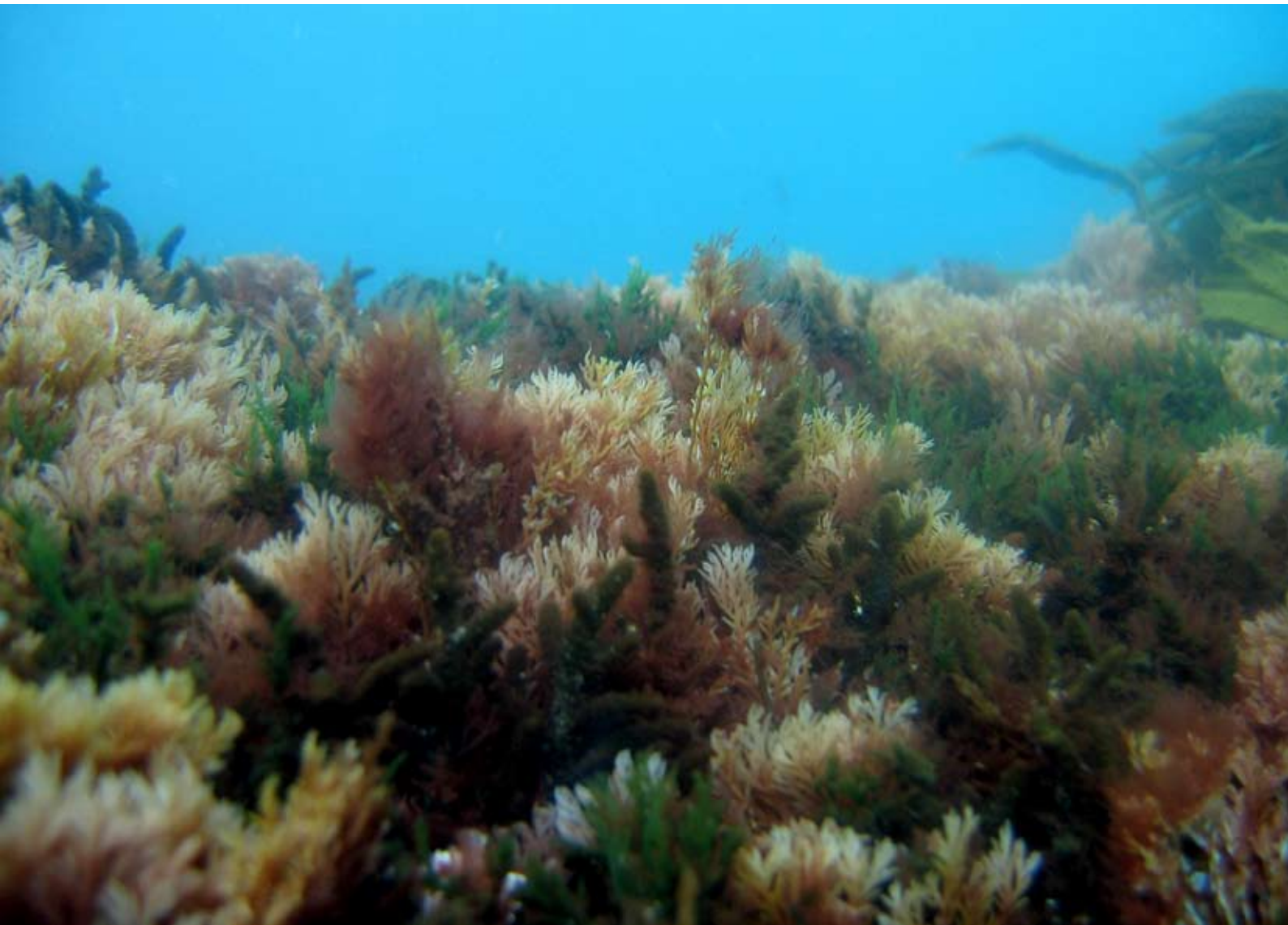


Biogeography, community  
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South Island West Coast,  
New Zealand

SCIENCE FOR CONSERVATION 281



Department of Conservation  
*Te Papa Atawhai*

# Biogeography, community structure and biological habitat types of subtidal reefs on the South Island West Coast, New Zealand

Nick T. Shears

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Cover: Shallow mixed turfing algal assemblage near Moeraki River, South Westland (2 m depth). Dominant species include *Plocamium* spp. (yellow-red), *Echinobamnium* sp. (dark brown), *Lophurella bookeriana* (green), and *Glossophora kuntzii* (top right).

*Photo: N.T. Shears*

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# Biogeography, community structure and biological habitat types of subtidal reefs on the South Island West Coast, New Zealand

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## ABSTRACT

There is currently little information on the biogeography and ecology of subtidal reef habitats along New Zealand's west coast. Without such information, it will not be possible to develop a system of marine protected areas (MPAs) in these areas. This report describes subtidal reef habitats at sites spanning more than 300 km of the highly wave-exposed South Island West Coast (SIWC), with a view to investigating relationships between biological communities and environmental variables. It tests existing biogeographic classification schemes for the SIWC. Nine biological habitat types were identified on the reefs examined. The reef communities within these habitats were biologically distinct, supporting their use for future classification and mapping of SIWC reefs. Analysis of seaweeds, mobile macroinvertebrates and fishes supported division of the SIWC into two biogeographic regions: northern Buller and South Westland. Variation within and between these regions was strongly related to water clarity. In general, Buller sites had low water clarity, shallow reefs with a high degree of sand-scour, and were dominated by encrusting invertebrates (especially mussels and sponges) and bare rock. In contrast, the South Westland sites were dominated by small seaweeds. The majority of sites sampled in this study were unusual for temperate reef systems in that both kelp and large grazers (sea urchins) were rare. This suggests that non-biological factors (e.g. water clarity and wave action) are largely responsible for shaping subtidal reef communities on the SIWC. The information gained in this study will assist planning for marine protected areas on the SIWC, particularly with regard to those unique habitat types like *Xenostrobus* mats.

