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P. B. Batson
P. K. Probert

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P. B. Batson
P. K. Probert

Department of Marine Science
University of Otago
PO Box 56
Dunedin

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EXECUTIVE SUMMARY

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A diverse assemblage of frame-building Bryozoa on the mid to outer shelf off Otago Peninsula dominates the epibenthos. Seven frame-building taxa occur here in ecologically significant densities: *Cinctipora elegans*, *Hornera robusta*, *Hornera foliacea*, *Celleporina grandis*, *Celleporaria agglutinans*, *Hippomenella vellicata*, and *Adeonellopsis* spp.

A dredge survey of 56 mid to outer continental shelf sites off Otago Peninsula (45-120 m in depth) was used in conjunction with the results of previous surveys to map the distribution of frame-building bryozoan species.

Frame-building bryozoans range from 65 to 120 m in depth off Otago Peninsula, and occur in thicket-forming quantities from 75 to 110 m. *Cinctipora elegans* dominates the 75–90 m zone overall, although massive colonies of *Celleporaria agglutinans* and *Celleporina grandis* outweigh *Cinctipora elegans* in some tows. The large frame-builders *Hornera robusta*, *Hippomenella vellicata*, and *Hornera foliacea* are also prominent in several localities.

Frame-building bryozoans contribute significantly to seabed complexity and enhance biodiversity on the Otago shelf. By analogy with similar bryozoan communities elsewhere in New Zealand, the Otago shelf bryozoan fauna may play a part in the life history of commercially valuable finfish and shellfish.

The impact of mobile fishing gear in several New Zealand bryozoan-dominated communities has been severe. The Otago shelf bryozoan grounds have been fished commercially for at least 40–50 years, and probably longer. The intensity and distribution of fishing effort in the area during this time are unknown. Likewise, fishing impacts in the bryozoan grounds are unknown, but could be locally significant.

1. INTRODUCTION

1.1 Overview

This report addresses aspects of the Otago shelf bryozoan ("lace coral") thickets of relevance to the Ministry of Fisheries, namely their distribution and composition, their exposure and vulnerability to mobile fishing gear, and the influence of this community type on commercial and non-commercial species.

Bryozoan thickets are a rare habitat type by global standards, and are uncommon in New Zealand waters (Batson 2000). Nevertheless, where bryozoans occur in thicket-forming densities, they are often ecologically and commercially important (Probert *et al.* 1979, Bradstock & Gordon 1983). Frame-building Bryozoa significantly enhance biodiversity where they occur by providing habitat for numerous sessile and mobile invertebrate species that may otherwise be absent or less abundant (Probert *et al.* 1979). They may also function as nursery areas for commercially valuable finfish and shellfish species (Vooren 1975).

Recognition of the growing role of habitat protection in marine fisheries management has led to increased benthic mapping research in New Zealand's marine estate. The basis of this report was a two-year study conducted by the Marine Science Department, University of Otago, to investigate the distribution and species composition of bryozoan thickets on the Otago shelf.

The report is divided into five sections. Because the Bryozoa is a poorly known group, we begin by describing key life history characteristics of the phylum. We then summarise the Otago shelf physical setting, the methods used and findings of our benthic mapping study, and the effects of bryozoan thickets on biodiversity. Finally, we examine fisheries issues relating to bryozoans on the Otago shelf, including their commercial significance and vulnerability to mobile fishing gear.

1.2 BRYOZOAN BIOLOGY

1.2.1 Characteristics of the phylum

Bryozoans are sessile, filter-feeding, colonial animals that are abundant and ecologically important in many marine benthic systems (Hayward & Ryland 1979). They occur from tropical to polar latitudes (Ryland 1970). Bryozoans produce colonies (zoaria) ranging in size from a few millimetres to a metre or more across. Colonies consist of several to hundreds of thousands of clonal individuals called zooids. Many bryozoans produce a calcareous skeleton, which encloses the individual zooids. This skeleton may persist long after death (Smith & Nelson 1996).

1.2.2 Structure

Bryozoan colonial form is highly plastic both within and among species. Bryozoan colonies may be 'encrusting', comprising one or more layers of zooids cemented to the substratum, often leading to a flattened scab-like appearance. 'Erect-flexible' bryozoans are commonly 'bushy' in appearance, and are occasionally mistaken for finely branching seaweeds or hydroids. 'Erect-rigid' bryozoans are usually heavily calcified species, which form coral-like structures in a diverse array of forms. Each of these forms can be further sub-divided into categories based upon the spatial arrangement of the individual zooids (Figure 1, Smith 1995). Colony form may be correlated with environmental factors such as the hydraulic regime and substratum type (Nelson *et al.* 1988a).

1.2.3 Distribution and diversity

Bryozoans inhabit benthic marine, brackish and freshwater habitats (Hayward & Ryland 1998). Marine bryozoans range from the intertidal zone (Ryland 1970) to abyssal depths (Gordon 1987). Bryozoan species diversity is highest at continental shelf depths (0-200 m), especially in areas of coarse sediment (Hayward & Ryland 1979). Bryozoans have been recorded as abundant from polar to tropical latitudes (Cuffey 1977, Barnes 1995).

New Zealand has 903 described living species of bryozoans within its Exclusive Economic Zone (D. Gordon, NIWA, pers. Comm., Gordon 1984, 1986, 1989), a high species diversity by global standards. In comparison, the British Isles, an archipelago comparable to New Zealand in area and climate, has about 300 bryozoan species (Hayward & Ryland 1998). A bryozoan diversity similar to that of the entire British fauna has been recorded from Spirits Bay, at the northern tip of New Zealand — the highest diversity of this phylum ever recorded in an area of this size (Cryer *et al.* 2000). Gymnolaemates make up the bulk of the New Zealand "bryofauna" (793 species). Significantly, the endemism of the New Zealand fauna is very high at about 60% (Gordon, pers. comm.). It is likely that the number of described species will increase with continued sampling effort in the region and improved taxonomic precision (see Nelson & Gordon 1997).

1.2.4 Life history

Reproduction in bryozoans is complex and poorly known. All bryozoans are hermaphroditic (Hayward & Ryland 1998), though sperm release into the water column (e.g., Bullivant 1967) allows cross-fertilisation. Self-fertilisation occurs in some taxa, though in most species cross-fertilisation is the norm (Hayward & Ryland 1998). Some species produce planktotrophic larvae (cyphonautes), which hatch after liberation from the parent zooid. Most taxa, however, release a lecithotrophic (non-feeding) larva that settles soon after release (Hayward & Ryland 1998). Upon settlement, the free-swimming larva metamorphoses into a founder zooid, the ancestrula. This primordial zooid then buds off other zooids. Further colony growth proceeds by continued zooidal budding at the colony periphery (McKinney & Jackson 1989).

Bryozoans feed using water currents generated by the lophophore (Bullivant 1968a), a crown-like organ equipped with a ring of elongate ciliated tentacles. The cilia beat rhythmically, causing water to flow towards the mouth of the animal (Bullivant 1968a). Microplankton and other small particles are entrained by these currents, and transported to the mouth. Phytoplankton (principally diatoms and dinoflagellates) are the most significant part of the bryozoan diet (Bullivant 1968b), although bryozoans will ingest other particles (Sanderson *et al.* 1996).

Bryozoans occur in most marine habitats (Ryland 1970). Their abundance and diversity has been shown to be correlated with various 'environmental controlling factors' (Hageman *et al.* 1997). Nearly all bryozoans require a stable substratum upon which to settle and grow, so substratum characteristics can be very important (McKinney & Jackson 1989). The reliance of this phylum upon filter-feeding has led to a generally low tolerance of high sedimentation rates (Ryland 1970). Water movement also has implications for feeding efficiency, thus bryozoan morphology and abundance are often correlated with hydraulic regime (*see* Smith 1995, Hageman *et al.* 1997). Water depth alone seems to exert little influence on bryozoan distribution, but, because some known controlling factors are themselves correlated with depth, many bryozoan distributions are bathymetrically stratified (Nair 1961, Probert *et al.* 1979, Hageman *et al.* 1997).

Most bryozoan species produce small (less than 5 cm) two-dimensional colonies or weakly calcified bush-like colonies. Some, however, produce large three-dimensional colonies which, when rigid and calcified, may be termed 'frame-building'. New Zealand hosts a reasonably diverse fauna (*see* Table 1) of frame-building bryozoan species ranging from a maximum size of about 100 mm to over 500 mm in height, and 6 kg in weight (e.g., Bradstock & Gordon 1983). These large bryozoans play a significant ecological and sedimentological role in some New Zealand benthic communities, and are important providers of habitat at a wide range of spatial scales.

1.2.5 Bryozoan communities in New Zealand

In New Zealand, bryozoans exert ecological or sedimentological dominance in a number of localities. Prominent bryozoan communities occur in Foveaux Strait, Paterson Inlet (Stewart Island), Separation Point (Tasman Bay), the Snares Platform, the South Maria Ridge/Three Kings Platform area, parts of the Wanganui shelf, in addition to the Otago shelf (*see* Table 2 for references). Other bryozoan-dominated communities exist in Cook Strait, and on the Southwest Fiordland shelf. These areas are usually characterised by an energetic hydraulic regime, and a coarse, usually biogenic, substratum (Nelson *et al.* 1988b). However, living frame-building bryozoan colonies are not necessarily abundant in all these localities. For instance, the dominance of bryozoan skeletal remains in sediments on the South Maria Ridge and Snares platform is mostly due to the lack of terrigenous sediment input, rather than a particularly high bryozoan biomass in these areas (Nelson *et al.* 1988a). Outside New Zealand, recent bryozoan-dominated communities or bioherms occur rarely. Among the few recorded localities are examples in the Bahaman, Mediterranean, and Australian seas (e.g., Cuffey *et al.* 1979, Reguant and Zammareno. 1987, Bone & James 1993).

