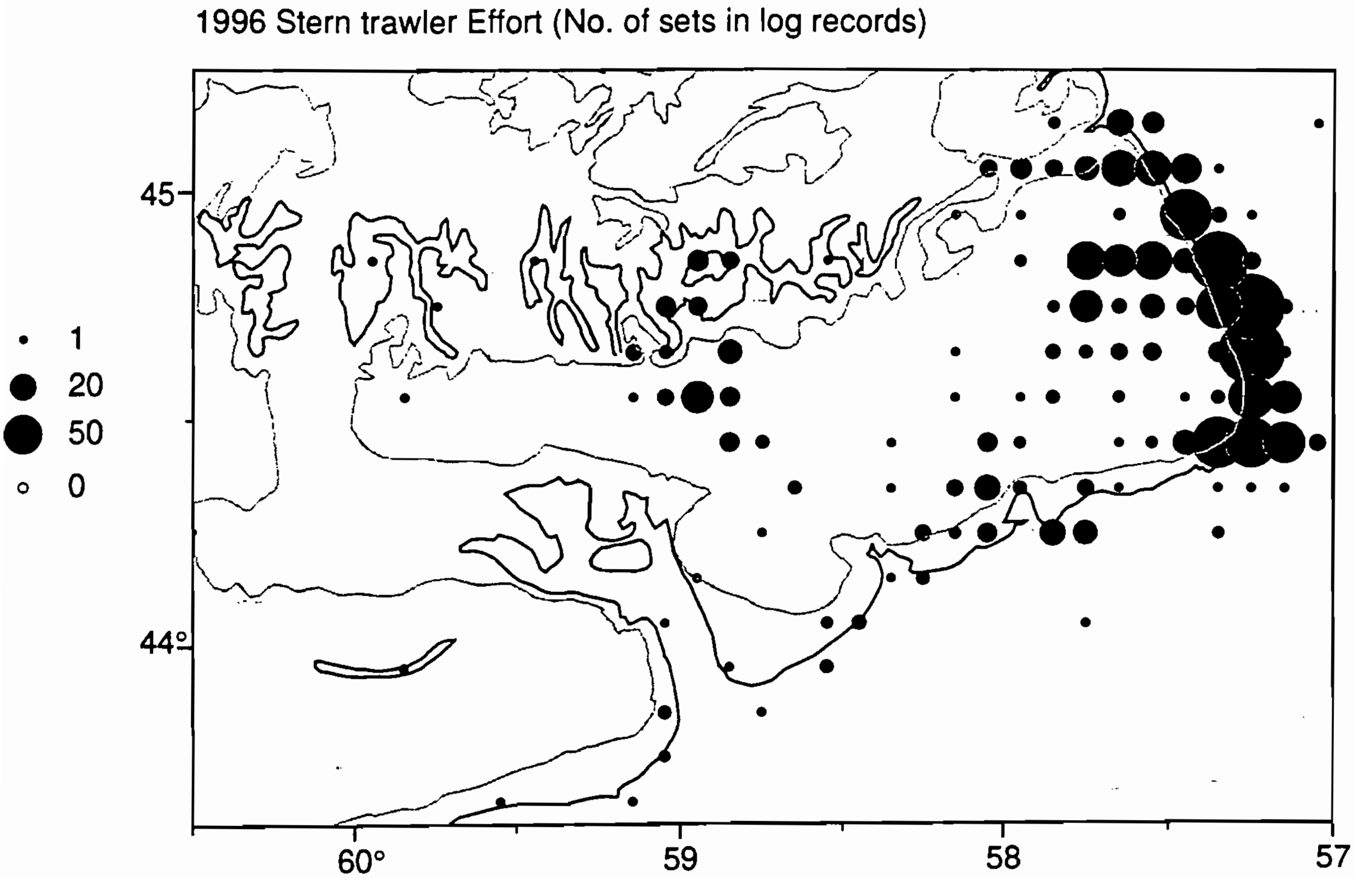


Fig. 7.1.11. (Continued)

1997 Stern trawler Effort (No. of sets in log records)

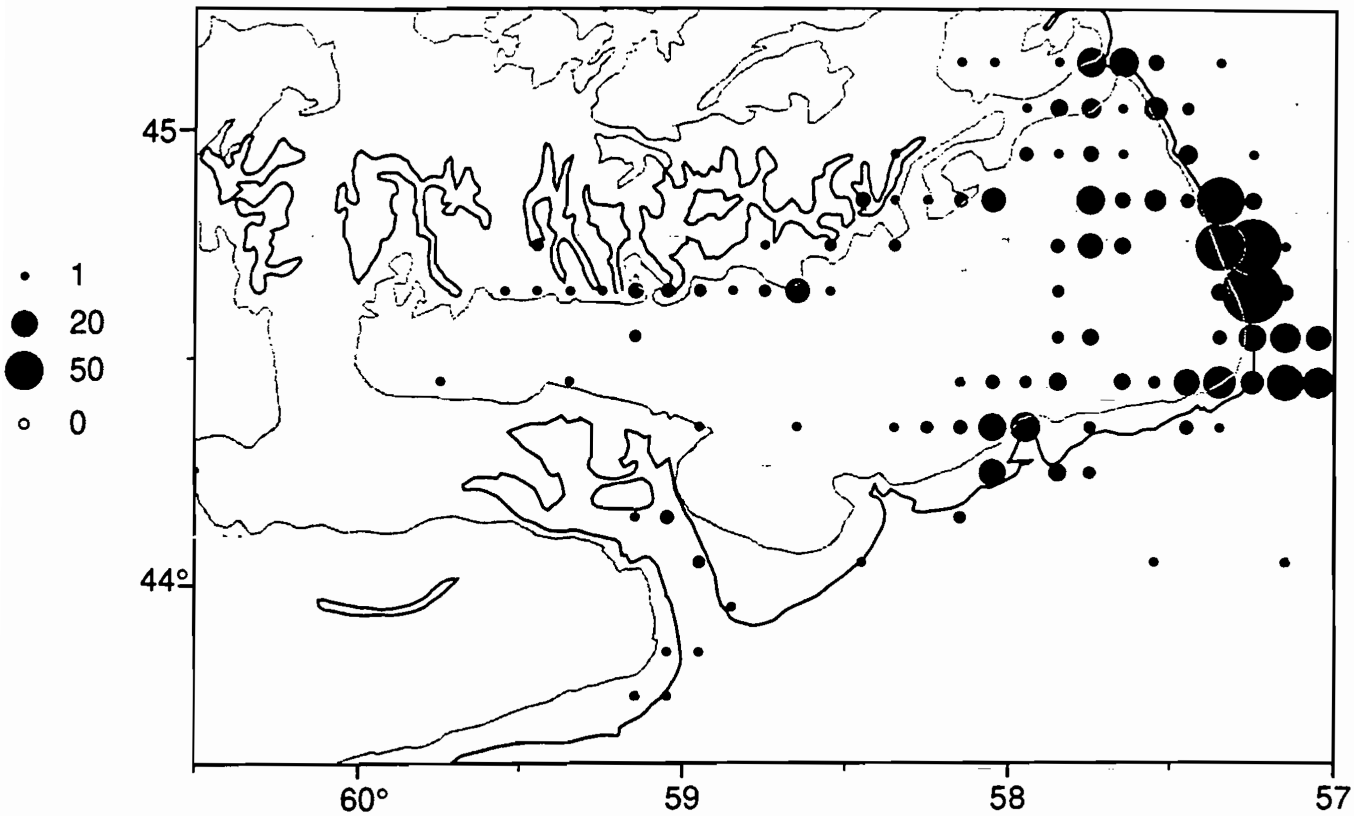


Fig. 7.1.11. (Continued)

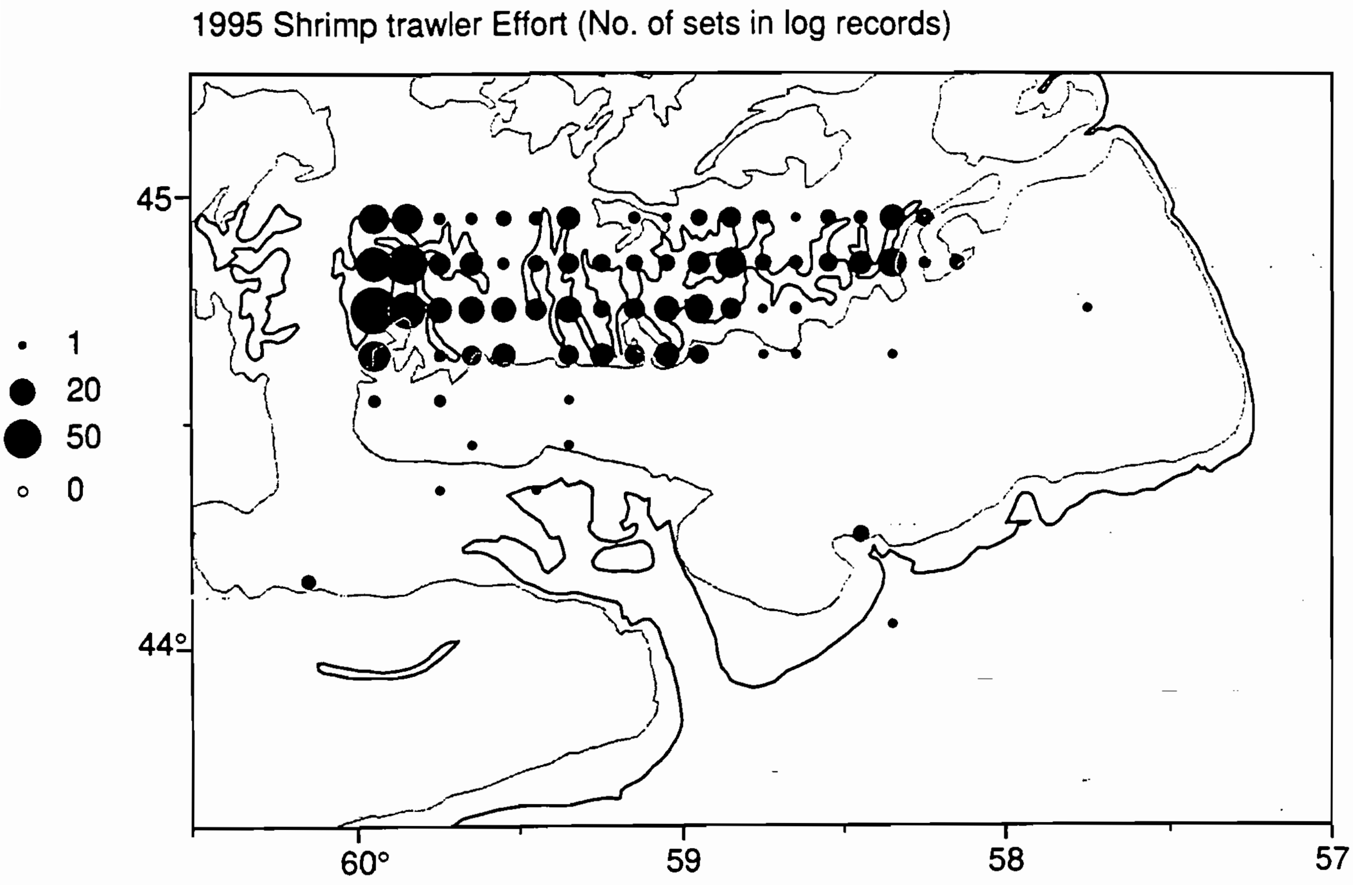


Fig. 7.1.12. Shrimp trawler effort distribution shown as the total number of sets recorded by 10 min square for the years 1995-1997.

1996 Shrimp trawler Effort (No. of sets in log records)

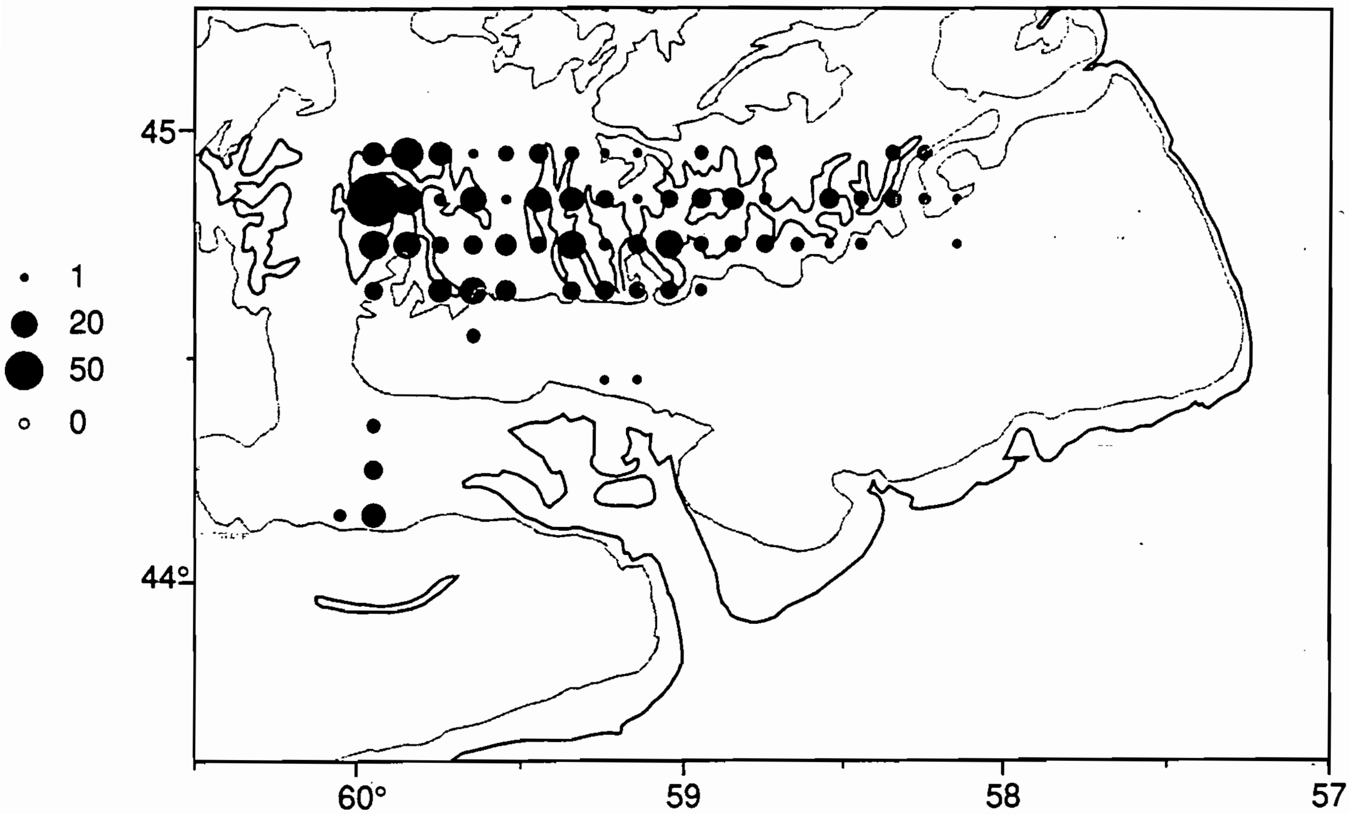
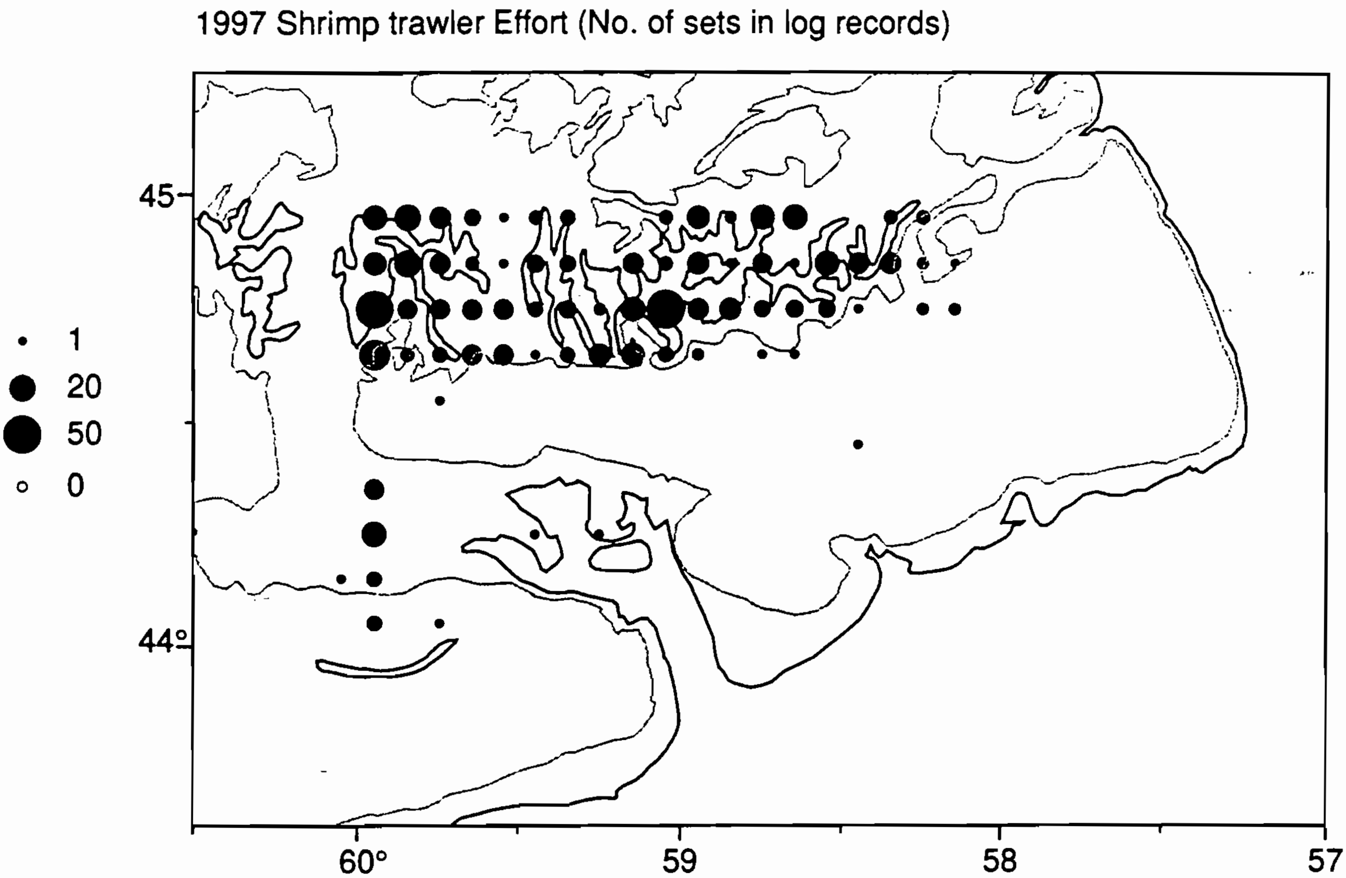


Fig. 7.1.12. (Continued)



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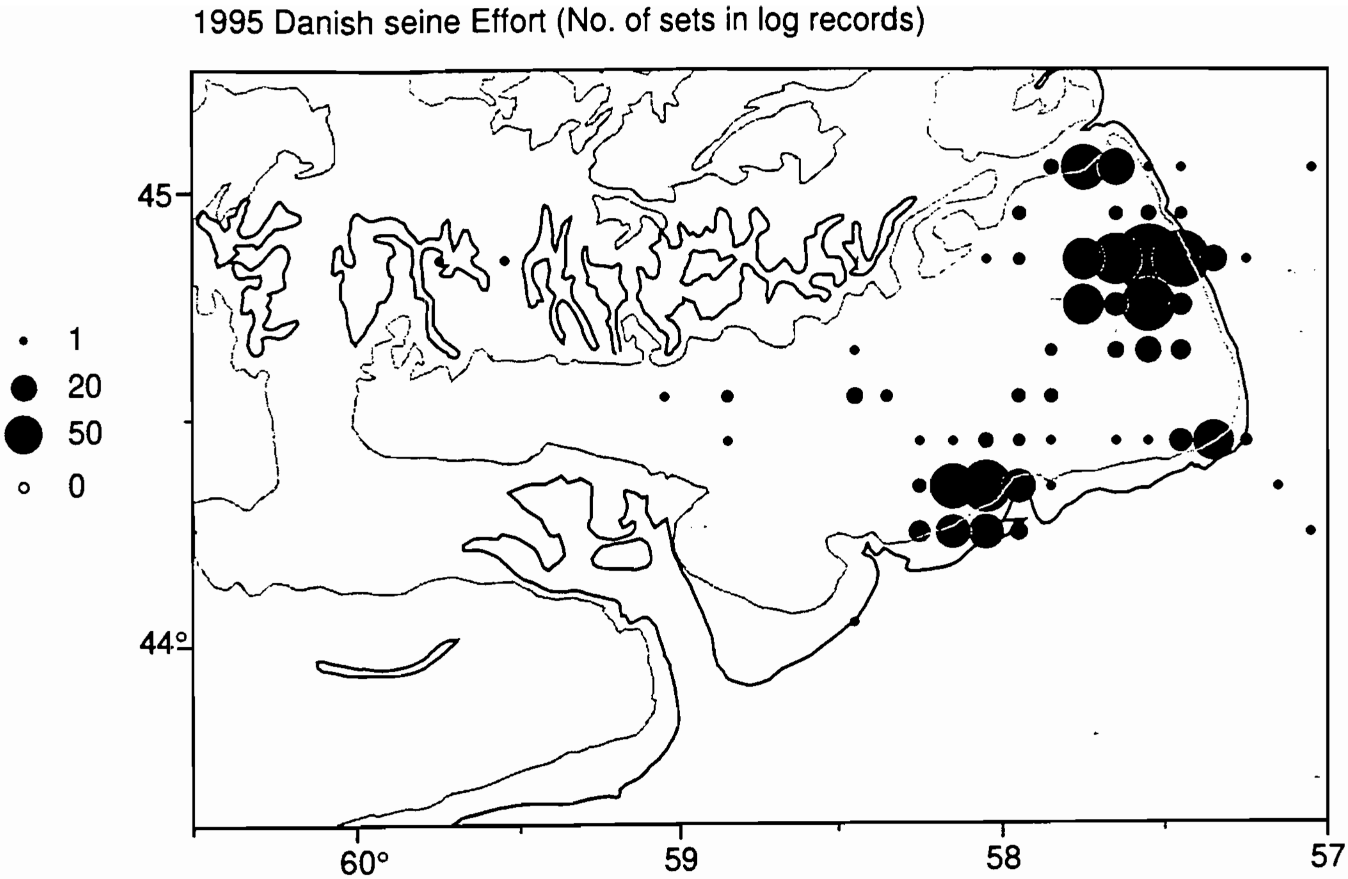

Fig. 7.1.13. Danish Seiner effort distribution shown as the total number of sets recorded by 10 min square for the years 1995-1997.

1996 Danish seine Effort (No. of sets in log records)

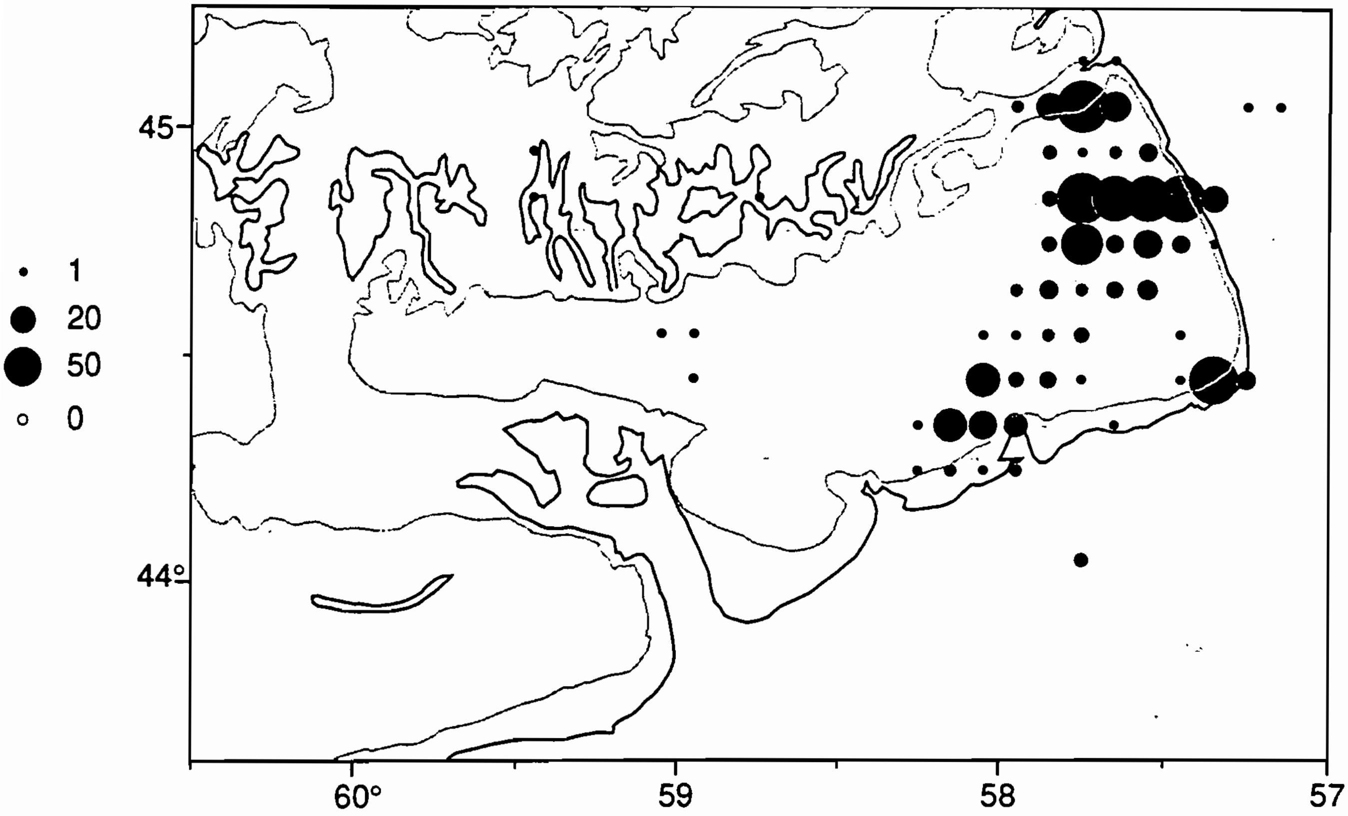

Fig. 7.1.13. (Continued)

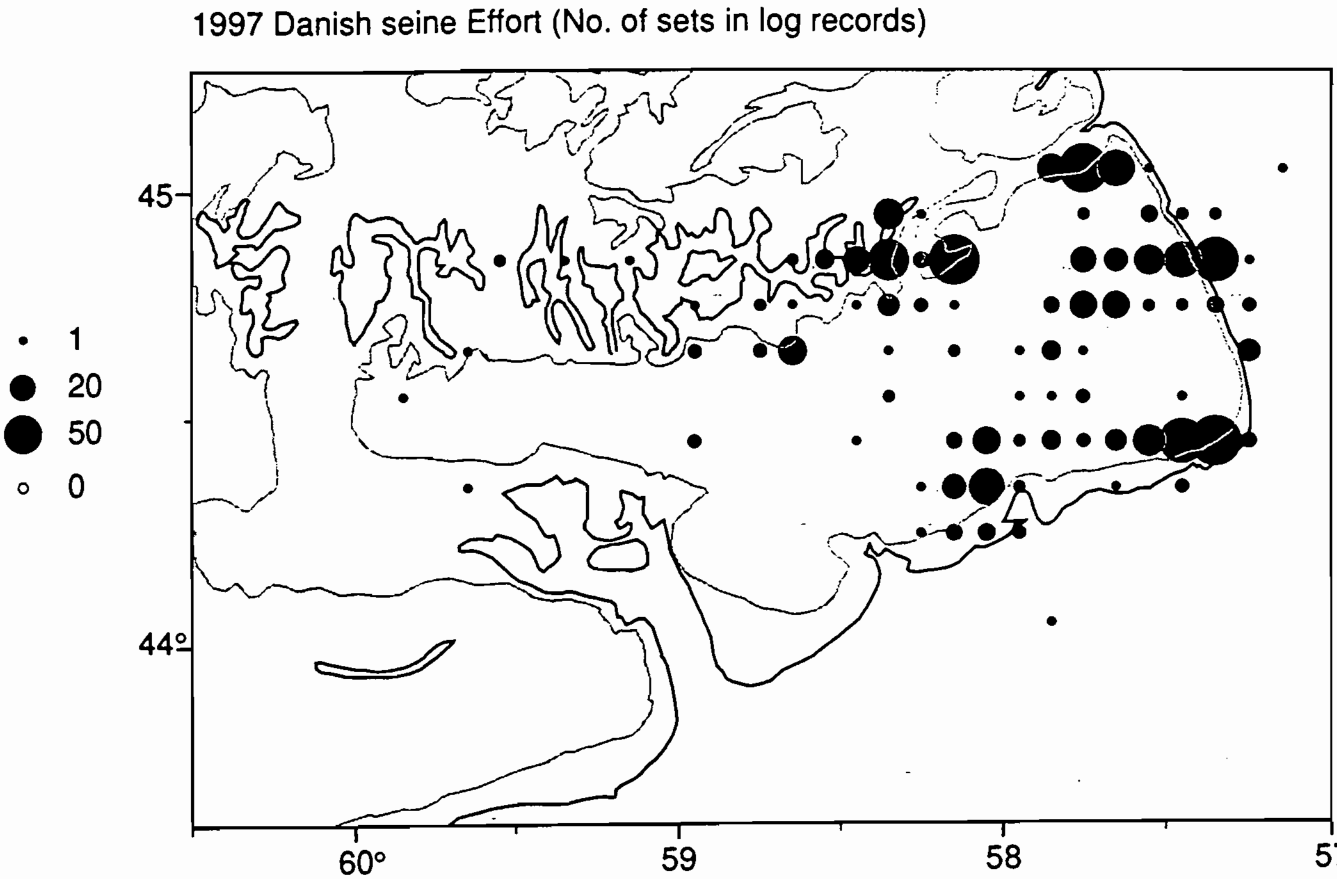

Fig. 7.1.13. (Continued)

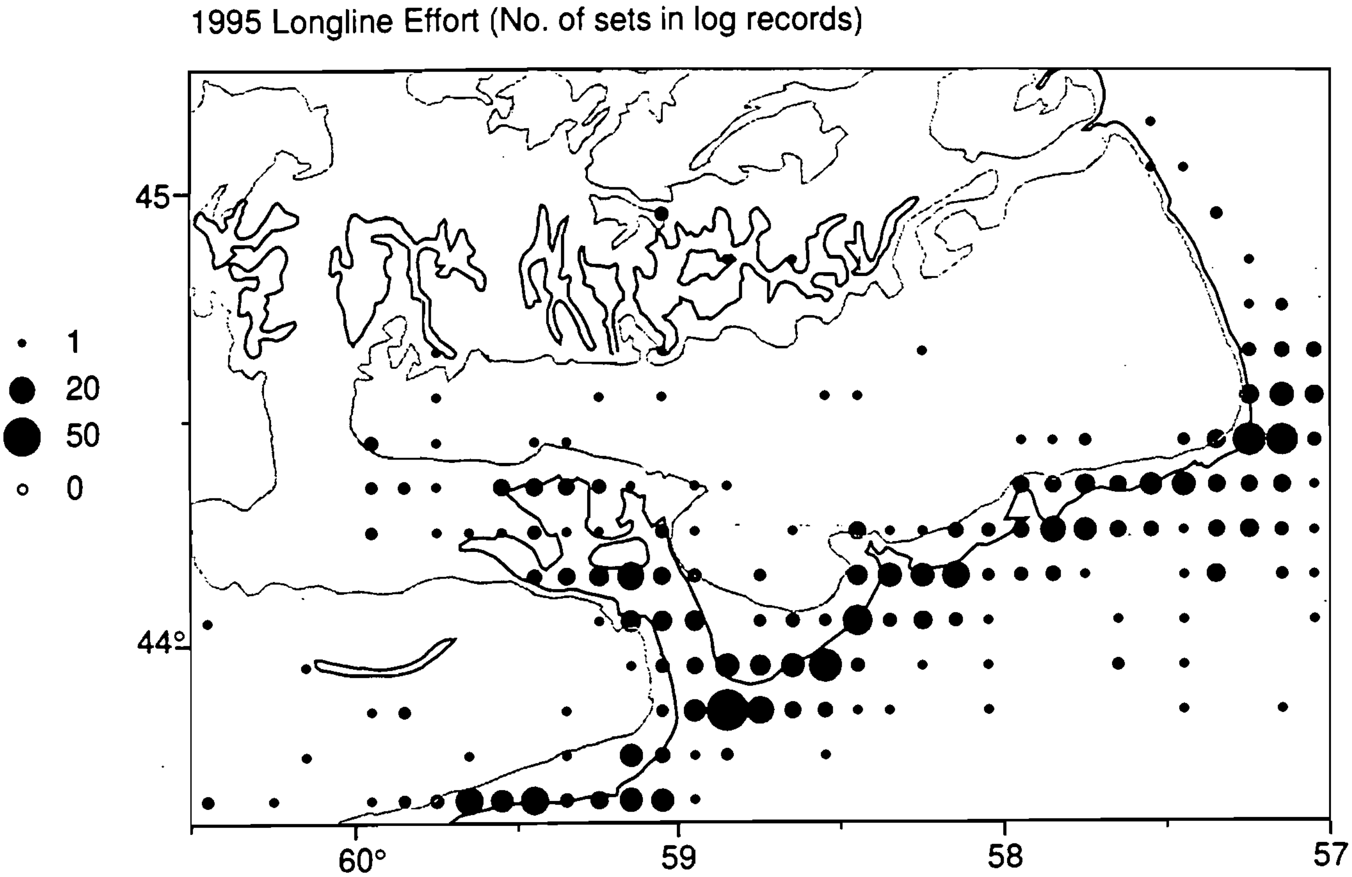

Fig.7.1.14. Longline effort distribution shown as the total number of sets recorded by 10 min square for the years 1995-1997.

1996 Longline Effort (No. of sets in log records)

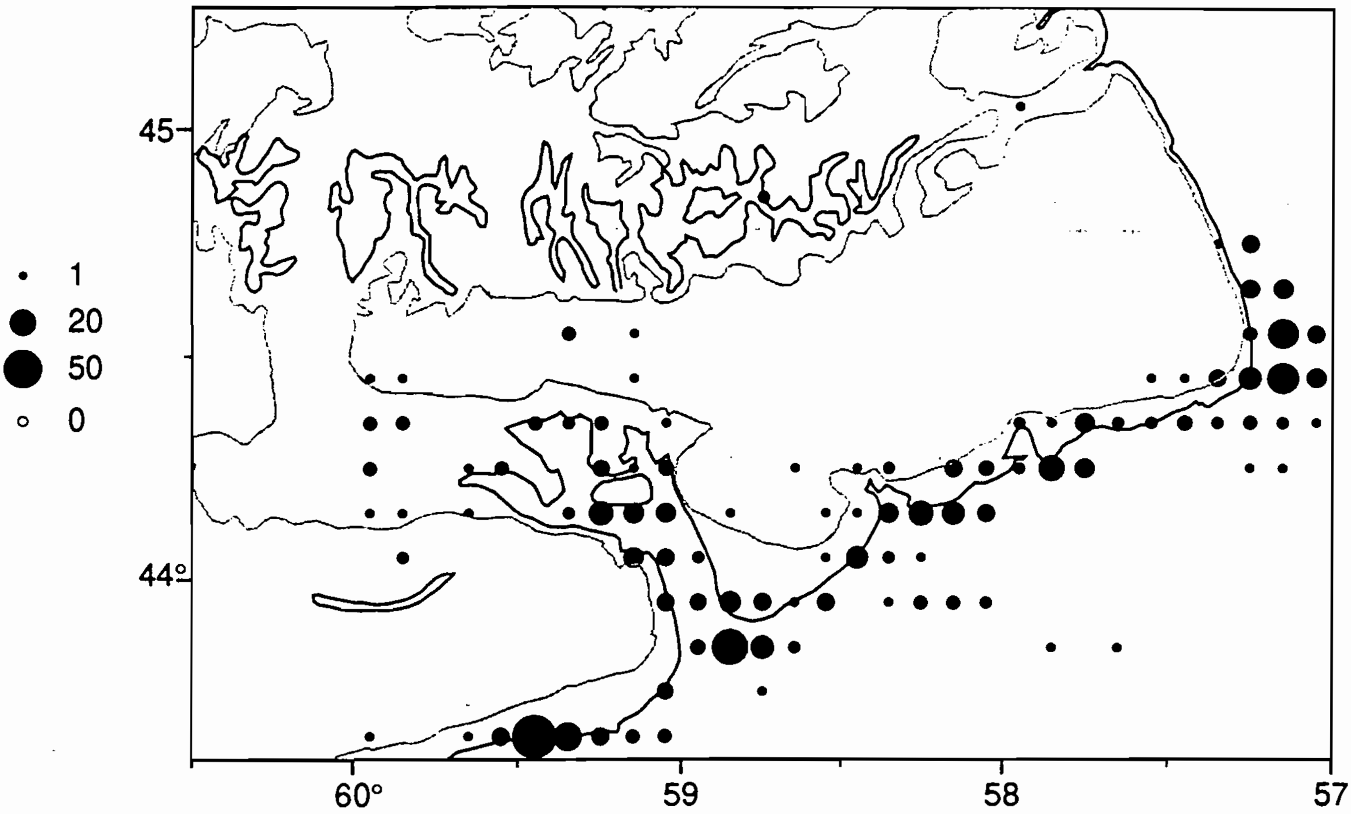

Fig. 7.1.14. (Continued)

1997 Longline Effort (No. of sets in log records)

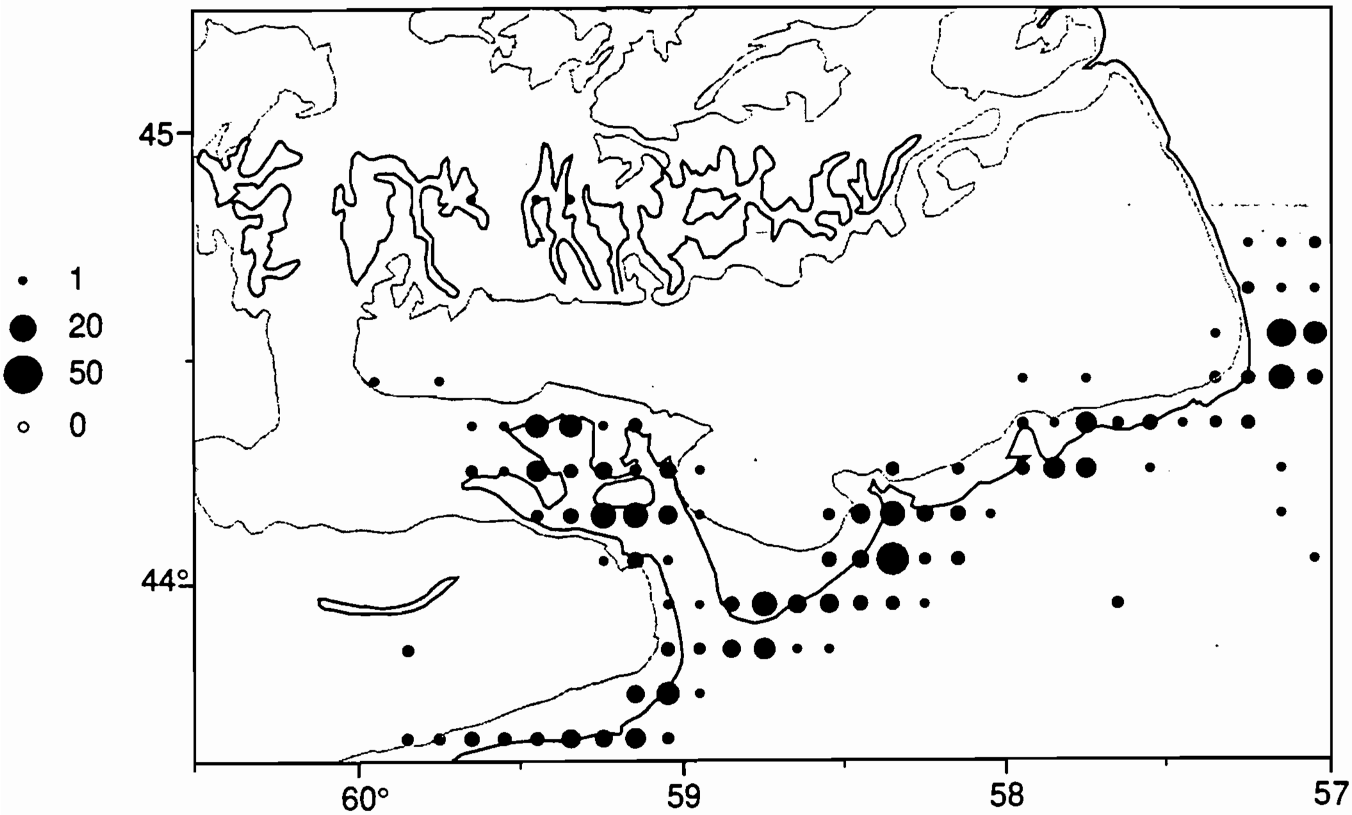

Fig. 7.1.14. (Continued)

7.2 Invertebrate Fisheries

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7.2.1 Introduction

Discussion papers prepared for the Canadian Wildlife Service, the World Wildlife Fund and Habitat Management Division have dealt with commercially fished invertebrates to some extent, but have not been comprehensive. The report for Habitat Management Division lists the following species as significantly fished within the trough portion of the Gully (most since 1993): scallops, shrimp, stone crab, propeller and surf clam. The sizes of the fisheries are not given, and most of these fisheries are unlikely to occur within the trough which is >200 m in depth. Finfish diversity and taxa are identified from groundfish surveys, but not invertebrates. The WWF report (Shackell *et al.* 1996) suggests future fishery development could include resumption of a clam fishery, scallop fishery, and trap fisheries for lobsters and crabs within the Gully area but few details are given.