Keywords: biogeographic classification, coastal reef fish, habitat mapping, macroalgae, marine reserves, marine protected areas, mobile macroinvertebrates, reef biodiversity, seaweeds, New Zealand

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# 1. Introduction

As part of New Zealand's commitment to the International Convention on Biological Diversity ([www.biodiv.org](http://www.biodiv.org)), the New Zealand Biodiversity Strategy aims to protect 10% of New Zealand's marine environment in a network of representative marine protected areas (MPAs) using an agreed bioregional classification system by 2010 (DOC & MfE 2000). A Marine Protected Area Policy and Implementation Plan (MPAPIP) has been developed by the New Zealand Government ([www.biodiversity.govt.nz/seas/biodiversity/protected/mpa\\_policy.html](http://www.biodiversity.govt.nz/seas/biodiversity/protected/mpa_policy.html)) to guide this process. A key step outlined in the MPAPIP is to develop a consistent approach to classification of marine habitats and ecosystems based on best available scientific information to ensure representativeness of future MPA networks. In order to represent the nested nature of biological patterns across a range of spatial scales, a hierarchical approach to marine classification is required (Lourie & Vincent 2004). For example, the Australian inshore bioregionalisation provides a framework that considers ecological patterns and processes which occur at the scale of provinces (macro-scale; > 1000s of km), regions or bioregions (meso-scale; 100s-1000s of km), local units (10s-100s of km), and individual sites (< 10 km) (Commonwealth-of-Australia 2006). Systematically collected biological data over broad geographic scales combined with analytical techniques provide an opportunity to objectively classify the marine environment at provincial and bioregional scales (e.g. Bustamante & Branch 1996; Edgar et al. 1997; Edgar et al. 2004; Shears et al. in press), while information on the distribution of biological habitat types is useful for classification and mapping the marine environment at smaller spatial scales (e.g. Connor 1997; Ward et al. 1999; Parsons et al. 2004).

In New Zealand, shallow subtidal reefs are highly important coastal habitats in terms of their ecological, cultural, recreational and economic attributes. Many important commercial, recreational and customary fisheries are focussed on these habitats, e.g. rock lobster *Jasus edwardsii*, kina *Evechinus chloroticus* and paua *Haliotis iris*. Biological information on the communities found in these habitats, and our general understanding of their ecology, is generally based on studies in a limited number of locations, e.g. northern New Zealand (Ayling 1981; Andrew & Choat 1982; Choat & Schiel 1982; Schiel 1990; Shears & Babcock 2002), and southern New Zealand (Schiel & Hickford 2001; Villouta et al. 2001; Wing et al. 2003). The majority of the areas studied so far have easy access and/or benign sea conditions. Based on these studies, broad generalisations about the structure of New Zealand's subtidal reef communities have been made in the international literature (e.g. Schiel 1990; Steneck et al. 2002). In general, New Zealand's reefs are considered to be typical of other temperate systems, being dominated by Laminarian and Fucallean macroalgae, with sea urchins *Evechinus chloroticus* being important structuring components, particularly in northern New Zealand (Choat & Schiel 1982; Schiel 1990).

Because of the extremely exposed nature of the South Island West Coast (SIWC), information on the biogeography, habitat types and ecology of shallow subtidal reefs in this region is very limited. The draft national classification framework for the MPAPIP proposes a biogeographic region covering the Department of Conservation's (DOC's) West Coast/Tai Poutini Conservancy from Kahurangi

Point in the north to Jackson Head in the south. However, the few biogeographic studies carried out on the SIWC have divided this proposed region into two or three distinct regions or ecological districts (Neale & Nelson 1998; Roberts et al. 2005; Shears et al. in press). Basing their studies predominantly on geomorphology and collections of intertidal and beach-cast macroalgae, Neale & Nelson (1998) proposed three marine ecological districts along the SIWC: Buller, Westland, and South Westland (Fig. 1A), with the central (Westland) region lying between Greymouth and Bruce Bay. A nationwide study of subtidal reef communities by Shears et al. (in press) supported biogeographic divisions between northern Buller, South Westland and Fiordland. However, in this study, no sampling was carried out in Neale & Nelson's (1998) Westland region. Roberts et al. (2005) recognised three marine regions on the SIWC based on physical characteristics and collections of coastal fishes (Fig. 1A). The area sampled in their study included Fiordland, and the inner Fiords were defined as one of the three marine regions. The other two regions were Fiordland open coast-South Westland and Westland-Buller, and a broad transition zone was proposed between these from Jackson Head in the north to Bruce Bay in the south. There are, therefore, a number of inconsistencies between the biogeographic classifications so far proposed for the SIWC (Neale & Nelson 1998; Roberts et al. 2005; Shears et al. in press).