1.2.6 Otago shelf bryozoans

The Otago shelf frame-building bryozoan fauna is strikingly diverse compared to most other New Zealand localities. In both the Foveaux Strait and Separation Point bryozoan grounds only two frame-building species have been recorded as structurally important (Bradstock & Gordon 1983, Cranfield *et al.* 1999). By comparison, on the Otago shelf at least seven structure-forming bryozoan species are abundant, and another five structure-forming species are present.

Over 100 bryozoan species occur on the Otago shelf (*see* Junge 1998, Batson 2000). Most form small two-dimensional colonies, but nearly 20 common taxa form large (greater than 50 mm) three-dimensional colonies (*see* Table 1). Among the common large colony-formers are four articulated species (two weakly calcified catenicellids and two heavily calcified cellariids), and two mobile tube-forming symbionts of hermit crabs (Taylor *et al.* 1989). The 12 remaining species construct solid colonies in a range of zoarial forms within the 'encrusting-multilaminar' and 'erect-rigid' categories defined by Smith (1995). Of these, the distribution of the seven most abundant frame-building bryozoans is surveyed here. These bryozoans, comprising three cyclostomes and four cheilostomes, are as follows.

Cyclostomatida

Cinctipora elegans Hutton

Cinctipora elegans, of the endemic family Cinctiporidae (Boardman *et al.* 1992) is the dominant Otago shelf bryozoan. Colonies of this species are tightly branched (Figure 2A), and may reach 30 cm in height (Gordon, pers. comm.) and 0.5 m^2 in lateral extent (Willan 1981). On the Otago shelf, however, colonies greater than 15 cm in height or width are rare. An indication of the dominance of this species is its representation in the gravel fraction of mid-shelf sediments (75–90 m depth). Here, *Cinctipora elegans* fragments generally outweigh the contribution of all other bryozoans combined (Batson 2000).

Hornera robusta MacGillivray

This is the second most abundant frame-building cyclostome on the Otago shelf (Batson 2000). Its tree-like colonies can exceed 130 mm in height, though most do not exceed 60 mm (Figure 2B). It is a zoarially variable species; some colonies have a gnarled "bonsai-like" appearance, while others comprise a series of vertically stacked "fan-like" branches.

Hornera foliacea MacGillivray

Hornera foliacea produces erect foliaceous colonies which, when alive, are tinged cream or apricot (Figure 2C). On the Otago shelf, colonies can grow to be at least 125 mm across and 110 mm high, although most specimens are less than 75 mm across.

Cheilostomatida

Adeonellopsis spp. MacGillivray

Colonies are erect, bilamellar, and dichotomously branching (Figure 2D). The largest colony encountered on the Otago shelf was at least 90 mm through all axes. In Doubtful Sound, Fiordland, colonies greater than 200 mm in height and 300 mm in width are common. At least two *Adeonellopsis* morphospecies occur on the Otago shelf (Lidgard & Buckley 1994, Batson 2000).

Celleporina grandis Gordon

Celleporina grandis forms thickly branched colonies that can be 100 mm or more in height (Figure 2E). Branches consist of multiple layers of frontally budded zooids. Adjacent branches can differ greatly in width and orientation. Usually branches radiate upwards or outwards if impeded by other branches, especially in large colonies.

Hippomenella vellicata (Hutton)

This bryozoan usually forms bilaminar erect-foliose colonies (Figure 2F). *H. vellicata* zoaria can be roughly spherical, somewhat flattened transversely, or elongated vertically. Most colonies are from 100 to 300 mm in diameter (Batson 2000).

Celleporaria agglutinans (Hutton)

This is a multilaminar encrusting species whose massive bright orange-red colonies weigh up to 6 kg (Figure 2G). Colonies are amorphous, often with large chimney-like structures dorsally. Colonies increase in thickness by frontal budding, or can extend laterally by the formation of lateral sheet-like growths, which can incorporate fragments of other species and sediment into their structure (Bradstock & Gordon 1983). The surface of a colony varies in texture, exposure to water currents, contact with substratum and the chamber dimensions, increasing habitat heterogeneity (Bradstock & Gordon 1983, Batson 2000).

2. OTAGO SHELF PHYSICAL SETTING

2.1 Bathymetry

Off Otago Peninsula the continental shelf is constricted. Shelf width is reduced from about 30 km north and south of the Peninsula to just 10 km off the peninsula. This constriction is due to the presence of two major features (see Figure 3). First, the Dunedin volcanic complex extends seawards (Gray 1993). Second, the shelf is incised by a series of submarine canyons off the Peninsula. The shelf-break is shallower (100–130 m) than elsewhere on the Otago coast, where it occurs down to 150 m (Carter *et al.* 1985).

2.2 Hydraulic regime

A persistent component of the local hydraulic regime is the northward-flowing Southland Current (Jillett 1969, Heath 1972, Chiswell 1996). Off the peninsula, the Southland Current is accelerated because of the constricted continental shelf, resulting in surface current velocities of up to 26 cm s^{-1} (Carter *et al.* 1985). A third component is the result of meteorological events, including a persistent ground-swell, which is regularly supplemented by regional weather patterns (Carter *et al.* 1985). Bottom current velocities are poorly known, particularly on the outer shelf. Underwater photographs and remotely operated vehicle (ROV) observations indicate significant bottom currents occur at depths of over 100 m (e.g., Gray 1993). On the mid to outer shelf off Otago Peninsula these currents are probably capable of transporting mud and sand on a regular basis (Carter *et al.* 1985).

2.3 Sediments

Sedimentary facies off the Otago Peninsula are:

1. an inner shelf belt of modern terrigenous sand,
2. a mid-shelf belt of relict terrigenous sand,
3. a mid- to outer shelf relict/palimpsest sand facies, and
4. an outer shelf biogenic sand/gravel facies (Carter *et al.* 1985).

The composition and distribution of these facies reflect different sediment sources, depositional and post-depositional processes, and a dynamic history of sea level change (Andrews 1973, Carter *et al.* 1985, Carter & Carter 1986). The mid-shelf off Otago Peninsula is dominated by a relict terrigenous gravel facies composed mainly of iron-stained quartz pebbles (*see* Figure 3). Carter *et al.* (1985) interpreted this facies as relict, an interpretation supported by the presence of nearshore molluscs and drowned estuarine deposits. Surficial sediments from the relict terrigenous gravel facies are rich in skeletal debris derived from molluscs and bryozoans (Andrews 1973). On the mid and outer shelf, skeletal carbonate ranges from 40 wt % to nearly 100 wt %. The main sources of carbonate are molluscs and bryozoans, the latter being proportionately more important on the mid-shelf (Andrews 1973, Batson 2000).

3. BENTHIC MAPPING OF THE OTAGO BRYOZOAN THICKETS

3.1 Methods

A dredge survey was undertaken to map the distribution and abundance of frame-building bryozoans on the Otago shelf. The survey focused upon the area where high bryozoan densities had previously been recorded (Probert *et al.* 1979). The survey worked outward from this area until no more bryozoans were encountered and the substratum became unfavourable for their growth. In addition, seabed photographs were taken at 80 m, and archived ROV video footage of the mid-shelf was examined (see Batson 2000 for methods).

The dredge survey of 41 sites on the mid to outer Otago shelf was conducted between May 1998 and July 1999. A 156 L capacity box dredge measuring 60 cm across and 26 cm in height was used. The leading edge of the dredge was fitted with an inclined steel plate, giving a sediment penetration depth of 2–5 cm. A 5 mm wire mesh probably prevented significant winnowing of sediments on the gravelly substrata sampled. The dredge was towed for a bottom time of about 2 minutes at 2 knots (1 m s^{-1}). Locality data were collected using differential GPS. Supplementary bryozoan presence/absence data was gathered from 15 sites that were sampled opportunistically by beam trawl (Batson 2000).

The 41 localities surveyed were arranged into four main transects. These were three cross-shelf transects: two at 5 m depth increments from 60 to 110 m, and one at 10 m depth increments from 60 to 120 m. A fourth transect comprising 12 stations followed the 80 m isobath (*see* Figure 6).

Upon recovery, the dredge contents were flattened, and a numbered grid was placed on top. Using random coordinates five sub-samples were collected from the dredge contents. Total sample volume for each station varied from 4 to 10 L. In addition, any large (over 50 mm) living bryozoan colonies remaining in the unsampled dredge contents were counted. These counts were used to assign an abundance value for each frame-building species at each site. The following scale was used: 0 = species absent, 1 = species present, 2 = species common, and 3 = species abundant. *Adeonellopsis* spp. was not counted because large colonies were often thoroughly fragmented, making colony counts difficult.

The samples were sorted to species in the laboratory. Fragments smaller than 15 mm were ignored. A ranking process was applied to each colony or colony fragment to give an indication of 'freshness', as a proxy for age since death (Table 3). This process was adopted because, in practice, it was difficult to assess whether a bryozoan fragment was alive at the time of collection. First, it was often hard to distinguish polypides from other organics present. Second, dredging commonly fragmented colonies and, because living polypides are not distributed uniformly through a bryozoan colony, it was not possible to determine whether a fragment came from a colony alive at the time of collection. Ranking methodologies, although subjective, have been shown to be internally consistent by Hageman *et al.* (1996). The two largest species, *Celleporaria agglutinans* and *Hippomenella vellicata,* were rare in sub-samples, and were not ranked. Instead, the abundance of large *C. agglutinans* and *H. vellicata* colonies (greater than 50 mm) in the dredge was used to determine their distribution. Fragments of the five remaining species considered recently living were weighed. At all sites the abundance of each species was calculated as the mass of live and recent fragments per litre of surface sediment. The ranking regime employed here, despite being consistent within species, prevented direct comparisons of standing stocks among species due to inherent taphonomic bias. This is primarily because the period that fragments remain 'fresh-looking' varies among species (Smith & Nelson 1996).

Qualitative bryozoan distribution data from other studies (Probert *et al.* 1979, Junge 1998) and sites that were opportunistically sampled by beam trawl during 1998 and 1999 have also been incorporated into the distribution map (see Batson 2000).