There are few active fisheries for invertebrates within the Gully (demarcated by 200 m contour) itself, but there is some potential for expansion of existing fisheries to this area, and for fisheries for new species. In addition there are some well developed fisheries on the adjacent Banks. Discussed below are (i) existing invertebrate fisheries relevant to the Gully area (ii) potential invertebrate fisheries, and (iii) some information gaps and possible sources of information.

7.2.2. Existing Invertebrate Fisheries

Table 7.2.1 provides a summary, with some estimates of catches in the Gully area

Scallops (*Placopecten magellanicus*) - On the eastern Scotian Shelf, scallop beds are present on Sable Island Bank, and on Western, Middle and Banquereau Banks (Black *et al.* 1993) at depths <125 m. Most of the catch comes from Western Bank, more than 100 km from the Gully (Fig. 7.2.1). More information on scallop distribution closer to the Gully may be available from 1997 exploratory survey of the eastern Scotian Shelf funded by industry.

Arctic Surfclam , Northern Propellerclam and Ocean Quahog - These bivalves are found on sand or mud bottoms, usually in depths <100 m. Arctic Surfclam (*Mactromeris polynyma*) has been an important offshore fishery since about 1987 (Roddick 1996). The catch has been on Banquereau Bank, mainly east of Shortland Canyon. Propellerclam (*Cyrtodaria siliqua*) and ocean quahog (*Arctica islandica*) are permitted as a bycatch.

Although generally not landed (Duggan 1996a, b), there is interest in developing markets for this species.

Snow Crab (*Chionoecetes opilio*) - Snow crab are fished commercially in deep areas (generally >120 m) on the eastern Scotian Shelf, where seasonal bottom temperatures are < 3 °C (Tremblay 1997). The fishery has extended out as far as the Gully, but the distance from port makes this area of secondary importance. Snow crab have been captured in groundfish trawls near the Gully, and on Sable Island Bank; they were rarely captured west of 61 degrees longitude (Fig. 7.2.2).

Shrimp (*Pandalus borealis*) - Like snow crab, most of the shrimp fishing on the eastern Scotian Shelf occurs in deep holes (Canso, Misaine and Louisbourg) shoreward of the Gully, at depths >180 m. The bottom type is fine mud (La Have Clay) (Koeller 1996). Groundfish surveys indicate a fishable biomass of shrimp in the Gully and there is anecdotal evidence that shrimp are larger there.

Lobster (*Homarus americanus*) - There is no offshore fishery for lobster on the eastern Scotian Shelf. There is a fishery to the west, but existing participants have not extended their effort to the east (where catch rates are lower) (Fig. 7.2.3). Groundfish trawl surveys in the 1980s and exploratory fishing with traps indicates low concentrations of lobsters in the Gully area (Fig. 7.2.4). Some fishers believe there is a recruitment link between offshore lobster on the eastern Scotian Shelf and nearshore lobsters off eastern Nova Scotia, but there is no evidence to substantiate this. It is unlikely that any Gully lobsters would migrate inshore to the Chedabucto Bay area given the low bottom temperatures and rough terrain in the intervening area.

Red Crab (*Chaceon quinquedens*) - are fished mainly in depths of 300-900 m at temperatures of 5-8 °C (Duggan and Lawton 1997). The current fishery (5 vessels) fishes west of 61° longitude (Western Bank) (Fig. 7.2.5). Exploratory fishing suggests catch rates decrease to the east. Fishing with different gear types south of Emerald Bank captured over 400 crab, while in the Gully only 2 crab were taken (Halliday and Cooper 1991).

Squid (*Illex illecebrosus*) - have been highly abundant on the Scotian Shelf but not in recent years. In 1979 73,000 metric tonnes (mt) of squid were caught on the Scotian Shelf (Rowell *et al.* 1985). Catches declined in the 1980's and the fishery is now primarily a bycatch of the silver hake fishery. Squid prefer warmer waters (>6.0) and are distributed on the outer shelf and slope, in Emerald and La Have Basins and in the Gully. Concentrations were observed in the Gully between July and September of 1980- 1981 but not in 1982-83 (Rowell *et al.* 1985). More recent data should be available from groundfish surveys.

7.2.3 Developing or Potential Fisheries

Stone Crab (*Lithodes maja*) - have been found at temperatures of 1-5 °C and depths of 65-800 m (Squires 1990, Dooley and Johnson 1994, Woll 1996). This crab has been taken sporadically in other trap fisheries (snow crab, jonah crab) and as a bycatch in finfish operations. Exploratory trap fishing to date has generally yielded catch rates too low for commercial exploitation but trap design modifications could result in increases. The Gully area appears to have a relatively high concentration of stone crab, given the results of exploratory trap fishing (Perry and Smith 1969), and groundfish surveys. A related species (porcupine crab, *Neolithodes grimaldi*) is restricted to deeper waters, generally >300 m (Pohle *et al.* 1992).

Other Crustaceans - Several deep-water species are listed as having commercial potential by DFO (1991) and Pohle *et al.* (1992). In addition to stone crab, several deep water shrimp species are mentioned, as are two cephalopod species. Data on these species on the slope of the Scotian Shelf is virtually non-existent.

7.2.4 Information Gaps

- Complete distribution data on red crab, stone crab, lobster, "other crustaceans" - the groundfish survey database has been accessed for some species but records for most invertebrates are not complete.

- Extent of movement between Gully and the rest of the Scotian Shelf (most species).

- Recruitment links between Gully and the rest of the Scotian Shelf (all species).

- Interactions between invertebrates and other species.

7.2.5 Summary

- Existing commercial fisheries (clams, scallops, snow crab, shrimp) occur adjacent to the Gully trough (>200 m).
- In the future there is potential for expansion of existing fisheries to the Gully (*e.g.* snow crab, shrimp) as well as some new benthic fisheries (*e.g.* stone crab).
- There are no data that suggest the Gully is of special significance to the populations of any benthic invertebrate species that have commercial potential, but data on shelfwide distribution of most species is currently not available, and any recruitment links between the Gully and the rest of the Scotian Shelf are unknown.

7.2.6 References

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Table 7.2.1. Invertebrates on the Eastern Scotian Shelf that are currently fished or that have fishery potential.

Species	Fishery stage/ location	Catch rates - Gully area	Peak annual landings 1991-95 (from the Gully or Sable/ Banquereau)	Abundance index (from groundfish surveys, other)
Scallops *Placopecten magellanicus*	Developed - Western, Sable Island & Banquereau Banks, Middle Ground	Not expected in Gully, moderate on adjacent banks	482 mt (4000 mt round); most from Western Bank	NA
Arctic Surfclam *Mactromeris polynyma*	Developed - Banquereau Bank (<100 m), just N & E of Gully	Not expected in Gully, high on Banquereau	11,600 mt ; most from eastern Banquereau	NA
Propellerclam *Cyrtodaria siliqua*	Bycatch in surfclam fishery	Not expected in Gully, moderate on Banquereau	negligible	
Ocean Quahog *Arctica islandica*	Bycatch in surfclam fishery	Not expected in Gully, moderate on Banquereau	negligible	
Snow Crab *Chinoecetes opilio*	Developed - mainly shoreward of Gully but could expand	Moderate-high in northern trough	<30 mt	- abundant in and around Gully
Red Crab *Chaceon quinquedens*	Developing - Slope west of 61 deg long; could expand	Expected to be low in Gully	0	?
Squid *Illex illecebrosus*	Bycatch in offshore silver hake fishery	?	?	-abundant in the Gully in some summers
Lobster *Homarus americanus*	Offshore fishery developed to the west	Expected to be low in Gully	0	- present around Gully
Stone Crab *Lithodes maja*	Early development - Exploring E. Scotian Shelf including Gully	Moderate-high in Gully area	<3 mt (1997)	?
Shrimp *Pandalus borealis*	Developed - shoreward of Gully but could expand	?	negligible	- abundant in and around Gully
Other shrimp, decapod crustaceans	Potential fisheries	?	0	?

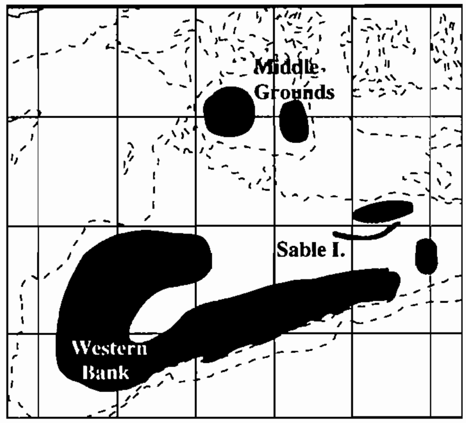

Fig. 7.2.1. Scallop fishing areas on the eastern Scotian Shelf adjacent to the Gully. From 1997 SSR by G. Robert, Invertebrate Fisheries Division, DFO.

Locations of snow crab occurrence during groundfish surveys, 1980-94. Sets were over entire Scotian Shelf. Total n of sets = 5801. N with snow crab = 96.

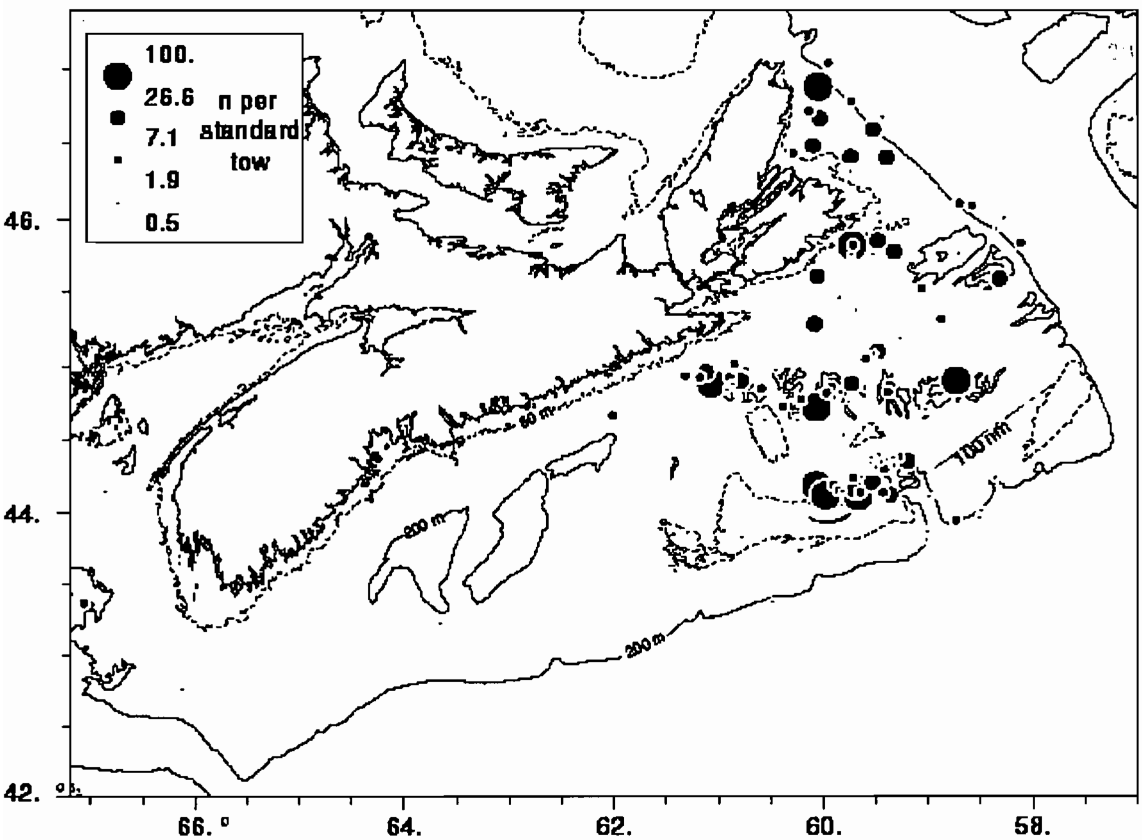

Fig. 7.2.2. Snow crab captured during Spring, 4VW Cod, Summer and Autumn groundfish surveys on the Scotian Shelf, 1980-1994. From Tremblay (1997).

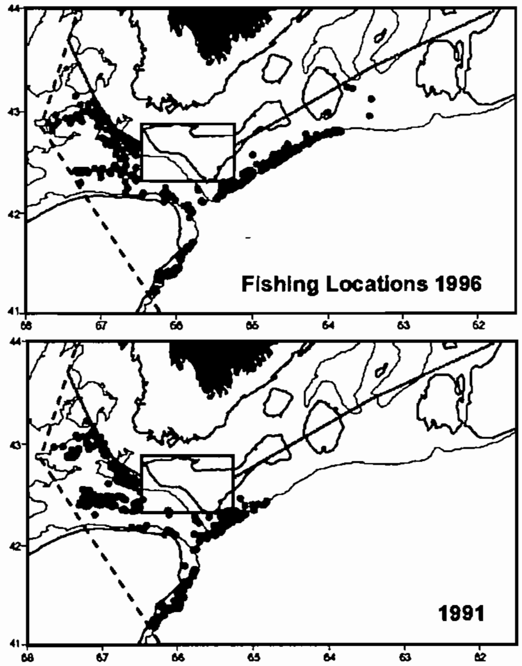

Fig. 7.2.3. Offshore lobster fishing effort. Figure from 1997 SSR by D. Pezzack, Invertebrate Fisheries Division, DFO.

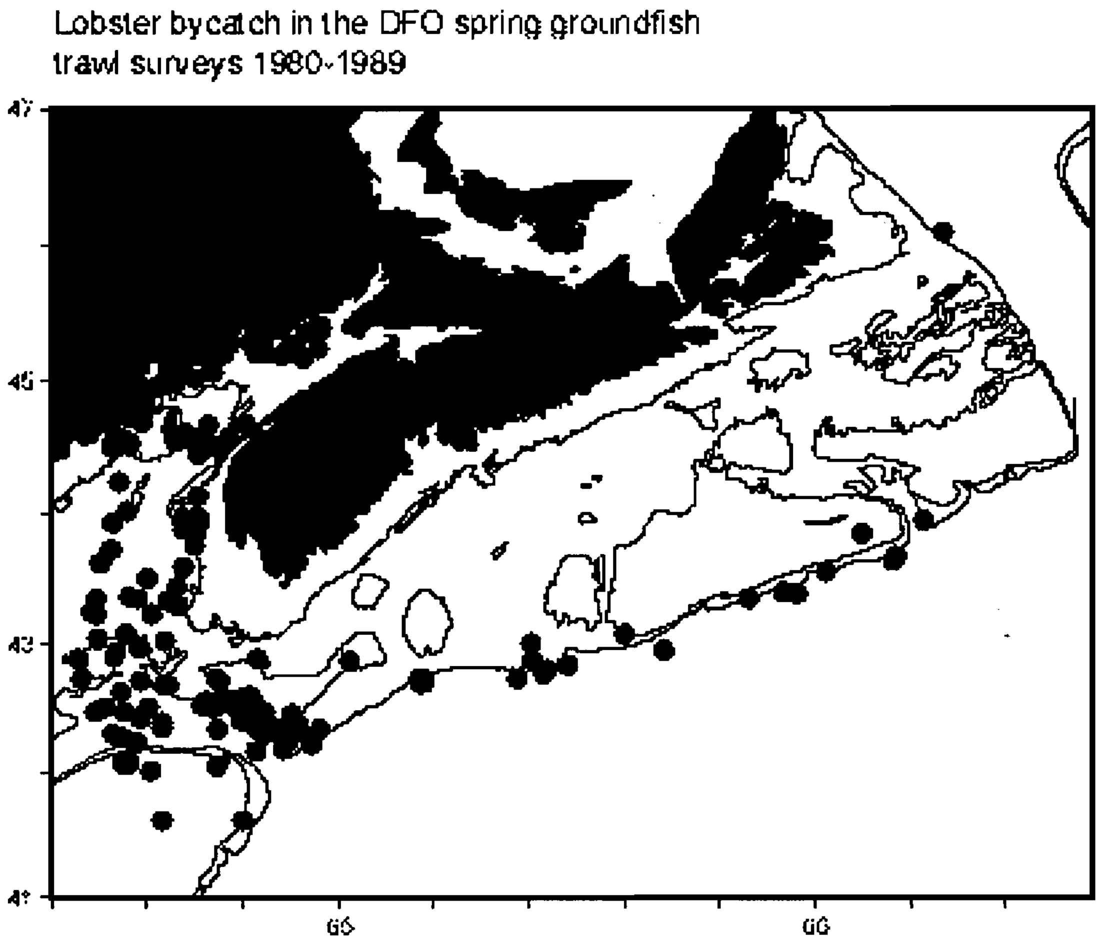

Fig. 7.2.4. Presence/absence of lobster in spring groundfish surveys during the 1980s. From 1997 SSR by D. Pezzack, Invertebrate Fisheries Division, DFO.

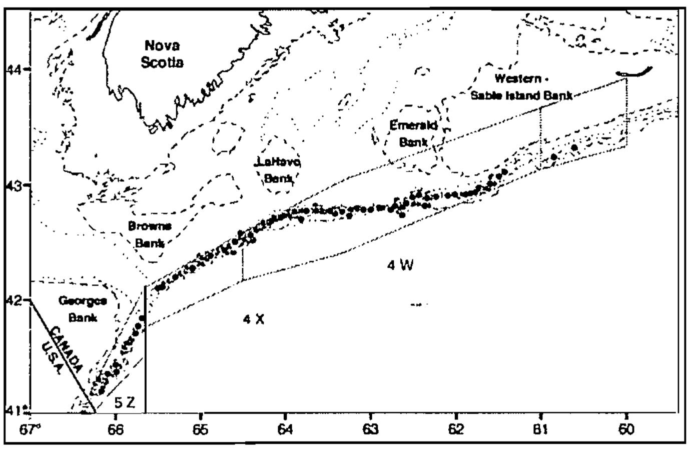

Fig. 7.2.5. Distribution of recent fishing effort for red crab. From 1997 SSR by P. Lawton and D. Duggan.

8.0 Pelagic Seabirds

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8.0.1 The Scotian Shelf

The continental shelf to the east of Nova Scotia is about 200 km wide, with several shallow areas less than 200 m deep. These banks, which have supported highly productive fisheries, are separated from the coast by trough of deeper water. Sable Island lies at the edge of one of the largest of these banks, and the Gully is a deep submarine trough penetrating the edge of the bank some 30 km to the east of Sable Island. The edge of the continental shelf is influenced by the warm, north-easterly flow of the Gulf Stream and the south-westerly flow of the Nova Scotia current mixing with residual Labrador current waters. The inshore area of the shelf is dominated by the cool, south-westerly Nova Scotia Current, which flows out of the Gulf of St. Lawrence and down to the Bay of Fundy and Gulf of Maine. A large, anti-clockwise gyre, roughly centered on Sable Island forms as a result of interactions of these shelf currents (Fig. 8.0.1).

8.0.2 Marine Birds

Marine birds can be broadly categorised into coastal birds (gulls, terns, cormorants, waterfowl), and pelagic birds, those which remain at sea all year, coming ashore only to breed. Coastal birds, living in a mechanically complex environment generally have higher rates of mortality than pelagic birds which live for most of the year in a simpler and less dangerous environment. To compensate for this higher mortality coastal birds tend to have larger clutches and earlier ages of first breeding. Pelagic birds usually have single-egg clutches, delayed maturity and low adult mortality rates.

Seabirds have not been dealt with seriously by oceanographers until very recently. The correlation of seabirds with schools of fish, upwellings and distinct water bodies was part of the traditional knowledge of navigators and fishermen, but a rigorous synthesis of ornithology and oceanography has been made only in the last half century (Brown, 1980 and Batty, 1989). It is a fair generalisation that seabirds are where they are for very good reasons, usually concerned with food abundance. Recognition of that fact allows us to infer a great deal about the structure of the ocean otherwise only detectable by oceanographic instruments.

The community of marine pelagic birds on the Scotian Shelf contains very few species and this community does not breed locally; at all times of year the majority of birds present in the offshore are Arctic or southern hemisphere breeders. Interestingly, the pattern of distribution of the summer and winter avian communities is similar even though totally different species are involved. The winter avifauna consists of auks, fulmars and kittiwakes while in summer shearwaters and storm-petrels and immature gannets predominate. The species making up the western Atlantic marine avifauna are identified below.

Tubenoses are relatives of the albatrosses, and five species are common on the Scotian Shelf Northern Fulmars (*Fulmarus glacialis)* are Arctic-breeding birds about the size of a Herring Gull. In the last few decades fulmars have increased throughout the Atlantic and extended their breeding range southwards to Labrador and insular Newfoundland. They are widespread at temperate latitudes in winter, retreating northward in spring as shearwaters move in. Greater and Sooty Shearwaters (*Puffinus gravis* and *P. griseus*) breed in the southern hemisphere, then migrate to moult in the northern hemisphere's summer. In early May, large numbers reach the Scotian Shelf on a clockwise circuit of the Atlantic Ocean. It is likely that most of the world population of Greater Shearwaters (5–10 million) pass over the Scotian Shelf to "winter" in the North Atlantic. Storm-Petrels are, starling-sized birds which pick small fish and zooplankton from the ocean surface. Leach's Storm-Petrels (*Oceanodroma leucorhoa*) breed in burrows on coastal islands from southern Labrador to Maine. Wilson's Storm-Petrels (*Oceanites oceanicus*) breed in the South Atlantic, arriving here at the same time as the shearwaters, and remaining until late summer.

Northern Gannets (*Sula bassanus*) are relatives of pelicans which catch fish near the surface by plunge diving. In eastern North America they breed at only six sites, three in eastern Newfoundland and three in the Gulf of St. Lawrence, and on the Scotian Shelf they are abundant only during migration.

Auks are compact, fast-flying birds which capture small fish by pursuit diving. Five species are common in North Atlantic pelagic waters. Two species of murres inhabit shelf waters in winter: Arctic-breeding Thick-billed Murres (*Uria lomvia)*, and Common Murres (*U. aalge*) which breed as far south as the Bay of Fundy. In summer they are to be found close to their colonies; in winter they are dispersed, with Atlantic Puffins (*Fratercula arctica*) and Razorbills (A*lca torda*) over the continental shelf off eastern Canada. Dovekies (*Alle alle*) are robin-sized auks that breed in Greenland and the European High Arctic. In summertime they are found on their breeding range, but in winter they are widely dispersed over the North Atlantic.

Gulls are not usually pelagic in habit, but Black-legged Kittiwakes (*Rissa tridactyla*) are pelagic gulls which breed mainly in the Arctic, though they have extended their breeding range south of Newfoundland to Nova Scotia around 1970, and began breeding in the Bay of Fundy in 1992. This species is a notable scavenger at fishing fleets and is increasing in numbers on both sides of the Atlantic.

8.0.3 Pelagic Distributions

Data on pelagic seabird distributions are derived from the Programme Intégré de Recherches sur les Oiseaux Pélagiques (PIROP) database maintained by the Canadian

Wildlife Service. This database stores counts of seabirds made from ships over a 25 year period, but unfortunately the data are not comprehensive, and only a few observations have been made near the Gully. A detailed examination of seabird distributions by month has shown that while the species present change throughout the year, there appear to be no major systematic changes in their distribution over the shelf with time. All observations made on the Scotian Shelf were combined and mapped in Fig. 8.0.1. This shows the mean numbers of pelagic seabirds seen in sample quadrats on the Scotian Shelf throughout the year. Seabird distributions are mapped as mean numbers of birds seen per kilometre of ship's track, the data accumulated in survey blocks covering 1/2° of longitude and 1/4° latitude. Areas in which no observations have been made are left white. Detailed mapping of individual species distributions on the Scotian Shelf is presented in Lock *et al.* (1994.)

The winter shelf avifauna is dominated by auks, fulmars and kittiwakes. Common Murres are the most common of the large auks, though significant numbers of the more northerly Thick-billed Murres are also present. By May most of the auks have withdrawn northwards to their breeding range, but a few stragglers, presumably non-breeders, linger into June. Northern Fulmars also withdraw to their Arctic breeding range as the shelf waters begin to warm and Shearwaters arrive in large numbers from their breeding range in the southern hemisphere. A few non-breeding fulmars remain on the shelf throughout the summer.

In summer shearwaters and storm-petrels are the dominant species. The shearwaters sweep north on an clockwise migration around the north Atlantic before returning south in November to breed. The majority moult and feed on the Grand Banks of Newfoundland to recover weight lost on their northern migration, but significant numbers linger on the Scotian Shelf reaching their greatest densities in July. The path of their migration through the Scotian shelf is primarily along the shelf edge where primary productivity, and concomitantly zooplankton stocks, are enhanced, (Fournier *et al.* 1979 and Brown, 1988). The shearwater migration parallels a migration of Wilson's Storm-Petrels, also sub-Antarctic breeders. These birds, and Leach's Storm Petrels which breed on coastal islands from Maine to Newfoundland, are abundant on the shelf in summer feeding on zooplankton and ichthyoplankton, with greatest densities on the shelf edge and fishing banks. By October most have left on their southward migration to their breeding range.

Gannets are present only on their migrations to and from their breeding range in the Gulf of St Lawrence and Newfoundland, being most abundant in April and September. Small numbers of non-breeders may linger on the shelf throughout summer but after November they on their winter range in US. waters.

Very few of the pelagic seabird species on the Scotian Shelf at any time of year breed locally. Of the summering community only Leach's Storm Petrels breed in the region. The majority of the birds are Shearwaters and Wilson's Storm Petrels from the Southern Atlantic and smaller numbers of non-breeding Arctic species such as fulmars and kittiwakes. The wintering pelagic community is made up of primarily Arctic-breeding species. The coastal seabird community, in contrast, is made up primarily of locally breeding species in winter and summer.

8.0.4 Conclusions

The high variability of seabird distributional data make it difficult, with the data available, to detect small, local anomalies of distribution. Highest concentrations of pelagic birds are found along the shelf edge and in the turbulence and mixing as currents round major headlands: East Point in P.E.I. and Cape North in Cabot Strait for instance. High seabird numbers also occur predictably in the area of mixing between Sable Island and the mainland generated by the Sable Island gyre.

The PIROP database unfortunately contains few observations made in the area of the Gully, but the few data that are available do not show any unusual enhancement of seabird numbers in the area. Weatherbee (1997) conducted a series of summertime seabird surveys at the Gully and noted that when compared with the rest of the Scotian Shelf some species appeared less abundant, and others: Greater Shearwaters and petrels for instance, appeared to be slightly more abundant. However the data available for comparison were PIROP data gathered more than a decade previously and inter-year variations in the numbers of these southern migrants may well account for the small differences observed. Furthermore his comparison was with data for the shelf as a whole rather than the adjacent shelf edge, and pelagic seabirds are generally more abundant near the shelf edge.

Yeats (Section 6.2) mapped nutrients, nitrate and phosphate, and found the Gully indistinguishable from the rest of the near-by continental shelf. Head and Harrison (Section 6.3) examined phytoplankton and zooplankton distributions in the region and did not detect any anomaly in the area around the Gully. The distributions of tuna and swordfish are determined, to some extent by the presence of small fish and invertebrates which are also the food of pelagic seabirds. Stone (Appendix 13.2) found no increase in abundance of tuna and Swordfish at the Gully.

The Gully does not appear based on the limited data available to cause upwelling or local enhancement of productivity greater than that which occurs elsewhere at the shelf edge, nor is there evidence, based on a wider view of pelagic seabird distributions off eastern Canada, that submarine canyons have any major effect on seabird distributions at the surface. Because of the poor spatial/temporal resolution of available data on pelagic seabird distributions off eastern Canada, there is not enough evidence to assess whether submarine canyons *per se* have any major effect on seabird distributions at the surface. To document small differences between seabird abundance at the Gully and elsewhere on the shelf, a series of contemporaneous observations at the Gully and over adjacent shelf areas at all seasons would be required.

8.0.5 References

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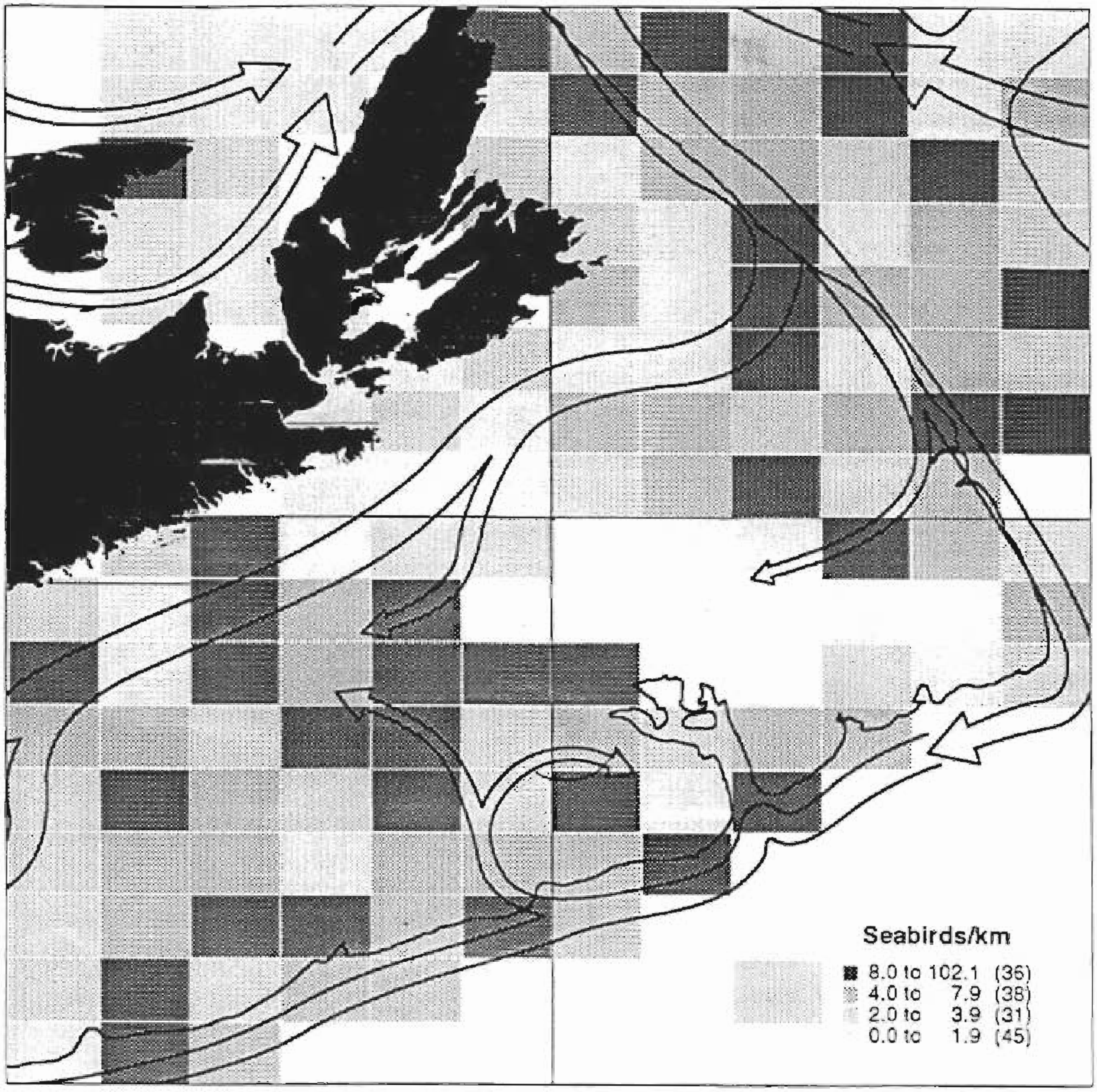

Fig. 8.0.1. Mean annual abundance of pelagic seabirds on the Scotian Shelf. The 200m isobath and major currents are also identified.

9.0 Marine Mammals

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9.0.1 Introduction

The two principal orders of marine mammals, and the only two found on the Scotian Shelf, are the whales and dolphins, order Cetacea, and the seals, order Pinnipedia. The waters in and near the Gully and Sable Island have been identified as significant for marine mammals several times in the scientific literature. For instance, Sergeant *et al.* (1970) noted that "the waters around Sable Island evidently have the most diverse cetacean fauna of the region [eastern Canada]." Amirault (1995) summarized more recent findings: "The diversity and density of marine mammals occurring in the area indicate that it is one of the most important habitats on the east coast of Canada, and possibly of global significance."

Two of the most established eastern Canadian field studies of marine mammals occur in the Sable Island/Gully region: the research on grey (*Halichoerus grypus*) and harbour (*Phoca vitulina*) seals on Sable Island by D. Bowen and colleagues (*e.g.* Bowen *et al.,* 1992a,b; Iverson *et al.* 1993; Boness *et al.,* 1994); and the studies of northern bottlenose whales (*Hyperoodon ampullatus*) and other cetaceans in the Gully canyon by H. Whitehead and colleagues (*e.g.* Gowans and Whitehead 1995 and Whitehead *et al.,* 1992, 1997a) (Fig. 9.0.1). Thus there is comparatively good information on marine mammal species in this area. However the data base contains significant temporal and geographical biases and gaps. There is also a lack of good comparable data for other areas of the Scotian Shelf, in particular its edge.

In this report, we first define our study area, indicate our data sources, outline their strengths and limitations, and then give a short report on each species known (or suspected) to occur in the study area including: habitat preferences, temporal use of the area, approximate numbers, and the significance of the Gully for the species. We then use this information to suggest some boundaries for conservation area(s), and summarize the importance of the study area for this group of animals.

9.0.2 Data Sources and Methods

For this summary, we adopt the following study area: 43° 30' - 44° 30' N and 58° 20' - 60° 10' W (Fig. 9.0.1). This includes the deep canyon of the Gully, the basin in the northern part of the Gully, the shallow waters around Sable Island, and slope waters to the southeast.

Data on the two orders of marine mammals were collected very differently, emphasize distinct areas of biology, and are strongly biased towards different parts of the study area. Pinniped studies, carried out on Sable Island, emphasize population biology, reproduction, and breeding behaviour. There is comparatively little information on at-sea distribution and feeding behaviour, although recent satellite tagging studies are beginning to fill these gaps.

In contrast, our knowledge of the population and reproductive biology of cetaceans in the area is weak to non-existent. However, there is useful quantitative information on at-sea distribution, but this was collected principally in the vicinity of the Gully canyon, and during the summer months.

9.0.2.1 Pinniped studies

Although five species of seals are known to occur in the study area, only the harbour seal and grey seal are common to abundant. For this reason, virtually all of the seal research has been conducted on these two species. Most of this research has been carried out on Sable Island during the breeding (May-June for harbour seals, December-January for grey seals) and summer moulting seasons for both species, although spring and fall research has also been conducted over the past decade. Grey seal and harbour seal population research began on Sable Island in the early 1960's and early 1970's, respectively, and continues annually. Diets were estimated from analysis of stomach contents in the 1970s and 1980s, and examination of fecal samples since 1990. The foraging behaviour of different age and sex classes of harbour seals has been studied periodically during the breeding season since 1989 using a combination of stable isotopes, time-depth recorders and VHF telemetry. Between 1992 and 1997, both time-depth recorders and satellite tags have been used to study the spatial and seasonal characteristics of at-sea foraging in adult male and female grey seals. Annual reproductive performance and survivorship have been studied since the mid 1970's in over 2000 individually branded grey seals ranging in age from 4 to 32 years.

9.0.2.2 Cetacean studies

Most of our information on cetaceans in the study area comes from studies of northern bottlenose whales and sperm whales (*Physeter macrocephalus*) by H. Whitehead and colleagues. Each summer (June-August) between 1988-1997 (except 1991 and 1992) researchers spent periods of between 2-66 days in the region of the Gully canyon observing cetaceans aboard 10m (1988-1990) or 12m (1993-1997) auxiliary sailing vessels (Table 9.0.1). Except in 1988 and 1989 when sperm whales received considerable attention, the focus of these studies was on northern bottlenose whales. However, sightings of all other cetaceans were recorded in a systematic manner and environmental data (including position, depth and sea temperature) were collected regularly (every hour for position, every 3 hours for other variables).