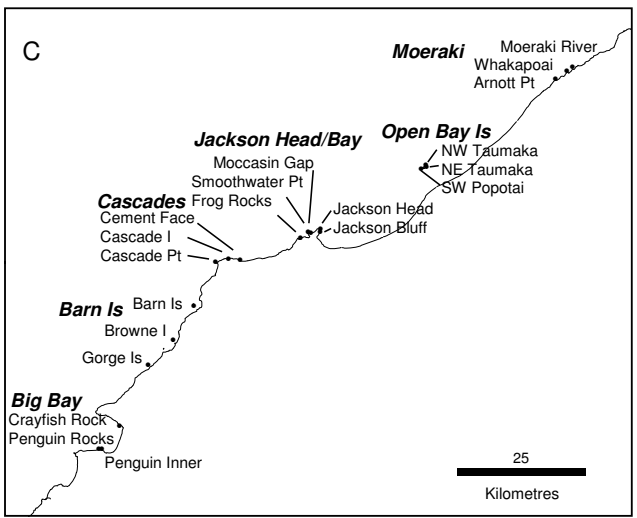
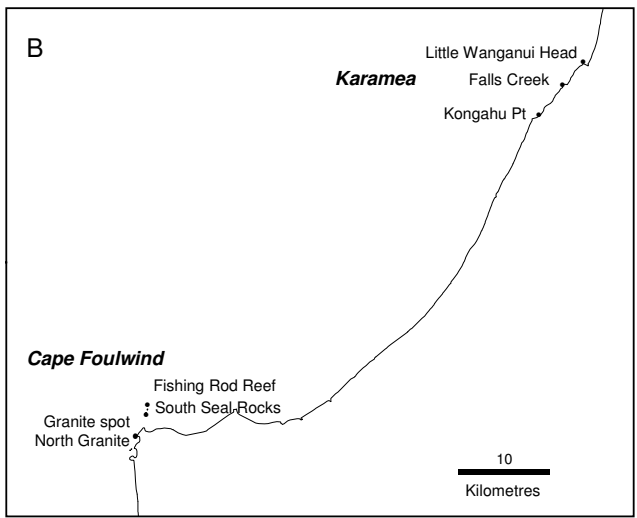
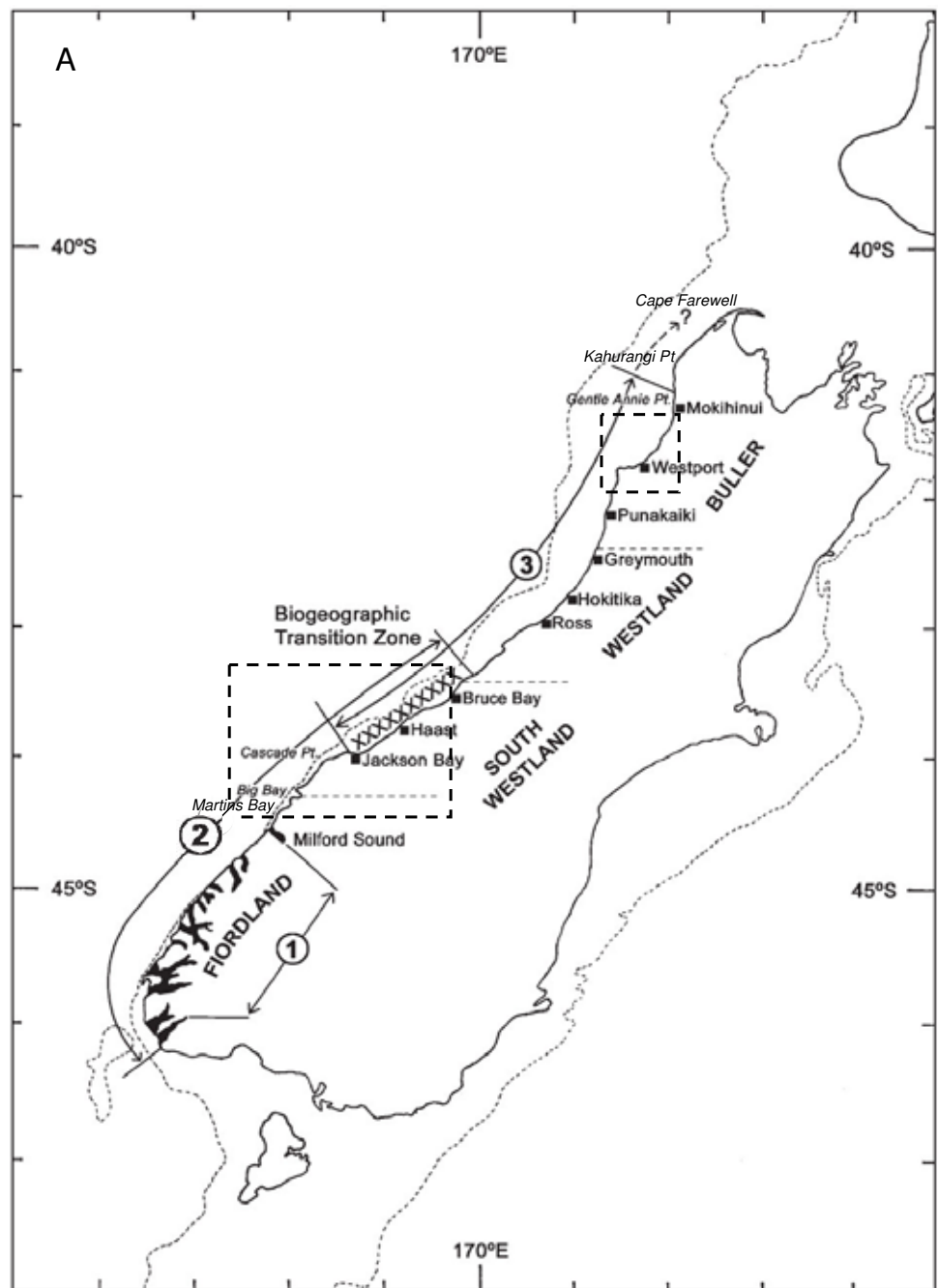
This report describes the biogeography, biological habitat types and community structure of subtidal reefs at the 27 sites surveyed by Shears et al. (in press), which span over 300 km of the SIWC (Fig. 1B, C). General descriptions of the benthic communities at these sites are provided from a national perspective in Shears & Babcock (2007). As the biological habitat types found on the SIWC reefs do not conform to the habitat classification developed for northeastern New Zealand reefs (reviewed in Shears et al. 2004) or other South Island locations such as Kaikoura (Schiel & Hickford 2001), the data were also used to develop and validate a biological habitat classification scheme for SIWC subtidal reefs. In addition, the existing biogeographic schemes proposed for the SIWC (Neale & Nelson 1998; Roberts et al. 2005) are tested using macroalgal data (this study) and fish distribution data from Roberts et al. (2005). It is hoped that this regional assessment of coastal reefs will assist the West Coast Marine Protection Forum process (under the MPAPIP) by providing a robust quantitative assessment of biogeographic patterns, identifying key reef habitat types on the West Coast, and describing spatial patterns in reef communities among sites. This information will allow assessment of the representativeness and distinctiveness of the sites sampled within the SIWC region.