3.2 Results

Within the area surveyed, the zone of bryozoan dominance was confined to a relatively narrow band off Otago Peninsula defined roughly by the 75 to 110 m depth contours (Tables 4–6; Figures 4–6). Bryozoan colonies did occur outside this zone, although in much lower densities. The seven bryozoans surveyed here were broadly sympatric, although *Celleporina grandis* and *Adeonellopsis* spp. extended into deeper waters (110–120 m) than the other five species.

Colonies were patchily distributed in the mid-shelf zone of bryozoan dominance. Bryozoan abundance often varied greatly between closely adjacent dredge samples. Seabed photographs and ROV video footage of the area showed reasonably discrete patches of bryozoans and other megafauna, separated by open gravel (Batson 2000). Dense patches, termed thickets, are also inhabited by other large sessile epifauna including sponges, hydroids, ascidians, and the large pinnid bivalve *Atrina novaezelandiae.*

4. ECOLOGICAL ASPECTS

4.1 Contribution of bryozoans to seabed structural complexity

In most mid to outer shelf environments, fine sediments are predominant and structural complexity is generally low. In these settings, biogenic structures can be a significant source of seabed complexity. Hermatypic corals, tube-forming polychaetes, and nest-building molluscs have been recorded as important in this role overseas (e.g., Bosence 1973, Rogers 1999, Hall-Spencer & Moore 2000). In New Zealand it is the Bryozoa that stand out as a key structure-forming phylum at mid to outer shelf depths.

As a consequence of their abundance and architecture, bryozoans are responsible for much of the fine-scale structural complexity of the seabed off Otago Peninsula. Their influence is not restricted to the topographic relief provided by their frames. Large bryozoan colonies are colonised by other taxa that may themselves add to seabed complexity, a process termed "taphonomic feedback" (Gillespie & Nelson 1996). Among the colonising taxa are sponges, ascidians, hydroids, polychaetes, and other bryozoans (Batson 2000). Bryozoans also increase sediment heterogeneity off Otago Peninsula. Coarse bryozoan-derived debris is well represented in mid-shelf surface sediments, where it may comprise half the mass of the gravel fraction (Batson 2000). In addition to sediment production, bryozoans also modify micro-scale sediment deposition patterns by acting as baffles (Cuffey 1974). By reducing water current velocities within and around colony interstices, fine suspended particles can become deposited. Thus bryozoan frames (and other large sessile epifauna) can increase surface sediment variability. Willan (1981) attributed the presence of various infaunal species growing among branches of *Cinctipora elegans* to sediment baffling. Evidence of self-burial by this means was commonly found among bryozoan colonies from the Otago shelf, suggesting that this process is locally significant (Batson 2000). Bryozoans may also help to stabilise and maintain relict bed-forms found off Otago Peninsula (Batson 2000).

4.2 Effects of seabed structural complexity on biodiversity

A study of Norwegian deep-water coral (*Lophelia pertusa*) bioherms found that megafaunal diversity was higher in areas of living and dead coral than on surrounding areas of soft sediment (Mortensen *et al.* 1995). Higher biodiversity associated with three-dimensional habitat has also been demonstrated in New Zealand shelf ecosystems (S. Thrush, NIWA, pers. comm.). However, quantitative data on the influence of frame-building bryozoan communities on biodiversity is lacking, although several studies have included lists of associated taxa (Probert *et al.* 1979, Bradstock & Gordon 1983, Junge 1998).

The Otago shelf frame-builder *Hippomenella vellicata* is an example of a bryozoan that hosts a diverse fauna of associated species (see Figure 2F). Foliose colonies provide a protected microhabitat suitable for settlement of epibiota. Junge (1998) reported that a single large colony provided a substratum for more than 1200 other bryozoan colonies. Bradstock & Gordon (1983) recorded 92 species of calcareous taxa (mainly bryozoans) colonising mixed *Hippomenella vellicata-Celleporaria agglutinans* mounds at a single Tasman Bay locality. A similar number of epizoic bryozoans have been recorded growing upon Otago shelf frame-building taxa (Junge 1998, Table 7). The large, semi-enclosed chambers of *H. vellicata* function as a protected microcosm for delicate epizoa. The fragile bryozoan *Idmidronea* sp. occurs almost exclusively within bryozoan frames and other biogenic structures on the Otago shelf. Other sessile organisms are abundant on large bryozoan colonies. Numerous hydroids, ascidians, brachiopods, barnacles, serpulid tubeworms, and sponges colonise these structures. Bryozoan frames also attract mobile megabenthos. Large *H. vellicata* colonies often contained ophiuroids, molluscs (gastropods, bivalves, and the cephalopod *Octopus huttoni*), crustaceans (brachyurans and anomurans, including the locally abundant galatheoid *Munida gregaria*), and small fish (Batson 2000). Where sediment infilling has occurred, infaunal taxa may be present within colonies, including small nestling bivalves and polychaetes (Willan 1981). Sediments trapped within a bryozoan frame can differ from those underlying and surrounding it, thus further increasing the diversity of infaunal habitats available. At the microscopic scale, Scholz & Krumbein (1996) found that bryozoans contain "nannohabitats" that are widely colonised by a range of microorganisms, such as bacteria, cyanobacteria, diatoms, filamentous microalgae, and fungi.

5. FISHERIES ISSUES

5.1 Value of bryozoan thickets to commercial fisheries

Strong links exist between habitat complexity, species diversity, and the life history of various commercial marine species (Auster *et al.* 1995, 1996, Collie *et al.* 1997). In New Zealand, frame-building bryozoans appear to play an important role in the life history of several commercially exploited species. Juvenile fish including snapper (*Pagrus auratus*) and tarakihi (*Nemadactylus macropterus*) congregate among *Hippomenella vellicata-Celleporaria agglutinans* thickets off Separation Point, Tasman Bay (Vooren 1975, Bradstock & Gordon 1983). Thrush (NIWA, pers. comm.) has documented higher numbers of juvenile stages of commercially and recreationally important fish species (such as snapper) over areas of the seabed with complex habitats created by physical and biological features. On the Otago shelf, juvenile blue cod (*Parapercis colias*) and red cod (*Pseudophycis bachus*) occurred in dredge samples and seabed photographs from bryozoan thickets collected during 1998 (Batson 2000). The attraction of juvenile fish to areas of complex habitat may serve to reduce predation mortality. This association may also serve a nutritional function in some cases. Jiang (unpubl. results) found differences in blue cod diet composition between two sites in Foveaux Strait, an unfished biogenic (*Cinctipora elegans*) reef and a heavily dredged site. Blue cod from the biogenic reef site consumed a significantly more diverse range of prey than fish from the modified site.

The valuable Bluff oyster (*Tiostrea chilensis*) was formerly associated with Foveaux Strait patch reefs formed by the endemic cyclostome bryozoan *Cinctipora elegans* (Cranfield *et al.* 1999). Oyster densities were highest in this habitat, and the decline of the Foveaux Strait oyster fishery may be related to destruction of these biogenic features. Bryozoan-derived structures also influence other commercially valuable shellfish. In the United Kingdom, juvenile queen scallops settle preferentially upon Bryozoa of the genus *Cellaria* (Mason 1983). This has not been directly observed in New Zealand. *Cellaria immersa* and *C. tenuirostris* are abundant off Otago Peninsula (Batson 2000).

5.2 Impacts of mobile fishing gear upon the benthos

A growing body of evidence indicates that mobile fishing gear (trawls and dredges) are capable of greatly modifying the marine benthic environment (Dayton *et al.* 1995, Auster *et al.* 1996, Turner *et al.* 1999). The nature and extent of these effects, many of which are complex and difficult to study, are not well understood. However, recent studies describing physical, sedimentological, and geochemical consequences of mobile fishing gear usage (e.g., Tuck *et al.* 1998, Schwinghamer *et al.* 1998, Pilskaln *et al.* 1998) have contributed to apprehension about the extent of wider fishing impacts.

The best understood (and possibly the most severe) effects of mobile fishing gear on the benthos are those that alter the physical structure of the seabed. Auster *et al.* (1996) found trawls and dredges reduced habitat complexity in the Gulf of Maine by direct removal of biogenic structures (e.g., bryozoans, sponges, amphipod tubes), by smoothing sedimentary structures (e.g., sand depressions, sub-aqueous dunes and ripples), and by the removal of organisms that create ephemeral structures by their presence and activity on the seabed (e.g., crabs, bivalves). A conceptual model developed by Auster (1998) showed that seabed structural complexity is reduced by fishing effort, and that the more complex a habitat initially, the greater its decline in complexity after fishing.

Because habitats with a high degree of structural heterogeneity are relatively rare, and tend to host elevated levels of biodiversity (e.g., Probert *et al.* 1979, Collie *et al.* 1997) it is important that they be mapped and protected. They are the marine equivalent of the terrestrial biodiversity hotspots described by Myers *et al.* (2000).

5.3 Vulnerability of frame-building bryozoans to fishing

In New Zealand there is strong evidence that bryozoan-dominated communities are vulnerable to trawling and dredging of the seabed. Areas inhabited by the large bryozoans *Celleporaria agglutinans* and *Hippomenella vellicata* off Separation Point, Tasman Bay were heavily fished until 1980. Before exploitation, bryozoan thickets in this area were far more extensive and physically complex (Bradstock & Gordon 1983, Turner *et al.* 1999). Unfortunately, the degree of post-closure recovery has not been monitored in this community (Turner *et al.* 1999).

In Foveaux Strait, kilometre-scale *Cinctipora elegans* patch reefs were heavily reduced in extent by dredging for the Bluff oyster, *Tiostrea chilensis*. A close association between oysters and *Cinctipora* was recognised by oystermen, who actively sought these patch reefs as dredging sites (Cranfield *et al.* 1999). In doing so, these biogenic reefs have been almost completely destroyed.

