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Subtidal reef and rockwall communities of the greater Foveaux Strait region, Southland, New Zealand

Helen Kettles, Franz Smith and Nick Shears

New Zealand Government

Department of Conservation
Te Papa Atawhai

Cover: The macroalgae *Xiphophora gladiata*, red coralline algae and a carpet shark in the surge zone of Paterson Inlet. *Photo: Kim Westerskov*.

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Abstract

Marine ecosystems contribute New Zealand's social, cultural and economic wellbeing, and appropriate conservation and management is essential for ensuring their long-term sustainability. Rocky reefs in the Foveaux Strait region of Southland represent an important element of New Zealand's coastal marine ecosystems but have been little studied to date. Therefore, in March 2005, 36 reef locations in the greater Foveaux Strait region were surveyed to characterise the macroalgae, epifauna (sessile and mobile macroinvertebrates) and cryptic and reef fishes inhabiting this region. Physical environmental data (e.g. wave exposure, turbidity, slope) were also collected to investigate underlying factors related to the observed biological patterns. In total, 125 macroalgal taxa, 106 sessile invertebrate taxa, 42 mobile macroinvertebrate species, 29 (14 closely associated with the reef including 8 cryptic) fish species were recorded across sites. Overall, wave exposure and sediment cover were most strongly correlated with the observed abundances of species, with more exposed sites generally having more macroalgal species, and fewer actinaria (i.e. anemones) and bryozoans (i.e. lacecorals); and sites with higher levels of sediment cover having more ascidians (i.e. sea squirts). The observed assemblages of mobile macroinvertebrates and cryptic and reef fishes were also related to these physical variables. Comparison with data from other parts of New Zealand showed that sites within the Foveaux Strait region are clustered in a distinct 'Stewart Island' biogeographic region and that the Green Islets are a unique part of the region. Further, the rockwalls of the Foveaux Strait region have similar levels of diversity to Fiordland, and similar levels of species richness to the Caribbean, South Africa, Antarctic Peninsula and Seychelle Islands. These data will assist management decisions in the region, including analyses to develop a network of Marine Protected Areas, ecological risk assessments and state of the environment reporting to understand any responses to changes in management or climate.

Keywords: Foveaux Strait, coastal marine ecosystems, biogeography, rocky reefs, macroalgae, epifauna, mobile macroinvertebrates, cryptic fishes, reef fishes, species assemblages

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1. Introduction

Marine biodiversity in New Zealand's coastal environment is under increasing threat from a wide range of anthropogenic impacts, including fishing, pollution, sedimentation, the introduction of exotic species and climate change. The need to manage coastal biodiversity was highlighted in the New Zealand Biodiversity Strategy (DOC & MfE 2000), with a desired outcome that 'a full range of marine habitats and ecosystems representative of New Zealand's indigenous marine biodiversity is protected by 2020'. However, to achieve this goal, we require baseline information to improve our knowledge of the nature and extent of different habitats and community types, as well as the key processes that maintain them. An assessment of threats and risks to these different habitat and community types will also be necessary to form a spatial framework that will enable prioritisation of the protected areas to include in the Marine Protected Area (MPA) network. Without this information, reserves and protected areas will necessarily be selected through *ad hoc* approaches, which may compromise both the protection of representative biodiversity features and the maintenance of ecological processes (e.g. Pressey et al. 1993; Pressey 1994), undermining the objective set out in the MPA Policy (DOC & MFish 2005).

Shallow subtidal reefs represent an important coastal habitat from an ecological, social, cultural and economic perspective. Many commercial and recreational coastal fisheries target species that live on or are associated with subtidal reefs at varying stages of their life-cycles (e.g. rock lobster *Jasus edwardsii*, sea urchin *Evechinus chloroticus* and pāua *Haliotis* spp.), and therefore it is important that these habitats are managed appropriately to ensure their wellbeing for future generations.

1.1 Subtidal reef communities in New Zealand

As is the case for most temperate areas, subtidal reef communities in New Zealand are dominated by large brown algae (Schiel 1990; Shears & Babcock 2007). These organisms are not only primary producers in shallow water benthic habitats, but also provide structural habitat for other reef organisms, and have been identified as important sites for the recruitment and post-settlement survival of reef fishes and mobile macroinvertebrates. Surveys of shallow subtidal reefs throughout mainland New Zealand (defined here as the North Island, South Island and Stewart Island/Rakiura) have provided a context for evaluating the standing stock (or biomass) of macroalgal assemblages, as well as biogeographic information to allow the identification of sites of distinct community composition (Shears & Babcock 2007).

Sessile invertebrates of subtidal reef habitats are suspension feeders, and so represent a guild of organisms that can provide a link between pelagic production and benthic habitats (e.g. Gili & Coma 1998). These organisms can also form important structural habitats that can facilitate the recruitment and post-settlement survival of fishes and mobile invertebrates (e.g. Bradstock & Gordon 1983). Surveys conducted throughout the New Zealand region (A. Smith, Massey University, unpubl. data) have allowed the levels of diversity in the context of national representativeness to be quantified, while comparative data from a global study using the same methodology (i.e. Witman et al. 2004) have provided a basis for making comparisons between local (or α-) diversity within New Zealand and global diversity.

The community structure and diversity of shallow subtidal reef sites are influenced by a combination of local-scale biological factors (such as predation) and broader-scale physical factors (such as current motion and wave exposure). For example, sea urchins are important grazers on many reefs throughout New Zealand (Shears & Babcock 2007), with the common sea urchin *E. chloroticus* (kina) having an important top-down structuring influence on algal assemblages (Andrew & Choat 1982; Villouta et al. 2001; Shears & Babcock 2002). In many areas, sea urchins occur at high densities and effectively remove all large brown algae, forming an 'urchin barrens' habitat (e.g. the northeastern coast, offshore islands on the west coast, northern South Island, Paterson Inlet/Whaka a Te Wera and Fiordland; Shears & Babcock 2007). Descriptive studies in northeastern New Zealand have shown that algal community structure and the importance of sea urchins as a controlling factor changes in a predictable manner over a wave exposure gradient (Grace 1983; Cole 1993; Shears & Babcock 2004a) – sea urchins are rare in sheltered locations that are subject to high levels of sedimentation, but become more prevalent and overgraze algae to greater depths with increasing exposure. However, at the most exposed northeastern New Zealand sites, sea urchins are rare and mixed stands of large brown algae predominate (Choat & Schiel 1982). The prevalence of sea urchins in many locations in northeastern New Zealand has been attributed to the overfishing of their predators, such as snapper (*Pagrus auratus*) and rock lobster (Babcock et al. 1999; Shears & Babcock 2002, 2003). However, such indirect effects of fishing on reef communities are not likely to occur throughout the country (Shears & Babcock 2004b), as urchin-dominated areas are typically rare and sea urchins are not thought to have an important top-down effect on algal assemblages along many parts of the New Zealand coast (e.g. Manawatāwhi/Three Kings Islands (Choat & Schiel 1982), Chatham Islands (Schiel et al. 1995) and large areas of the southeastern coast from East Cape to The Catlins (Schiel & Hickford 2001; Shears & Babcock 2007).

In addition to sea urchins, other mobile macroinvertebrates (e.g. sea stars and gastropods) also represent important consumers on rocky subtidal reefs that have been shown to influence the structure of subtidal benthic communities (e.g. Mann 1977; Glynn et al. 1979; Witman 1987; Andrew 1993). The distribution of these organisms can also be influenced by physical environmental conditions, which can result in the creation of spatial refuges for sessile invertebrates and algae (e.g. Menge & Lubchenco 1981; Witman 1985; Witman & Grange 1998). Some of these organisms also serve as dietary items for secondary and tertiary consumers (e.g. fishes and rock lobsters), making them important links between benthic production and higher trophic levels. Although we generally know less about the relative importance of these organisms as consumers within these habitats than we do about sea urchins, their distribution and abundance provides some indication of potential consumer forces acting on sessile benthic assemblages (Shears & Babcock 2007).

Fishes associated with subtidal rocky reefs are key consumers of macroalgae, sessile and mobile invertebrates, other fish species, and plankton (Jones 1988). Juvenile and adult forms of reef fishes potentially respond to different physical environmental conditions and/or have different habitat requirements (e.g. some juveniles refuge in macroalgal stands; see Levin 1993). As with mobile macroinvertebrates, the abundance and distribution of reef fishes provides information on potential consumer forces acting on sessile invertebrate and algal assemblages. Smaller 'cryptic fishes' (including species of blenny and triplefins) represent smaller consumers of rocky reef habitats and can also serve as an indicator of physical environmental conditions. These fishes may also be food items for larger reef fishes, representing a pathway from lower to higher trophic levels in subtidal reef environments. Since these fishes are comparatively smaller, and are often associated with macroalgal understories and sessile invertebrates (e.g. sponges, ascidians) – hence the name 'cryptic fishes' – they require a different sampling technique to characterise their relative abundance. However, to date few sampling programmes have been able to characterise the species assemblages of cryptic fishes, indicating a gap in our knowledge of this group as a potential indicator of reef status.

1.2 Subtidal reef communities of the Foveaux Strait region

Increasing pressures within the Foveaux Strait region, including from climate change, aquaculture, fishing and land-based developments, have led to the need to develop a framework to be able to manage the impacts of human activities at a regional scale and to protect marine biodiversity that is directly or indirectly affected by these activities. Such a spatial framework for the marine environment has been developed in areas such as Fiordland, which has assisted in the development, analysis and monitoring for the region (Guardians of Fiordland's Fisheries & Marine Environment Inc. 2003).

Very little quantitative information is available on subtidal reef communities of the Foveaux Strait and Stewart Island region. However, a number of descriptive surveys of marine communities have been carried out in Paterson Inlet/Whaka a Te Wera and other inlets around Stewart Island/Rakiura, which are reviewed in Grange & McKnight (1987) and Hare (1992).

Shallow subtidal suspension-feeding invertebrate assemblages of Fiordland and the subantarctic islands have previously been characterised in terms of their species richness and diversity (e.g. Smith 2001; A. Smith, unpubl. data). Since the Foveaux Strait region represents an intermediate zone between these two regions, the level of biological interchange across this zone is of particular interest, considering the position of the Subtropical Convergence in the region. Direct comparisons between this region and other regions that have a similar geographic extent and strong gradients of physical environmental variables (e.g. wave exposure, tidal currents, freshwater inputs) can provide a better understanding of how the combination of physical and biological processes within Foveaux Strait compare nationally. In addition, comparison with a global dataset (e.g. Witman et al. 2004) allows us to determine how the richness and diversity of epifaunal assemblages compares with distinct biogeographic regions globally.

1.3 Objectives

The primary objective of the present study was to quantitatively describe shallow subtidal reef communities at sites throughout the Foveaux Strait region, and to assess how this area compares with other parts of New Zealand and other biogeographic regions globally. Thirty six sites were surveyed within the Foveaux Strait region and reef communities quantitatively described at 31 of these sites using the same methodology as Shears & Babcock (2007) and rockwall epifauna communities described at 18 sites using the same methodology as Smith (2001). The data from both of these surveys are combined to describe regional patterns in macroalgal communities and the diversity of epifaunal invertebrate assemblages, as well as to provide data on associated mobile macroinvertebrate and fish species assemblages throughout the Foveaux Strait region. The relationship between these patterns and a number of local- and broad-scale environmental factors are also investigated. In addition, the findings are discussed in relation to national patterns of reef community structure (Shears & Babcock 2007) and biogeography (Shears et al. 2008), and comparisons are made with the diversity of epifaunal invertebrates from other regions nationally and internationally (A. Smith, unpubl. data; Witman et al. 2004).

These data and analysis of the relationship between biological communities and physical environmental factors will provide us with a better understanding of the basic ecology of the Foveaux Strait region, and can be used to assist the development of spatial frameworks to better manage activities and mitigate risks for the region. Consistency in the data-gathering approaches and analytical tools used can also form the basis for MPA network design and allow modelling approaches to be used to make spatial predictions in poorly sampled regions.

2. Methodology

2.1 Study locations

Survey sites were located along the southern coast of the South Island of New Zealand, from the Green Islets to Shag Point; along the northern and eastern coasts of Stewart Island/Rakiura, from Codfish Island / Whenua Hou to Port Adventure; and on Ruapuke Island. Searching for suitable sampling sites was also conducted from Long Reef (towards Puysegur Point) in the west to Tiwai Point in the east, as well as at locations along the northern shore of Stewart Island/Rakiura and surrounding Ruapuke Island (Fig. 1). The majority of data (36 sites) were collected during surveys conducted from 12 to 24 March 2005. In addition, survey data that were collected by Shears & Babcock (2007) from 13 sites around Paterson Inlet/Whaka a Te Wera and the Titi/Muttonbird Islands on 1 to 7 February 2000 using the same methodology were also analysed (Table 1).

Reef sites were selected to provide a representative coverage of exposure conditions in the Foveaux Strait region; however, in many cases the actual locations and number of sites sampled was largely determined by sea conditions at the time of sampling. In most cases, sites with moderately sloping reefs were selected so that reefs could be sampled to a depth of 12 m. Epifaunal invertebrates were only sampled where there was sufficient rockwall habitat present. The names and positions of all sampling sites are given in Table 1. The sites sampled were generally divided among nine locations: Preservation Inlet (two sites), Green Islets (four sites), Bluff (seven sites), Codfish-Ruggedy (nine sites from Codfish Island / Whenua Hou, Ruggedy Islands and the northwestern corner of Stewart Island/Rakiura), Titi/Muttonbird Islands (four sites), Paterson Inlet/Whaka a Te Wera (eight sites), Halfmoon Bay (seven sites which included three sites between Port William/Potirepo and the entrance of Paterson Inlet/Whaka a Te Wera), Ruapuke Island (four sites) and Port Adventure (four sites). For photos of some of the representative sites see Fig. 2.

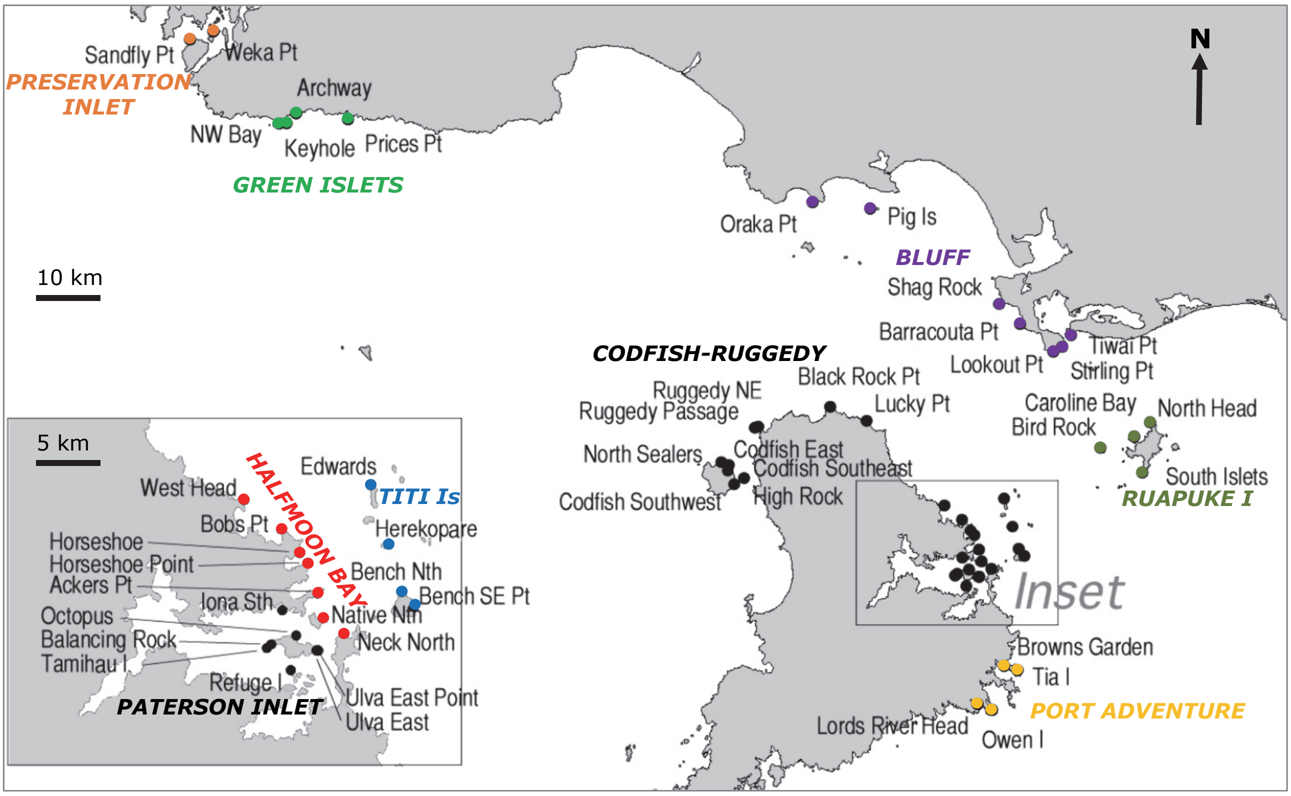


Figure 1. Locations and study sites in the Foveaux Strait region. See Table 1 and Appendix 1 for site details and what was surveyed at each site.

Table 1. Names, location groupings, and sampling dates and methods undertaken for the 36 survey sites surveyed plus the 13 sites surveyed by Shears & Babcock (2007). See Fig. 1 and Appendix 1 for site locations.

LOCATION GROUPING	SITE NAME	DATE	SITE ID	ROCKWALL (EPIFAUNA, CRYPTIC FISHES AND MOBILE INVERTEBRATES)	SHALLOW SUBTIDAL REEF BENTHIC COMMUNITIES	REEF FISHES
Preservation Inlet	Weka Point	16 Mar 2005	24		✓	✓
Preservation Inlet	Sandfly Point	16 Mar 2005	25		✓	✓
Green Islets	Prices Point	15 Mar 2005	20	✓	✓	✓
Green Islets	Archway	15 Mar 2005	21	✓	✓	
Green Islets	Keyhole	15 Mar 2005	22	✓		
Green Islets	NW Bay	15 Mar 2005	23		✓	✓
Bluff	Pig Island	22 Mar 2005	30	✓	✓	✓
Bluff	Oraka Point	22 Mar 2005	31	✓	✓	
Bluff	Barracouta Point	23 Mar 2005	32		✓	✓
Bluff	Shag Rock	23 Mar 2005	33	✓	✓	✓
Bluff	Lookout Point	23 Mar 2005	34		✓	✓
Bluff	Stirling Point	24 Mar 2005	35		✓	✓
Bluff	Tiwai Point	24 Mar 2005	36		✓	✓
Codfish-Ruggedy*	Codfish Southeast	14 Mar 2005	15		✓	✓
Codfish-Ruggedy*	Codfish Southwest	14 Mar 2005	16	✓		
Codfish-Ruggedy*	North Sealers Bay	17 Mar 2005	17	✓	✓	✓
Codfish-Ruggedy*	High Rock	17 Mar 2005	18	✓		
Codfish-Ruggedy*	Codfish East	17 Mar 2005	19		✓	✓
Codfish-Ruggedy*	Ruggedy Passage	14 Mar 2005	11	✓	✓	✓
Codfish-Ruggedy*	Ruggedy NE	17 Mar 2005	12	✓	✓	✓
Codfish-Ruggedy*	Black Rock Point	18 Mar 2005	13		✓	✓
Codfish-Ruggedy*	Lucky Point	18 Mar 2005	14		✓	✓
Titi/Muttonbird Islands	Motunui/Edwards Island	03 Feb 2000	45		✓	
Titi/Muttonbird Islands	Herekopare Island (Te Marama)	03 Feb 2000	46		✓	
Titi/Muttonbird Islands	Bench Island Nth	04 Feb 2000	47		✓	
Titi/Muttonbird Islands	Bench Island SE Point	04 Feb 2000	48		✓	
Paterson Inlet/Whaka a Te Wera	Tamihau Island	19 Mar 2005	5	✓	✓	
Paterson Inlet/Whaka a Te Wera	Ulva Island E Point	19 Mar 2005	6	✓		
Paterson Inlet/Whaka a Te Wera	Ulva Island E Reef	19 Mar 2005	7		✓	✓
Paterson Inlet/Whaka a Te Wera	Refuge Island	31 Jan 2000	37		✓	
Paterson Inlet/Whaka a Te Wera	Octopus Island	31 Jan 2000	38		✓	
Paterson Inlet/Whaka a Te Wera	Balancing Rock	01 Feb 2000	40		✓	
Paterson Inlet/Whaka a Te Wera	Ulva Island E	01 Feb 2000	41		✓	
Paterson Inlet/Whaka a Te Wera	Iona Island S	02 Feb 2000	44		✓	
Halfmoon Bay	The Neck N	01 Feb 2000	39		✓	
Halfmoon Bay	Ackers Point	02 Feb 2000	42		✓	
Halfmoon Bay	Native Island N	02 Feb 2000	43		✓	

* The Codfish-Ruggedy location grouping included five sites from Codfish Island/Whenua Hou, two sites at the Ruggedy (or Rugged) Islands and two sites on the northern-most coast of Stewart Island/Rakiura.

Continued on next page.

Table 1 continued.

LOCATION GROUPING	SITE NAME	DATE	SITE ID	ROCKWALL (EPIFAUNA, CRYPTIC FISHES AND MOBILE INVERTEBRATES)	SHALLOW SUBTIDAL REEF BENTHIC COMMUNITIES	REEF FISHES
Halfmoon Bay	Horseshoe Bay	07 Feb 2000	49		✓	
Halfmoon Bay	Horseshoe Point	21 Mar 2005	8	✓		
Halfmoon Bay	Bobs Point	21 Mar 2005	9		✓	✓
Halfmoon Bay	West Head	21 Mar 2005	10	✓	✓	✓
Ruapuke Island	Bird Rock	20 Mar 2005	26	✓	✓	
Ruapuke Island	South Islets	20 Mar 2005	27	✓	✓	✓
Ruapuke Island	North Head	20 Mar 2005	28		✓	✓
Ruapuke Island	Caroline Bay	20 Mar 2005	29		✓	✓
Port Adventure	Browns Garden	12 Mar 2005	1	✓	✓	
Port Adventure	Tia Island (Entrance)	13 Mar 2005	2		✓	✓
Port Adventure	Horomamae/Owen Island	13 Mar 2005	3		✓	✓
Port Adventure	Lords River Head	14 Mar 2005	4		✓	✓

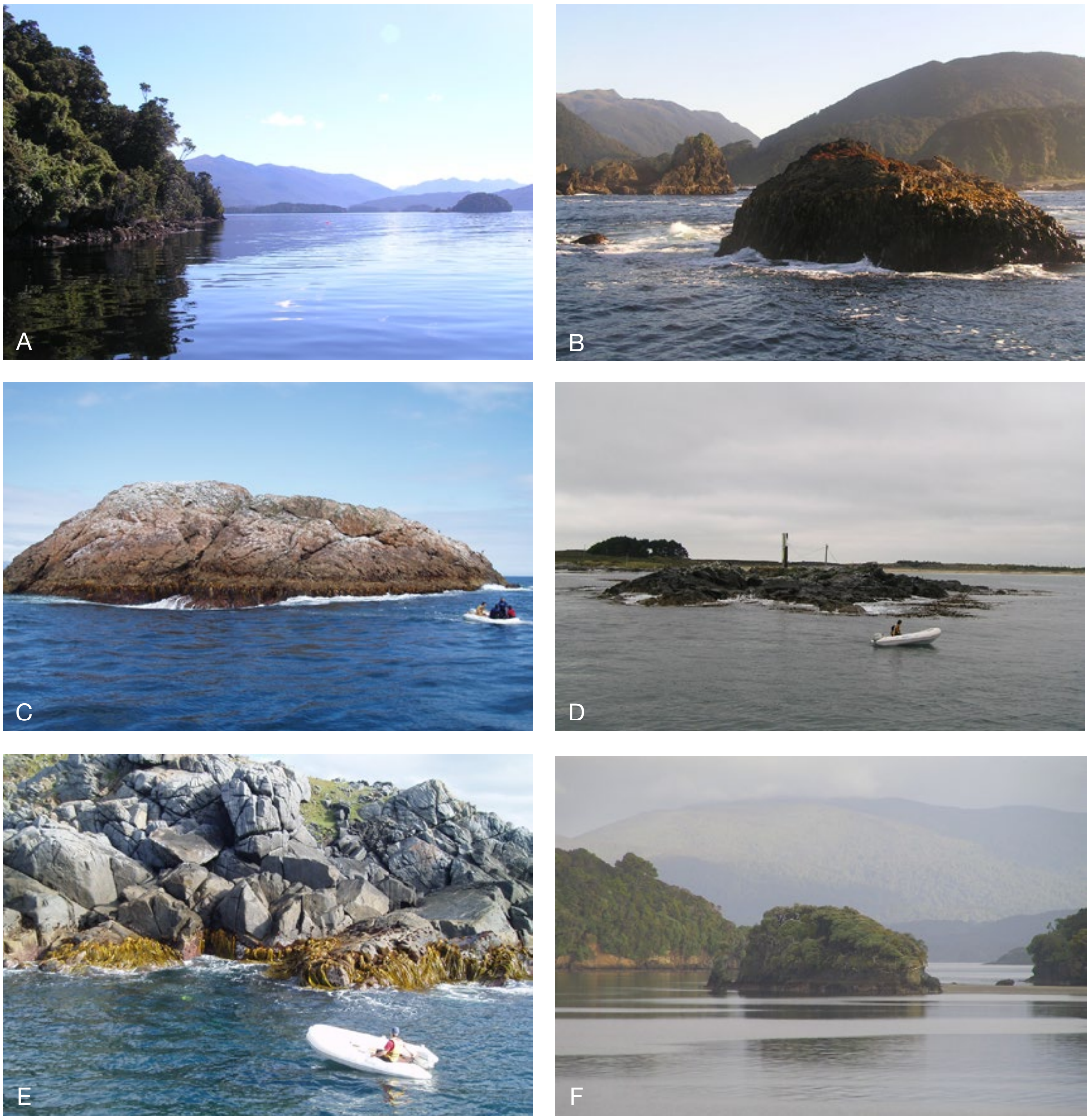


Figure 2. A selection of the study sites surveyed in the Foveaux Strait region: A. Preservation Inlet, B. Green Islets, C. Bluff, D. High Rock, Codfish Island, E. Ruapuke I, F. Paterson Inlet/Whaka a Te Wera.

When selecting sites for surveying subtidal rockwall, steep topographic gradients were identified on available marine bathymetric charts, and profiles near the coastal fringe were made using the ecosounder with supporting knowledge from the skipper (Dan Young, Oban, Stewart Island/ Rakiura). This methodology enabled rockwalls of similar topography to be identified, with some local variation in reef morphology. The target depth for rockwalls was 15 m.

In total, 49 sites were surveyed in the Foveaux Strait region between Preservation Inlet (Fiordland) and Port Adventure (Stewart Island/Rakiura) (Fig. 1, Table 1 & Appendix 1). Of these sites, 44 were sampled with the shallow subtidal reef methodology and 18 with the rockwalls methodology.

2.2 Sampling methodology

2.2.1 Reef macroalgae and mobile macroinvertebrates

At each site, five 1 m^2 quadrats were sampled in each of four depth ranges (< 2, 4–6, 7–9 and 10–12 m) to provide information on the abundance and size structure of macroalgae and macroinvertebrates. This methodology is consistent with that used throughout New Zealand to provide a general quantitative description of the shallow reef communities found at a given site (Shears & Babcock 2007). Depths were corrected to the mean low water mark to ensure accurate positioning of quadrats within the desired depth range. Where the maximum depth was less than 10 m (e.g. Oraka Point and Octopus Island), the deepest categories were omitted. At each site a lead-weighted rope was run out perpendicular to the shore from the shallow subtidal to 12 m depth, or the edge of the reef, whichever came first. Quadrats were positioned haphazardly within c. 5 m of the rope in the desired depth range and the distance along the rope recorded to enable subsequent re-sampling in the same general area.

Within each quadrat, all macroalgae and macroinvertebrates were measured and counted. Measurements were made using a 5 m interval ruler for macroinvertebrates and a 5 cm interval 100 cm tape measure for macroalgae.

For macroalgae, the total lengths of individual fronds were measured, as it is often difficult to determine individual plants for many species. In addition, measurements of stipe length and lamina length were made for *Ecklonia radiata, Lessonia variegata* and *Durvillaea* spp. For *Durvillaea* spp., the stipe diameter was also recorded; and for *L. variegata*, the total length of the whole plant was measured and the number of thalli was counted. For small foliose algal species (< 30 cm in height), it was impractical to count and measure all individual plants, so the percent cover of these species was estimated. The primary (substratum) percent cover of turfing algae, encrusting algal species, sessile invertebrates and sediment in each quadrat were also visually estimated. Quadrats were divided into quarters to assist with estimating the percent cover of dominant forms, while the cover of minor forms was estimated on the basis that a 10 × 10 cm area equates to 1% cover. This technique was considered to be the most suitable for the purposes of this study as it is efficient and ensures that the cover of all forms is recorded. All quadrat sampling was carried out by the same three experienced divers in order to minimise inter-observer variability.

For mobile macroinvertebrates, the test diameter of all sea urchins > 10 mm was measured to the nearest 5 mm and the largest shell dimension (width or length) of gastropods was measured – the actual measurement varied depending on species shell morphology (i.e. shell height for *Cantharidus opalus*; shell width for *Turbo smaragdus*, *Trochus viridis* and *Cookia sulcata*). The total length of *Haliotis* spp. and limpets (*Cellana stellifera*) was also measured.

2.2.2 Epifaunal assemblages on subtidal rockwalls

Photographic quadrats of 0.25 m^2 were sampled along a 25 m transect at each site that followed reef contours at depths of 10–15 m. Individual quadrats were sampled at random intervals marked on a transect tape from a haphazard starting point. In most instances, quadrats were placed on near-vertical surfaces oriented along the rockwall, with slight deviations in placement dictated by reef morphology. Additional replicates were also haphazardly taken along each transect where possible. The number of replicates for each transect varied from 13 to 16 quadrats.

The photographic quadrat system consisted of a Nikonos V camera fitted with a 15 mm lens and two strobes fixed to a rigid framer, providing a high-resolution 35 mm slide image that could identify organisms > 2–3 mm in size (Witman 1985). It should be noted that although this methodology is ideal for sampling the majority of fauna present on rock walls, it is impractical for sampling a few species of more widely dispersed taxa (such as large sponges). Therefore, these species are under-represented in these analyses. The rockwalls were also chosen to have few cracks and fissures present therefore cryptic species such as *Haliotis* spp. will also be underrepresented. To aid species identification within quadrat images, close-up photographs were taken of voucher specimens found outside the transects.

The photoquadrat methodology follows that of Witman (1985), Smith & Witman (1999) and Smith (2001). The use of this technique provides a standard measure of diversity that can be compared across sites throughout the New Zealand region.

2.2.3 Mobile macroinvertebrates of subtidal rockwalls

The abundance of mobile macroinvertebrate consumers such as gastropods, echinoderms and crustaceans was quantified by counting all mobile macroinvertebrates in a 1 m swath in five contiguous 5 m^2 blocks at a depth of 15–20 m along the 25 m transects used for the epifaunal survey (see section 3.2.2). The raw species abundances for individual 5 m^2 quadrats were then used to calculate average densities for sampling sites. Limited voucher specimens were collected to assist with the positive identification of species. Spatial information of species abundance was maintained for future analyses in relation to biological habitat characteristics.

2.2.4 Cryptic fishes

Individual species of cryptic fishes were identified, counted and recorded in five contiguous 5 m^2 blocks at a depth of 10–15 m along the same transects that were used for the epifaunal and mobile macroinvertebrate surveys (see sections 3.2.2 & 3.2.3). Since these fishes are not typically disturbed by diver presence, often maintaining their positions within a 1 m radius, there is likely to be relatively little bias in these counts compared with those of reef fishes (see section 3.2.5). The search time at each site was standardised due to the same time being needed to sample the photographic quadrat replicates.

2.2.5 Reef fishes

Visual underwater censuses of reef fishes were conducted along two to three replicate 25 × 5 m transects at two depth strata: 12–15 m and 5–7. The number of transects was limited by weather and the number of divers. A diver attached a transect tape at a haphazard starting point and swam along the reef contours while reeling out the tape, counting all reef fishes in a 2.5 m swath on either side of the transect tape. Counts were not taken over the first 5 m of each transect to minimise bias due to diver disturbance to the reef fish assemblages while making visual censuses. For schools of fish aggregations, such as those that occur with telescopefish, an estimate of abundance was made to the nearest ten individuals. Due to the considerable local harvesting interest, blue cod (*Parapercis colias*) were recorded in three distinct size classes (< 150 mm, 150–300 mm and > 300 mm which is the legal size in Southland) in an effort to distinguish between juveniles, sub-adults and adults.

2.3 Biological and environmental datasets

2.3.1 Shallow subtidal reef sites

The biological data collected from the 44 shallow subtidal reef sites were compiled into four datasets for the purpose of carrying out multivariate analyses to investigate the structural patterns in reef communities. Three of these datasets reflected the dominant organisms that were sampled and identified to species level (e.g. macroalgae and mobile macroinvertebrates) across all study sites, while the fourth included the percent cover of all sessile groups (macroalgae and sessile epifaunal invertebrates):

1. **Macroalgal species composition** – In total, 106 macroalgal taxa were recorded across all sites. Data were condensed to presence/absence to investigate biogeographic patterns, and the relationships between algal species composition and explanatory variables.
2. **Macroalgal community structure** – Patterns in macroalgal community structure were investigated among sites and locations by analysing the biomass of major structural groups. Large habitat-forming species formed their own groups, while other less conspicuous species were grouped together (e.g. red foliose algae). This approach was taken to reduce the influence of species composition and emphasise structural patterns among algal communities. In total, all macroalgal species were divided into 24 groups (Table 2). To allow all algal groups to be compared irrespective of the sampling units used (e.g. percent cover coralline turf vs. counts and measurements for large brown algae) and to adjust counts for different sizes of algae, all algal measurements were converted to biomass

Table 2. Macroalgal groups and species used in the analyses of macroalgal community structure.

GROUPS	CODE	SPECIES
Phaeophyta		
Brown encrusting	Brown_encr	e.g. *Ralfsia* spp.
Brown turf	Brown_turf	e.g. *Colpomenia sinuosa*
Small browns	Small_browns	e.g. *Carpomitra costata*, *Zonaria turneriana*
Large browns	Flex	*Carpophyllum flexuosum*
	Cplaty	*Cystophora platylobium*
	Cysto	*Cystophora* spp e.g. *Cystophora retroflexa*, *C. scalaris*, *C. torulosa*
	Dwillana	*Durvillaea willana*
	Ecklonia	*Ecklonia radiata*
	Lessonia	*Lessonia variegata*
	Lands	*Landsburgia quercifolia*
	Macrocystis	*Macrocystis pyrifera*
	Mboryana	*Marginariella boryana*
	Murvilliana	*Marginariella urvilliana*
	Sargassum	*Sargassum sinclairii*
	Xiphoph	*Xiphophora gladiata*
Rhodophyta		
Coralline turf	Cturf	
Crustose corallines	CCA	
Red encrusting	Red encr	
Red foliose	Red_fol	e.g. *Euptilota formosissima*, *Plocamium* spp.
Red turf	Red turf	
Chlorophyta		
Greens	Caulerpa	*Caulerpa brownii*
	Codium	*Codium* spp.e.g. *Codium convolutum*
	Green	Other greens e.g. *Ulva* spp., *Chaetomorpha* spp., *Cladophora* spp.
Filamentous algae	Fuzz	

(dry-weight). Biomass was calculated using length-weight relationships for large algal species, and percent cover-weight relationships for turfing and encrusting algal species (see Shears & Babcock (2007) for biomass equations).

3. **Mobile macroinvertebrate assemblages** – This dataset included count data (averaged for each site across all quadrats) for all mobile macroinvertebrate species that were confidently identified.
4. **Benthic community structure** – To investigate patterns in benthic community structure among sites and locations, the percent cover estimates for all sessile organisms were divided into 23 broad structural classes (Table 3). This dataset was included to ensure that the relative contributions of both macroalgae and sessile invertebrates to overall community structure were considered.

At each site, a number of local-scale environmental variables were estimated, including wave exposure (wind fetch), turbidity (secchi disc), sedimentation, overall reef slope, maximum depth and the density of sea urchins (*E. chloroticus*):

- **Wind fetch** was calculated at each site by summing the potential fetch for each 10 degree sector of the compass rose. The radial distance was arbitrarily set to 300 km for open sectors of water. Average wind speeds were not factored into these estimates, but further work incorporating such information would strengthen the wave exposure estimates for sites. See Fig. A2.1 (Appendix 2) for wave exposure estimates.
- **Turbidity** was measured using a standard 25 cm diameter black and white secchi disc. The reading was taken as the average depth (m) of descending disappearance and ascending reappearance.

Table 3. Structural groups used in the analyses of benthic community structure of shallow subtidal reef sites.

GROUP	STRUCTURAL GROUP	CODE	EXAMPLE
Algae	Crustose coralline	CCA	
	Red encrusting	Red encr	*Hildenbrandia* spp.
	Coralline turf	Cturf	*Corallina* spp., *Amphiroa* spp., Haliptilon spp.
	Red turf	Red turf	
	Filamentous	Filamentous	
	Red foliose	Red foliose	*Hymenena* spp.
	Green	Greens	*Caulerpa brownii*
	Brown encrusting	Brown encr	*Ralfsia* sp.
	Small browns	Small browns	*Halopteris* spp.
	Large browns	Large browns	*Marginariella* spp., *Ecklonia radiata*
Annelida	Tubeworms	Tubeworm	*Galeolaria* sp.
Chordata	Ascidians	Ascidian	*Didemnum* spp.
Crustacea	Barnacles	Barnacles	*Balanus* spp.
Mollusca	Oysters	Oyster	*Anomia walteri*
	Mussels	Mussels	*Perna canaliculus*, *Mytilus* spp.
Brachiopoda	Brachiopods	Brachiopods	
Bryozoa	Bryozoans	Bryozoan	
Cnidaria	Anemones	Anemones	*Anthothoe albocincta*
	Cup corals	Cup coral	*Culicia rubeola*
Hydrozoa	Hydroid turfs	Hydroid	
Porifera	Encrusting sponges	Sponge	*Cliona celata*
Bare rock		Bare	
Sediment		Sediment	

- **Sedimentation** was estimated as the percent cover of sediment on the substratum at each site, as calcualted during quadrat sampling. See Fig. A2.2 (Appendix 2) for sediment cover estimates.
- The **overall reef slope** at each site was expressed as a percentage of the maximum depth divided by the transect distance.
- The **density of sea urchins** was also used as an explanatory variable in multivariate analyses, as it has a strong controlling influence on macroalgal community structure. Densities of sea urchins were averaged across all depths at each site.