## 2. Methods

### 2.1 SAMPLING LOCATION

The West Coast/Tai Poutini Conservancy's coastal boundaries are located at Kahurangi Point in the north and Awarua Point (northern point of Big Bay) in the south (Fig. 1). A detailed description of the oceanography and geomorphology of this region is given in Neale & Nelson (1998). This coastline is highly exposed to

Figure 1. Map of South Island (A) from Roberts et al. (2005), showing locations of the three marine biogeographic regions they proposed for the SIWC: (1) Fiord, (2) Fiordland open coast–South Westland, and (3) Westland–Buller. Horizontal dashed lines indicate boundaries of Neale & Nelson’s (1998) ecological districts: Buller, Westland and South Westland. The dashed boxes indicate the two study areas where sites were sampled in the present study at Buller (B) and South Westland (C). Note: most of South Westland coast (marked XXXX) was proposed as a broad transition zone between regions 2 and 3 by Roberts et al. (2005).





the prevailing southwesterly swell and wind, sheltered reefs are rare, and there is a high degree of sand-scour on reefs in most places. High annual rainfall and large rivers lead to high sediment loading and turbidity in the nearshore zone. Reefs extend into deep water around headlands (e.g. Jackson Head), offshore rock stacks (e.g. Cascade Island and Barn Island) and islands (e.g. Open Bay Islands (Taumaka and Popotai)), and the levels of sand scour and turbidity appear to be reduced in these areas. Upwelling (of colder, deeper water) is considered to play an important role in the ecology of intertidal communities (Menge et al. 1999; Menge et al. 2003; but see Schiel 2004); however, the importance of upwelling to subtidal systems, and the relative importance of terrestrially-derived nutrients associated with the high river inflow, has not been investigated in this region.

## 2.2 SAMPLING PROCEDURE

Sampling was carried out at eight sites in South Westland and seven sites in Buller in February 2001, and twelve additional sites were sampled in December 2003 at Big Bay, Barn Island, Jackson Head, Open Bay Islands and Moeraki (See Shears & Babcock (2007) for site positions and sampling dates). All sites were sampled using the same methodology, which is described in Shears & Babcock (2007). The 27 sites were divided between nine sampling locations: Karamea (3), Cape Foulwind (4), Moeraki (3), Open Bay Islands (3), Jackson Bay (2), Jackson Head (3), Cascades (3), Barn Islands (3) and Big Bay (3) (Fig. 1). The numbers of sites sampled, and locations sampled, were largely influenced by sea conditions at the time of sampling. As far as possible, sampling was standardised to sites that had contiguous sloping reef between 0 and 12 m deep. In most cases, sampling sites were located on the northwestern side of intertidal reefs, rock-stacks or islands to provide some protection from the prevailing southwesterly swell. Because of adverse sea conditions and high turbidity, no sampling was carried out between Moeraki and Cape Foulwind. Local information and assessment of maps and photos indicate that there are few suitable sampling sites between Greymouth and Bruce Bay.