Hooker *et al.* (submitted m/s) have compiled the sightings data from 1988-1996 into a Geographic Information System data base, along with regular environmental and position records, for the geographic area bounded by 43° 38' - 44° 17' N and 58° 44' - 59° 31' W (Fig. 9.0.1), where there was a reasonable amount of effort. This data base contains 1885 hours of daylight effort in this study area. The sightings and effort data permit the construction of effort-corrected images of the geographic distribution of each species, along with analyses of how abundance varies with environmental variables (such as date, sea temperature and depth). The displays and analyses of Hooker *et al.* form the bulk of our presentation about cetaceans.

Table 9.0.1. Trip dates of cetacean fieldwork in the Gully.

Year	Trip Dates	Daylight hours spent in Gully
1988	July 8 - 21, July 25 - Aug 6	213
1989	July 16 - 30, Aug 1 - 15	215
1990	June 14 - 28, July 2 - 18, July 25 - Aug 12	399
1993	July 10 - 23	153
1994	July 31 - Aug 18	170
1995	Aug 20 - Sept 2	80
1996	June 7 - 25, July 4 - 21, July 27 - Aug 12, Aug 19 - Sept 2	667

Taken from Hooker *et al.* are the following summaries of the data:

a) Summary of effort (Table 9.0.1);

b) Sightings of different cetacean species by year with mean group sizes (Table 9.0.2);

Table 9.0.2. Cetacean species sighted in the Gully by year

Species	No. of sightings	'88	'89	'90	'93	'94	'95	'96	group size mean (± SD)
blue whale	8	-	-	-	-	-	3	5	1.38 (± 0.52)
fin whale	32	6	4	6	5	1	-	10	1.31 (± 0.78)
sei whale	3	-	-	-	-	-	-	3	1 (± 0)
minke whale	8	4	-	-	1	-	-	3	1.25 (± 0.46)
humpback whale	38	2	15	1	2	12	-	6	1.47 (± 1.13)
sperm whale	92	65	5	1	1	3	1	16	1.09 (± 0.32)
northern bottlenose whale	577	11	58	180	70	39	12	207	3.29 (± 2.21)
long-finned pilot whale	54	9	9	7	2	8	8	11	11.44 (± 13.41)
striped dolphin	29	-	5	3	10	7	3	1	13.42 (± 2.49)
Atlantic white-sided dolphin	148	11	15	53	17	7	-	45	8.80 (± 8.39)
short-beaked common dolphin	104	7	25	11	18	21	-	22	15.60 (± 25.94)
bottlenose dolphin	7	-	-	2	1	-	1	3	11.29 (± 13.28)
TOTALS	1100	115	136	264	127	98	28	332	

c) Mean water depth, sea floor slope, sea-surface temperature, and calendar month for sightings of cetacean species as well as for regularly-collected environmental data (effort) (Table 9.0.3);

d) Distribution of cetacean sightings with depth and calendar month as sightings per hour of effort (Hooker *et al.* found that, of those environmental parameters that were considered, these two variables explained almost all the dependence of cetacean abundance) (Fig. 9.0.2);

e) Distribution of cetacean sightings by geographic area (Fig. 9.0.3). The small study area is divided into regions based on depth regimes, such that effort was similar in each region, and the rate of sighting each species in each region is plotted in sightings per hour of effort.

Table 9.0.3. Depth, slope, SST and calendar month sighting values (mean and standard deviation) for each cetacean species.

Species	Depth (m)	Slope ( )	SST (C)	Month
blue whale	919 (561)	14 (9)	18.0 (1.8)	8 (0)
fin whale	923 (469)	10 (6)	16.6 (3.2)	7.53 (0.51)
minke whale	166 (89)	3 (2)	13.1 (3.5)	6.75 (0.46)
humpback whale	1012 (456)	12 (9)	17.3 (3.2)	7.61 (0.59)
sperm whale	731 (428)	9 (7)	15.4 (2.2)	7.24 (0.62)
northern bottlenose whale	1196 (291)	14 (8)	14.5 (3.9)	7.11 (0.77)
long-finned pilot whale	946 (549)	11 (7)	17.3 (3.1)	7.65 (0.59)
striped dolphin	1378 (382)	13 (8)	16.8 (3.0)	7.55 (0.51)
Atlantic white-sided dolphin	1171 (411)	13 (7)	13.5 (3.6)	6.88 (0.70)
short-beaked common dolphin	1097 (479)	12 (7)	16.5 (2.9)	7.49 (0.54)
bottlenose dolphin	949 (487)	16 (8)	16.0 (2.1)	7.86 (0.38)
EFFORT (n = 1885, 1885, 703, 703)	1025 (497)	11 (8)	15.2 (3.7)	7.27 (0.73)

This analysis is augmented with:

- sightings from cetacean surveys of the area outside the June-August period by members of the Dalhousie cetacean research group (A. Faucher in September-October 1989 and February 1990; P. Simard in April 1997);

- distribution charts of catches of large whales from the Blandford, Nova Scotia, whaling station between 1966-1972 as plotted by Sutcliffe and Brodie (1977);

- distribution charts of marine mammals on and near the Scotian Shelf prepared by Kenney (1994) for the period 1966-1992 based on: shipboard and airplane sightings by U.S. researchers; Blandford whaling station records of catches and sightings (1966-1972); and incidental sightings and catches recorded by the Department of Fisheries and Oceans. This extensive data base has no measure of effort and is clearly biased against the Gully area, which was less frequently visited by whalers working from Blandford, Nova Scotia and US research cruises than the waters of the western Scotian Shelf.

- sightings from shipboard and aerial surveys carried out by Parsons (1995) in November 1994 in conjunction with Canadian Naval Patrol Frigate Shock Trials;

- information on cetacean strandings on Sable Island (Sergeant *et al.*, 1970, pre 1970; Lucas and Hooker, 1997 for 1990-1996). This information is particularly useful for the winter months (especially January and February) when pinniped scientists and other researchers identified and recorded cetacean strandings on Sable Island, but when ship sighting data from the study area are very scarce.

- from these data sources, we have a good picture of cetacean distribution and abundance in the deep canyon of the Gully during the summer months, but data become much more sparse and inferential as we move away from the deep canyon and the summer season.

9.0.3 Species Accounts: Cetaceans

In this section we give separate accounts for each species found in the study area. We first briefly describe the species and its usual habitat. We then provide information on its temporal and spatial use of the study area, the approximate numbers that might be found in the study area at any time, the likely identity of the population to which the Gully animals belong, the status of the population, and the significance of the study area for members of this population.

9.0.3.1 Blue whale (*Balaenoptera musculus*)

The blue whale, the largest animal on Earth, reaches to 30m, although North Atlantic animals tend to be smaller. Blue whales feed by engulfing large schools of zooplankton, especially euphausiids (krill).

Use of Gully area: A few blue whales are consistently found in and near the deep canyon of the Gully in mid and late August, but not earlier in the summer (Beck 1996; Hooker *et al.* Submitted m/s; Fig. 9.0.2b). A stranding on Sable Island in February 1958 suggests that these animals may use the Gully at other times of year (Sergeant *et al.*, 1970), and Kenney (1994) and Parsons (1995) data show that blues were sighted on the western and central Scotian Shelf quite often between May-November. No more than four members of this very conspicuous species have been seen at any time in the Gully. Therefore, we suspect that maximum numbers in the study area at any time are of the order of ten.

Stock identity and status: Stock relationships of blue whales in the western North Atlantic are unclear. One photographically identified animal from the Gully had been previously seen in the Gulf of St. Lawrence (R. Sears pers. comm.), and there are matches between the Gulf of St. Lawrence and Gulf of Maine (Sears *et al.*, 1990). Northwest Atlantic blues probably number a few hundred (Reeves and Brown, 1994) and are classified as "Vulnerable" by the Committee on the Status on Endangered Wildlife in Canada (COSEWIC).

Significance of study area: The consistency with which blue whales are sighted in and near the deep canyon suggests that the area has some importance to them, perhaps especially in late summer. Although numbers in the study area are generally small, this is the only known area on the Scotian Shelf where blues are consistently found.

9.0.3.2 Fin whale (*Balaenoptera physalus*)

The fin whale, second largest of all whales, reaches to 24m in the northern hemisphere. Bulk feeders, fin whales take schooling fish, zooplankton and squid.

Use of Gully area: Fin whales are sighted quite consistently in the Gully in July and August (Fig. 9.0.2b). Within Hooker *et al.*'s study area, there was no statistically significant preference for any depth regime. Kenney (1994) shows sightings and catches in the Gully region during all months from May to August, as part of a widespread distribution on the Scotian Shelf throughout most of the year. Parsons (1995) saw fin whales near the shelf break southwest of Sable Island in November 1994 . Fin whales generally seem to prefer the deeper waters of the Scotian Shelf (Kenney, 1994). Acoustic monitoring by US Navy hydrophone systems indicates that fin whales are the most common baleen whale species in the deep waters off the Shelf, and that they are present in these waters from late August, through the winter, until late spring when vocal activity stops (Clark, 1994). Sightings of this species in the study area have never been very numerous at any time, so we think it unlikely that there are ever many more than a few tens of animals in the study area.

Stock identity and status: The International Whaling Commission is unsure whether the fin whales found off Labrador/Newfoundland and on the Scotian Shelf are a single stock or separate stocks; together they probably number at least a few thousand animals (International Whaling Commission, 1992). The general seasonal migrations of fin whales in the western North Atlantic (Mitchell, 1974) may mean that a substantial number of animals pass through the Gully area in any year. None of the identification photographs taken in the Gully match any of the 800 animals catalogued from the Gulf of St Lawrence and the Gulf of Maine (Beck, 1996). Fin whales are classified as "Vulnerable" by COSEWIC.

Significance of study area: Although fin whales are quite widespread on the Scotian Shelf (Kenney, 1994), the Gully seems to be a particular (although not very emphatic) area of concentration.

9.0.3.3 Sei whale (*Balaenoptera borealis*)

The sei whale, a slim baleen whale which principally feeds by skimming copepods and other zooplankton, reaches about 18m in the northern hemisphere. Sei whales are quite difficult to identify definitively (Leatherwood and Reeves, 1983) and so sightings of this species are likely to be under-represented in many data bases.

Use of Gully area: Definitive identifications of sei whales are rare in Hooker *et al.*'s data base (Table 9.0.2), no sei whales are shown within our study area in Kenney's plots (although the species was commonly sighted and caught on the western Scotian Shelf), and no sei whales are reported as having stranded on Sable Island (Lucas and Hooker, 1997; Sergeant *et al.*, 1970). Although our study area would seem to be crossed by Mitchell's (1974) assumed seasonal migration of seis along the Scotian Shelf, there is no evidence that they linger long within it.

Stock identity and status: Mitchell and Chapman (1977) suggest that the sei whales migrating along the Scotian Shelf form a distinct stock numbering in the low thousands. The status of sei whales has not been considered by COSEWIC.

Significance of study area: The study area appears to have little importance to sei whales.

9.0.3.4 Minke whales (*Balaenoptera acutorostrata*)

Minke whales, the smallest of the balaenopterids (about 9m), are often seen alone and have a wide distribution which sometimes includes waters very close to shore. They feed on schools of fish and plankton, and are not conspicuous.

Use of Gully area: There have been a few sightings of minke whales in the study area (Table 9.0.2; Kenney, 1994; Parsons, 1995), but generally in shallow water (Figs. 9.0.2a and 9.0.3). Their migrations are unknown, although it is likely that some animals remain on or near the Scotian Shelf in winter while others migrate to warmer waters (*e.g.* Reeves and Brown, 1994). It is probable that a maximum of a few tens of animals are in the study area at any time.

Stock identity and status: The International Whaling Commission assumes an "eastern Canadian stock" (Donovan, 1991) whose numbers have never been assessed but probably are in the thousands (*e.g.* Reeves and Brown, 1994). The status of minke whales has not been considered by COSEWIC.

Significance of study area: The study area seems to have no more significance to minke whales than many other parts of the Scotian Shelf. In fact, this is the only species of Cetacea sighted at a significantly higher rate outside Hooker *et al.*'s study area compared with inside it (see Table 9.0.4).

9.0.3.5 Humpback whale (*Megaptera novaeangliae*)

The 14m humpback whale is the world's best known baleen whale. Like the fin whale, the humpback feeds on euphausiids, fish and squid. It is distinctive for its stocky body, long white (in the N. Atlantic) flippers, pronounced seasonal migrations, bubble-net feeding techniques, and the songs sung by males on the wintering grounds (*e.g.* Winn and Reichly, 1985).

Use of Gully area: Humpback whales are regularly sighted in the Gully during the summer months (Table 9.0.2). Kenney (1994) also shows sightings of humpbacks in or near the study area in May and September, and Parsons (1995) observed 7 animals in the Gully in November 1994. In Hooker *et al.*'s data set, they show no particular depth preference (Fig. 9.0.2a), but their abundance increases through the summer months (Fig. 9.0.2b). As most humpbacks migrate to warm waters in winter (Winn and Reichly, 1985), numbers are likely reduced between November and May. Like fin whales, sightings of this species have never been very numerous at any time, so we think it unlikely that there would ever be more than a few tens of animals in the study area at a time.

Table 9.0.4. Sighting rates of groups of cetaceans inside Hooker *et al.*'s Gully study area and elsewhere on the Scotian Shelf, per hour searching.

Species	in Hooker *et al.*'s area	outside Hooker *et al.*'s area	rate in Hooker *et al.*'s area	rate outside Hooker *et al.*'s area
blue whale	8	0	0.0042	0
fin whale	32	1	0.0170	0.0009
sei whale	3	1	0.0016	0.0009
minke whale	8	16	0.0042	0.0142
humpback whale	38	0	0.0202	0
sperm whale*	92	6	0.0488	0.0054
northern bottlenose whale*	577	0	0.3061	0
long-finned pilot whale	54	11	0.0286	0.0098
striped dolphin	29	0	0.0154	0
Atlantic white-sided dolphin	148	19	0.0785	0.0169
short-beaked common dolphin	104	23	0.0552	0.0205
bottlenose dolphin	7	0	0.0037	0
white-beaked dolphin	0	1	0	0.0009
harbor porpoise	0	1	0	0.0009

Effort: in core = 1885 hours, outside core = 1121 hours

* comparison unreliable as these species were sought out in the Hooker *et al.* area.

Stock identity and status: The stock structure of humpback whales in the western North Atlantic is well known by means of photographic identifications. Almost distinct feeding aggregations (animals usually adopt their mother's aggregation) from the Gulf of Maine (ca. 240 animals), Gulf of St. Lawrence (ca. 150), Newfoundland/Labrador (ca. 2,310), Greenland and Iceland mingle on winter breeding grounds near the West Indies (Katona and Beard, 1990). Our study area is in an interesting position, roughly equidistant between the Gulf of St. Lawrence, Gulf of Maine and Newfoundland/Labrador aggregations. Three humpbacks photo-identified in the Gully had been seen earlier in other parts of the western North Atlantic: one in the Great South Channel (Gulf of Maine); one off Newfoundland; and one on the Grand Banks as well as off the Dominican Republic, West Indies (Beck, 1996). These limited data suggest that members of at least two feeding aggregations are found in the Gully. The western North Atlantic humpback whales are classified as "Vulnerable" by COSEWIC.

Significance of study area: Although only a few humpback whales are seen in the study area at any time, and it does not compare with other centres of humpback abundance in the western North Atlantic (such as the Southeast Shoal of the Grand Bank and Stellwagen Bank in the Gulf of Maine), the Gully is the only place on the Scotian Shelf where humpbacks are sighted with reasonable consistency.

9.0.3.6 Sperm whale (*Physeter macrocephalus*)

The sperm whale, the largest of the toothed whales, is generally an animal of deep waters where it feeds on mesopelagic and benthic squids and fishes. The two sexes have quite different distributions: females (about 10-11m long) and young are usually restricted to waters warmer than about 15° C and latitudes less than about 40°, whereas the much larger males (up to about 18m) are found in temperate and polar waters, with larger, and older, males generally reaching waters furthest from the equator (Rice, 1989).

Use of Gully area: Male sperm whales are an important feature of the biota of the Gully. Although sperms can be found in any water deeper than 200m, there is a particular concentration in the basin at the northern end of the Gully where water depths are between 200-400m (Fig. 9.0.3; Whitehead *et al.,* 1992). Sperm whales can be consistently found there during the summer months, and probably during much or all of the rest of the year (as there have been strandings on Sable Island in October, January and February and sightings in the Gully in November (Parsons, 1995; Reeves and Whitehead, 1997; Sergeant *et al.,* 1970; R.W. Baird pers. comm.). In these northern Gully waters their distinctive clicks can be heard much of the time through a hydrophone (Whitehead *et al.*, 1992). Individual males have been photographed in the Gully over periods of several years (J. Christal, unpublished) indicating long-term fidelity or regular return to the area. These Gully sperms are mostly maturing males of about 12.5-15.5m, although groups of females have been observed to enter the Gully briefly on two occasions (Reeves and Whitehead, 1997; Whitehead *et al.,* 1992). From the rate at which Whitehead *et al.* (1992) re-identified individual males, we suggest that the population size in the study area at any time might number of the order of 10-30 animals.

Stock identity and status: The sperm whales in the North Atlantic are assumed by the International Whaling Commission to form a single stock (Donovan, 1991), partly on the basis of a male which was tagged on the Scotian Shelf and caught off Spain (Mitchell, 1975). There is no credible estimate of the size of this population, but it probably numbers at least in the thousands (see Reeves and Whitehead, 1997). Sperm whales are not considered at risk by COSEWIC.

Significance of study area: Eastern Canadian waters rarely contain female sperm whales, but they seem to be important feeding grounds for males (Reeves and Whitehead, 1997). The northern portion of the Gully is one of two areas noted for sperm whale abundance off eastern Canada, the other being the entrance of the Hudson Strait (Reeves and Whitehead, 1997). The Gully may be the most important habitat for sperm whales on the Scotian Shelf, and it may contain long-term residents.

9.0.3.7 Northern bottlenose whale (*Hyperoodon ampullatus*)

The northern bottlenose whale, a 7-9m member of the beaked whale family, is only found in the northern North Atlantic, and is the animal most identified with the Gully. These are deep-diving animals which mostly eat squid (Mead, 1989).

Use of Gully area: Northern bottlenose whales are consistently present in those waters of the Gully canyon deeper than about 500m (Whitehead *et al.,* 1997b; Figs 9.0.2a and 9.0.3). Females are present throughout the year: they have been sighted in every survey of the Gully of which we are aware (in which there were good sighting conditions for more than a few hours), in the months of February, May, June, July, August, October and November. The females are accompanied by young animals which are thought to be born during the summer months (Whitehead *et al.,* 1997a). The same individuals have been identified in the Gully in both summer and winter (Whitehead *et al.*, 1997a). Mature males are rare in early summer, but are commonly sighted in August. Animals enter and leave the Gully at an unknown rate, but very approximately half the population of approximately 230 animals is in the Gully at any time (Whitehead *et al.,* 1997b). Time-depth recorders attached to northern bottlenose whales in the Gully indicate that they are consistently diving to beneath 1000 m, near or to the bottom of the canyon (S.K. Hooker and R.W. Baird, unpublished data). These are the deepest known modal dives of any mammal.

Stock identity and status: There are indications (smaller size, apparently different breeding seasonality, and lack of substantial migration) that the northern bottlenose whales found in the Gully are partially or wholly distinct from those off northern Labrador, the nearest other population concentration (Whitehead *et al.,* 1997a). As there are sightings in other deep waters off the Scotian Shelf (Kenney, 1994; Parsons, 1995; Whitehead *et al.,* 1997b), it is thought that the Gully bottlenose whales may spend the part of the year when they are not in the canyon south of the Scotian Shelf. The population of northern bottlenose whales that uses the Gully is classified as "Vulnerable" by COSEWIC.

Significance of study area: The Gully canyon is likely to be very important for this population, as it contains about half the population at any time. The study of these animals in the Gully is the only long-term research on living beaked whales of any species anywhere in the world (there are two recently initiated studies of *Mesoplodon densirostris* off the Bahamas and *Ziphius cavirostris* off Greece). Therefore most of what will be discovered in the next five years about some aspects of the biology of beaked whales (especially social organization) will likely come from the Gully.

9.0.3.8 Beaked whales of the genus *Mesoplodon*

The 13 or so beaked whales of the genus *Mesoplodon* are the least known of marine mammals. They are deep-diving, elusive, small (4-6m) whales which are hard to sight and identify at sea.

Use of Gully area: *Mesoplodon* have been sighted several times in the deep waters of the Gully. Sowerby's beaked whale (*Mesoplodon bidens*) has been identified positively, and Blainville's beaked whale (*Mesoplodon densirostris*) tentatively. There has also been a single stranding of Sowerby's beaked whale on Sable Island (preliminary identification by I.A. McLaren). The difficulties in sighting and identifying these animals mean that information is very sketchy and estimates of numbers impossible.

Stock identity and status: Nothing is known about the stock identity or status of these animals, although there has been a substantial by-catch of *Mesoplodon* in the US east-coast pelagic drift-net fishery, principally in and near shelf-edge canyons to the southwest of the Gully (Read, 1994 and 1996). Sowerby's beaked whale is considered "Vulnerable" by COSEWIC.

Significance of study area: Canyons are thought to be important habitat for *Mesoplodon* (*e.g.* Read, 1996) but the significance of the Gully for these animals is unknown.

9.0.3.9 Long-finned pilot whale (*Globicephala melas*)

The long-finned pilot whale is a moderate-sized (5-6m) highly social and vocal odontocete which principally feeds on squid. Pilot whales are common over the Scotian Shelf, and especially along its edge (Kenney, 1994).

Use of Gully area: Pilot whales are common in the study area in all summer months, although densities rise during August (Gowans and Whitehead, 1995). Sightings plotted by Kenney (1994) show a distribution along the edge of the shelf during springtime, and there have been strandings on Sable Island in January and February (Sergeant *et al.*, 1970) as well as sightings off the shelf in November (Parsons, 1995), suggesting that pilot whales are in the study area through much of the year. During the summer months they show no particular depth preference within Hooker *et al.*'s study area (Figs 9.0.2a and 9.0.3). Pilot whales often occur in large schools of tens of animals, so that, given the density of schools throughout the study area, it would not be surprising if there were, on occasion, more than one thousand animals in the area.

Stock identity and status: Stock distinctions among western North Atlantic long-finned pilot whales are unclear, as are population sizes, although Hay (1982) estimated 13,000 for the waters off Newfoundland and Labrador. Although the pilot whales in the Newfoundland area are likely to be still substantially depleted following a very intense drive fishery from 1947-1971 (Nelson and Lien, 1996) long-finned pilot whales are not considered at risk by COSEWIC.

Significance of study area: The waters in our study often contain many long-finned pilot whales, but densities are probably not much higher than in other outer waters of the Scotian Shelf (Table 9.0.4).

9.0.3.10 Striped dolphin (*Stenella coeruleoalba*)

Striped dolphins are small (2.5m), social and lively dolphins which are found in temperate and tropical waters around the world. They eat squid and fish.

Use of Gully area: Striped dolphins are common in the study area in late summer when water temperatures reach above about 15° C (Fig. 9.0.2b). Within the study area, their habitat is the deeper waters in the southern part of the Gully canyon, and south of the shelf break (Fig. 9.0.3). Strandings in autumn and early winter on Sable Island (Baird *et al.,* 1993a) suggest that they may stay in the area after the water has cooled. Given the quite large schools sometimes seen, it is probable that numbers in the study area may sometimes exceed 1,000.

Stock identity and status: In the western North Atlantic, stock distinctions and population sizes are unknown for this species. It is not considered at risk by COSEWIC.

Significance of study area: The great majority of Canadian striped dolphin sightings have been made in the Gully (Baird *et al.,* 1993a; Kenney, 1994). The study area seems to be the most significant habitat for this species in Canadian waters.

9.0.3.11 Short-beaked common dolphin (*Delphinus delphis*)

The common dolphin is a very cosmopolitan species of tropical and temperate waters. Like the striped dolphin, these animals are small (2m) and gregarious, eating schooling fish and squid.

Use of Gully area: Short-beaked common dolphins are very abundant in the southern half of the study area in the later part of the summer (Figs 9.0.3 and 9.0.2b). They were frequently observed both on and off the Scotian Shelf during the November shipboard surveys reported by Parsons (1995). They have large group sizes (Table 9.0.2). Atlantic white-sided dolphins, the only small cetacean species with a higher sighting rate, live in much smaller groups. Therefore, in July and August common dolphins are probably the most abundant cetacean species in the study area, with numbers likely to be well into the thousands.

Stock identity and status: Stock distinctions and sizes in the western North Atlantic are unknown for this species. It is classified as not at risk by COSEWIC.

Significance of study area: Although common dolphins are seen all along the edge of the Scotian Shelf in late summer (Kenney, 1994), their very high abundance in the Gully suggests that this area is of particular importance for them, perhaps the most significant habitat in Canadian waters.

9.0.3.12 Atlantic white-sided dolphin (*Lagenorhynchus acutus*)

The Atlantic white-sided dolphin (ca 2.5m), with its colourful flank markings, is perhaps the most characteristic cetacean of the Scotian Shelf. These animals eat squid and small fish.

Use of Gully area: White-sided dolphins are found in substantial numbers in the study area throughout the summer (although less in August; Fig. 9.0.2b), and there are strandings on Sable Island during the winter months (Sergeant *et al.*, 1970). They seem to prefer the deeper waters in and near the canyon (Fig. 9.0.3). Numbers in the study area throughout the summer are likely to be well into the thousands.

Stock identity and status: Stock distinctions and population sizes in the western North Atlantic are unknown for this species, although its range is from about Cape Hatteras to Greenland and it seems to be quite numerous (Gaskin, 1992). It is classified as not at risk by COSEWIC.

Significance of study area: The deeper waters of the Gully are clearly important for members of this species.

9.0.3.13 Bottlenose dolphin (*Tursiops truncatus*)

The well-known bottlenose dolphin (2-3m) has a tangled taxonomy, possibly consisting of more than one species. They eat fish and squid.

Use of Gully area: Bottlenose dolphins are occasionally sighted in the study area in late summer (Fig. 9.0.2b), often in mixed schools with striped or common dolphins. It is unlikely that more than a few hundred would be in the study area at one time.

Stock identity and status: The Gully would seem to be at almost the extreme northeast limit of the bottlenose dolphin's range in the western North Atlantic (Baird *et al.,* 1993b). Animals that visit the Gully are likely part of the "offshore form" stock which is found near the edge of the continental shelf east of the U.S. (Baird *et al.,* 1993b). It is classified as not at risk by COSEWIC.

Significance of study area: The Scotian Shelf is likely of marginal importance for these animals (Reeves and Brown, 1994).

9.0.3.14 Other species

There are several cetacean species which have been sighted only very rarely in the Gully area, or for which we have no reliable records, but are likely occasional visitors:

Right whale (*Eubalaena glacialis*): The endangered 15m northern right whale has important habitat on the western Scotian Shelf, although it is occasionally sighted further east (Kenney, 1994). We know of no sightings in the study area, although Kenney shows one sighting in August just off the Scotian Shelf south of Sable Island, about 20km south of the study area.

Pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*Kogia simus*): There are records of strandings of three pygmy sperm whales and one dwarf sperm whale on Sable Island (Sergeant *et al.,* 1970; Lucas and Hooker, 1997). These small (2-3m) members of the sperm whale family are difficult to sight at sea.

Harbour porpoise (*Phocoena phocoena*): This small (1.5m), and generally inshore, odontocete was sighted once in the Gully canyon, and twice off Sable Island during the summer of 1997 (S. Hooker, unpublished), and there are two January strandings on Sable Island (Lucas and Hooker, 1997), but the study area is likely to have little significance for this species.

White-beaked dolphin (*Lagenorynchus albirostris*): At about 3m, the white-beaked dolphin is the largest dolphin to be found on the Scotian Shelf. It is very common off Newfoundland, and is sighted frequently in inshore Nova Scotian waters. We know of no sightings for the study area (except for some poorly authenticated skulls from Sable Island: Sergeant *et al.,* 1970), although it is likely to be present, at least occasionally, in winter.

Killer whale (*Orcinus orca*): Killer whales (7-9m) are occasionally sighted on the Scotian Shelf (Mitchell and Reeves, 1988). There have been no sightings during recent Gully research but Blandford whalers took one male from the Gully in 1964 (Mitchell and Reeves, 1988).

Risso's dolphin (*Grampus griseus*): There have been a few sightings of this large (4m) deep-water dolphin off the Scotian Shelf (Baird and Stacey, 1991 and Parsons, 1995) but none in the Gully.

Fraser's dolphin (*Lagenodelphis hosei*): This 2.5m tropical dolphin has been tentatively sighted in the Gully on two occasions, but identifications were not confirmed.

9.0.4 Species Accounts: Pinnipeds

9.0.4.1 Grey seal (*Halichoerus grypus*)

This is a medium-sized (2-3m) member of the Family Phocidae inhabiting continental shelf waters throughout the year in eastern Canada and in the northeastern Atlantic. It is the most abundant pinniped on the Scotian Shelf. Diet varies seasonally and geographically, but in the vicinity of Sable Island sandlance (*Ammodytes* sp.), flatfishes, Atlantic cod (*Gadus morhua*), and squid (*Illex illecebrosus*) are commonly eaten (Benoit and Bowen, 1990; Bowen *et al.*, 1993; and Bowen and Harrison, 1994).

<u>Use of the Gully area</u>: Approximately 70% of grey seal pup production in eastern Canada is associated with Sable Island breeding colonies (Mohn and Bowen, 1996). All age and sex classes of grey seals forage in the waters of the Gully area throughout much of the year. However, grey seals are known to disperse widely throughout their range during the non-breeding season (Stobo *et al.*, 1990; Beck, Bowen, and McMillan unpublished data). Thus, it is not currently possible to estimate with any degree of confidence what fraction of the grey seal population uses the Gully area seasonally. Such estimates will be possible once the satellite tagging study has been completed. A preliminary estimate based on population size would suggest thousands of grey seals use the Gully area.

<u>Stock identity and status</u>: Grey seals in Eastern Canada all belong to one interbreeding population. This conclusion is based on mitochondrial DNA studies (M. Hammill, pers. comm.) and the intermixing of breeding adults from grey seals branded at weaning in both the Gulf of St. Lawrence and Sable Island (Zwanenburg and Bowen, 1991; and Bowen unpublished data). The Sable population of grey seals has been increasing at about 12% per year and was estimated at about 150,000 animals in 1994 (Mohn and Bowen, 1996).

<u>Significance of the study area</u>: The area is part of the core range of the grey seal on the Scotian Shelf. Sable Island supports the largest breeding colony of grey seals in the world.

9.0.4.2 Harbour seal (*Phoca vitulina*)

This is a small (1.7 m) coastal species of the Family Phocidae that inhabits temperate waters of the northern hemisphere. Diet varies seasonally and geographically (Bowen and Harrison, 1996), but around Sable Island sandlance appears to be the dominant prey (W. D. Bowen, unpublished data).

<u>Use of the Gully area</u>: Harbour seals breed on Sable Island and forage in the Gully area throughout the year. However, like the grey seal, harbour seals disperse widely throughout eastern Canada during the non-breeding season and thus it is not

currently possible to reliably estimate the number of seals that use the area seasonally. However, given the size of the population, it is likely that no more than hundreds of harbour seals use the Gully area.

Stock identity and status: Based on pelage colouration and dentition, Boulva and McLaren (1979) suggested that the Sable harbour seals were a distinct population within eastern Canada. However, microsatellite data (Coltman, Bowen, and Wright, unpublished data) and annual changes in pup production of greater than 20% indicate periods of genetic mixing with mainland populations. During the late 1980's, annual pup production on Sable Island (about 600 pups) made this colony the largest in eastern Canada. However, since 1992 pup production has plummeted to only 31 in 1997 (W. D. Bowen, unpublished data). The causes of this decline are uncertain, but are known to include increased shark predation on juveniles, reduced female fertility, and lack of female recruitment.

Significance of the study area: The Sable Island population is unique in that it is the only truly offshore breeding population of this species in eastern Canada, if not the world.

9.0.4.3 Other species

Harp seal (*Phoca groenlandica*). This is a highly migratory phocid species, slightly larger than the harbour seal (at 1.7m), that breeds on the pack ice off Labrador and in the Gulf of St. Lawrence in March (Sergeant, 1991). Although considered rare on the Scotian Shelf a decade ago, juvenile harp seals are now common (dozens of sightings) on Sable Island. This increase on the Scotian Shelf, and further south, is roughly correlated with an increase in population size, but changes in ocean climate may also have played a role. Recent population estimates indicate about 4.3 million harp seals in the northwest Atlantic (Anon. 1995).

Hooded seal (*Cystophora cristata*). This is another highly migratory phocid species that breeds mainly on the pack ice off southern Labrador, although there is also a small (several thousand) population in the Gulf of St. Lawrence. Hooded seals are a medium-sized species (3m). Like harp seals, hooded seals were rare on the Scotian Shelf until the last few years; recently dozens of juveniles have been routinely sighted on Sable Island. The hooded seal population has increased over the past decade and recent estimates indicate that there are about 500,000 hooded seals in the northwest Atlantic (Stenson *et al.*, 1997).

Ringed seal (*Phoca hispida*). This small (1.4m) arctic phocid is very occasionally sighted on Sable Island.

Atlantic walrus (*Odobenus rosmarus rosmarus*). The walrus (3m) used to breed on Sable Island but was extirpated in the 18th Century. Very occasional migrants from arctic populations are seen off Nova Scotia (Katona *et al.*, 1983), but we know of no reports from the study area.

9.0.5 Significance of the Gully for Marine Mammals

9.0.5.1 Diversity

In the study area there are:

- 8 frequently sighted cetacean species (those with 25 or more sightings in Hooker *et al.*'s data base: fin, humpback, sperm, northern bottlenose, and pilot whales, and striped, Atlantic white-sided and short-beaked common dolphins);

- 5 cetacean species which are sighted quite often, but which have problems of identification (Sowerby's beaked whale, sei whale), a restricted temporal presence (bottlenose dolphins, blue whales) or a distribution distinct from the northern bottlenose whale, which determined much of the distribution of effort (the minke whale);

- 7 cetacean species which are known to be, or are very likely to be, rare visitors (right whale, harbour porpoise, killer whale, white-beaked dolphin, Risso's dolphin, pygmy sperm whale, dwarf sperm whale);

- 2 cetacean species whose presence is suspected but which have not been positively identified (Blainville's beaked whale, Fraser's dolphin);

- 2 abundant or common breeding pinniped species (grey and harbour seals);

- 2 fairly commonly sighted migratory pinniped species (harp and hooded seals);

- 1 rarely observed migrant pinniped (the ringed seal).

It is impossible to compare diversity in the study area with other regions in a rigorous manner, but the Gully seems to have a higher cetacean diversity than other areas, even much larger ones, in the northwest Atlantic (using definitions of "common" of scientists in different regions):

- Gully area: 8-13 common species (depending on how many of category B are included)

- Scotian Shelf (excluding Hooker *et al.*'s study area): 5 species sighted more than once during 1,121 daylight hours of transit to and from the Gully (Table 9.0.4)

- Gulf of Maine: 6 "common" species (Katona *et al.*, 1983)

- Bay of Fundy: 6 "common" species (Gaskin, 1983)

- Shelf-edge (91-2000m) region from Cape Hatteras to George's Bank (62,100km): 12 "common" species (Hain *et al.*, 1985)

- Newfoundland-Labrador (inshore and offshore waters): 9 "commonly sighted" species (Lien *et al.*, 1985)

Pinniped diversity (with 2 breeding species, 2 regularly sighted migrants, and one rare migrant) is no different to that of other parts of the eastern Scotian Shelf, and similar to other eastern Canadian waters.

9.0.5.2 Density

The study area contains the world's largest breeding colony of grey seals, and a large proportion of the Canadian population of this species. In the study of Whitehead *et al.* (1993) sperm whales were heard much more frequently (per monitoring session) in the northern part of the Gully than elsewhere on the Scotian Shelf. The sighting rates of cetaceans in Hooker *et al.*'s study area are compared to those on other parts of the eastern Scotian Shelf in Table 9.0.4. Data for species which were the objects of study in the Gully but not outside (sperm and northern bottlenose whales) cannot be compared legitimately in this way. Differences between sighting rates inside and outside Hooker et al.'s study area were significant ($P<0.05$) for all the other species with sufficient data to make a likelihood ratio G-test valid (fin whale, humpback whale, minke whale, pilot whale, striped dolphin, white-sided dolphin, and common dolphin). All of these species, except the minke whale, were sighted more frequently inside Hooker et al.'s study area than elsewhere on the Scotian Shelf. There may be a bias towards the Gully because of generally better sighting conditions, although this is unlikely to be large (probably less than a factor of 1.5). Even with these provisos considered, it is clear from Table 9.0.4, that the density of most species of cetaceans in the Gully area is substantially higher than on other parts of the Shelf.

We were able to make a quantitative comparison of the density of large whales in the Gully with that on other parts of the edge of the Scotian Shelf using the data of the Blandford whalers summarized by Sutcliffe and Brodie (1977). We divided the shelf edge region up into contiguous areas each roughly the size of the Hooker *et al.* study area (as shown in Fig. 9.0.4). For each area we calculated the distance to the whaling station at Blandford, and the number of whales killed. These are plotted against one another in Fig. 9.0.5. As noted by Mitchell (1974), the whalers concentrated their attentions on sea areas within about 150 nautical miles from the whaling station, and the catch of whales (logged) falls roughly linearly with the log of the distance from Blandford (Fig. 9.0.5; the power relationship has exponent -2.31). The catch of whales in the Gully is approximately twice what would be expected from this relationship (Fig. 9.0.5), and significantly higher than in the other shelf edge areas, accounting for distance from Blandford (Analysis of Covariance, one-tailed $P=0.045$). Thus large whales seem to have been more available to the Blandford whalers in the Gully than in other similar-sized areas along the edge of the Scotian Shelf (including the entrance of the Fundian Channel). It can be seen, in Fig. 9.0.6, that catches in the overall Gully region are concentrated within the deep canyon and northern basin of the Gully, mostly over depths greater than 200m and that the high abundance of whales in the Gully area indicated in Fig. 9.0.5 is not an artifact of where the boundary lines (indicated in Fig. 9.0.4) were drawn.

Other measures of the high density of cetaceans in the Gully area include:

- the almost 100% record of sighting northern bottlenose whales in the deep canyon on any survey of a few hours or more in good sighting conditions;

- the high rate (50-100% of listening stations depending on area) at which sperm whales are heard through hydrophones in the northern part of the Gully (Whitehead *et al.,* 1992);

- the high sighting rates of Atlantic white-sided and short-beaked common dolphins (Gowans and Whitehead, 1995).

