## 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.

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## 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.

Family Primnoidae

*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

Family Caryophylliidae

*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.

Family Flabellidae

*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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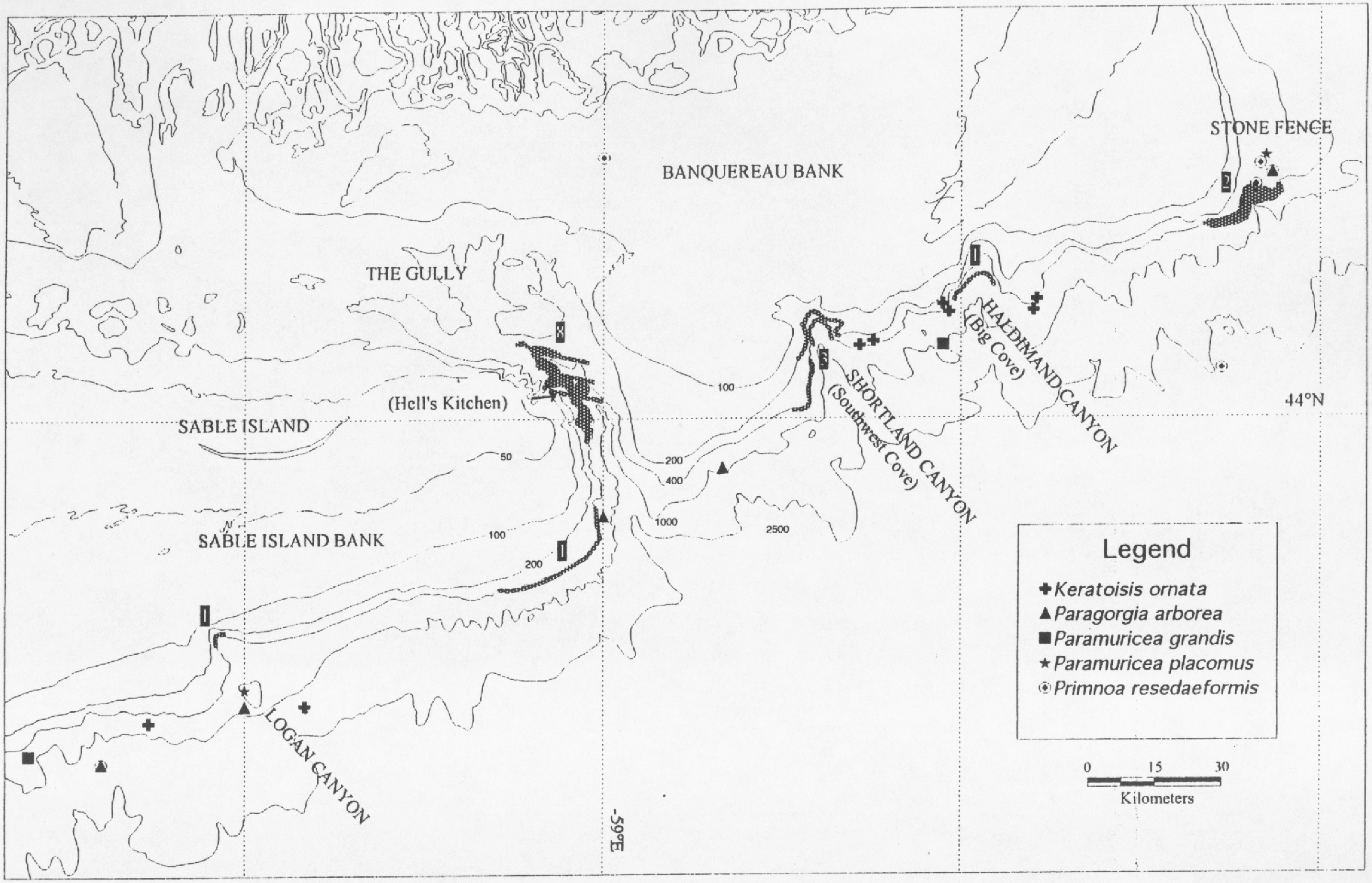


**Fig 6.5.2.1. Reports of coral findings in the area of The Gully. Fishermen's reports are shaded and not distinguished by species. Numbers inside shaded areas correspond to the number of fishermen who reported coral from that area. The legend shows symbols corresponding to species from museum and scientific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