The depth distribution of biological habitat types and counts of dominant species were recorded at 5-m intervals along a line transect run perpendicular to the shore at each site, and benthic communities were quantified by sampling five 1-m<sup>2</sup> quadrats within each of four depth ranges (0-2, 4-6, 7-9 and 10-12 m). At sites where the reef was truncated at shallow depths by sand, the deeper strata were omitted. Within each quadrat, all large brown macroalgae were counted and measured, while the percentage cover of smaller algal species was estimated. Red algal species less than 5 cm in height or length were divided into the following groups: crustose corallines, coralline turf, red encrusting algae, and red turfing algae. Where possible, all larger macroalgal species were identified to species level in the field. The percentage cover of sediment, bare rock and other sessile forms (e.g. sponges, bryozoans, hydroids, ascidians and anemones) was also estimated in each quadrat. Counts and measurements of conspicuous mobile macroinvertebrates species were also made.

### 2.3 ENVIRONMENTAL VARIABLES

A number of environmental variables were estimated for each site. These were: wave exposure, wind fetch, turbidity (secchi disc), sedimentation, reef slope and maximum depth. Wave exposure estimates (m) for all sites were derived from the New Zealand regional wave hindcast model 1979–98 (Gorman et al. 2003). Wind fetch (km) was calculated for each site by summing the potential fetch for each 10° sector of the compass rose—as in Thomas (1986)—to provide an additional estimate of wave exposure at each site. For open sectors of water, the radial distance was arbitrarily set to be 300 km. Turbidity was measured using a standard 25-cm-diameter black and white secchi disc (Larson & Buktenica 1998). The reading was taken as the average depth (m) of descending disappearance and ascending reappearance. The percentage cover of sediment on the substratum at each site from quadrat sampling was used as an estimator of sedimentation. Reef slope at each site was expressed as a percentage, where the maximum depth sampled was divided by the total length of a transect line which was run out perpendicular to the shore from low water to 12 m depth or the edge of the reef (whichever came first). The density of exposed *Evechinus* (averaged across all depths at each site) was also used as an explanatory variable in multivariate analyses because of its strong influence on macroalgal community structure (Ayling 1981; Andrew & Choat 1982; Villouta et al. 2001; Shears & Babcock 2002).

### 2.4 HABITAT CLASSIFICATION

Because of the lack of information on subtidal reef habitat types on the SIWC, the line transect data were used to identify, describe and validate common habitat types. The majority of quadrats sampled along the line transects were assigned to nine subjective habitat types in the field (Table 1). In addition to assigning each quadrat to a habitat type, the abundance of dominant species and percentage cover of dominant macroalgal and sessile benthic groups were estimated. This allowed an assessment of the biological distinctiveness of the habitats identified in the field using the same technique used to validate habitat types in northeastern New Zealand (Shears et al. 2004). In some cases, quadrats were not clearly assigned to a specific habitat type (e.g. occurred at a transition), so were not included in the analysis. Sand and Cobble habitats were also excluded.

Analysis of similarity (ANOSIM, Clarke & Warwick 1994) and canonical analysis of principal coordinates (CAP, Anderson & Willis 2003) were used to test for differences in assemblages between the nine habitats and to carry out a leave-one-out classification of habitat types to determine the classification success of each habitat type, as in Shears et al. (2004). Analyses were carried out on untransformed count data for *Ecklonia radiata*, *Durvillaea* spp., other large brown algal species (pooled) and *Evechinus chloroticus*, and  $\log(x+1)$  transformed percentage cover data for 18 macroalgal, sessile invertebrate and physical groups (Appendix 1). The two physical groups (sediment and bare rock) were included in the classification analysis as their occurrence was a key feature of some of the biological habitats recorded.

TABLE 1. DESCRIPTION OF BIOLOGICAL HABITAT TYPES RECORDED ON SOUTH ISLAND WEST COAST REEFS (HABITATS WERE DETERMINED IN THE FIELD BY SUBJECTIVE ASSESSMENT OF DOMINANT SPECIES). ABUNDANCES GIVEN IN THE DESCRIPTIONS ARE INDICATIVE ONLY, ACTUAL MEAN ABUNDANCES AND COVERS OF DOMINANT SPECIES WITHIN EACH HABITAT ARE PRESENTED IN APPENDIX 1.

HABITAT	DEPTH RANGE (m)	DESCRIPTION
<i>Durvillaea</i> fringe (Dur)	< 1	Shallow fringe of <i>Durvillaea willana</i> and/or <i>D. antarctica</i> . Substratum predominantly covered by crustose corallines and, to a lesser extent, red encrusting algae and red turfing algae.
<i>Ecklonia</i> forest (Eck)	< 5	Generally monospecific stands of <i>Ecklonia radiata</i> (>4 adult plants per m <sup>2</sup> ). Urchins at low numbers (<1 exposed urchin per m <sup>2</sup> ).
Mixed brown algae (MB)*	< 7	Mixture of large brown algal species. No clear dominance of one particular species and urchins may occur in low numbers (<2 exposed urchins per m <sup>2</sup> ).
Mixed turfing algae (MT)*	All	Substratum predominantly covered by turfing (e.g. articulated corallines and other red turfing algae) and foliose algae (>30% cover). Low numbers of large brown algae (<4 adult plants per m <sup>2</sup> ) and urchins may be common.
Scoured rock (Sco)*	> 5	The reef is predominantly bare, often with high sediment cover. Crustose corallines are the dominant encrusting form. The mussel <i>Xenostrobus</i> and encrusting bryozoans may also be common.
Invertebrate turf (IT)*	> 5	Substratum predominantly covered by community of encrusting ascidians, sponges, hydroids, and bryozoans, with a high cover of sediment. Large brown algae and <i>Evechinus</i> are generally absent.
Urchin barrens (UB)*	5-12	Very low numbers of large brown algae present (<4 adult plants per m <sup>2</sup> ), substratum typically dominated by crustose coralline algae and red turfing algae. Usually associated with grazing activity of <i>Evechinus</i> (>2 exposed urchins per m <sup>2</sup> ).
Perna beds (Per)	< 3	Dominance of <i>Perna canaliculus</i> , which may be covered in a variety of encrusting flora and fauna.
<i>Xenostrobus</i> mats (Xen)*	2-10	<i>Xenostrobus pulex</i> , crustose corallines and the hydroid <i>Amphisbeta bispinosa</i> . Encrusting bryozoans and anemones are also common.