9.0.5.3 Significance for particular species

The significance of the study area for different marine mammal populations can be tentatively classified as follows:

Species with populations which breed in the study area, and seem very dependent on habitat within it:

- Grey seal
- Harbor seal
- Northern bottlenose whale

Species for which the Gully is the most important habitat so far identified on the Scotian Shelf and one of the most significant areas in Canadian waters:

- Sperm whale
- Short-beaked common dolphin
- Striped dolphin

Species for which the Gully is important habitat on the Scotian Shelf:

- Fin whale
- Humpback whale
- Atlantic white-sided dolphin

Common species for which the study area does not seem to contain particularly important habitat:

- Pilot whale
- Minke whale
- Harp seal
- Hood seal

Unknown significance of study area:

- Beaked whales of genus *Mesoplodon*

9.0.6 Implications of marine mammal presence for other parts of the Gully biota

The distribution of marine mammals correlates very well with that of their important resources. The large number of pinnipeds in the study area is directly related to the presence of suitable breeding areas on Sable Island. Similarly, the presence of cetaceans implies an important resource which is almost certainly food. In most cases we know little about the diets of the cetaceans that use the Gully. However a few species are sufficiently stenophagous that their presence in the Gully allows inferences about the increased availability of certain organisms. For instance, that blue whales are found in the Gully in August implies that there are concentrated schools of euphasiids in the area at that time. The consistent presence of northern bottlenose whales in the deep waters of the Gully throughout the year is particularly interesting as it suggests a substantial biomass of the deep-water squid *Gonatus fabricius*, which seems to be their predominant prey in the region (S. Hooker et al., unpublished data). Overall, the large numbers of cetaceans of many trophic habits found in the Gully indicates enhanced biomass of many types.

9.0.7 Cetaceans in canyons, large and small

Kenney and Winn (1987) tested the hypothesis that canyons are good cetacean habitat using data from the 'CETAP' surveys of the edge of the US east coast continental shelf. They found, contrary to expectation, that cetacean biomass was significantly less in areas containing canyons than adjacent parts of the shelf. Kenney and Winn (1987) caution that the biological significance of their result may be relatively minor, as there was no significant difference between canyons and non-canyon areas for any species (except *Stenella* spp. which were more abundant in canyon areas), and no significant differences for any separate season. However, their findings seem in conflict with our result that large cetaceans were about twice as available to Nova Scotian whalers in the Gully than along other parts of the edge of the continental shelf, as well as suggestions that other submarine canyons and their environs support increased numbers of cetaceans: Kaikoura Canyon, New Zealand (Donoghue, 1996); Trincomalee Canyon, Sri Lanka (Alling, 1986 and Gordon, 1991); and Monterey Canyon, California (Advanced Research Projects Agency, 1994).

We suspect that some of this apparent contradiction may be due to the different sizes of canyons. Therefore we compared dimensions of the canyons used by Kenney and Winn (1987) as well as the Gully, and Kaikoura, Trincomalee and Monterey canyons, as defined by the 200 m and 1000 m contours (Table 9.0.5).

The Gully is the largest of the measured canyons in three of the four measured dimensions, and is particularly prominent when defined by the length of the 200 m indentation, which, at 70.7 km, is over twice that for any of the other canyons. Its breadth is only rivaled by Trincomalee canyon. Although longest according to the 1000 m contour, it is closely rivaled by Hudson canyon. The Gully's width when defined by the 1000 m contour, is not unusual among these canyons.

The Monterey, Trincomalee and Kaikoura Canyons do not appear obviously different in dimension from those measured by Kenney and Winn. However unlike the US east coast canyons and the Gully, these are adjacent to land, and so in very different physical settings. Thus it is probably unwise to extrapolate results from the US east coast canyons to the Gully, because of its much greater size, and to Kaikoura, Trincomalee and Monterey canyons because of their proximity to shore. Both size and distance from shore will affect physical oceanography, and thus potentially the resources available to cetaceans.

9.0.8 Biological Boundaries

In considering boundaries our goal was to suggest parts of the study area that seemed most important for pinnipeds and for cetaceans, and whose degradation would have the most severe consequences. Two such areas stand out:

Sable Island and adjacent waters: The island and its surrounding waters are vital habitat for the two species of breeding pinniped.

The Gully canyon and northern basin: All cetacean species for which the study area is prime breeding habitat (northern bottlenose whale), or the most important habitat so far identified on the Scotian Shelf (sperm whale, short-beaked common dolphin, striped dolphin) have primarily deep water distributions. In the case of sperm whales, waters greater than about 200m deep seem to be important. All cetacean species that have been seen in Hooker *et al.*'s study area, including those without clear depth preferences, are sighted in these deep waters. The catches of large cetaceans in the study area were also concentrated in the deeper waters of the canyon and the northern basin (Fig. 9.0.6).

Therefore, if the goal is to protect vital cetacean habitat, we suggest the following boundaries (Fig. 9.0.1):

- A core area of those waters deeper than 200m with latitudes greater than 43° 40' N and longitudes between 58° 30' N - 59° 30' W;

- A buffer zone around this core area to protect it from threats which act at long ranges (such as noise, chemical pollutants). The width of the buffer zone would depend on the range of the threats.

We recognize that boundaries must consider other aspects of the natural system as well as human activities, and it may be more practical to have straight boundaries.

Table 9.0.5. Dimensions of submarine canyons used in the analysis of Kenney and Winn (1987), together with Monterey, Kaikoura, Trincomalee canyons and the Gully. Dimensions (in km) are approximate landward indentations of 200 m and 1000 m contours from general shelf-edge trend ("length", as in Kenney and Winn), and breadth of canyon, as defined by the 200 m or 1000 m contour, half way into the indentation ("breadth"). Measurements were made from nautical charts by S. Dufault.

	200 m contour		1000 m contour	
Canyon	**Length**	**Breadth**	**Length**	**Breadth**
Norfolk, US	15.2	2.9	6.9	1.3
Washington, US	8.8	4.5	10.2	2.6
Baltimore, US	13.7	4.2	10.5	1.7
Wilmington, US	12.2	8.5	10.7	2.2
Hudson, US	31.2	5.0	25.2	6.0
Veatch, US	8.7	5.3	6.8	2.3
Hydrographer, US	17.0	2.4	11.2	2.8
Welker, US	9.2	7.0	8.4	2.3
Oceanographer, US	21.8	4.2	18.3	2.8
Gilbert, US	11.2	6.0	13.0	3.3
Lydonia, US	18.0	4.0	10.0	3.1
Powell, US	8.7	5.2	6.8	2.0
Corsair, US	12.3	3.3	5.8	4.4
Monterey, US	24.8	8.1	16.9	3.0
Trincomalee, Sri Lanka	13.5	3.0	4.5	4.5
Kaikoura, New Zealand	13.0	15.0	15.8	3.5
The Gully, Canada	**70.7**	**16.4**	**28.4**	**2.4**

9.0.9 Data Deficiencies

Our review of the marine mammals of the Gully area is hampered by deficiencies, of which we think the following are most significant:

Lack of data on at-sea distribution of pinnipeds: Although recent studies on adult grey seals have begun to address this deficiency, there is a nearly complete lack of information on the at-sea distribution of harbour seals. Such studies could be important in understanding the causes of the dramatic population decline in this species.

Lack of data on cetacean distribution outside the summer months: Aerial surveys would be a good way to get such information. Parsons (1995) showed how valuable a short aerial survey of the Gully with experienced observers can be. Records collected by experienced and interested fishermen could also help fill this gap.

Lack of information on how cetaceans use the Gully area: For instance, which species breed there? For most species we do not know how individuals use the Gully. Are the humpback whales observed in the Gully passing through or resident for much of their summer feeding season? Do they return in subsequent years? Additional photo-identifications should help address these issues.

9.0.10 Acknowledgments

We thank Robert Kenney for sending us data, and Susan Dufault who checked the manuscript.

9.0.11 Summary

- Available evidence strongly suggests that the Gully/Sable Island area is the most important habitat for both cetaceans and pinnipeds on the Scotian Shelf.

- The area contains one of the longest and most productive pinniped research programmes anywhere in the world, as well as the only long-term study of any beaked whale species.

- The area is notable for:
  - ⇒ a high diversity of cetaceans (8-13 common species)
  - ⇒ a high density of cetaceans in the Gully canyon. Densities of most species of Cetacea are considerably higher in the Gully than on other parts of the eastern Scotian Shelf, and large whale density is higher in the Gully than elsewhere along the edge of the Scotian Shelf (including the entrance of the Fundian Channel).
  - ⇒ a high density of grey seals breeding on Sable Island
  - ⇒ particular significance (within a Canadian context) for:
    - Grey seals
    - Harbour seals
    - Northern bottlenose whales
    - Sperm whales
    - Striped dolphins

Atlantic white-sided dolphins
Short-beaked common dolphins

- The most significant marine mammal habitat within the area is:
  - ⇒ for pinnipeds: Sable Island and surrounding waters
  - ⇒ for cetaceans: the deep canyon and northern basin of the Gully (>200m in depth)

9.0.12 References

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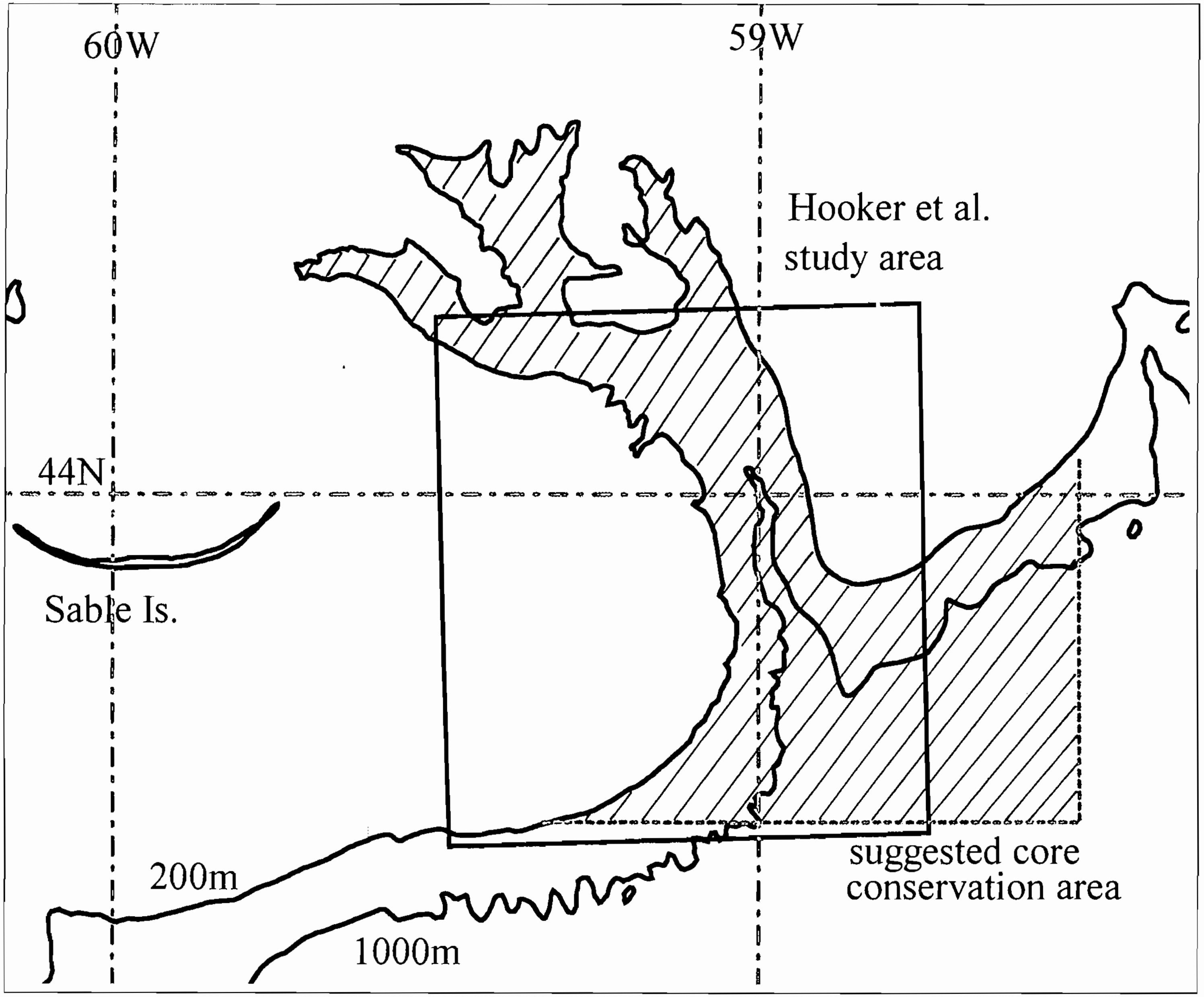


Fig. 9.0.1. Study area, showing Sable Island, 200m and 1,000m contours, the Gully Canyon, Hooker *et al.*'s (Submitted m/s) study area, and a suggested boundary for a core conservation area for cetaceans.

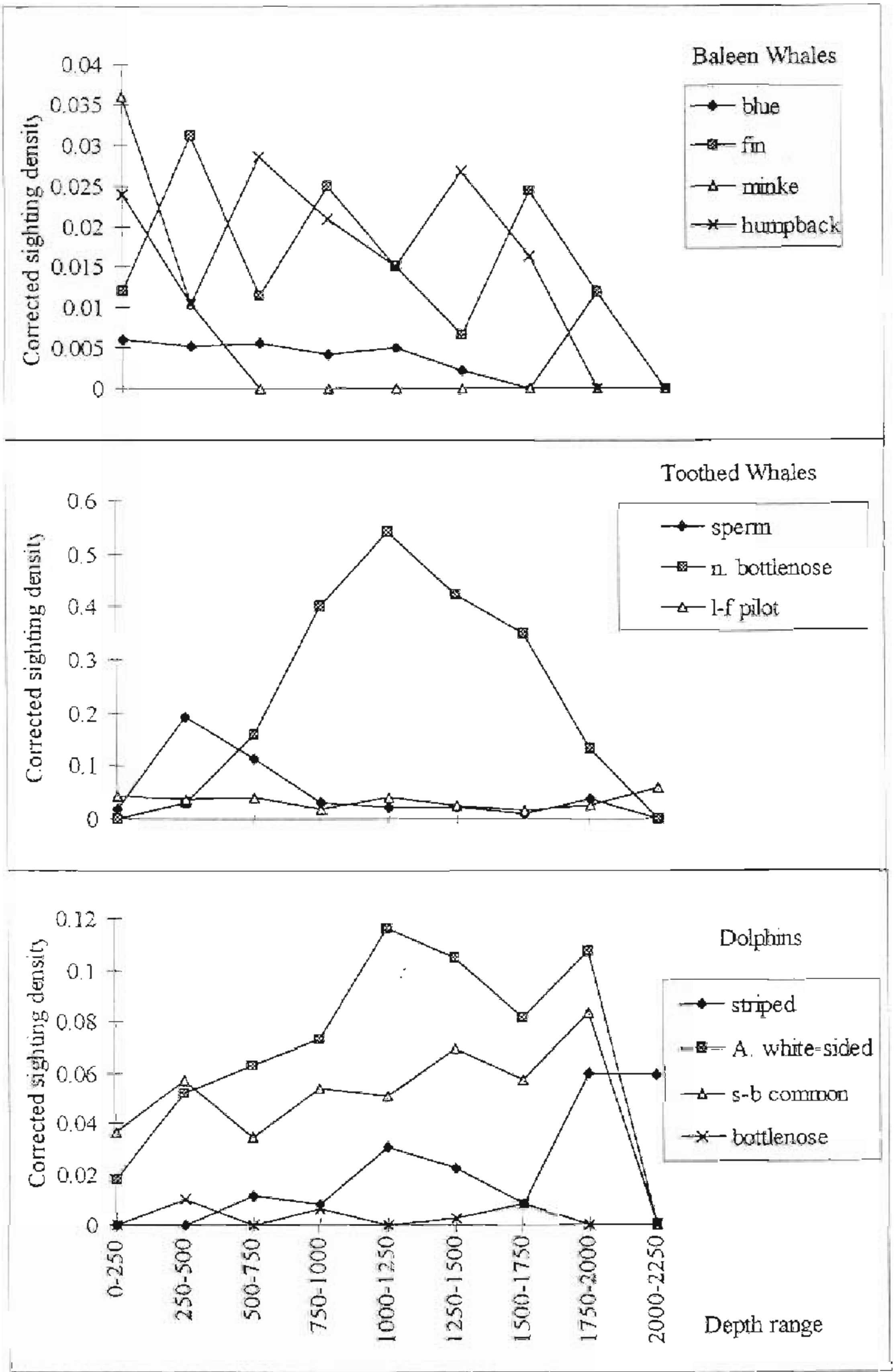


Fig. 9.0.2. Sighting rates of cetacean species (in sightings of groups per hour of effort) in Hooker *et al.*'s study area with water depth (Fig. 9.0.2a) and calendar month (Fig. 9.0.2b).

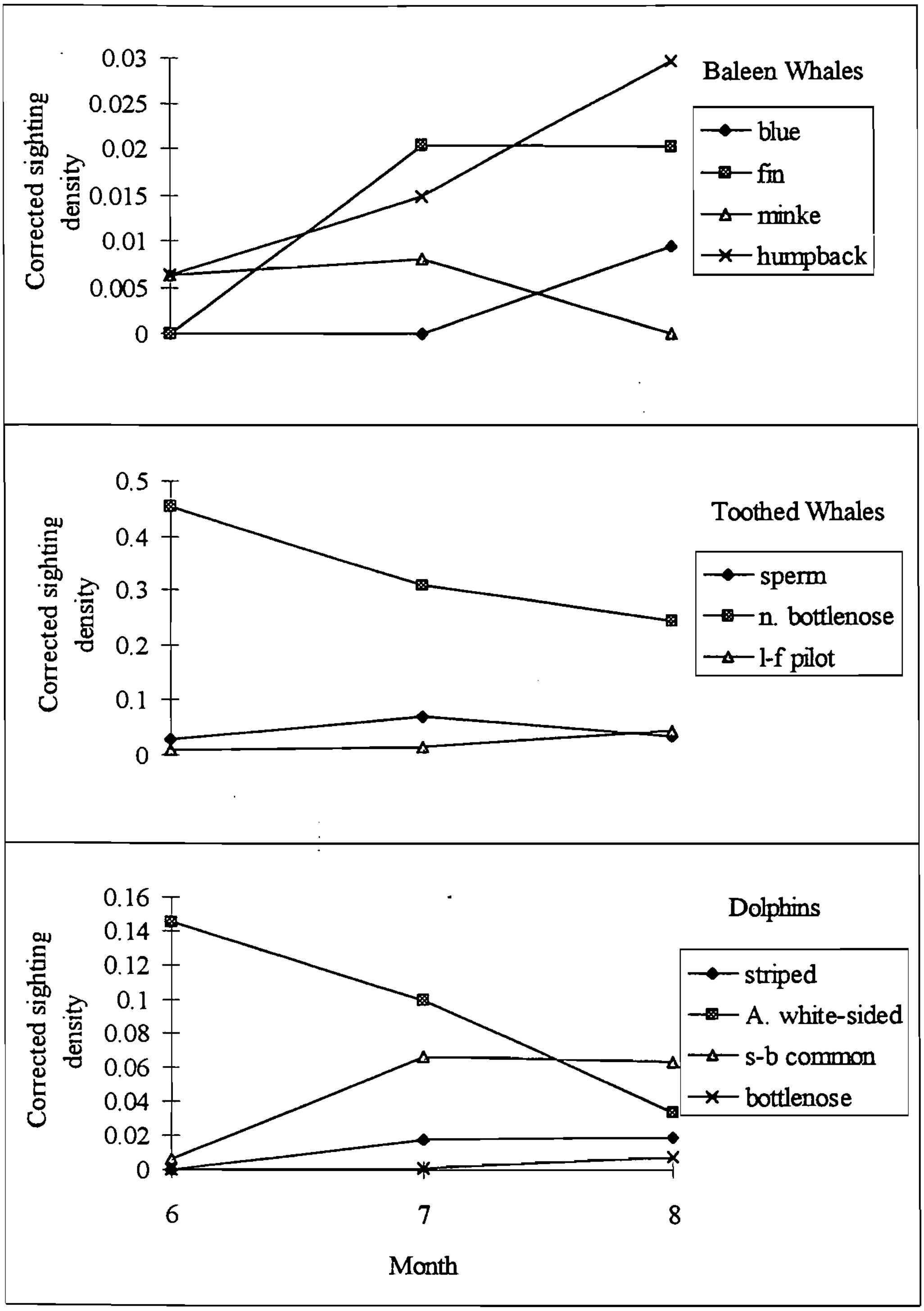


Fig. 9.0.2. (Continued)

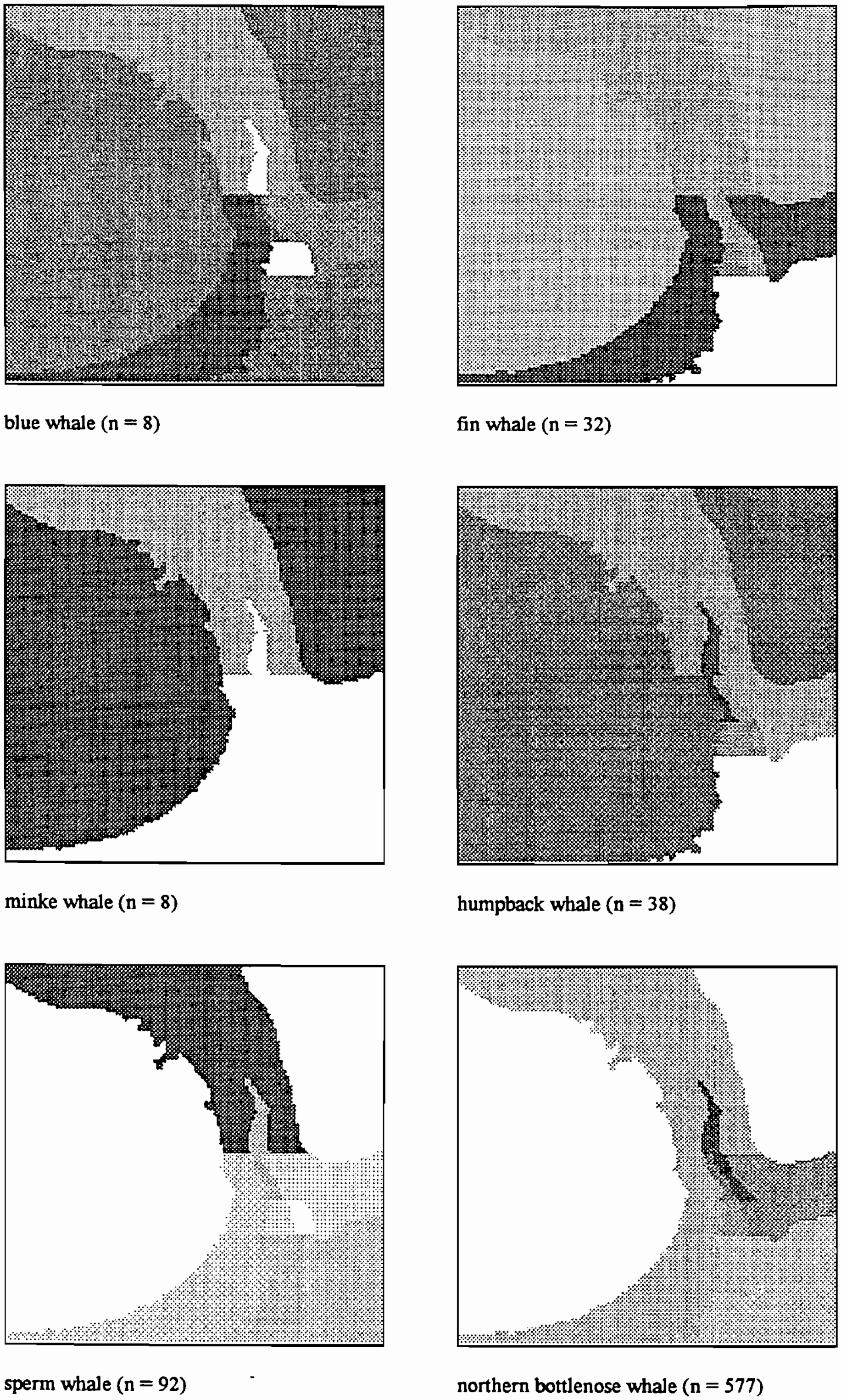
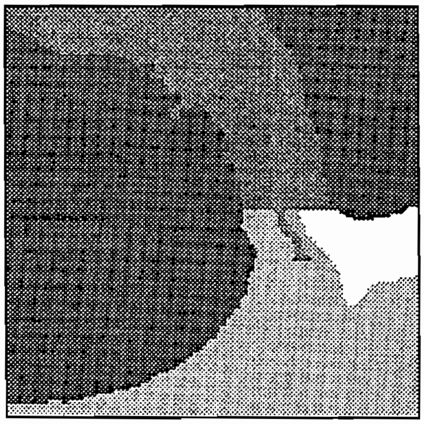
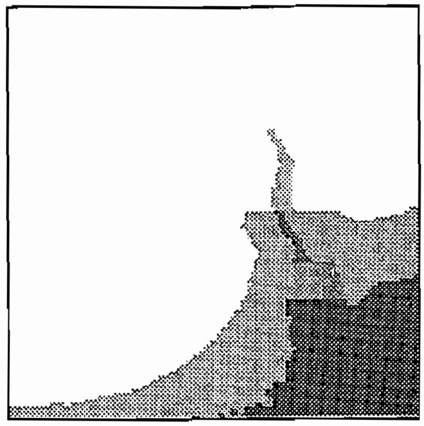


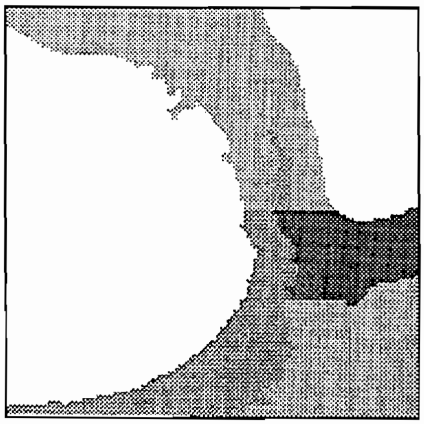
Fig. 9.0.3. Maps of distributions of cetacean species in Hooker *et al.* study area using regions defined by depth (0-200m, 200-1,000m, >1,000m), and north-south and east-west boundaries in the centre of the Gully canyon. For each species, shading ranges from black for the region of highest sightings per hour of effort to white for regions without sightings of the species.



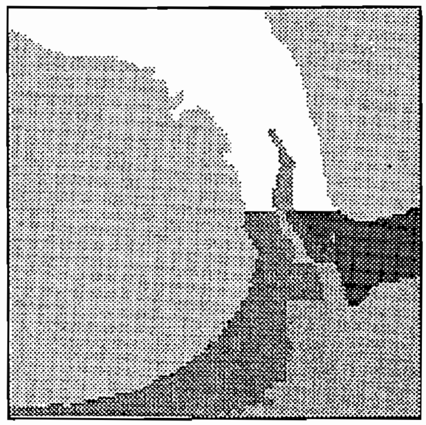
long-finned pilot whale (n = 54)



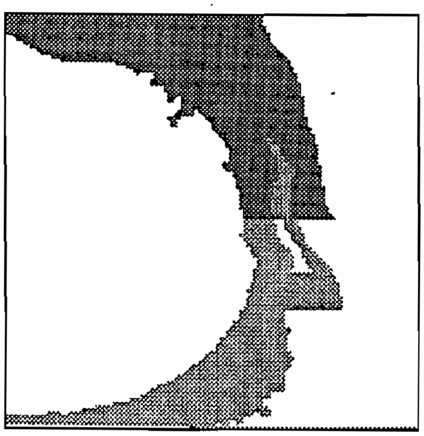
striped dolphin (n = 29)



Atlantic white-sided dolphin (n = 148)



short-beaked common dolphin (n = 104)



bottlenose dolphin (n = 7)

Fig. 9.0.3, (Continued)

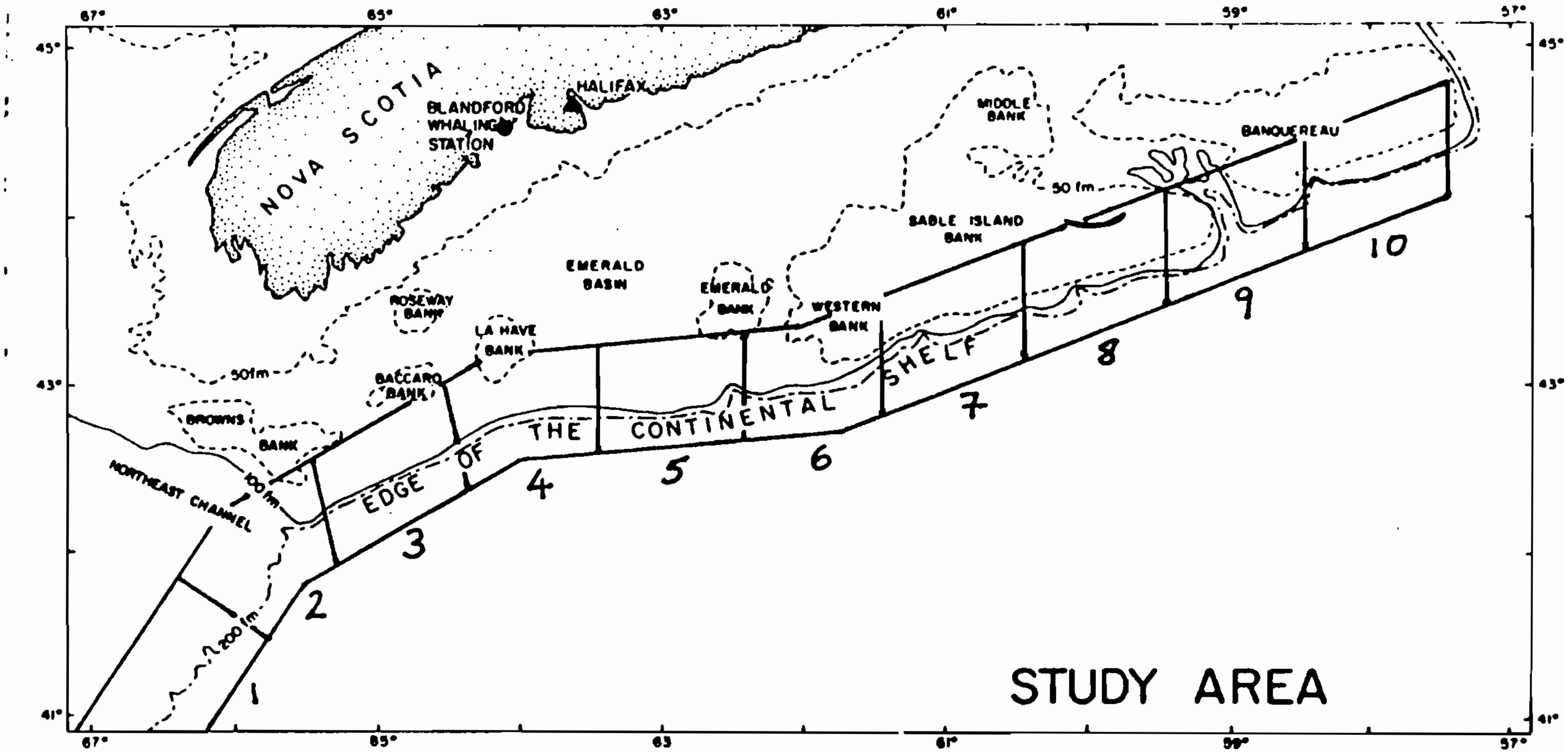


Fig. 9.0.4. Map of Scotian Shelf showing Blandford whaling station and areas used (marked by integers 1-10) for comparison of numbers of whale kills along the edge of Shelf (see Fig. 9.0.5).

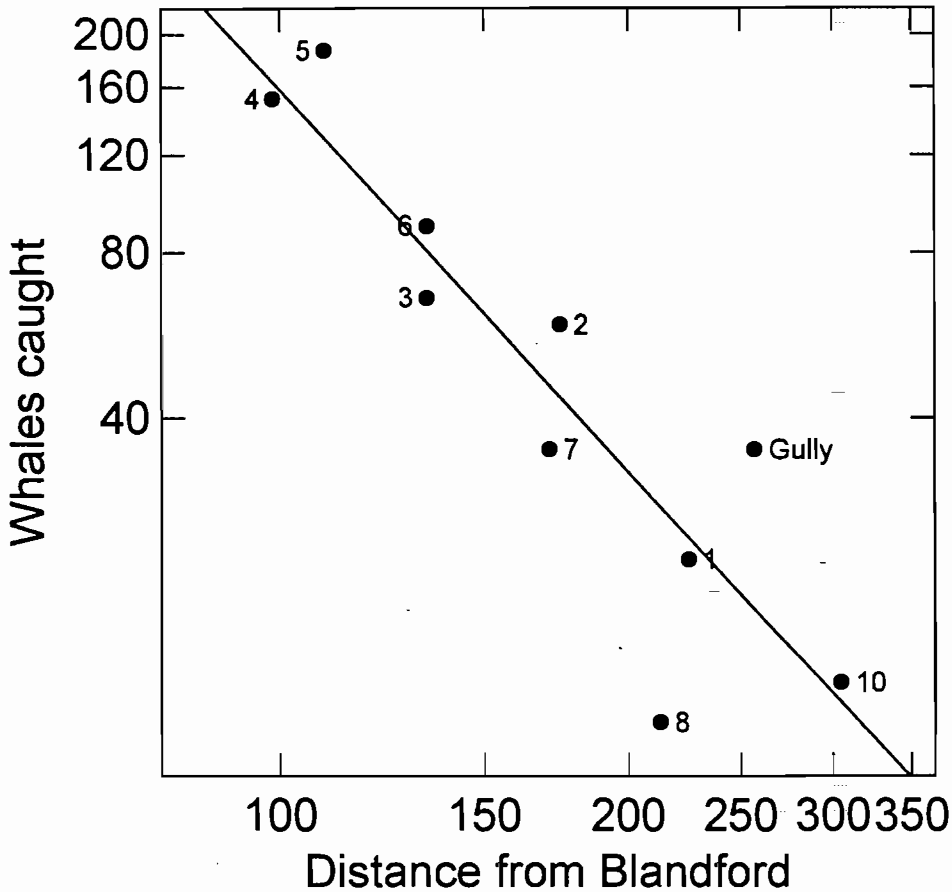


Fig. 9.0.5. Number of whales killed by whalers working from Blandford, Nova Scotia, in ten areas along the edge of the Scotian Shelf (marked by integers 1-10, and shown in Fig. 9.0.4) plotted against distance, in nautical miles, from Blandford (from Sutcliffe and Brodie 1977). A log-log regression line is also shown.

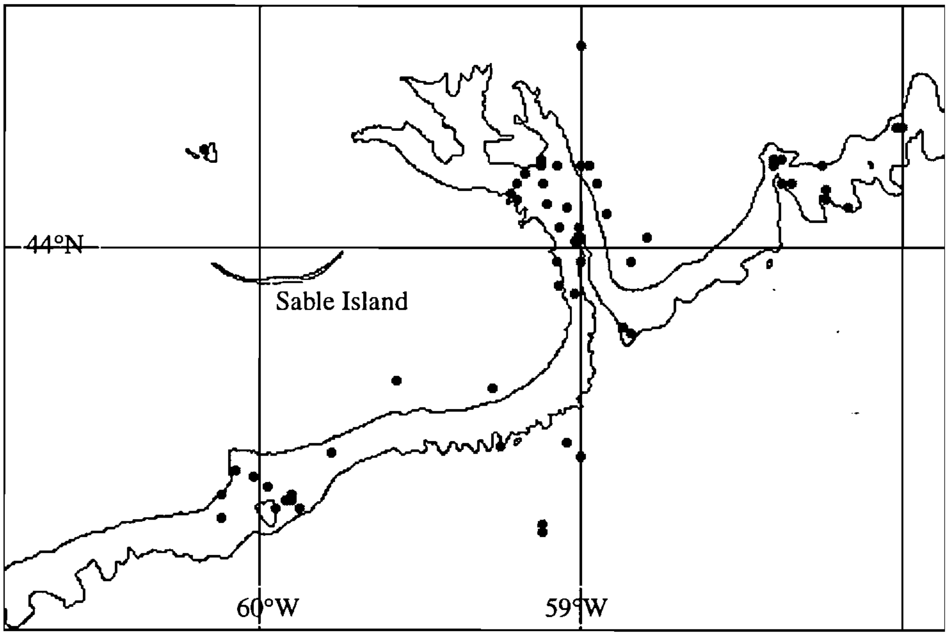


Fig. 9.0.6. Distribution of Blandford Whaling Station catches around the Gully area (1966-1972).

10.0 Ecosystem Classification

10.1 A System Planning Approach to Marine Classification and Boundary Considerations

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10.1.1 Defining Marine Representivity and a Hierarchical Classification System

As our understanding of the relationships between biological characteristics and physical factors within ecosystems has evolved, so has our ability to use ecological principles to determine which are the more appropriate areas or spaces for protection. In terrestrial ecosystems, the term 'enduring features' has a specific meaning that incorporates those 'enduring' elements of the landscape; in terms of human life spans, these do not change, and they are known to control and influence the diversity of biological systems. For the purposes of identifying terrestrial protected spaces, 'enduring features' are closely associated with terrestrial abiotic (or physical) features (Kavanagh and Iacobelli, 1995). This includes such stable features as landforms, physiography and soils that have been demonstrated to play a significant role in the distribution and diversity of flora and fauna at small to medium scales. Furthermore, these features can be readily mapped in a two dimensional format, and there are considerable data at various scales throughout Canada to accomplish such mapping.

Marine systems are basically different from terrestrial ones, but they also consist of interacting physical and biological components. However marine systems exhibit more complex spatial-temporal relationships than terrestrial systems; this has made the development of comparable ecological classification techniques for marine systems more difficult. Furthermore, the concept of stable, enduring features as a basis of delineating marine natural regions is made more difficult, because two very different communities - the pelagic and the benthic - exist in three and two dimensions respectively, with dynamic and variable interactions between them. Unlike terrestrial enduring features, the equivalent ecological attributes of marine ecosystems may change spatially and temporally in predictable or unpredictable ways, particularly in pelagic seascapes. In marine environments two broad sets of attributes can be recognized:

1. more-or-less enduring physiographic features such as geographical position, geological history, bathymetry, slope, sediment particle size, substrate heterogeneity (the closest analog of terrestrial enduring features);

2. generally less enduring, but recurrent oceanographic features or processes such as

salinity, water masses, temperature, dimensional segregation, stratification, light penetration, and exposure that may not be at all permanent, but which may re-occur daily, monthly, seasonally or yearly in predictable fashion in the same geographical area.

Using the terrestrial representation paradigm (Hill, 1961) as a starting point, a marine classification framework has been developed by Geomatics International (1996) and modified by Day and Roff (1998). Their approach to marine classification utilizes the enduring and recurrent oceanographic and physiographic features of the marine environment. The framework is a natural hierarchical classification of marine environments which leads to the delineation of marine representative units (MRUs). When applied, this framework is believed to capture and represent the ecological diversity of marine communities in Canadian waters. The framework has been developed through the collaborative efforts of World Wildlife Fund Canada, consultants and various academic and agency personnel.