Mechanical destruction of colonies may not be the only impact of mobile fishing gear on bryozoans. Bottom trawling is known to increase suspended sediment fluxes (e.g., Pilskaln *et al.* 1998), and may be a primary source of suspended loads between 100 and 400 m in depth (Churchill 1989). Sediments resuspended by trawls or dredges may settle nearby, possibly affecting the surrounding benthos. Because of their filter feeding lifestyle, bryozoans generally have a low tolerance to high sedimentation rates (Ryland 1970), and may be susceptible to smothering by sediments mobilised by fishing activity.

The recovery time of affected bryozoan communities is probably of the order of decades because of the relatively slow growth rates of local frame-building species (e.g., Jamet 1999, Smith *et al.* in press). Furthermore, other fishing effects upon the substratum may impede recovery. Batson (2000) found that frame-building bryozoans on the Otago shelf usually grew on bioconsolidated sediments, particularly those stabilised by the tubeworm *Phyllochaetopterus socialis*. If trawling or dredging were to affect sediment-consolidating infauna, recolonisation by frame-building bryozoans would be further delayed. It should not be assumed that the recovery of affected bryozoan communities could be guaranteed simply by preventing future fishing. Prior fishing impacts could modify bryozoan life history factors such as recruitment potential, growth and mortality rates, and competitive ability, thus preventing regeneration of the original community type. Cranfield (NIWA, pers. comm.) observed that a heavily fished *Cinctipora elegans* reef in Foveaux Strait was replaced by a sponge-dominated community after the area was dredged for oysters. It is unknown whether this change is permanent, or part of a succession that leads to the formation of a new *Cinctipora* patch reef. In either case, the use of bryozoan growth rates as a direct proxy for habitat recovery time is clearly inappropriate.

5.4 Fishing history of the Otago shelf – a survey of commercial fishers

5.4.1 Introduction

To ascertain whether the Otago bryozoan thickets are subjected to commercial fishing pressure we surveyed local fishers known to operate in the area. The fishing history in the bryozoan grounds off Otago Peninsula is poorly known. The statistical area for which catches are reported to the Ministry of Fisheries (O24) covers the area offshore of Oamaru south to Taieri Mouth. Of the area covered by O24, the bryozoan grounds are a very small fraction. For this reason, reported catch data provide little useful information, and are not presented here. Instead, we have compiled anecdotal evidence from past and present commercial fishers, an approach that has been successfully applied in New Zealand (e.g., Cranfield *et al.* 1999). The present fisher's survey is not comprehensive, and has focused on Port Chalmers-based fishers.

5.4.2 Methods

A week before individual fishers were contacted, we placed an information display in the Port Chalmers Fishermen's Cooperative. The display included specimens of important frame-building bryozoan species, information on the reasons for the survey, and a list of the questions they would be asked. Individual fishers who used dredging or trawling were later contacted by phone, and asked if they would be interviewed. Seven fishers who worked in the area off Otago Peninsula provided information on fishing activity in the area dating back to 1955. They were asked where and when they fished, the species they targeted, and about their experiences with benthic bycatch.

5.4.3 Survey results

Unless otherwise indicated, the information below was supplied by current or retired commercial fishers who have worked in the Otago Peninsula area. The term "Otago bryozoan grounds" describes the area directly offshore from Otago Peninsula (Taiaroa Head to St. Kilda beach) from 70 to 110 m in depth.

Bottom fishing of the Otago shelf by dredging and trawling dates back to the late 19th century when the first trawlers began fishing the Otago shelf (Brett 1999). From this time until the 1930s bottom trawling of the Otago shelf was conducted by up to three vessels. Trawling for barracouta (*Thyrsites atun*) and red cod (*Pseudophycis bachus*) formed the basis of the Otago trawl fishery at this time (Tony Brett, pers. comm.). Many other demersal fish species were also landed by these early trawlers (*see* Ayson 1903). The mid-shelf bryozoan grounds may have been fished during this period, although probably not intensively owing to the unfavourable substratum for trawling – some bryozoan species found on the Otago shelf are capable of damaging nets made from natural fibres (Bradstock & Gordon 1983).

After World War II, fishing pressure on the Otago shelf remained steady until the 1960s, when fishing increased (Brett 1999). From the 1960s onwards, according to local fishers, parts of the Otago bryozoan grounds were trawled for red cod, tarakihi, silver warehou (*Seriolella punctata*), tarakihi (*Nemadactylus macropterus*), and rig (*Mustelus lenticulatus*). Benthic invertebrate bycatch and damage to trawl nets was somewhat reduced by the use of attached floats, allowing the areas of dense bryozoans to be fished more easily by inshore vessels. Nevertheless, some inshore fishers avoided parts of the bryozoan grounds because they were "terribly hard on gear".

The intensity of trawling in the area is hard to gauge – fishing activity varied greatly from year to year, depending upon other factors (many of these vessels also worked the inshore flatfish fishery). Since the 1960s (or earlier) locally based trawlers have worked the bryozoan grounds periodically, mainly for rig and tarakihi. Large bags of "cornflakes" (another of the fishers' terms for bryozoan bycatch) have occasionally been landed by these vessels, usually in depths between 70 and 100 m. The size of these catches can be gauged by the fact that fishers sometimes found it difficult to land the trawl because of the weight of the "corals" in the cod end. Usually there were few fish in trawls dominated by bryozoans, and fishers would subsequently move to another area, rather than continue fishing in the area. Several fishers described "corals" as being "very patchy" in their distribution. Most current Port Chalmers trawlers target the flatfish grounds, usually in depths of less than 50 m.

Larger foreign or "joint-venture" fishing vessels equipped with synthetic nets and steel bobbins have also fished in the general area of the Otago bryozoan grounds since the 1960s and 1970s. Several inshore fishers recalled regular encounters with larger trawlers working off Otago Peninsula during this period, suggesting that the area was actively fished. Species targeted by these joint venture vessels probably included red cod, silver warehou, and tarakihi.

The Otago shelf queen scallop (*Zygochlamys delicatula*) fishery is active in the deeper region of the Otago shelf. This fishery developed during the late 1980s. One might expect scallop dredging impacts on bryozoans to be strong because a clear association between frame-building Bryozoa and queen scallops has been noted in studies on the Otago mid to outer shelf (Probert *et al.* 1979, J. McKay, Unviersity of Otago, unpublished data). However, most queen scallop dredging is concentrated in areas where bryozoan densities are low. According to one scallop boat skipper working off Otago Peninsula, most queen scallop dredging occurs at between 110 and 150 m in depth – deeper than the main bryozoan grounds which range from about 70 to 110 m in depth off Otago Peninsula. Nevertheless, scallop boat skippers are familiar with frame-building bryozoans, which are occasionally caught in significant quantities on the Otago outer shelf, particularly in the area south of Hoopers Canyon in 90–110 m. It is unknown whether this bryozoan bycatch is alive at the time of capture, or is actually coarse bryozoan-derived sediments (unlikely, due to the use of bobbins). In either case, such bycatch is unwelcome to scallopers, who actively avoid these "coral patches" after they have encountered them. Large amounts of bryozoan-sponge bycatch make catch sorting cumbersome, and labour intensive.

Since the mid 1960s the University of Otago and the New Zealand Oceanographic Institute/NIWA have dredged the Otago shelf bryozoan grounds for research purposes. Research dredging by the University of Otago in the bryozoan grounds during 1998 and 1999 covered a seabed area of about 35 000 m^2 (Batson 2000).

5.5 Fishing impacts on the Otago bryozoan grounds

Sustainable management of marine ecosystems is invariably hindered by incomplete information. Our knowledge of the Otago shelf bryozoan grounds is reasonable in some respects, but clearly lacking in others. Where direct information is absent, our knowledge of the structure and function of analogous bryozoan communities elsewhere in New Zealand is potentially useful. Thus, in the following discussion of likely fishing impacts on the Otago shelf we have drawn from our direct knowledge of the area and assumptions based on findings from other areas.

Our dredge survey, combined with data from Probert *et al.* (1979) and Junge (1998), indicates that the main bryozoan grounds occur off the body of Otago Peninsula between 75 and 100 m in depth. Seven frame-building bryozoan species occur in medium to high densities within this zone. Based on a comparison of the survey of Probert *et al.* (1979) with that of Batson (2000) there is no compelling evidence for a range contraction in the Otago bryozoan grounds in the last 30 years, although a contraction may have occurred.

Our survey of fishers shows that the Otago bryozoan grounds have a history of trawling and dredging that dates back to at least the 1950s, and possibly back to 1900. The frequency and extent of fishing in this area is unknown, but may be significant. No information exists on the pre-exploitation area and condition of the bryozoan-dominated habitat.

It is known that the Tasman Bay bryozoan beds (Bradstock & Gordon 1983) and Foveaux Strait *Cinctipora elegans* patch reefs (Cranfield *et al.* 1999) occupied a far greater area before they were affected by fishing. The dominant Bryozoa found at these sites are also key species in the Otago bryozoan grounds (where similar fishing methods are employed). It is therefore reasonable to assume that fishing off Otago Peninsula has adversely affected the bryozoan grounds. Local fishing effects may be expressed by relative changes in colony density and population size structure among the different frame-building bryozoan species, or by undetected range contractions.

The regular occurrence of large (20–30 cm) colonies of delicate bryozoan species in dredge samples taken off Otago Peninsula during the 1998—99 survey indicates that commercial fishing impacts must be somewhat dispersed in space and time, infrequent enough to leave some colonies untouched or to allow for growth of new colonies. Many colonies examined did show evidence of post-damage regeneration (Batson 2000), but it is unknown whether this was due to fishing or to natural disturbances (e.g., foraging by skates and rays).