2.3.2 Epifaunal invertebrate assemblages of subtidal rockwalls

The photoquadrat images were analysed to quantify the species diversity and community attributes of epifaunal invertebrate assemblages at the sampled locations. Images were projected onto a viewing screen to count taxa, which were identified to the lowest taxonomic level possible. Any species that could not be identified were given field names that were kept consistent throughout the image analysis process and/or referred to voucher specimens with corresponding field names. It should be noted that this taxonomic uncertainty would not significantly affect the results presented in this report; however, subsequent analysis of community composition would require more detailed taxonomic information to be obtained.

Species counts within photographic quadrats provided a quantitative basis for deriving several different measures of epifaunal invertebrate diversity and community attributes, including:

1. **Species density** – This was calculated as the number of species per 0.25 m2 quadrat and provides a measure of diversity where smaller scale interactions (i.e. on a scale of centimetres to tens of centimetres) are likely to be important (e.g. spatial competition: Connell 1961; Jackson 1977). Sites with higher species densities would be predicted to be characterised by more interactive communities and potentially greater resistance to invasion (e.g. Case 1990; Stachowicz, et al. 1999).
2. **Variation in species density** – This provides an index of the 'patchiness' of the species assemblages at the scale of metres to tens of metres, and may be indicative of disturbance or variation in the strength of species interactions at the site level (e.g. Ayling 1981; Smith & Witman 1999). The standard deviation of species density was used to indicate variation in species density, whereby higher standard deviations would be more 'patchy', and possibly reflect areas with higher local disturbance regimes and/or higher variation in species interactions.
3. **Change in community composition between quadrats** – This provides an additional measure of diversity that characterises the 'turnover' of species along a transect (or 'beta-diversity'). This index was measured by calculating Routledge's β_I, which takes into account species incidence (i.e. the frequency of occurrence) and species number (Magurran 1988). This can be regarded as a measure of diversity at a scale that is relevant to species interactions over the scales of metres, which can occur among suspension feeders in dense aggregations (e.g. food-depletion: Peterson & Black 1987; Lesser et al. 1992).
4. **Species richness** – This represents the total number of species observed along a transect (i.e. S_{obs}). Since the number of species found in a community is generally proportional to sampling effort, estimates of species richness were also calculated using the Chao 2 incidence-based estimator in the program EstimateS (Version 8.0, R.K. Colwell). The calculation of estimated richness involves a randomisation procedure during calculations, and in this case Chao 2 estimations were made using 50 randomisations. Plots of sampling effort against the number of species observed (S_{obs}) and estimated species richness (Chao 2) can be used as an indicator of the adequacy of sampling at an individual site (Colwell & Coddington 1994). In this analysis, a levelling off or a downward trend in the Chao 2 estimates ('conversion') indicates that an adequate sample has been obtained. Where convergence occurs, the Chao 2 estimation of species richness provides the best estimate

of true species richness with the least amount of sampling (Colwell & Coddington 1994). Combined, the estimated and observed species richness measures provide information about the community at a scale that is relevant to species at both the local level, such as recruitment into a given reef system over monthly time scales (e.g. Bingham 1992; Smith & Witman 1999), to a much broader scale, such as colonisation history over centuries – which potentially covers a spatial extent of hundreds of kilometres (e.g. Smith 2001).

5. **Community structure of epifaunal assemblages** – This was quantified by determining the proportion of species belonging to each of the 12 major taxonomic groups at each site (Table 4). This approach was adopted because the datasets were consistent across sites at a higher taxonomic level. This measure provides an indication of the shift in the relative prevalence of sessile invertebrate taxa (e.g. sponges, ascidians, bryozoans) across sites in the Foveaux Strait region. Data were arcsin square-root transformed to calculate the Bray-Curtis dissimilarity.

Table 4. Major taxonomic groupings of epifaunal invertebrate assemblages that were used in the community analyses among sites in the Foveaux Strait region.

TAXONOMIC GROUP	EXAMPLES (GENERA)
Phylum Porifera	*Latrunculia*, *Leucosolenia*, *Crella*
Phlyum Cnidaria, Class Hydroidea	*Amphisbeta*, *Solandaria*, *Errina*
Phlyum Cnidaria, Class Anthozoa	*Actinothoe*, *Bunodactis*, *Culicea*
Phlyum Cnidaria, Class Scyphozoa	?*Aurelia*
Phlyum Cnidaria, Class Actinaria, Order Alcyonacea	*Alcyonium*, ?*Telesto*
Phlyum Annelida	*Spirorbis*, *Protula*
Phlyum Mollusca	*Aulacomya*, *Ostrea*
Phlyum Bryozoa	*Cinctipora*, *Bugula*, *Celleporaria*
Phlyum Echinodermata	*Ocnus*, ?*Psolus*
Phlyum Chordata, Class Ascidiacea	*Hypistozoa*, *Didemnum*, *Cnemidocarpa*, *Pyura*
Phlyum Brachiopoda	*Terebratella*, *Liothyrella*
Phlyum Arthropoda, Class Cirripedia	*Megabalanus*

2.3.3 Mobile macroinvertebrates of subtidal rockwalls

Two measures were made for mobile macroinvertebrates of subtidal rockwalls:

1. **Average abundance of species** – This was calculated for each 5-m2 block, and allowed broader scale patterns of distribution and abundance throughout the Foveaux Strait region to be visualised.
2. **Community structure** – The Bray-Curtis dissimilarity was calculated using square-root transformed data. This provided a basis for multivariate analysis of site similarity and correlations with physical environmental factors (see section 3.5.4 below).

2.3.4 'Cryptic fishes' of subtidal rockwalls

Two measures were made for cryptic fishes of subtidal rockwalls:

1. **Average abundance of species** – This was calculated for each 5-m2 block, and allowed relative abundance across the region to be plotted so that broader scale patterns could be visualised.
2. **Community structure** – The Bray-Curtis dissimilarity was calculated using square-root transformed data. These data were then used in a multivariate analysis of community composition at individual sites.

2.3.5 Reef fishes

Two measures were made for reef fishes:

1. **Depth-averaged abundance of species** – This was calculated at each site (per 25 × 5 m transect) and mapped across the region. Preliminary analysis of the depth-stratified data showed that the depth-averaged abundance (i.e. average abundance across both depths) was significantly related to the abundance at an individual depth stratum for all species (with the exception of marblefish *Aplodactylus arctidens*), with r^2 values of depth-averaged predictions of depth strata ranging from 0.590 to 0.989 (excluding species with less than eight occurrences). Therefore, the depth-averaged abundance was used as an estimate of abundance at an individual depth stratum. These depth-averaged values provided consistent measures of abundance to those used for the macroalgal assemblages.
2. **Community structure** – The Bray-Curtis dissimilarity was calculated using log(x+1) transformed data. This provided a basis for multivariate analysis of community structure across the region.

2.4 Statistical analysis

2.4.1 Shallow subtidal reef sites

To visualise the variation in biological patterns between the reef locations and sites, and how these relate to explanatory variables, non-metric multidimensional scaling (nMDS) analyses were carried out on each dataset, based on Bray-Curtis dissimilarities, using PRIMER v6 software package. All datasets were transformed before performing these analyses: algal species composition was transformed to presence/absence, algal community structure (biomass of 24 algal groups) and mobile macroinvertebrates (counts of 28 species) were log(x+1) transformed, and benthic community structure (percent cover of 23 structural groups) data was arcsin square-root transformed. The local-scale environmental variables were correlated with MDS axes 1 and 2, and the results were graphed as bi-plots in which the position of the label along each axis indicates the correlation between the explanatory variable and the MDS axes. Hierarchical cluster analysis (PRIMER) was also used to group sites based on Bray-Curtis disimilarities to aid in interpreting the site-level patterns.

2.4.2 Epifaunal invertebrates of subtidal rockwalls

The species density, variation in species density, turnover diversity and species richness (observed and estimated (Chao 2)) of epifaunal invertebrates were calculated and compared with data from Fiordland and the Hauraki Gulf using analysis of variance (ANOVA) and planned post-hoc tests (Tukey HSD). ANOVA was also used to compare richness values (Chao 2) with global values calculated by Witman et al. (2004) using the same methodology.

Multivariate statistics (nMDS) were based on the Bray-Curtis dissimilarities calculated on the proportion of 12 major taxonomic groups (i.e sponges, ascidians, bryozoans) at each site (see Table 4). Proportions were arcsin square-root transformed prior to calculating Bray-Curtis values. The first two principal axes were plotted and correlated with the proportion of major taxonomic groups and physical environmental variables.

2.4.3 Mobile macroinvertebrates of subtidal rockwalls

Square root-transformed densities of mobile macroinvertebrates for each 5 m^2 block were used to calculate Bray-Curtis dissimilarities between sites. Non-metric MDS was then used to visualise the separation of sites in terms of their species composition. Individual taxa and physical environmental variables were correlated with the principal axes.

2.4.4 'Cryptic fishes' of subtidal rockwalls

The abundance of cryptic fishes in each 5 m^2 block was square root-transformed and used to calculate Bray-Curtis dissimilarities. Non-metric MDS was then used to compare species composition between sites. The abundance of individual taxa and physical environmental variables were also correlated with the principal axes and plotted.

2.4.5 Shallow subtidal reef fishes

The depth-averaged abundance of reef fishes at each site for each 25 m transect was $\log(x+1)$ transformed and used to calculate Bray-Curtis dissimilarities. A non-metric MDS was then performed and the sites were plotted along the first two principal axes. The abundance of individual taxa and physical environmental variables were correlated with the principal axes and plotted.

3. Results

3.1 Benthic assemblages at shallow subtidal reef sites

3.1.1 Dominant macroalgal species

A rich variety of macroalgae-dominated habitats were found on the shallow reefs surveyed in the Foveaux Strait region (Fig. 3). A total of 125 macroalgal taxa were recorded during the quadrat sampling (see Appendix 3), with the top 50 most dominant species (greatest biomass) listed in Table 5. The top 9 species were all large brown algal species, which made up 75% of the total algal biomass, with *Lessonia variegata* being the most common (18% of total biomass) (Table 5). The distributions of these species are given in Fig. 4. *Lessonia variegata* was typically most common at relatively exposed sites, along with *Xiphophora gladiata* and *Landsburgia quercifolia* (Fig. 4A, C & D). By contrast, *Ecklonia radiata*, which was the second most dominant species, was more common at semi- to moderately- exposed sites that were protected from large southwesterly swells, as were *Marginariella* spp., *Macrocystis pyrifera* and *Carpophyllum flexuosum* (Fig. 4B & F–I). *Durvillaea willana* was relatively rare, only being recorded in 2.2% of quadrats (Table 5),

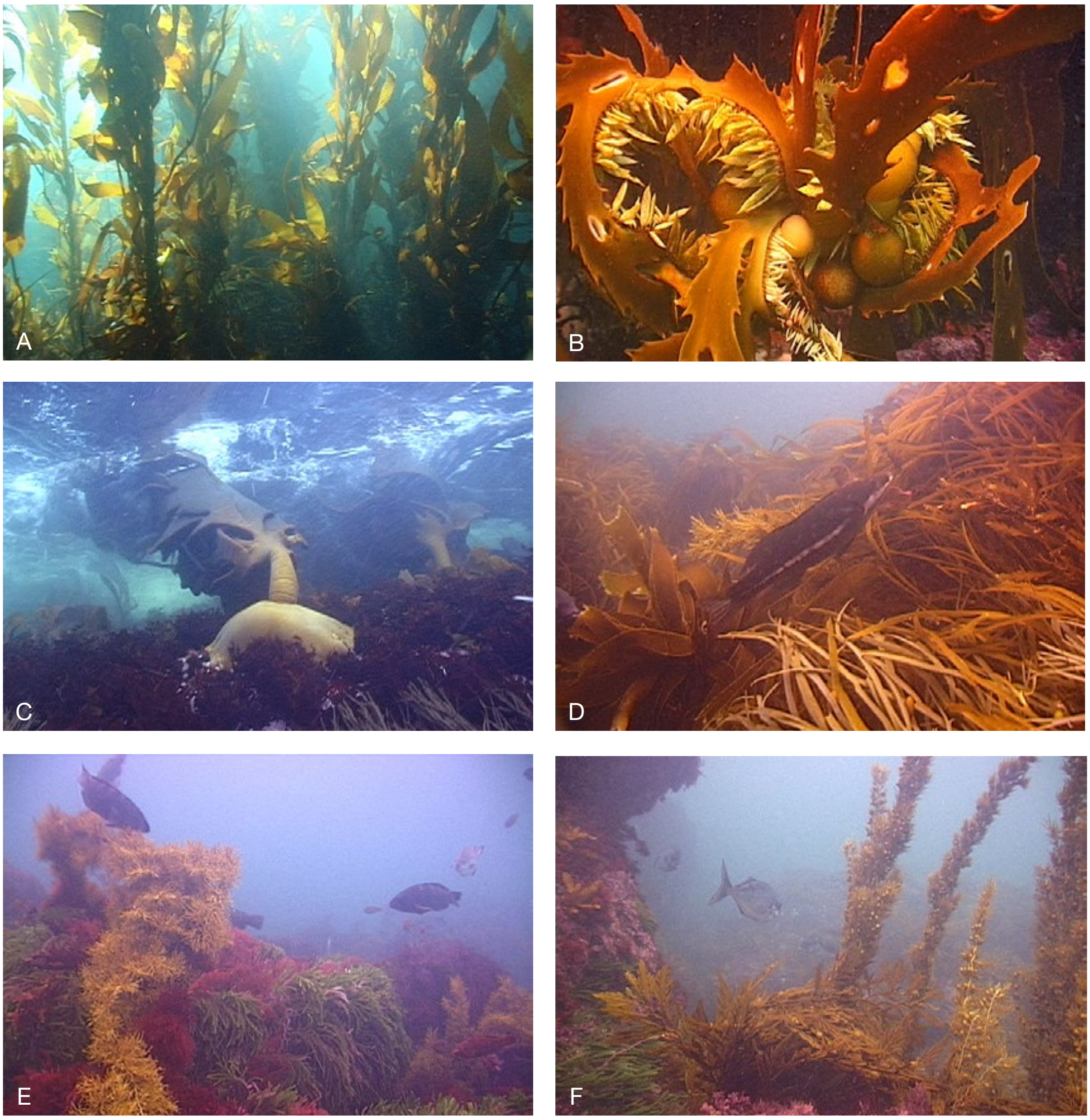


Figure 3. Macroalgal communities found in the Foveaux Strait region: A. *Macrocystis pyrifera*; B. *Marginariella boryana*; C. *Durvillaea willana*; D. *Lessonia variegata*, *Marginariella urvilliana* (and butterfish *Odax pullus*); E. *Caulerpa brownii*, red foliose algae (and banded wrasse *Notolabrus fucicola*); and F. *Cystophora retroflexa*, *Cystophora platylobium*, coralline turf (and terakihi *Nemadactylus macropterus*).

Table 5. Top 50 most dominant macroalgal species recorded during quadrat sampling at all sites in the Foveaux Strait region. The total estimated biomass (g DW/m^2) is given for each species across all quadrats, along with the percent occurrence (i.e. the % of all quadrats (N = 863) that each species was recorded in). A code is given for species shown in Fig. 5.

RANK	SPECIES	CODE	TOTAL BIOMASS (g)	% TOTAL BIOMASS	NO. QUADRATS	% QUADRATS
1	*Lessonia variegata*	Less	65 106.3	17.82	151	17.5
2	*Ecklonia radiata*	Eck	36 410.3	9.97	162	18.8
3	*Xiphophora gladiata*	Xgla	35 890.3	9.83	247	28.6
4	*Landsburgia quercifolia*	Land	31 058.0	8.50	307	35.6
5	*Durvillaea willana*	–	24 030.3	6.58	19	2.2
6	*Marginariella urvilliana*	–	23 012.8	6.30	136	15.8
7	*Marginariella boryana*	Mbor	21 478.2	5.88	140	16.2
8	*Cystophora platylobium*	Cplat	18 846.0	5.16	95	11.0
9	*Macrocystis pyrifera*	Macr	14 438.9	3.95	103	11.9
10	*Carpophyllum flexuosum*	Flex	13 252.0	3.63	144	16.7
11	*Caulerpa brownii*	Cbro	13 153.8	3.60	139	16.1
12	Coralline turf	–	11 310.8	3.10	599	69.4
13	*Halopteris* spp.	Halo	5748.7	1.57	425	49.2
14	*Codium convolutum*	–	5709.6	1.56	226	26.2
15	*Hymenena palmata*	Hpal	5492.6	1.50	223	25.8
16	*Plocamium* spp.	Ploc	4961.2	1.36	295	34.2
17	*Hymenena durvillaei*	Hdur	3950.5	1.08	140	16.2
18	*Lophurella hookeriana*	Loph	2631.8	0.72	90	10.4
19	*Craspedocarpus erosus*	Cras	2392.5	0.65	162	18.8
20	*Cystophora retroflexa*	Cret	2056.6	0.56	69	8.0
21	*Ballia callitrichia*	Ball	1980.0	0.54	72	8.3
22	*Euptilota formosissima*	Eupt	1764.8	0.48	185	21.4
23	*Cystophora scalaris*	Csca	1505.1	0.41	44	5.1
24	*Durvillaea antarctica*	–	1428.5	0.39	16	1.9
25	*Rhodophyllis gunnii*	Rgun	1135.4	0.31	112	13.0
26	*Streblocladia glomerulata*	Stre	1074.8	0.29	81	9.4
27	*Echinothamnion lyalli*	Elya	1008.2	0.28	80	9.3
28	*Sargassum sinclairii*	–	929.6	0.25	75	8.7
29	*Schizoseris* spp.	Schi	852.6	0.23	110	12.7
30	*Desmerestia ligulata*	Desm	841.2	0.23	169	19.6
31	*Cladhymenia oblongifolia*	Clad	793.8	0.22	96	11.1
32	*Zonaria turneriana*	Zona	702.5	0.19	101	11.7
33	*Heterosiphonia* sp.	Hete	630.0	0.17	64	7.4
34	*Asparagopsis armata*	–	627.5	0.17	53	6.1
35	*Lenormandia chauvinii*	Leno	622.5	0.17	18	2.1
36	*Dictyota kunthii*	Glos	608.6	0.17	190	22.0
37	*Anotrichium crinitum*	Anot	540.6	0.15	76	8.8
38	*Plocamium costatum*	Pcos	390.3	0.11	55	6.4
39	*Callophyllis callibrepharoides*	–	382.5	0.10	34	3.9
40	*Callophyllis ornata*	–	350.7	0.10	65	7.5
41	*Callophyllis variegata*	Call	330.0	0.09	53	6.1
42	*Phitymophora* sp.	Phit	297.5	0.08	33	3.8
43	*Rhodymenia obtusa*	Robt	294.9	0.08	36	4.2
44	*Laingia hookeri*	Lain	248.8	0.07	39	4.5
45	*Microzonia velutina*	Micr	225.0	0.06	51	5.9
46	*Colpomenia sinuosa*	Colp	225.0	0.06	43	5.0

Continued on next page.

Table 5 continued.

RANK	SPECIES	CODE	TOTAL BIOMASS (g)	% TOTAL BIOMASS	NO. QUADRATS	% QUADRATS
47	*Ulva* spp.	–	224.0	0.06	56	6.5
48	*Delisea plumosa*	–	222.6	0.06	23	2.7
49	*Delisea elegans*	Dele	192.7	0.05	28	3.2
50	*Spatoglossum chapmanii*	Spat	165.5	0.05	80	9.3

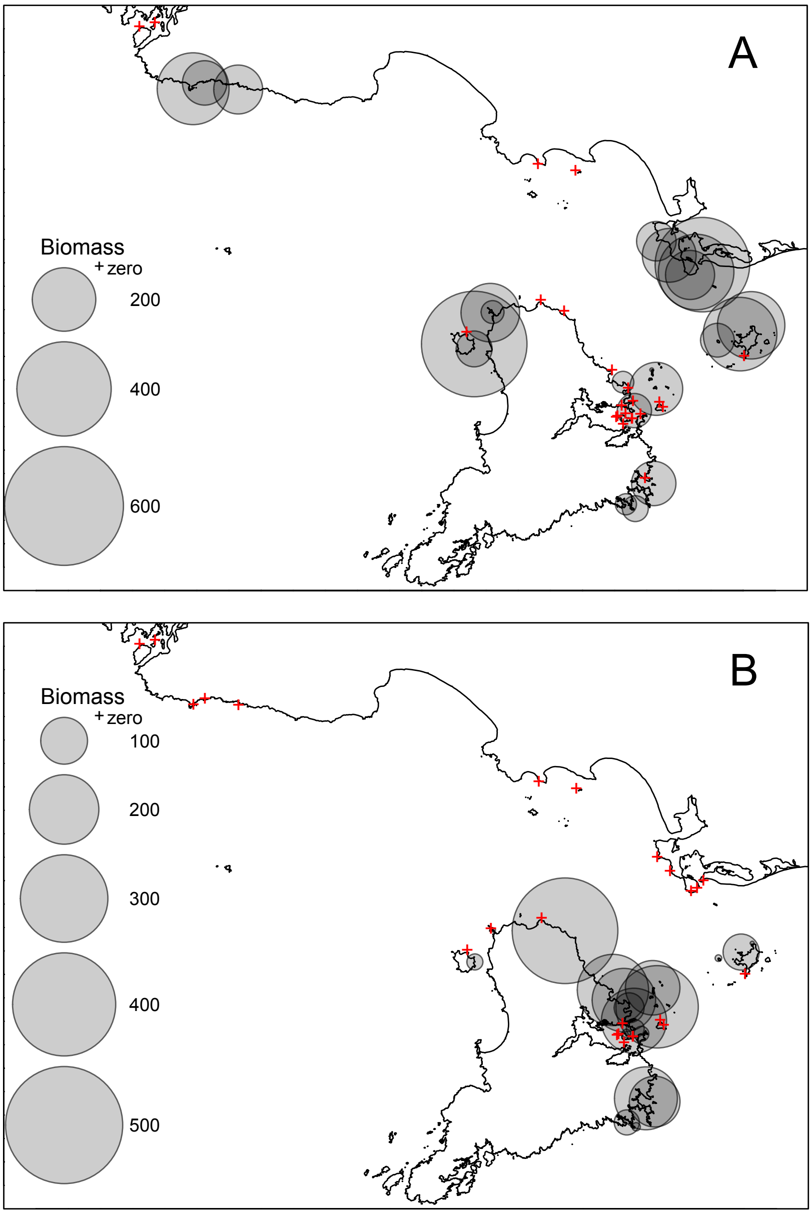


Figure 4. Distributions of the dominant macroalgal species or subgroups at shallow subtidal reef sites in the Foveaux Strait region, shown by biomass (g DW/m^2). A. *Lessonia variegata*; B. *Ecklonia radiata*.

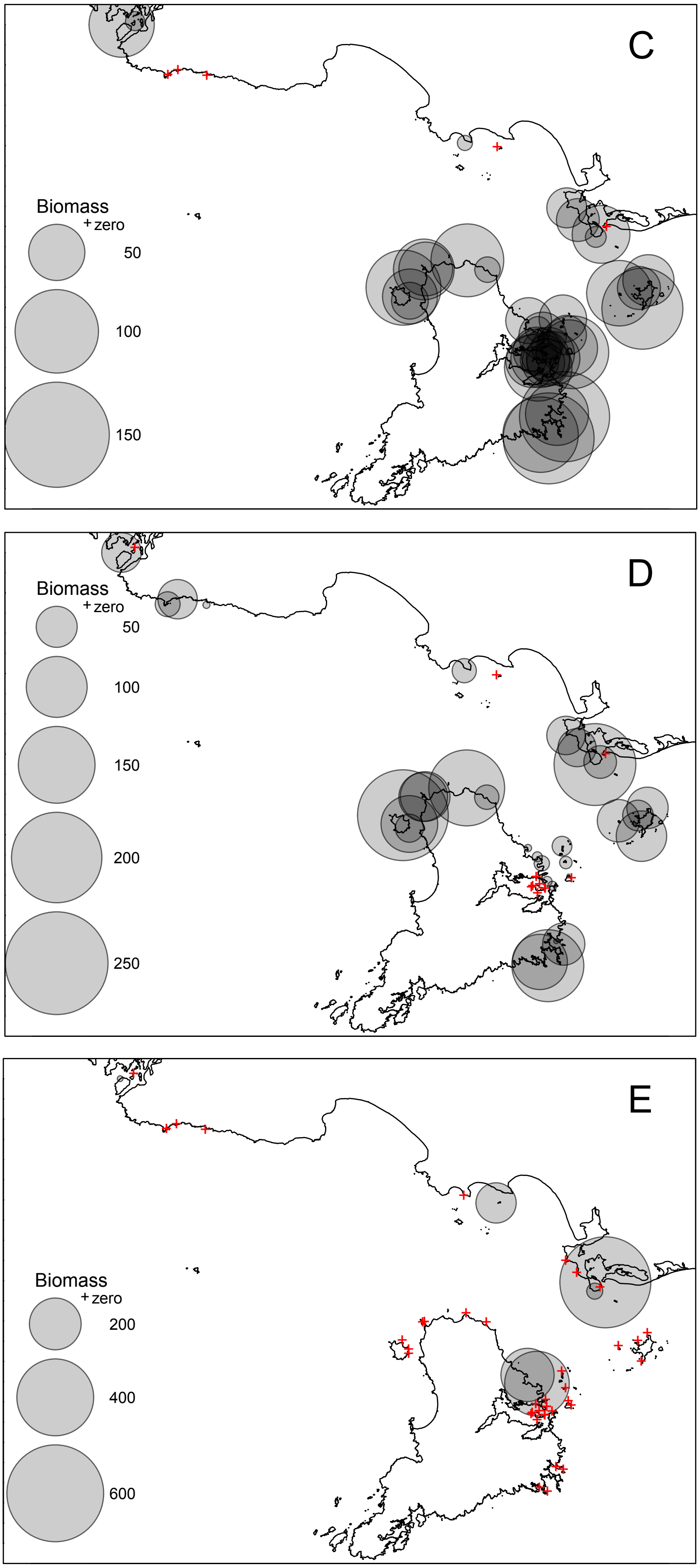


Figure 4 *continued*. Distributions of the dominant macroalgal species or subgroups at shallow subtidal reef sites in the Foveaux Strait region, shown by biomass (g DW/m^2). C. *Xiphophora gladiata*; D. *Landsburgia quercifolia*; E. *Durvillaea willana*.

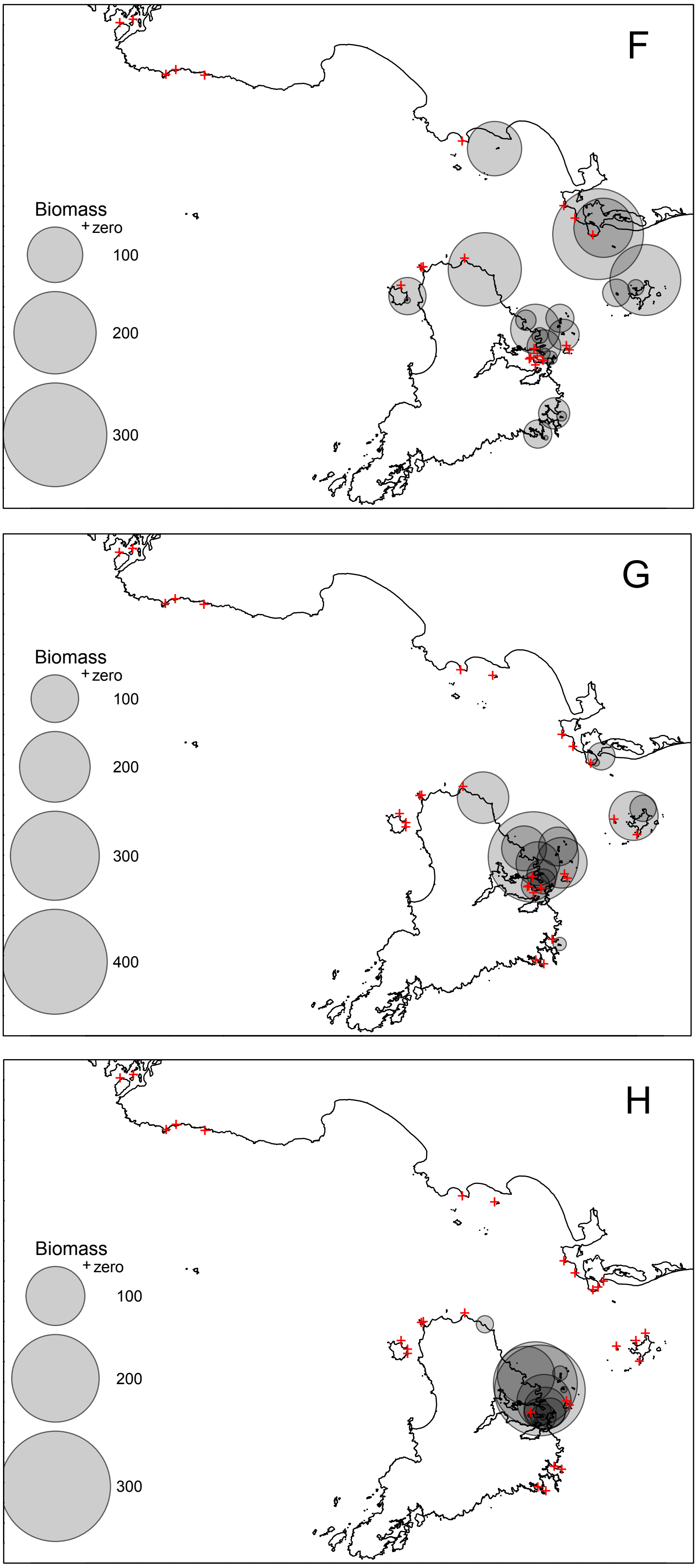


Figure 4 *continued*. Distributions of the dominant macroalgal species or subgroups at shallow subtidal reef sites in the Foveaux Strait region, shown by biomass (g DW/m^2). F. *Marginariella urvilliana*; G. *Marginariella boryana*; H. *Macrocystis pyrifera*.

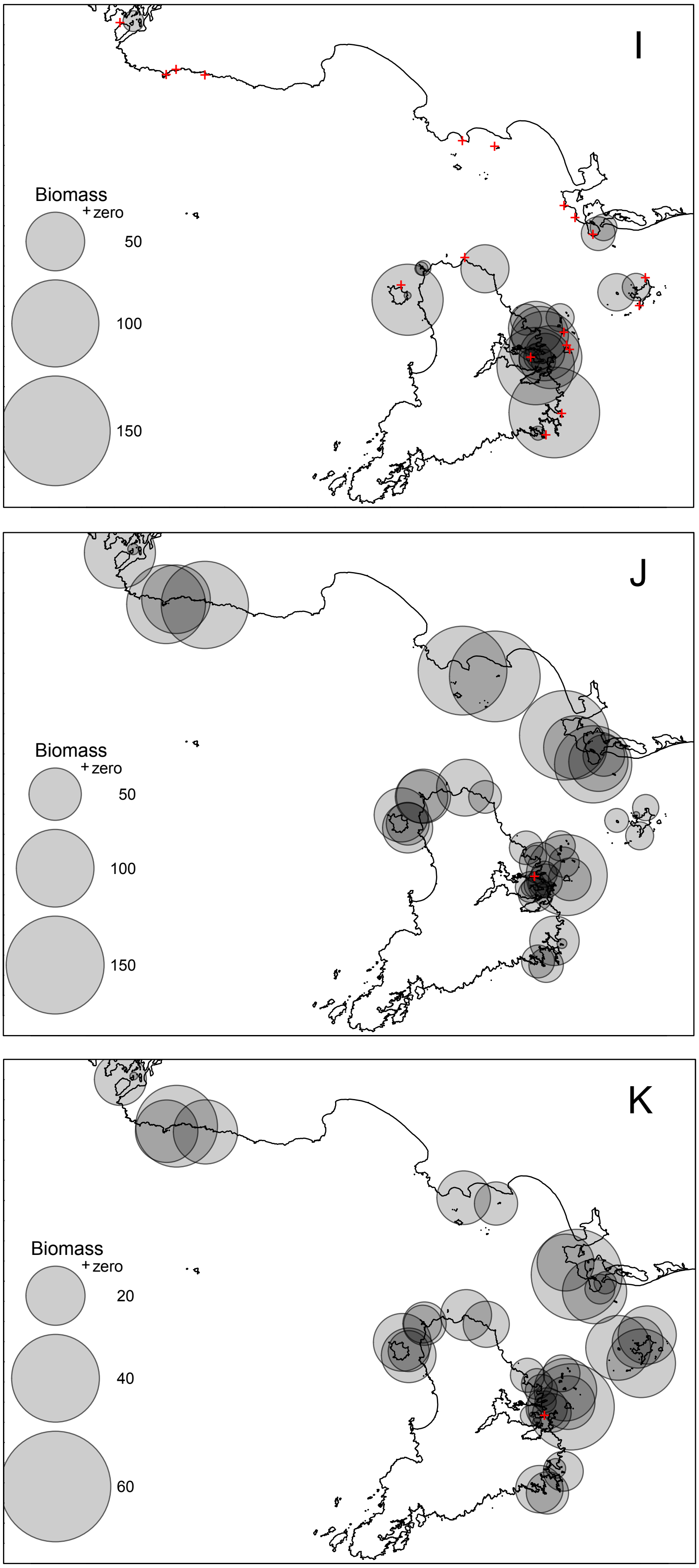


Figure 4 *continued*. Distributions of the dominant macroalgal species or subgroups at shallow subtidal reef sites in the Foveaux Strait region, shown by biomass (g DW/m^2). I. *Carpophyllum flexuosum*; J. red foliose algae; K. coralline turf.

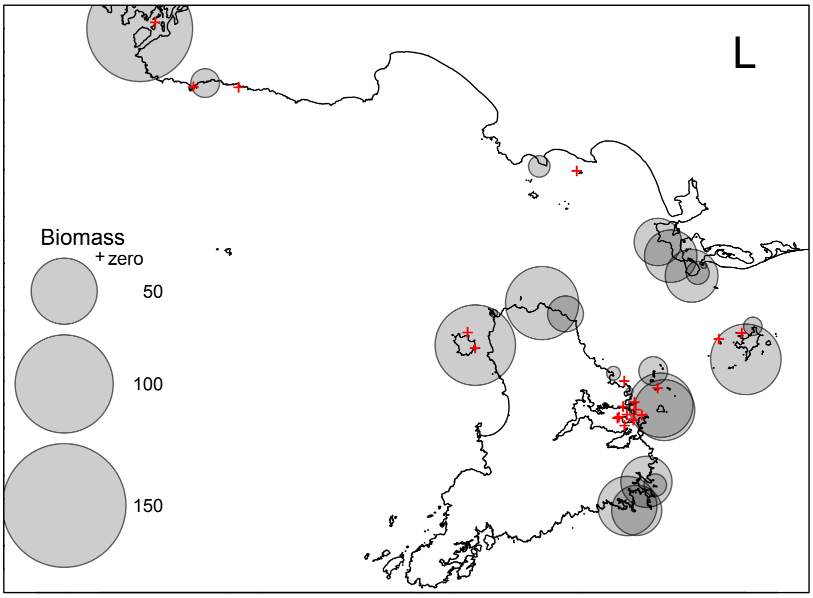


Figure 4 *continued*. Distributions of the dominant macroalgal species or subgroups at shallow subtidal reef sites in the Foveaux Strait region, shown by biomass (g DW/m^2). L. *Caulerpa brownii*.

but made up 6.65% of the total biomass due to the occurrence of very large plants at a few sites (Fig. 4E). Other large brown algal species that were relatively common included a number of *Cystophora* species and *Sargassum sinclairii*. A number of small brown algal species were also very common, e.g. *Halopteris* spp., *Dictyota kunthii*, *Zonaria turneriana* and *Desmerestia ligulata* (Table 5).

Red algal species were taxonomically the most diverse group of seaweeds. However, although they occurred at all sites (Fig. 4J), they only made up a relatively small proportion of overall algal biomass (c. 10%). *Hymenena* and *Plocamium* species were generally the most common red foliose algal species (Table 5).

Crustose coralline algae were ubiquitous at all sites but were not identified to species level. Similarly, articulated coralline algae (coralline turf) were highly abundant at a large number of sites (Fig. 4K) but were not identified to species level.

Green algae were generally only small contributors to total algal biomass (Table 5). However, *Caulerpa brownii* (Fig. 4L) was ranked 11th based on total biomass. Other green algal species such as *Codium convolutum* and *Ulva* spp. were locally abundant at some sites.

