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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.

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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.

Information Gaps:

- 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.

Acknowledgements

The editors and DFO wish to thank the review team and in particular those members from outside the Department for the time and effort they put into their reports and the meetings and discussions associated with the development of this document. We also wish to thank the many additional observers from the petroleum and fishing industries, environmental consulting companies, universities and conservation groups who attended our meetings, contributed to the discussion, and provided valuable suggestions. Finally, we wish to express special thanks to Drs. Peter Auster, Stephen Brown and Frank Almeida who served as external examiners for our Regional Advisory Process (RAP) and provided valuable suggestions for the improvement of our Review.

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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.

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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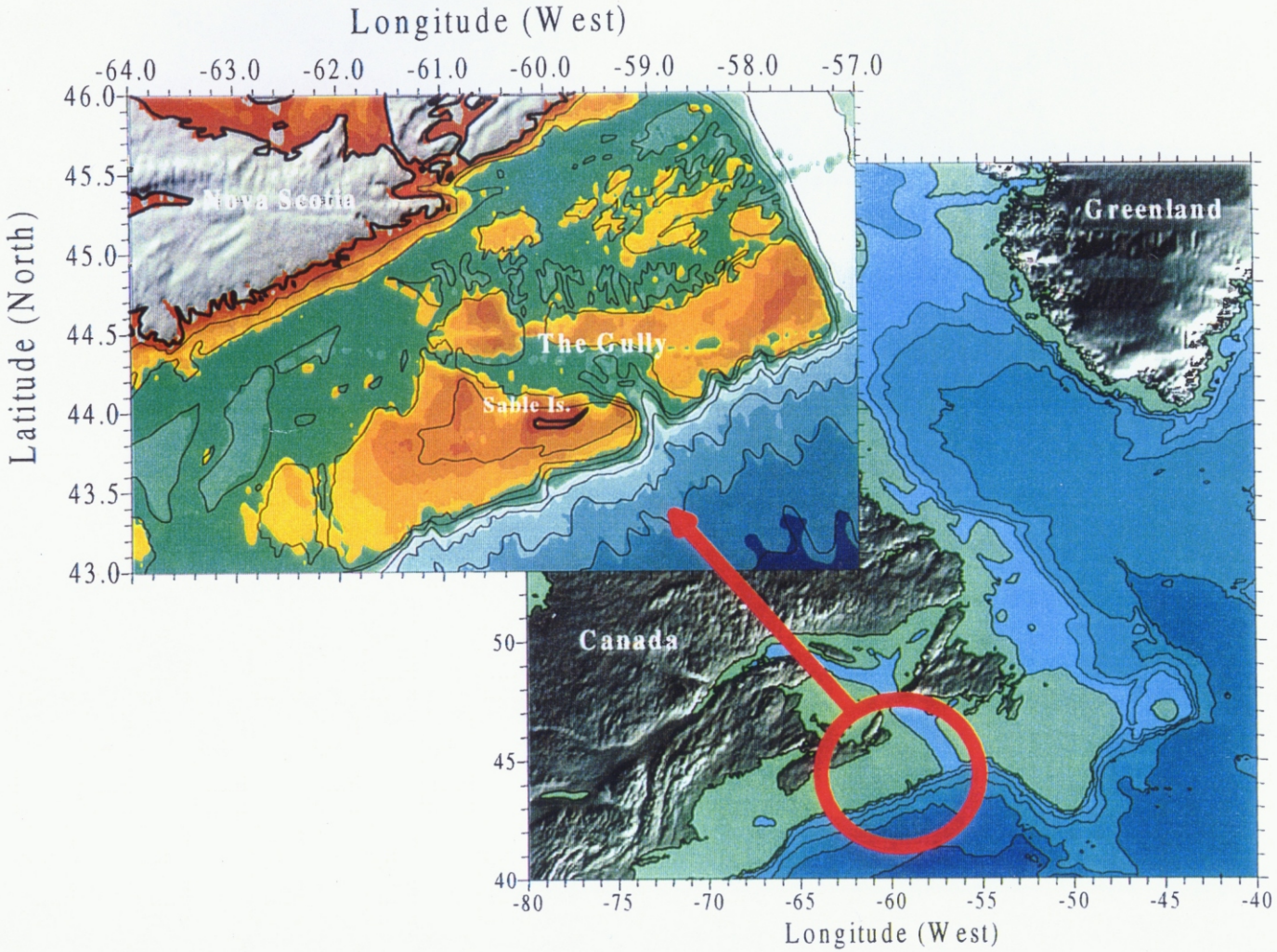

Fig. 1.0.1. The Gully: a deep submarine canyon approximately 40 kilometres east of Sable Island (200 km off Nova Scotia), on the eastern Scotian Shelf.