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***Table 1*: Otago shelf bryozoans that form colonies greater than 50 mm in elevation above the substratum.**
*** Species surveyed in the present study; frame-building species underlined**

Species	Family	Colony Growth Form	Abundance
*Cinctipora elegans**	Cinctiporidae	Erect-Rigid delicate-branching	Abundant
*Hornera robusta**	Horneridae	Erect-Rigid robust-branching	Abundant
Hornera foliacea *	Horneridae	Erect-Rigid fenestrate	Common
*Celleporina grandis**	Celleporidae	Erect-Rigid massive-branching	Abundant
*Celleporaria agglutinans**	Lepraliellidae	Encrusting multilaminar	Common
Adeonellopsis spp.* (at least 2)	Adeonidae	Erect-Rigid robust-branching	Common
*Hippomenella vellicata**	Schizoporellidae	Erect-Rigid foliose	Common
Orthoscuticella ventricosa?	Catenicellidae	Erect-Flexible delicate-branching	Abundant
Cellaria immersa	Cellariidae	Erect-Flexible articulated	Abundant
Cellaria tenuirostris	Cellariidae	Erect-Flexible articulated	Common
Tetrocycloecia neozelanica	Heteroporidae	Erect-Rigid robust-branching	Common
Arachnopusia unicornis	Arachnopusiidae	Erect-Rigid foliose	Rarely > 50
Diaperoecia purpurascens	Diaperoeciidae	Erect-Rigid delicate-branching	Common
Galeopsis polyporus	Celleporidae	Erect-Rigid delicate-branching	Rarely > 50
Hippellozoon novaezelandiae	Phidolophoridae	Erect-Rigid fenestrate	Rarely > 50

***Table 2*: The location and relevant environmental parameters of seven New Zealand locations where bryozoan thickets, or bryozoan-dominated sediments have been recorded**

Location	Position & extent of bryozoan beds	Depth (m)	Hydraulic regime	Substratum	Dominant Bryozoa*	References
Snares Platform	South of Stewart Island; 50,000km^2	< 250	high energy, open shelf	$CaCO_3$ gravels	Ce, Dp, Gp, Fc	Nelson *et al.* 1988a
Foveaux Strait	Western Foveaux Strait; Historically bryozoan beds much larger	25–45	strong tidal flows	terrigenous /$CaCO_3$ gravels	Ce, Hv, Cat	Fleming 1952; Cranfield *et al.* 1999
Paterson Inlet	localised at inlet entrance; patchy thickets	< 25	moderate to strong tidal currents	gravels	Ce, Cyc	Willan 1981
Separation Point	Tasman Bay; < 300 km^2	10–35	strong tidal flows	mud-rich, some gravel	Ca, Hv	Bradstock and Gordon 1983
South Maria Ridge	Off North Cape; 10,000 km^2 (includes Three Kings Platform)	< 500	high energy, open shelf	$CaCO_3$ gravels	Sm, Cg, Csp, Hn, Iy, Pa, Gp, Hr, Mm	Nelson *et al.* 1982, 1988b; Nelson & Hancock 1984
Wanganui shelf	Wanganui mid-shelf; approx 2000 km^2	50–80	variable	$CaCO_3$ sandy gravels	Cg, Asp	Gillespie and Nelson 1996
Otago Shelf	Off Otago Peninsula; at least 100 km^2	70–120	high current velocities off Peninsula	$CaCO_3$ gravels	Ce, Hr, Asp, Cg, Ca, Ci, Fen, Otion	Probert *et al.* 1979; Batson 2000

* Asp = *Adeonellopsis* spp.; Ca = *Celleporaria agglutinans*; Cat = Catenicellids; Ce = *Cinctipora elegans*; Cg = *Celleporina grandis*; Ci = *Cellaria immersa*; Csp = *Celleporaria* sp.; Cyc = Cyclostomata; Dp = *Diaperoecia purpurascens*; fen = fenestrate cheilostomes; Fc = *Foveolaria cyclops*; Gp = *Galeopsis* spp.; Hr = *Hornera robusta*; Hn = *Hippellozoon novaezelandiae*; Iy = *Iodictyum yaldwyni*; Mm = *Metroperiella mucronifera*; Otion = *Otionellina* spp.; Pa = *Phidolopora avicularis*; Sm = *Steginoporella magnifica*.

Table 3: **The application of ranking criteria of 'freshness' to the five species ranked in this study. N/A = trait not used to rank age; x, trait sometimes used; X, trait regularly used**

Ranking criterion	*Cinctipora elegans*	*Hornera robusta*	*Hornera foliacea*	*Celleporina grandis*	*Adeonellopsis* spp.
presence of polypide	X	x	x	x	x
fragment colour	X	X	x	x	N/A
fragment size	X	N/A	X	N/A	X
presence of delicate structures	X	X	N/A	X	N/A
frontal wall damage: present/absent	X	X	x	X	x
gradient in damage across fragment	N/A	N/A	N/A	X	X
sediment within zooids	x	X	X	N/A	N/A
epizoic fauna on fragment	x	x	x	X	x
iron staining: present/absent	X	X	X	X	X
breakage plane condition	N/A	N/A	N/A	X	X
collar of epizoic fauna	X	N/A	N/A	x	x
bleached carbonate colour	X	X	X	X	X
presence of operculum	N/A	N/A	N/A	x	x
fragment number per sample	N/A	x	X	N/A	X
presence of attached substratum	x	x	x	X	X

***Table 4*:** **Location of box dredge tows and the abundance of fresh (live- and recent-ranked) bryozoan fragments of five frame-building bryozoans taxa**

		Location		Live/recent fragments (g/L sed)				
Station number	Depth (m)	Latitude	Longitude	*Cinctipora elegans*	*Hornera robusta*	*Hornera foliacea*	*Celleporina grandis*	*Adeonellopsis* spp.
B1	60	45° 50.672' S	170° 48.219' E	0.00	0.00	0.00	0.00	0.00
B2	65	45° 50.593' S	170° 48.784' E	0.00	1.79	0.52	0.00	0.10
B3	70	45° 50.555' S	170° 49.466' E	0.29	0.19	0.00	0.00	0.76
B4	75	45° 50.625' S	170° 50.907' E	0.70	1.10	0.05	1.20	0.72
B5	80	45° 50.660' S	170° 51.540' E	10.36	3.53	2.64	3.40	3.47
B6	85	45° 50.432' S	170° 52.321' E	6.82	3.72	1.85	3.09	1.10
B7	90	45° 50.439' S	170° 52.931' E	4.19	3.06	1.67	3.05	0.84
B8	95	45° 50.333' S	170° 53.243' E	2.35	1.93	1.46	5.08	0.64
B9	100	45° 50.745' S	170° 53.495' E	4.82	0.49	0.05	5.68	0.65
B10	105	45° 50.553' S	170° 54.522' E	0.41	0.00	0.00	2.64	0.11
B11	110	45° 50.874' S	170° 55.373' E	0.00	0.00	0.06	0.00	0.15
B12	60	45° 53.975' S	170° 44.795' E	0.00	0.00	0.00	0.00	0.00
B13	65	45° 54.196' S	170° 45.712' E	0.00	0.00	0.00	0.00	0.15
B14	70	45° 55.202' S	170° 46.200' E	1.31	0.16	0.08	1.23	0.56
B15	75	45° 55.545' S	170° 46.660' E	3.96	1.53	0.13	0.00	0.23
B16	80	45° 55.869' S	170° 46.919' E	8.28	4.30	1.48	3.57	0.24
B17	85	45° 56.030' S	170° 47.101' E	6.66	2.05	0.18	23.31	2.06
B18	90	45° 56.169' S	170° 47.427' E	6.84	0.38	0.00	0.99	1.33
B19	95	45° 56.290' S	170° 47.590' E	0.19	0.75	0.00	13.01	26.20
B20	100	45° 56.413' S	170° 48.157' E	0.00	0.18	0.00	4.87	2.40
B21	105	45° 56.418' S	170° 48.792' E	0.00	0.00	0.00	18.13	2.52
B22	110	45° 56.496' S	170° 49.369' E	0.00	0.00	0.00	0.70	0.65
B23	60	45° 58.194' S	170° 40.506' E	0.00	0.00	0.00	0.00	0.00
B24	70	45° 59.553' S	170° 41.981' E	0.00	0.00	0.00	0.00	0.16
B25	80	46° 00.546' S	170° 42.932' E	10.78	2.04	0.43	1.40	5.36
B26	90	46° 01.612' S	170° 44.142' E	0.09	0.00	0.00	0.00	1.15
B27	100	46° 02.849' S	170° 45.147' E	0.00	0.04	0.00	9.17	2.38
B28	110	46° 03.593' S	170° 45.883' E	0.00	0.03	0.04	16.26	2.58
B29	120	46° 04.569' S	170° 46.506' E	0.24	0.00	0.00	6.00	0.88
B30	80	45° 51.435' S	170° 51.013' E	3.91	0.59	0.00	0.68	1.20
B31	80	45° 52.284' S	170° 50.211' E	2.63	0.56	0.13	0.29	0.27
B32	80	45° 52.997' S	170° 49.584' E	10.13	0.13	0.13	1.86	0.84
B33	80	45° 53.917' S	170° 48.943' E	1.96	0.53	0.53	0.00	0.26
B34	80	45° 54.763' S	170° 48.180' E	2.82	3.96	3.25	8.82	0.53
B35	80	45° 55.499' S	170° 47.457' E	2.27	0.76	0.34	0.71	0.24
B36	80	45° 56.407' S	170° 46.715' E	8.87	4.28	1.66	6.57	4.73
B37	80	45° 57.717' S	170° 45.509' E	7.97	4.86	2.74	2.45	1.83
B38	80	45° 59.451' S	170° 43.915' E	9.43	2.61	1.06	1.78	3.16
B39	80	46° 01.161' S	170° 42.518' E	2.26	1.29	0.15	1.85	6.13
B40	90	46° 01.811' S	170° 42.982' E	1.46	0.31	0.28	0.00	1.21
B41	70	46° 00.269' S	170° 41.985' E	3.30	1.11	0.27	0.76	0.55