\* Pictured in Fig. 2.

## 2.5 COMMUNITY ANALYSIS

Community analyses were carried out separately for benthic community structure, macroalgal species composition and mobile macroinvertebrate assemblages. Analyses of benthic community structure were carried out on log(x+1) transformed percentage cover data for 21 sessile benthic groups (these were the same groups used above for the habitat classification, excluding *Evechinus* (Appendix 1)). Analysis on macroalgal species composition was carried out on presence-absence data of the 48 macroalgal species recorded and analysis of mobile macroinvertebrates was carried out on log(x+1) transformed count data of the 28 macroinvertebrate species recorded. All analyses were performed on the depth-averaged data for each site. Depth-related patterns in the abundance, biomass or cover of key species and groups are presented for each of the SIWC sampling locations in Shears & Babcock (2007).

Patterns in benthic community structure, macroalgal species composition and mobile macroinvertebrate assemblages were investigated among sites using principal coordinates analysis based on Bray-Curtis similarities (using the PCO program, Anderson 2003). The original species variables were also correlated with principal coordinates axes, and the correlation coefficients plotted as bi-plots, to give an indication of the relationship between individual species and the multivariate patterns. The relationship between the multivariate data sets and environmental variables was investigated using non-parametric multivariate multiple regression (McArdle & Anderson 2001) with the computer program DISTLM (Anderson 2002). Individual variables were analysed for their relationship with each community dataset, then subjected to a forward-selection procedure whereby each variable was added to the model in the order of greatest contribution to total variation. All analyses were based on Bray-Curtis similarities. Marginal tests (examining a single variable or the entire set of variables) were carried out with 4999 permutations of the raw data, while conditional tests (used for the forward-selection procedure) were based on 4999 permutations of residuals under the reduced model.

For each of the three community datasets, general patterns in the abundance of cover of the dominant groups or species are presented. This provides an indication of the variation among sites within locations and between Buller and South Westland.

## 2.6 BIOGEOGRAPHIC CLASSIFICATION

The existing biogeographic schemes proposed for the SIWC (Fig. 1A) were tested using the macroalgal species composition dataset (presence-absence of 48 species) collected in the present study and fish species composition data from the appendices of Roberts et al. (2005) (compiled by D. Neale, DOC; presence-absence data for 90 fish species from 46 stations). Fish stations were located from Milford Sound (Fiordland) in the south to Wekakura Point (north of Karamea) in the north. However, no sampling was carried out on the Fiordland open coast, and only two stations were sampled between Bruce Bay and Greymouth (Westland). Analyses were restricted to the macroalgal species composition data collected in the present study, as this group of taxa display greater biogeographic disjunction than mobile macroinvertebrates (for reasons discussed in Shears et al. (in press)). Differences in algal and reef fish species composition were investigated among sites or stations within each of the regions using ANOSIM and CAP (as in the habitat classification analysis). A leave-one-out classification of sites was also carried out using CAP to determine the classification success of each region and scheme. The following regions were tested for each scheme:

- Neale & Nelson (1998): Buller, Westland, South Westland and Fiordland (note: Fiordland was included as this was considered as a distinct region by these authors).
- Roberts et al. (2005): Fiords, Fiordland open coast-South Westland, Transition and Westland-Buller (note: the Transition zone was treated as its own region).

## 3. Results

### 3.1 HABITAT CLASSIFICATION

The present study identified nine biological habitat types on the SIWC reefs sampled (Fig. 2); these are summarised in Table 1. The mean abundance or percentage cover of dominant benthic species groups within each of these habitats is given in Appendix 1. Three of the habitat types were characterised by large brown algae—‘mixed brown algae’, ‘*Ecklonia* forest’ and ‘*Durvillaea* fringe’—although these habitats were generally rare with low numbers of the quadrats sampled being classified in these categories (Appendix 1). ‘Mixed brown algae’ habitat (MB, Fig. 2A) comprised a mixed assemblage of large brown algal species such as *Landsburgia quercifolia*, *Ecklonia radiata* and/or *Sargassum sinclairii*, but also included relatively high numbers of small brown algal species, red foliose and turfing species, coralline turf and crustose corallines. ‘*Ecklonia* forest’ was clearly dominated by *Ecklonia radiata*, but other large brown algae were present in low numbers, and the substratum was dominated by crustose corallines and ascidians. ‘*Durvillaea* fringe’ habitat occupied the sublittoral fringe at some sites, and was predominantly characterised by *Durvillaea willana* and, in some cases, *Durvillaea antarctica*. The substratum in this habitat was dominated by crustose corallines and, to a lesser extent, red turfing algal species such as *Ballia callitrichia*.