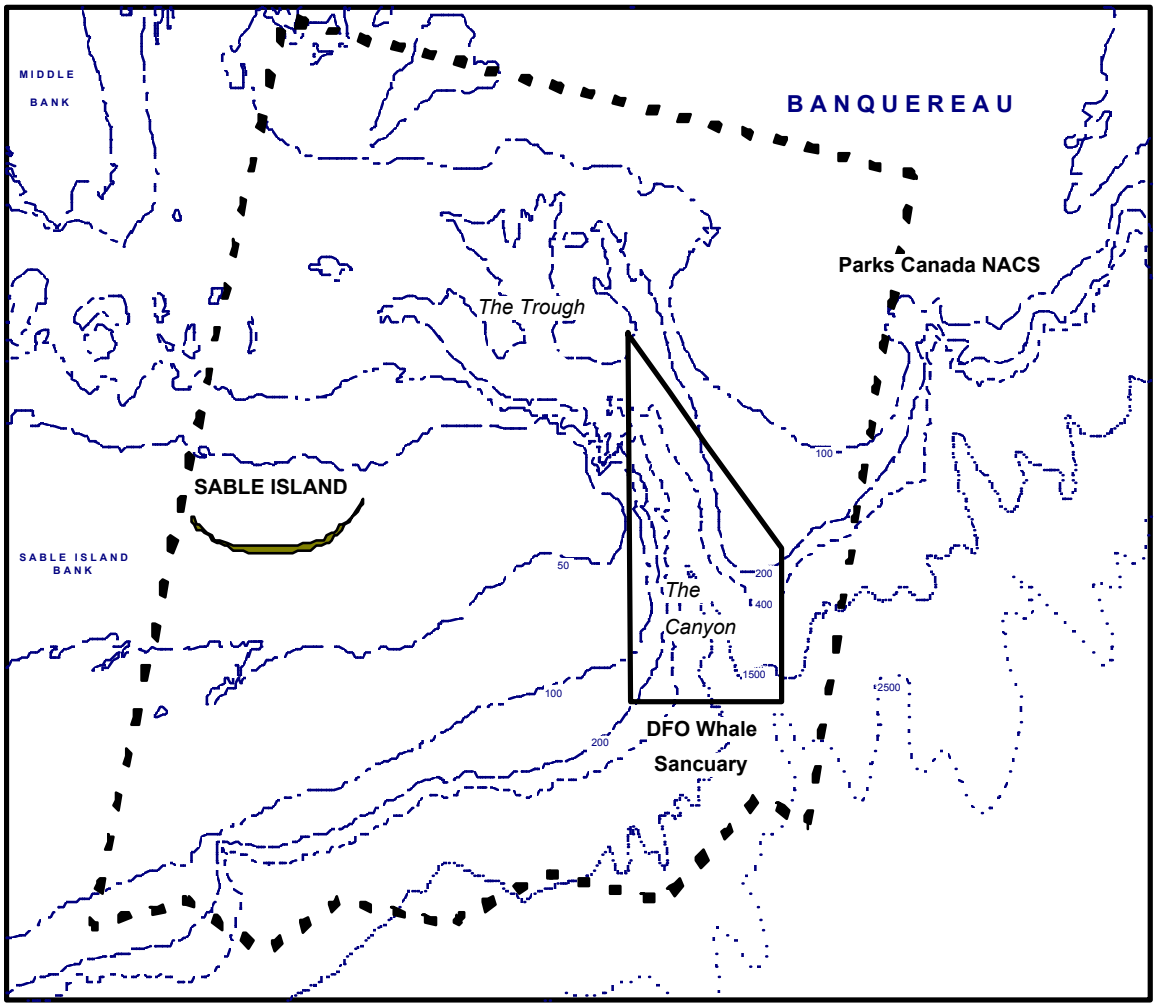

Fig. 1.0.2. The Gully. Source: Habitat Management Division, P. Lane and Associates Limited (1992), DFO (1996). The solid line depicts DFO Whale Sanctuary boundaries, dashed line depicts Parks Canada's NACS boundaries.