3.1.2 Macroalgal species composition

There was a clear gradient in macroalgal species composition (presence/absence) between sites and locations (Fig. 5), which generally corresponded with large-scale differences in wave exposure regimes (Figs 6 and A2.1 (Appendix 2)) rather than clear biogeographic differences between locations. At the 30% similarity level, there was a clear division between very sheltered sites at Paterson Inlet/Whaka a Te Wera and Preservation Inlet (clustered on the left of the MDS ordination in Fig. 5), and more open coastal sites, which formed a large group in the centre and right of the ordination. At the 55% similarity level, the open coastal sites were further divided into four groups (Groups 3–6) that generally corresponded to differences in wave exposure between sites (Fig. 6). At this similarity level, highly exposed sites at locations on the south coast of the South Island (e.g. Bluff and Green Islets) were grouped with sites from the Codfish-Rugged Islands and two sites from the Titi/Muttonbird Islands (Group 4); whereas at the 60% similarity level, sites from Bluff and the Green Islets were separated from the other sites within Group 4 (Fig. 6). Moderately exposed locations that are somewhat protected from prevailing southwesterly swells (e.g. Halfmoon Bay, Ruapuke Island and Port Adventure) were generally

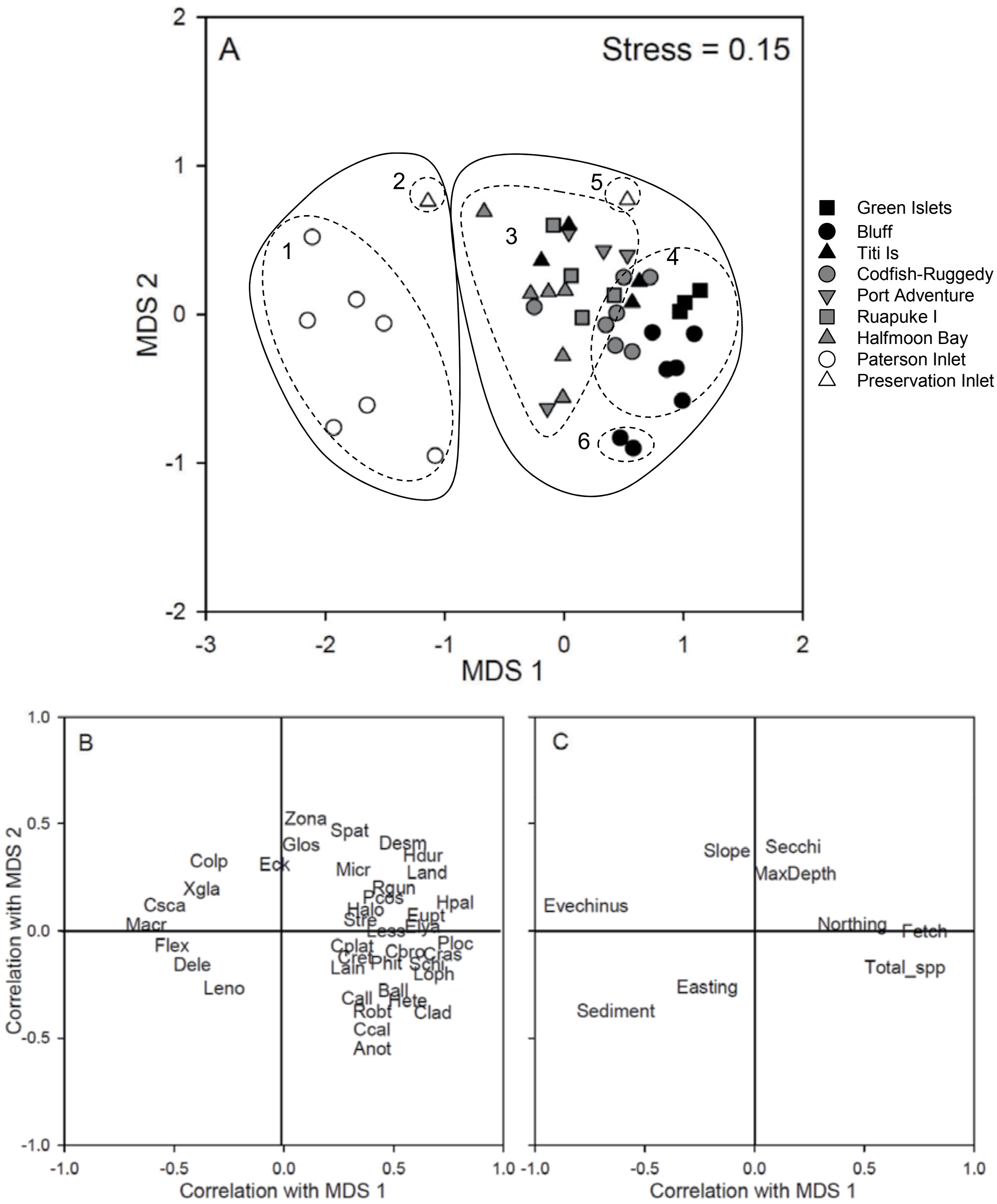


Figure 5. A. multidimensional scaling (MDS) plot of macroalgal species composition (presence/absence) at shallow subtidal reef sites in the Foveaux Strait region; B. correlations between macroalgal species and the MDS axes; C. correlations between environmental variables and the MDS axes. Note: Macroalgal species are only shown in B if the correlation coefficient with either MDS axis was > 0.3. The MDS was based on Bray-Curtis dissimilarities. Solid lines in A indicate two major groupings at the 30% similarity level, while dashed lines indicate the six groups that were apparent at the 55% similarity level (Appendix 4). See Table 5 for species codes.

grouped in the middle of the ordination (Group 3). The exposed site at Preservation Inlet (Sandfly Point) formed its own group (Group 5), as did the two sites at the entrance to Bluff Harbour (Stirling Point and Tiwai Point) (Group 6). Further details about the separation of sites can be found in Appendix 4 (Fig. A4.1).

Correlation coefficients (> 0.3) between macroalgal species sites presence/absence and both MDS axes are plotted in Fig. 5B. This gives a general indication of how each individual species is positioned in multivariate space based on MDS axes 1 and 2. Visual comparison of the positions of and species on the two plots (Fig. 5A & B) indicates which species are more characteristic of a particular site. For example, sheltered sites in Paterson Inlet/Whaka a Te Wera were typically characterised by the large brown algae *Cystophora scalaris, Carpophyllum flexuosum* and

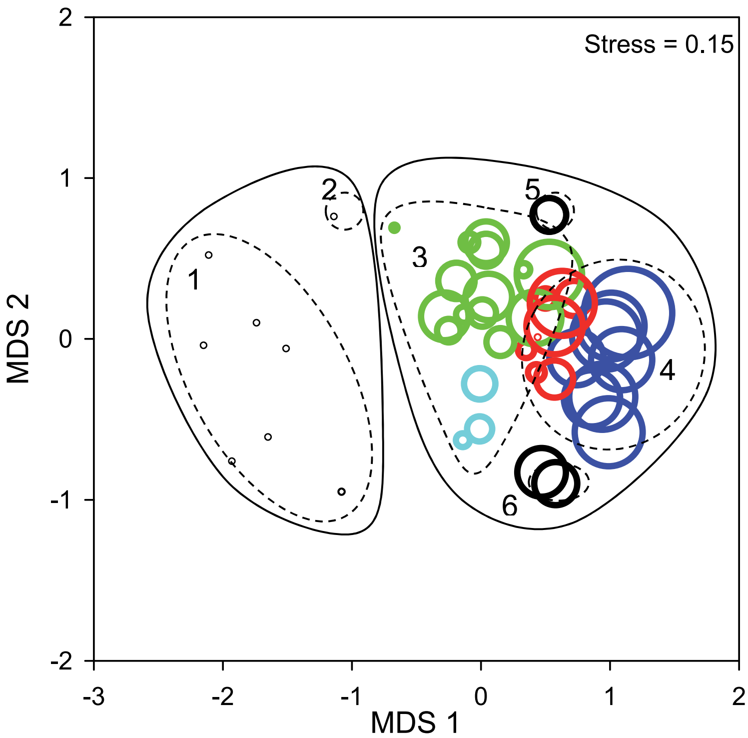


Figure 6. Multidimensional scaling (MDS) plot of macroalgal species composition (Fig. 5A) with relative wind fetch at each site indicated by the size of the bubble. Solid lines indicate two major groupings at the 30% similarity level, while dashed lines indicate the six groups that were apparent at the 55% similarity level. The coloured symbols in Groups 3 and 4 indicate groupings that were further separated at the 60% similarity level (see Fig. A4.1 (Appendix 4)). See Fig. A2.1 (Appendix 2) for actual fetch estimates for each site.

Macrocystis pyrifera, and a number of small red and brown ephemeral species (e.g. *Cutleria multifida*, *Asperococcus bullosus*, *Polysiphonia* spp. and *Dasya collabens*); while exposed sites at Bluff and the Green Islets were typified by *Landsburgia quercifolia*, *Lessonia variegata*, and a high diversity of red algal species including *Plocamium*, *Hymenena* and *Schizoseris* species.

Correlations between environmental variables and the two MDS axes are plotted in Fig. 5C, and indicate the importance of environmental variables in explaining multivariate patterns in species composition. As mentioned above, wave exposure (fetch) was strongly correlated with MDS axis 1; however, a number of other variables were also strongly correlated with this axis, e.g. abundance of the sea urchin *E. chloroticus* and sediment cover (Fig. A2.2 (Appendix 2)). In general, sites on the left of the ordination had a high abundance of sea urchins and sediment cover, and low wave exposure (Paterson Inlet/Whaka a Te Wera and Preservation Inlet sites), while sites on the right of the ordination were at exposed locations with low numbers of sea urchins and sediment cover. None of the environmental variables were strongly correlated with MDS axis 2; however, turbidity was weakly positively correlated and sediment negatively correlated with this axis, and more turbid sites with high sediment cover were generally clustered at the bottom of the ordination, e.g. the two sites at the entrance to Bluff Harbour (Stirling Point and Tiwai Point).

3.1.3 Macroalgal species richness

The total number of macroalgal species recorded at each site was positively correlated with MDS axis 1 (Fig. 5C). In general, exposed and moderately exposed sites had higher numbers of seaweed species, while sites at Paterson Inlet/Whaka a Te Wera and Preservation Inlet had the lowest species richness (Fig. 7). Over 40 seaweed species were recorded at a number of sites at Bluff (Shag Rock, Lookout Point, Stirling Point), Codfish-Ruggedy Islands (Codfish E, Black Rock Point, Ruggedy NE, Ruggedy Passage), Halfmoon Bay (Native N, Horseshoe Bay) and one site at the Titi/Muttonbird Islands (Bench N).

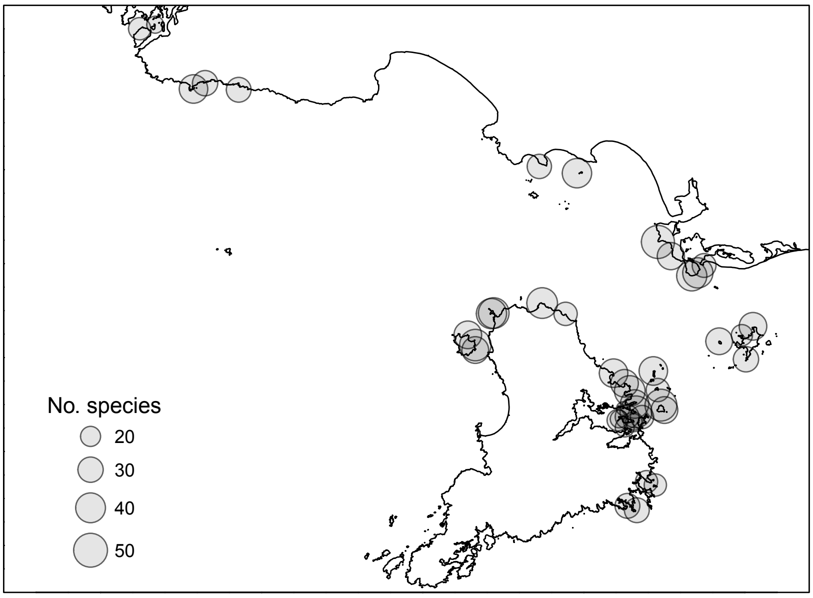


Figure 7. Total number of macroalgal species recorded during quadrat sampling at shallow subtidal reef sites in the Foveaux Strait region.

3.1.4 Macroalgal community structure

Macroalgal community structure varied among sites (Fig. 8A) in a consistent manner to that seen for macroalgal species composition (section 4.1.2), with the greatest variation along MDS axis 1 reflecting a wave exposure gradient (Fig. 9). As for macroalgal species composition, the greatest separation occurred between sheltered and open coastal sites (c. 40% similarity; Fig. A4.2 (Appendix 4)). At the 55% similarity level, hierarchical cluster analysis divided the sites into four groups based on algal community structure (Fig. A4.2 (Appendix 4)). While there was some variability in the fetch values for sites within each group (Fig. 9), the groupings broadly reflected large-scale differences in wave exposure among sites. These were therefore described as a 'Sheltered' group, a 'Semi-exposed' group, an 'Exposed' group and a '*Durvillaea*' group, which included two exposed sites where *Durvillaea willana* and *Marginariella urvilliana* were dominant (Fig. 8B). The correlations between environmental variables and the two MDS axes (Fig. 8C) were similar to those seen for species composition, with MDS axis 1 being strongly positively correlated with wave exposure (fetch), and negatively correlated with the abundance of sea urchins and sediment cover. General descriptions of the algal community structure in each of these groups are provided below, while further information on depth-related patterns in algal community structure for each site can be found in Shears & Babcock (2007).

Sheltered group

This group consisted of all of the sites inside Paterson Inlet/Whaka a Te Wera and the inner Preservation Inlet site (Weka Point). Crustose coralline algae, brown encrusting algae (e.g. *Ralfsia* spp.) and filamentous algae were dominant at sites in this group (Fig. 8B). By contrast, large brown algae were rare, with species such as *Carpophyllum flexuosum*, *Cystophora* spp., *Macrocystis pyrifera* and *Xiphophora gladiata* generally only occurring in a shallow subtidal fringe (< 2 m depth) at some sites.

Semi-exposed group

This group mainly included sites along the northeastern coast of Stewart Island/Rakiura (e.g. Halfmoon Bay sites and Lucky Point), and the most sheltered sites at Port Adventure (Browns Garden) and the Titi/Muttonbird Islands (Motunui/Edwards Island). These sites were dominated by the large brown algae *Ecklonia radiata*, *Carpophyllum flexuosum*, *Xiphophora gladiata* and *Marginariella boryana*, as well as *Macrocystis pyrifera* at some sites. *Durvillaea willana* was also dominant in the shallow strata (< 2 m) at some sites (Horseshoe Bay, Bobs Point and West Head).

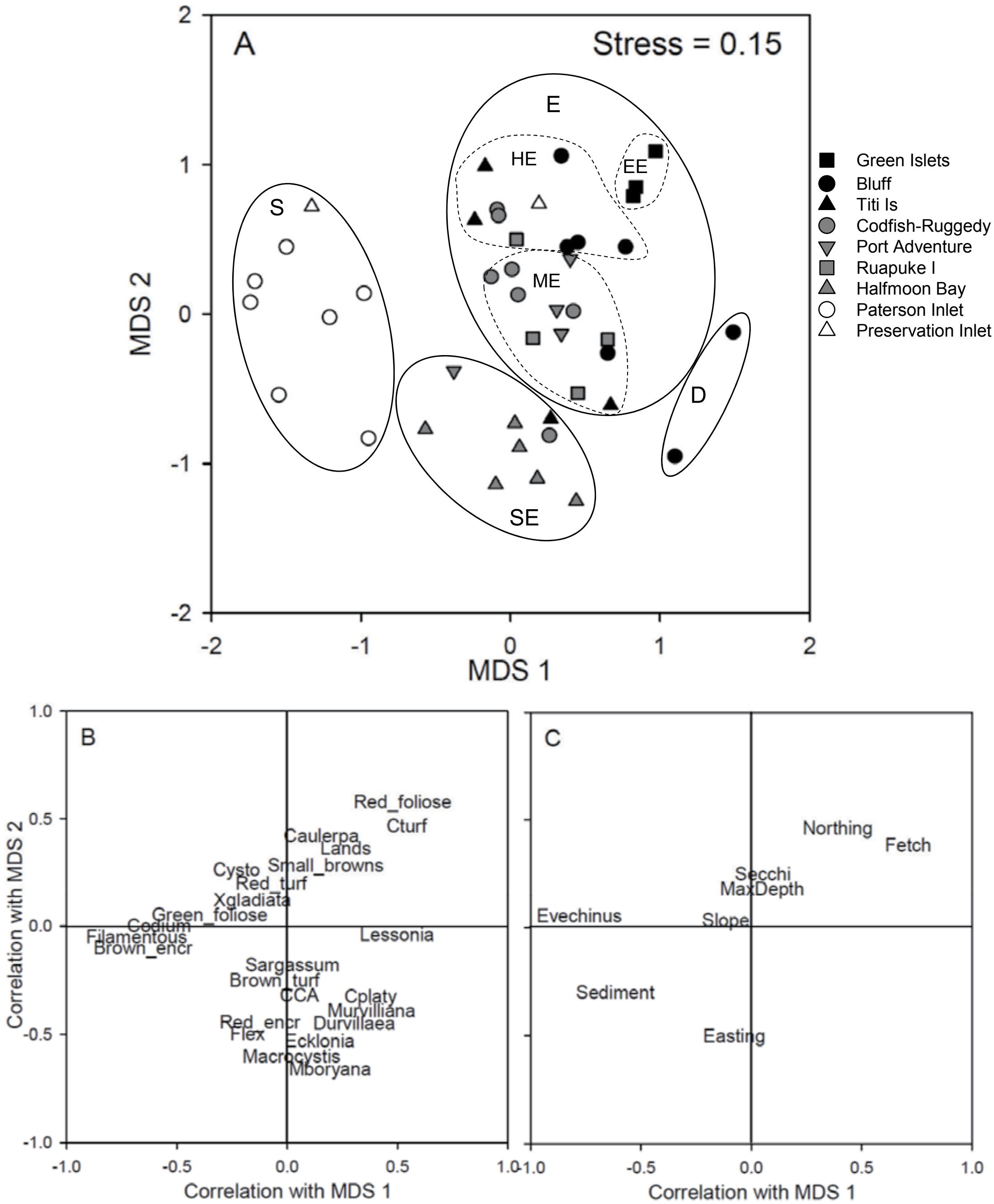


Figure 8. A. multidimensional scaling (MDS) plot of macroalgal community structure (log(x+1) biomass of 24 groups) at shallow subtidal reef sites in the Foveaux Strait region; B. correlations between macroalgal groups and the two MDS axes; C. correlations between environmental variables and the two MDS axes. Solid circles indicate the four groups (S = sheltered, SE = Semi-exposed, E = Exposed and D = *Durvillaea*) identified at the 55% similarity level (Fig. A4.1). Dashed circles indicate grouping of sites within the Exposed group at the 65% similarity level (ME = 'Moderately exposed', HE = 'Highly exposed', EE = 'Extremely exposed; See Table 2 for group codes.

Exposed group

This group included sites with the highest wind fetch values (e.g. Green Islets), but also a number of sites at Codfish-Ruggedy Islands and Port Adventure that had relatively low wind fetch values. In general, sites within the Exposed group were dominated by varying combinations of *Landsburgia* spp., *Lessonia* spp., red foliose algae, coralline turf and *Caulerpa brownii*. *Xiphophora gladiata* was typically most abundant at sites in this group, but was also common at sites in most of the other groups.

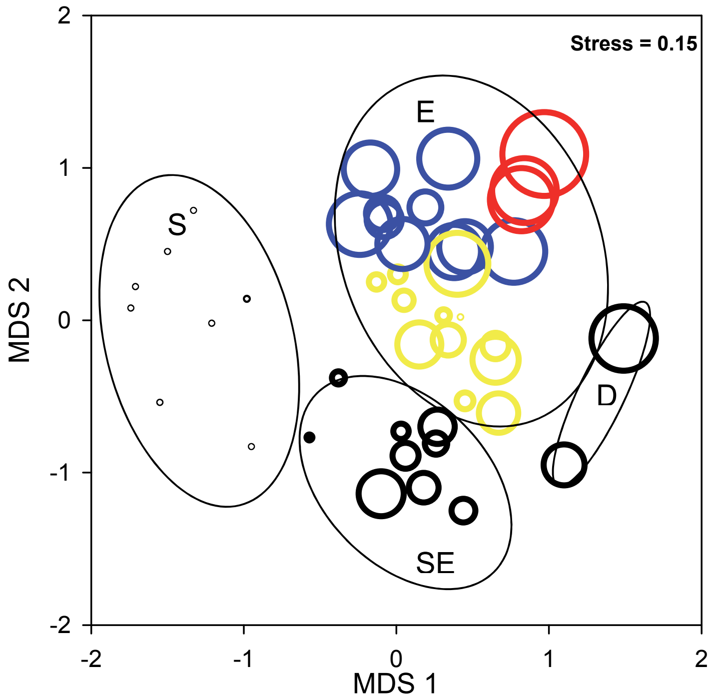


Figure 9. Multidimensional scaling (MDS) plot of macroalgal community structure (Fig. 8A) with relative wind fetch at each site indicated by the size of the bubble. Solid circles indicate grouping at the 55% similarity level (S = sheltered, SE = Semi-exposed, E = Exposed and D = *Durvillaea*), while the coloured symbols in the Exposed group indicate groupings at the 65% similarity level ('Moderately exposed' = yellow, 'Highly exposed' = blue, 'Extremely exposed' = red). See Fig. A2.1 (Appendix 2) for actual fetch estimates for each site.

At the 65% level, three distinct subgroups were also apparent within this group (Figs 8 and A4.2 (Appendix 4)), which also generally corresponded with differences in wave exposure between sites (Fig. 9):

- 'Extremely exposed' – This subgroup consisted of very exposed sites at the Green Islets. These sites were typically dominated by Lessonia spp., red foliose algae and coralline turf.
- 'Highly exposed' – This subgroup consisted of exposed coastal sites at Bluff (Oraka Point, Shag Rock, Barracouta Point and Lookout) and the most exposed sites sampled at Ruapuke Island (South Islets), Codfish-Ruggedy Islands (North Sealers Bay, Black Rock Point), Titi/Muttonbird Islands (Bench N and Bench SE Point) and Preservation Inlet (Sandfly Point). These sites were typically dominated by *Landsburgia* spp., *Xiphophora gladiata*, red foliose algae, coralline turf and *Caulerpa brownii*.
- 'Moderately exposed' – This subgroup was comprised of the more sheltered sites from Bluff (Stirling Point), Ruapuke Island (North Head, Caroline Bay, Bird Rock), Codfish-Ruggedy Islands (Codfish E, Codfish SE, Ruggedy NE, Ruggedy Passage) and the remaining Port Adventure sites (Tia Island, Lords River Head and Horomamae/Owen Island). These sites were typically characterised by a mix of large brown algae, particularly *Xiphophora gladiata*, *Lessonia* spp. and *Landsburgia* spp., but were also the only sites in the Exposed group where *Ecklonia* spp., *Carpophyllum flexuosum*, *Marginariella urvilliana* and *M. boryana* were recorded.

Durvillaea group

Two sites at Bluff (Pig Island and Tiwai Point) formed their own distinct group, where *Durvillaea willana* formed dense stands down to a depth of c. 5 m. *Marginariella urvilliana* and *Cystophora platylobium* were also abundant at these sites, while a number of species that were common at other exposed sites were conspicuously absent, e.g. *Xiphophora gladiata*, *Landsburgia* spp. and *Caulerpa brownii* (Appendix 4).

3.1.5 Benthic community structure

The percent cover of dominant structural groups (see Table 3) was recorded as a measure of benthic community structure. In general, the MDS ordination of sites based on the percent cover of structural groups revealed a similar pattern to that seen for algal community structure, with a gradient between sites that was related to wave exposure along MDS 1 (Fig. 10A). The reefs at sheltered sites in Paterson Inlet/Whaka a Te Wera and Preservation Inlet were typically covered by filamentous algae, brown encrusting algae, tube worms, bare rock and sediment, while the most exposed sites (e.g. at the Green Islets) tended to have a higher cover of bryozoans, red foliose algae and coralline turf (Fig. 10B). Sites on the northeastern coast of Stewart Island/Rakiura (Halfmoon Bay) and at the entrance to Bluff Harbour (Stirling Point and Tiwai Point) were transitional between the sheltered and more exposed sites, and clustered in the centre of

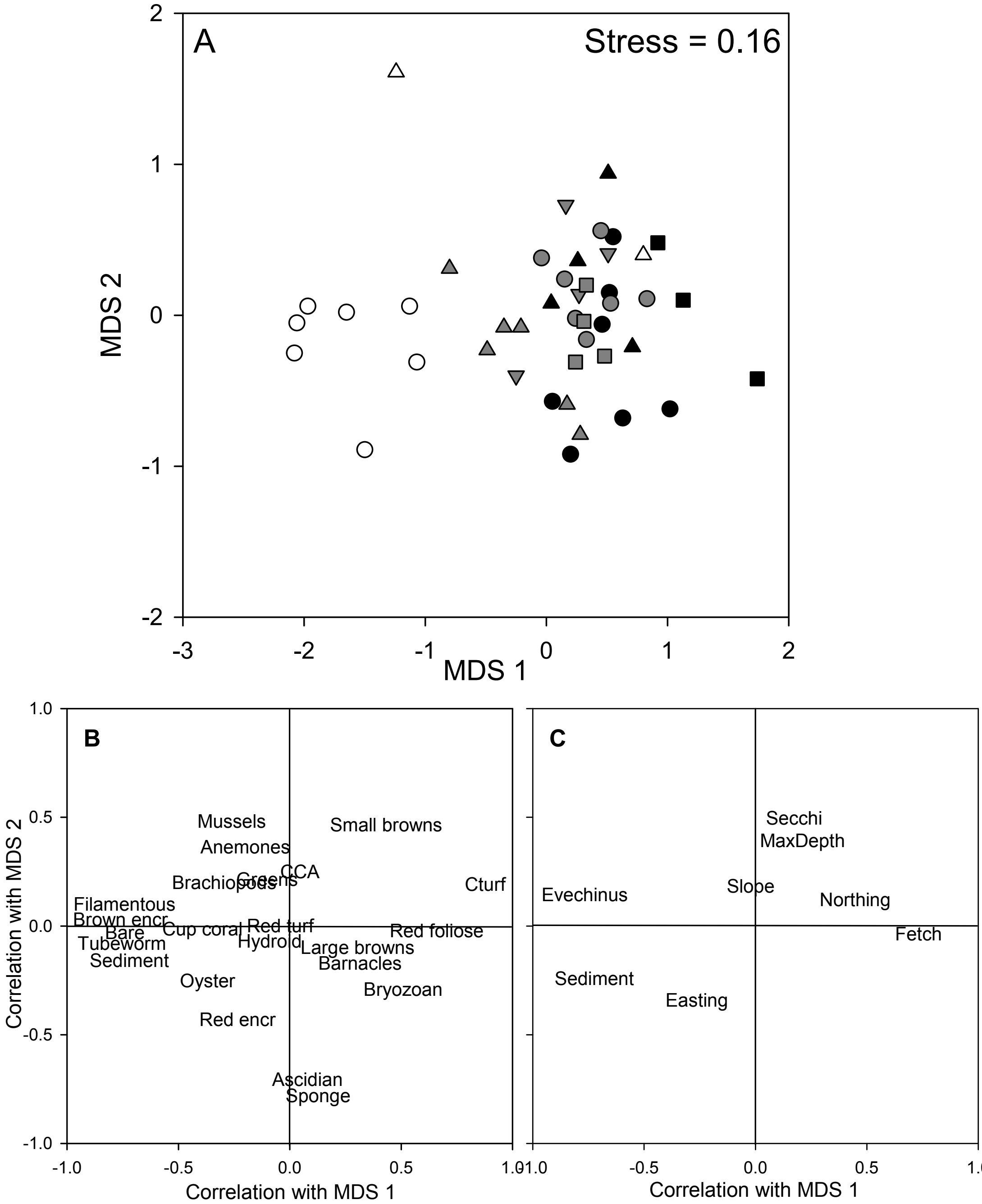


Figure 10. A. multidimensional Scaling (MDS) plot of dominant substratum cover (percent cover for 23 groups; see Table 3) at shallow subtidal reef sites in the Foveaux Strait region; B. correlations between cover groups and MDS axes 1 and 2; C. correlations between environmental variables and MDS axes 1 and 2. See Table 3 for structural group codes.

the ordination. These sites typically had a higher cover of sediment, crustose coralline algae and large brown algae than the more exposed sites at Bluff and the Green Islets. As for macroalgal species composition and community structure, MDS axis 1 was strongly correlated with fetch, the abundance of sea urchins and sediment (Fig. 10C), suggesting that these factors explained the greatest variation in benthic community structure among the sites sampled.

In contrast to macroalgae, however, there was also a separation of sites along MDS axis 2. In particular, the inner Preservation Inlet site (Weka Point) was clearly separated along this axis, most likely due to the high cover of mussels (*Mytilus* sp.) and anemones in the shallow strata (0–2 m). Similarly, a number of sites at Bluff were negatively correlated with MDS axis 2, corresponding to strong negative correlations with ascidians and sponges (Fig. 10B). Water clarity (secchi) was relatively strongly correlated with MDS axis 2 (Fig. 10C) and may be important in explaining differences in substratum cover between sites. For example, the more turbid sites at Bluff tended to have a higher dominance of encrusting invertebrates such as sponges and ascidians, whereas sites with clearer water were typically dominated by macroalgae.

The sea tulip *Pyura pachydermatina* was a conspicuous component of subtidal reefs at a number of sites (Fig. 11). This species was particularly abundant at two Bluff sites (Pig Island and Tiwai Point) and one site at Ruapuke Island (Bird Rock), which appeared to have high tidal currents, with the greatest densities typically occurring in the deeper strata (> 5 m). It was very rare at a number of locations, however, e.g. Preservation Inlet, Green Islets, Codfish-Ruggedy Islands and Port Adventure.

Further information about depth-related patterns for the percent cover of structural groups for each site can be found in Shears & Babcock (2007).

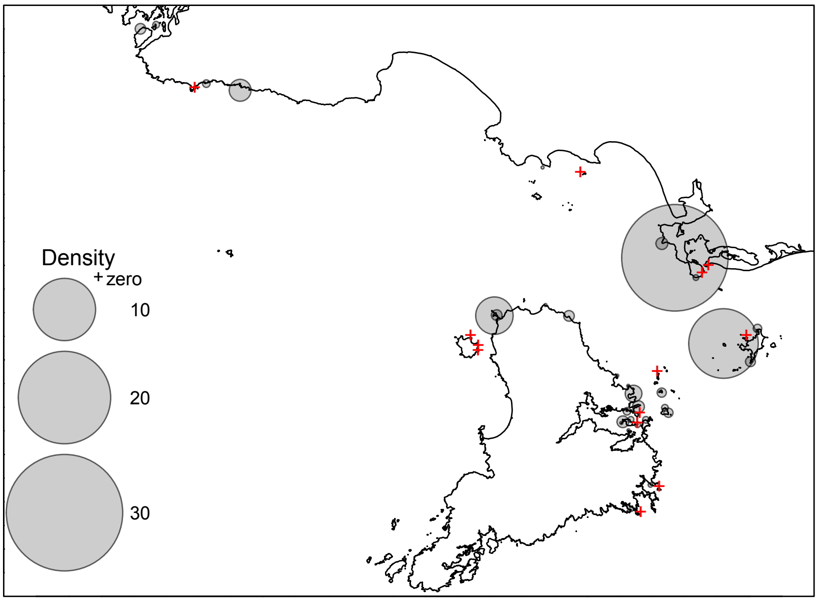


Figure 11. Mean counts (/m^2) of the sea tulip *Pyura pachydermatina* from quadrat sampling at shallow subtidal reef sites in the Foveaux Strait region.

3.2 Epifaunal invertebrates on subtidal rockwalls

3.2.1 Patterns of species diversity

Data from the image analysis of the photographic quadrats (Fig. 12) were used to calculate the estimated species richness of epifaunal invertebrates according to the Chao 2 index (see Appendix 5). Rockwalls had a very high diversity of encrusting invertebrates with 106, largely undescribed taxa recorded (distributed across 71 Families in 9 Phyla) across the sites. Overall, the average species density of epifaunal invertebrates on rockwalls (i.e. average number of species per 0.25 m^2 quadrat) was 25.96 (± 4.23 SD). The highest species densities were found at Horseshoe Point, South Islets and Keyhole, while relatively lower species densities occurred at Tamihau Island (Fig. 13A). All other sites fell within one standard deviation of the global mean.

Variation in species density can be used as an indicator of the 'patchiness' of the epifaunal invertebrate assemblages. Overall, the average variation was 5.04 (± 1.28 SD), with the highest values occurring at Browns Garden and Ulva Island (E Point), and relatively lower variation being found at Ruggedy Passage and High Rock (Fig. 13B). All other sites were within one standard deviation of the global mean.

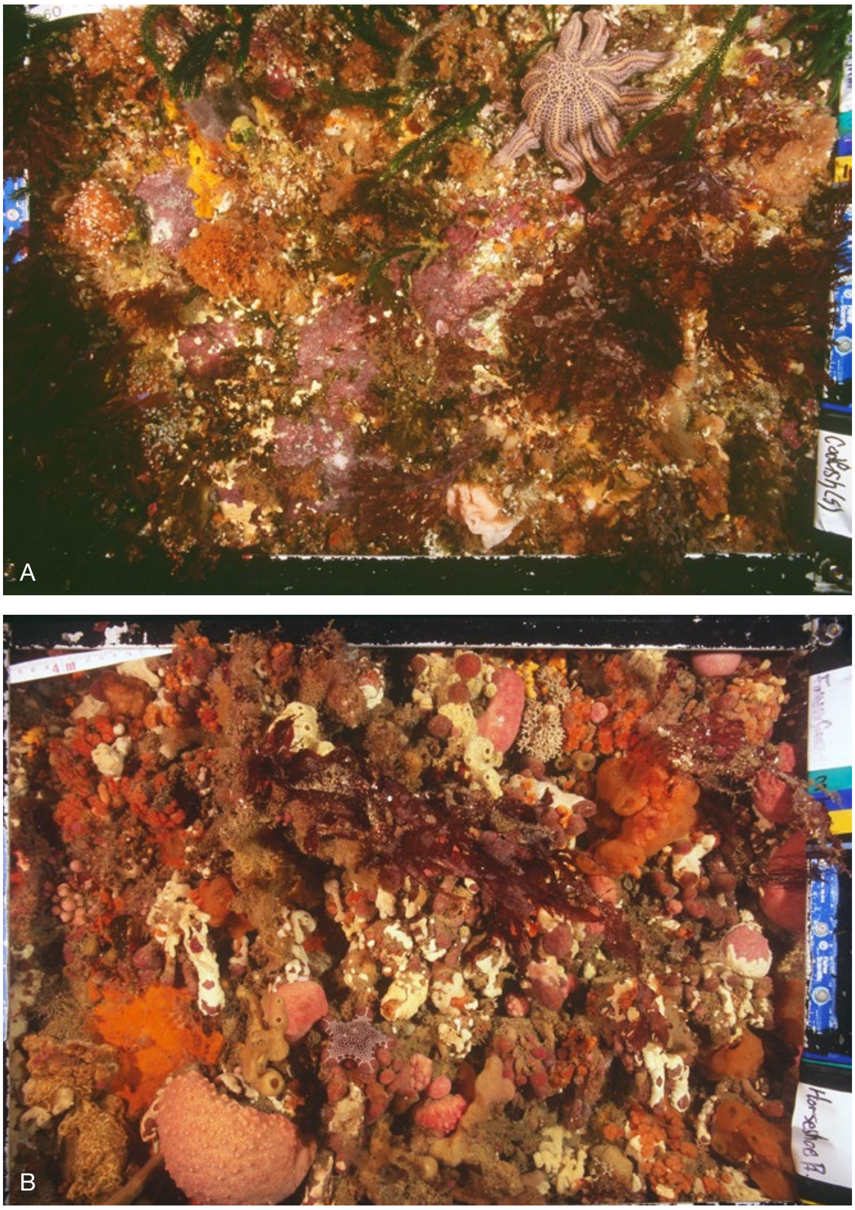


Figure 12. Photoquadrat data and rock wall diversity for A. Codfish Island/Whenua Hou and B. Horseshoe Bay.

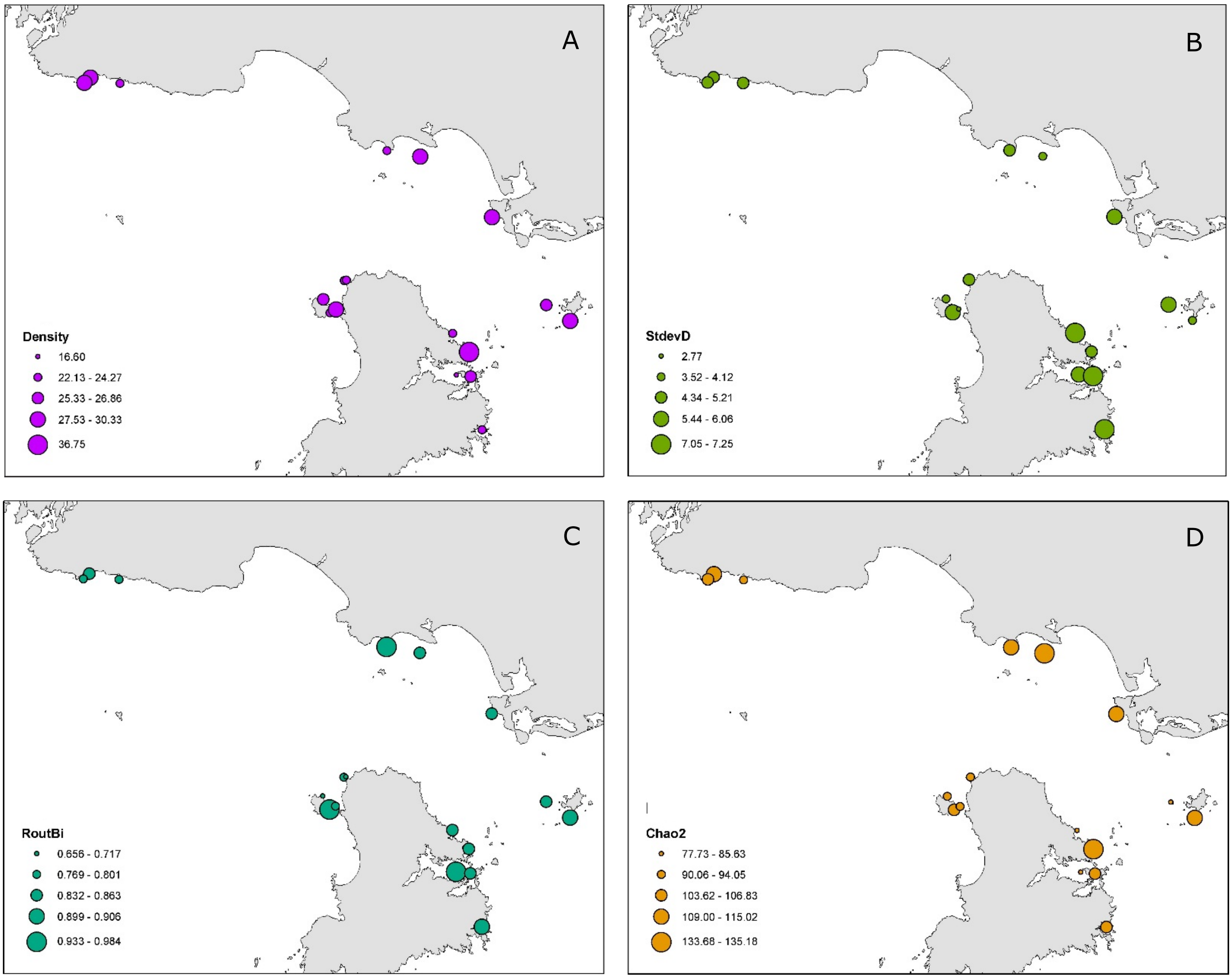


Figure 13. Spatial patterns of A. species density (/0.25 m^2 quadrat); B. variation in species density (standard deviation /0.25 m^2 quadrat); C. turnover diversity, as measured by Routledge's β_I; and D. estimated species richness (Chao 2 index) at rockwall sites in the Foveaux Strait region.

Patterns of turnover diversity were measured by calculating Routledge's β_I, which showed an overall average of 0.837 (± 0.081 SD). The highest values were found at Tamihau Island, Codfish SW and Oraka Point, while relatively lower values occurred at North Sealers Bay and Ruggedy NE (Fig. 13C). The remaining sites reflected the global mean of turnover diversity.