The most common reef habitat was ‘mixed turfing algae’ (MT, Fig. 2B), which was dominated by red turfing algal species but also a combination of small brown algal species, red foliose species, coralline turf and crustose corallines. *Evechinus* often occurred in low numbers in this habitat, encrusting invertebrates had a low percentage cover (<10%), and there was a relatively high cover of sediment (trapped in amongst the algal turfs) (Appendix 1, Tables A1.2, A1.3). Two other commonly occurring reef habitats were ‘invertebrate turf’ and ‘scoured rock’. ‘Invertebrate turf’ (IT, Fig. 2C) was dominated by sessile invertebrate groups such as ascidians, bryozoans, hydroids, sponges, tube worms and anemones, as well as sediment (Appendix 1). Large brown algae were absent, but other algal groups were common, with red turfing algae being the dominant algal group in this habitat. All algal groups except crustose corallines were rare in the ‘scoured rock’ habitat (Sco, Fig. 2D), which was dominated by bare rock. Encrusting invertebrates were also rare in the Sco habitat (Appendix 1, Table A1.2), with the mussel *Xenostrobus pulex* being the most common. In some cases, *Xenostrobus* was the dominant substratum cover on the reef and these areas were classified as ‘*Xenostrobus* mats’ habitat (Xen, Fig. 2E). Hydroids (predominantly mussel beard *Amphisbetia bispinosa*), anemones and bryozoans (encrusting forms) were common in this habitat. The starfish *Stichaster australis* was particularly abundant in this habitat (Fig. 2E). The greenshell mussel *Perna canaliculus* also dominated the substratum on some reefs and these areas were classified as ‘*Perna* beds’. A variety of groups were recorded growing on or in association with the mussels, e.g. red foliose algae, barnacles, anemones, hydroids.



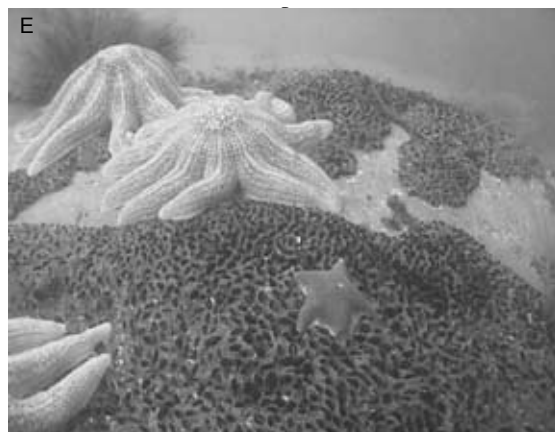
Mixed brown algae (Big Bay)



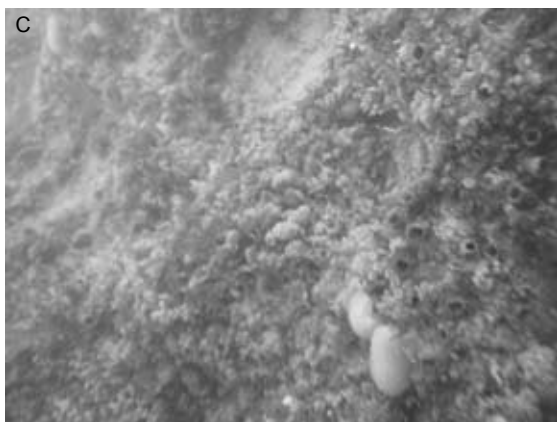
Scoured rock (Cape Foulwind)



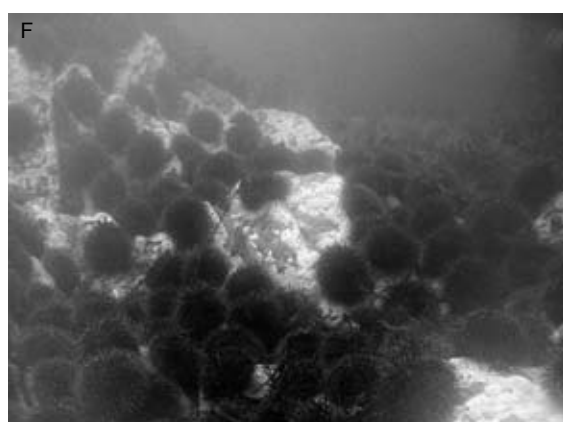
Mixed turfing algae (Jackson Head)



*Xenostrobus* mats (Cape Foulwind)



Invertebrate turf (Moeraki)



Urchin barrens (Big Bay)

Figure 2. Biological habitat types recorded on West Coast reefs (excluding *Ecklonia* forest, *Durvillaea* fringe and *Perna* beds). See Table 1 for a description of each habitat type. Photos B, C, D, E—NTS; A, F—P. Ross.

'Urchin barrens' habitat (UB, Fig. 2F) was also recorded at some sites in association with high densities of the sea urchin *Evechinus chloroticus* (Appendix 1, Table A1.3). Large brown algae were absent in this habitat and the substratum was dominated by red turfing algae, crustose corallines and sediment. Encrusting invertebrates were generally rare in this habitat.