The framework that has been applied is basically a "community level" analysis of marine systems and differs from classification previously developed (e.g. Harper et al. 1993) in a couple of ways:

- it uses physical attributes alone and essentially predicts the expected biocoenosis (community type) on the basis of documented habitat characters (i.e. reconstructing the biotopes). A major advantage of this approach is that MRUs can be identified from already mapped geophysical features, or by remote sensing of appropriate surrogate variable. Most importantly, boundaries between community types can be functionally defined, even where detailed biological data is lacking;

- it recognizes and classifies the two major marine communities (the pelagic realm and the benthic realm) which have entirely different communities and are driven by different processes.

There are six levels in the hierarchical classification (Table 10.1.1).

Level One: separates all aquatic environment into one of the following:

- Lotic (streams and rivers)
- Lentic (lakes)
- Estuaries
- Marine

Level Two: separates the lentic (lakes), estuaries and marine environments on a geographical/temperature basis:

- Lentic	Arctic
  Sub-Arctic
  Temperate
  (no sub-tropical in Canada)

- Estuaries — Arctic (seasonal ice)
  Sub-Arctic (Atlantic)
  Temperate (Atlantic)
  Temperate (Pacific)
  (No tropical in Canada)

- Marine — Arctic (permanent ices)
  Arctic (Atlantic)
  Sub-Arctic (Atlantic)
  Temperate (Atlantic)
  Sub-tropical (Atlantic)
  Temperate (Pacific)

Level Three: is a dimensional segregation that separates all relevant communities in Levels One and Two in Pelagic and Benthic realms.

Level Four (Benthic): is a vertical division that distinguishes between depth classes on the substrate.

Light condition is particularly relevant to benthic communities and is used to delineate the sub-littoral euphotic zone (<50 m). Between 50-200 m is the dysphotic zone where light is still present, but is too low in intensity to support plant growth; below this again, the great majority of the oceans' depths lie within the aphotic zone, where no light penetrates. Rather more arbitrarily, the benthos is also divided into the bathyal zones (200m to 2000m) and abyssal/hadal zones (>2000 m).

Level Four (Pelagic): is a vertical division which distinguishes between depth classes within the water column.

Within the water column, depth, pressure, light penetration and turbidity are all inter-correlated. Moving from the shoreline onto the Continental Shelf and then offshore beyond the Continental Slope, water column depth increases, light penetrates further (because of grater water clarity and lower turbidity), and pressure increases with depth. Water column depth itself therefore acts as a suitable discriminant of community type, also accounting for the correlated factors of light penetration and pressure.

Level Five (Pelagic): distinguishes whether water is stratified, non-stratified (well-mixed), or frontal (also referred to as "transititional").

The vertical stratification of a water column separates its communities both spatially and temporally. Stratified and non-stratified waters will differ both in their annual productivity regimes and in their annual community structures. Thus, many banks and coastal regions of high tidal amplitude will remain unstratified and may retain or accumulate populations of important pelagic species *(e.g. larval fish, lobsters, etc.)*

Level Five (Benthic): segregation is based on substrate type

The substrate within specific deposition and erosional regimes tends to be relatively constant and is a major factor influencing the biota associated with the bottom. There is a relation between sediments and water motion and the latter may be significant both as an erosional force as well as one which brings food and nutrients to the zone. There are obvious difference between rocky, sandy and muddy shores though in deep waters the distinctions are reduced and only muds and sands are distinguished. Fine sands, silts and clays are found in the deeper regions.

Level Six (Benthic): distinguishes between degree of exposure for the intertidal and immediate sub-tidal areas; or the degree of slope in water >50 m.

Stable marine slopes for sediment accumulation are much lower angles than terrestrial slopes for similar grain sizes. Mass movements of materials have been known to occur at angles as low as 1°.

Marine biological ecosystems include extremely disparate communities within the same 'area' as defined using two-dimensional mapping. It is therefore difficult to identity boundaries in marine systems because they are so dynamic (e.g., Tremblay and Roff, 1983), particularly when using traditional mapping techniques. Nevertheless, it is still appropriate to examine marine ecological characteristics and to define representative and distinctive communities in terms of their relationships to enduring physical factors or recurrent processes. While such a classification will not account for large scale or unpredictable disturbances, like hurricanes, communities generally re-establish themselves in due course and due composition based on the enduring physiographic and recurrent oceanographic factors.

This proposed hierarchical classification framework is theoretical. However, it is currently being tested on a region of the Atlantic coast known as the Scotian Shelf as part of a collaboration between World Wildlife Fund Canada, consultants, and various academic and government agency personnel. The results of applying this framework to the Scotian Shelf will be the selection and delineation of marine natural regions and MRUs within the study area. As a feature of the Scotian Shelf, the Gully will be part of this evaluation.

10.1.2 Boundaries Refined by Ecological Principles

Once enduring features are mapped, the boundaries of a proposed *representative or distinctive protected area* need to be evaluated using ecological criteria that will support the long-term viability of the protected area. Such long-term protection of biodiversity requires that important ecological processes are maintained. As a result, protected areas systems planning should reflect the scales at which these ecological processes occur. Protected areas must be judged to be in the right place, of the right size, and the right configuration to help protect biodiversity over the long-term.

According to Noss (1995), "simply representing the enduring features of the vegetation of a natural region in a reserve network will not guarantee that all species native to the region will survive there or be able to migrate elsewhere when conditions change. Nor does representation by itself assure the maintenance of natural processes necessary to keep ecosystems and their component populations health". Subsequently, a complementary goal to adequate representation is to maintain ecological integrity. The Canadian Council on Ecological Areas (CCEA) defines ecological integrity as "the capability of an ecological area of supporting and maintaining processes and assemblages of organisms (communities) that have a composition and function organization comparable to that of similar landscape units of the region." (Gauthier, 1992).

WWF is currently refining the methodology that will use the hierarchical classification framework to identify marine natural regions and marine representative units (MRUs) and assess marine protected area proposals from an ecological perspective. In a report prepared for WWF, Shackell *et al.* (1996) examined ecological principles that could be used as criteria in defining boundaries for marine protected areas (MPAs). These principles are discussed in the context of *core* and *buffer* zones which would allow for several levels of protection (Salm and Clark, 1984; Noss, 1995). The purpose of a core zone would be to protect fully the representative biodiversity and physical features and to allow for natural rates of variability. The core zone would include the representative area itself. The buffer zone is designed to surround the core zone to safeguard it against harmful human activities and to monitor activities which may affect the core zone. The following list of ecological principles is drawn from their report.

10.1.3 List of Ecological Principles for Boundary Considerations

10.1.3.1 Habitat Heterogeneity and Resilience

Because organisms are associated with a given set of physical factors, physical gradients (temperature, salinity, depth, current strength, sediment type) reflect habitat heterogeneity within a seascape. A scientific hypothesis is that biological diversity and community structure contribute to resilience. The principle is that a system comprised of diverse components is more resilient to unfavorable environmental conditions than a simpler system.

The concept of increased resilience with increased diversity can be applied to natural systems from the genetic to the global scale; whether the concept applies depends on the scale and the system. When applied to the scale of an ecologically representative area, the resilience of the entire area increases with an increase in the number of habitats within an area. One method for protecting natural areas is to including a diverse array of habitats within an ecologically representative area. In this way, the shape and size of a protected area would be designed to maximize habitat heterogeneity among seascapes.

<u>Implications For Boundaries</u>

Habitat heterogeneity in a protected area is maximized by including environmental gradients within the core (Rowley, 1994 and Noss, 1995). Depth is related to salinity, temperature, light levels, current strength and sediment type. Interactions among physical factors results in an array of habitat types, which are further modified by biological processes. In offshore regions, the maximization of habitat heterogeneity can be generally accomplished by representing the entire depth gradient, and corresponding surface waters, within the core area. In the event that other biophysical factors are sufficiently known to alter habitat heterogeneity, that knowledge should be used to design core and buffer boundaries.

10.1.3.2 Water movement

In offshore regions, wind-driven, density-driven and tidal currents are a major determinant of the abundance and distribution of flora and fauna on a regional scale. Autotrophic production in surface waters is the basis of offshore food chains (see Fader, 1991 for a description of chemosynthetically-based biological communities on the seabed). Photosynthetic production is influenced primarily by light, which attenuates in deeper waters. Within a region receiving relatively constant surface light, the availability of nutrients becomes important; nutrients are distributed by horizontal and vertical mixing (see Sections 6.1 - 6.3).

Turbulence affects primary productivity by concentrating or dispersing nutrients and/or the plankton itself. For example, turbulence can cause phytoplankton cells to sink to depths at which there is insufficient light to support photosynthesis, or turbulence can distribute nutrients to the euphotic zone. Generic forms of turbulence include: upwelling (upward flow of nutrient-rich water), Langmuir cells (wind-generated turbulence that results in circulating vertical cells), internal waves (subsurface waves generated by the density difference between two water masses), fronts (boundaries between two distinct water masses), and gyres (rotating circulation as a result of a balance between the force of the earth's rotation and the force of a pressure gradient, *i.e.* geostrophic balance).

The distribution and rate of phytoplankton growth determine secondary production. In turn, the distribution of planktonic secondary producers is determined by water movement. For example, copepods are advected onto the Western Bank of Sable Island Bank from the northeast, and are associated with high concentrations of cod (*Gadus morhua*) larvae. Presumably, the copepods and larvae are entrained in a gyre over Western Bank (McLaren and Avendano, 1995).

The organic matter which falls to the ocean floor (dead flora and fauna, fecal pellets, exudate, etc.) is used by benthic animals as food. Benthic communities are influenced by the rate and type of organic matter flux as determined by water movement, depth, temperature, and bacterial consumption en route. The extent of benthic/pelagic coupling varies among systems (see Section 6.4.1).

Benthic communities are also influenced by sedimentary characteristics (*e.g.* deposit feeders predominate in mud, filter feeders predominate in sand). Sediment type and size are a result of geological processes, and are continually modified by water currents. The general rule is that sediment size is larger in high energy (strong currents) environments and smaller in low energy (weak currents) environments. Wind-driven currents decrease with depth and so have less influence in deeper water, although all currents are commonly modified by topography (Pinet, 1992). On a smaller scale, biological interactions, such as predation and bioturbation

(Posey, 1990) and behavior (Langston *et al.* in press) can regulate the composition of benthic communities.

Implications for Boundaries

Water movement and depth influence the extent of benthic-pelagic coupling, and levels of productivity. Physical mechanisms of turbulence and consequent productivity and distribution vary on spatio-temporal scales. Both the benthic and pelagic ecosystems should be included in the core area.

10.1.3.3 Spatial/Temporal Environmental Variability

Temperature, salinity, and therefore density vary on spatio-temporal scales (see Section 6.1). Such variability can result in spatial shifts in the distribution of marine species.

Implications for Boundaries

The core and buffer zones of the Gully should be sufficiently large to accommodate variation in physical factors.

10.1.3.4 Life History Strategy of Marine Species

Many of the abundant marine species are highly fecund but larval survival is low and highly variable. This life history pattern is common because the marine environment is variable. Organisms optimize the chances of survival by spawning a large number of eggs over time and space to counteract environmental variability. That is, if organisms are highly fecund, there is a higher probability that at least some of those eggs will experience a favorable environment and survive to reproduce.

Implications for Boundaries. See 10.1.3.5 below.

10.1.3.5 Migratory Behaviour and Larval Dispersal

Many of the larger species migrate long distances either seasonally or during different life history stages. Both large and small species can have pelagic larvae which disperse widely (see Section 7.1).

Implications for Boundaries

Protection of widely-ranging populations may be achieved through establishing a network of ecologically representative areas within a region, and through the use of high conservation standards outside of protected areas.

10.1.3.6 Variable Food Webs

Marine species distributed throughout the water column are linked through the food web.

Primary producers (phytoplankton and chemoautotrophs) are food principally for zooplankton and bottom-dwelling invertebrates, which in turn are food for others (crustaceans, fish, seabirds, mammals).

It is important in considering the boundaries to recognize that the strength of various linkages among groups in the food web is not fully understood. For example, researchers have only recently discovered that bacteria can play a far greater role in production and nutrient regeneration than had been previously thought (Fuhrman, 1992). Our incomplete knowledge of marine systems re-enforces the need to define physical measures that will act as a surrogate for the biological measures we do not completely understand.

Implications for Boundaries

If some areas are relatively free from human activities we can partially compensate for our lack of knowledge of ecological processes, such as energy transfer in food webs. A sufficiently large protected area should be designed to ensure that food webs are maintained.

10.1.3.7 State of Knowledge and Uncertainty

Marine ecosystems are large-scale. The method of protecting *ecosystem integrity* is difficult to apply on a practical basis because of natural variability, the large scale of various ecological processes, and our general lack of understanding of marine systems. In temperate marine regions, it is improbable that we could delineate boundaries that would enclose a "self-sustaining" ecosystem.

Implications for Boundaries

In the absence of empirical evidence, the use of oceanographic principles and theory, combined with a precautionary approach, is appropriate for designing boundaries.

10.1.4 Conclusion

The gaps in our knowledge about marine species, habitats, and processes and the growing conservation imperative for the marine environment "... dictates a need to balance fine-scale, detailed information gathering exercises with coarse-scale planning that can operate in shorter time frames while still delivering protection to a significant proportion of Canada's native biodiversity" (Kavanagh and Iacobelli, 1995). A system planning approach, similar to the terrestrial approach, can assist in striking this balance by: 1) providing a framework that will help identify the most appropriate scale within which planning can operate; and 2) once the appropriate scale is identified, help to identify the ecological criteria that can be used to define the *landscape* or *seascape* units that will serve to delineate boundaries.

10.1.5 References

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Table 10.1.1. Framework for a hierarchical classification of all aquatic environments. (Day and Roff, 1998).

LEVEL ONE Environment Type/Salinity	LEVEL TWO Geographic/ Temperature	LEVEL THREE Dimensional Segregation		LEVEL FOUR Vertical Division	LEVEL FIVE Benthic - Substrate Type Pelagic - Stratification Mixing	LEVEL SIX Exposure or Slope
Lotic [Stream + Rivers]	(Not considered in this Framework)					
Lentic [Lakes]	ARCTIC	(Not considered in this Framework)				
	SUB-ARCTIC	SMALL LAKES	(Not considered in this Framework)			
		LARGE LAKES	(Not considered in this Framework)			
	TEMPERATE	SMALL LAKES	(Not considered in this Framework)			
		LARGE LAKES	PELAGIC			
			BENTHIC			
Estuarine	ARCTIC [Seasonal Ice]		PELAGIC			
			BENTHIC			
	SUB-ARCTIC [Atlantic]		PELAGIC			
			BENTHIC			
	TEMPERATE [Atlantic]		PELAGIC			
			BENTHIC			
	TEMPERATE [Pacific]		PELAGIC			
			BENTHIC			
Marine	ARCTIC [Permanent Ice]		PELAGIC	EPIPELAGIC (0-200 m)	Not Applicable	
				MESOPELAGIC (200- 1000 m)	Not Applicable	
				BATHYPELAGIC (1000-2000 m)	Not Applicable	
				ABYSSAL/HADAL (> 2000 m)	Not Applicable	
			BENTHIC	SUB-LITTORAL DYS/APHOTIC (50-200 m)	Gravel/Sand	Low Slope
						High Slope (Shelf Edge/Sea Mounts/Gullys/ Canyons)

				Mud/Silt	
			BATHYAL (200-2000m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts / Gullys/ Canyons
				Mud/Silt	
			ABYSSAL/HADAL (>2000m)	Gravel/Mud	Low Slope
					High Slope (Sea Ridges/Canyons)
				Mud/Silt	
	ARCTIC **[Seasonal Ice]**	PELAGIC	EPIPELAGIC (0-200m)	Stratified (salinity effect)	
				Non-stratified	
			MESOPELAGIC (200- 1000m)	(Winter Polynyas)	
			BATHYPELAGIC (1000-2000 m)		
			ABYSSAL/HADAL (> 2000 m)		
		BENTHIC	LITTORAL (=Intertidal)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/Very Sheltered
				Pebbles/Gravel/Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL EUPHOTIC (0-50M)	Rock/ Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/Very Sheltered
				Pebbles/Gravel/ Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL DYS/APHOTIC (50-200M)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/ Canyons
				Mud/Silt	
			BATHYAL (200-2000 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/ Canyons
				Mud/Silt	

			ABYSSAL/HADAL (>2000m)	Not Applicable	
	SUB-ARCTIC **[Atlantic]**	PELAGIC	EPIPELAGIC (0-200m)	Stratified (T & S effects)	
				Frontal	
			MESOPELAGIC (200-1000m)	Non-stratified (T& S effects)	
			BATHYPELAGIC (1000-2000 m)		
			ABYSSAL/HADAL (>2000 m)		
		BENTHIC	LITTORAL (=Intertidal)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/Very Sheltered
				Pebbles/Gravel/Coarse Sand	
				Fine Mud	
				Mud/Silt	
			SUB-LITTORAL EUPHOTIC (0-50M)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/Very Sheltered
				Pebbles/Gravel/Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL DYS/APHOTIC (50-200M)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/SeaMounts/Gullys/ Canyons)
				Mud/Silt	
			BATHYAL (200-2000 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/Canyons)
				Mud/Silt	
			ABYSSAL/HADAL (>2000 m)	Not applicable	
	TEMPERATE **[Atlantic]**	PELAGIC	EPIPELAGIC (0-200 m)	Stratified ("S" > 1.5)	
				Frontal ("S" = 1-2)	
				Non-stratified ("S" < 1.5)	
			MESOPELAGIC (200-1000 m)		

			BATHYPELAGIC (1000-2000 m)		
			ABYSSAL/HADAL (>2000 m)		
		BENTHIC	LITTORAL (= Intertidal)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/Moderately Sheltered
				Pebbles/Gravel/ Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL EUPHOTIC (0-50 m)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/Moderately Sheltered
				Pebbles/Gravel/ Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL DYS/APHOTIC (50-200 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/Canyons
				Mud/Silt	
			BATHYAL (200-2000 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/Canyons
				Mud/Silt	
			ABYSSAL/HADAL (>2000m)	Not Applicable	
	SUB-TROPICAL **[Atlantic]**	PELAGIC	EPIPELAGIC (0-200 m)	Not Applicable - Always stratified	
			MESOPELAGIC (200-1000 m)	Not Applicable	
			BATHYPELAGIC (1000-2000 m)	Not Applicable	
			ABYSSAL/HADAL (>2000 m)	Not Applicable	
		BENTHIC	BATHYAL (200-2000 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/ Sea Mounts/Gullys /Canyons
				Mud/Silt	

			ABYSSAL/HADAL (>2000m)	Not Applicable	
	TEMPERATE **[Transitional]** **[Pacific]**	PELAGIC	EPIPELAGIC (0-200 m)	Stratified ("S" > 1.5)	
				Frontal ("S" = 1-2)	
				Non-stratified ("S" < 1.5)	
			MESOPELAGIC (200-1000 m)		
			BATHYAL (200-2000 m)		
			ABYSSAL/HADAL (>2000m)		
		BENTHIC	LITTORAL (= Intertidal)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/ Very Sheltered
				Pebbles/Gravel/Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL EUPHOTIC (0-50 m)	Rock/Boulders	Exposed/Very Exposed
					Moderately Exposed
					Sheltered/ Very Sheltered
				Pebbles/Gravel/Coarse Sand	
				Fine Sand	
				Mud/Silt	
			SUB-LITTORAL DYS/APHOTIC (50-200 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/Canyons
				Mud/Silt	
			BATHYAL (200-2000 m)	Gravel/Sand	Low Slope
					High Slope (Shelf Edge/Sea Mounts/Gullys/Canyons
				Mud/Silt	
			ABYSSAL/HADAL (>2000m)	Not Applicable	

10.2 Submarine Landscapes

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10.2.1 Introduction

The identification of landscape elements using biophysical parameters is a useful tool for studying landscape processes within a defined geographic area. Landscape elements of the Nova Scotia land area, including the coast, have been described in the *Natural History of Nova Scotia* (Simmons *et al.* 1984). The second edition of this publication provides descriptions of landscape elements that occur in the sea (Table 10.2.1). These elements have been identified using a method similar to that used to identify terrestrial landscapes but also including the physical characteristics of the sea bottom and overlying water (Davis and Browne, 1997 and Davis *et al.* 1994). The submarine landscapes identified by this method are similar to those being proposed as part of a national marine classification system (Geomatics International Inc., 1997; see also Section 10.1).

Table. 10.2.1. Natural History of Nova Scotia - Hierarchic System

Ecological Landsurvey Equivalent	Ecoregion	Ecodistrict	Ecosection	-	Ecosite (Landform)	Ecoelement	-
Natural History	Region	District	Unit	Sub-Unit (Geographic)	Habitat	Vegetation Association	Plant and Animal Species Inventory
					Based Upon Physical Description	Based Upon Biological Description	

The marine Region 900 is the area around Nova Scotia covered by seawater and extends from the shoreline to the Provincial and National boundaries and to the limits of the declared fisheries and mineral resource management areas. The Region is divided into four Districts of which two (930 and 940) have relevance to a greater management area for the Gully as proposed by Shackell *et al* . (1996). District 930 (Outer Shelf) is divided into two Units; 931 (Outer Shelf Banks) and 932 (Saddles, Shelf Edge, Submarine Canyons and Channels). Unit 931 has two Sub-Units; 931e (Sable Island Bank) and 931f (Banquereau) as separate geographic elements of the same landscape Unit. District 940 is the area of the Scotian Slope which begins at 200 m depth and extends onto the Continental Rise at depths of between 4000 and 5000 m. The locations of these landscapes are shown in Fig. 10.2.1.

The following descriptions have been slightly edited for the purposes of this document but are otherwise taken directly from Volume 2, *Theme Regions,* of the second edition of the *Natural History of Nova Scotia* (1997). Sections of the original descriptions dealing with Cultural Environment and the lists of Associated Topics and Associated Habitats used to cross reference with Volume 1 have been omitted here. Descriptions of other areas of Units 931 and 932, that are not part of the proposed greater management area for the Gully, have been retained to provide a broader context for the features described. The area of the Gully has representative elements of four of the 30 submarine landscapes described in the *Natural History of Nova Scotia.* The four landscapes are elements of more widely occurring landscapes. Unique features of the Gully may be detected at higher levels of resolution such as an analysis of habitats and species associations. However, a detailed classification of habitats and species associations similar to that used for terrestrial landscapes needs to be developed for submarine landscapes.

The text descriptions of Region 900 and the map (Fig. 10.2.1) which follow are reproduced with the permission of the Nova Scotia Museum.

10.2.2 District 930 - Outer Shelf

Geology and Landscape Development. The Outer Shelf is a broad zone (50-75 km wide) consisting of banks and intervening areas (saddles, channels and one major submarine valley, the Gully) extending from Banquereau on the east to Georges Bank on the west. The main banks (Banquereau, Sable, Western, Emerald, LaHave, Browns, and Georges in Unit 931) are relatively large, shallow (30-80 m), and more or less flat topped, representing features in the ancient bedrock which were overlain with glacial till and then leveled by the advancing sea following the latest glaciation (see also Section 3.0). Sable Island protrudes to a height of 26 m above the surface of Sable Island Bank and is the furthest offshore island. Relief of the banks relative to the other features of the Outer Shelf is comparable to areas of the mainland today: elevations of the outer banks are generally less than that of the Cobequid Mountains in the Wentworth area of Cumberland County and much less than the Cape Breton Highlands. On the other hand, the Gully, a submarine canyon between Sable Island Bank and Banquereau, is about half as deep as the Grand Canyon in the United States.

Sediments. The bank tops contain sand and gravel deposits, and, in the case of Sable Island, have been reworked and moved around to form extensive sand fields. Below a depth of about 110 m the bottom sediment consists of sand with silt and clay mixtures. The Outer Shelf contains no basins and the only clay deposits are found in the Laurentian Channel, which borders the eastern end of the District.

Oceanography. The front off the Scotian Shelf lies on average about 100 km seaward of the shelf break. This shelf break front is caused primarily by the confluence of relatively cool and fresh shelf water with warmer, saltier slope waters. Strong tidal flows, particularly over Browns and Georges Banks, also generate fronts whose positions are strongly related to the topography of the banks. In general, the shallower areas of these banks have large tidal currents that can keep the waters well mixed throughout the year. As the depth increases, tidal currents, and consequently mixing, decrease leading to stratified conditions and a temperature and salinity front. The tidal mixing can also be augmented by winds. In addition, this mixing and other tidal processes can lead to the formation of gyres around these banks. The resulting circulation can contribute to the retention of fish eggs and larvae.

Plants. The plant life is dominated by phytoplankton, but encrusting algae may occur in shallow water on suitable hard substrate in some of the bank areas. The outer edge of the continental shelf has enhanced plant productivity due to the interaction of shelf and slope water masses which bring nutrients to the surface.

Animals. The offshore banks are inhabited by many species of fish (see also Section 7.1). Some species prefer the finer bottoms around the margins. Groundfish live on or near the bottom and feed on invertebrates and other fish. Several species of large burrowing molluscs occur in the sandy substrate of offshore banks.

Lobster commonly move from the Inner Shelf to the Outer Shelf banks and continental slope, and can occur along the Outer Shelf and upper slope from Browns Bank to south-east of Sable Island.

10.2.2.1 Unit 931 - Outer Shelf Banks

Geology and Landscape Development. The Outer Shelf Banks include 931a East Georges Bank, 931b Browns/Baccaro Banks, 931c LaHave Bank, 931d Emerald Bank, 931e Sable Island Bank and 931f Banquereau. They were initially bedrock features known as cuestas, typically formed in coastal plain environments by erosion during early geological periods, before they were submerged. Their appearance has been transformed by deposition of glacial till, which has been reworked by the sea to form the present-day surfaces. The banks have moderate relief, generally between 100 and 150 m.

The sandy components of the sand and gravels that are found on the tops of the banks can be shaped by wave and current activity into a variety of seabed features, including sand ridges, sand waves, ripples and megaripples. Significant sand wave fields are seen on the western and eastern bars of Sable Island and magaripples, sand ridges and ribbons occur on west Sable Island Bank (sub-Unit 931e) and Middle Bank (sub-Unit 921e). On Browns Bank (sub-Unit 931b) there are sand waves that have megaripples on their sides. Sand waves and megaripples also occur in parts of Georges Bank (sub-Unit 931a) and there are large tidal ridges on the bank tops. Sand ridges are the largest of the features and migrate over long periods of time. Various ridges on Sable Island Bank mark the "footprint" of Sable Island as it moves to the east.

Patches of gravel, shell beds and even boulders occur. Many of the surface features change with each storm or tidal event, and many of the small scale features are erased during intervening periods. The northern edges of Sable Island Bank and Banquereau (sub-Unit 931f) have numerous steep-sided hanging valleys formed by glacial meltwater that ran over their edges. These hanging valleys extend onto the bank under the cover of surface sediments and are called tunnel valleys. Sediments moving off the edge of the shelf in these areas contribute material to the Gully, a major submarine canyon and a probable remnant of an early drainage system. Similar movements of sediments on the outer edges of the Outer Shelf Banks, particularly during low sea level stand, have led to the formation of distinct submarine canyons.

Sediments. The surfaces of the Outer Shelf Banks shallower than about 110 m consist chiefly of sands and gravels in various combinations in a layer generally less than 15 m in thickness. In some areas (such as the top of sub-Unit 931d Emerald Bank), gravel predominates, while Sable Island Bank is predominantly covered in sand. Where gravel is found, it can form a protective pavement of rounded stones embedded in the bottom. The sand tends to be hard, smooth and flat with a variety of surface bedforms as previously mentioned. Both types of bottom are classified as Sable Island Sand and Gravel. The margins of Outer Shelf Banks below 110 m have sediments that are principally sand, and that contain small amounts of clay, silt and (frequently) gravel. The surface may be flat and smooth to undulating and hummocky. Called Sambro Sand, these deposits cover the saddles adjacent to the Outer Shelf Banks in many cases.

Oceanography. The currents over the outer shelf banks are mainly caused by the interaction of the southwestward mean flow originating from the Gulf of St. Lawrence and the Newfoundland shelf-slope area with local topographic features, by tidal currents, and by wind-forced flows. The mean flow-topography interaction contributes to the gyre-like circulation in the Gully region and over Western Bank. Tidally generated currents are major features of the circulation around Browns and Georges Banks. From time to time, wind-forced flows dominate the circulation over all of the banks, particularly during winter storms. Tides and wind driven currents also contribute to vertical mixing over the banks. Tidal currents are strong enough to maintain well-mixed areas over Georges and Browns Banks year round.

Plants. The biomass and seasonal pattern of phytoplankton and productivity of the waters over the shelf edges is similar to those of the adjacent banks and saddles, with the exception of the outer edges. Here phytoplankton productivity is greater as a result of the interaction of shelf and slope water that occurs in the area.

Animals. More phytoplankton production reaches the seabed on the banks than in adjoining areas. Consequently benthic animal populations, including groundfish which feed near the bottom, are more significant on the offshore banks than in adjoining areas.

Cod stocks from Banquereau and Sable Island Bank migrate during the summer to the outer coast of Nova Scotia and northern Cape Breton Island. Some of the fish also go to the Gulf of St. Lawrence. Southern Scotian Shelf cod overwinter in deeper water around LaHave and Browns Banks. Some move from deeper water to the shallower areas of the banks in summer. On Georges Bank, Atlantic Cod occur principally on the eastern part.

Notable concentrations of Atlantic Halibut occur along the edges of Georges Bank, Sable Island Bank and Banquereau. Witch Flounder have localized areas of high abundance in the deep holes of Banquereau. Sand and gravel bottom typical of the banks is suitable for haddock spawning. They aggregate around the offshore banks at the beginning of the year and move onto the banks to spawn as the water temperature rises. Pollock (Boston Bluefish) spawn on the northeast part of Georges Bank and Browns Bank. They also spawn at several other locations on the Scotian Shelf and at Jeffries Ledge in the Gulf of Maine, and migrate as juveniles to inshore areas. Eggs and larvae of cod, haddock, pollock and Silver Hake are abundant on Western and Sable Island Banks. Those of cod and pollock are there during midwinter and early spring , and those of Silver Hake during midsummer.

Sea Scallop occur on Georges and Browns Banks particularly where the bottom consists of firm gravel, shells and rock. Two other large bivalve mollusc species, Ocean Quahog (*Arctica islandica*) and Stimpson's Surf Clam (*Mactromeris polynyma*), are found typically on most of the offshore banks but they are only locally abundant. The Ocean Quahog is the main species on Georges Bank and concentrations have also been found on Western and Sable Island Banks. Stimpson's Surf Clam is found mainly on Banquereau.

Sandy areas which make up much of Sable Island Bank provide habitat for benthic organisms such as the sand dollar, *Echinarachnius parma,* and the amphipods *Uniciola irrorata* and *Leptocheirus pinguis.* Sand dollars are extremely abundant in some locations. Parts of the banks having coarse substrate (gravel) are expected to have populations of Horse Mussel (*Modiolus modiolus*), brittlestars (*Ophiopholis aculeata*), Sea Scallops, lobster and Toad Crab (*Hyas coarctatus*).

10.2.2.2 Unit 932 - Saddles, Shelf Edge, Submarine Canyons and Channels

Geology and Landscape Development. The banks of the Outer Shelf are bordered by intervening deep-water areas which include saddles and channels, submarine canyons and the continental slope. Saddles generally have gentle relief and are shallower than about 200 m, while channels are deep, broad lowland features occurring at a similar depth to the basins of the Middle Shelf. Saddles are found between Sable Island/Western Bank and Emerald Bank, and between Emerald Bank and LaHave Bank. Northeast Channel separates Browns and Georges Banks and Laurentian Channel separates Banquereau and the eastern Scotian Shelf from the banks off the coast of Newfoundland.

Submarine canyons occur along the outer edges of the Outer Shelf and extend down the continental slope. These are narrow, deep and steep-sided features and include the Gully, and Verrill, Dawson, Bonnecamps, Logan, Shortland, and Haldimand Canyons. The Gully is a submarine canyon that approaches Colorado's Grand Canyon in depth, extending from 100 m to more than a kilometer between Sable Island Bank and Banquereau Bank (the Cape Breton Highlands by comparison are roughly 500m high). The Gully probably originated as a drainage channel and later developed into a canyon.

The river and submarine canyon at the mouth of the Hudson River on the United States East Coast is an analogous feature.

Northeast Channel joins the Outer Shelf between Browns and Georges Banks with the basins of the Gulf of Maine at depths between 200 and 300 m. Megaripples occur on the northern and eastern flanks of Northeast Channel at depths of 100-150 m, and sand waves on the bottom of Northeastern Channel at depths of 230-260 m are evidently caused by tidal currents. These are some of the deepest recorded sand waves on the continental shelf, caused by the strong tidal currents in the Bay of Fundy-Gulf of Maine.

Laurentian Channel is the most impressive of these features, arising as a former river valley deepened by glacial ice and having a sill (a shallower portion near the outer edge). The Channel extends 700 km from the junction of the Saguenay and the St. Lawrence Rivers in Quebec to the edge of the continental shelf between Nova Scotia and Newfoundland, and was cut 300 m below the rest of the shelf by the advancing ice. Down the slope from the Channel the Laurentian Fan occurs, a delta-like feature containing sediments from the ancestral St. Lawrence River and from recent sediment flow activity.

At the edge of the shelf, the bottom plunges downward to the continental slope. The shelf edge is marked by the occurrence of submarine canyons and glacial features which demonstrate the furthest extent of the ice sheets.

Sediments. Saddles between Outer Shelf Banks (Unit 931), parts of Northeast Channel and the Gully generally have a cover of sand containing clay, silt and frequently gravel (Sambro Sand, see above). The outer and inner ends of Northeast Channel, in addition, have a cover of glacial till, consisting of mixtures of significant amounts of silt and clay in addition to sand, gravel and boulders. The glacial till is classed as Scotian Shelf Drift.

In the Laurentian Channel the bottom consists of glacial sediments, mainly clay, with silt exposed in some places. Flows of sediment down the slope from the Channel can leave coarse deposits.

Oceanography. Saddles occur at depths less than 200m, and form an entrance to the basins of the Middle Shelf (District 920) for subsurface water masses, typically the warmer, deeper Slope Water from the shelf edge. Georges Bank with depths greater than 200m is profoundly influenced by tides and serves as a pathway for water exchanges between the Gulf of Maine and the slope region. The deep Laurentian Channel permits incursions of deep water of Atlantic origin into the Gulf of St. Lawrence.

Plants. Productivity of the waters, biomass of phytoplankton and seasonal patterns in saddles and canyons are similar to that of the adjacent shelves. The outer margin of the continental shelf, however, has greater plant productivity due to the interaction of shelf and slope water masses in a "frontal zone" whose position changes from year to year.

The elevated productivity is used by, and is believed to enhance, populations of fish and other organisms in the area.

The edge of the Outer Shelf is exposed periodically to water masses derived from the Gulf Stream which flows to the south. Occasionally masses of the seaweed *Sargassum* can be found floating in the area.

Animals. Witch Flounder are associated with deep holes and channels between the coastal banks, along the deep edges of the banks where water temperatures are suitable, and in gullies where bottom is usually clay, muddy sand or mud. This species has localized areas of high abundance along the edge of the Laurentian Channel, between Sable Island and Banquereau and in deep holes of Banquereau. Notable concentrations of Atlantic Halibut occur along the edges of Georges, Sable Island and Banquereau Banks. Various flatfish species occur in areas fringing the banks. Owing to the warmer water there, the outer margin of the shelf is a principal area of concentration of Silver Hake which move onto the Scotian Shelf as temperatures warm in summer. The main known overwintering area for Atlantic Mackerel is the continental shelf south and south-west of Georges Bank.

Short-finned Squid are usually most common along the outer edge of the Scotian Shelf in June, usually between Emerald and LaHave Banks and in some years along the entire edge of the Shelf. They spread over the shelf later in the summer and still later migrate south-west down the North American east coast. The young are brought back into the area by the Gulf Stream. Juveniles live in the Gulf Stream frontal zone and Slope Water off the edge of the continental shelf until they reach about 10 cm in length.

Deep-sea Red Crab (*Geryon quinquedens*) are abundant along the shelf edge from the Fundian Channel to Sable Island at depths of 180-550 m. Significant quantities of lobster occur at the shelf edge from Browns Bank to Sable Island Bank.

One of the two best-known areas of concentration of the Northern Bottlenose Whale is in the Gully (see also Section 9.0).

Seabird concentrations are greater in the shelf edge region owing to the elevated productivity there (see also Section 8.0). Wintering Dovekies are most common over the edges of the Scotian Shelf. On Georges Bank, Wilson's Storm Petrels are most common over the shelf-break.

10.2.3 District 940 - Scotian Slope

The Scotian Slope District is a very large area extending from the outer limit of District 930 (at approximately 200 m deep) to the political and resource management boundaries at depths of 4,000 to 5,000 m. This is a fully oceanic environment.

Geology and Landscape Development. The District includes the continental slope and rise, but as the boundary between them is not distinct no attempt has been made to separate them as Units. The slope is indented by canyons and channels, including the Gully and the Laurentian Channel, both of which originate in District 930.

The area is underlain by thick post-Atlantic Rift sediments which have been accumulating continuously in the Scotian Basin since the Mesozoic. The Jurassic and Cretaceous rocks are mildly folded and faulted along the continental margin. Both the Shelbourne sub-Basin in the southwest and Sable sub-Basin in the northeast have extensive salt deposits. Late Tertiary and Quaternary deposits are horizontally bedded and some outcrop in canyons and scarp features on the continental slope. The area is subject to high seismic activity with main stress in a southwest/northeast direction with the earthquakes up to magnitude 6. The Newfoundland earthquake of 1929 registered 7.2 on the Richter Scale.

Sediments. Recent sediments accumulating on the continental shelf are slumped along the shelf break and travel down the slope, often in the canyons, as turbidity currents. Thick accumulations of these slumped sediments are found on the slope between 200 m and 2,000 m depth. This talus material includes sand (Sable Island Sand and Gravel), marine silty clay (LaHave Clay), glaciomarine silty clay (Emerald Clay) and Diamicton/Till. The surfaces of these deposits are marked with pockmarks, palaeoiceberg scour marks and sand ridges (Laurentian Fan). From the base of the slope towards the deep water there is a gradation of surficial sediments; discontinuous, stratified mud series, muds alternating with silt and sand and finally a sand sheet of Later Pleistocene or Holocene age. These deposits are cut by erosion channels of the same age. The deep water sediments are covered with a thin layer of pelagic or hemipelagic sediment which include fine mineral particles and the shells and spicules of marine organisms, *e.g.* Radiolaria.

Oceanography. This District is generally oceanic in character though on average a surface wedge of shelf water approximately 50 m deep extends 100 km seaward of the shelf break. Two main types of slope water underlie the shelf water. Labrador Slope Water is relatively cool and fresh, and Warm Slope Water, derived from a mixture of shelf waters and offshore waters associated with the Gulf Stream, is warmer and more saline. A number of processes contribute to the mixing of shelf and slope waters; however, one of the most effective mechanisms is caused by the entrainment of shelf water by Gulf Stream rings and meanders. Wind-induced upwelling and the generation of internal tides and waves at the shelf break contribute to the vertical mixing and transport of nutrients in the region.