The total number of species observed along a transect (S_{obs}) and the estimated number of species based on the Chao 2 index averaged 83.72 (± 12.54 SD) and 101.94 (± 15.99 SD), respectively. Sites located along the northern coast of Stewart Island/Rakiura tended to have lower species richness, particularly sites that were located within channels, such as the Rugged Islands (Fig. 13D). The estimated species richness also showed a similar pattern, with higher values tending to occur in areas of the Green Islets and Ulva Island (E Point), which had estimated species numbers of between 100 and 110 species (Fig. 13D). Areas along the eastern coast of Stewart Island/Rakiura and points along the southern coast of the South Island also had relatively high estimated species richness, with South Islets and Horseshoe Point having observed species richness above the global average (Fig. 13D).

3.2.2 Patterns of community structure

Multivariate analysis of major taxonomic groupings showed two major clusters of sites with more than 85% similarity in community composition. The first group tended to be in areas of higher wave exposure towards the western part of the Foveaux Strait region (e.g. Codfish N, Archway), while the second group occurred in sheltered and semi-sheltered areas (i.e. Ruapuke Island, Halfmoon Bay, Paterson Inlet/Whaka a Te Wera) (Fig. 14A).

Correlations of the major taxonomic groups with the first two principal axes of the MDS showed a separation of sites with a higher proportion of ascidians from those sites with a higher proportion of bryozoans and actinarians (Fig. 14B). Axis 2 was strongly correlated with the proportion of sponge species and holothuroids.

With regard to physical environmental factors, sites tended to be separated according to sediment cover and secchi depth along axis 1 (Fig. 14C). Sites were less separated along axis 2 (i.e. all variables < 50% correlated), indicating that the separation of sites along this axis was not strongly correlated with broad-scale physical environmental factors.

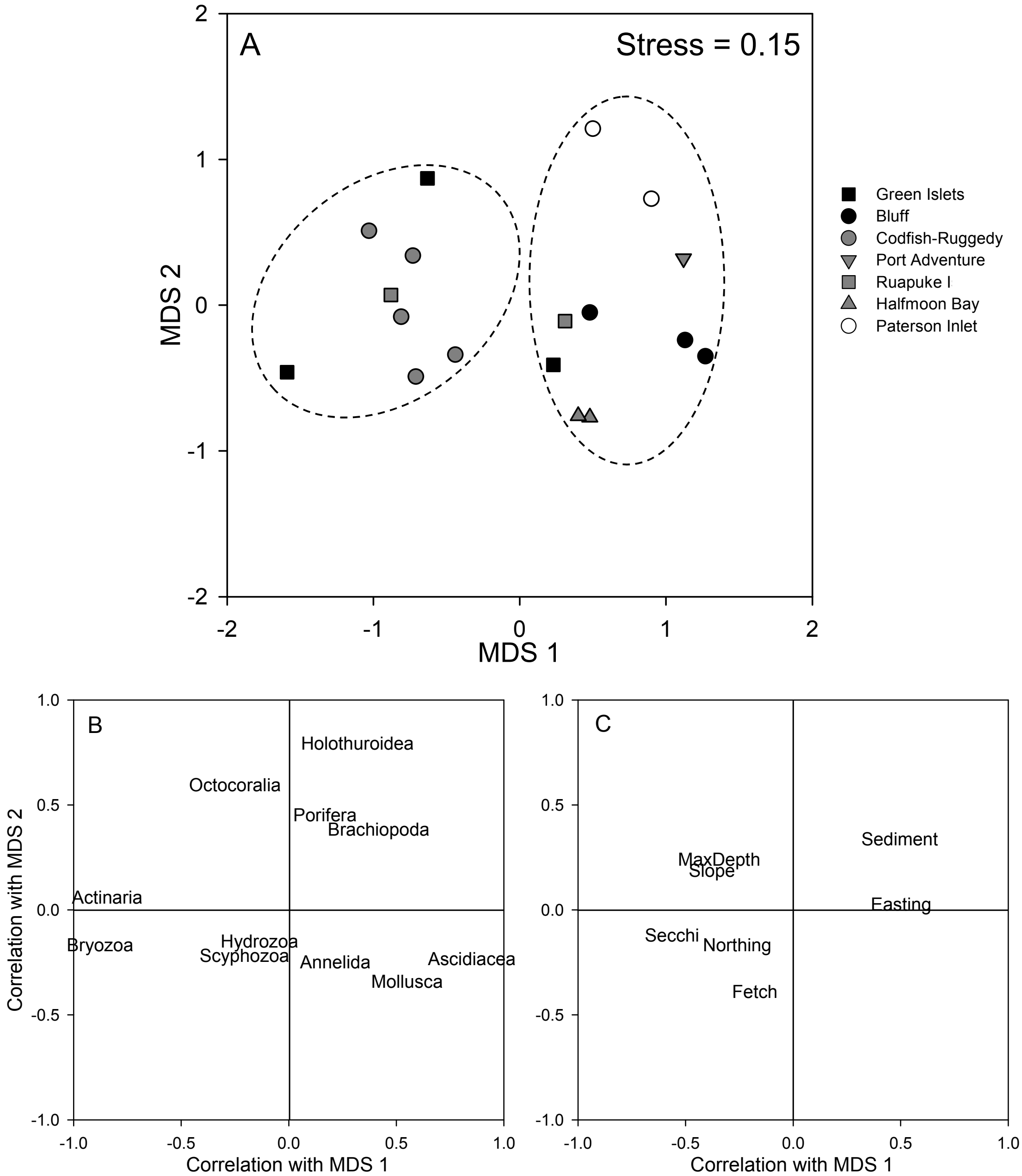


Figure 14. A. Multidimensional Scaling (MDS) plot of community composition at the 18 rockwall sampling sites for the major taxonomic groups of sessile epifaunal invertebrates; B. correlations between the major taxonomic groups and MDS axes 1 and 2; and C. correlations between environmental variables and MDS axes 1 and 2. Dashed circles indicate groupings at the 85% similarity level.

3.3 Mobile macroinvertebrates

3.3.1 Shallow subtidal reef sites

Patterns of species abundance

Twenty-eight species of mobile macroinvertebrates were recorded during quadrat sampling at the subtidal reef sites (Table 6, Appendix 3 for the full species list including those outlined in section 4.3.2 and Appendix 6 for site presence/absence data). The sea urchin *E. chloroticus* was by far the most abundant mobile macroinvertebrate species recorded among these sites (Table 6) – see Appendix 7 for size distributions at each location and Shears & Babcock (2007) for the depth distribution of sea urchins at each site. A number of species of gastropods (e.g. *Cellana stellifera* and *Maoricolpus roseus*) and echinoderms (*Ophiopsammus maculata, Patiriella* spp., *Pentagonaster pulchellus* and *Australostichopus mollis*) were also relatively common.

In general, most mobile macroinvertebrate species were present in low numbers at open coastal sites and were most abundant at sites located in sheltered embayments, such as Paterson Inlet/ Whaka a Te Wera and Preservation Inlet. Species that were particularly abundant in sheltered embayments included *Evechinus chloroticus, Ophiopsammus maculata, Cellana stellifera, Patiriella* spp. and *Australostichopus mollis* (Fig. 15A–E). The turret shell *M. roseus* was abundant

Table 6. Mobile macroinvertebrate species recorded during quadrat sampling at shallow subtidal reef sites in the Foveaux Strait region. The mean density (/m²) is given for each species from all quadrats, along with the percent occurrence.

SPECIES	CODE	CLASS	MEAN DENSITY	TOTAL COUNT	% TOTAL	NO. QUADRATS	% OCCURRENCE
Evechinus chloroticus	Evechinus	Echinoidea	0.914	789	26.12	276	31.98
Ophiopsammus maculata	Ophiop	Ophiuroidea	0.517	446	14.76	218	25.26
Cellana stellifera	Cellana	Gastropoda	0.409	353	11.69	119	13.79
Maoricolpus roseus	Maori	Gastropoda	0.407	351	11.62	54	6.26
Patiriella spp.	Patiriella	Asteroidea	0.269	232	7.68	131	15.18
Australostichopus mollis	Stichopus	Holothuroidea	0.166	143	4.73	101	11.70
Pentagonaster pulchellus	Pentag	Asteroidea	0.161	139	4.60	120	13.90
Haliotis australis	Haustralis	Gastropoda	0.093	80	2.65	58	6.72
Trochus viridis	Trochus	Gastropoda	0.080	69	2.28	43	4.98
Eudoxochiton nobilis	Eudo	Polyplacophora	0.076	66	2.18	54	6.26
Cookia sulcata	Cookia	Gastropoda	0.075	65	2.15	35	4.06
Modelia granosa	Modelia	Gastropoda	0.053	46	1.52	35	4.06
Astraea heliotropium	Astraea	Gastropoda	0.048	41	1.36	27	3.13
Ocnus sp.	Redholo	Holothuroidea	0.045	39	1.29	16	1.85
Haliotis iris	Hiris	Gastropoda	0.031	27	0.89	19	2.20
Coscinasterias muricata	Cosci	Echinoidea	0.029	25	0.83	22	2.55
Stichaster australis	Stichaster	Echinoidea	0.025	22	0.73	19	2.20
Ocnus sp.	Whiteholo	Holothuroidea	0.022	19	0.63	8	0.93
Cantharidus opalus	Copalas	Gastropoda	0.016	14	0.46	13	1.51
Diplodontias spp.	Diplodon	Asteroidea	0.015	13	0.43	13	1.51
Cryptoconchus porosus	Crypto	Polyplacophora	0.013	11	0.36	10	1.16
Scutus breviculus	Scutus	Gastropoda	0.010	9	0.30	9	1.04
Astrostole scabra	Astrostole	Asteroidea	0.006	5	0.17	5	0.58
Turbo smaragdus	Turbo	Gastropoda	0.006	5	0.17	3	0.35
Dicathais orbita	Thais	Gastropoda	0.006	5	0.17	5	0.58
Calliostoma punctulatum	Cpunct	Gastropoda	0.005	4	0.13	4	0.46
Argobuccinum pustulosum	Argobucc	Gastropoda	0.002	2	0.07	2	0.23
Buccinulum linea	Buccinulum	Gastropoda	0.001	1	0.03	1	0.12

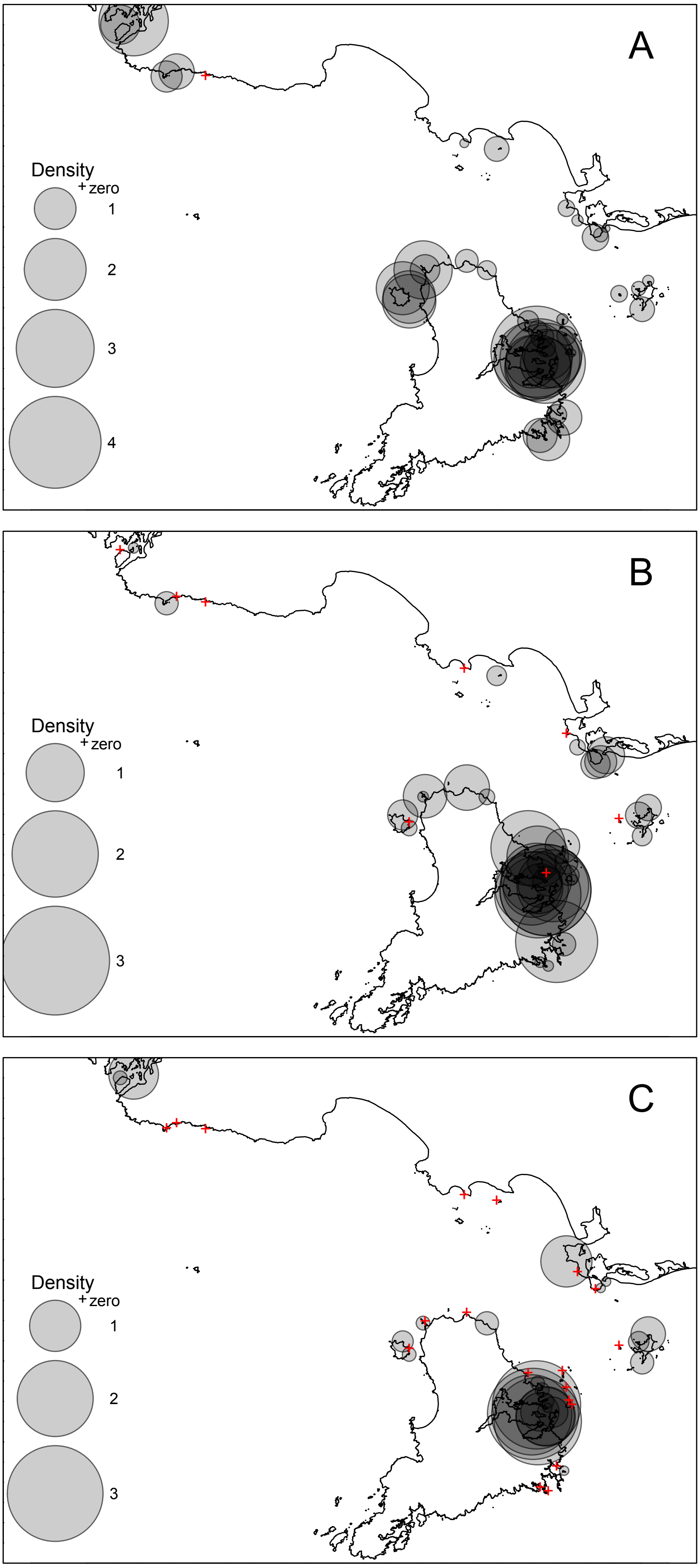


Figure 15. Depth-averaged density (/m^2) of dominant mobile macroinvertebrate species at shallow subtidal reef sites in the Foveaux Strait region: A. *Evechinus chloroticus*; B. *Ophiopsammus maculata*; C. *Cellana stellifera*.

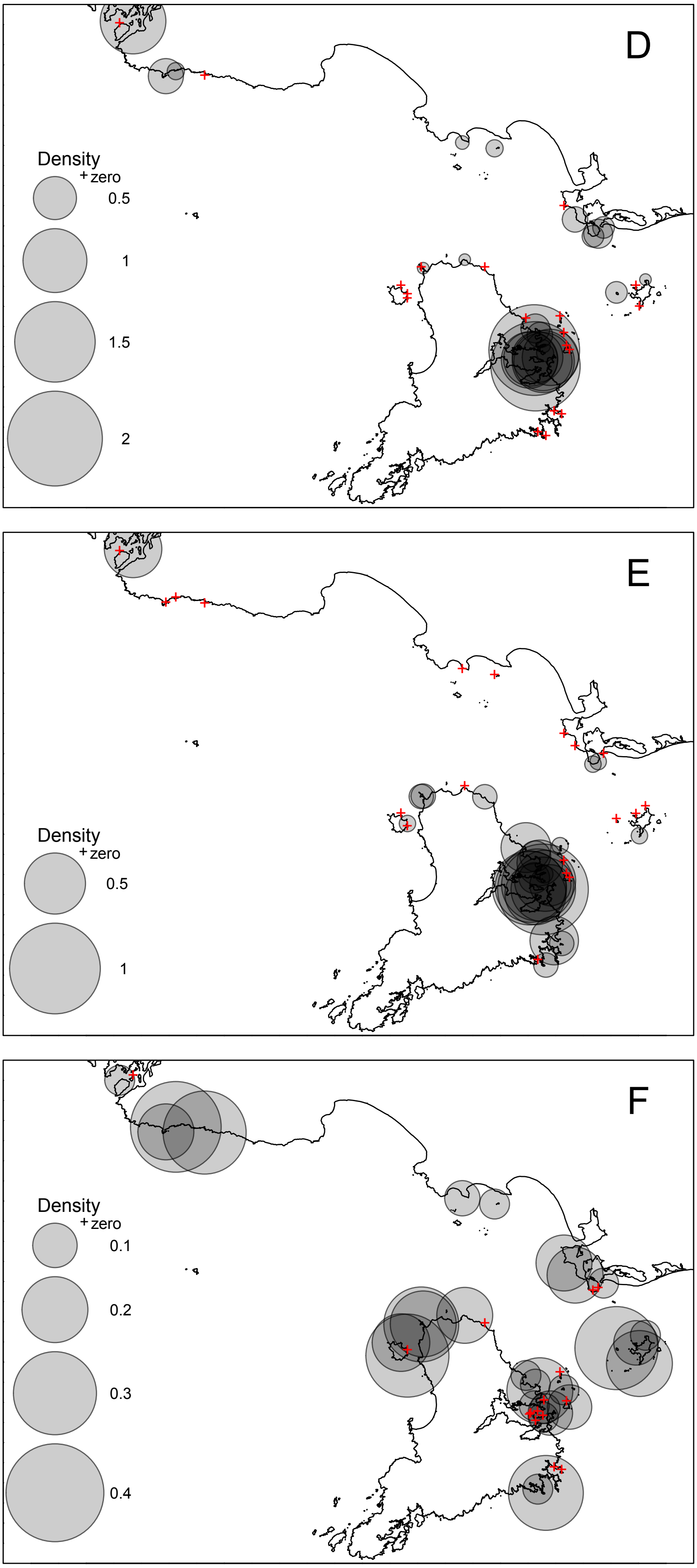


Figure 15 *continued.* Depth-averaged density (/m^2) of dominant mobile macroinvertebrate species at shallow subtidal reef sites in the Foveaux Strait region: D. *Patiriella* spp.; E. *Australostichopus mollis*; F. *Haliotis australis*.

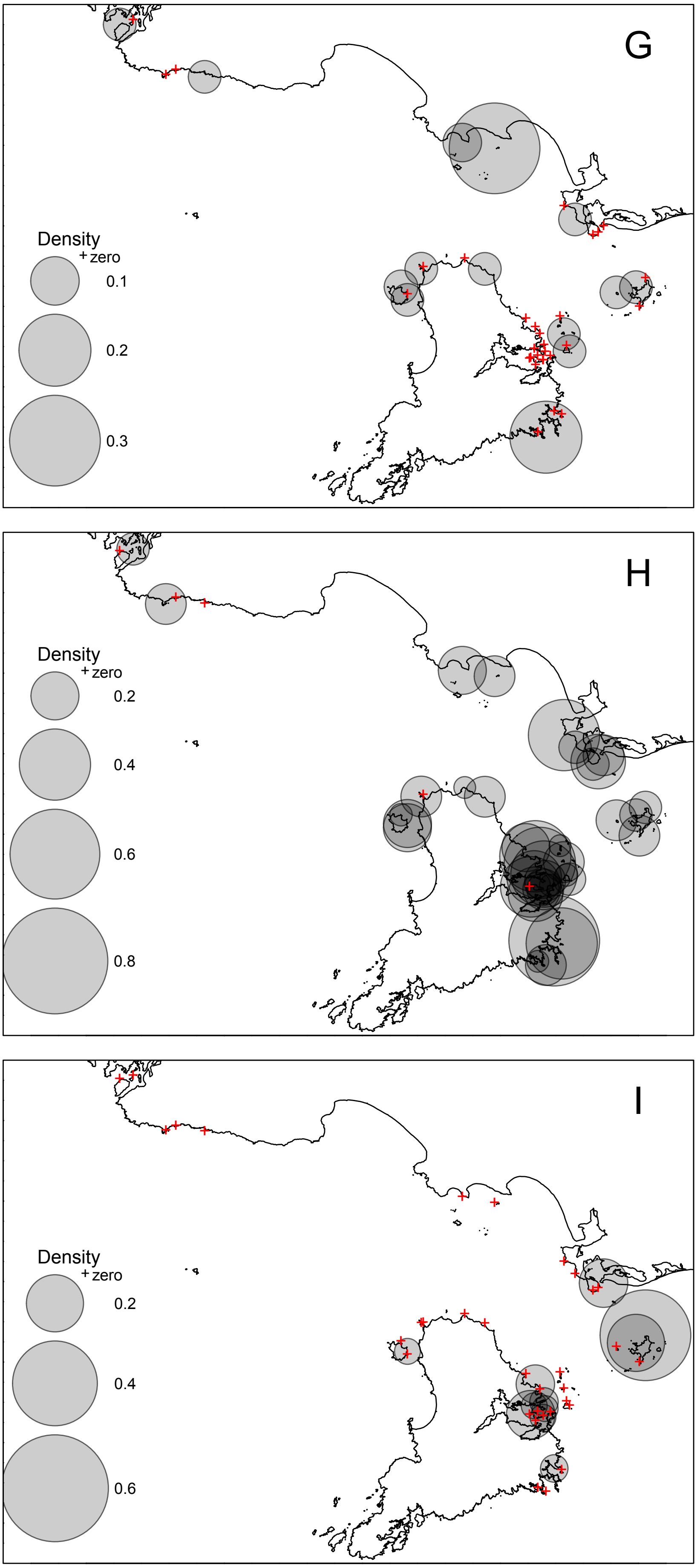


Figure 15 *continued*. Depth-averaged density (/m^2) of dominant mobile macroinvertebrate species at shallow subtidal reef sites in the Foveaux Strait region: G. *Stichaster australis*; H. *Pentagonaster pulchellus*; I. *Haliotis iris*.

at most sites inside Paterson Inlet/Whaka a Te Wera and the inner Preservation Inlet site (Weka Point), but was also abundant at the site located at the entrance of Bluff Harbour (Stirling Point). *Trochus viridis* was one of the most commonly recorded gastropod species, but was typically only common at sites in Preservation Inlet, Halfmoon Bay and one site at the Titi/Muttonbird Islands (Motunui/Edwards Island).

A number of species were typically more common at the most exposed sites, however, e.g. *Haliotis australis* and *Stichaster australis* (Fig. 15F & G). Similarly, the sea stars *Diplodontias* spp. and *Astrostole scabra* were only found at open coastal sites such as Oraka Point, Herekopare, NW Bay and Horomamae/Owen Island, although these were relatively rare. The gastropod *Cookia sulcata* was also common at sites located at Preservation Inlet, Green Islets and Bluff, but was very rare at the other locations sampled, possibly reflecting the typically more northern distribution of this species. A few species, such as *Pentagonaster pulchellus* and *Haliotis iris*, exhibited no apparent relationship with wave exposure, but generally only occurred at very low densities (< 0.5/m2) (Fig. 15H & I).

Patterns of species richness

The number of mobile macroinvertebrate species recorded at shallow subtidal sites was highest at sites within Paterson Inlet/Whaka a Te Wera, Preservation Inlet and at Halfmoon Bay sites (11–16 species) (Fig 16). The number of species recorded was generally lower on the more exposed open coasts, and was particular low at Prices Pt (3 species) and Motunui/Edwards Is (5 species).

Patterns of community structure

Overall, there was a clear gradient in mobile macroinvertebrate species assemblages between sites, which corresponded to large-scale differences in wave exposure (Fig. 17A). As for macroalgae (Figs 5 & 8) and substratum cover (Fig. 10), sheltered sites at Paterson Inlet/Whaka a Te Wera were clustered on the left of the ordination, the more exposed sites from the Green Islets, Bluff and the Titi/Muttonbird Islands were clustered on the right, and semi- to moderately exposed sites at Halfmoon Bay, Codfish-Ruggedy Islands, Ruapuke Island and Port Adventure were generally clustered in the middle of the ordination (Fig. 17A). This gradient in sites along MDS axis 1 was reflected by strong correlations with individual species (Fig. 17B), and the environmental variables sediment cover and wind fetch (Fig. 17C).

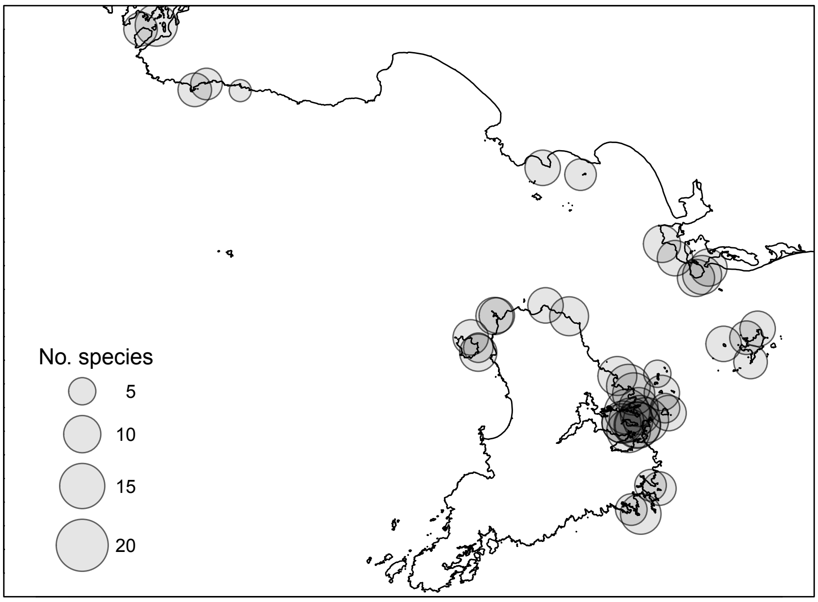


Figure 16. Spatial patterns of species richness of mobile invertebrates from shallow subtidal reef sites in the Foveaux Strait region.

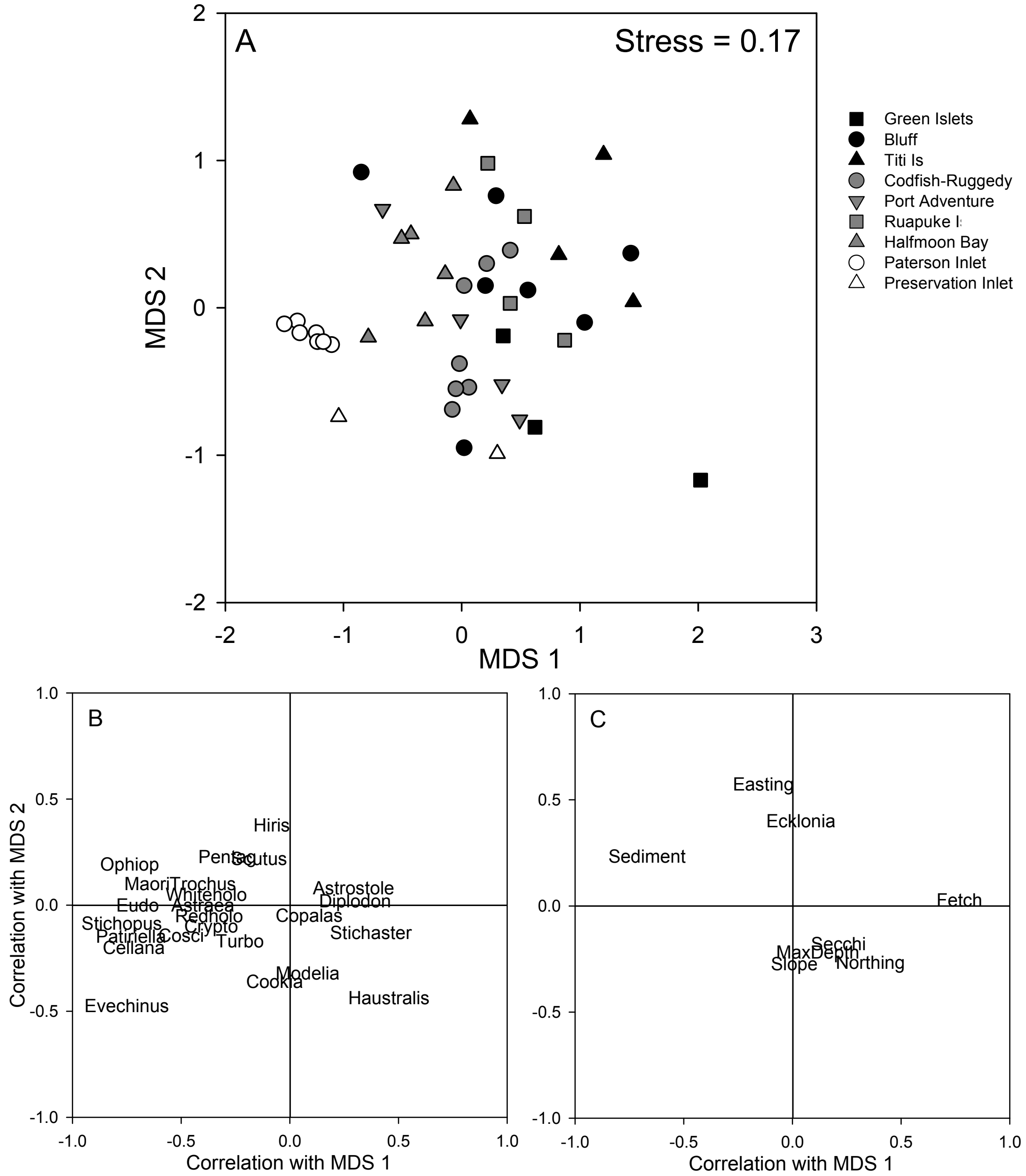


Figure 17. A. multidimensional Scaling (MDS) plot based on 28 species of mobile macroinvertebrate communities based on square-root transformed count data from shallow subtidal reef sites in the Foveaux Strait region; B. correlations between mobile macroinvertebrate species and MDS axes 1 and 2; and C. correlations between environmental variables and MDS axes 1 and 2. See Table 5 for species codes.

3.3.2 Subtidal rockwalls

Patterns of species abundance

Thirty species of mobile macroinvertebrates were recorded across the 18 subtidal rockwall sites sampled in the Foveaux Strait region (Table 7). The ophiuriod *Ophiopsammus maculata* was one of the most abundant species, with a maximum abundance of 14 individuals per 5 m^2 block (Browns Garden) and an average abundance of 2.51 per 5 m^2 block. The sea urchin *E. chloroticus* and the sea stars *Pentagonaster* spp. were also abundant, with maximum abundances of 13.6 and 6.6 individuals per 5 m^2 block, and average abundances of 2.99 and 2.69 individuals per 5 m^2 block, respectively (Table 7). Most other species had considerably lower abundances (maximum average abundance < 1 individual per 5 m^2 block, average abundance < 0.1 individual per 5 m^2 block).

Table 7. Numerical abundance of mobile macroinvertebrates along transects on subtidal rockwalls in the Foveaux Strait region, including observed minimum and maximum average abundance in 5 m^2 replicate blocks across sites. Number of sites = 18 (see Table 1).

SPECIES	MINIMUM	MAXIMUM	AVERAGE	STANDARD DEVIATION
Ophiopsammus maculata	0.0	14.0	2.51	4.41
Evechinus chloroticus	0.0	13.6	2.99	3.39
Pentagonaster spp.	0.6	6.6	2.69	1.68
Australostichopus mollis	0.0	7.8	1.11	2.14
Astraea heliotropium	0.0	4.0	0.32	0.97
Maoricolpus roseus roseus	0.0	4.0	0.33	0.97
Coscinasterias muricata	0.0	1.6	0.27	0.50
Modelia granosa	0.0	2.0	0.31	0.60
Patiriella regularis	0.0	2.6	0.36	0.70
Chromodoris aureomarginata	0.0	1.2	0.20	0.41
Phlyctenactis tuberculosa	0.0	0.6	0.06	0.17
Trochus viridis	0.0	1.0	0.11	0.27
Maurea punctulatum	0.0	0.8	0.11	0.23
Scutus breviculus	0.0	0.8	0.07	0.19
Allostichaster spp.	0.0	0.6	0.08	0.17
Cryptoconchus porosus	0.0	0.6	0.08	0.17
Sypharochiton pelliserpentis	0.0	0.6	0.06	0.15
Argobuccinum spp.	0.0	0.2	0.04	0.09
Astrostole scabra	0.0	0.2	0.01	0.05
Buccinium sp. 1	0.0	0.2	0.01	0.05
Buccinium sp. 2	0.0	0.2	0.01	0.05
Calliostoma (*Maurea*) *tigris*	0.0	0.2	0.01	0.05
Cellana radians	0.0	0.2	0.01	0.05
Cominella spp.?	0.0	0.2	0.01	0.05
Haliotis australis	0.0	0.2	0.03	0.08
Jasus edwardsii	0.0	0.2	0.01	0.05
Pagurus spp.	0.0	0.2	0.03	0.08
Pycnogonida	0.0	0.2	0.01	0.05
Stegnaster inflatus	0.0	0.2	0.01	0.05
Turbo smaragdus	0.0	0.2	0.02	0.07

The spatial distributions of abundant species were highly variable across the Foveaux Strait region, with sites that contained the highest abundance of mobile macroinvertebrates being found close to areas with comparatively lower abundances (Fig. 18). The sea urchin *E. chloroticus* was most abundant in the vicinity of Codfish Island / Whenua Hou and the Ruggedy Islands, and at one site in the Green Islets, with all other sites having comparatively lower abundances of this species (Fig. 18A). The sea stars *Pentagonaster* spp. showed a more consistent pattern of abundance within areas of the Foveaux Strait region, with a generally lower abundance along the eastern edge of Stewart Island/Rakiura (Fig. 18B). By contrast, the brittle star *Ophiopsammus maculata* generally had a higher abundance along the eastern edge of Stewart Island/Rakiura and a comparatively lower abundance in Foveaux Strait proper (Fig. 18C). The brown sea cucumber *Australostichopus mollis* had the highest abundance in areas around Stewart Island/Rakiura (both eastern and northern seaboard) and a generally lower abundance elsewhere (Fig. 18D).

The small sea star *Patiriella regularis* had a relatively higher abundance in Paterson Inlet/ Whaka a Te Wera and at Pig Island, and tended to have a lower abundance elsewhere (Fig. 18E). The eleven-armed sea star *Coscinasterias muricata* showed a similar pattern to *P. regularis*, with sites of high abundance along the eastern portion of Stewart Island/Rakiura (i.e. including Port

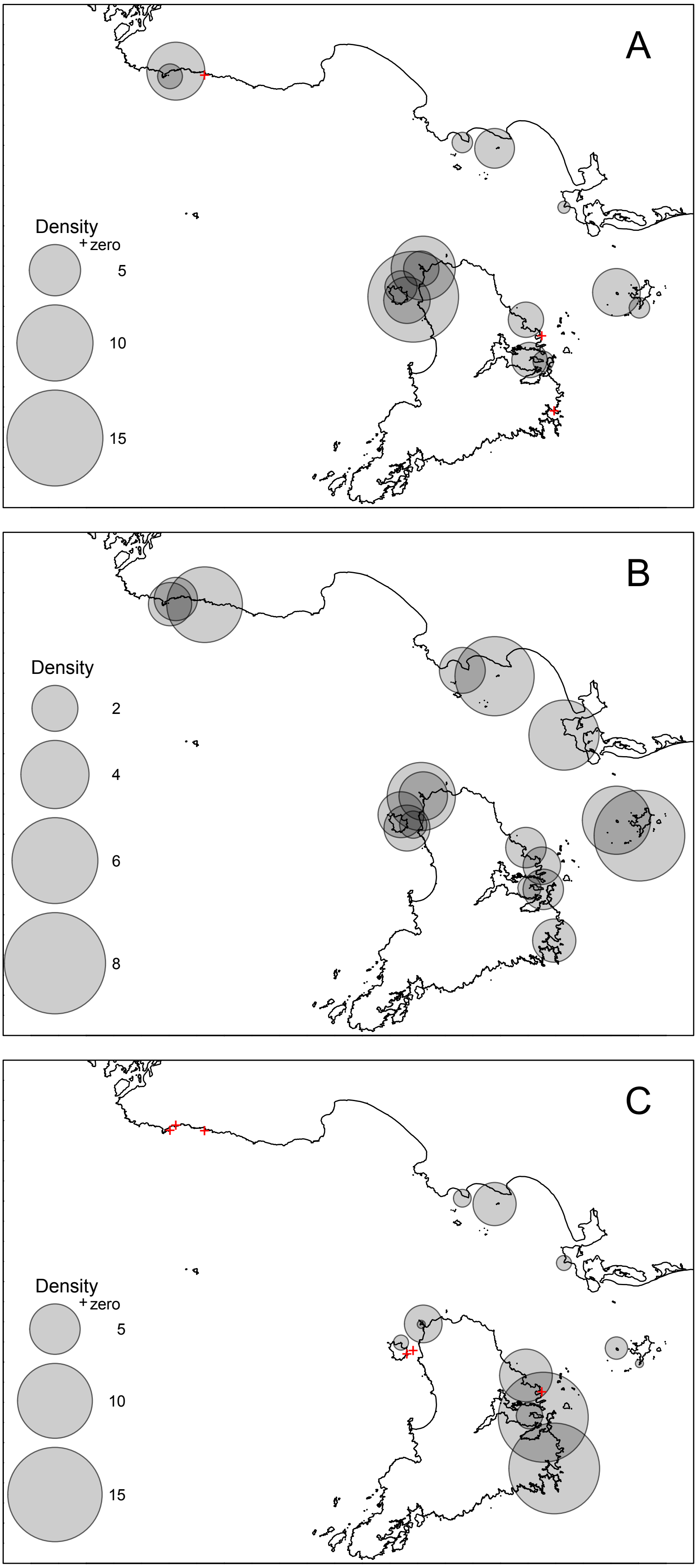


Figure 18. Spatial patterns of average abundance (/5 m^2 block) on subtidal rockwalls for A. *Evechinus chloroticus*; B. *Pentagonaster* spp.; C. *Ophiopsammus maculata*.