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
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	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.

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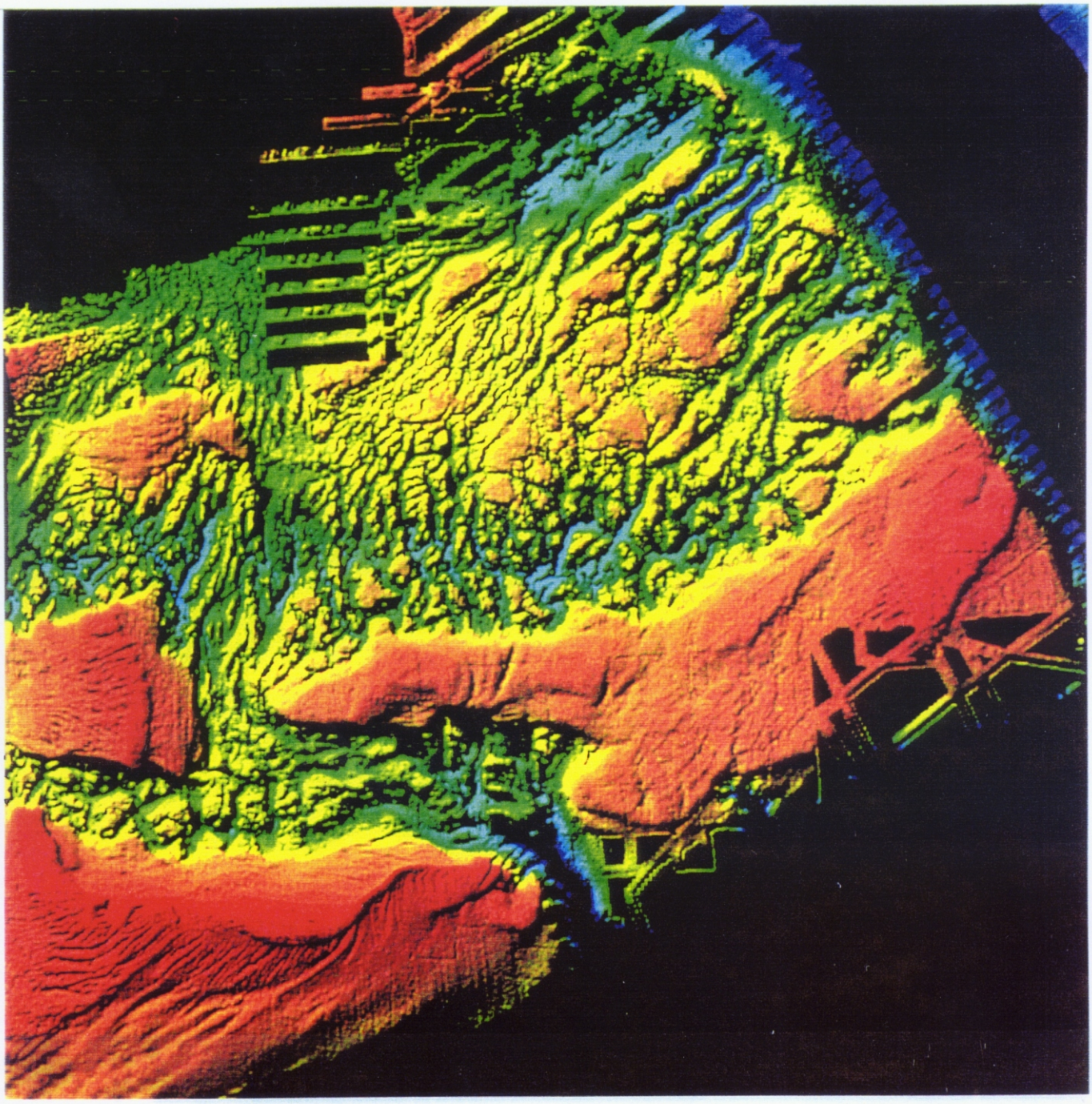

Fig. 3.0.1. A digital terrain model of the morphology of the eastern Scotian Shelf including the Gully. The image was prepared from digital bathymetric data collected by the Canadian Hydrographic Service and is a higher resolution version of a similar image published by Loncarevic et al., 1992. The image 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.