Plants. Phytoplankton in the surface water is responsible for the primary productivity that occurs in the District. However, this is only significant in the area of the shelf break as the level of nutrients available diminished rapidly towards the deep water. Some floating patches of *Sargassum* weed occur which are of relatively little ecological significance although they support a distinct community of animals and may, rarely, reach the Nova Scotia coast.

Animals. The deep water and oceanic conditions of District 940 support communities of species of animals not normally encountered in continental shelf waters. The two Habitats of the Offshore, Open Water Ocean and Benthic Ocean, will be treated separately.

Open water ocean species of pelagic animals depend upon the primary productivity of the surface waters. Phytoplankton is grazed by herbivorous zooplankton; copepods, cladocerans, euphausiids and a wide range of larval forms. There are many carnivorous species including crustaceans, medusae and the larvae and juveniles of fish. The nekton or free-swimming animals range in scale from jellyfish to whales, but the predominant forms are crustaceans, cephalopods and fish. In the deep water these animals are grouped into vertically zoned communities; epipelagic (top), mesopelagic (middle) and bathypelagic (bottom).

The epipelagic community includes surface swimming molluscs (*Janthina* and *Argonauta*), coelenterates (*Valella* and *Physalia*) and fish (Swordfish and Flyingfish). A number of species of invertebrates and fish are associated with *Sargassum* weed and Goosebarnacles (*Lepas*) are associated with floating objects. The mesopelagic community is characterised by a diurnal vertical migration; rising to the surface at night and descending to the depths at day. This migration of several hundred metres allows the deep water species to take advantage of surface productivity. The mesopelagic community is composed of crustaceans (shrimps and amphipods), cephalopods (squid and pelagic octopus) and fish, particularly the distinctive Lanternfish, Viperfish and Hatchetfish). These species are all predatory carnivores, often darkly coloured and may have reflective plates and photophores (light-producing organs). Lanternfish are found at a depth of 700 to 1200 m during the day but rise to within 100 m of the surface to feed at night. The bathypelagic community lives in close association with the bottom and includes economically important types such as grenadier that occur down to 2,500 m depth. Many of the species that occur in the bathypelagic zone, such as the Giant Squid which appears on a thirty-year cycle, are poorly known.

The benthic ocean habitat includes those communities that live in or on the ocean bottom. In District 940 this is an environment without light. The generally soft sediments support an infauna of worms; Pogonophora and Polychaeta, coelenterates; seapens, gorgonian (*Radicipes*) and solitary corals (*Flabellum*), a wide variety of scaphopod, pelecypod and gastropod molluscs and echinoderms. The crinoid (sea lily), *Rhizocrinus lofotensis*, has been found on the slope at a depth of 1700 m. Epifauna includes any animal that roams around the sea bottom or attaches itself to a solid object. Old ice-rafted boulders are colonised by sponges, coelenterates, bryozoa and brachiopods while crustaceans, seaspiders and brittlestarfish are vagrants. Rock bottoms provide habitat for a distinct community of gorgonian corals, including *Paragorgia*, *Primnoa* and *Keratoisis.* A variety of bottom feeding fish occurs including the Atlantic Batfish, Monkfish, anglerfish and Chimaera. Blue Hake, *Antimora rostrata*, occur between 1300 and 2500 m depth.

10.2.4 References

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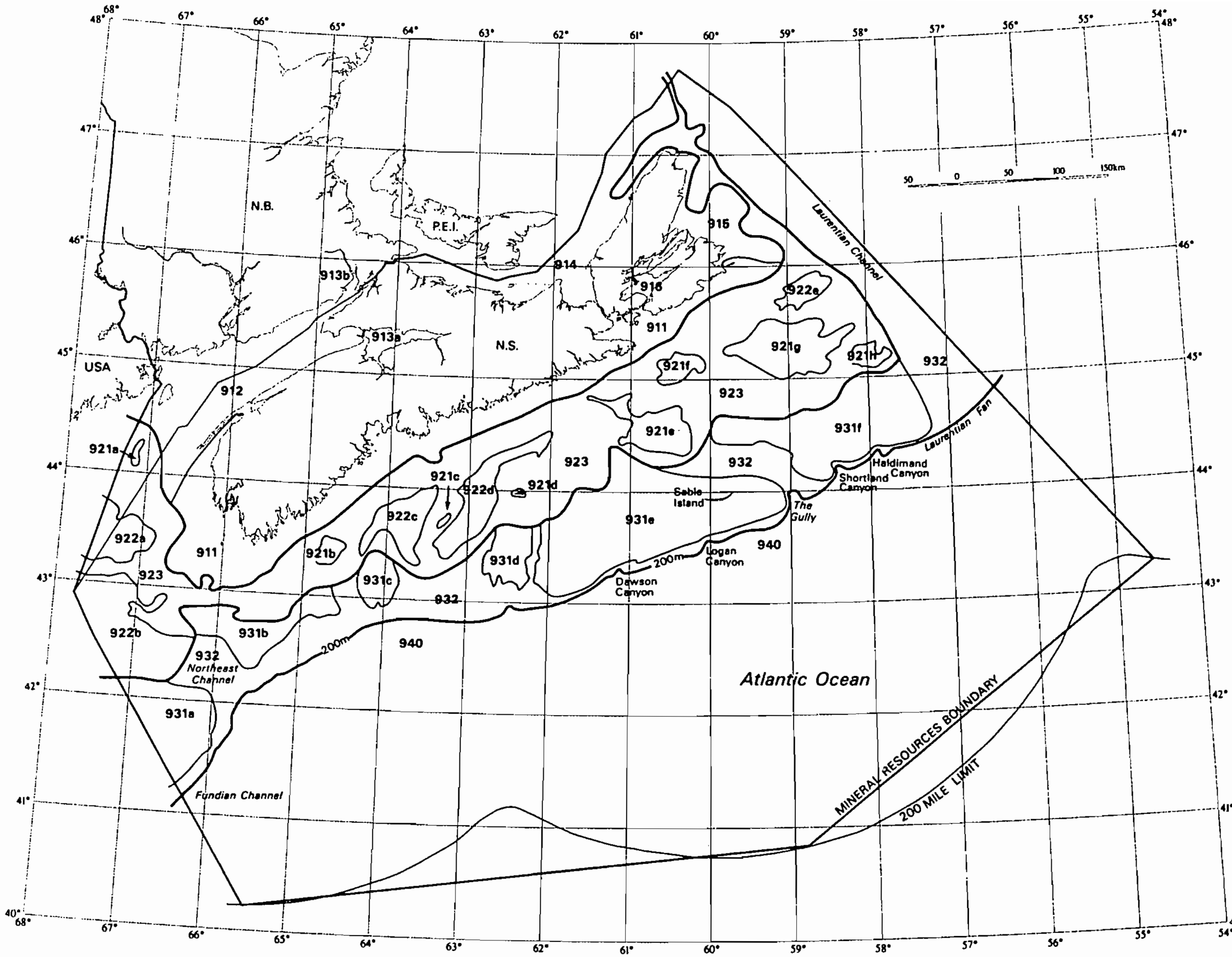

Fig. 10.2.1. Submarine landscapes of the Scotian Shelf. (from *The Natural History of Nova Scotia* 1997. Vol 2). The four landscapes in the Gully area are sub-units 931e and 931f (Outer Shelf Banks), Unit 932 (Saddles, Shelf Edge, Submarine Canyons and Channels) and District 940 (Scotian Slope).

11.0 Knowledge Gaps, Recommendations and Future Research Requirements

The goal of the Gully Science Review was to provide a comprehensive description of the Gully's environment and its ecosystems. Ideally, the available information would be sufficient for developing an integrated ecosystem view of the Gully with an understanding of it components, how they interact, and how they respond to their environmental regulating forces. Despite the substantial amount of data the Science Review team has compiled, there are still key components of the Gully ecosystem for which we have virtually no quantitative information and other key components for which we have incomplete information (Table 11.0.1). As a consequence:

a complete ecosystem description of the Gully is not possible now, although the same could be said for our understanding of the environment and ecosystems of the Scotian Shelf in general.

The Science Review has produced a general description of the regional geology, oceanography, fisheries and higher trophic level fauna (seabirds and mammals) of the Gully. However, none of these components could be identified as having a comprehensive dataset. For example, most current meter moorings in the Gully have been single deployments lasting for a short time; arrays of instruments have not been set in conjunction with complementary hydrographic, biological and chemical sampling. As a consequence, a description of the general circulation in the area rests largely on model simulations.

In the case of the benthos of the Gully, virtually nothing is known about community structure and distribution. Data have been collected on the occurrence of deep sea corals but nothing is known quantitatively about their ecology or biology. Additionally, some information on the occurrence of commercial benthic invertebrates exists but their distribution in the Gully, movements between the Gully and the rest of the Scotian Shelf, recruitment and interactions with other species are unknown. This lack of information on a fundamental component of the Gully ecosystem requires that:

further research is needed to establish a baseline of information on the distribution, structure and functioning of the benthic communities of the Gully.

The concern has also been expressed that much of the existing data are old (collected decades ago) and may not reflect the contemporary situation (e.g. ichthyoplankton, and seabird distributions). Have there been significant changes in these components in the intervening time? Other datasets are reasonably up to date although often sparse and scattered (e.g. geology, physical and chemical oceanography, finfish, mammals). Thus:

scientific surveys are required to collect current information on variables that are susceptible to change with time.

Another recurring concern is that the spatial and temporal resolution of the available data are inadequate to address unambiguously questions relating to: (1) the uniqueness of the Gully as compared to the rest of the Scotian Shelf and slope, (2) the processes occurring within the Gully that influence productivity of the region and (3) the issue of defining operational "boundaries" for the Gully. Notably, descriptions of the physical, chemical and biological oceanography from limited small-scale studies showed that oceanographic conditions conducive to enhanced nutrient supply and productivity might exist in the Gully but were not discernible from conventional coarse-scale sampling. A similar argument was made in evaluating the distribution of pelagic seabirds in the vicinity of the Gully. Clearly, data with a spatial resolution considerably less than the 10s of km that define the bathymetric "boundaries" of the Gully (e.g. the 200m contour) and temporal resolution shorter than seasonal or monthly means would be required to address the dynamics that characterize the Gully on the small scale. At present, the only data with adequate spatial resolution are the multibeam bathymetry for geological and hydrographical studies, acoustics and towed instrumentation (including video) for oceanography and fish, and airborne surveillance for seabirds and mammals. These data are limited to small areas of the Gully or are simply unavailable, however. It is evident, therefore, that:

the more widespread use of technology that permits rapid, high spatial resolution sampling will be required to adequately address questions relating to the characteristics of the Gully with regard to its ecologically dynamic features and will be required to delineate Gully boundaries based on biological as well as physical properties.

Filling information gaps will be a necessary but not sufficient condition to develop an integrated ecosystem description of the Gully. Fundamental questions remain about the functional linkages between ocean physics-chemistry and productivity of the plankton, the benthos (i.e. benthic-pelagic coupling) and the aggregation of seabirds and marine mammals in the region. No single research organization, including DFO, has the capabilities to carry out a complete system study. It is essential, therefore, that:

the various government and NGO researchers and stakeholders should commit resources for more focused, coordinated and comprehensive research in the Gully region in order to develop a better understanding of the processes that account for its abundant and diverse biota. Scientific information collection will also benefit from and should be supplemented by the working knowledge of resource users, i.e. traditional ecological knowledge.

The Science Review team acknowledged that information gaps will exist even if all recommendations are implemented. Therefore:

in cases where crucial scientific information is lacking, the "precautionary principle" as stated in the Oceans Act must be applied.

The Gully Science Review team was given the task of assembling information on a geographically small area of the Scotian Shelf but without being given strict guidelines on the nature and scope of the review. This can be described as a "bottom-up" approach for developing an understanding of a region's environment and ecology. That is to say, the primary focus is on the description of a specific region with its relationship to surrounding regions being secondary. The Gully Science Review has taken almost a year to complete and has involved the commitment of considerable time from numerous experts from within and outside the government. Two reports at the end of the Science Review propose that a "top-down" approach based on a systems classification scheme may be a more logical and efficient starting point. Here, the specific region of interest is placed in the context of the surrounding regions right at the onset. The science of system planning is, in fact, a mature one, developed decades ago and successfully applied as a tool for classifying terrestrial ecosystems. It is currently being adapted to marine ecosystems. It is the consensus of the Gully Science Review team in judging the merits of "bottom-up" versus "top-down" approaches that consideration of the time and resources that went into the Gully Science Review, the prospect for others in the future, and considering that much of the ground work has already been laid in systems classification of the Scotian Shelf:

a systems approach to ecosystem classification should be implemented by DFO as a framework for meeting future departmental requirements for science information for our regional waters.

Systems classification is not considered a substitute for the site-based, focused research required to address region-specific questions but will provide the background information necessary for more efficient use of research personnel and resources and for placing the scientific understanding gained in the broader system context.

Table 11.0.1. Current status of information on the environment and ecosystem of the Gully.

Component	Information: Good	Useful	Poor	Analog	Data*	Gaps
Geology		X		X	x	Limited to shallow zone (<600 m); Little multibeam data.
Hydrography		X		X		Coverage <1% of the bottom area.
Ambient Noise			X		x	Not addressed in Gully Science Review.
Oceanography						
Physical		X		X		Limited to shallow zone; Sparce data for circ. model calibration.
Chemical		X				No contaminants data; Poor small-scale spatial/temporal coverage.
Biological		X				Lack of contemporary data; Poor small-scale spatial/temporal coverage.
Benthos			X	X	?	No quantitative data.
Fish						
Finfish	X			X	x	Poor small-scale spatial/temporal coverage.
Invertebrates			X	X	x	Lack of data on distribution, movements, recruitment.
Seabirds			X			Poor small-scale spatial/temporal coverage.
Mammals	X			X		Lack of data on at-sea distribution of pinnipeds; Lack of data on cetacean distribution outside summer.

*Additional data available but not analyzed

12.0 The Gully Ecosystem - An Integrated View

Despite gaps in our knowledge of a number of important environmental and ecological elements of the Gully (Section 11.0), enough is presently known from this and analogous regions to describe the key processes and interactions which define submarine canyon ecosystems in general and the Gully in particular (Fig. 12.0.1).

The Science Review revealed that the Gully is the largest of the submarine canyons which cut into the eastern continental margin of North America. It is equally distinctive for its penetration well onto the continental shelf and for its depth (>2000 m) and extremely steep walls. Collectively, these physiographic features have important implications for local circulation, onshelf nutrient fluxes, sediment dynamics, and the distribution and structure of biological communities.

On the basis of scientific observations in the Gully, modelling results and more extensive studies in analogous regions, it is clear that circulation in submarine canyons is strongly influenced by the local topography and mean flows along the adjacent continental shelf and slope. Evidence suggests that the Gully may act at times as a significant conduit for material transport onto and off of the shelf and may be an area of significant material retention, thus influencing local deposition. Its steep slopes make it an area where internal wave activity may be enhanced, leading to stronger local mixing, nutrient transport to surface waters and to increased local primary production. Patterns of circulation and flow strengths also contribute to the distribution and nature of surficial sediments; circulation and sediment type, in turn, influence the distribution, abundance and community structure of the benthos.

Locally enhanced primary production can provide energy for zooplankton in the water column and/or for benthic filter-feeders when transported to depth as phyto-detritus. The zooplankton are in turn an important food source for larval finfish and invertebrates which are consumed by adult pelagic finfish, seabirds and marine mammals. The benthic communities are an additional food source for marine mammals and for demersal finfish. The diversity of feeding types of cetaceans found in the Gully suggests that the food sources which support their activity are likewise diverse.

Besides providing a localized food source, submarine canyons may also provide refuge for a variety of organisms from plankton to mammals. These and the deep basins that are found on the Scotian Shelf, for example, are known to harbour large populations of over-wintering meso and macrozooplankton, *e.g.* krill. The steep and complex bathymetry of submarine canyons also provides for high substrate (habitat) diversity which is associated with high biodiversity. The Science Review has documented, for example, that the Gully is a region of strong demersal ichthyiofaunal boundaries and that their diversity is high compared to the eastern Scotian Shelf as a whole. High benthic species diversity has been noteworthy in studies of other canyon features along the North Atlantic coast.

It is not unreasonable, therefore to conclude that the aggregation of fish, seabirds and mammals within or in proximity of submarine canyons can be explained by: (1) an enhanced supply of food mediated by processes which favor localized production and its retention there and (2) a diversity of habitats, providing both substrate and shelter to support a complex array of biotic communities within a geographically confined region. The extent to which the Gully conforms to this generic view of submarine canyon ecosystems can only partially be evaluated at present; more (multidisciplinary) research in the region will be required to fill the critical knowledge gaps and quantify the key processes and interactions.

Submarine Canyons

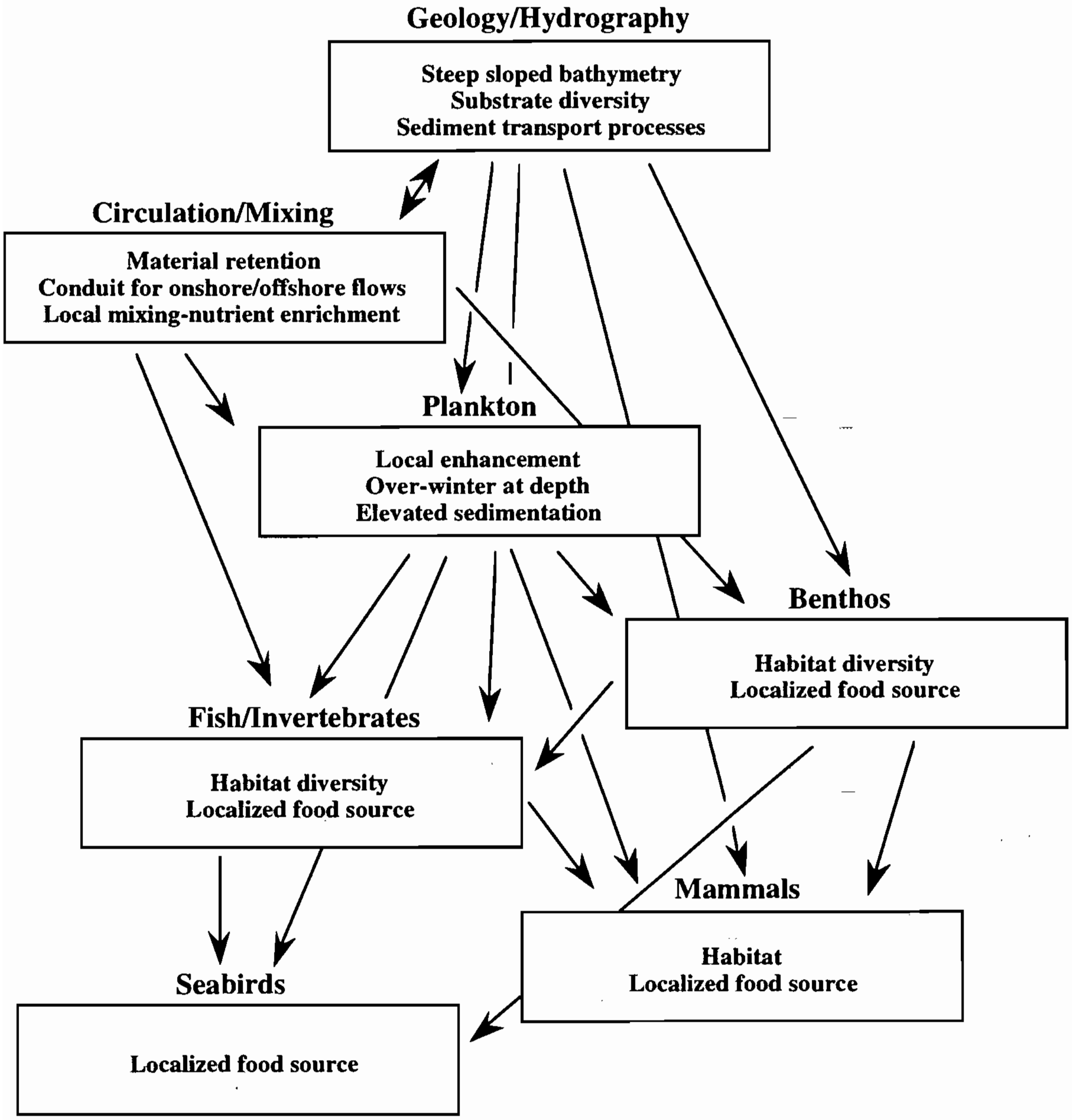

Fig. 12.0.1. Linkages among the major environmental and ecosystem components of submarine canyons.

APPENDICES

Appendix 13.1 Fish and Fisheries: Mackerel

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13.1.1 Background

The Marine Fish Division (MFD) group which met related to the Gully Science Review requested that I comment on the distribution of mackerel on the Scotian Shelf from the survey work that I participated in some years ago. The work referred to is Kulka and Stobo (1981).

That work (November-December, 1976) was conducted before MFD has initiated the spring surveys. Our hypothesis was that juvenile mackerel may stay on the Scotian Shelf over winter rather than migrating south to Subarea 5 with the adults; the results support that hypothesis. The objective was to determine if mackerel remained on the Scotian Shelf over the winter in large numbers, and if so, was the distribution contiguous from the Scotian Shelf to the western portion of Georges Bank where the main winter fishery occurred. We used both a mid-water and bottom trawl; the vessel cruised a pre-determined tract and made a set, with the appropriate gear, whenever the sonar indicated trawlable numbers of fish. The cruise tract covered out to the edge of the Scotian Shelf and most of the deeper basins, the northeastern part of Georges, restricted the vessel to the near edge area of western Georges, and then expanded again bank-wide off Cape Cod (Fig. 13.1.1). The western extension inshore was due to the location of the winter mackerel fishery off Cape Cod and our desire to ensure that the vessel could catch mackerel with both gear types.

The survey therefore was not systematic, but rather exploratory. It did cover the area of the Gully, but that was essentially the most eastward point and it did not extend onto Banquereau Bank to any extent. We actually had only one set in the Gully, but no mackerel were found there. In fact, we found relatively few species in the study area east of Sable Island; the most abundant species was yellowtail, with American plaice and witch flounder the next two most abundant species.

Mackerel were found around Sable Island and across the Scotian Shelf, but mainly age groups 0 and 1. The data suggest that the overwintering mackerel are distributed in the offshore areas of the shelf; we also examined previous specialized winter cruises (between 1958-76) and observed similar results. The mean bottom depth for the Scotian Shelf mackerel catches was 118 m, considerably shallower than that in the Gully. Most of the mackerel were either caught in the bottom trawl or when the mid-water trawl was towed close to the bottom, suggesting a near bottom existence during winter. Examination of the summer RV survey results for the 1958-76 period suggested a more mid-shelf distribution, but again no obvious concentrations were observed near the Gully.

From that work I would conclude that the Gully is not an important aspect of mackerel population dynamics; nor would one expect another result. Mackerel spawn off Cape Cod in early spring and in the Gulf of St. Lawrence in mid-summer; there has been no documentation of mackerel spawning in the offshore areas of the Scotian Shelf. The migration of adults north appears to be along the mid- and inner areas of the Scotian Shelf from observations of trap catches and recreational fishery activity. Although there appears to be an annual run of mackerel going past Sable during mid-summer (W. Stobo, pers. comm.), there is no documented fishery in the area. The return migration in fall is even less well understood. The limited winter work suggests that there are relatively few adult mackerel on the Scotian Shelf during winter and that juveniles are probably scattered across the outer shelf.

13.1.2 References

Kulka, D.W. and W.T. Stobo. 1981. Winter distribution and feeding of mackerel on the Scotian Shelf and outer Georges Bank with reference to the winter distribution of other finfish species. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1038.

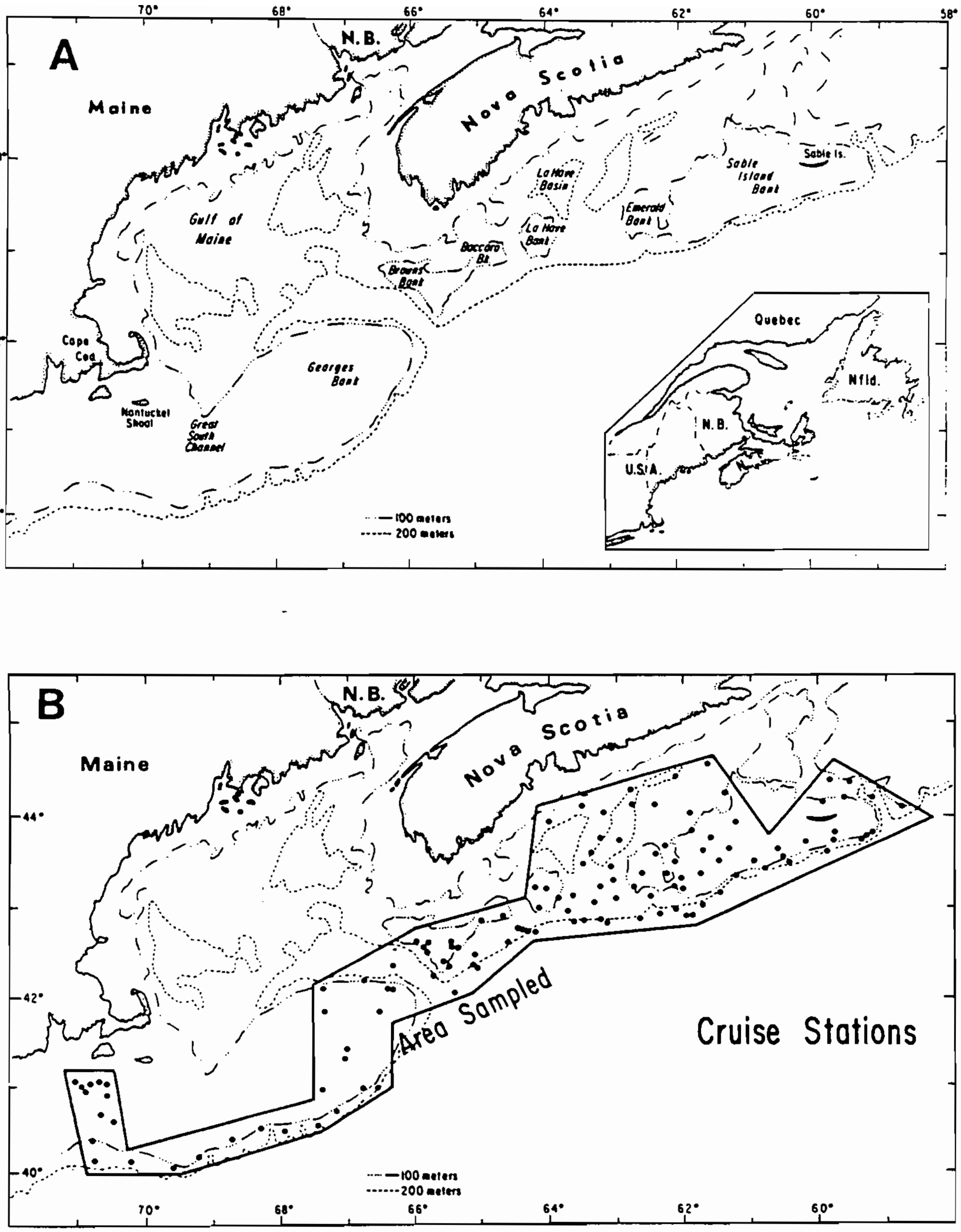

Fig. 13.1.1. Chart of the Scotian Shelf and Georges Bank showing: (A) depth contours; and (B) stations sampled, Nov. - Dec. 1976.

Appendix 13.2 Fish and Fisheries: Large Pelagic Fisheries

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13.2.1 Introduction and Methods

This document reviews the current geographic and seasonal distribution of large pelagics fisheries (swordfish, bluefin tuna, other tunas) within the Canadian Fishing Zone. These analyses are intended to provide background information for a Science Review of the Gully area on the Scotian Shelf, which is being considered for "Marine Protected Area" status. Most of the data used for this analyses originates from commercial log records provided by swordfish longline (1994-1996) and bluefin tuna (1988-96) fishermen. Although the harpoon fishery for swordfish accounts for up to 12% of the annual landings, information on catch location is insufficient for an analysis of swordfish distribution.

Detailed set information (*i.e.* latitude and longitude) for swordfish longline from log monitoring data is only available back to 1994, however, the number of observations since that time are considered adequate for determining the extent of this fishery. Plots of longline fishing effort are based on individual set locations while plots of nominal catch per unit effort (CPUE) are based on aggregated data (number or weight of fish per trip divided by total number of hooks per trip). The proportion of swordfishing trips, sets and catch in a rectangle approximating the Gully area (latitude: 43° 30'-44 ° 10'; longitude: 58 ° 40'-59 ° 20') was calculated and compared with annual totals for 1994 through 1996. Plots of catch location for bluefin tuna were based on positions reported by commercial fishermen in the bluefin log records.

Additional information on swordfish distribution was available from the Canadian International Observer Program database (1980-96) and from research surveys (1980, 1990-93) conducted by Science Branch. Distribution plots from this series show set locations and number of swordfish sampled.

13.2.2 Results and Discussion

Swordfish Longline - The Canadian swordfish longline fishery operates from Georges Bank to the western edge of the Grand Banks when swordfish migrate into Canadian waters during summer and fall. Pelagic longline gear is used to capture swordfish at night when they feed in surface waters. The gear is set early in the evening and hauled back the following morning. Typically, a trip consists of 8-14 sets of the gear with up to 1500 hooks/set, covering a distance of up to 60 km. Fishing effort generally progresses from west to east and back again along the edge of the continental shelf, following swordfish movements associated with seasonal warming trends of surface water temperature.

During the 1994, 1995 and 1996 fishing seasons, effort commenced in June with sets occurring in deeper waters along the edge of the Gulf Stream off the western and eastern Scotian Shelf (Figs. 13.2.1-3). Effort then spread along the shelf slope and off the western Grand Banks in July, becoming more concentrated in a narrow band along the edge of the continental shelf in August. During September and October, the fishery occured mainly along the edge and central portion of the Scotian Shelf. In 1996, fishing effort was greatly reduced due to poor environmental conditions (cold water temperatures and high winds) along the Shelf Slope.

Nominal CPUE (average number of fish per 1000 hooks) for 1994, 1995 and 1996 generally shows a pattern of increasing swordfish abundance from June to September, declining in October and November (Figs. 13.2.4, 5, and 6, respectively). In 1995, catch rates in the central Scotian Shelf region during September and October tended to be much higher than in 1994 and 1996, due to a shift in effort directed at larger fish (> 180 kg), which were concentrated in the deep basins.

The Canadian swordfish longline fleet has operated at the entrance of the Gully from 1994 through 1996 (Figs. 13.2.1-3), with moderate to high catch rates for swordfish (Figs. 13.2.4-6). During this period, the proportion of trips and sets in the Gully area averaged about 3% of the total for each fishing season, while catches represented 2-5% of total landings (Table 13.2.1).

Table 13.2.1. Number of trips, sets and total catch for the entire Canadian swordfish fishery vs the Gully area (latitude: 43° 30'-44° 10'; longitude: 58° 40'-59° 20') for 1994-96.

Year	Area	No. of Trips	No. of Sets	Landed wt (kgs rnd)
1994	All	427	3855	1583
	Gully	8	52	26
1995	All	418	3338	1376
	Gully	12	91	37
1996	All	343	2719	637
	Gully	9	90	29

Additional information on swordfish distribution in the Canadian Fishing Zone is available from sampling by Canadian research and observer programs. Research surveys for swordfish were conducted in 1980 and 1990 through 1993 during summer and fall. Observer data is available for the summar/fall (June-October) Canadian domestic fishery (1993-95) and for swordfish bycatch from the fall/winter (September-February) directed

Japanese tuna longline fishery (1980-1996). Set locations and relative number of swordfish sampled per set from Canadian research and observer program collections (Fig. 13.2.7) and Canadian observer sampling on Japanese longline vessels (Fig. 13.2.8) indicate that catches in the Gully area did occur, but were of the same order of magnitude as in other areas along the Shelf slope.

The distribution and relative abundance of swordfish in the Canadian Fishing Zone is greatly influenced by oceanographic conditions and can vary considerably both seasonally and geograhically from one year to the next (Fig. 13.2.9). Therefore, it is difficult to distinguish between areas of localized high swordfish abundance attributed to oceanographic features or a preference for a specific physical habitat (*i.e.* like the Gully). Individual swordfish probably have a relatively short residence period in any particular area during their search for food on the Shelf and Shelf Slope. Tagging results have shown movements from west to east along the Shelf slope during the fishing season. Swordfish can feed on a wide variety of prey found throughout the water column (*i.e.* groundfish, pelagics, deepwater fish and invertebrates). While the Gully may offer a greater variety of prey items than other areas on the Scotian Shelf and Slope (due to higher levels of productivity), it is unlikely that the relative abundance of swordfish is higher in this area compared with other regions in Canadian waters (see Fig. 13.2.9).

Albacore, Bigeye and Yellowfin Tuna Bycatch from Swordfish Longline - Since 1993, there has been increase in the number of swordfish longline trips directed for other tunas (albacore, bigeye and yellowfin), which is attributed in part to declining quotas for swordfish. These trips occur mainly during June and July when water temperatures are quite variable and the relative abundance of swordfish tends to be low. Fishermen use circle hooks (which have better retention for tunas) in combination with conventional J-hooks on their longline gear, and a squid/mackerel bait mixture to attract these fish.

From 1994 through 1996, nominal catch rates (kgs round per 1000 hooks) were highest during June and July for albacore (Figs. 13.2.10-12) and yellowfin (Figs. 13.2.13-15), and from June through September for bigeye (Figs. 13.2.16-18). During these months, all three species were captured primarily along the western edge of the Scotian Shelf slope, and in deeper waters along the edge of the Gulf Stream. Overall, the relative abundance of all three species tends to be quite low in the vicinity of the Gully (and eastern Scotian Shelf) where their occurrence appears to be incidental.

Bluefin Tuna Fishery - The Canadian bluefin tuna fishery currently operates in several geographic areas off the Atlantic coast from July to November when bluefin migrate into Canadian waters. Since the late 1980's, the main commercial fisheries have included: Hell Hole tended line, Bay of Fundy harpoon, St. Margarets Bay trap, Gulf of St. Lawrence tended line/rod and reel, Chedabucto Bay rod and reel, and Grand Banks tended line/rod and reel. Recently, a tended line/rod and reel fishery has developed off Halifax, Nova Scotia.

Bluefin tuna capture locations within these geographic areas (fisheries) have been highly variable during the time series for which data on fishing location is available (1988-96, Figs. 13.2.17-19). Most notable in recent years is: a) the expansion of catches from the Hell Hole to adjacent areas on Georges Bank, Browns Bank and the Scotian Shelf, b) the development of an electric harpoon fishery in the Bay of Fundy in 1991 and a tended line/rod and reel fishery off Halifax in 1995, c) an expanding rod and reel fishery in Chedabucto Bay (beginning in 1990), d) a general decline followed by a recent increase in catches from the Grand Banks region off Newfoundland and e), a concentration of catches from the Gulf of St. Lawrence to the southern part of this region with higher catches in recent years.

Based on these spatial distributions, it is apparent that bluefin tuna form distinct aggregations in Canadian waters which can vary from one year to the next. However, no major concentrations are found offshore in the vicinity of the Gully or on the eastern Scotian Shelf. Although bluefin may be captured in this region on swordfish longline gear, the Canadian fleet is not allowed to land them so there is no information available from their log records.

13.2.3 Conclusions

It is apparent from this analysis of commercial log record data that the swordfish longline fishery currently operates within and adjacent to the Gully area on the Scotian Shelf. In terms of large pelagics species composition and relative abundance, there is no indication that this area is of greater or lesser importance as foraging habitat for swordfish than the rest of the Scotian Shelf, and it does not appear to be an area commonly occupied by any of the other tuna species (albacore, bigeye, yellowfin). Since there is no directed fishery for bluefin in this area or anywhere offshore on the eastern Scotian Shelf, it is not clear if they commonly occur in the Gully or not.

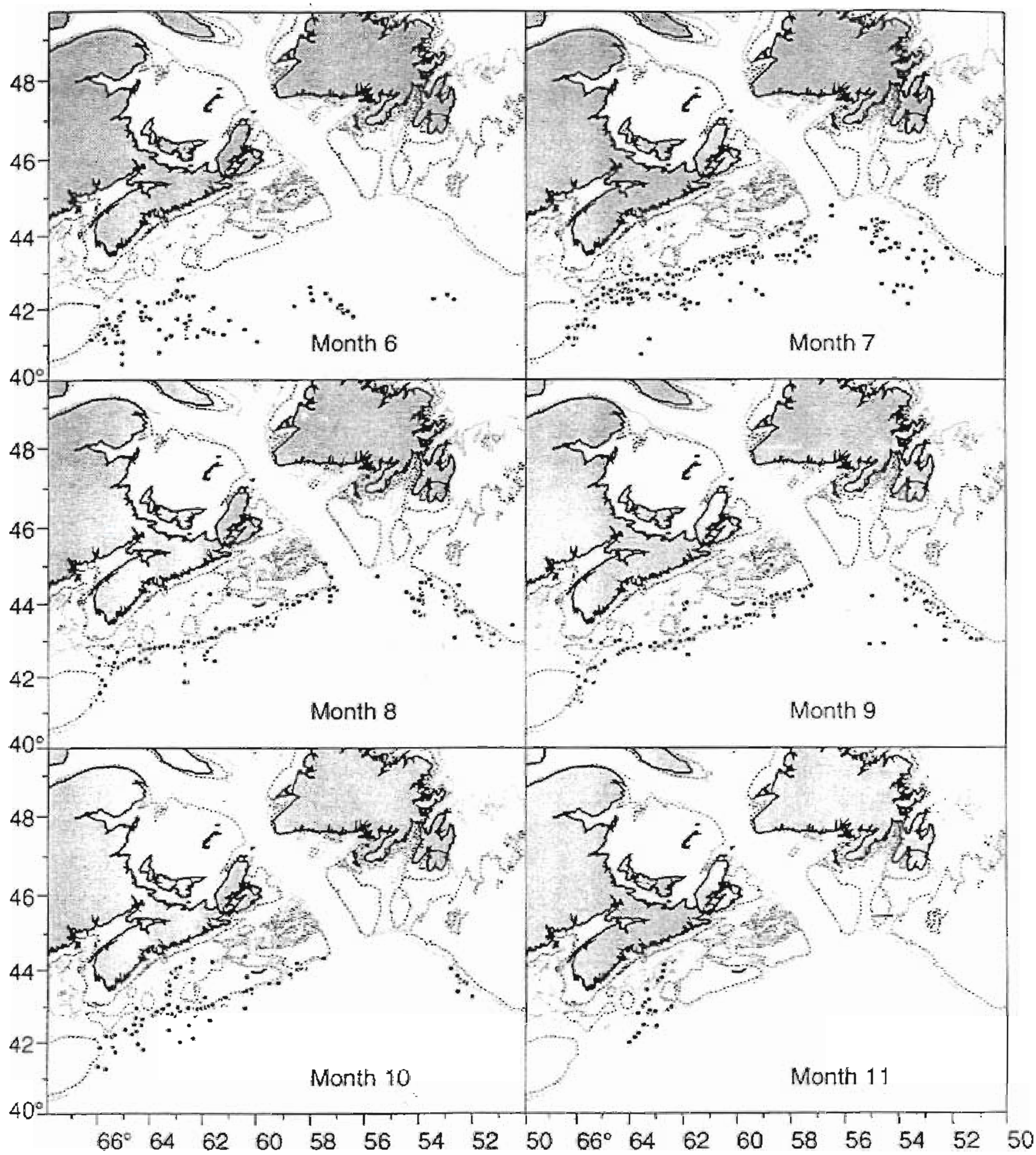

Fig. 13.2.1. Set locations by month for Canadian swordfish longline, June-November, 1994.