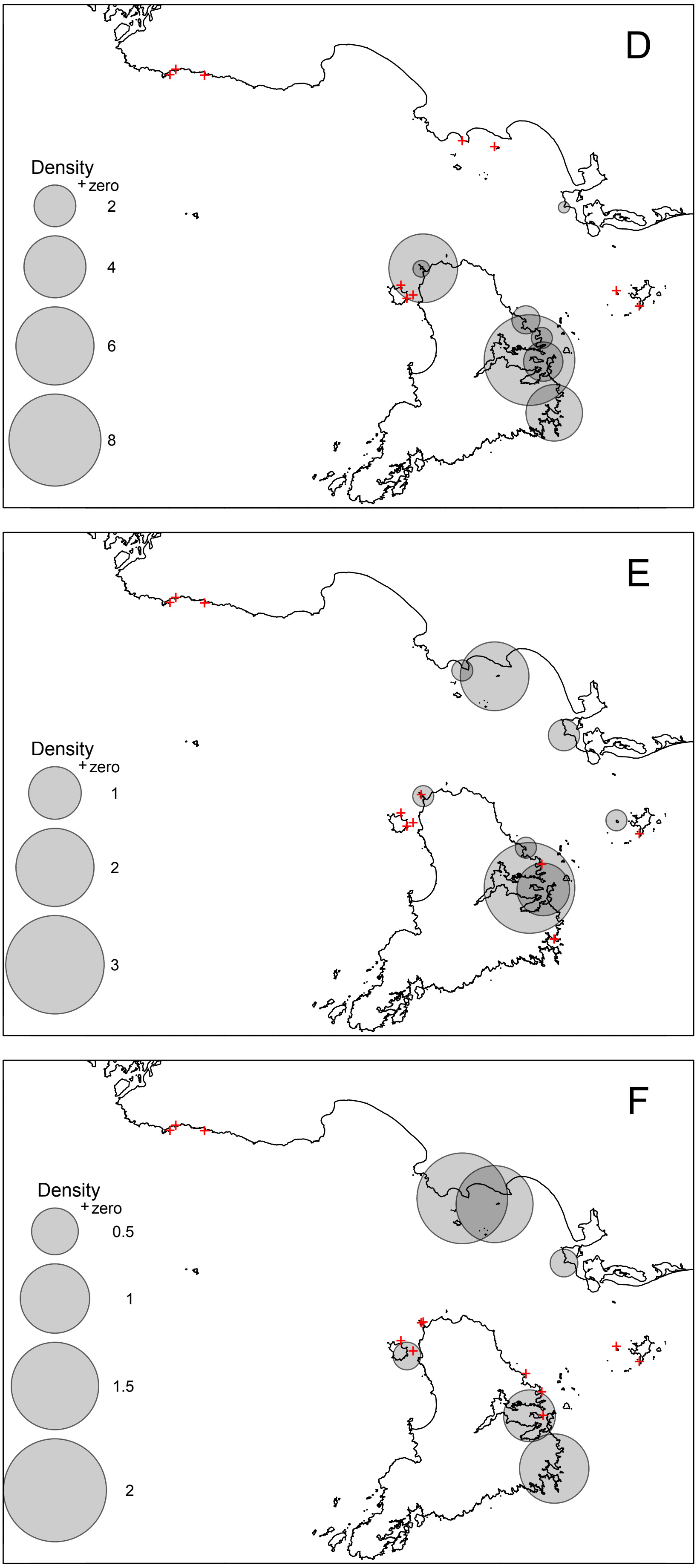


Figure 18 *continued*. Spatial patterns of average abundance (/5 m^2 block) on subtidal rockwalls for D. *Australostichopus mollis*; E. *Patiriella regularis*; F. *Coscinasterias muricata*.

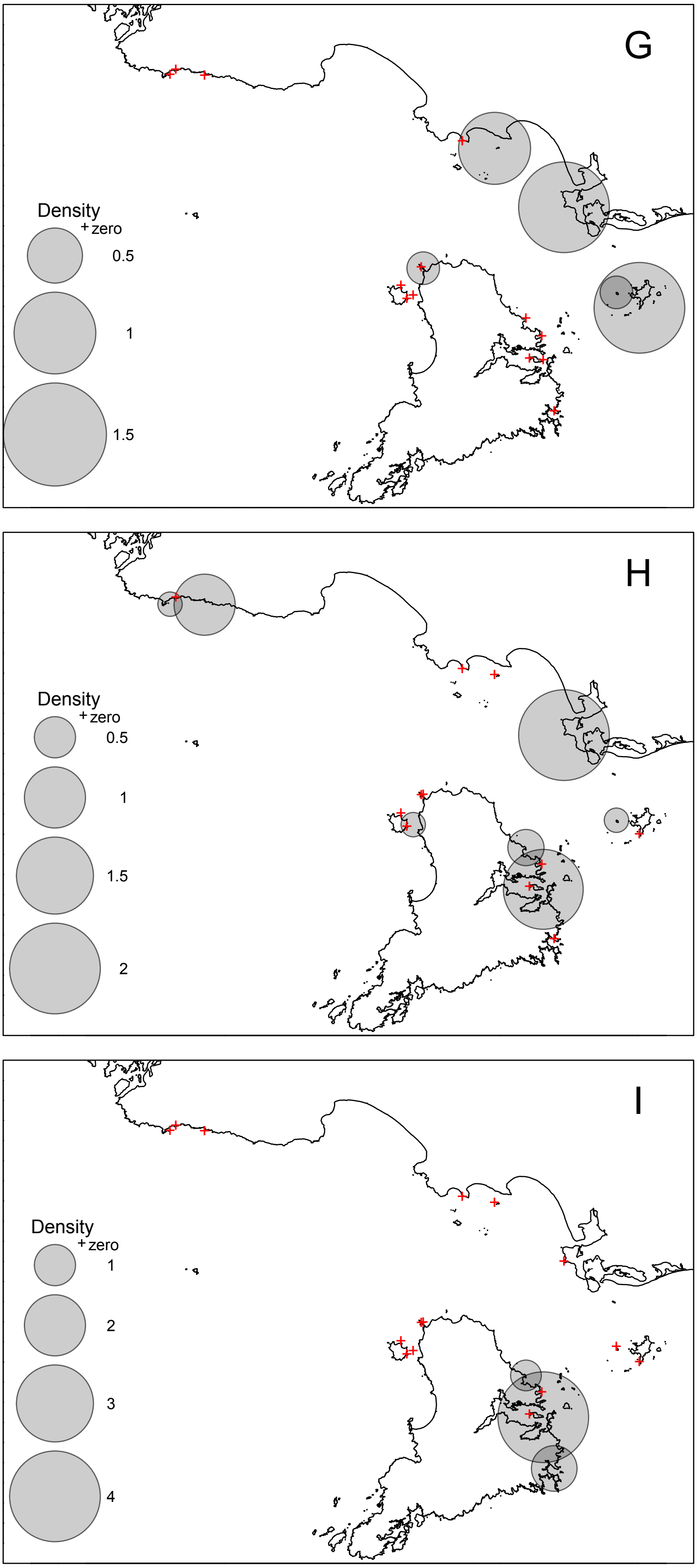


Figure 18 *continued*. Spatial patterns of average abundance (/5 m^2 block) on subtidal rockwalls for G. *Chromodoris aureomarginata*; H. *Modelia granosa*; I. *Astraea heliotropium*.

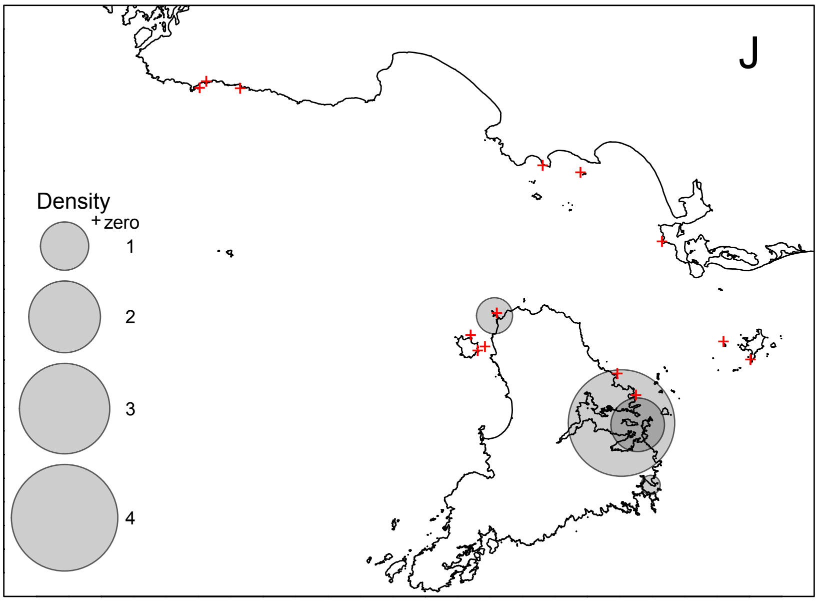


Figure 18 *continued*. Spatial patterns of average abundance (5 m^2 block) on subtidal rockwalls for J. *Maoricolpus roseus roseus*.

Adventure and Paterson Inlet/Whaka a Te Wera) and sites along the southern mainland coast (Oraka Point and Pig Island) (Fig. 18F). The nudibranch *Chromodoris aureomarginata* had the highest relative abundance along the southern coast of the South Island and at Ruapuke Island, but tended to have lower abundance throughout Stewart Island/Rakiura and towards the Green Islets (Fig. 18G). The small gastropod *Modelia granosa* showed a variable pattern of abundance, with sites of relatively high abundance at Prices Point, Shag Rock, and Ulva Island (Paterson Inlet/Whaka a Te Wera) and comparatively lower abundance elsewhere (Fig. 18H).

The gastropod *Astraea heliotropium* had higher local abundances (i.e. up to four individuals per 5 m^2 block) at three sites along the eastern coast of Stewart Island/Rakiura (Fig. 18I). The gastropod *Maoricolpus roseus roseus* also had a relatively higher local abundance (i.e. up to four individuals per 5 m^2 block), but was only present at four sites around Stewart Island/Rakiura, including Browns Garden, Tamihau Island, Ulva Island E Point and Ruggedy Passage (Fig. 18J).

Patterns of species richness

Overall, sites in Paterson Inlet/Whaka a Te Wera and headlands within the Foveaux Strait region (e.g. Shag Rock, Bird Rock, Pig Island) had relatively higher numbers of species (i.e. > 10 species per site) than other sites sampled in the region (Fig. 19). Fewer species were located in the Green Islets and at Prices Point, suggesting that there is general trend of decreasing numbers of species moving towards Puysegur Point.

Patterns of community structure

Multivariate analysis of the 30 species that were found across the 18 rockwall sites sampled in the Foveaux Strait region showed that there were four major groups of sites at the 50% similarity level (Fig. 20A). The largest group included sites within the Green Islets region and areas of the western entrance to Foveaux Strait (i.e. Codfish Island / Whenua Hou). A second group included other sites that tended to be moderately exposed towards the eastern entrance of Foveaux Strait (i.e. Bluff and Ruapuke Island). The third group included sheltered sites of Stewart Island/Rakiura (i.e. Paterson Inlet/Whaka a Te Wera, Port Adventure), while the fourth consisted of an island and a site in the eastern Foveaux Strait area (i.e. Green Islets and Halfmoon Bay). The MDS had a stress value of 0.15.

The brittle star *Ophiopsammus maculata*, the sea urchin *E. chloroticus* and the sea star *Patiriella* spp. were found to be correlated with these site separations (Fig. 20B). The separation of sites

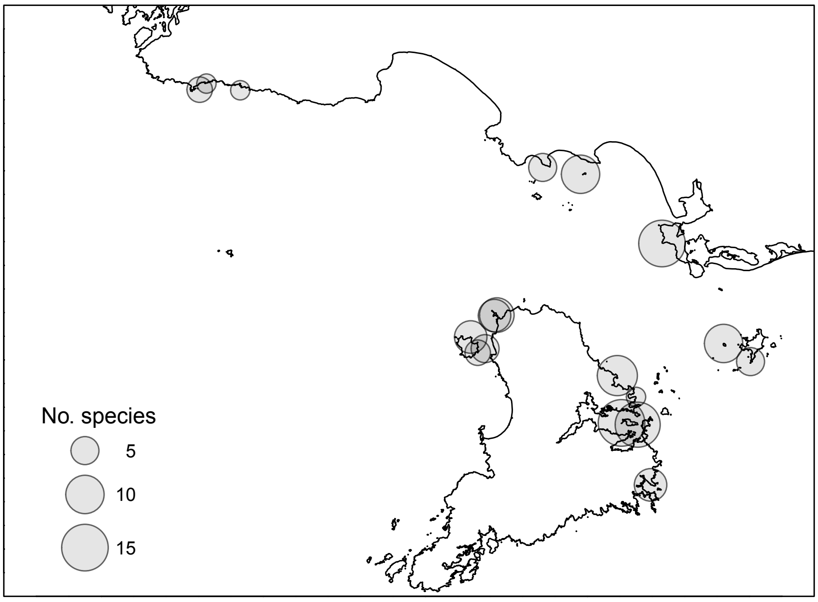


Figure 19. Spatial patterns of species richness of mobile invertebrates from rockwall sites in the Foveaux Strait region.

along axis 1 of the MDS was negatively correlated with the abundance of most species, with the most negatively correlated species including *O. maculata* and *Australostichopus mollis*.

With respect to the physical environmental variables, fetch, sediment cover geographic position (e.g. easting, northing), and species richness were correlated with axis 1 of the MDS (Fig. 20C). This was largely driven by the Paterson Inlet sites, which were sheltered, had high sediment cover and the highest species richness. Sites along axis 2 were also characterised by differences in fetch and sediment cover, although with relatively weaker correlations. Other physical variables, such as secchi depth, slope and maximum depth, tended to have a weaker correlation (i.e. < 50%) with the principal axes.

3.4 Cryptic fishes of subtidal rockwalls

3.4.1 Patterns of species abundance

Eight species of cryptic fishes were found across 17 of the 18 sampling sites on subtidal rockwalls in the Foveaux Strait region, all of which were triplefins (Table 8; see Appendix 3 for full species lists and Appendix 6 for site presence/absence data). No cryptic fishes were recorded along transects at the three sites located at Green Islets.

The most common and abundant species was the variable triplefin (*Forsterygion varium*), which was present at 12 of the 18 sites, with an average abundance of 1.8 fish per 5 m^2 block. Variable triplefins had one of the broadest distribution patterns of the cryptic fishes, with highest relative abundances at Ruapuke Island sites and the Ruggedy Islands; comparatively high abundances also occurred at headlands of eastern Stewart Island/Rakiura and at sites along the southern South Island coast from Pig Island to Shag Rock (Fig. 21A).

The blue-eyed triplefin (*Notoclinops segmentatus*), the mottled triplefin (*Forsterygion malcomi*) and the common triplefin (*F. lapillium*) were also relatively common, being present at 10 of the 18 sites and ranging from 0.7 to 1.3 fish per 5 m^2 block (Table 8). Blue-eyed triplefins had relatively higher abundances at three sites in the Foveaux Strait region, including sites in the Ruggedy Islands and Shag Rock, but had a relatively lower abundance throughout other parts of the region (Fig. 21B). The mottled triplefin showed a broader spatial distribution, being present at 10 of the 18 sites, with highest densities in Paterson Inlet/Whaka a Te Wera, the Ruggedy Islands and Shag Rock (Fig. 21C); however, this species was either not present or uncommon at sites around Codfish

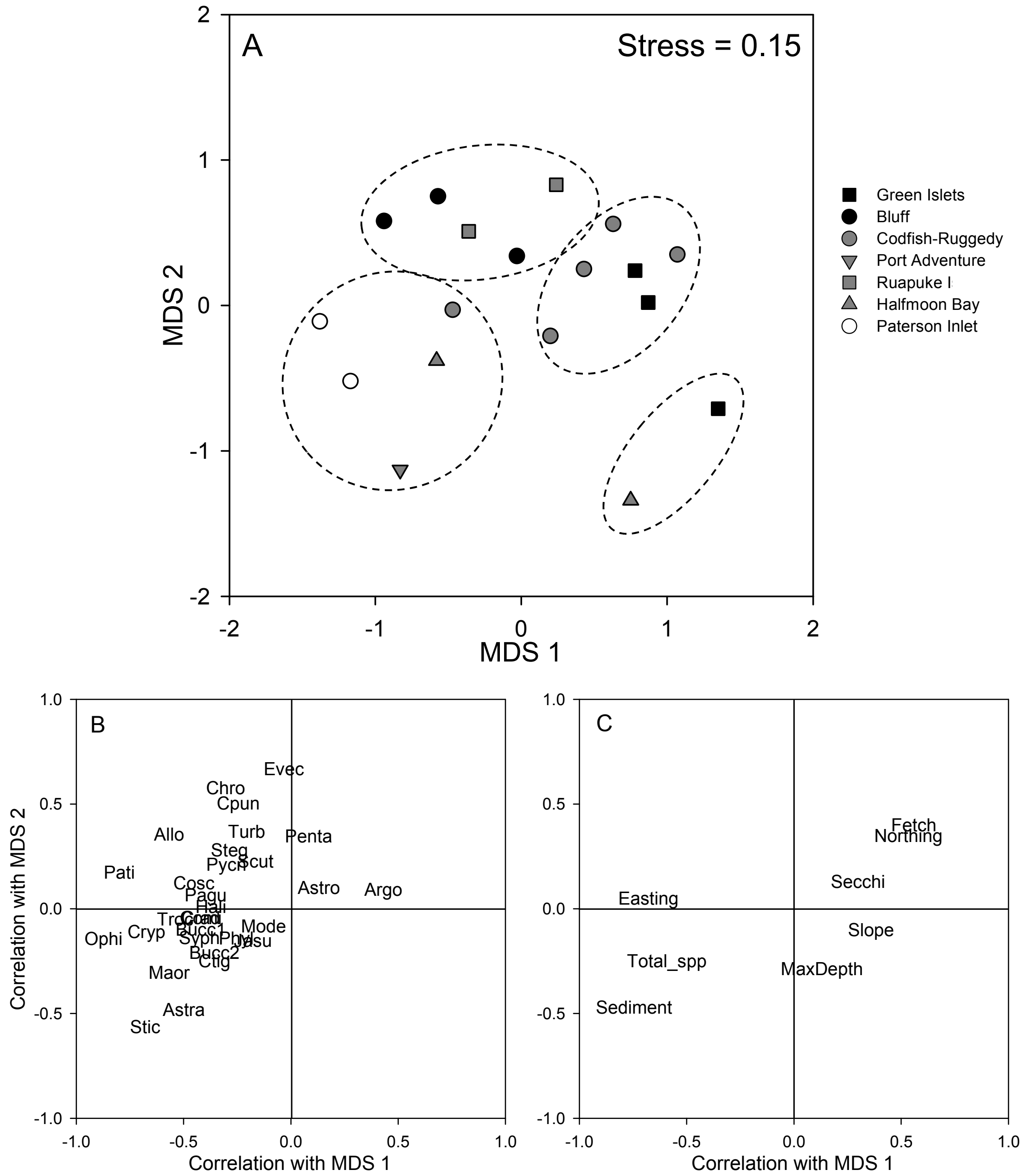


Figure 20. A. Multidimensional scaling (MDS) plot based on the abundance of 31 species of mobile invertebrates from subtidal rockwalls in the Foveaux Strait region (square-root transformed data); B. correlations between the abundance of mobile invertebrates and MDS axes 1 and 2; and C. correlations between environmental variables and MDS axes 1 and 2. Dashed circles indicate groupings at the 50% similarity level.

Table 8. Average abundance of cryptic fishes in 5 m^2 blocks at subtidal rockwall sites in the Foveaux Strait region, including observed minimum and maximum average abundance across sites. Number of sites = 18. The yellow-black triplefin and longfinned triplefin are excluded from the analysis as they were present at only 4 and 3 sites respectively.

COMMON NAME	SCIENTIFIC NAME	MINIMUM	MAXIMUM	AVERAGE	STANDARD DEVIATION
Blue-eyed triplefin	*Notoclinops segmentatus*	0	5.6	1.3	1.9
Common triplefin	*Forsterygion lapillum*	0	5.0	0.8	1.3
Mottled triplefin	*Forsterygion malcolmi*	0	3.8	0.7	1.1
Oblique-swimming triplefin	*Forsterygion maryannae*	0	17.6	1.3	4.3
Spectacled triplefin	*Ruanoho whero*	0	0.6	0.1	2.0
Variable triplefin	*Forsterygion varium*	0	5.8	1.8	2.0

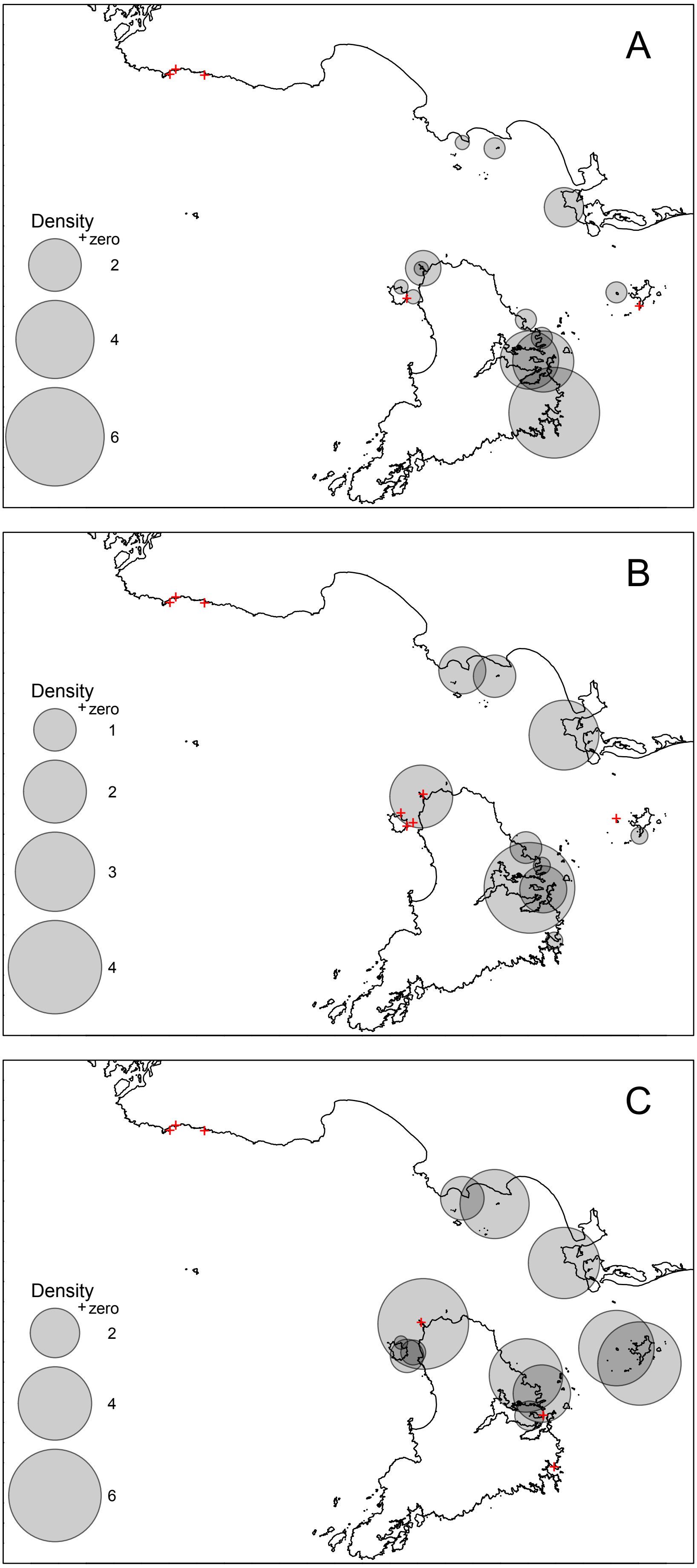


Figure 21. Spatial patterns of cryptic fish abundance from subtidal rockwalls in the Foveaux Strait region (average density (/5 m^2 block) of transect at each site) for A. variable triplefin *Forsterygion varium*; B. blue-eyed triplefin *Notoclinops segmentatus*; C. mottled triplefin *F. malcolmi.*

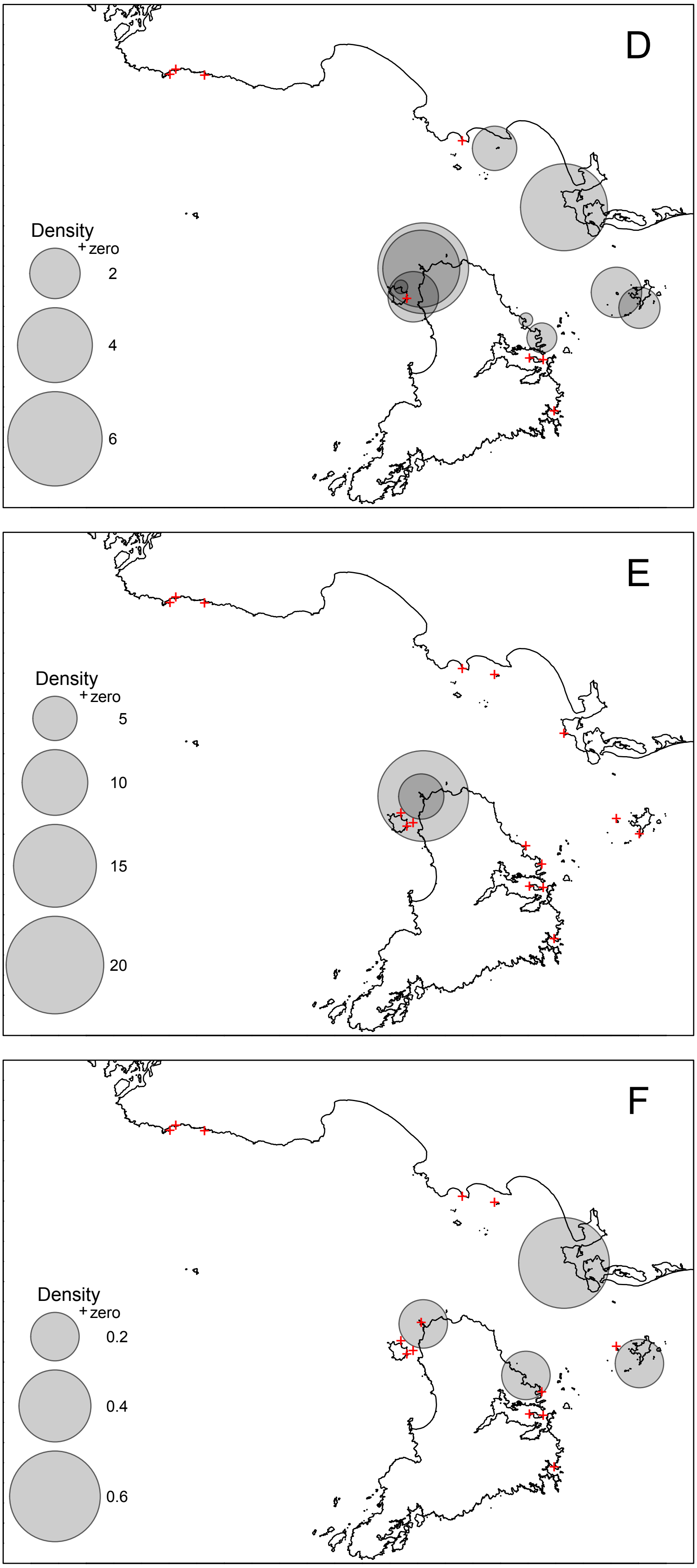


Figure 21 *continued*. Spatial patterns of cryptic fish abundance from subtidal rockwalls in the Foveaux Strait region (average density (5 m^2 block) of transect at each site) for D. common triplefin *F. lapillum*; E. oblique-swimming triplefin *F. maryannae*; and F. spectacled triplefin *Ruanoho whero*.

Island / Whenua Hou, the Green Islets and Ruapuke Island. The common triplefin showed the highest densities at three sites in inlets of Stewart Island/Rakiura (Port Adventure, Paterson Inlet/ Whaka a Te Wera), while densities were low throughout the rest of the region (Fig. 21D).

The oblique-swimming triplefin (*Forsterygion maryannae*) was only observed at 2 of the 18 sites, where it had an average abundance of 11.4 (± 8.77) fish per m^2. This species had a relatively restricted distribution (i.e. two sites in the Ruggedy Islands) but was locally abundant (Fig. 21E). By contrast, the spectacled triplefin (*Ruanoho whero*) was present at 4 of the 18 sites (distinct points associated with headlands, including the Ruggedy Islands, West Head, South Islet (Ruapuke Island) and Shag Rock), but at a relatively low abundance, with an average of 0.3 fish per 5 m^2 block (Fig. 21F).

3.4.2 Patterns of species richness

Overall, cryptic fishes had relatively higher species richness in the vicinity of Stewart Island/ Rakiura, where most sites had more than three species, and Horseshoe Point and Ruggedy NE had the most species (n = 5) (Fig. 22). By contrast, no cryptic fishes were observed at locations towards Puysegur Point.

3.4.3 Patterns of community structure

Multivariate analysis of the six species of cryptic fishes across 15 subtidal rockwall sites showed weak groupings according to location (Fig. 23A). Sites that were relatively sheltered (e.g. Paterson Inlet/Whaka a Te Wera, Port Adventure) tended to form an outgroup, while other locations (e.g. Codfish-Ruggedy Islands) showed a large degree of variation along the second principal MDS axis (Fig. 23A). Sites at Bluff and Halfmoon Bay tended to have similar assemblages.

The abundance of mottled, common and variable triplefins tended to separate the sites along the first principal axis, while the relative abundance of oblique-swimming triplefins was largely responsible for the separation of sites along the second axis, with lower abundances corresponding to sites in the Codfish-Ruggedy Islands region (Fig. 23B).

In terms of physical environmental variables, the percent cover of sediment, fetch and secchi depth were all correlated with axis 1 (Fig. 23C). Maximum depth and slope appeared to be most strongly correlated with axis 2, but these correlations were lower than for axis 1, indicating that the separation of sites in terms of species composition of cryptic fishes was only weakly correlated with other physical variables along this axis.

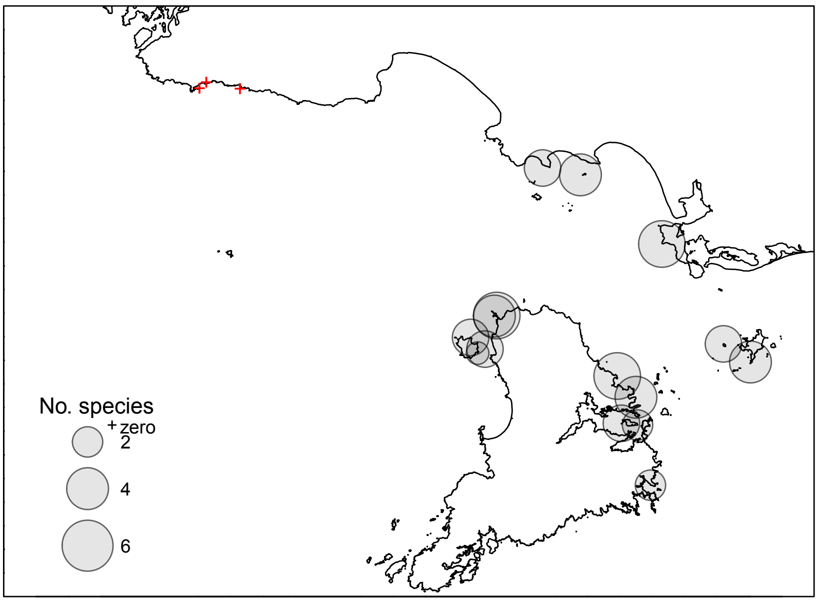


Figure 22. Spatial patterns of species richness for cryptic fishes at rockwall sites in the Foveaux Strait region.

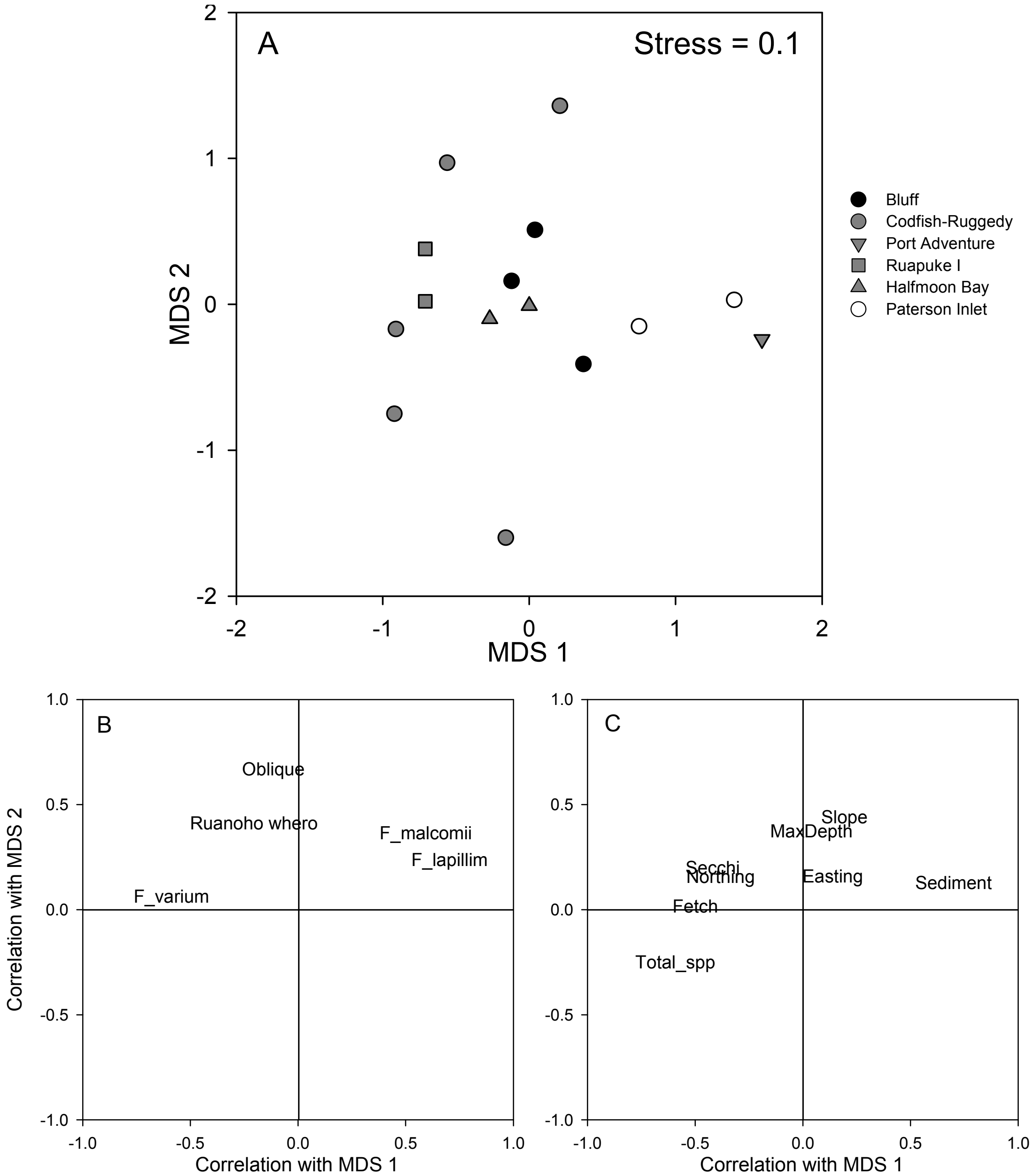


Figure 23. A. Multidimensional scaling (MDS) plot for the abundance of six cryptic fish species from subtidal rockwalls in the Foveaux Strait region (log(x+1) transformed data); B. correlations between the abundance of species and MDS axes 1 and 2; and C. correlations between environmental variables and MDS axes 1 and 2.

3.5 Reef fishes

3.5.1 Patterns of species abundance

Twenty one species of fishes (excluding cryptic fishes) were documented across the 26 sampling sites in the Foveaux Strait region (Table 9; see Appendix 3 for a full species list and Appendix 6 for site presence/absence data). Fourteen of these fish are considered to be reef fishes associated with the habitats surveyed. Other species included seahorse, conger eel, and carpet shark. These included a suite of herbivores (e.g. butterfish *Odax pullus*), omnivores (e.g. girdled wrasse *Notolabrus cinctus*), planktivores (e.g. butterfly perch *Caesioperca lepidoptera*) and carnivores (e.g. blue cod *Parapercis colias*). Schooling fish, such as butterfly perch and telescope fish (*Mendosoma lineatum*), had the highest maximum densities across sites, while a number of wrasse species, such as banded and scarlet wrasse (*Notolabrus fucicola* and *Pseudolabrus*

Table 9. Depth-averaged abundances of reef fishes per 25 × 5 m transect on subtidal reefs in the Foveaux Strait region, including observed minimum and maximum average abundance across sites. Number of sites = 26.

COMMON NAME	SCIENTIFIC NAME	MINIMUM	MAXIMUM	AVERAGE	STANDARD DEVIATION
Banded wrasse	*Notolabrus fucicola*	0.7	8.7	3.33	2.13
Blue cod—small (< 150 mm fork length)	*Parapercis colias*	0.0	7.3	0.58	1.45
Blue cod—medium (150–300 mm fork length)	*Parapercis colias*	0.0	3.0	0.42	0.63
Blue cod—large (> 300 mm fork length)	*Parapercis colias*	0.0	1.2	0.14	0.29
Blue moki	*Latridopsis ciliaris*	0.0	5.2	0.82	1.10
Butterfish	*Odax pullus*	0.0	3.0	0.88	0.94
Butterfly perch	*Caesioperca lepidoptera*	0.0	11.7	1.24	3.13
Girdled wrasse	*Notolabrus cinctus*	0.0	6.3	0.79	1.42
Leatherjacket	*Meuschenia scaber*	0.0	2.2	0.51	0.65
Marblefish	*Aplodactylus arctidens*	0.0	0.5	0.04	0.12
Scarlet wrasse	*Pseudolabrus miles*	0.0	7.0	2.51	2.10
Southern pigfish	*Congiopodus leucopaecilus*	0.0	0.2	0.01	0.03
Spotty	*Notolabrus celidotus*	0.0	5.2	0.70	1.47
Tarakihi	*Nemadactylus macropterus*	0.0	2.5	0.11	0.49
Telescope fish	*Mendosoma lineatum*	0.0	23.3	1.32	4.90
Trumpeter	*Latris lineata*	0.0	2.0	0.36	0.58

miles), had the highest depth-averaged abundances (3.33 and 2.51 individuals per 25 m transect, respectively). Blue cod was also common across sites (Fig. 24), with the small (i.e. < 150 mm) and medium (i.e. 150–300 mm) size classes being most abundant (average abundance = 0.58 and 0.42 individuals per 25 m transect, respectively), and large blue cod (i.e. > 300 mm in size) being considerably less abundant (average abundance = 0.14 individuals per 25 m transect) (Table 9).

Spatial patterns of abundance for reef fishes showed contrasting patterns, with some species showing high inter-site variability throughout the Foveaux Strait region and others exhibiting lower inter-site variability in delimited areas of the region For example, banded wrasse generally had a high abundance along the northern edge of Stewart Island/Rakiura, but was variable elsewhere throughout the Foveaux Strait region (Fig. 24A). By contrast, small blue cod (< 150 mm) had a relatively higher abundance in the vicinity of Paterson Inlet/Whaka a Te Wera and Bluff,

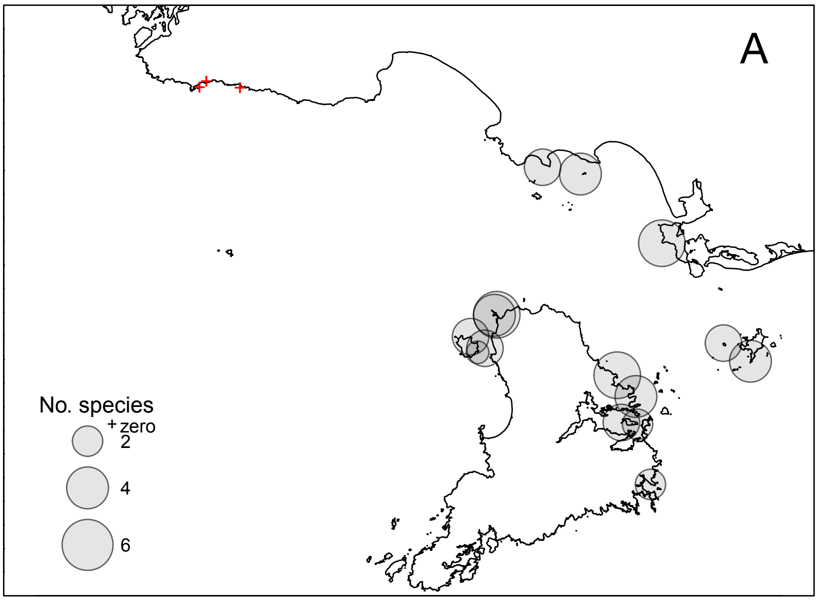


Figure 24. Spatial patterns of depth-averaged abundances per 25 × 5 m transect (125 m^2) for blue cod (*Parapercis colias*) at shallow subtidal reef sites in the Foveaux Strait region: A. all size classes.