***Table 5*: Bathymetric distribution of six frame-building bryozoan species in transects 1, 2 and 3 on the Otago shelf. At each location the abundance of each species is ranked on an abundance scale ('-', absent; small case 'x', present; capital letter 'X', common; capital letter, bold 'X', abundant; blank, no data)**

Depth (m)	*Hippomenella vellicata*			*Cinctipora elegans*			*Hornera robusta*			*Hornera foliacea*			*Celleporaria agglutinans*			*Celleporina grandis*		
Transect	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
65	–	–		–	–		–	–		–	–		–	–		–	–	
70	–	–	–	–	X	–	–	–	x	–	X	–	–	x	–	–	–	–
75	–	–		–	X		X	X		x	X		x	–		–	–	
80	–	–	–	–	X	X	–	X	X	–	x	–	–	–	X	–	X	x
85	x	x		X	X		–	X		x	X		X	x		X	X	
90	–	–	X	**X**	X	–	–	X	–	X	–	–	X	X	–	–	X	–
95	x	–		X	–		–	x		–	–		–	–		–	X	
100	x	–	–	–	–	–	–	–	–	–	–	–	–	–	x	X	X	–
105	–	–		–	–		–	–		–	–		–	–		X	X	
110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X

***Table 6*: Abundance of six frame-building bryozoan species in dredge stations on the 80 m isobath. This line transect runs southward for approximately 20 km. Station B5 is the northern-most site in this transect. See Figure 7 for sample locations ('–', absent; 'x', present; 'X', common; 'XX', abundant)**

Location (N to S)	*Hippomenella vellicata*	*Cinctipora elegans*	*Hornera robusta*	*Hornera foliacea*	*Celleporaria agglutinans*	*Celleporina grandis*
B5	–	–	–	–	–	–
B30	–	XX	–	X	–	x
B31	–	X	–	X	x	–
B32	–	XX	XX	X	XX	X
B33	–	XX	XX	–	XX	X
B34	–	X	XX	x	X	X
B35	–	X	XX	X	x	x
B16	–	XX	XX	x	–	X
B36	X	XX	XX	x	XX	–
B37	–	XX	XX	XX	X	–
B38	–	XX	XX	X	X	X
B25	–	X	X	–	XX	x
B39	–	XX	XX	XX	X	X

Table 7: **Bryozoa recorded from the Otago shelf by Junge (1998)**

GYMNOLAEMATA: CHEILOSTOMATIDA

Flustridae	*Gregarinidra serrata*	Gigantoporidae	*Gigantopora* sp.
Calloporidae	*Retevirgula sejuncta*	Schizoporellidae	*Hippomenella vellicata*
	Ellisina sericea		*Chiastosella ?umbonata*
	Ellisina ?antarctica		*Chiastosella enigma*
	Crassimarginatella ?cucullata	Lacernidae	*Phonicosia circinata*
	Crassimarginatella (Corbulella) corbula	Smittinidae	*Hemismittoidea hexaspinosa*
	Crassimarginatella (Valdemunitella)		*Parasmittina* n.sp.
	Crassimarginatella (Valdemunitella)		*Smittina palisada*
	Foveolaria (Odontionella) cyclops		*Smittina rosacea*
Chaperiidae	*Chaperiopsis (Chaperiopsis) lanceola*	Buffonellodidae	*Aimulosia* sp.
	Chaperiopsis (Chaperiopsis) rubida	Bitectiporidae	*Parkermavella punctigera*
	Chaperiopsis (Chaperiopsis) spiculata		*Schizosmittina cinctipora*
	Chaperiopsis (Chaperiopsis) cf. *cristata*		*Schizosmittina conjuncta*
	Chaperiopsis (Chaperiopsis) cervicornis	Crepidacanthidae	*Crepidacantha ?crinispina*
	Chaperiopsis (Chaperiopsis) n.sp.	Microporellidae	*Microporella agonistes*
	Chaperiopsis (Clipeochaperia) funda		*Microporella* cf. *intermedia*
Aeteidae	*Aetea* sp.		*Fenestrulina gelasinoides*
Beaniidae	*Beania discodermiae*		*Fenestrulina reticulata*
	Beania magellanica		*Fenestrulina* sp.
Candidae	*Caberea solida*	Celleporidae	*Galeopsis polyporus*
	Caberea sp.		*Galeopsis porcellanicus*
Microporidae	*Micropora gracilis*		*Lagenipora* cf. *pinnacula*
	Micropora variperforata		*Lagenipora* sp.
	Micropora sp.		*Celleporina grandis*
	Opaeophora lepida		*Celleporina sinuata*
Cellariidae	*Melicerita augustifolia*		*Osthimosia* cf. *bicornis*
	Cellaria immersa	Phidoloporidae	*Hippellozoon*
	Cellaria tenuirostris		*Reteporella* sp.
Cribrilinidae	*Figularia mernae*		*Brodiella longispinata*
	Figularia huttoni	Romancheinidae	*Escharella spinosissima*
Euthyroididae	*Euthyroides episcopalis*	Lepraliellidae	*Celleporaria agglutinans*
Catenicellidae	*Orthoscuticella ventricosa*		*Celleporaria* sp.
Hippothoidae	*Hippothoa flagellum*	Adeonidae	*Adeonellopsis* cf. *pentapora*
	Celleporella aff. *delta*		*Adeonellopsis* sp.
Arachnopusidae	*Arachnopusia unicornis*		

STENOLAEMATA: CYCLOSTOMATIDA

Annectocymiidae	?*Annectocyma* sp.	Plagioeciidae	*Plagioecia* cf. *sarniensis*
	Entalophora sp.		*Plagioecia* sp.
Cinctiporidae	*Cinctipora elegans*		?*Plagioecia* sp.
Diaperoeciidae	*Diaperoecia purpurascens*	Stomatoporidae	?*Stomatopora* sp.
Heteroporidae	*Tetrocycloecia neozelanica*	Theonidae	*Supercytis digitata*
	Tetrocycloecia parapelliculata		*Telopora ?lobata*
Horneridae	*Hornera foliacea*		*Telopora* sp.
	Hornera robusta	Tubuliporidae	*Idmidronea* aff. *fraudulenta*
	Hornera sp.		*Tubulipora* sp.
Oncousoeciidae	*Eurystrotos ?ridleyi*	Lichenoporidae	*Disporella* aff. *buski*
	?*Oncousoecia* sp.	Frondiporidae	*Fasciculipora* cf. *fruticosa*

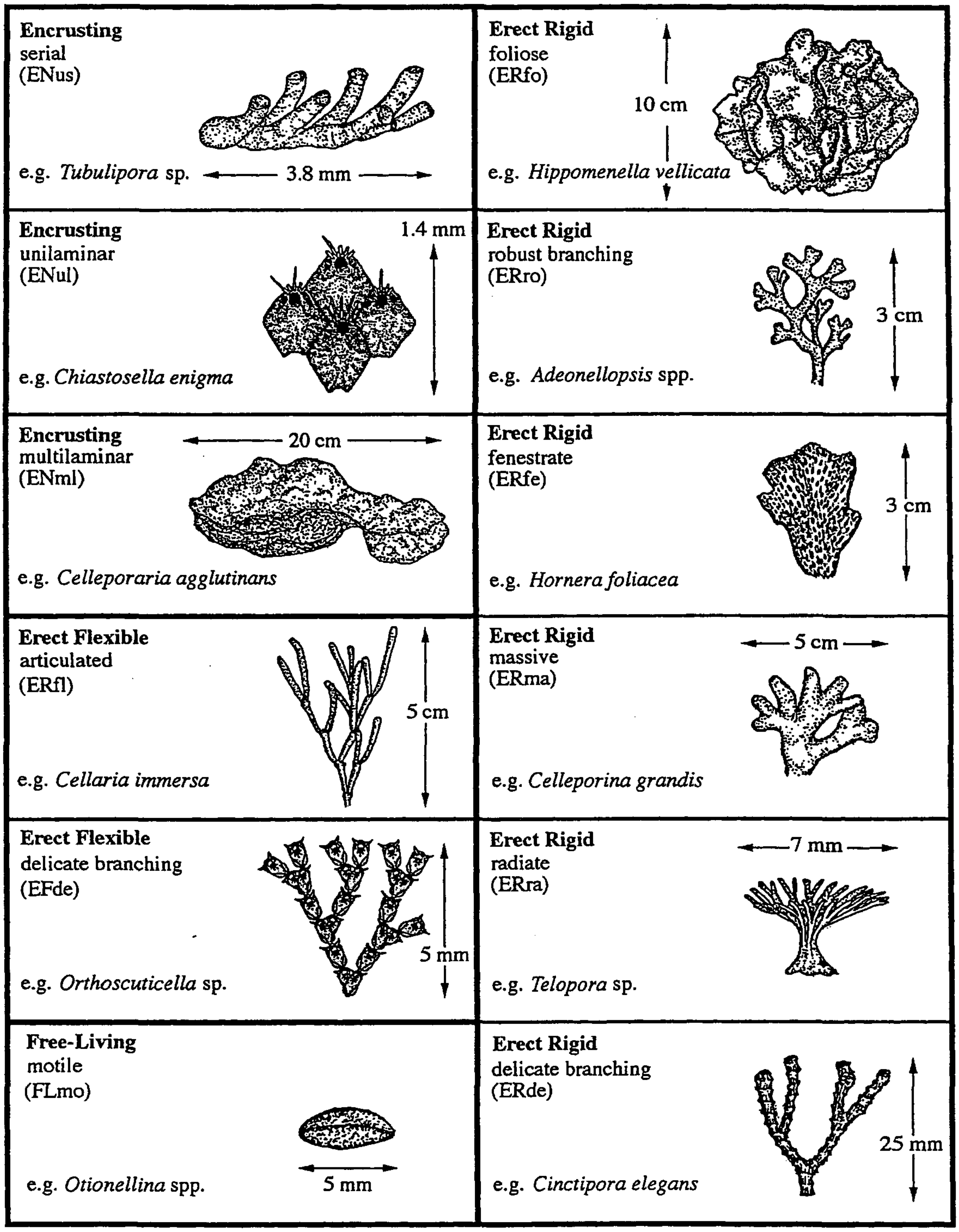

Figure 1: **Colonial forms of Bryozoa commonly encountered on the Otago shelf. Terminology based on the classification of Smith (1995).**