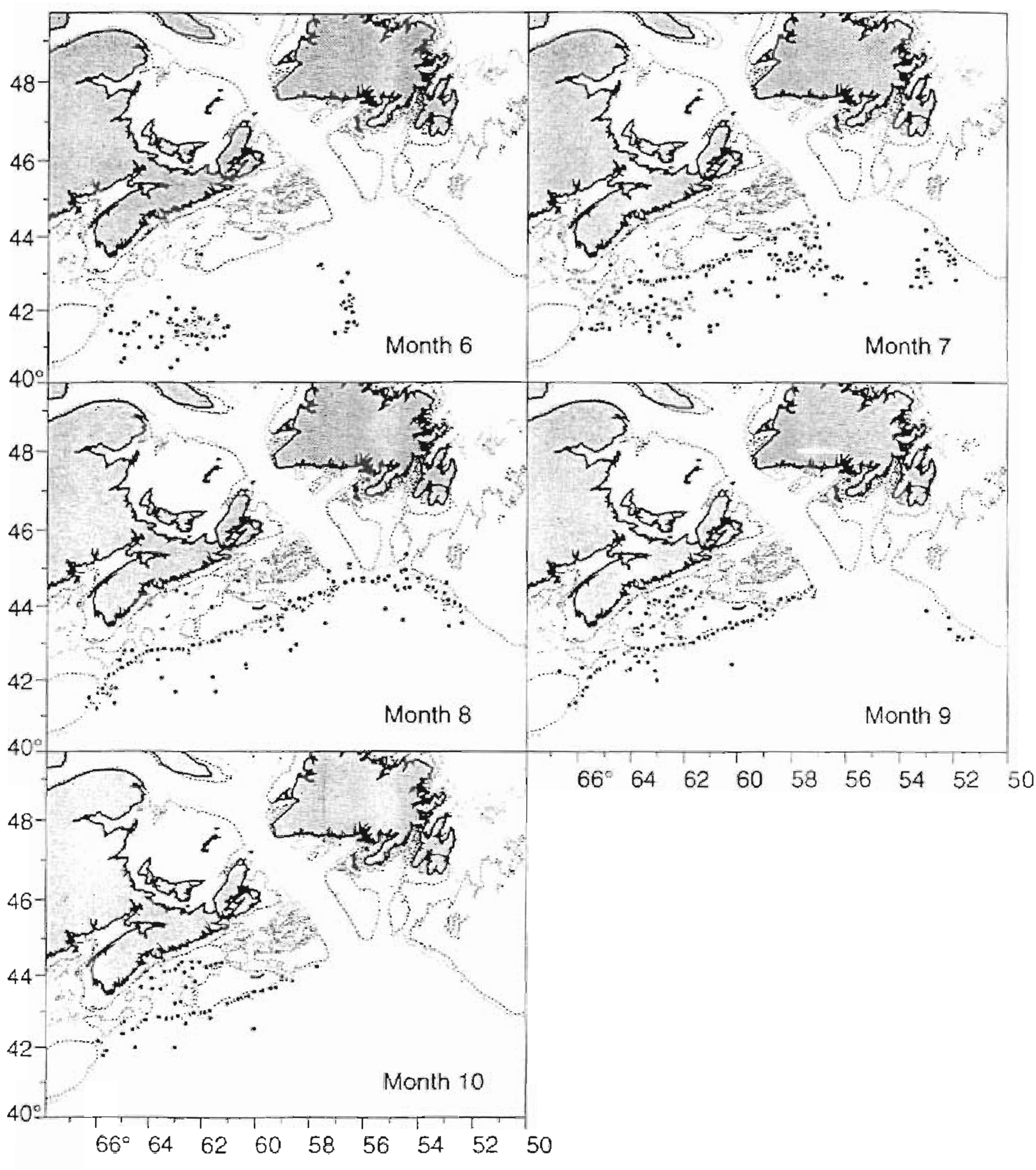

Fig. 13.2.2. Set locations by month for Canadian swordfish longline, June-October, 1995.

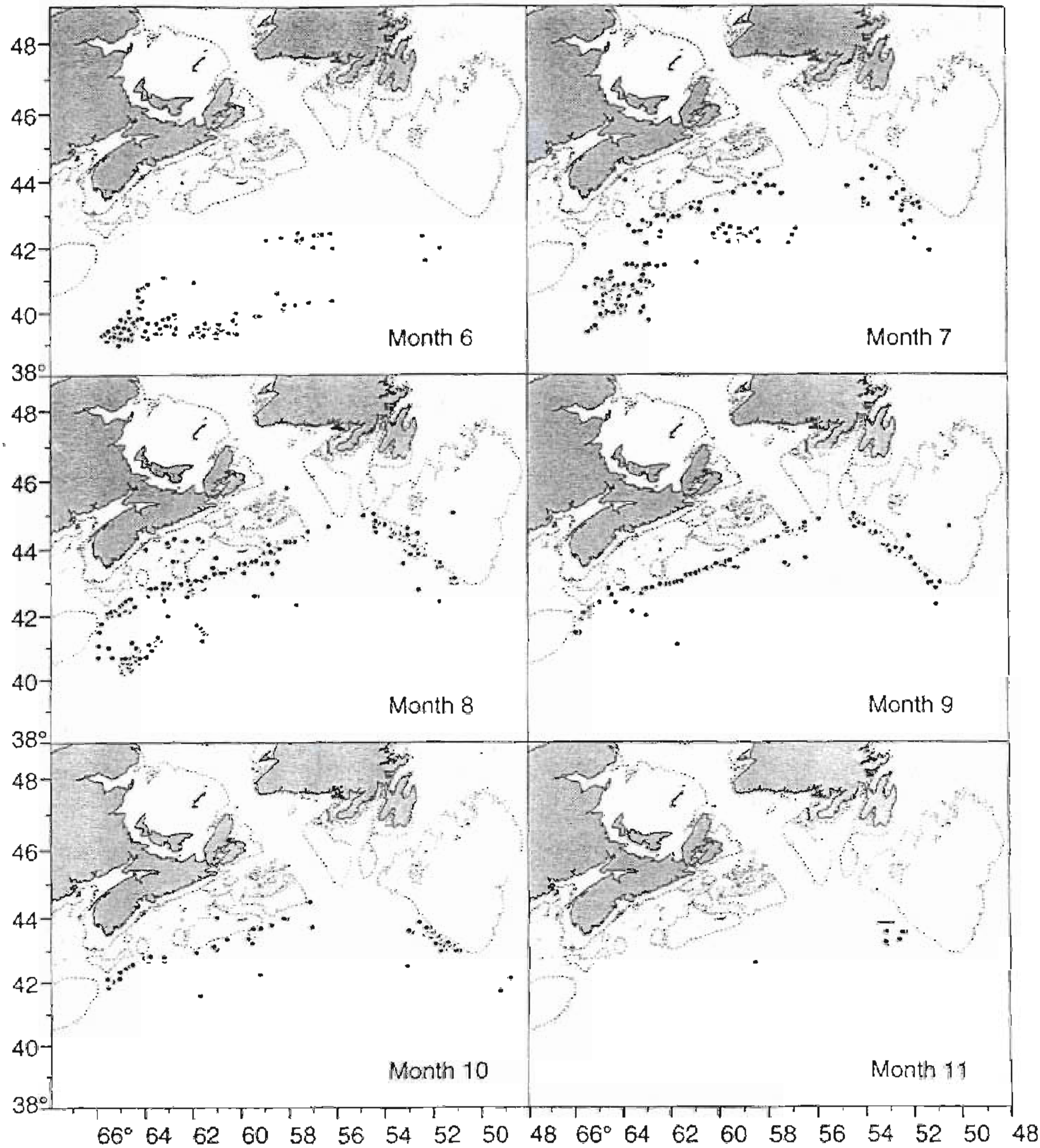

Fig. 13.2.3. Set locations by month for Canadian swordfish longline, June-November, 1996.

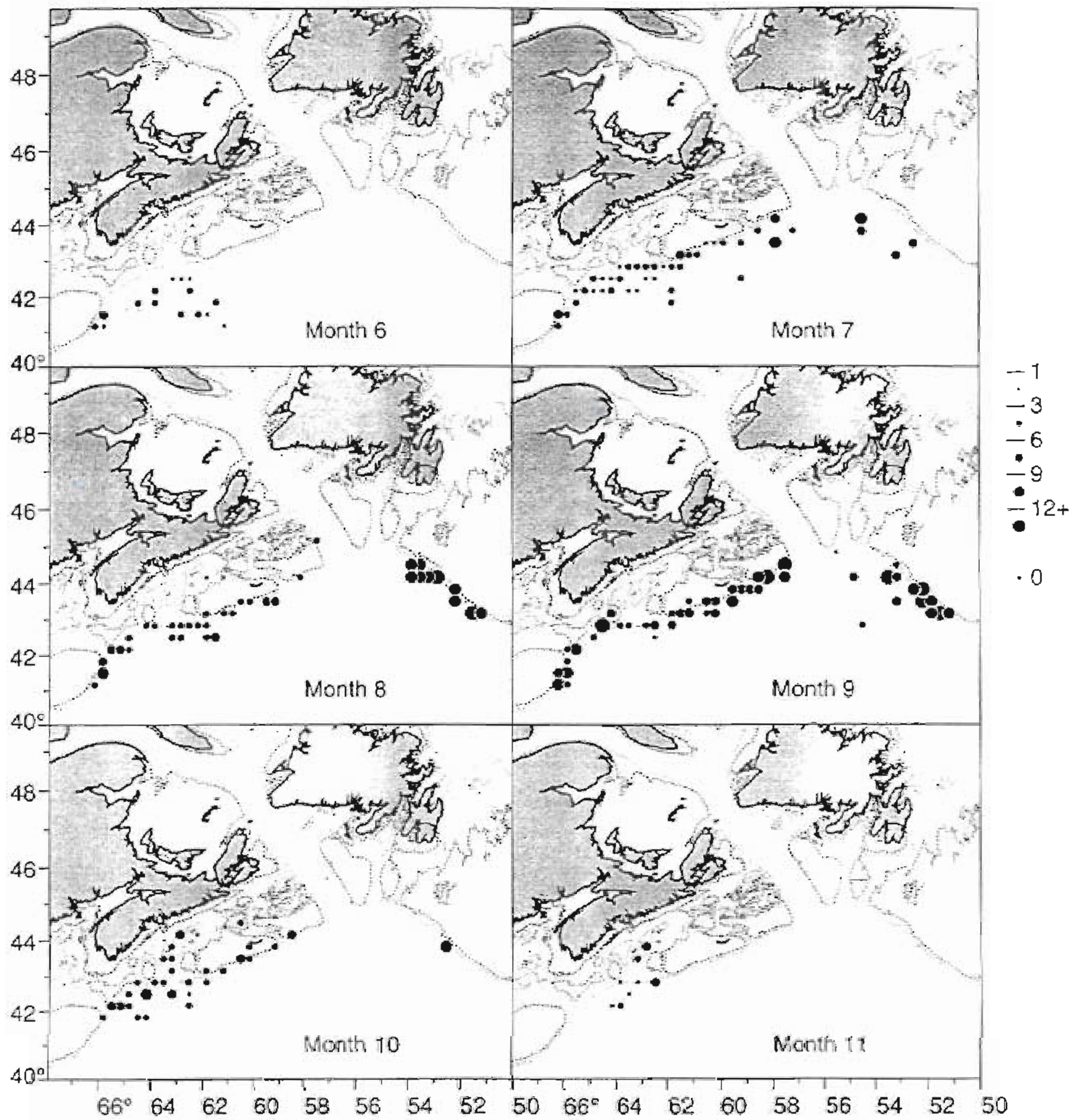

Fig. 13.2.4. Nominal CPUE (number of fish per 1000 hooks) aggregated by 20 minute squares for Canadian swordfish longline, June-November, 1994.

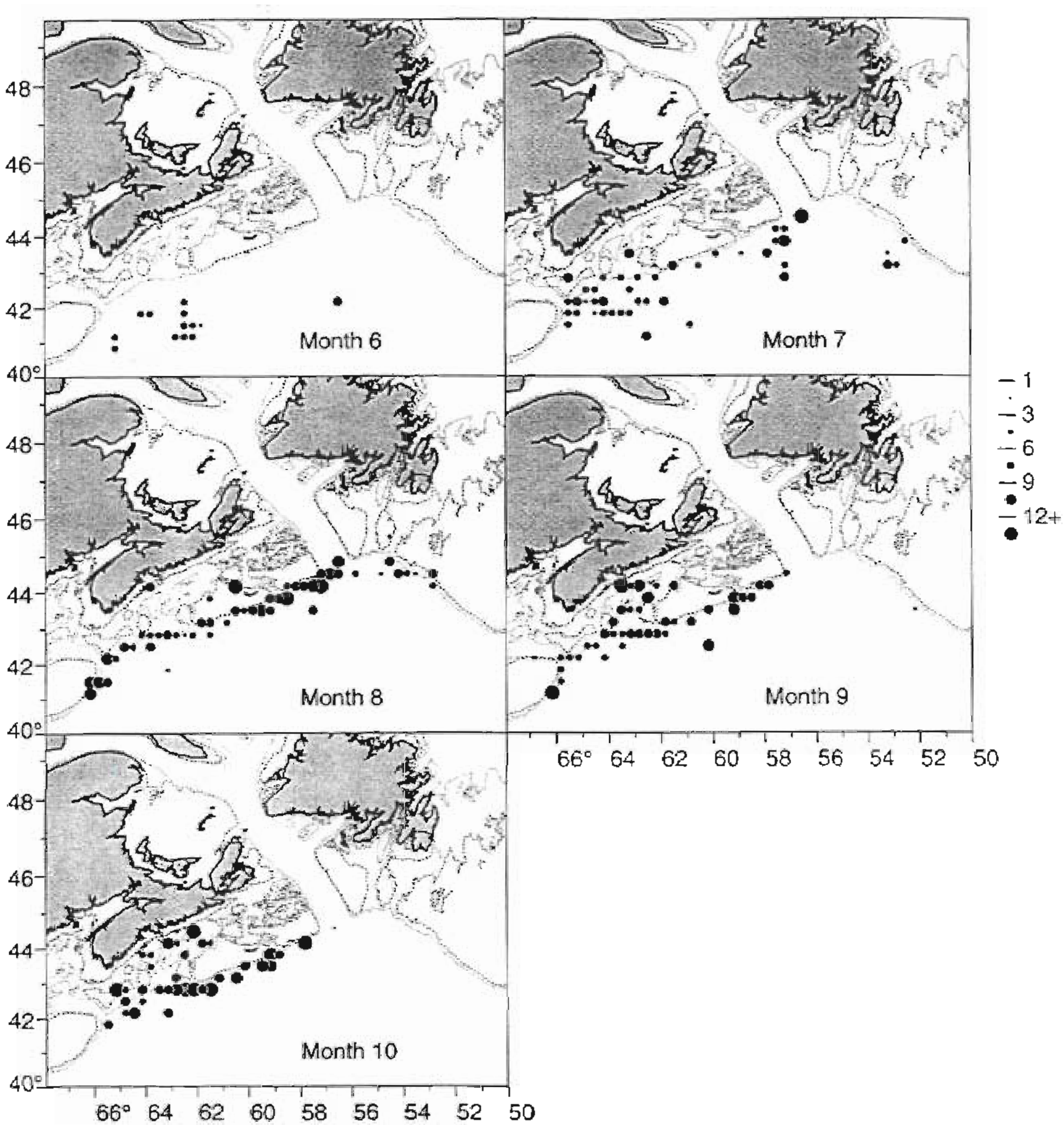

Fig. 13.2.5. Nominal CPUE (number of fish per 1000 hooks) aggregated by 20 minute squares for Canadian swordfish longline, June-October, 1995.

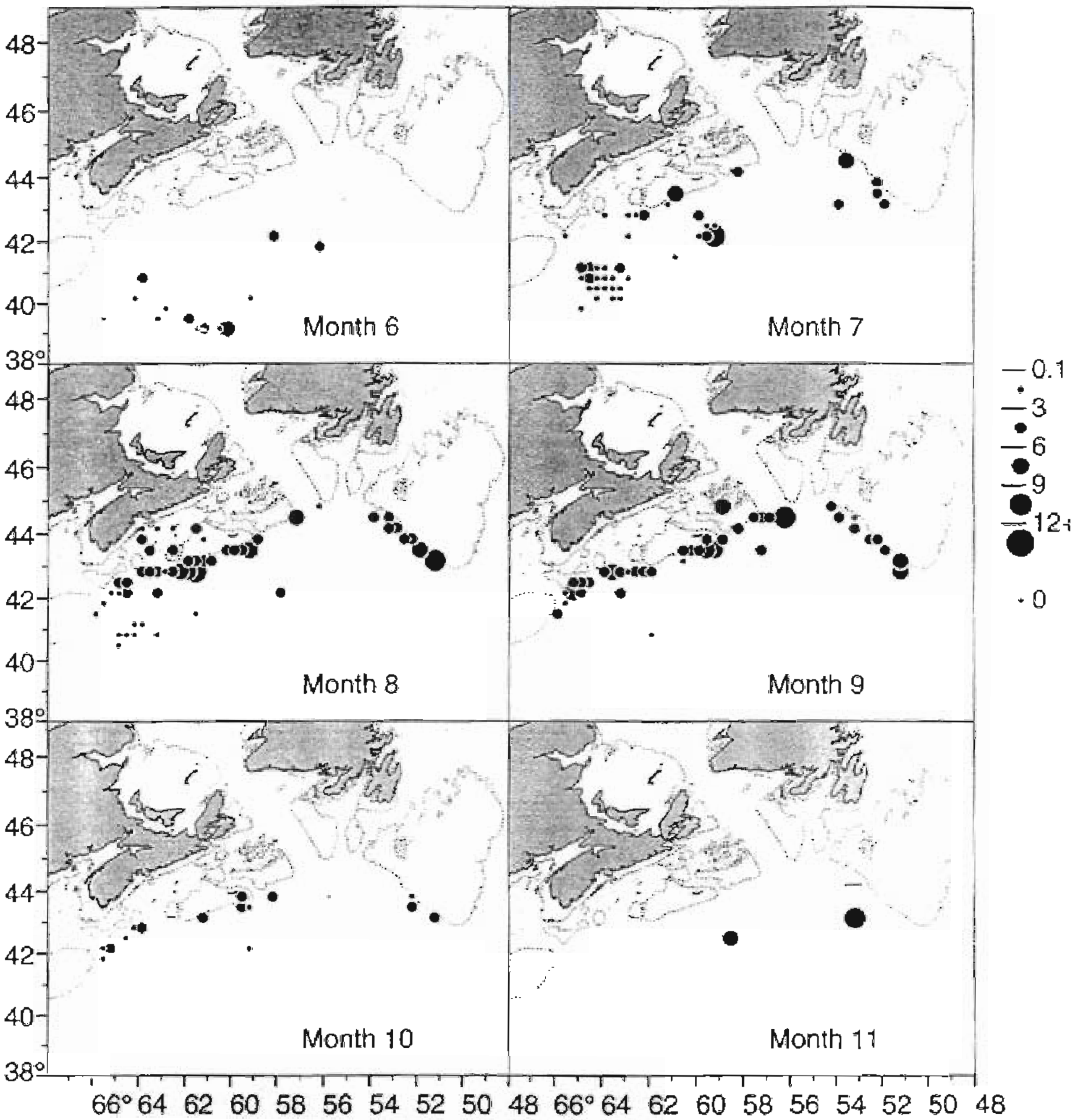

Fig. 13.2.6. Nominal CPUE (number of fish per 1000 hooks) aggregated by 20 minute squares for Canadian swordfish longline, June-November, 1996.

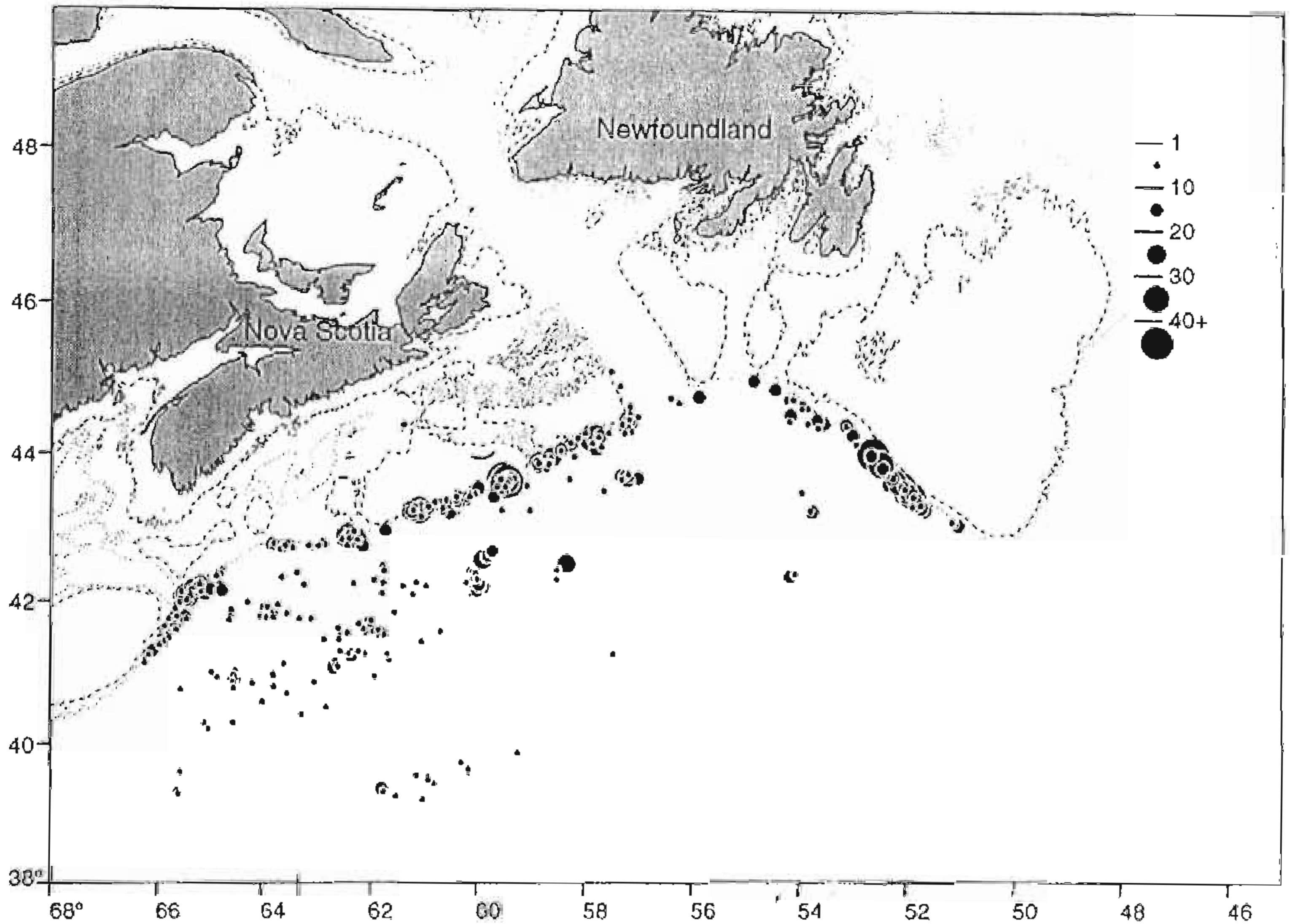

Fig. 13.2.7. Set locations and relative number of swordfish sampled per set from Canadian research and observer program sample collections, 1980-1996.

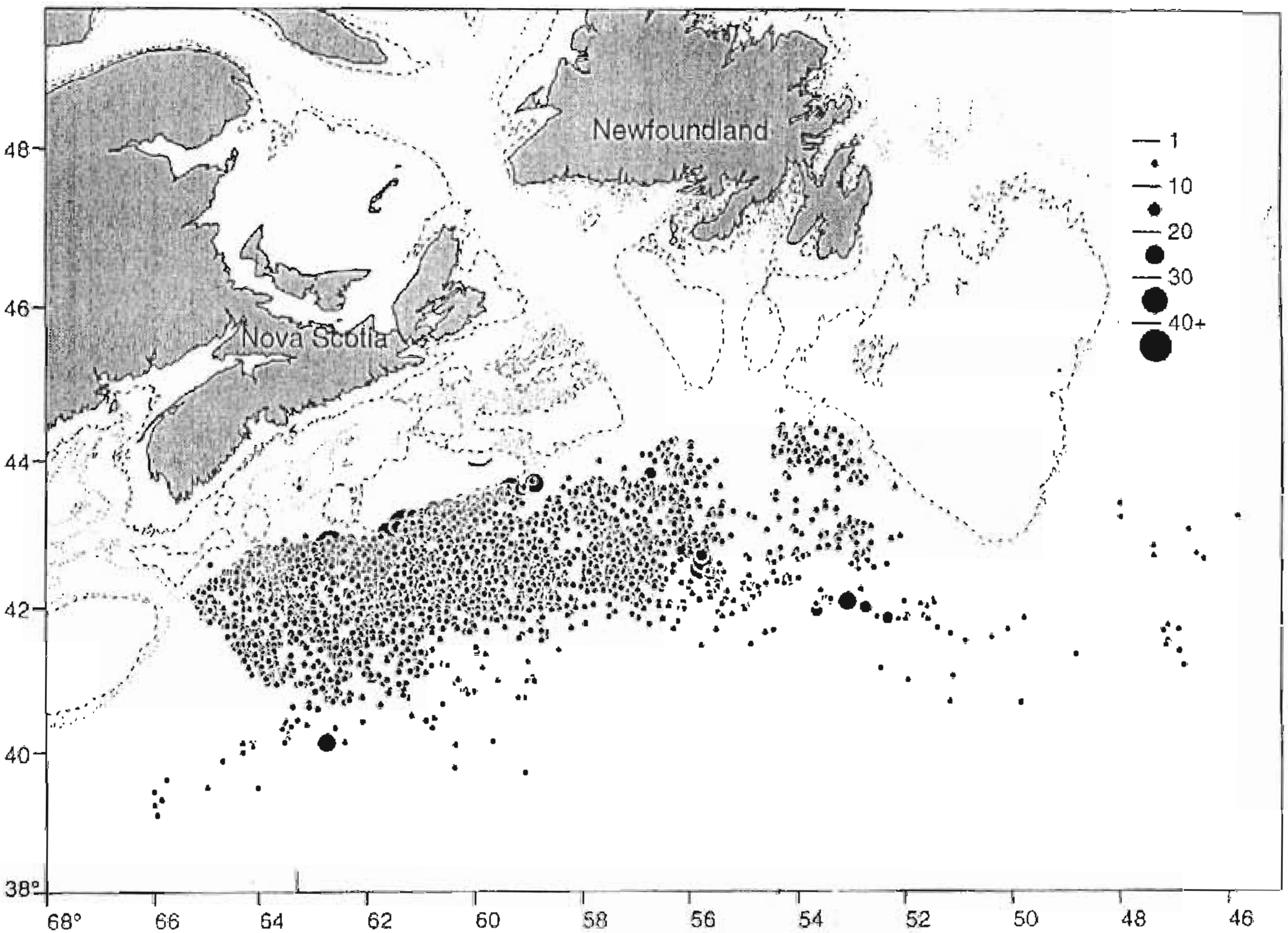

Fig. 13.2.8. Set locations and relative number of swordfish sampled per set on Japanese longline vessels from Canadian observer program sampling, 1980-1996.

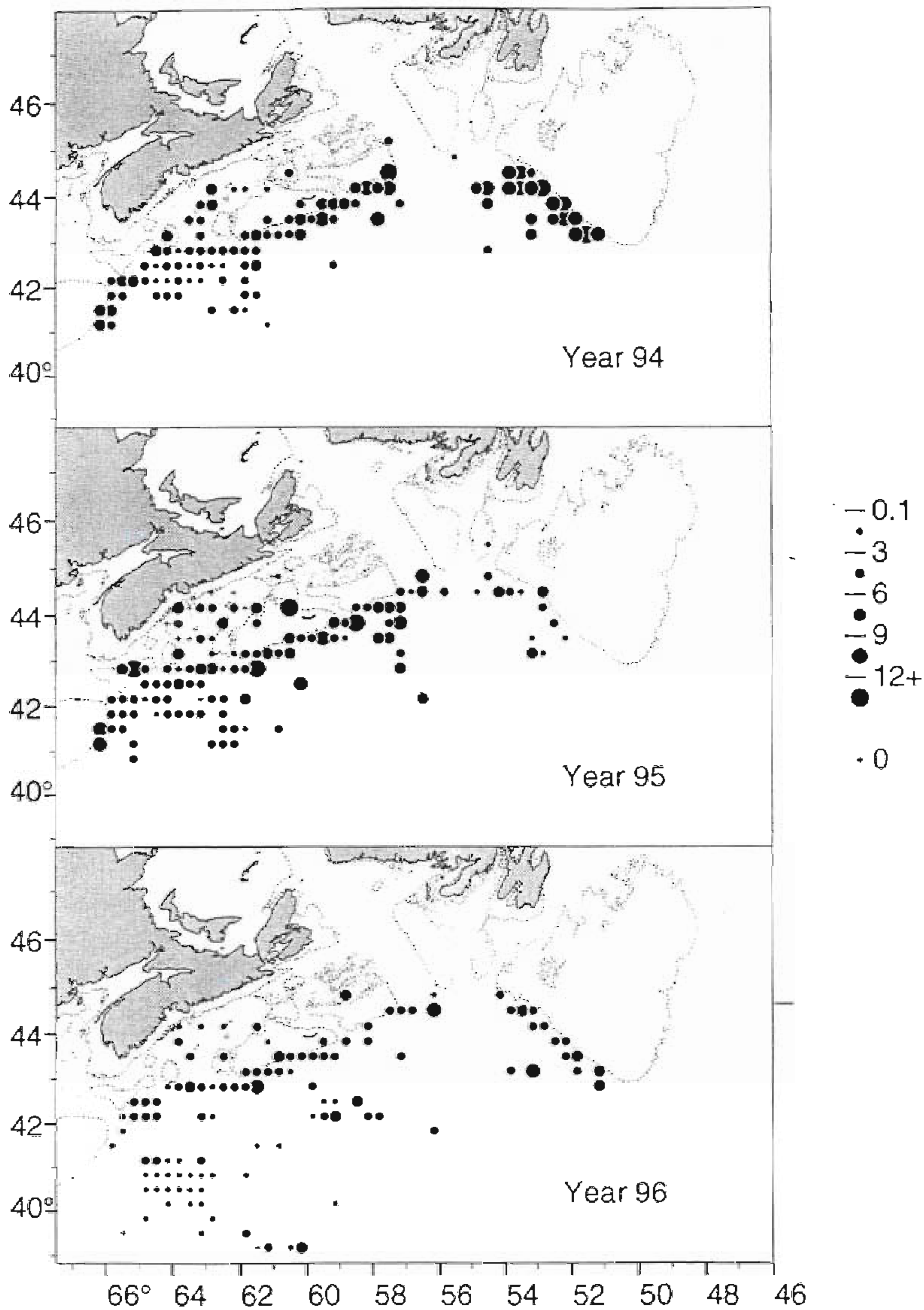

Fig. 13.2.9. Nominal CPUE (average number of fish per 1000 hooks) aggregated by 20 minute rectangles for the Canadian swordfish longline, 1994-1996.

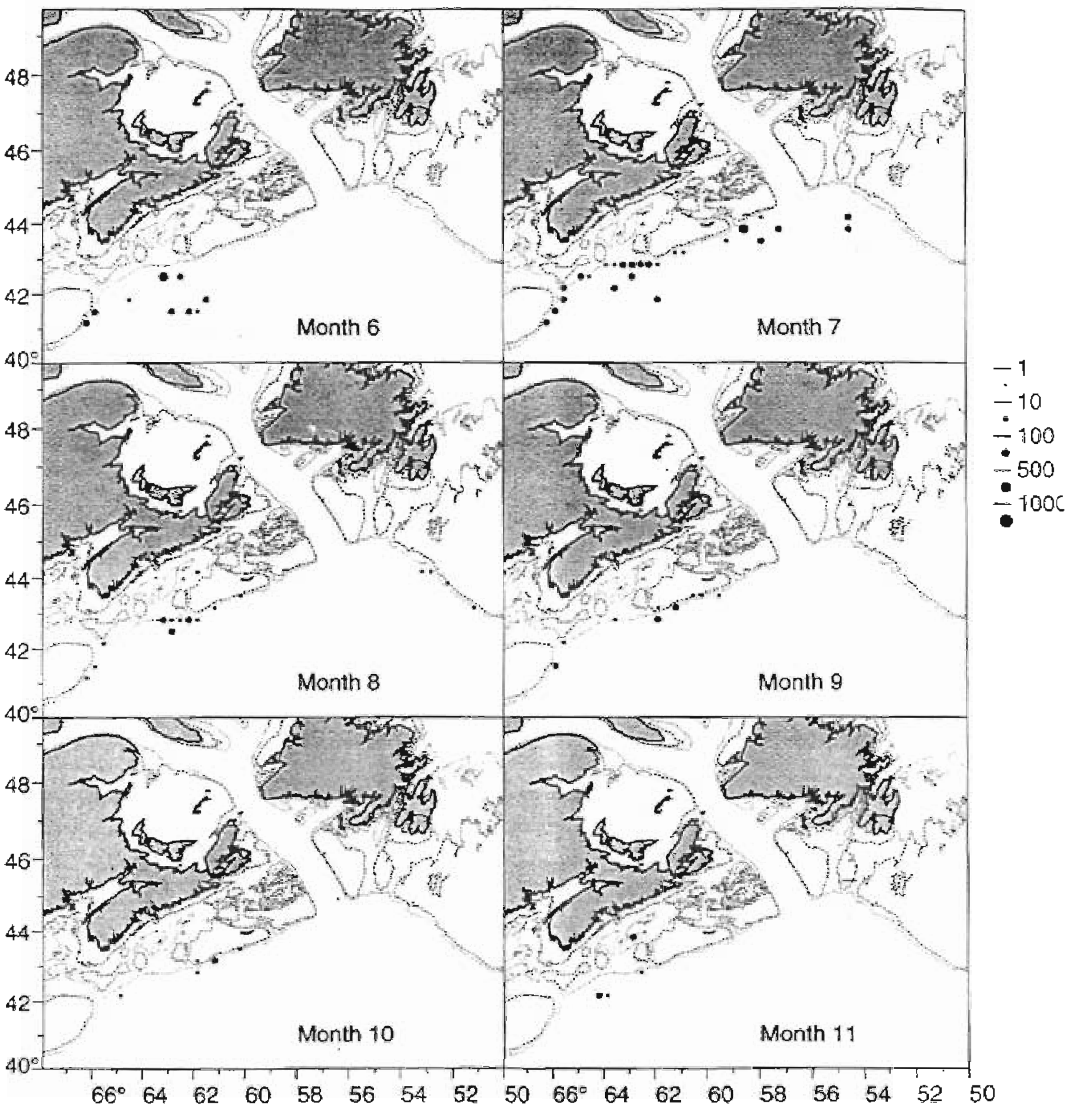

Fig. 13.2.10. Nominal CPUE (kgs of fish per 1000 hooks) for albacore aggregated by 20 minute rectangles from Canadian swordfish longline, 1994.

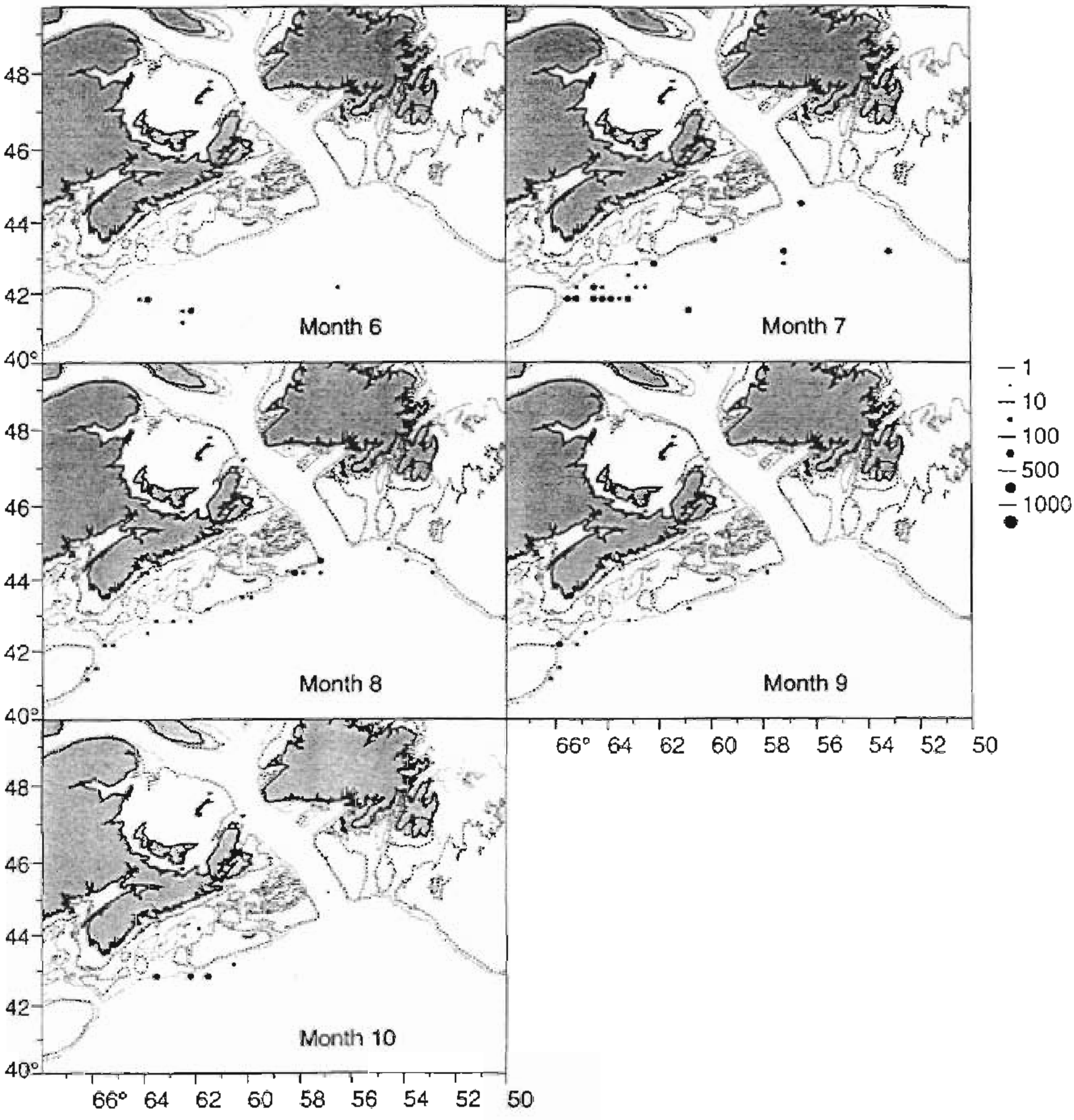

Fig. 13.2.11. Nominal CPUE (kgs of fish per 1000 hooks) for albacore aggregated by 20 minute rectangles from Canadian swordfish longline, 1995.