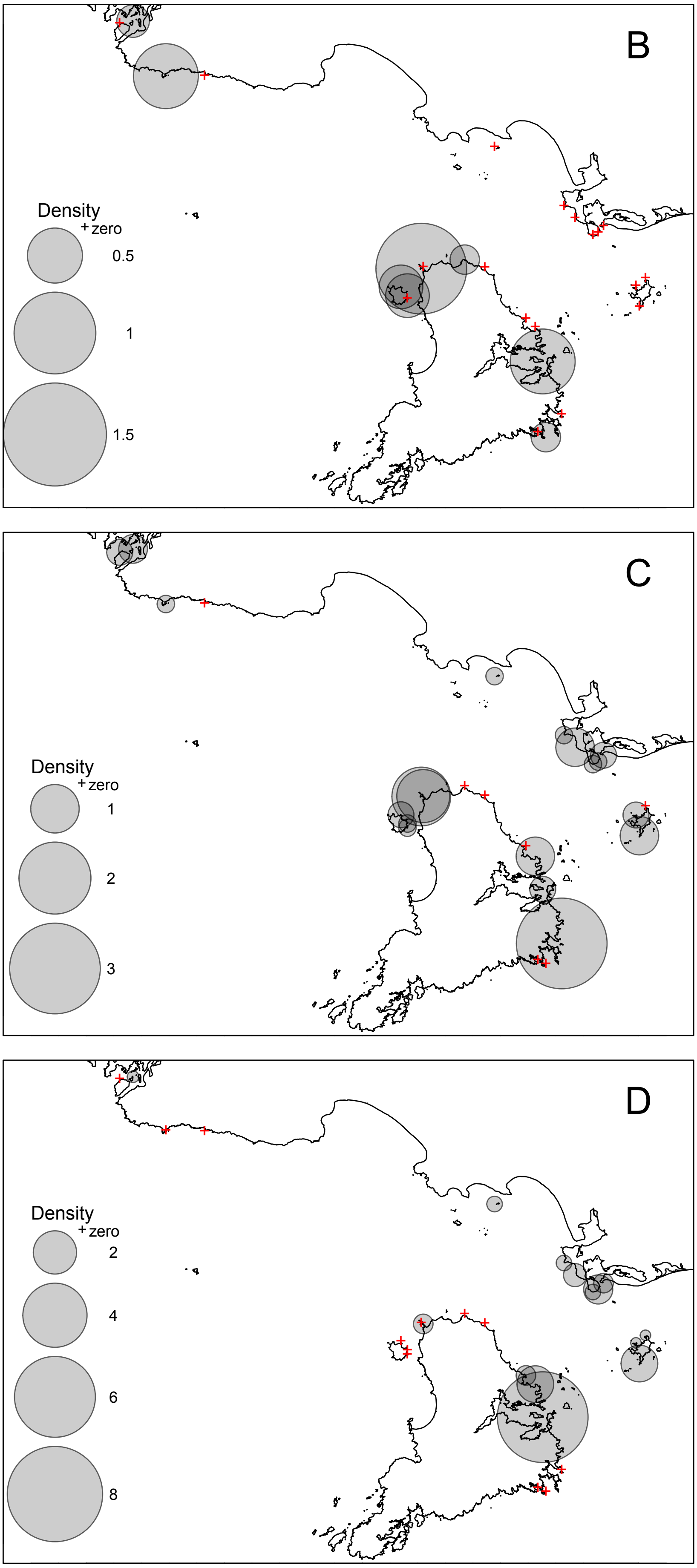


Figure 24 *continued*. Spatial patterns of depth-averaged abundances per 25 × 5 m transect (125 m^2) for blue cod (*Parapercis colias*) at shallow subtidal reef sites in the Foveaux Strait: region: B. large (> 300 mm fork length); C. medium (150–300 mm fork length); and D. small (< 150 mm fork length).

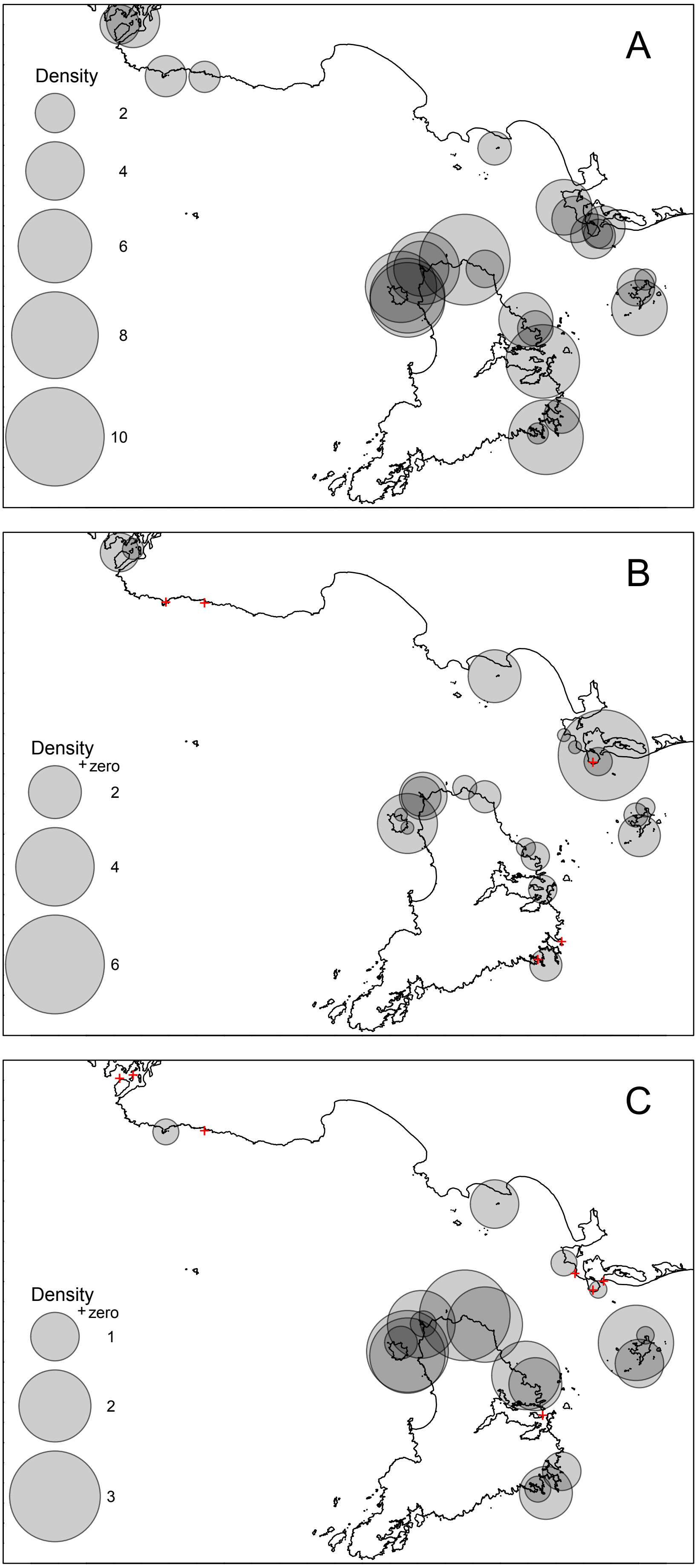
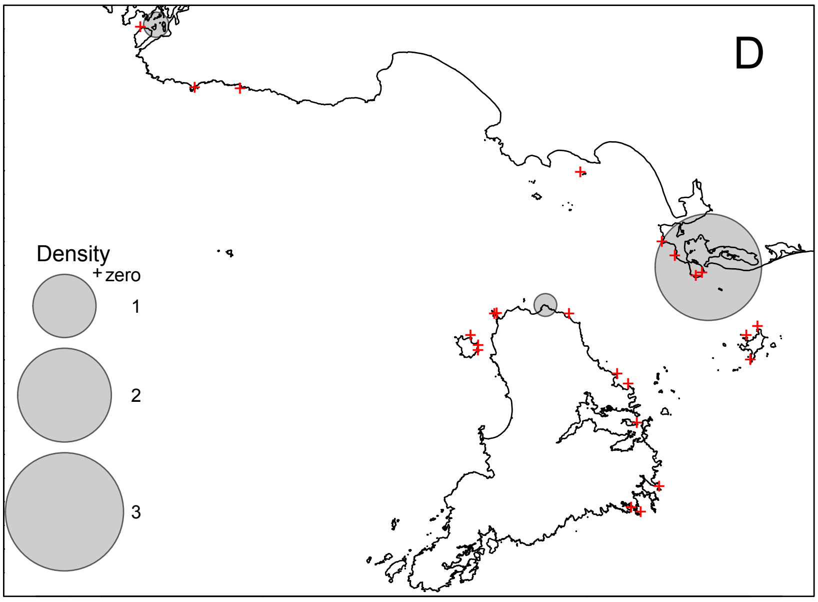
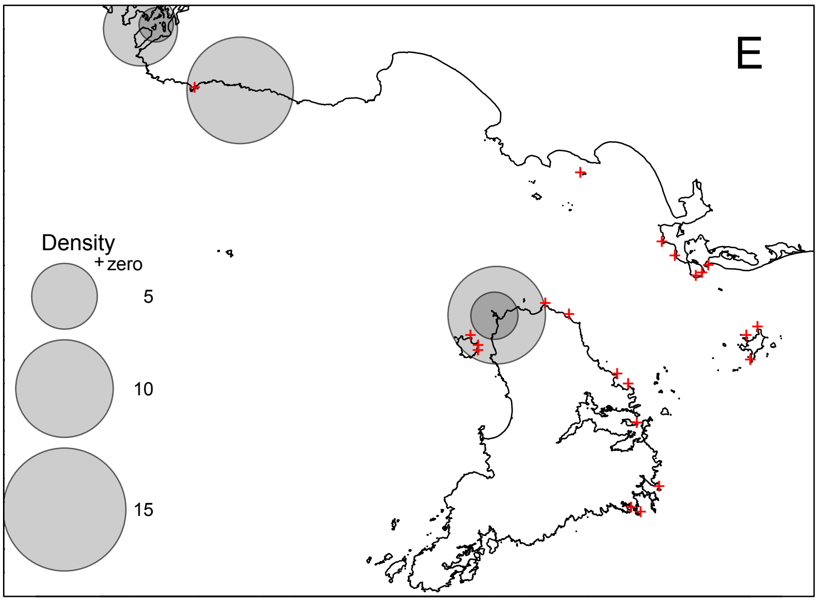


Figure 25. Spatial patterns of depth-averaged abundances per 25 × 5 m transect (250 m^2) of other reef fish species at shallow subtidal reef sites in the Foveaux Strait region: A. banded wrasse *Notolabrus fucicola*; B. blue moki *Latridopsis ciliaris*; C. butterfish *Odax pullus*.





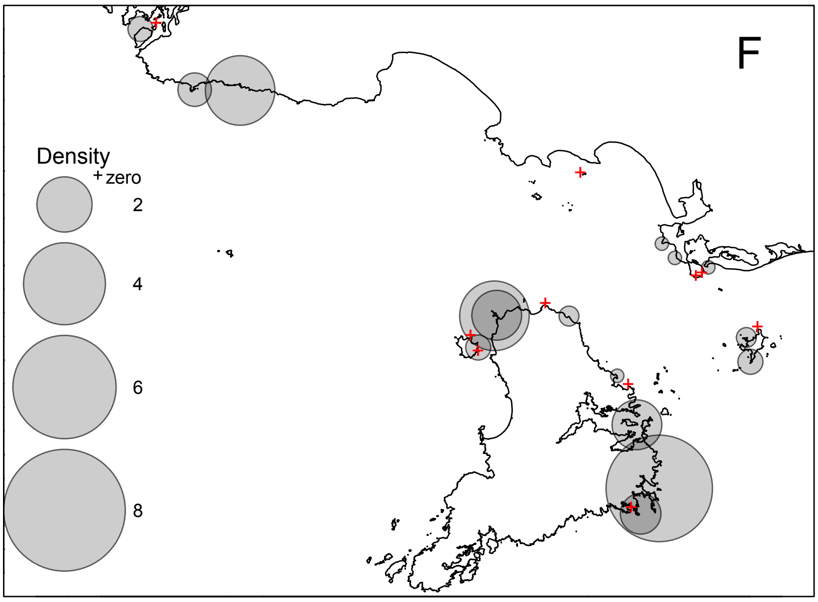


Figure 25 *continued*. Spatial patterns of depth-averaged abundances per 25 × 5 m transect (250 m^2) of other reef fish species at shallow subtidal reef sites in the Foveaux Strait region: D. tarakihi *Nemadactylus macropterus*; E. butterfly perch *Caesioperca lepidoptera*; F. marblefish *Aplodactylus arctidens*.

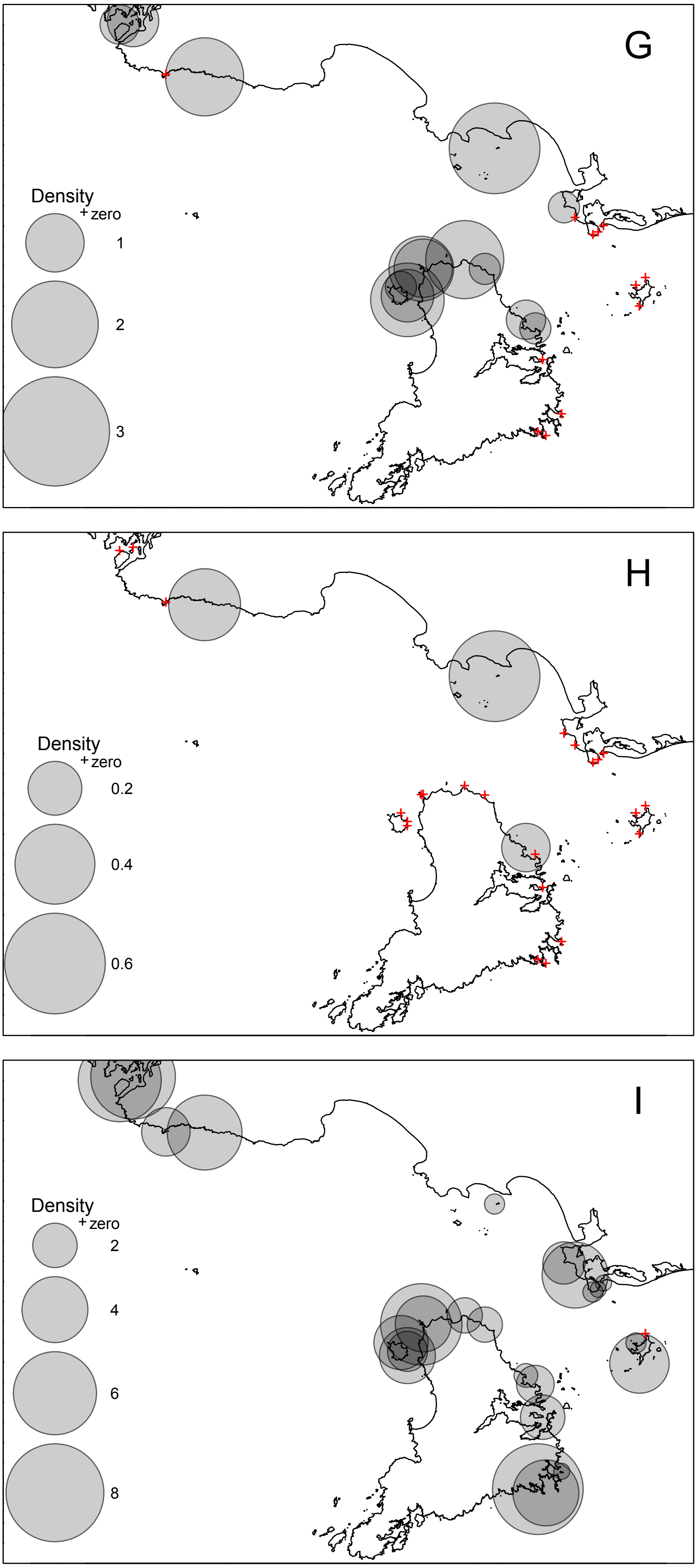


Figure 25 *continued*. Spatial patterns of depth-averaged abundances per 25 × 5 m transect (250 m^2) of other reef fish species at shallow subtidal reef sites in the Foveaux Strait region: G. girdled wrasse *Notolabrus cinctus*; H. leatherjacket *Meuschenia scaber*; I. scarlet wrasse *Pseudolabrus miles*.

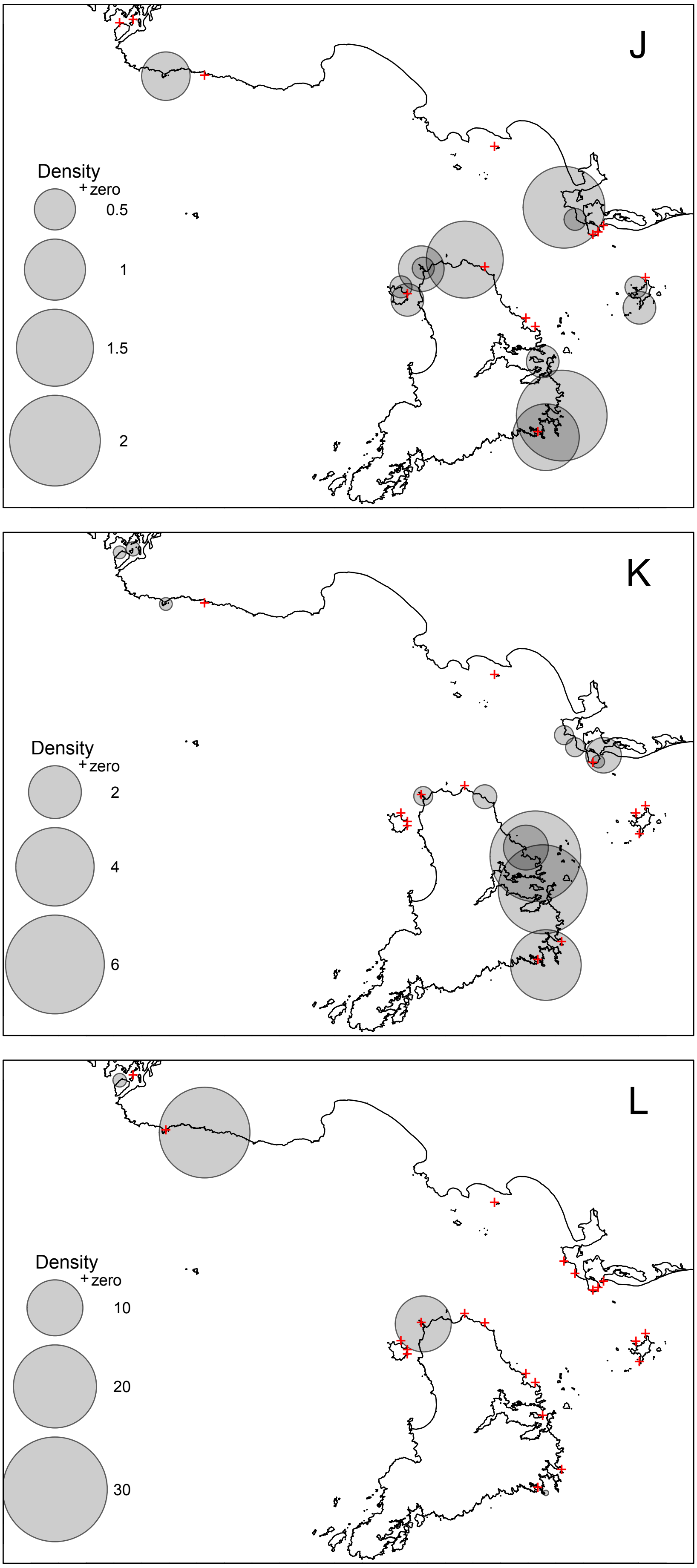


Figure 25 *continued*. Spatial patterns of depth-averaged abundances per 25 × 5 m transect (250 m^2) of other reef fish species at shallow subtidal reef sites in the Foveaux Strait region: J. trumpeter *Latris lineata*; K. spotty *Notolabrus celidotus*; and L. telescope fish *Mendosoma lineatum*.

but a generally low abundance elsewhere (Fig. 24D); while the larger size classes were more dispersed throughout the region, particularly those > 300 mm, which were most abundant in the most remote areas, such as Green Islets and Ruggedy Passage (Fig. 24B). Blue moki (*Latridopsis ciliaris*) showed a similar pattern, with areas of relatively higher abundance along the southern coast of the South Island and the northwestern tip of Stewart Island/Rakiura, but a generally low abundance elsewhere (Fig. 25B). Butterfish (*Odax pullus*) abundance was relatively high on the northern coast of Stewart Island/Rakiura, Codfish Island / Whenua Hou and Ruapuke Island, but relatively low in Paterson Inlet/Whaka a Te Wera and along the southern coast of the South Island (Fig. 25C).

Tarakihi (*Nemadactylus macropterus*) were only recorded on transects at three sites, with particularly high abundances at Tiwai Point (Fig. 25D) Butterfly perch (*Caesioperca lepidoptera*) had a relatively high abundance at two sites in the Foveaux Strait region and one site in Preservation Inlet, but a considerably lower abundance at all other sites surveyed (Fig. 25E). Similarly, marblefish (*Aplodactylus arctidens*) had a relatively high abundance at only two sites, which were located along the southern coast of the South Island (Fig. 25F). By contrast, girdled wrasse showed a highly variable pattern of abundance, with numerous sites of relatively higher abundance (including Prices Point, the Ruggedy Islands and Port Adventure), but nearby sites of intermediate abundance (Fig. 25G). Leatherjackets (*Meuschenia scaber*) had a high abundance in the vicinity of Codfish Island / Whenua Hou, the Ruggedy Islands and Pig Island, but generally had a lower abundance elsewhere throughout the Foveaux Strait region (Fig. 25H).

Scarlet wrasse had a more homogeneous abundance throughout the Foveaux Strait region, with areas of highest abundance towards the extremes of the region, including Preservation Inlet, the Green Islets and Lords River; other sites had moderate abundances, with the exception of coastal sites near Riverton (Oraka Point and Pig Island) (Fig. 25I). By contrast, trumpeter (*Latris lineata*) had a heterogeneous pattern of distribution, with sites of relatively high abundance scattered throughout the study region in proximity to areas of low abundance (Fig. 25J). Spotty (*Notolabrus celidotus*) had an area of relatively high abundance on the eastern edge of Stewart Island/Rakiura but generally lower abundances elsewhere in the Foveaux Strait region (Fig. 25K). Telescope fish abundance was low throughout most of the Foveaux Strait region, with only two sites of relatively higher abundance, at Prices Point and the Ruggedy Islands (Fig. 25L).

3.5.2 Patterns of species richness

The visual underwater censuses of reef fishes showed a more variable pattern of species richness than observed for cryptic fishes, with sites of relatively higher species numbers being found adjacent to locations with lower species numbers (Fig. 26). The highest species richness was observed at the two sites in the Ruggedy Islands (9 and 11 species), and Owen Island, Black Rock Pt, Sandfly Point and West Head (9 species each). By contrast, only 3 or 4 species were observed at Lookout Point, Lords River and North Head (Fig. 26).

3.5.3 Patterns of community structure

Multivariate analysis of 14 reef fish species across the 26 sites in the Foveaux Strait region showed that there was little clear grouping of site locations along the first and second principal MDS axes (Fig. 27A). There was a tendency for sites at the Codfish-Ruggedy Islands location to have a similar community structure to sites at Halfmoon Bay, Ruapuke Island, indicating some broad-scale grouping in the northern to northeastern region around Stewart Island/Rakiura. Sites in Preservation Inlet also appeared to be more similar to these sites than to other sites that were in closer proximity (Fig. 27A).

The abundance of most species tended to be negatively correlated with the first principal axis, with scarlet wrasse, butterfly perch and telescope fish having the highest negative correlations (Fig. 27B). Similarly, leatherjackets, marblefish and blue cod were negatively correlated with the second principal axis, while blue moki and spotty also contributed to the separation of sites along this axis (Fig. 27B).

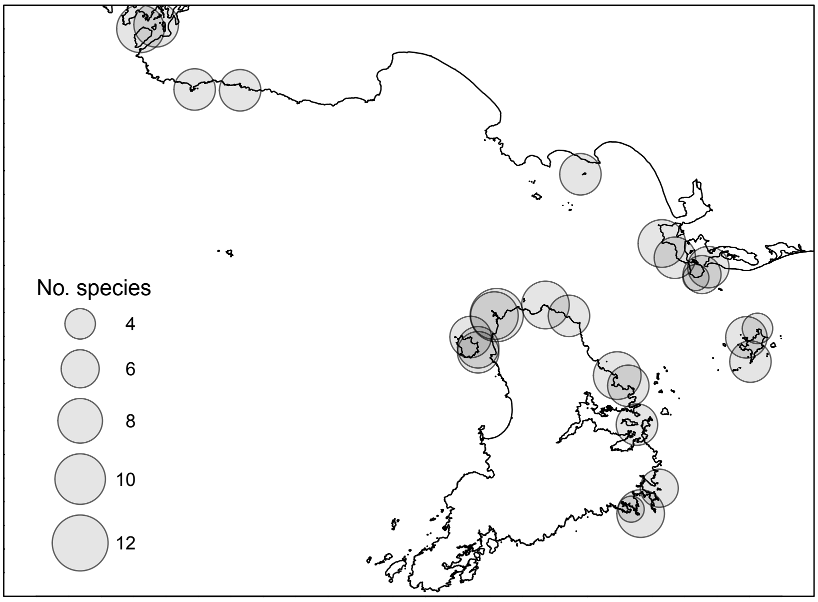


Figure 26. Spatial patterns of species richness for reef fishes at shallow subtidal reef sites in the Foveaux Strait region.

In terms of physical environmental parameters, geographic position (e.g. easting), maximum depth, slope and secchi depth were all correlated with the first principal MDS axis (Fig. 27C). Physical parameters tended to have a low correlation with the second principal MDS axis. Fetch did not have a strong correlation with either of the major axes.

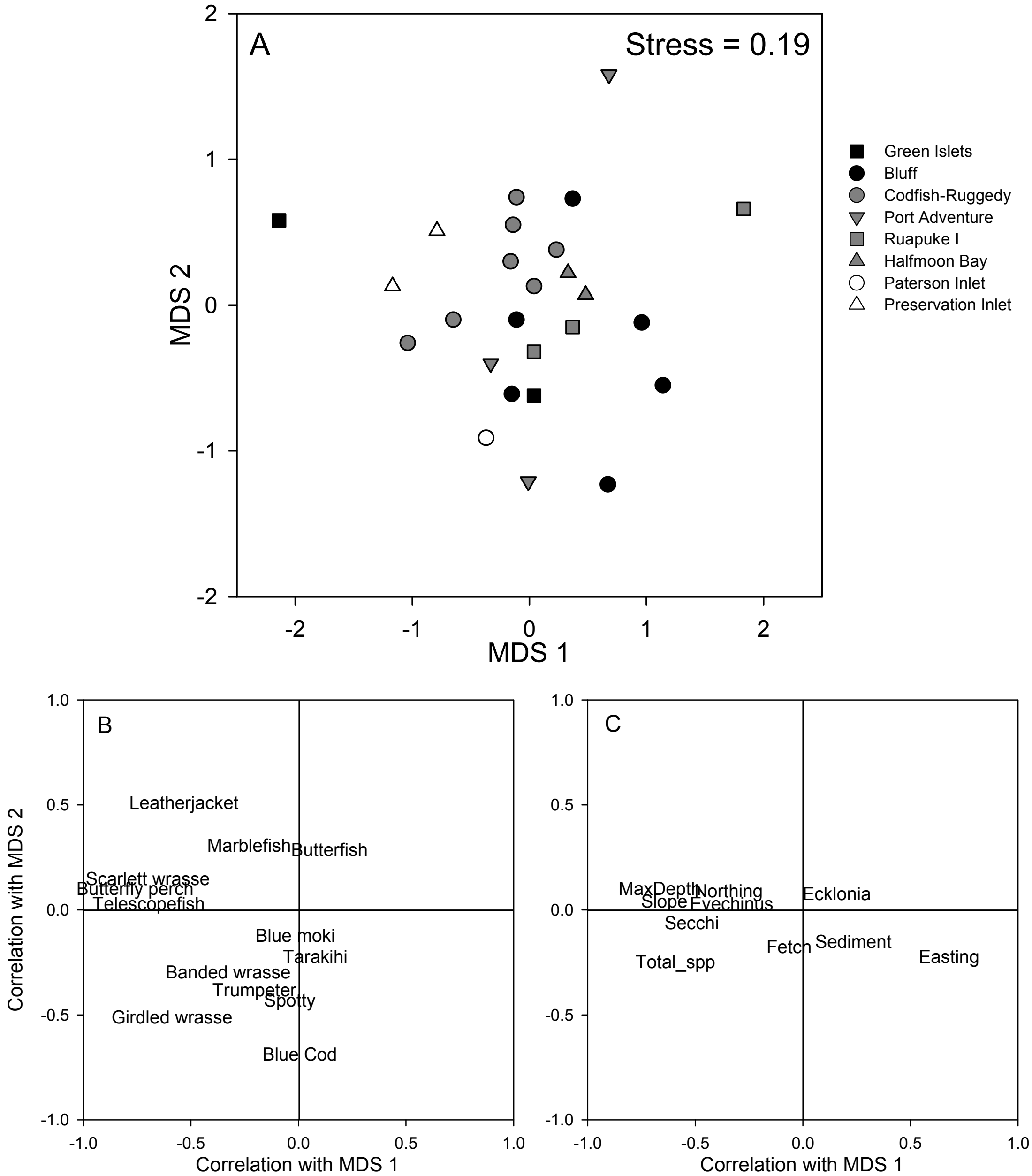


Figure 27. A. Multidimensional scaling (MDS) ordination based on the abundance of 14 reef fish species from shallow subtidal reef sites in the Foveaux Strait region, (log(x+1) transformed data; B. correlations between the abundance of reef fishes and MDS axes 1 and 2; and C. correlations between environmental variables and MDS axes 1 and 2.

4. Discussion

Shallow subtidal reef assemblages were quantified at 44 sites in the Foveaux Strait region from Preservation Inlet, Fiordland, through to Ruapuke Island and Port Adventure on the southeast coast of Stewart Island/Rakiura. This area represents a highly energetic, complex and dynamic part of the New Zealand coastline. Sites were sampled at locations that are exposed to prevailing southwesterly swells (e.g. Bluff and Green Islets), that are somewhat protected from large swells (e.g. Halfmoon Bay, Port Adventure) and that are subject to a variety of wave conditions (Codfish Island / Whenua Hou, Ruapuke Island and the Titi/Muttonbird Islands), as well as in highly protected embayments (e.g. Preservation Inlet and Paterson Inlet/Whaka a Te Wera). In general, reef community structure, species composition and the distribution of individual species were found to be highly variable between sites and locations. In most cases, this reflected large-scale environmental gradients, particularly differences in wave exposure between sites throughout the Foveaux Strait region.

4.1 Macroalgal assemblages

4.1.1 Species composition and distribution

Macroalgal species presence/absence data were initially analysed to investigate potential biogeographic differences between the sites and locations sampled. However, the results suggested that patterns in macroalgal species composition throughout the Foveaux Strait region reflect varying environmental conditions between sites rather than any clear biogeographic divisions. To summarise these patterns site groupings are overlayed on a map of the sites in Fig. 27 and relative differences in wave exposure (wind fetch) are also shown. The grouping of sites based on hierarchical cluster analysis broadly reflected large-scale differences in wave exposure between sites, with a general division between sheltered sites (Groups 1 and 2) and more exposed open coastal sites (Groups 3–6) at the 30% similarity level (Fig. 28). This division

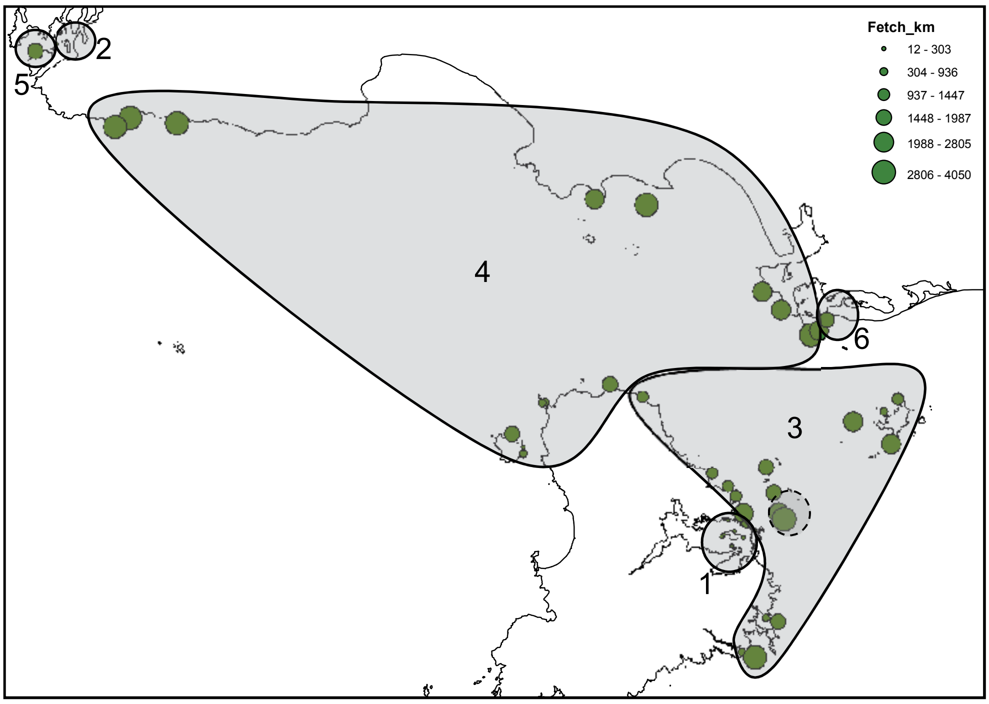


Figure 28. General grouping of shallow subtidal reef sites in the Foveaux Strait region based on macroalgal species composition (groups identified using hierarchical cluster analysis at the 55% similarity level; Figs 5 & A4.1). Division between sheltered (1 and 2) and exposed (3–6) groups is apparent at the 30% similarity level. Dashed circle indicates Bench Island sites, which were grouped in Group 4.

was largely due to sheltered sites having low species richness and an absence of many species that are common at more open coastal sites. The sites within Paterson Inlet/Whaka a Te Wera (Group 1) were grouped with the inner Preservation Inlet site (Group 2), despite these being two of the most widely geographically separated sampling locations. In both of these locations, sites on the outer coast had considerably different species composition and were highly segregated in multivariate space from the sheltered sites, despite often being less than 1 km away. Although the Preservation Inlet sites were divided between each of the two broad exposure groups, they formed discrete groups within each (Groups 2 and 5; Fig. 28), suggesting that these sites contain a rather unique assemblage of macroalgae compared with other Foveaux Strait region locations.

Based on algal species composition, the open coastal sites were divided into four groups at the 55% similarity level (Groups 3–6; Fig. 28). At this similarity level, there was no clear division between mainland and island sites, with sites from Green Islets and Bluff being grouped with sites from Codfish-Ruggedy Islands and the exposed Titi/Muttonbird Islands. However, at the 60% similarity level, the mainland and island sites were separated (Fig. A4.1, Appendix 4), with Ruapuke Island (which is relatively close to the mainland) being more closely grouped with sites in the eastern portion of the Foveaux Strait region (Halfmoon Bay, Titi/Muttonbird Islands and Port Adventure; Group 3), which are more protected from southwesterly swells than sites on the mainland. Therefore, the clustering of sites based on algal species composition also appears to reflect a large-scale gradient in wave exposure throughout the region. The two exposed sites at the entrance to Bluff Harbour formed their own distinct group (Group 6). While these sites did not contain any unique species, a number of species were present that were rare or absent from the other highly exposed mainland sites, e.g. *Carpophyllum flexuosum*, *Marginariella boryana* and *M. urvilliana*. These species were typical of more moderately exposed sites (e.g. Group 3), and so it is possible that the protection from southwesterly swells at the Bluff Harbour entrance allows these species to persist, in addition to other species that are common on the exposed mainland coast, e.g. *Ballia callitrichia*, *Callophyllis callibrepharoides* and *Rhodymenia obtusa*.

Lessonia variegata was by far the greatest contributor to total biomass among the sites sampled, making up 18% of the total biomass and occurring in 18% of the quadrats sampled. However, this species had a highly patchy and somewhat unpredictable distribution, as has previously been found nationally (Shears & Babcock 2007). In general, *L. variegata* was dominant at some of the most exposed sites sampled, such as Green Islets and some Bluff sites, but was conspicuously absent from others, e.g. Pig Island and Oraka Point. Similarly, at the offshore islands (Ruapuke Island, Codfish Island / Whenua Hou and Titi/Muttonbird Islands), it was abundant at some sites and absent from others, with no clear relationship with differences in wave exposure or any of the other environmental parameters measured.

Landsburgia quercifolia was the most commonly recorded large brown algal species (36% occurrence, 8.5% biomass), generally being most common and achieving the highest biomasses at the most exposed sites sampled (Group 4). *Xiphophora gladiata* was also very common (29% occurrence, 9.8% biomass), occurring at all sites except the Green Islets sites, Pig Island and Tiwai Point, and also generally achieved the greatest biomasses at exposed sites.