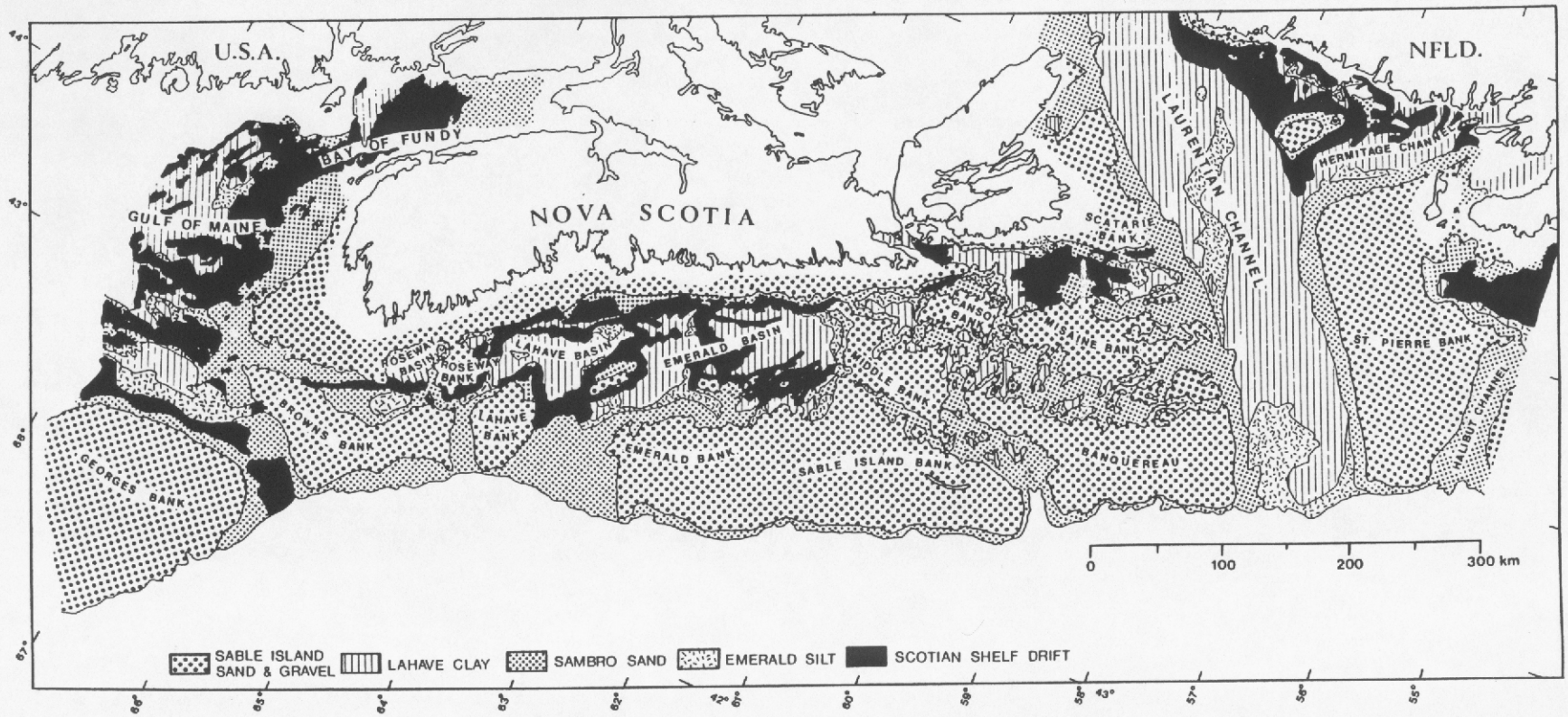

Fig. 3.0.2. The distribution of surficial sediments on the Scotian Shelf (King and Fader, 1986).