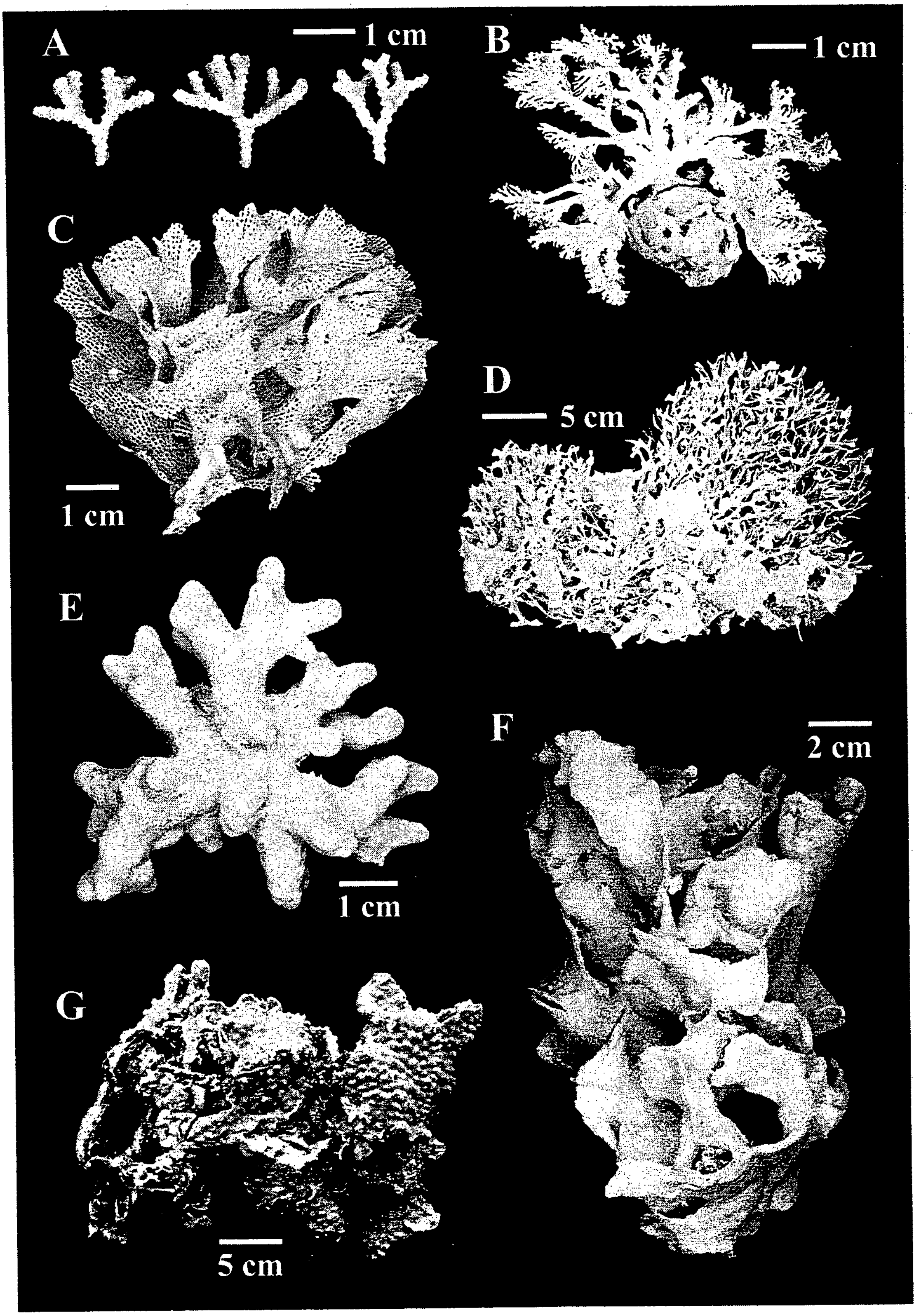

Figure 2: **Important Otago shelf frame-building bryozoans. A.** ***Cinctipora elegans*****, B.** ***Hornera robusta*****, C.** ***Hornera foliacea*****, D.** ***Adeonellopsis*** **sp., E.** ***Celleporina grandis*****, F.** ***Hippomenella vellicata*****, G.** ***Celleporaria agglutinans*****.**

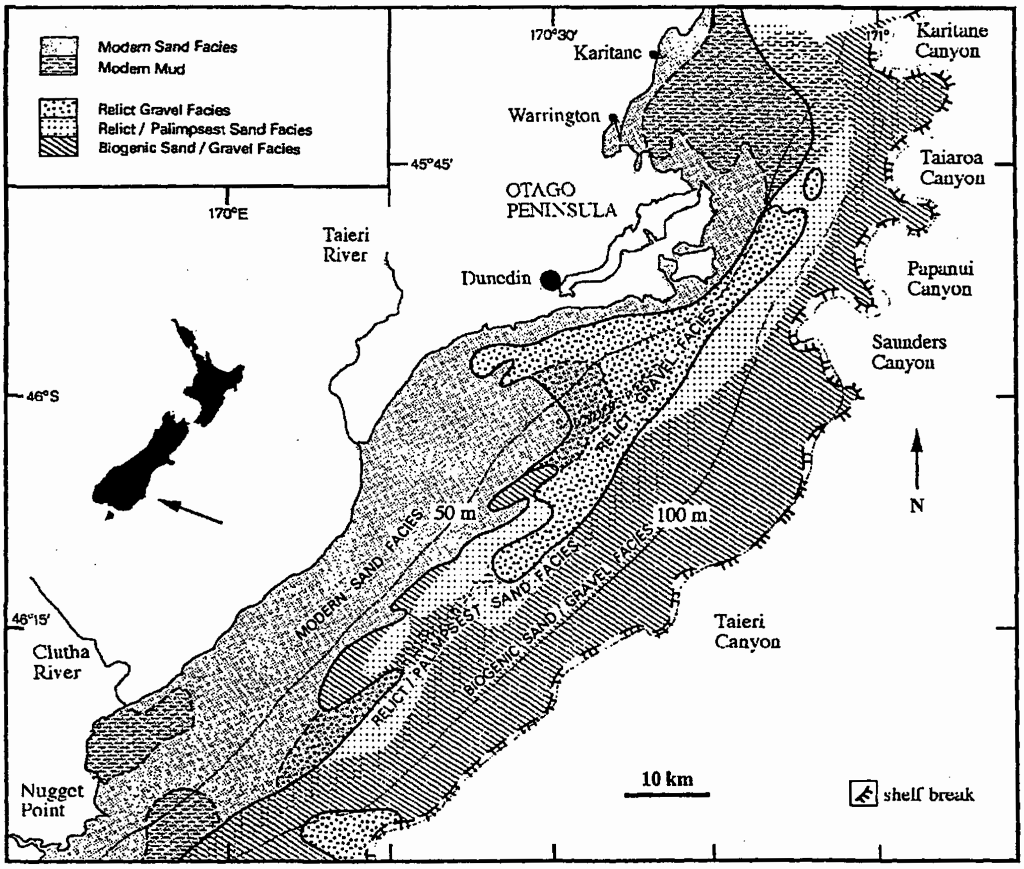

Figure 3: **Sediment map of the Otago shelf (modified from Carter et al., 1985).**