Ecklonia radiata was the second most abundant (by biomass) species recorded (10.0% biomass, 18.8% occurrence), but was only common at sites at Stewart Island/Rakiura and other offshore islands (e.g. Ruapuke Island) where there was some shelter from southerly and southwesterly swells. This species was not recorded at the two sites sampled in Preservation Inlet, but does occur in Dusky Sound (Villouta et al. 2001) and on the outer coast of the northern fiords (Shears & Babcock 2007). In general, *E. radiata* was absent from highly exposed sites and all the mainland sites sampled, which is consistent with the findings of Shears & Babcock (2007), who did not record it at sites at Otago Peninsula and The Catlins. However, *E. radiata* has been reported in Otago Harbour (Batham 1956) and observed on the outer coast at Karitane (J. Fyfe, Department of Conservation, pers. comm.). These patterns suggest that wave exposure, as well as other factors such as turbidity and water temperature, may be major determinants in controlling the distribution of this species. A number of other dominant species also had distributions that were comparable to *E. radiata*, being most common at moderately exposed sites (Group 3), e.g. *Marginariella urvilliana*, *M. boryana*, *Macrocystis pyrifera* and *Carpophyllum flexuosum*.

Durvillaea willana made up a considerable portion of the total biomass (7%) but was relatively rare (only 2.2% of quadrats) due to the occurrence of stands of large *D. willana* plants at a small number of sites (Pig Island, Tiwai Point and Lookout Point). *Durvillaea willana* is a dominant component of subtidal algal assemblages at exposed sites in the Otago-Catlins region (Shears & Babcock 2007); however, this species was only found at some exposed sites at Bluff (see above), the exposed site at Preservation Inlet and semi-exposed sites on the northeastern coast of Stewart Island/Rakiura (West Head, Bobs Point and Horseshoe Bay) in the present study. These contrasting conditions, alongside the absence of *D. willana* from the Green Islets, suggest that factors other than wave exposure influence the distribution of this species, e.g. water temperature or possibly hydrodynamics associated with reef topography and substratum type. Interestingly, sites with a high biomass of *D. willana* also had the greatest numbers of *Pyura pachydermatina*.

Further analysis of species distributions and species composition in relation to regional-scale variables such as temperature, tidal currents and nutrients may provide better insights into the potential processes controlling the observed patterns in the Foveaux Strait region.

4.1.2 Community structure

Patterns in macroalgal community structure were also strongly correlated with wave exposure, with a large division between sheltered sites and more exposed open coastal sites at the 40% similarity level (Fig. 9). Sites inside Paterson Inlet/Whaka a Te Wera and Preservation Inlet had low species richness and a very low overall biomass of dominant macroalgal groups, most likely due to the high abundances of the sea urchin *E. chloroticus* at these sites. By contrast, at open coastal sites, the numbers of sea urchins are generally lower and large brown macroalgal forests dominate. These findings are consistent with previous descriptions of subtidal assemblages at sites inside and outside Paterson Inlet/Whaka a Te Wera (Hare 1992), as well as previous findings of the contrasting pattern in sea urchin abundance and macroalgal biomass between embayments and open coastal sites in other parts of New Zealand, e.g. Marlborough Sounds, Abel Tasman National Park, Nelson and northeastern New Zealand (Shears & Babcock 2007). The only exception to this pattern was at the site in the upper reaches of Port Adventure (Browns Garden), where there were very few sea urchins and the algal assemblages were dominated by large brown algae (e.g. *Ecklonia radiata*, *Carpophyllum flexuosum*, *Xiphophora gladiata* and *Marginariella urvilliana*). Potential explanations for this contrasting pattern include possible differences in levels of sea urchin harvesting, fresh water or sediment inputs, predator abundance, or other environmental or oceanographic parameters affecting sea urchin recruitment and/or algal productivity at this site compared with those inside Paterson Inlet/Whaka a Te Wera. Additional sampling at Port Adventure as well as other inlets around Stewart Island/Rakiura (e.g. Port Pegasus) may provide further explanation for these contrasting patterns.

While the abundance of sea urchins likely explains some of the variation in algal community structure and overall biomass between 'Sheltered' and open coastal sites, there was also large variation in algal community structure between the open coastal sites. These sites were divided into three broad groupings (based on hierarchical cluster analysis), which generally followed a wave exposure gradient ('Semi-exposed', 'Exposed' and '*Durvillaea*'). The 'Semi-exposed' group generally included sites on the northeastern coast of Stewart Island/Rakiura and the most sheltered sites from the Titi/Muttonbird Islands and Port Adventure. These sites were dominated by a dense canopy of large brown algae, including *Macrocystis pyrifera*, *Ecklonia radiata*, *Marginariella* spp., *Carpophyllum flexuosum* and *Xiphophora gladiata*. Sea urchins were generally rare, except at the two sites at the entrance of Paterson Inlet/Whaka a Te Wera.

The 'Exposed' group included three subgroups: 'Moderately exposed', 'Highly exposed' and 'Extremely exposed'. The 'Moderately exposed' subgroup included sites that had some protection from southerly and southwesterly swells, e.g. on the eastern side of Codfish Island / Whenua Hou, Ruggedy Islands, Port Adventure and Ruapuke Island. Algal communities typically consisted of a mixed canopy of large brown algae, particularly *Xiphophora gladiata*, *Lessonia variegata* and *Landsburgia quercifolia*, but a number of species that were more typical of the 'Semi-exposed' group were also recorded, e.g. *Ecklonia radiata*, *Carpophyllum flexuosum*, *Marginariella urvilliana* and *M. boryana*. These species were generally absent from the 'Highly exposed' subgroup, which included sites that were more exposed to southwesterly and southerly swells at Bluff, Codfish Island / Whenua Hou, Titi/Muttonbird Islands and Ruapuke Island. These sites had a relatively open canopy, a lower large brown algal biomass (predominantly *Landsburgia quercifolia* and *Xiphophora gladiata*, but also *Lessonia variegata* and *Cystophora platylobium* at some sites), and high biomasses of red and green algae (in particular *Caulerpa brownii*). The 'Extremely exposed' subgroup included the Green Islets sites, which were highly exposed to the southwest. Algal assemblages at these sites were dominated by *Lessonia variegata* and red foliose algae across all depths, and *Landsburgia quercifolia* and coralline turf were also important components. The organisation of algal assemblages at these sites was very similar to very exposed sites on the Catlins-Otago coast (Shears & Babcock 2007), the main difference being that *Durvillaea willana*, which forms large stands in the shallow subtidal region at The Catlins, was not recorded at the Green Islets. The '*Durvillaea*' group included two exposed sites (Stirling Point and Tiwai Point), which had a fairly unique algal community structure, with stands of *D. willana* extending down to 4–5 m depth.

The grouping of sites based on algal community structure described above generally corresponded with broad-scale differences in wave exposure between sites. This was supported by a strong concordance between the groupings and wind fetch measurements for each site, which were used as a proxy for wave exposure. Wind fetch appears to provide reasonable explanatory power, but it does not take into account prevailing swell direction or refraction. Therefore, a more accurate estimate of wave exposure may explain greater variation in assemblages between sites. A number of other variables also co-varied with wind fetch. For example, sediment cover and sea urchin abundance were highest at sites with low wind fetch. Sediment cover is negatively correlated with wave exposure due to high levels of resuspension at exposed sites and high levels of sedimentation on reefs in sheltered areas, e.g. Paterson Inlet/ Whaka a Te Wera. Sedimentation has been shown to have negative effects on juvenile sea urchin survival and settlement (Walker 2007). However, sea urchins tended to be most abundant in these locations in the present study, suggesting that the levels of sedimentation at the sheltered sites were not sufficient to inhibit them – indeed, sedimentation rates in both Paterson Inlet/ Whaka a Te Wera and Preservation Inlet are thought to be relatively low, and therefore is unlikely to have an important influence on marine communities in these areas (Hare 1992). The higher abundances of sea urchins, and potentially other mobile macroinvertebrates, in these sheltered inlets compared with open coastal sites is likely to be due to greater retention of larvae, as has been proposed for sea urchins in Fiordland (Wing et al. 2003). Wave action itself may also influence the abundance of sea urchins, particularly in shallow water (Shears & Babcock 2004a), and this was seen in this study, with sea urchins appearing to be restricted to dense aggregations in deep water (> 10 m), and not appearing to form the grazing fronts and urchin barrens habitat that are seen in sheltered areas and in northern New Zealand (Shears & Babcock 2007). Consequently, sea urchins appear to have a fairly localised effect on algal assemblages at the majority of exposed sites. However, the effect of commercial harvesting on the observed distribution patterns is unknown. Therefore, information on harvesting levels, along with other environmental factors such as tidal currents, sediment and freshwater input, may help explain the observed patterns in sea urchins.

The organisation of algal assemblages varied greatly with depth. In northern New Zealand, macroalgae have been described as having a bimodal depth distribution, with a shallow fucalean assemblage and deep *Ecklonia* forests, but reduced algal biomass at mid-depths as a result of sea urchin grazing (Choat & Schiel 1982). A similar bimodal algal distribution has also been recorded in Dusky Sound (Villouta et al. 2001). However, in the present study, this was only recorded at two of the Foveaux Strait region sites (Tia Island and Herekopare), where dense stands of *E. radiata* occurred in deeper water. Instead, at the majority of sites, algal biomass was found to decline with depth, with an absence of the large, high biomass algal stands that are common at depths of 8–12 m in northeastern New Zealand. This may be due to a number of factors, such as a high abundances of sea urchins at greater depths (e.g. Paterson Inlet/Whaka a Te Wera and Preservation Inlet), low light levels (high turbidity), low nutrients, and high levels of sedimentation and sand-scour. There was no clear relationship between turbidity (estimated by secchi disc) and algal species composition or community structure; however, sampling was carried out during optimal conditions so that water clarity was relatively good at most sites (except Oraka Point (< 5 m)) at the time of sampling. Turbidity is likely to be important in restricting the depth distribution of large brown algae along the mainland coast (particularly at Bluff) due to large sediment inputs from rivers and high levels of resuspension. This was reflected in the analysis of the benthic structural groups, sampled concurrently with the macroalgal communities. This suggested a relationship between turbidity and the cover of ascidians and sponges, with sites from Bluff having the highest covers of these groups. Encrusting invertebrates typically dominate highly exposed and turbid reefs around New Zealand, e.g. sites at Westland, Buller and Raglan (Shears 2007).

4.2 Epifaunal invertebrate diversity

For sessile invertebrates, there were highly variable patterns of diversity over tens of kilometres within the greater Foveaux Strait region, with sites in relatively close proximity showing large differences in species density, turnover diversity and species richness (Fig. 13). There was a general broad-scale pattern of areas along the east coast of Stewart Island/Rakiura and in the lee of Codfish Island / Whenua Hou having relatively higher variation in species density. Since variation in species density can be considered a measure of the ‘patchiness’ of epifaunal invertebrate assemblages, this suggests that broad-scale variation in ecological processes may contribute to this pattern. The high variation in species density seen along the eastern coast of Stewart Island/Rakiura raises some interesting questions about which physical variables may be contributing to this pattern. Colonies inhabiting areas of higher wave stress may experience increased dislodgement or have greater variation in recruitment into localised reefs. Since smaller-scale patchiness tends to be attributed to biological disturbance (e.g. grazing from sea urchins), this broad-scale pattern could also be a result of the interaction between physical and biological variables on subtidal rockwalls – that is, in areas of lower wave stress, consumers may play a more important role in contributing to the variation in species numbers at the quadrat level than in areas of higher wave stress. Analyses of the physical environmental variables at these sites combined with information on the consumer assemblages may be able to distinguish between these hypotheses.

The lack of any clear spatial patterning for the other diversity indices suggests that ecological processes at smaller spatial scales contribute to the observed patterns across the entire Foveaux Strait region. Areas with higher species density and richness tended to occur in areas of potentially higher tidal currents, suggesting that this may be a key driver of biological processes within the region. A finer scale (i.e. 50 m to 250 m resolution) tidal current model for the region could help to determine the degree to which this forcing is tied to local topography.

4.3 Mobile macroinvertebrates

4.3.1 Shallow subtidal reefs

On shallow subtidal reefs, mobile macroinvertebrate assemblages exhibited a gradient in species composition that was associated with wave exposure, similar to that seen for macroalgae. In general, mobile macroinvertebrates were rare at open coastal sites in the Foveaux Strait region, which is typical for much of the New Zealand coastline (Shears & Babcock 2007). Instead, the highest abundances tended to occur in sheltered embayments (Paterson Inlet/Whaka a Te Wera and Preservation Inlet) where sea urchins, herbivorous gastropods (e.g. *Trochus viridis*, *Cellana stellifera* and *Turbo smaragdus*), sea stars (e.g. *Patiriella* spp.), holothurians (e.g. *Australostichopus mollis*) and ophiuroids (*Ophiopsammus maculata*) were most common. This is possibly related to greater retention of larvae within these embayments compared with the open coast. The only exceptions to this were the sea stars *Pentagonaster pulchellus* and *Diplodontias* spp., and the yellow-foot pāua *Haliotis australis*, which were typically more common at open coastal sites.

Sea urchins were also common in deeper water (> 10 m) at some of the exposed sites sampled, e.g. Green Islets and Codfish Island / Whenua Hou, where they were found in dense aggregations. The populations at these sites were comprised of very large individuals (100–190 mm test diameter), with very few juveniles recorded, suggesting that these populations are predominantly recruitment limited (Wing et al. 2003). Consequently, these populations are likely to be highly vulnerable to commercial-scale harvesting of sea urchins, which was observed to be occurring in many of the locations sampled, e.g. Green Islets and Bluff (pers. obs.).

The black-foot pāua *Haliotis iris* has historically been heavily fished in this region (Annala et al. 2004) and very few individuals were recorded during this study (n = 27). The highest numbers were recorded at sites at Ruapuke Island where commercial fishing is prohibited, but densities were still below 0.5/m^2. None of the large aggregations of pāua that Stewart Island/Rakiura was once famous for were observed.

4.3.2 Subtidal rockwalls

Along rockwalls, the distribution of mobile macroinvertebrates showed several different patterns of abundance, with some species having a relatively high abundance in limited areas of the Foveaux Strait region (e.g. *Ophiopsammus maculata*, *Australostichopus mollis*, *Chromodoris aureomarginata*) and other species having a less-variable pattern across the region (e.g. *Pentagonaster pulchellus*). Some species (e.g. *Evechinus chloroticus*, *Coscinasterias muricata*) showed a more variable pattern, with sites of high abundance proximal to sites of comparatively lower abundance (e.g. Figs 17A & 17F). These patterns suggest that different species of mobile macroinvertebrates may respond in different ways to physical environmental parameters. For example, species that have limited areas of high (or low) abundance and/or less variation across space may be responding to some physical environmental cue that varies at that same spatial scale. Patterns that are more highly variable in space are more difficult to explain using physical environmental parameters, except where these may potentially vary at the scale of individual sites (e.g. wave exposure). The community analysis of mobile macroinvertebrates from rockwalls suggests that fetch and the percent cover of sediment influence the species composition of sites (Fig. 20). Therefore, more detailed analysis may provide more information on the relative importance of these factors in explaining spatial trends in abundance.

Some species were present at relatively high densities at some sites but were not widely distributed throughout the region (e.g. *Astraea heliotropium* and *Maoricolpus roseus roseus*; Fig. 18I & 18J). This raises questions about which factors are responsible for constraining local dispersal and population numbers across different taxonomic groups (e.g. gastropods v. echinoids). Comparison of these patterns with those of species that are more widely distributed may provide some insight into which physical conditions may be restricting the occurrence of some species or enabling some populations to attain higher local densities.

The compilation of similar datasets nationwide would provide an opportunity to address questions about the generality of patterns observed within the Foveaux Strait region and allow for a better understanding of how ‘representative’ these patterns are in a broader spatial context.

4.4 Cryptic fishes of subtidal rockwalls

Cryptic fishes (six species of triplefin) tended to occur along prominent headlands in the region. The exception to this general trend was the common triplefin, which tended to be most abundant in inlets of Stewart Island/Rakiura (Fig. 21D). No triplefin species were found in the Green Islets (towards Puysegur Point), suggesting that there could be aspects of the physical environment that preclude the occurrence and/or higher abundance of triplefins in this area (e.g. wave stress).

Some species occurred at few sites but in relatively high abundances (e.g. the oblique-swimming triplefin), suggesting that local site conditions may be important for the distribution of these species (e.g. higher tidal currents, clearer water). Alternatively, behavioural responses (e.g. schooling behaviour) may account for the high local abundances of some species. Further analysis of which environmental conditions are correlated with these distribution patterns may provide insight into which factors allow these species to obtain higher relative abundances.

4.5 Reef fishes

There was considerable variation in the levels of abundance of reef fishes in the Foveaux Strait region. This may in part be due to the relatively low sample size at each site (n = 5–6 transects), but also due to the complex nature of the coastline and reef topography in this region. Despite this variability, the level of sampling carried out was deemed to sufficient to provide a general characterisation of the reef fish assemblages at each site. Banded wrasse, scarlet wrasse and girdled wrasse were well represented, having depth-averaged abundances of 3.33, 2.51 and 0.79 fish per 5 × 5 m transect, respectively. Since labrids have been identified as key consumers on rocky reefs (e.g. Jones & Andrew 1990), the relatively larger numbers of these fish suggest that their feeding may be significant at individual reef sites. It should be noted, however, that these fish are also notorious for being attracted to divers and areas disturbed by divers (pers. obs.), so it is uncertain to what degree these patterns reflect diver-positive behaviour of these wrasse species.

Planktivorous fish, such as butterfly perch and telescope fish, also had a relatively high abundance, but were only present at such abundance at two to three locations throughout the study region (Table 9; Figs 24E & 24L). Schools of these fish are often associated with rock walls and pinnacles near to deep water. The occurrence of these fish schools may be highly variable through time and may not be reliably surveyed with one-off diver surveys. Blue moki, leatherjackets and blue cod (< 300 mm) had intermediate levels of abundance, with overall averages between 0.65 and 0.8 fish per 25 m transect. Marblefish, southern pigfish (*Congiopodus leucopaecilus*) and large blue cod (> 300 mm) were generally present in low abundances, potentially due to these species (particularly southern pigfish and marblefish) having specific habitat requirements.

Several different spatial patterns of abundance were observed for the different reef fish species. Some species (or size classes of species) had their centres of abundance in relatively restricted areas (e.g. the east coast of Stewart Island/Rakiura) – e.g. blue cod < 150 mm, spotty and leatherjackets. This could reflect differences in the relationships between physical environmental factors (such as current flow or sea surface temperature deviations), or result from larger scale recruitment processes occurring throughout the region. By contrast, other species had areas of high abundance spread throughout the Foveaux Strait region, but these were separated by sites of low abundance – e.g. girdled wrasse, banded wrasse and trumpeter. This pattern could reflect a response to physical conditions that vary at more localised scales and/or the association of adult fishes with particular habitat features. It is also unknown how fishing effort affects the size and distribution of reef fish in this region.

The number of species of cryptic fishes and reef fishes showed different degrees of spatial heterogeneity. Cryptic fish richness was relatively constant across sites, but these fishes were largely constrained to the Stewart Island/Rakiura and eastern areas of the Foveaux Strait region

(Fig. 22). By contrast, reef fishes were documented across the entire region, but with more variable species numbers between sites (Fig. 26). This suggests that the distributions of these fishes are likely to be explained by different causal processes and/or physical environmental factors that vary over local scales and across the entire region. It is uncertain to what extent observer bias, sampling effort, fish behaviour and physical conditions at the time of survey (e.g. water clarity) influenced these patterns – although cryptic fishes are not thought to be disturbed to the same extent as reef fishes and counts occurring within a delimited area from close distance are likely to provide more consistent counts across sites, there could be some variation in the reliability of counts between areas containing different levels of invertebrate or macroalgal cover.

Sites that contained a relatively higher abundance and number of species of reef fishes occurred next to sites of lower abundance. This suggests that trophic interactions at individual reef sites may vary considerably at the scale of kilometres, which will have flow-on effects to observed patterns in the benthic flora and fauna. Therefore, a more complete analysis of the overlap in distributions of key fish consumers, mobile macroinvertebrates, and benthic macroalgae and epifaunal invertebrates may provide some insight into the spatial scale at which such overlaps occur and lend further support to hypotheses about differences in the functional ecology of different reef sites. Comparisions with survey data for reef fishes and cryptic fishes would also provide a better understanding of how 'representative' these assemblages are at a regional and national scale.

4.6 Bioregional classification of Foveaux Strait region locations

One of the primary aims of this study was to determine how reef assemblages in the Foveaux Strait region fit into a national perspective. To this end, data on macroalgal species composition (presence/absence) collected in the present study have been analysed alongside existing data from over 200 sites across New Zealand (Shears & Babcock 2007; Shears et al. 2008). A variety of classification analyses were carried out by Shears et al. (2008), but it was found that macroalgal species composition data (presence/absence) had the highest concordance with previous biogeographic classifications of mainland New Zealand. Not surprisingly, Shears et al. (2008) found that the Foveaux Strait region sites were clustered in the Southern New Zealand biogeographic province. The majority of sites sampled in the present study were grouped together and considered to be part of the Stewart Island bioregion. However, Preservation Inlet was grouped with locations from the Fiordland bioregion and the Green Islets were more closely grouped with locations in the Chalmers bioregions (The Catlins and Otago). The latter was largely due to the absence of some key species that are common in other Foveaux Strait locations (e.g. *Cystophora* spp., *Marginariella* spp.) and suggests that the Green Islets are a unique part of the Foveaux Strait – however, further analysis of the data at a higher taxonomic resolution is needed to explain this discontinuity.

4.7 Regional and global comparisons of epifaunal diversity

The rockwalls of the Foveaux Strait region had similar levels of diversity to Fiordland (for all indices) and almost twice as many species per quadrat at the site level as the Hauraki Gulf (Table 10). The average variation in species density was higher for the Foveaux Strait region than for the Hauraki Gulf and Fiordland; however, post-hoc tests showed that the difference between the Foveaux Strait region and Fiordland was not significant. There were no significant differences in turnover diversity (measured as Routledge's β_I) between locations, with a P value of 0.141 (Table 10). There was a significant difference in the observed number of species and the Chao 2 species estimator between locations ($P < 0.0001$), although post-hoc tests again showed that Foveaux Strait and Fiordland had similar values.

Table 10. A. Comparative data on epifaunal diversity in the Hauraki Gulf (HG), Fiordland (FD) and the Foveaux Strait region (FS); numbers in parentheses are the standard deviations of the mean for each index. B. The results of a one-way analysis of variance and post-hoc Tukey HSD tests, with different letters denoting significant differences.

A

LOCATION	NUMBER OF SITES	SPECIES DENSITY (SD)	VARIATION IN SD	TURNOVER DIVERSITY	No. SPECIES (S_{obs})	SPECIES RICHNESS (Chao 2)
Hauraki Gulf	38	14.11 (± 4.36)	4.00 (± 1.22)	0.77 (± 0.19)	43.95 (± 14.52)	54.98 (± 19.61)
Fiordland	23	24.22 (± 4.12)	4.57 (± 1.37)	0.85 (± 0.12)	78.39 (± 13.14)	96.62 (± 16.42)
Foveaux Strait	18	25.97 (± 4.23)	5.04 (± 1.29)	0.84 (± 0.08)	83.72 (± 12.54)	101.94 (± 15.99)

B

FACTOR	r^2	*F*-ratio	*P* value	HG	FD	FS
Species density	0.631	64.991	<0.0001	A	B	B
Variation in SD	0.101	4.276	0.0174	A	A/B	B
Turnover diversity	0.050	2.009	0.1411	A	A	A
No. species (S_{obs})	0.653	71.769	<0.0001	A	B	B
Species richness (Chao 2)	0.061	59.536	<0.0001	A	B	B

These results suggest that similar ecological processes are occurring at the quadrat and site level in Fiordland and the Foveaux Strait region. This is despite the majority of sites within the Fiordland dataset being from the mid- to inner fjord region, and thus representing a different range of physical environmental conditions than those seen in most areas of the Foveaux Strait region – with the possible exception of sites in Paterson Inlet/Whaka a Te Wera and Port Adventure. These similar levels of diversity despite differences in physical environmental conditions may indicate that regional processes are contributing to the observed patterns of diversity (Smith 2001; Witman et al. 2004).

The observed differences between the southern part of the South Island and the Hauraki Gulf are more difficult to explain. Since the Hauraki Gulf represents a larger basin, regional processes may contribute to local patterns in a different way from the Foveaux Strait region and Fiordland. Further analyses of the spatial, physical and biological variables at each of these locations may provide insight into the relative importance of regional processes in each of these regions.

The levels of species richness (Chao 2 index) observed in the Foveaux Strait region are similar to those found in the Caribbean, South Africa, Antarctica and the Seychelles (Witman et al. 2004). Sites that had a richness below 120 are typical of marine sites at a global scale. However, individual sites with a site-level richness of >135 species are considered particularly species rich. Horseshoe Point had a Chao 2 estimation of 135.18 species, comprised of 37% ascidians, 26% bryozoans and 27% sponges, ranking it among the richest sites globally. High species numbers have also been found to occur in Fiordland, with Bauza Island also ranking within the >135 species group (Witman et al. 2004). In this study there was a large biomass of ascidians and sponges, at Horseshoe Point but it is not clear why this particular site has such high species richness. An analysis of body (or colony) size may provide some insight into the relative number of species that are 'packed' at the local level versus trends in biomass.

These data on the diversity of subtidal epifaunal assemblages can contribute to the development of a marine environment classification for the greater Foveaux Strait region by providing a consistent regional dataset. This will enable validation of the importance of individual physical layers and the biological relevance of the overall classification. Finer-scale physical information would provide a means to test the generality of results obtained in other locations (e.g. the Hauraki Gulf and Fiordland) and would support any decision-making that is more pertinent to the Foveaux Strait region. For example, a risk assessment for the establishment of introduced species in the Foveaux Strait region based on results from Fiordland or the Hauraki Gulf may not be valid if these regions have different relationships between biological patterns (and processes) and physical environmental layers. By contrast, if there are similarities between the types of physical layers and the biological 'responses' to those layers between these regions (or a subset of regions), it would provide additional support for management decisions/actions in these regions.

4.8 Conservation and management implications

Historically, the Foveaux Strait region has supported large inshore commercial fisheries for species such as black-foot pāua, rock lobster and blue cod. There is also now increasing pressure on the coastal marine environment in this region from newly established fisheries (e.g. sea urchins / kina), increased tourism and, subsequently, recreational fishing pressure on species such as blue cod. The impacts that the removal of many of these species would have on the patterns observed in the present study are unknown. As well as having direct effects, such as the extremely low numbers of pāua recorded, these fisheries are also likely to have indirect effects. For example, there is strong evidence that the overfishing of predators (predominantly snapper and rock lobster) has resulted in an increase in sea urchins and a decline in kelp forests in many parts of northern New Zealand (Babcock et al. 1999; Shears & Babcock 2002, 2003). Similar indirect effects may explain the proliferation of sea urchins and absence of large kelp forests at the sites sampled in Paterson Inlet/Whaka a Te Wera and Preservation Inlet. Sea urchins have been shown to affect algal species composition in southern Fiordland (Villouta et al. 2001) and therefore there is potential for the removal or recovery of predator species such as rock lobster and blue cod to result in changes in algal communities in parts of the fiords and around Stewart Island/Rakiura. However, such indirect effects are not likely to occur at all of the Foveaux Strait region sites, as other factors may restrict the distribution of sea urchins (Shears & Babcock 2004b). Furthermore, the establishment of a sea urchin fishery is likely to mask such indirect effects. While pāua were only recorded in low numbers at Stewart Island/Rakiura sites, anecdotal reports from a former commercial fisherman suggest that they used to be extremely abundant at many of the sites examined, occurring in patches devoid of macroalgae.The sampling design used in this study was not designed specifically nor appropriate to estimate pāua populations; more targeted surveys would be needed to better understand paua populations in this region. In general, the ecological role of pāua on reefs in this region, and their interactions with sea urchins and rock lobsters, are poorly understood, and fishing at multiple trophic levels severely compromises our ability to separate anthropogenic impacts from the 'natural' dynamics of the system, as has been shown in California (Dayton et al. 1998).

Under the New Zealand Biodiversity Strategy (DOC & MfE 2000) the New Zealand Government committed to protect 10% of habitats and ecosystems in MPAs. The information collected in the present study provides an initial assessment of general patterns in biodiversity on shallow reef habitats in the Foveaux Strait region. This will be an important basis for management decisions when assessing the representativeness and/or uniqueness of future marine reserve locations. From the initial sampling, Foveaux Strait region sites were divided into six groups based on algal species composition and algal community structure. The algal species composition analysis tended to reflect bioregional differences between sites, e.g. algal assemblages at Preservation Inlet were generally distinct and this area is likely to be more closely grouped with other southern fiord sites than with Foveaux Strait region locations. By contrast, the community structure analysis grouped sites with similar community types, reflecting ecological processes rather than bioregional patterns. In both cases, only one of the groups identified (Paterson Inlet/ Whaka a Te Wera) currently has any form of protection. Paterson Inlet/Whaka a Te Wera appears to be fairly unique at a national level and is currently protected by a mataitai, but also includes a small complex marine reserve. The present study identified a number of locations that contained a wide variety of community types within a relatively small geographic area, such as some of the island locations (e.g. Codfish-Ruggedy Islands and Titi/Muttonbird Islands). Therefore, the establishment of a few large reserves with simple boundaries that include a variety of the community types identified would provide the most ecologically effective and economically viable way of achieving the goals set out in the New Zealand Biodiversity Strategy. Further exploration of wave exposure as a surrogate for broad ecosystem types would potentially be of valuable for future marine protected area planning in the region.

The establishment of marine reserves would provide an opportunity for the localised recovery of some of the species present in this region, to examine the interactions between species and to better understand the ecological effects of fishing in this region. In particular, the establishment of reserves appears to be a necessary step for the reestablishment of pāua populations, given that Stewart Island/Rakiura continues to support a contracting commercial pāua fishery. Experience from marine reserves in other parts of the country would also predict an increase in other heavily fished species, such as rock lobster and particularly blue cod, which are historically very common in southern New Zealand.

It has been predicted that, in 100 years' time, sea temperatures off Southland will become more like those in the present-day Marlborough Sounds (Cortese et al. 2013). This would represent a significant change for these marine ecosystems. Having consistent, regional data such as that collected in the present study is crucial for monitoring change in the Foveaux Strait region. This baseline information will also enable agencies to monitor responses to changes in management and the presence of exotic species.

4.9 Conclusions

This study provided the first quantitative assessment of shallow subtidal reef communities at a number of locations throughout the Foveaux Strait region of New Zealand. This area represents a highly unique, dynamic and complex part of the New Zealand coastline. While the sites sampled only covered a relatively small portion of the Foveaux Strait region, a disproportionately high variety of reef assemblages and a high diversity of macroalgal species were recorded. Regional patterns in algal species composition, macroalgal community structure, benthic community structure and mobile macroinvertebrate species assemblages generally reflected broad-scale differences in the exposure of sites to prevailing southwesterly swells, which dominate the physical setting in this region. From a national perspective, the majority of locations sampled formed part of a unique Stewart Island bioregion within the Southern New Zealand biogeographic province (Shears et al. 2008).

5. Recommendations

5.1 Shallow subtidal reef communities

The information presented in this report provides some insight into ecological processes that occur on shallow subtidal reefs in the greater Foveaux Strait region, as well as proposed directions for future research in this and other southern South Island localities. Ideally, this information will be integrated with information on other aspects of the habitats and biological diversity that are present throughout New Zealand to form the basis for informed decision-making, and to help achieve the goals set out in the New Zealand Biodiversity Strategy (DOC & MfE 2000) and MPA Policy (DOC & MFish 2005).

Additional sampling is recommended to fill in the gaps and to further develop a classification system for subtidal reefs of the Foveaux Strait region. Priority areas for further sampling include additional sites in Preservation Inlet and other southern fiords; the mainland coast between Green Islets and Oraka Point, and east of Bluff to The Catlins; the west and southeast coasts of Stewart Island/Rakiura; and a number of offshore islands, e.g. Centre Island and Solander Island (Hautere). Many of these areas are in highly exposed parts of the country and thus will require optimal sampling conditions to allow the collection of data that are comparable to those obtained in the present study.

It would also be beneficial to analyse the data collected in relation to regional-scale environmental variables e.g. sea surface temperature (SST), tidal currents, freshwater input and wave exposure. This will provide insight into potential mechanisms that are responsible for the patterns observed and will help to validate the classification of reefs in the Foveaux Strait region. The collation and development of finer-scale physical environmental information (e.g. < 200 m) would provide a more accurate representation of depth and wave exposure that may account for site-level variation within a particular location. Predictive modelling based on these factors could then be used to create continuous spatial layers, which could be used as part of a gaps analysis for the region.

The sites sampled in Paterson Inlet/Whaka a Te Wera in 2000 and 2005 will provide valuable baseline information, allowing the detection of any changes in the benthic communities as a result of the newly established marine reserve (four sites are located in the reserve and four outside). The methodology used in this study has been successfully used for monitoring long-term changes in benthic communities in northeastern New Zealand marine reserves (e.g. Shears & Babcock 2003) and could easily be implemented as a benthic monitoring programme in Paterson Inlet/Whaka a Te Wera.

5.2 Epifaunal invertebrates on subtidal rockwalls

It would be advantageous to obtain additional information on other biological elements of the subtidal rockwalls to better understand the structure and function of these assemblages. For example, further analyses of the quadrats to determine the percent cover of macroalgal groups or the incorporation of information from surveys of mobile macroinvertebrates would provide a basis for looking at potential consumer-resource interactions and provide a better understanding of the relative importance of macroalgal species in driving patterns of sessile invertebrate diversity (e.g. through potential spatial competition). Alternatively, quantification of patterns in the body (or colony) size of sessile invertebrate species would also provide a context for understanding the patterns of diversity described in this report. For example, the colony size of sponges and ascidians may increase with increasing latitude, which would potentially differentiate assemblages within the Foveaux Strait region from those in Fiordland where these have similar species densities. Measurement of the dynamics of these assemblages (in terms of the associated mobile macroinvertebrates, fishes and macroalgae) would also be advantageous to establish a baseline of multiple ecosystem elements and to provide some basic understanding of their changes through time. This information is essential for the interpretation of further monitoring of subtidal rockwalls, and for understanding any responses to changes in management and/or alterations in climatic variables.

Further examination of the relationships between the observed patterns of diversity and physical environmental parameters (such as depth, sea surface temperature and wave exposure) would provide further insight into physical determinants of patterns of species diversity on subtidal rockwalls. Such work could form the basis for predictive modelling of species and community attributes, which could then be used to further explore the nature of heterogeneity, patch size and isolation, and could contribute towards a scientific basis for MPA design. Similar analyses have been conducted in other areas, e.g. the Hauraki Gulf and Fiordland, which have contributed to the development of a spatial framework for visualising broad-scale patterns.

The extension of this information to include not only physical variables, but also patterns of use of the marine environment (e.g. shipping routes and anchorages) would be helpful in the development of a risk assessment for invasive species. The identification of sensitive (or potentially sensitive) areas to invasion by potential mobile or sessile invertebrates and macroalgae such as *Undaria pinnatifida*, could be one element of such a risk assessment.

Further analysis of the community structure data could provide a means of assessing the representativeness and of identifying unique features of sites in the greater Foveaux Strait region. Additional statistical tools, such as analysis of similarity (ANOSIM), would provide a quantitative basis for identifying differences and similarities in overall community structure, and would complement the data analyses presented in this report. Where there were differences in the observed and estimated species richness at a particular site, it would be of benefit to sample additional quadrats so that the full array of species can be characterised.

Finally, comparable sampling at other coastal and island locations in the southern South Island (such as the West Coast, The Catlins and Otago) would provide a basis for understanding the extent to which the patterns documented in this report are 'representative' of the South Island region and would also corroborate the findings of other comparable analyses that have been carried out in other parts of New Zealand – as has already occurred with the macroalgal dataset (Shears et al. 2008). Such an understanding would better support the decision-making process when selecting areas for potential marine protection, for example, and would provide a sound basis for risk analyses and resource management for the greater Foveaux Strait region.

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Data are stored at the Department of Conservation electronically as file DOCDM-513888. Original quadrat data sheets are held by Nick Shears and rockwall quadrat photos by Franz Smith. A seaweed collection is held at the Museum of New Zealand Te Papa Tongarewa. An underwater DVD, with information booklet, was also produced from the expedition with underwater videographer Dave Abbott of Liquid Action Films (DOC 2006).