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

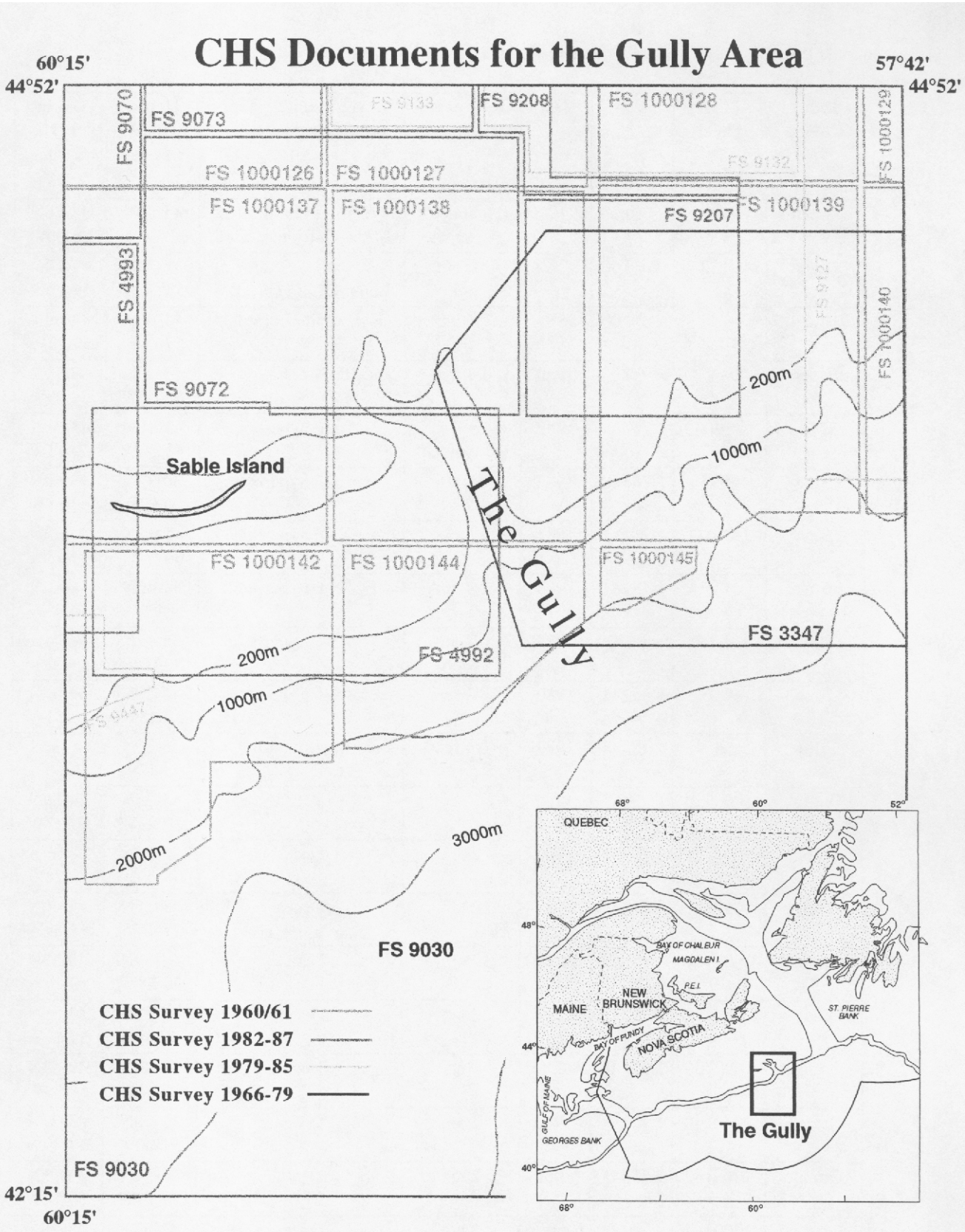

Fig. 4.0.1. CHS documents for the Gully area.

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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