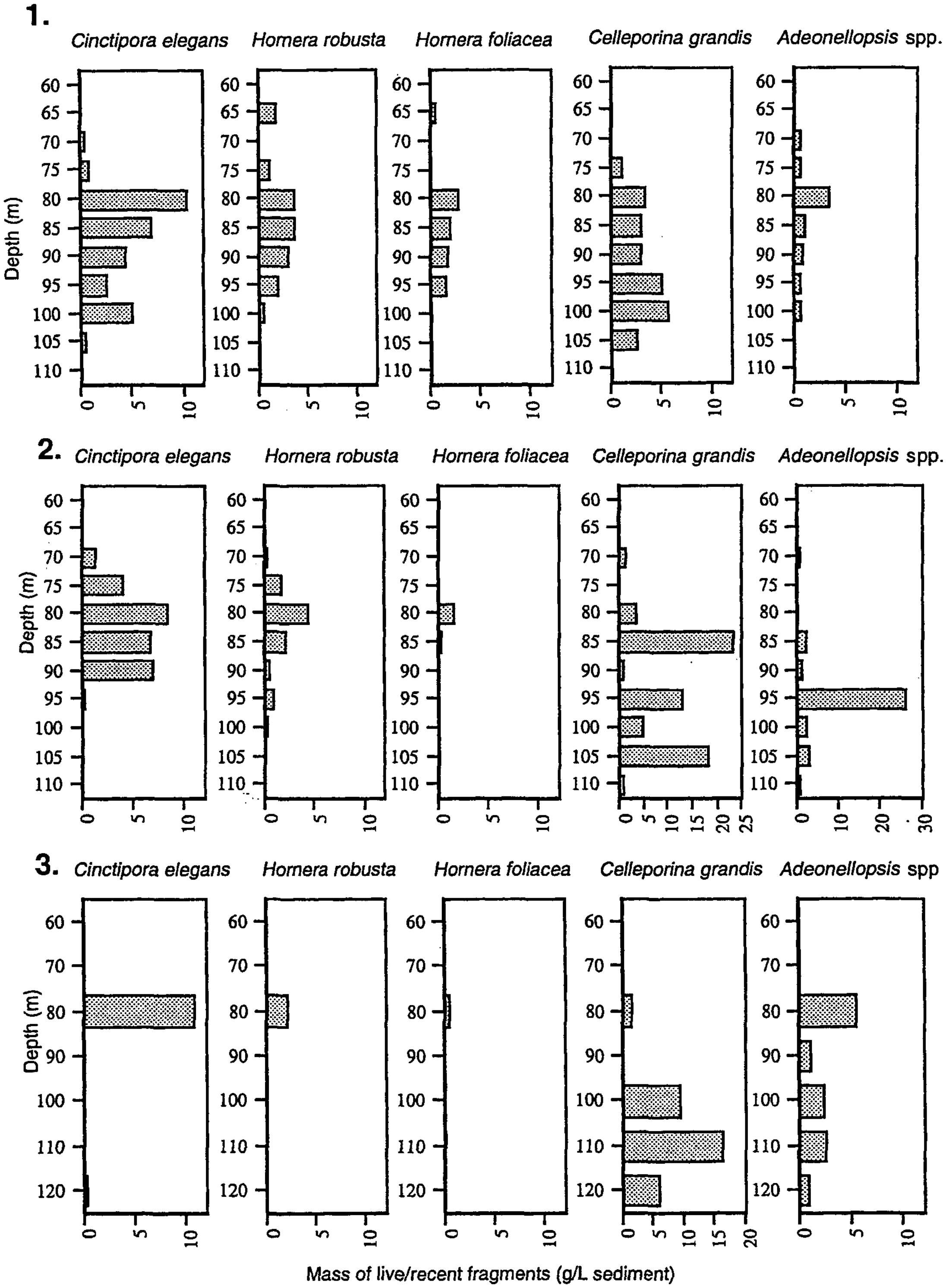

Figure 4: **Distribution of live- and recent-ranked fragments of five frame-building bryozoan species in transects 1, 2, and 3.**

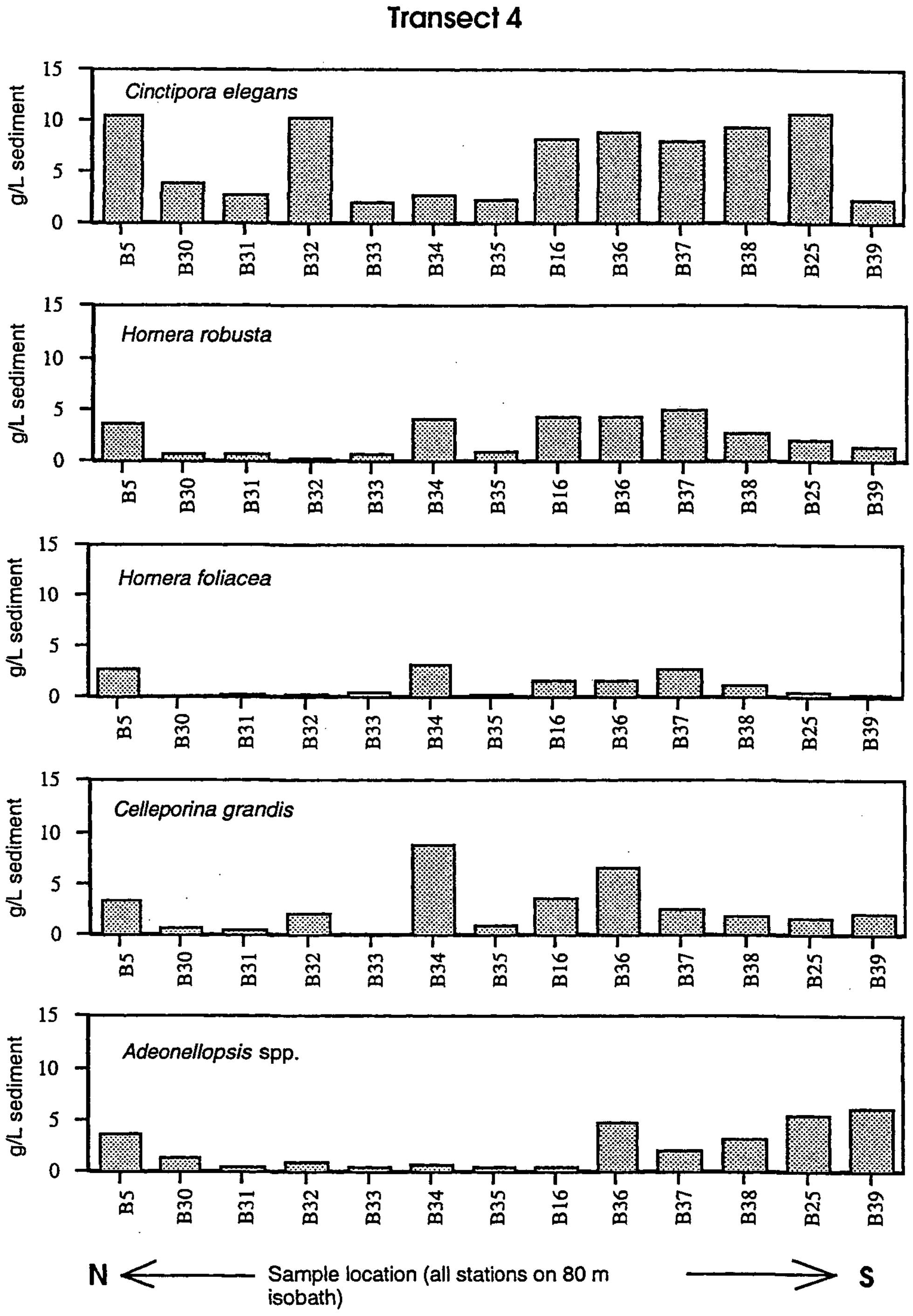

Figure 5: **Distribution of live- and recent-ranked fragments of five frame-building bryozoan species on transect 4, along the 80 m isobath (samples run southwards from station B5 at left).** ***See*** **Figure 7 for sample locations.**

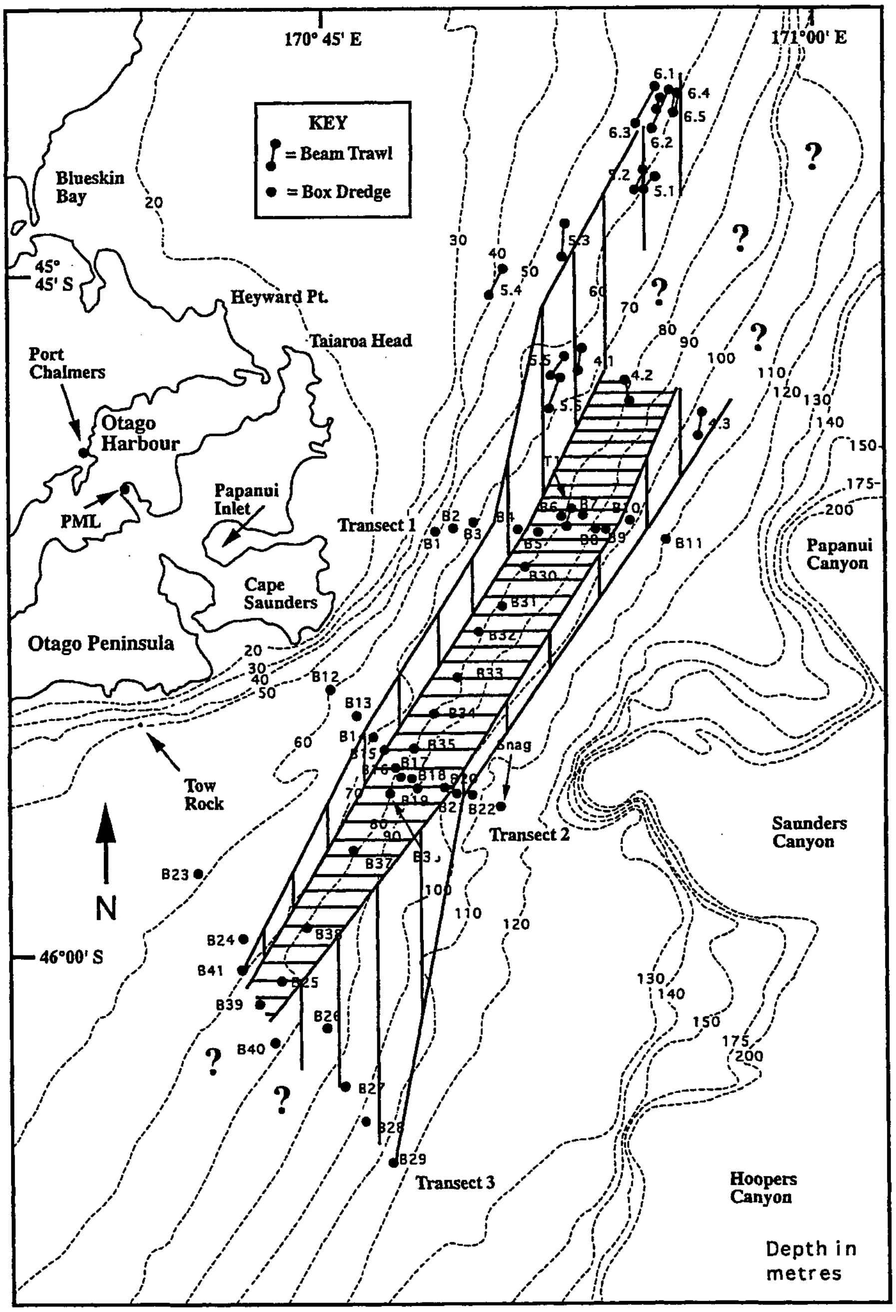

Figure 6: Map showing the area off Otago Peninsula known to be dominated by frame-building bryozoans. The region delineated by horizontal hatching contains thicket-forming densities of bryozoans. Vertical hatching indicates the zone where frame-building bryozoans usually occur in lower densities. Depth contours deeper than 200 m have been omitted for clarity.