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Appendix 1

Survey site locations

SITE ID	SITE NAME	AREA	LONGITUDE	LATITUDE	EASTING	NORTHING
1	Browns Garden	Port Adventure	168.1952	–47.0643	2144760	5338590
2	Tia Island (Entrance)	Port Adventure	168.2224	–47.0713	2146867	5337926
3	Horomamae/Owen Island	Port Adventure	168.165	–47.125	2142866	5331715
4	Lords River Head	Port Adventure	168.1358	–47.1157	2140594	5332620
5	Tamihau Island	Paterson Inlet/Whaka a Te Wera	168.1055	–46.9333	2137091	5352726
6	Ulva Island East Point	Paterson Inlet/Whaka a Te Wera	168.1555	–46.937	2140912	5352538
7	Ulva Island E Reef	Paterson Inlet/Whaka a Te Wera	168.1535	–46.9368	2140763	5352545
8	Horseshoe Point	Halfmoon Bay	168.1504	–46.8783	2140141	5359032
9	Bobs Point	Port William/Potirepo	168.1268	–46.8548	2138192	5361525
10	West Head	Port William/Potirepo	168.0928	–46.8332	2135454	5363772
11	Ruggedy Passage	Ruggedy Islands	167.7138	–46.7064	2105692	5376044
12	Ruggedy NE	Ruggedy Islands	167.7209	–46.7052	2106226	5376207
13	Black Rock Point	Stewart Island/Rakiura NW	167.8712	–46.6839	2117548	5379304
14	Lucky Point	Stewart Island/Rakiura NW	167.9439	–46.7069	2123254	5377092
15	Codfish Southeast	Codfish Island / Whenua Hou	167.6636	–46.7839	2102422	5367193
16	Codfish Southwest	Codfish Island / Whenua Hou	167.6619	–46.7848	2102300	5367090
17	North Sealers Bay	Codfish Island / Whenua Hou	167.6404	–46.7516	2100414	5370663
18	High Rock	Codfish Island / Whenua Hou	167.6847	–46.7762	2103972	5368152
19	Codfish East	Codfish Island / Whenua Hou	167.6638	–46.7734	2102363	5368359
20	Prices Point*	Green Islets	166.9294	–46.2298	2041905	5424702
20	Price's Point+	Green Islets	166.9301	–46.2306	2041971	5424614
21	Archway	Green Islets	166.8251	–46.2157	2033766	5425664
22	Keyhole	Green Islets	166.8042	–46.2285	2032263	5424123
23	NW Bay	Green Islets	166.7891	–46.2281	2031101	5424077
24	Weka Point	Preservation Inlet	166.6703	–46.0912	2020786	5438548
25	Sandfly Point	Preservation Inlet	166.6219	–46.0998	2017127	5437298
26	Bird Rock	Ruapuke Island	168.4205	–46.7653	2159992	5372755
27	South Islets	Ruapuke Island	168.5037	–46.8036	2166573	5368849
28	North Head	Ruapuke Island	168.5255	–46.7334	2167810	5376729
29	Caroline Bay	Ruapuke Island	168.4911	–46.7523	2165302	5374494
30	Pig Island	Bluff	167.9792	–46.4074	2123913	5410486
31	Oraka Point	Bluff	167.8624	–46.393	2114848	5411531
32	Barracouta Point	Bluff	168.2706	–46.584	2147406	5392227
33	Shag Rock	Bluff	168.2305	–46.5538	2144141	5395393
34	Lookout Point	Bluff	168.3354	–46.6259	2152629	5387851
35	Stirling Point	Bluff	168.3543	–46.6196	2154032	5388640
36	Tiwai Point	Bluff	168.3738	–46.6039	2155425	5390468
37	Refuge Island	Paterson Inlet/Whaka a Te Wera	168.1274	–46.9489	2138857	5351088
38	Octopus Island	Paterson Inlet/Whaka a Te Wera	168.1348	–46.9260	2139273	5353661
39	The Neck North	Halfmoon Bay	168.1812	–46.9267	2142802	5353784
40	Balancing Rock	Paterson Inlet/Whaka a Te Wera	168.1100	–46.9308	2137416	5353010
41	Ulva Island East	Paterson Inlet/Whaka a Te Wera	168.1544	–46.9371	2140838	5352512
42	Ackers Point	Halfmoon Bay	168.1581	–46.8989	2140868	5356773
43	Native Island North	Halfmoon Bay	168.1622	–46.9156	2141284	5354940
44	Iona Island S	Paterson Inlet/Whaka a Te Wera	168.1228	–46.9086	2138244	5355536
45	Motunui/Edwards Island	Titi/Muttonbird Islands	168.2162	–46.8285	2144826	5364838

Continued on next page

Appendix 1 continued

SITE ID	SITE NAME	AREA	LONGITUDE	LATITUDE	EASTING	NORTHING
46	Herekopare Island (Te Marama)	Titi/Muttonbird Islands	168.2300	–46.8691	2146140	5360395
47	Bench Island N	Titi/Muttonbird Islands	168.2398	–46.9012	2147096	5356879
48	Bench Island SE Point	Titi/Muttonbird Islands	168.2507	–46.9117	2147989	5355765
49	Horseshoe Bay	Halfmoon Bay	168.1431	–46.8712	2139545	5359778

* Reef macroalgae and mobile macroinvertebrates, and reef fishes.

+ Sessile epifaunal assemblages and mobile macroinvertebrates on subtidal rockwalls, and cryptic fishes.

Appendix 2

Wave exposure and sediment cover estimates in the Foveaux Strait region

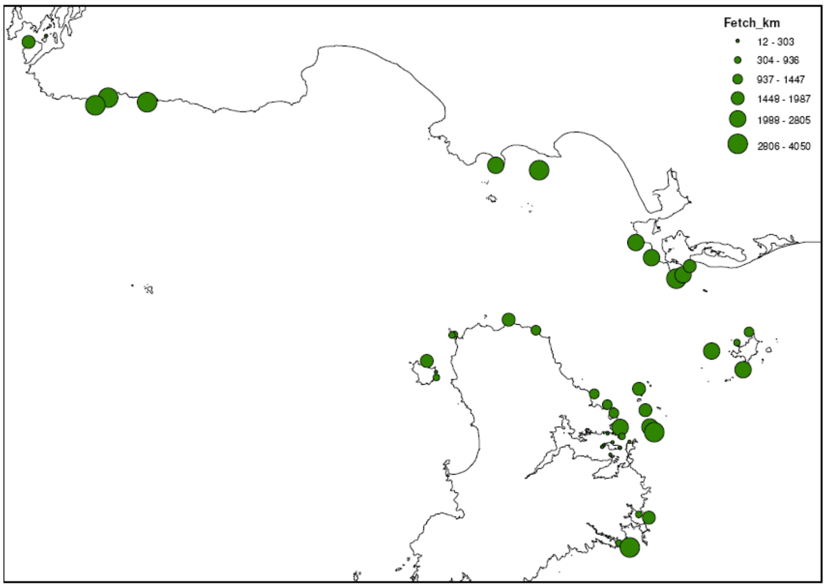

Figure A2.1. Wave exposure estimates (wind fetch) at shallow subtidal reef sites in the Foveaux Strait region.

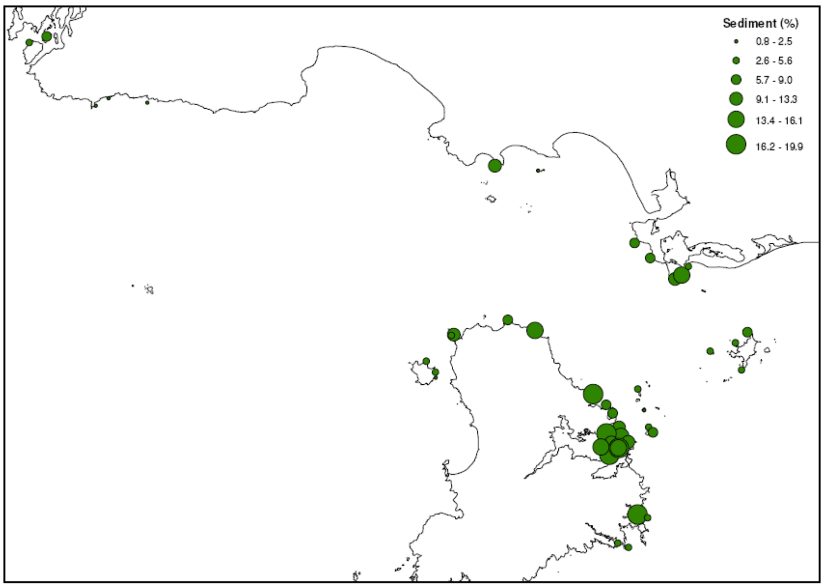

Figure A2.2. Mean sediment cover at shallow subtidal reef sites in the Foveaux Strait region.

Appendix 3

Scientific and common names of species found in the Foveaux Strait region

A3.1 Macroalgae

DIVISION	SPECIES	COMMENTS
Chlorophyta	*Bryopsis pinnata*	
	Caulerpa brownii	
	Chaetomorpha coliformis	
	Cladophora feredayi	
	Cladophoropsis herpesticata	
	Codium convolutum	
	Codium fragile	
	Codium gracile	
	Ulva spp.	*Ulva lactuca* form
Phaeophyta	Brown encrusting	Predominantly *Ralfsia* spp.
	Large brown algae	
	Carpophyllum flexuosum	
	Cystophora platylobium	
	Cystophora retroflexa	
	Cystophora scalaris	
	Cystophora torulosa	
	Durvillaea antarctica	
	Durvillaea willana	
	Ecklonia radiata	
	Landsburgia quercifolia	
	Lessonia variegata	
	Macrocystis pyrifera	
	Marginariella boryana	
	Marginariella urvilliana	
	Sargassum sinclairii	
	Xiphophora gladiata	
	Small brown algae	
	Asperococcus bullosus	
	Carpomitra costata	
	Colpomenia sinuosa	
	Cutleria multifida	
	Desmerestia ligulata	
	Dictyota papenfussii	
	Dictyota kunthii	
	Halopteris spp.	Not identified to species level in field
	Microzonia velutina	
	Ralfsia spp.	Not identified to species level in field
	Spatoglossum chapmanii	
	Sporochnus sp.	
	Zonaria turneriana	
Rhodophyta	Articulated coralline turf	Not identified to species level in field
	Crustose coralline	Not identified to species level in field
	Filamentous	Not identified to species level in field

Continued on next page

Table A3.1 continued

DIVISION	SPECIES	COMMENTS
	Red encrusting	Not identified to species level in field
	Red turfing	Not identified to species level in field
	Acrothamnion sp.	This genus not reported from Stewart Island/Rakiura – but poorly understood in NZ (Wendy Nelson, NIWA, pers. comm.)
	Adamsiella chauvinii	Formerly *Lenormandia chauvanii*
	Anotrichium crinitum	
	Asparagopsis armata	
	Ballia callitrichia	
	Brongniartella australis	
	Callophyllis atrosanguinea	
	Callophyllis callibrepharoides	
	Callophyllis depressa	
	Callophyllis hombroniana	
	Callophyllis ornata	
	Callophyllis variegata	Difficult to distinguish from *Craspedocarpus* in many cases
	Carmontagnea hirsuta	Formerly *Ballia hirsuta*
	Carmontagnea scoparia	Formerly *Ballia scoparia*
	Ceramium apiculatum	
	Ceramium rubrum	
	Champia chathamensis	
	Chondria sp.	Unknown *Chondria* sp.
	Cladhymenia oblongifolia	
	Craspedocarpus erosus	Difficult to distinguish from *Callophyllis variegata* in many cases
	Cryptonemia sp.	Undescribed species (Wendy Nelson, NIWA, pers. comm.)
	Curdiea flabellata	
	Dasya collabens	
	Dasyptilon roseum	
	Delesseria nereifolia	
	Delesseria sp.	
	Delisea elegans	
	Delisea plumosa	
	Echinothamnion hystrix	
	Echinothamnion lyalli	
	Euptilota formoissima	
	"*Gelidium*" *ceramoides*	Genus unknown for this species—restricted to southern NZ (Wendy Nelson, NIWA, pers. comm.)
	Gigartina circumcincta	
	Gigartina dilatata	
	Gigartina livida	
	Gigartina sp.	Unknown *Gigartina* sp.
	Gigartina sp. "forks"	Unknown *Gigartina* sp.
	Gracilaria secundata	
	Griffithsia antarctica	
	Griffithsia crassiuscula	
	Griffithsia spp.	Not identified to species level in field
	Griffithsia traversii	
	Gymnogongrus humilis	
	Halymenia "pink"	Undescribed species (Wendy Nelson, NIWA, pers. comm.)
	Halymenia sp. 1	Undescribed species (Wendy Nelson, NIWA, pers. comm.)
	Heterosiphonia concinna	
	Hymenena durvillaei	

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Table A3.1 continued

DIVISION	SPECIES	COMMENTS
	Hymenena palmata	
	Hymenocladia sanguinea	
	Kallymenia sp. 1	Undescribed species (Wendy Nelson, NIWA, pers. comm.); refractile
	Kallymenia sp. 2	Undescribed species (Wendy Nelson, NIWA, pers. comm.); glossy leaf-like
	Laingia hookeri	
	Lophurella hookeriana	
	Medeiothamnion lyallii	
	Microcladia pinnata	
	Pachymenia dichotoma	
	Phitymophora linearis	
	Platoma sp.?	Undescribed species (Wendy Nelson, NIWA, pers. comm.)
	Platythamnion lindaueri	
	Pleptophyllum sp.	
	Plocamium cirrhosum	Formerly *P. costatum*
	Plocamium microcladioides	Undescribed species (Wendy Nelson, NIWA, pers. comm.)
	Plocamium spp.	Including *P. cartilagineum*, *P. angustum*
	Polysiphonia muelleriana	
	Polysiphonia rhododactyla	
	Polysiphonia sp.	Not identified to species level in field
	Pterosiphonia pennata	
	Ptilonia willana	
	Ptilopogon botryocladus	
	Rhodophyllis acanthocarpa	
	Rhodophyllis gunnii	
	Rhodymenia obtusa	
	Rhodymenia sp.	Unknown species
	Sarcothalia lanceata	Formerly *Gigartina lanceata*
	Schizoseris spp.	*S. dichotoma*, *S. griffithsia*, plus undescribed species sensu Adams (1994)
	Schizymenia sp.	"*Nemastoma lanciata*" sensu Adams (1994) (Wendy Nelson, NIWA, pers. comm.)
	Scinaia australis	
	Spyridia dasyoides	
	Stenogramme intermedia	
	Streblocladia glomerulata	
	Tsengia sp. 1	Undescribed species (Wendy Nelson, NIWA, pers. comm.)
	Tsengia sp. 2	Undescribed species (Wendy Nelson, NIWA, pers. comm.)

A3.2 Fishes

GROUP	SPECIES	COMMON NAME
Chordata	*Aplodactylus arctidens*	Marblefish
	Bovichthys variegatus	Thornfish
	Caesioperca lepidoptera	Butterfly perch
	Cephaloscyllium isabellum	Carpet shark
	Conger verreauxi	Conger eel
	Congiopodus leucopaecilus	Southern pigfish
	Forsterygion flavonigrum	Yellow-black triplefin
	Forsterygion lapillum	Common triplefin
	Forsterygion malcolmii	Banded triplefin

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Table A3.2 continued

GROUP	SPECIES	COMMON NAME
	Forsterygion varium	Variable triplefin
	Helicolenus percoides	Sea perch
	Hippocampus abdominalis	Seahorse
	Latridopsis ciliaris	Blue moki
	Latridopsis forsteri	Copper moki
	Latris lineata	Trumpeter
	Mendosoma lineatum	Telescope fish
	Nemadactylus macropterus	Tarakihi
	Notoclinops segmentatus	Blue-eyed triplefin
	Notolabrus celidotus	Spotty
	Notolabrus cinctus	Girdled wrasse
	Notolabrus fucicola	Banded wrasse
	Forsterygion maryannae	Oblique triplefin
	Odax pullus	Butterfish
	Paracercii colias	Blue cod
	Meuschenia scaber	Leatherjacket
	Pseudolabrus miles	Scarlet wrasse
	Ruanoho decemdigitatus	Longfinned triplefin
	Ruanoho whero	Spectacled triplefin
	Thyrsites atun	Barracouta

A3.3 Macroinvertebrates

GROUP	SPECIES	COMMON NAME
Echinodermata	*Allostichaster* sp.	Dividing star
	Astrostole scabra	Seven-armed star
	Australostichopus mollis	Brown sea cucumber
	Coscinasterias muricata	Eleven-armed star
	Diplodontias sp.	Brooch star
	Evechinus chloroticus	Sea urchin
	Oncus sp. 1	Little red holothorian
	Oncus sp. 2	White holothorian
	Ophiopsammus maculata	Snake star
	Patiriella regularis	Cushion star
	Pentagonaster pulchellus	Biscuit star
	Stegnaster inflatus	Inflated star
	Stichaster australis	Reef star
Mollusca	*Argobuccinum pustulosum*	Pustular triton
	Argobuccinum sp.	Whelk
	Astraea heliotropium	Circular saw shell
	Buccinium linea	Lined whelk
	Buccinium sp. 1	Whelk
	Buccinium sp. 2	Whelk
	Calliostoma (*Maurea*) *punctulatum*	Spotted topshell
	Calliostoma (*Maurea*) *tigris*	Tiger topshell
	Cantharidus opalus	Opal topshell
	Cellana stellifera	Star limpet
	Chromodoris aureomarginata	Gold-margin nudibranch
	Cominella sp.?	Whelk
	Cookia sulcata	Cooks turban

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Table A3.3 continued

GROUP	SPECIES	COMMON NAME
	Cryptoconchus porosus	Butterfly chiton
	Dicathais orbita	White rock shell
	Eudoxochiton nobilis	Noble chiton
	Haliotis australis	Yellow-foot pāua
	Haliotis iris	Black-foot pāua
	Maoricolpus roseus roseus	Turret shell
	Modelia granosa	Southern cat's eye
	Octopus sp.	Octopus
	Scutus breviculus	Shield shell slug
	Sypharochiton pelliserpentis	Snake's skin chiton
	Trochus viridis	Green topshell
	Turbo smaragdus	Cat's eye
Arthropoda	*Jasus edwardsii*	Rock lobster
	Pagurus sp.	Hermit crab
	Pycnogonid sp.	Sea spider
Cnidaria	*Phlyctenactis tuberculosa*	Wandering anemone

Appendix 4

Shallow subtidal reef community hierarchical cluster analyses

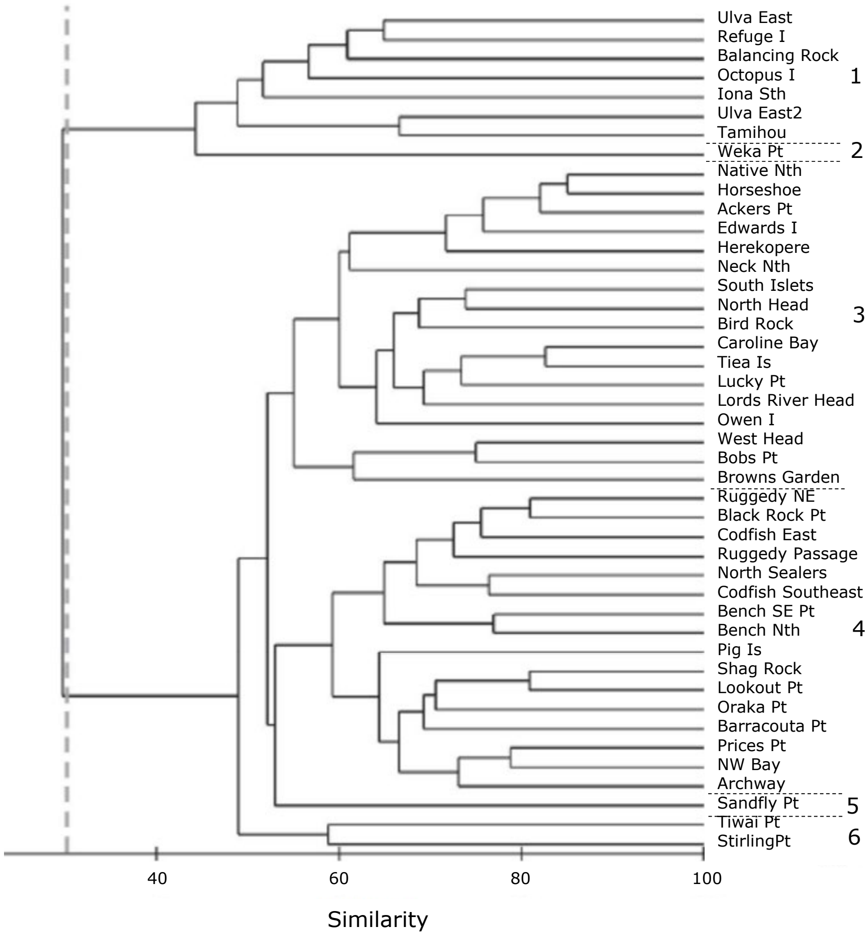

Figure A4.1. Macroalgal species composition based on the presence/absence of 106 macroalgal taxa. This indicates six groups at the 30% similarity level.

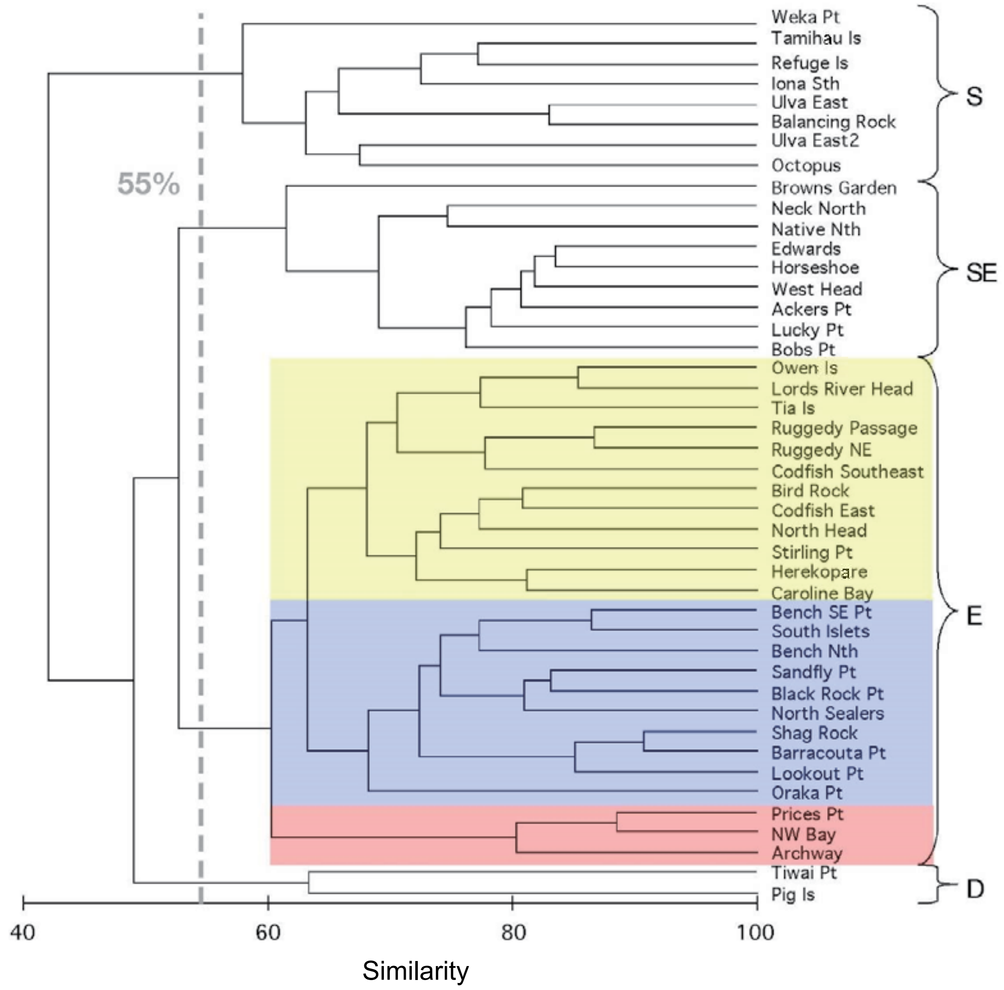

Figure A4.2. Macroalgal community structure based on log(x+1) transformed biomass estimates of 24 macroalgal subgroups. This indicates four broad groupings at the 55% similarity level: S = Sheltered, SE = Semi-exposed, E = Exposed and D = *Durvillaea* (see Figs. 6 and 34). Coloured areas indicate three subgroups within the 'Exposed' group: red = 'Extremely exposed', blue = 'Highly exposed' and yellow = 'Moderately exposed'.

Appendix 5

Epifauna invertebrates on subtidal rockwalls – species accumulation curves for 18 sites in the Foveaux Strait region

In general, there was a tendency towards convergence of the Chao 2 index of subtidal epifaunal invertebrate species richness and the observed number of species (S_{obs}), which indicates that an adequate number of quadrats were sampled in order to characterise the species assemblages present (Colwell & Coddington 1994). However, at Browns Garden, Codfish SW and Archway there was no obvious convergence of the Chao 2 index and S_{obs}, which suggests that further sampling is required to characterise the full complement of species present at those sites. There was also no clear trend of convergence in the accumulation curves for Pig Island and Oraka Point, although this may be partly due to the low species abundances (i.e. rarity) at these two sites. At the Keyhole and Ulva Island (E Point) sites, the Chao 2 index and S_{obs} also did not fully converge; however, the levelling off of the Chao 2 index suggests that a 'stable' sampling of the species assemblage was achieved – although it would be advantageous to carry out further sampling at these sites to ensure adequate characterisation of the assemblages. Since the Chao 2 index provides the most accurate estimation of the true species richness where there are few samples (Colwell & Coddington 1994), the estimated number of species according to Chao 2 can be considered reliable estimates for making comparisons between locations.

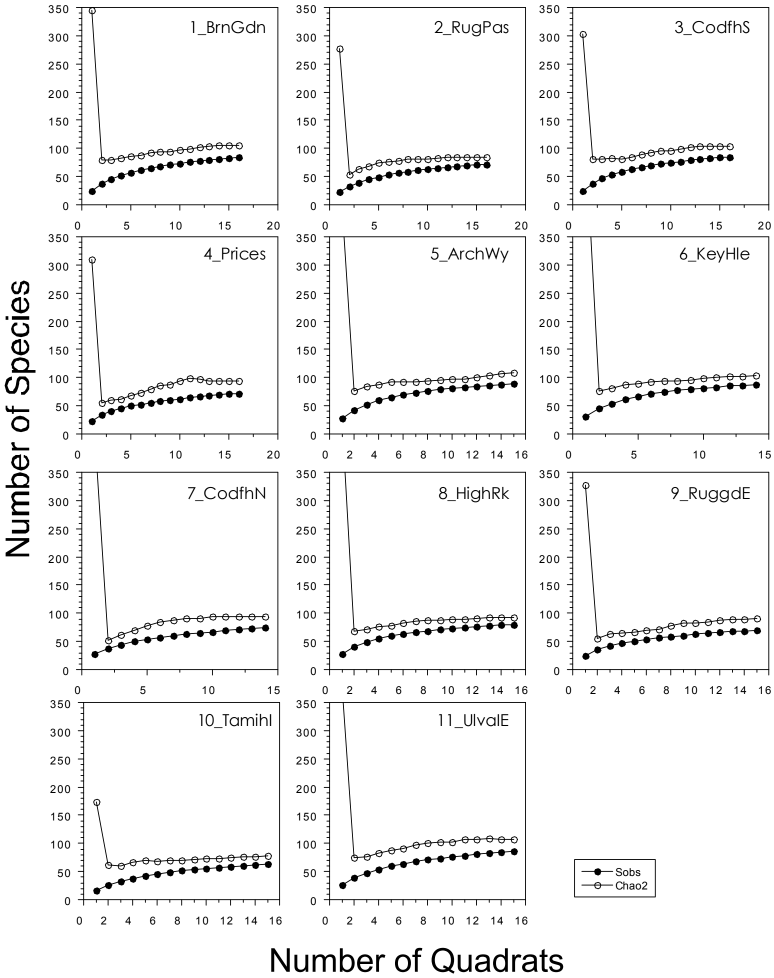

Figure A5.1. Curves of the observed number of species (S_{obs}) and statistical estimation of species richness according to the Chao 2 index at the 18 sampling locations. Successive quadrats along transects were randomised 50 times to produce the accumulation curves and the calculation of Chao 2 (i.e. each point represents an average of 50 randomisations).

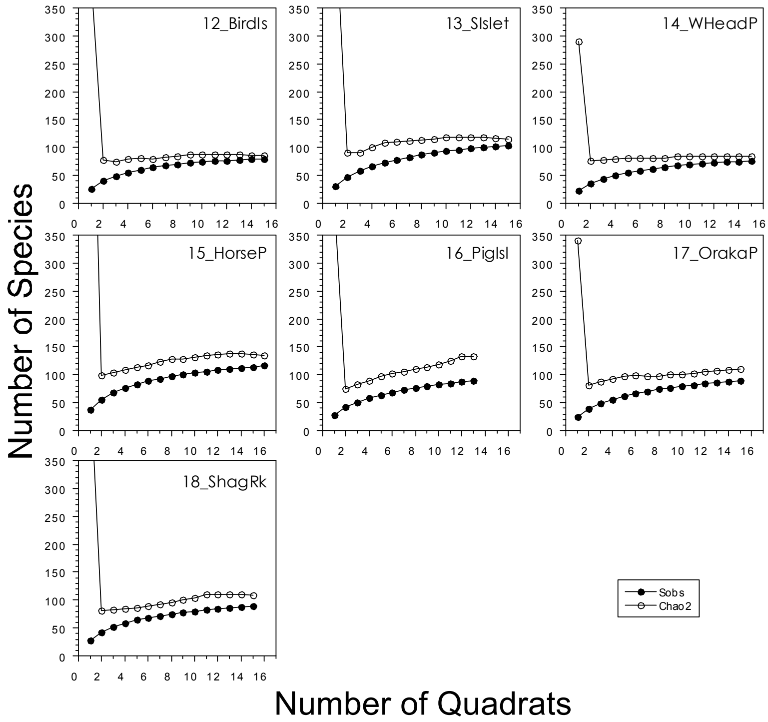

Figure A5.2 Species accumulation curves for observed number of species (S_{obs}) and the Chao 2 species estimator for sites 12 – 18.

Appendix 6

Species presence/absence across all sampled reef sites in the Foveaux Strait region

Species by taxa group	Reef site (number and name)																																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	BrnGdn	Tia I	Owen I	Lords	Tamihl	UlvalE	UlvalEReef	HorseP	BobPt	WHeadP	RugPas	RuggdE	BlkRc	LkyPt	CodfhSE	CodfhSW	CodfhN	HighRk	CodfhE	Price	ArchWy	KeyHle	NWBay	WekaP	SandFPt	Birdls	SIslet	NHead	CarBay	PigIs	OrakaPt	BarrCta	ShagRk	LookPt	StirlPt	TiwPt
Chordata																																				
Aplodactylus arctidens										✓							✓			✓					✓					✓	✓	✓	✓			✓
Bovichthys variegatus									✓																											
Caesioperca lepidoptera	✓										✓	✓								✓	✓			✓	✓											
Cephaloscyllium isabellum							✓																													
Conger verreauxi																								✓												
Congiopodus leucopaecilus												✓	✓																							
Forsterygion flavonigrum	✓											✓												✓												
Forsteryygion lapillum	✓	✓			✓		✓			✓	✓	✓					✓									✓				✓	✓		✓			
Forsterygion malcolmii	✓				✓		✓			✓	✓		✓											✓	✓		✓			✓	✓		✓			
Forsteryygion varium		✓	✓		✓		✓		✓	✓		✓	✓	✓			✓									✓	✓		✓	✓	✓		✓		✓	
Helicolenus percoides	✓																							✓												
Hippocampus abdominalis																																		✓		
Latridopsis ciliaris	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Latridopsis forsteri													✓						✓						✓					✓						✓
Latris lineata	✓	✓	✓	✓			✓			✓	✓	✓	✓	✓	✓		✓		✓		✓		✓				✓		✓			✓	✓	✓		
Mendosoma lineatum	✓		✓									✓								✓					✓											
Nemadactylus macropterus												✓	✓											✓			✓									✓
Notoclinops segmentatus	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓			✓							✓		✓	✓			✓			✓			
Notolabrus celidotus	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓	✓									✓	✓	✓	✓	✓		✓			✓	✓	✓	✓	✓
Notolabrus cinctus	✓	✓	✓	✓	✓		✓			✓	✓	✓	✓	✓					✓	✓			✓		✓	✓	✓	✓	✓			✓	✓			✓

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Appendix 6 continued

Species by taxa group	Reef site (number and name)																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	BrnGdn	Tia I	Owen I	Lords	TamihI	UlvaIE	UlvaIEReef	HorseP	BobPt	WHeadP	RugPas	RuggdE	BlkRc	LkyPt	CodfhSE	CodfhSW	CodfhN	HighRk	CodfhE	Price	ArchWy	KeyHle	NWBay	WekaP	SandFPt	BirdIs	SIslet	NHead	CarBay	PigIs	OrakaPt	BarrCta	ShagRk	LookPt	StirlPt	TiwPt
Notolabrus fucicola	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Forsterygion maryannae	✓		✓				✓				✓	✓	✓	✓										✓					✓							
Odax pullus	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓			✓	✓	✓	✓	✓	✓		✓		✓	✓
Paracercii colias	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Meuschenia scaber							✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
Pseudolabrus miles	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Ruanoho decemdigitatus		✓		✓								✓													✓											
Ruanoho whero	✓				✓		✓		✓	✓		✓	✓											✓		✓	✓		✓				✓	✓	✓	
Thyrsites atun																														✓						
Echinodermata																																				
Allostichaster spp.					✓																					✓				✓			✓			
Astrostole scabra																	✓										✓							✓		
Australostichopus mollis	✓				✓	✓		✓	✓	✓	✓	✓															✓						✓	✓		
Diplodontias sp.																																				
Evechinus chloroticus					✓	✓			✓	✓	✓	✓				✓	✓	✓			✓	✓				✓	✓			✓	✓		✓	✓		
Oncus sp. 1																																				
Oncus sp. 2																																				
Ophiopsammus maculata	✓				✓	✓			✓	✓	✓	✓					✓									✓	✓			✓	✓		✓	✓		
Patiriella regularis					✓	✓			✓	✓		✓														✓				✓	✓		✓	✓		
Pentagonaster pulchellus	✓				✓	✓		✓	✓	✓	✓	✓				✓	✓	✓		✓	✓	✓				✓	✓			✓	✓		✓	✓		
Stegnaster inflatus																																	✓			
Stichaster australis																																				
Mollusca																																				
Argobuccinum pustulosum																																				
Argobuccinum spp.											✓						✓	✓				✓														
Astraea heliotropium	✓					✓				✓																										
Buccinium sp. 1					✓																															
Buccinium linea						✓																														

Continued on next page

Appendix 6 continued

Species by taxa group	Reef site (number and name)																																		
	1 BrnGdn	2 Tia I	3 Owen I	4 Lords	5 Tamihl	6 UlvalE	7 UlvalEReef	8 HorseP	9 BobPt	10 WHeadP	11 RugPas	12 RuggdE	13 BlkRc	14 LkyPt	15 CodfhSE	16 CodfhSW	17 CodfhN	18 HighRk	19 CodfhE	20 Price	21 ArchWy	22 KeyHle	23 NWBay	24 WekaP	25 SandFPt	26 Birdls	27 SIslet	28 NHead	29 CarBay	30 Pigls	31 OrakaPt	32 BarrCta	33 ShagRk	34 LookPt	35 StirlPt	36 TiwPt
Buccinium sp. 2						✓																														
Calliostoma (Maurea) punctulatum						✓										✓		✓									✓			✓			✓			
Calliostoma (Maurea) tigris																		✓																		
Cantharidus opalus																																				
Cellana stellifera					✓	✓			✓																											
Cominella spp.?					✓																															
Coscinasterias muricata	✓				✓											✓														✓	✓		✓	✓		
Chromodoris aureomarginata									✓			✓														✓	✓			✓			✓	✓		
Cookia sulcata																	✓																	✓		
Cryptoconchus porosus					✓	✓				✓																							✓			
Dicathais orbita																																				
Eudoxochiton nobilis																																				
Haliotis australis									✓	✓		✓					✓																✓			
Haliotis iris																																		✓		
Maoricolpus roseus roseus	✓				✓	✓					✓																									
Modelia granosa						✓				✓							✓	✓		✓		✓				✓							✓			
Octopus spp.																											✓									
Scutus breviculus										✓							✓													✓				✓		
Sypharochiton pelliserpentis					✓	✓											✓																	✓		
Trochus viridis					✓	✓			✓			✓														✓										
Turbo smaragdus						✓																				✓				✓						
Arthropoda																																				
Jasus edwardsii										✓																										
Pagurus spp.					✓						✓																						✓			
Pycnogonad spp.																																	✓			
Cnidaria																																				
Phlyctenactis tuberculosa	✓																✓									✓								✓		

Appendix 7

Size frequency distributions of *Evechinus chloroticus* at shallow subtidal reef locations in the Foveaux Strait region

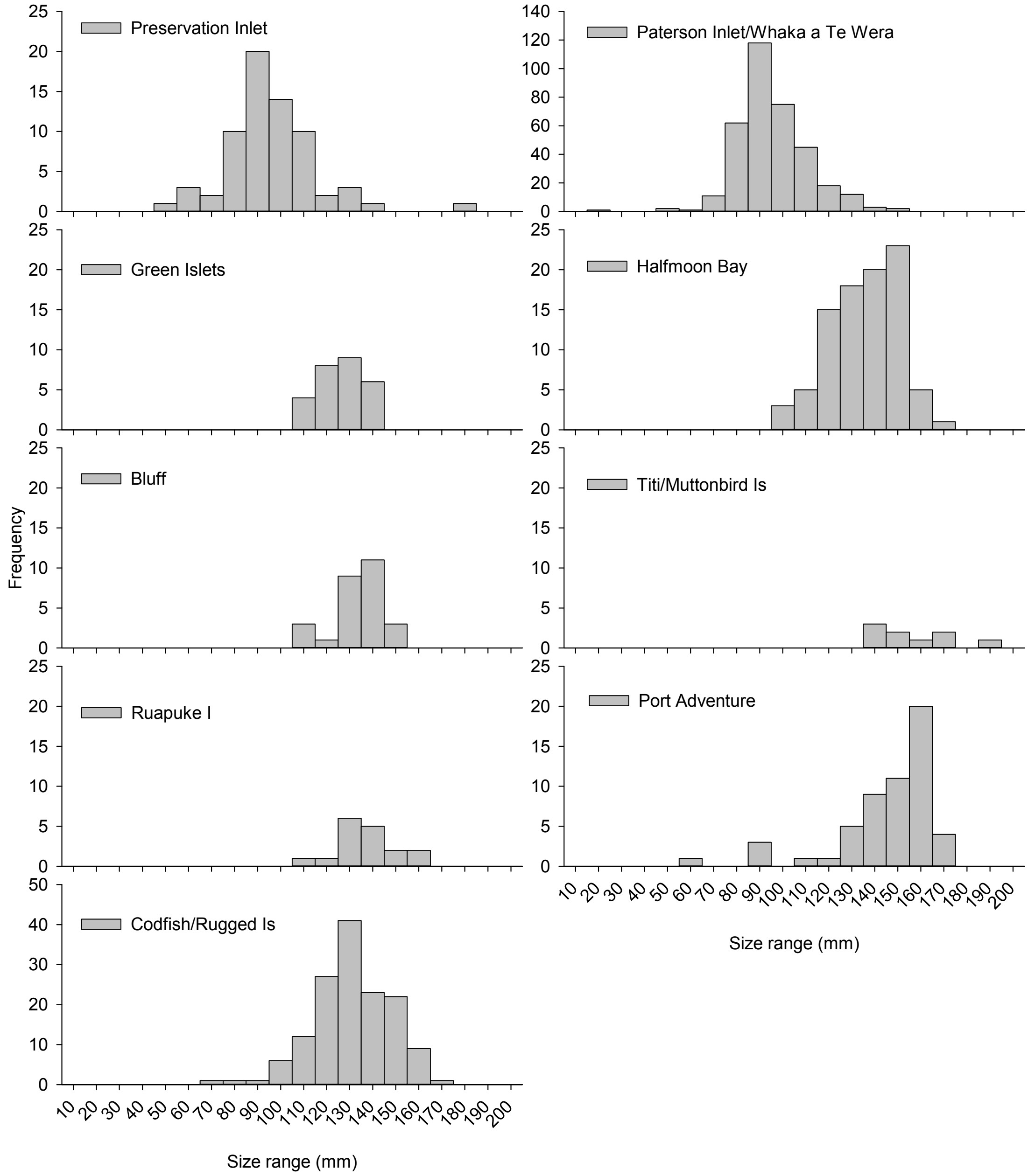

Figure A7.1. Size frequency distributions of *Evechinus chloroticus* at shallow subtidal reef locations in the Foveaux Strait region.