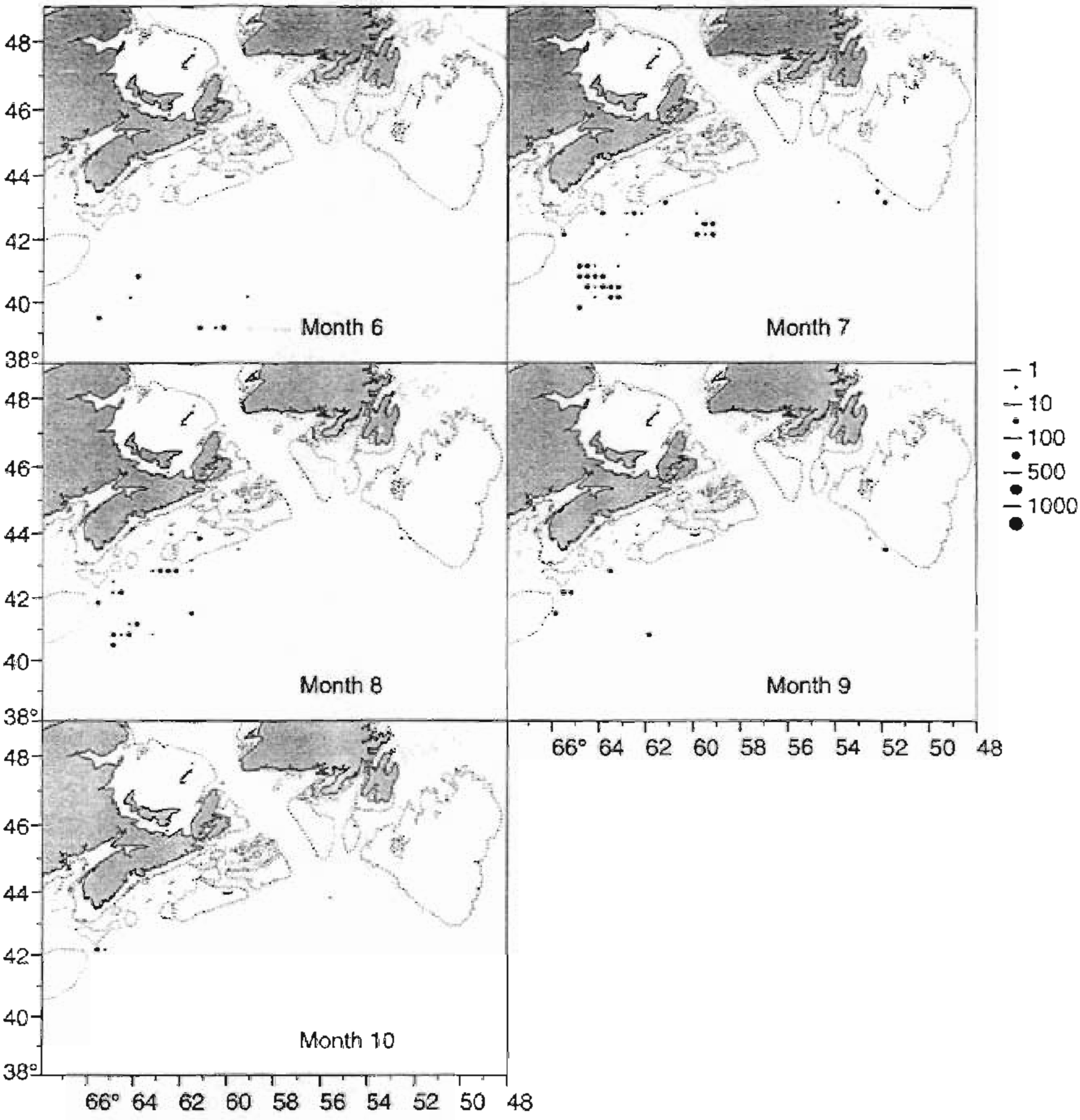

Fig. 13.2.12. Nominal CPUE (kgs of fish per 1000 hooks) for albacore aggregated by 20 minute rectangles from Canadian swordfish longline, 1996.

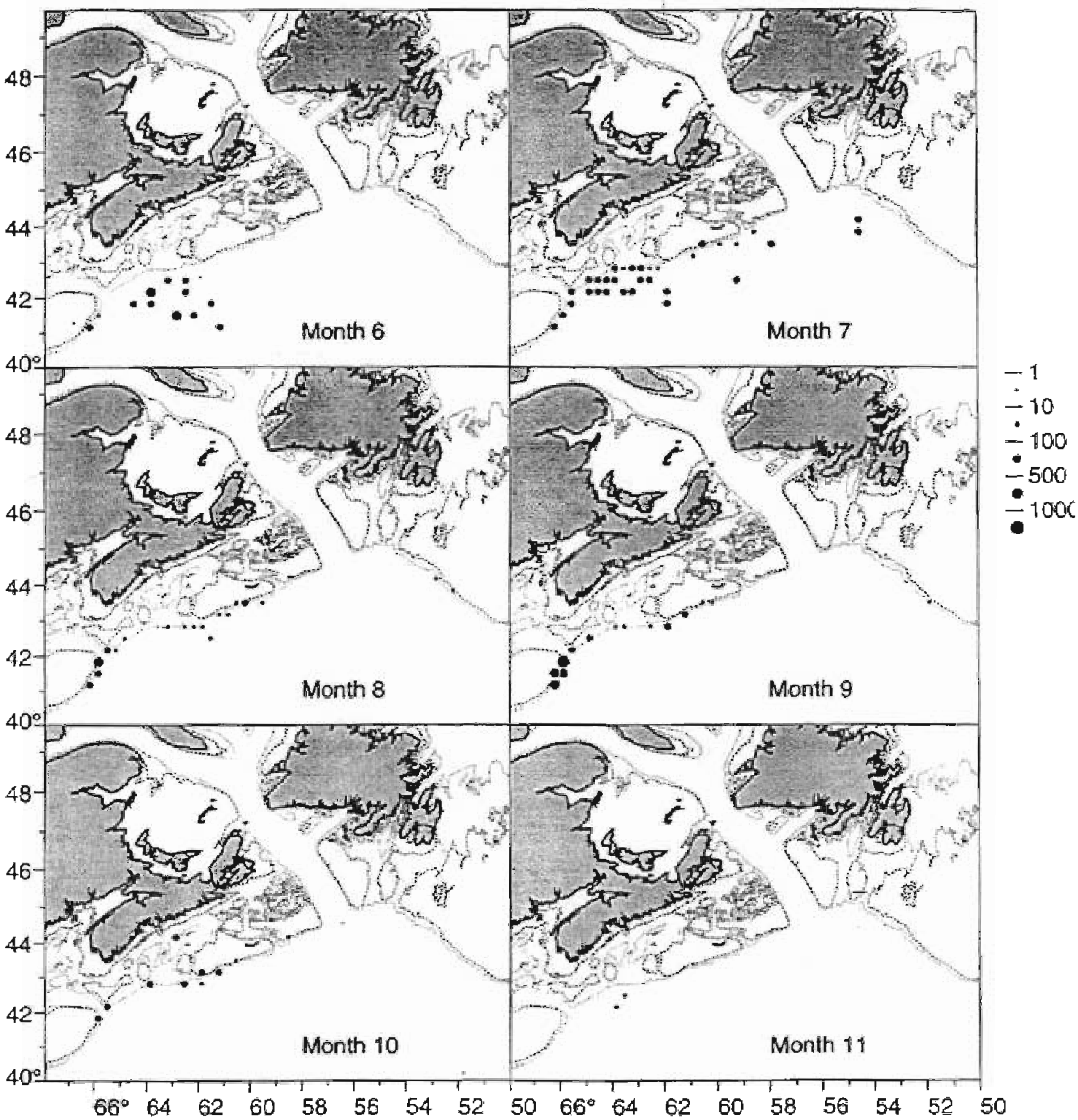

Fig. 13.2.13. Nominal CPUE (kgs of fish per 1000 hooks) for yellowfin aggregated by 20 minute rectangles from Canadian swordfish longline, 1994.

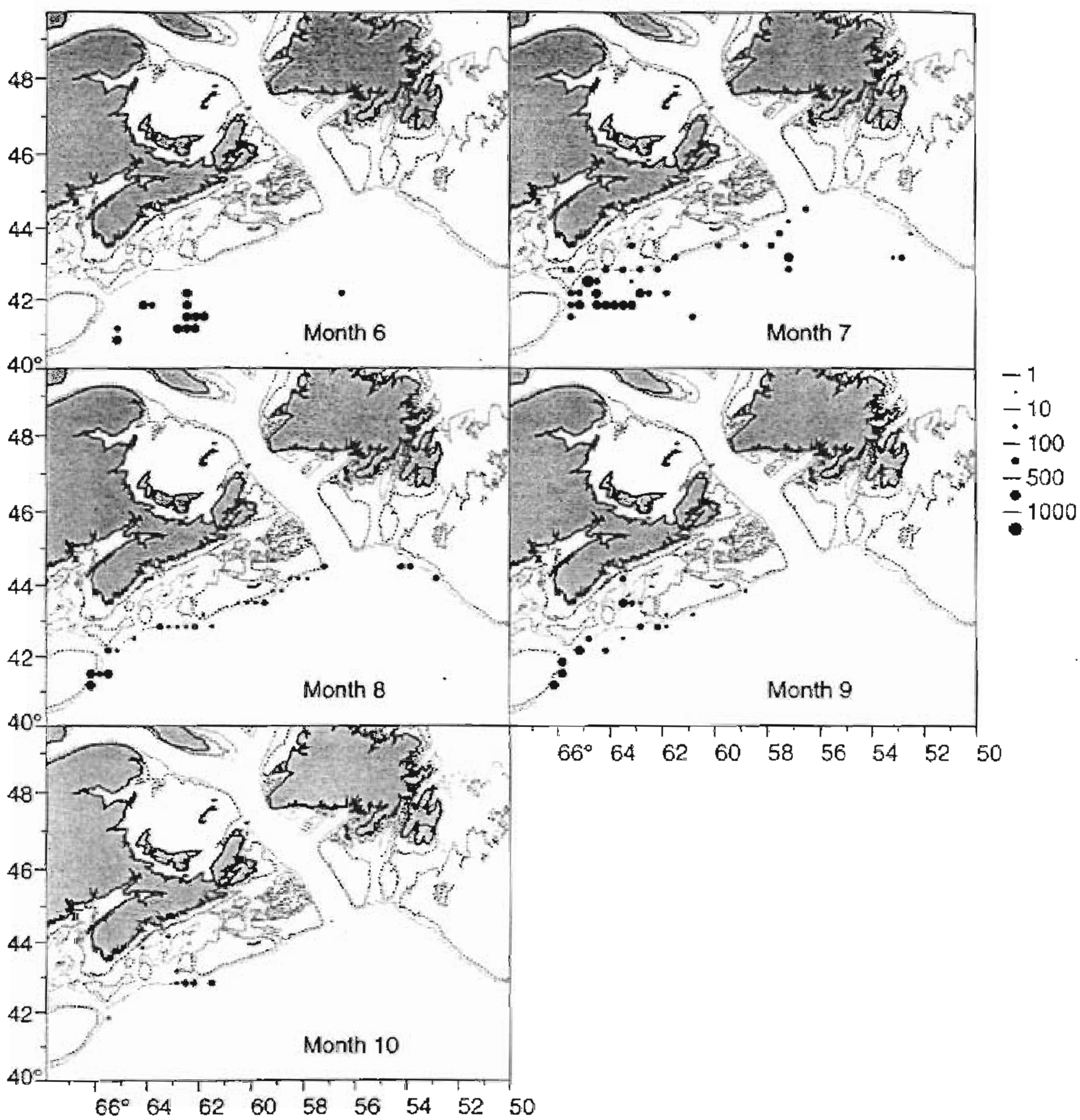

Fig. 13.2.14. Nominal CPUE (kgs of fish per 1000 hooks) for yellowfin aggregated by 20 minute rectangles from Canadian swordfish longline, 1995.

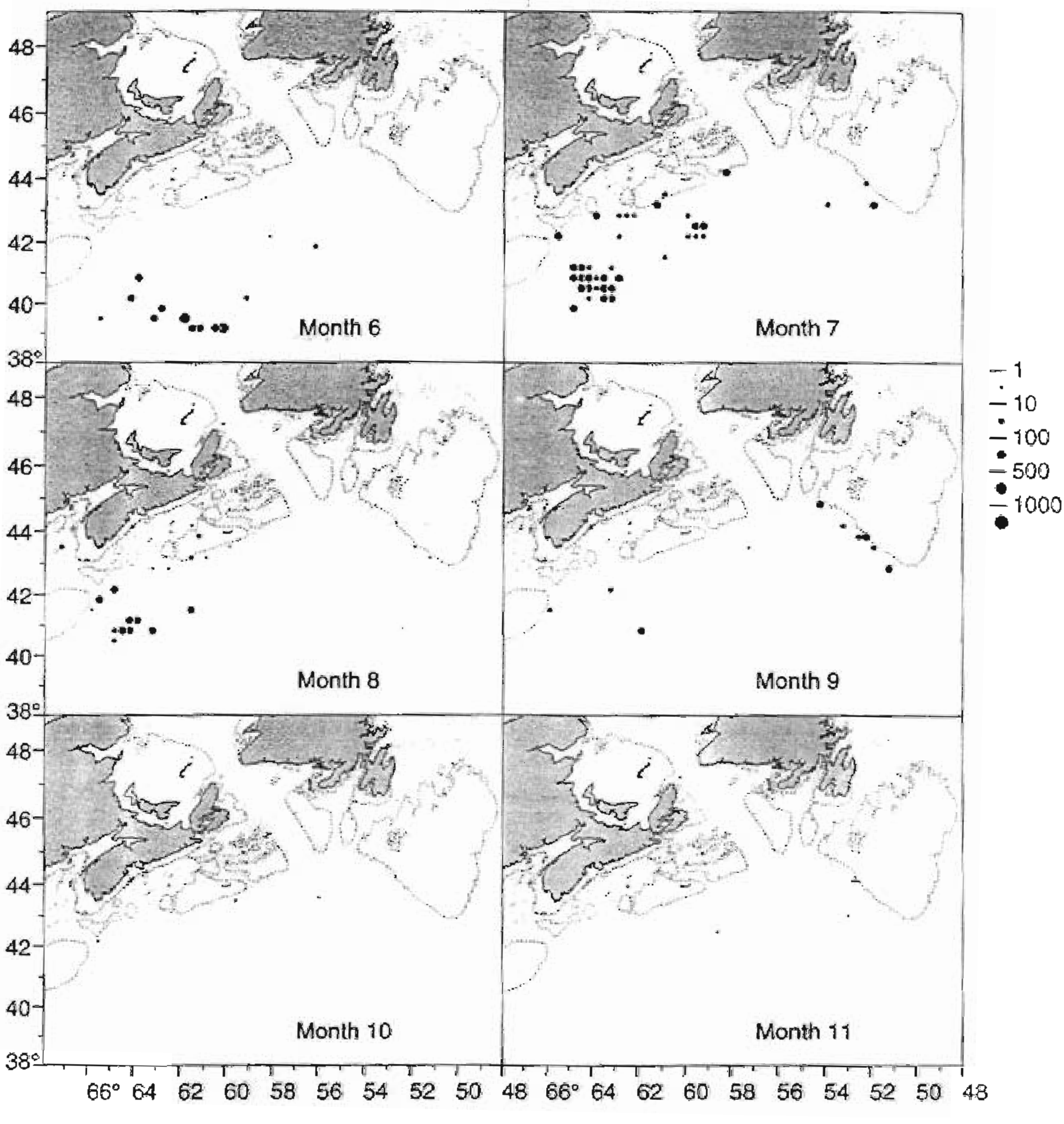

Fig. 13.2.15. Nominal CPUE (kgs of fish per 1000 hooks) for yellowfin aggregated by 20 minute rectangles from Canadian swordfish longline, 1996.

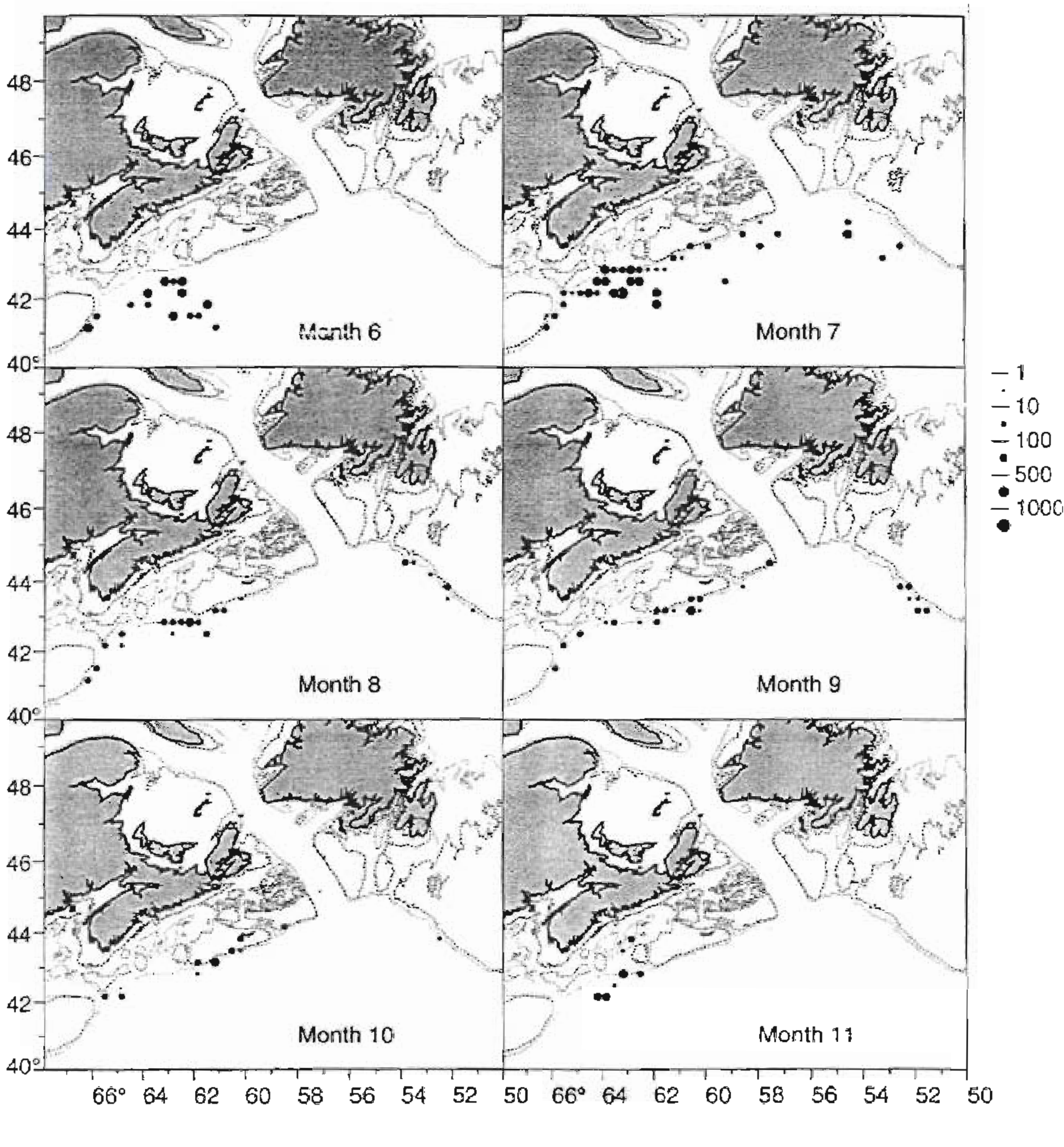

Fig. 13.2.16. Nominal CPUE (kgs of fish per 1000 hooks) for bigeye aggregated by 20 minute rectangles from Canadian swordfish longline, 1994.

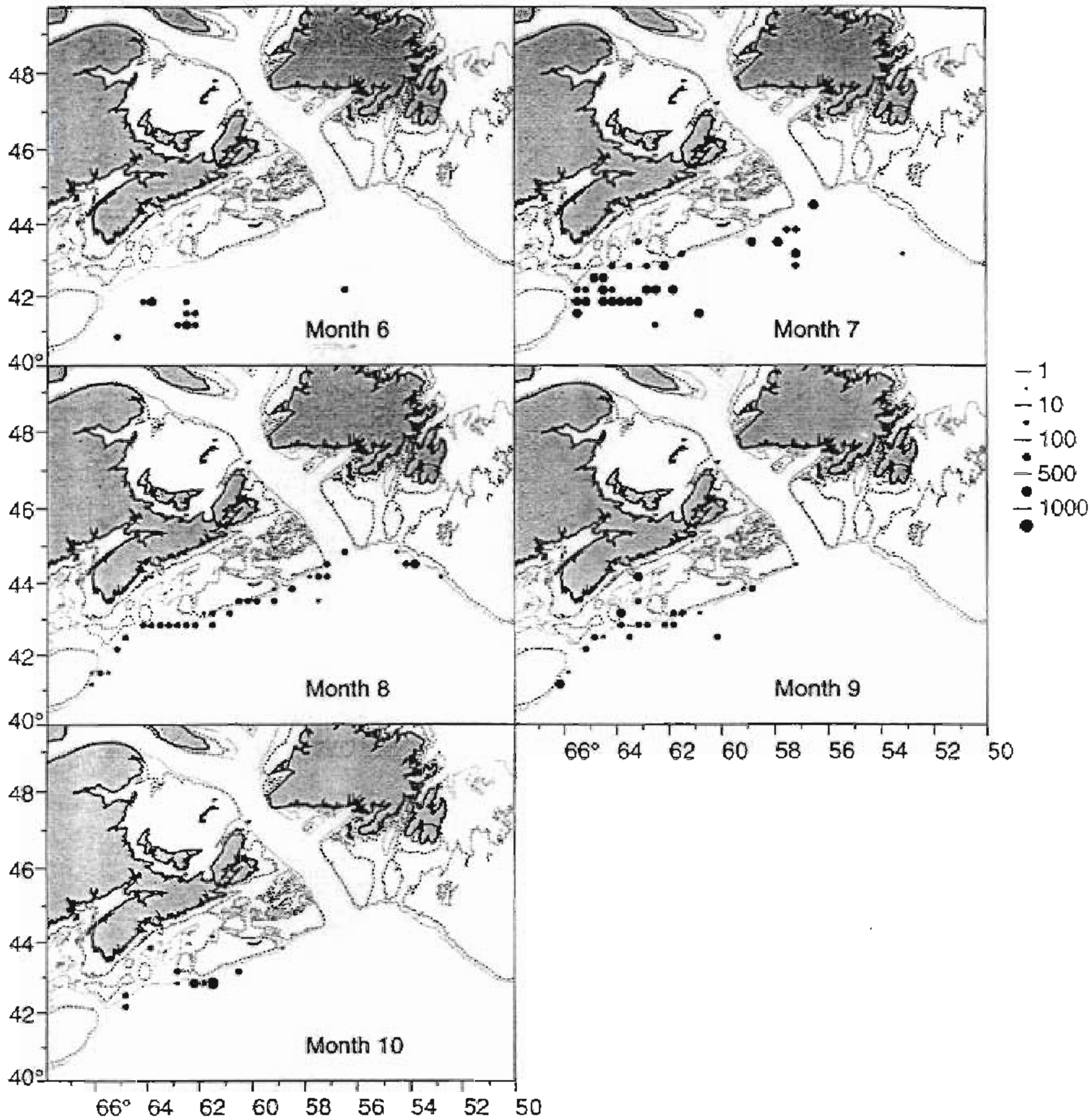

Fig. 13.2.17. Nominal CPUE (kgs of fish per 1000 hooks) for bigeye aggregated by 20 minute rectangles from Canadian swordfish longline, 1995.

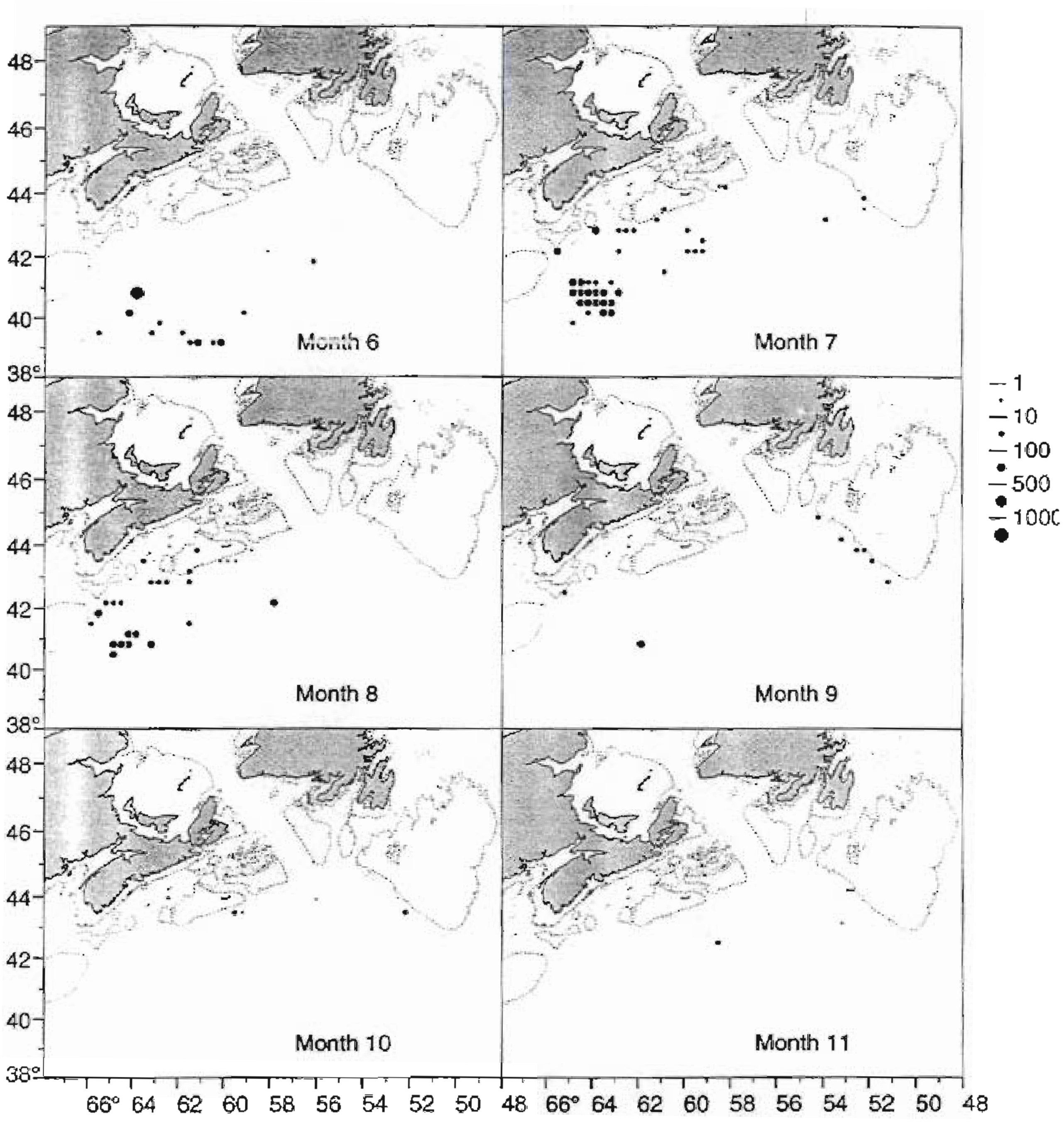

Fig. 13.2.18. Nominal CPUE (kgs of fish per 1000 hooks) for bigeye aggregated by 20 minute rectangles from Canadian swordfish longline, 1996.

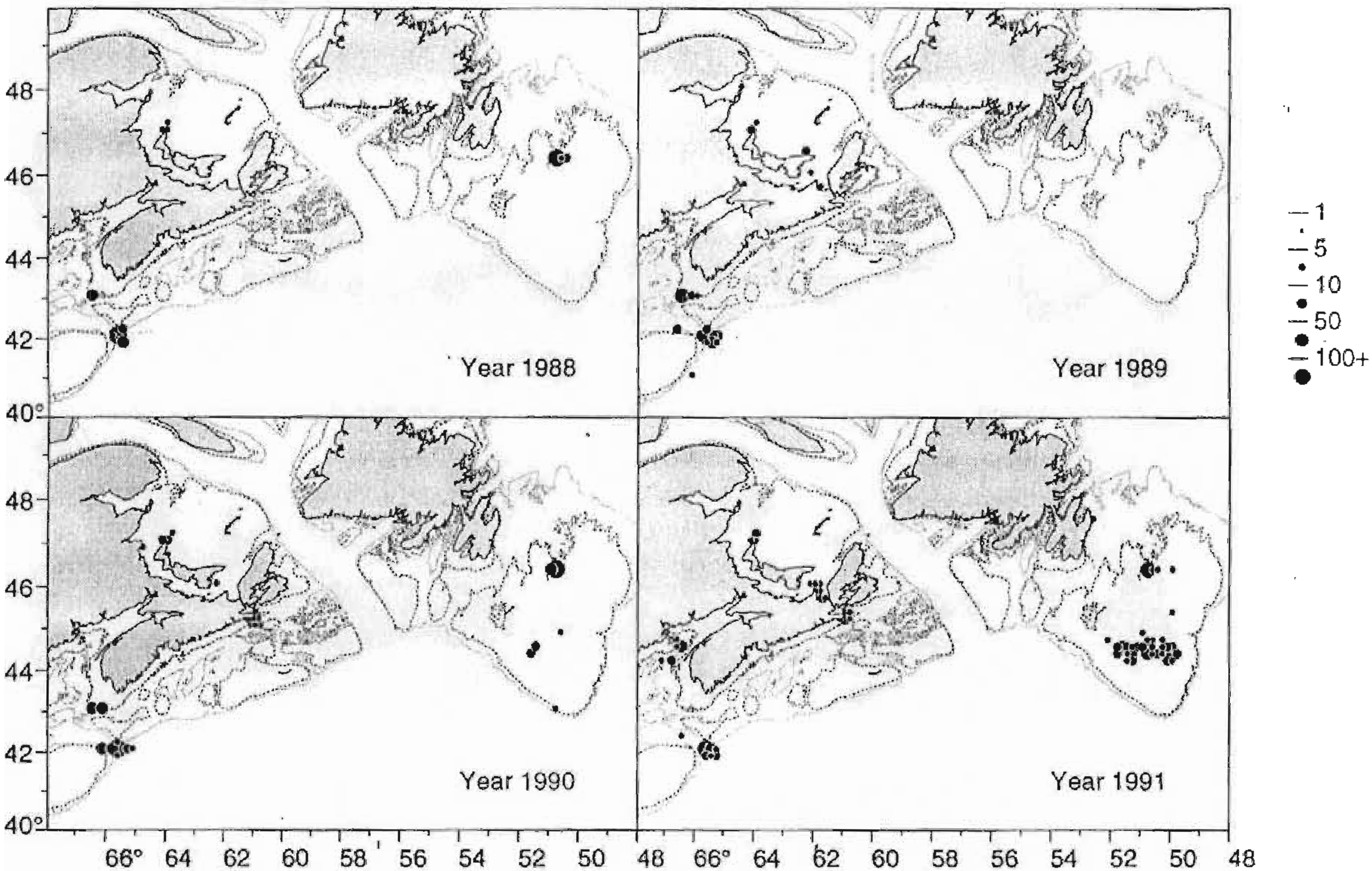

Fig. 13.2.19. Canadian bluefin tuna catch from log record data aggregated by 10 minute rectangles for 1988 through 1991 (Not all catch locations were available for plotting).

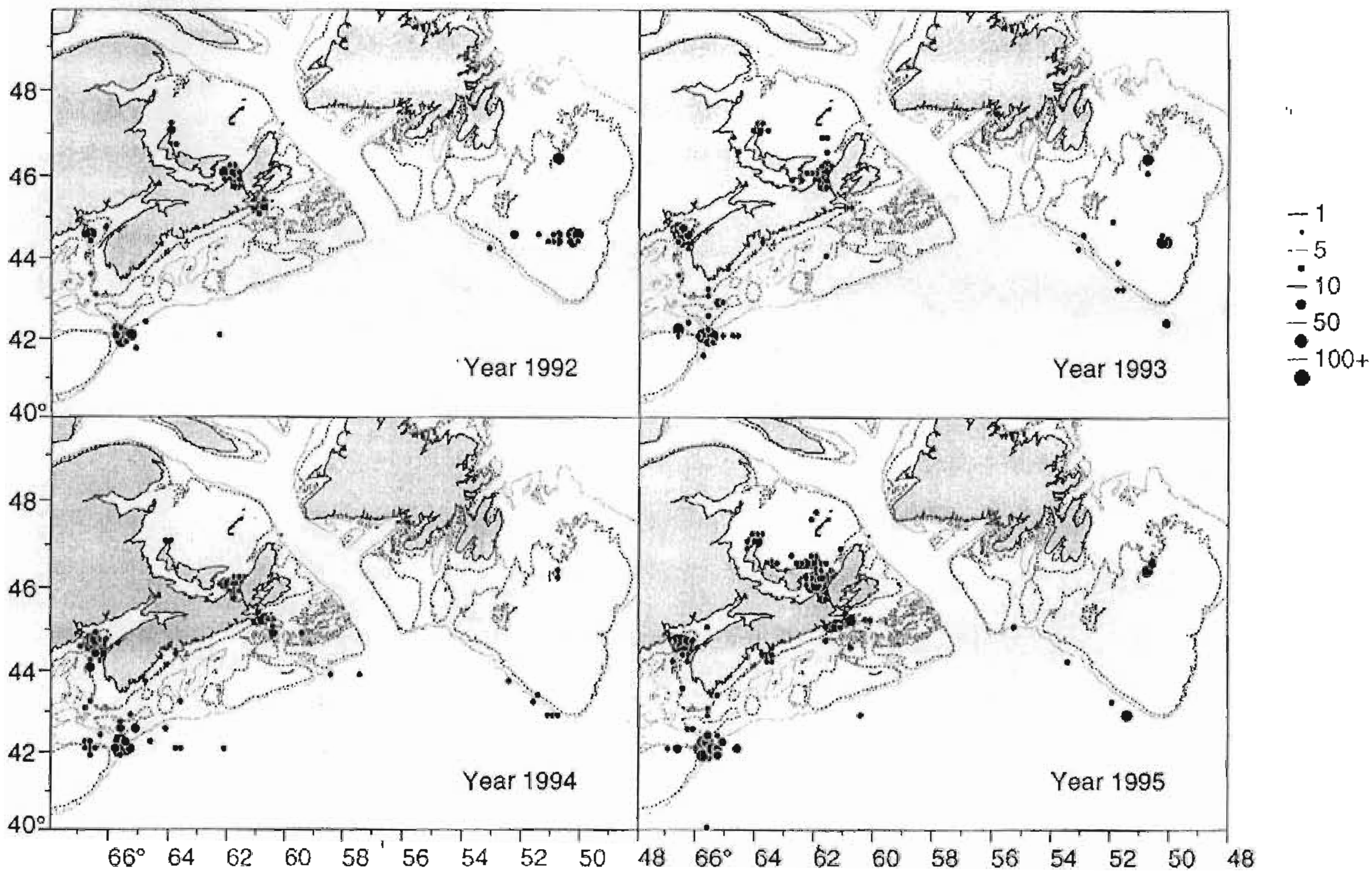

Fig. 13.2.20. Canadian bluefin tuna catch from log record data aggregated by 10 minute rectangles for 1992 through 1996 (Not all catch locations were available for plotting).

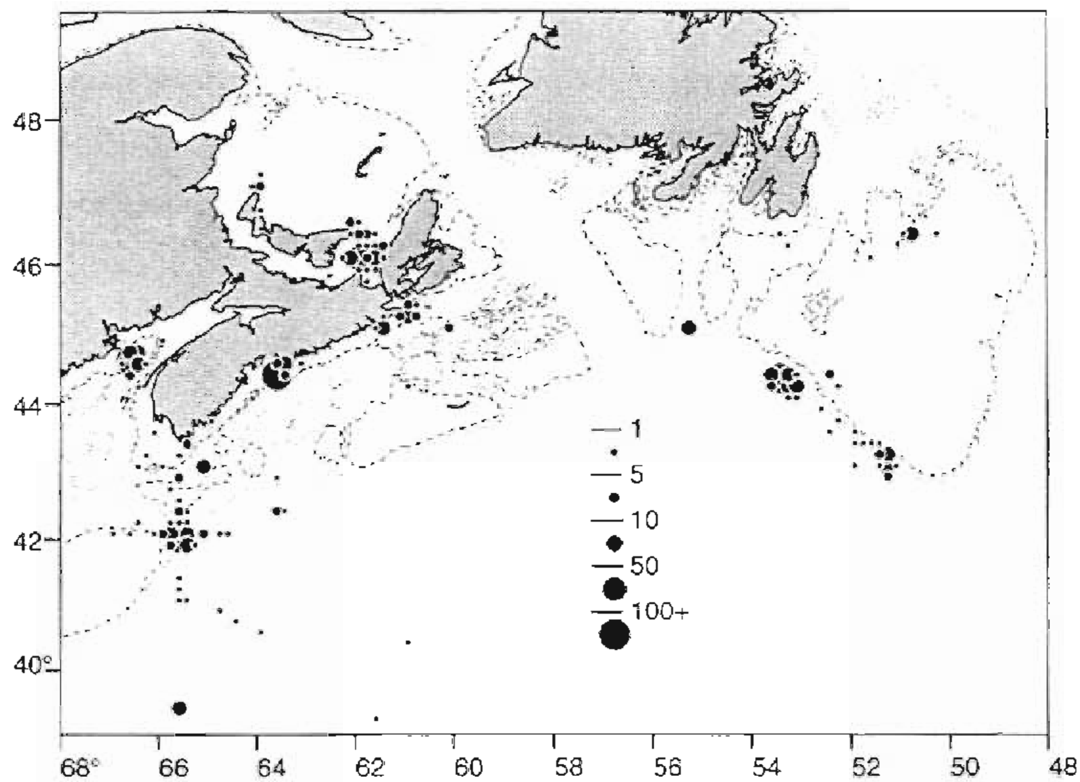

Fig. 13.2.21. Canadian bluefin tuna catch/10 minute square - 1996.