Unconstrained ordination of the quadrat data from line transects revealed some clear groupings of samples from different habitats (Fig. 3A). Sco and Xen samples were grouped on the left of the ordination, while the large brown algal habitats,

IT and MT, were grouped on the right. The covers of bare rock and *Xenostrobus* were negatively correlated with PC1, while a number of algal groups were positively correlated. Similarly, there was a clear gradient in habitats along PC2, with IT samples at the bottom of the ordination, MT in the middle, and large brown algal habitats at the top (Fig. 3A). Sediment and invertebrate groups (e.g. tube worms and ascidians) were negatively correlated with PC2, while *Ecklonia*, *Durvillaea* and other large brown algae were positively correlated. Despite some overlap among samples from different habitats, ANOSIM revealed significant differences in benthic communities between the nine habitats (Global  $R = 0.729$ ,  $P = 0.001$ ). However, pair-wise tests revealed no significant

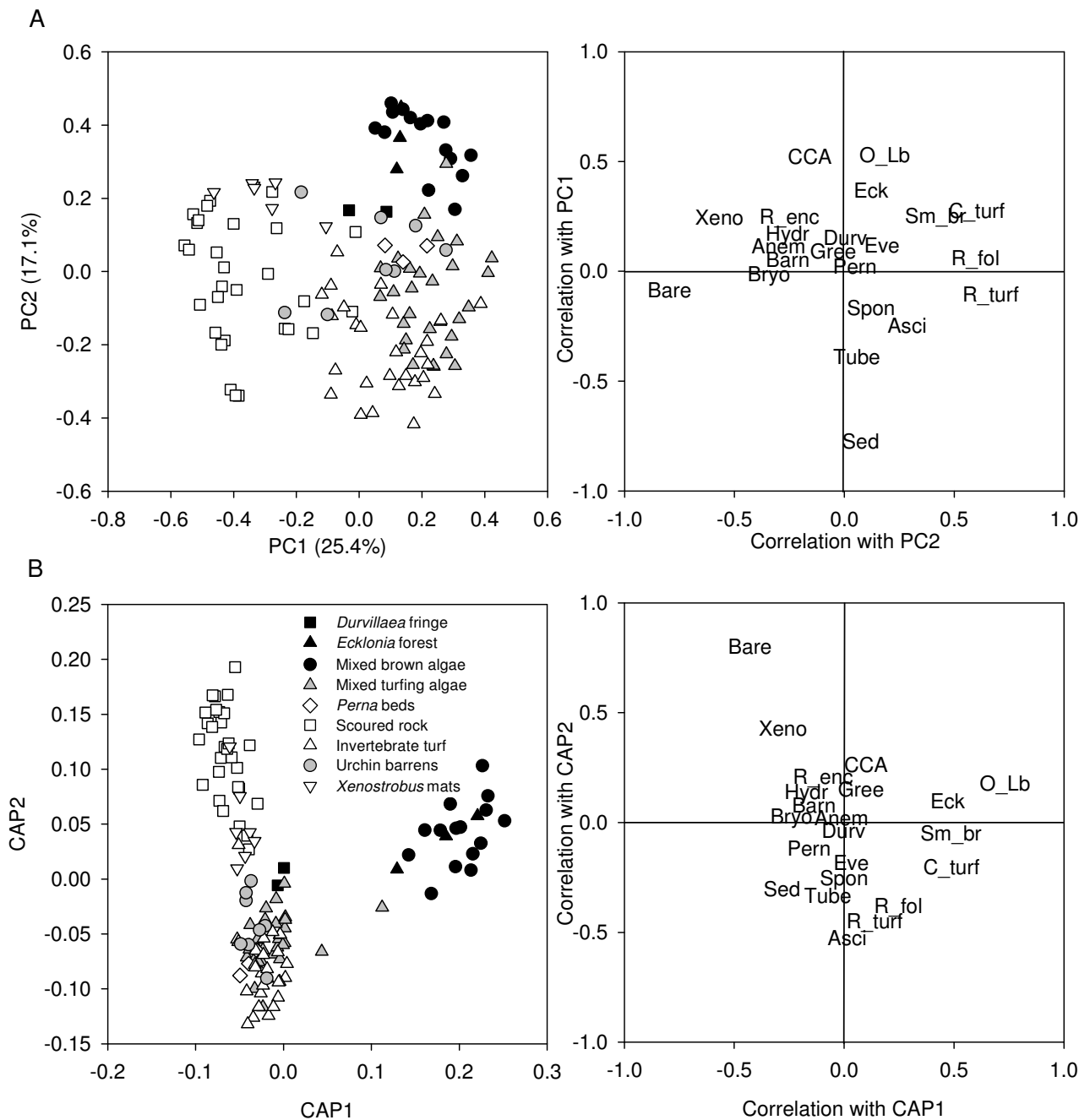


Figure 3. Habitat classification for West Coast reefs. A—Unconstrained (principal coordinates analysis) of benthic assemblages from quadrat sampling. B—Constrained (CAP) ordination of benthic assemblages from quadrat sampling. Each symbol represents one quadrat and indicates the habitat type it was assigned to in the field. Bi-plots show correlations between the benthic species group variables, and (A) the two principal coordinate axes, and (B) the two CAP axes. See Table 2 for variable codes.

differences between *Durvillaea* fringe and *Ecklonia* forest, *Durvillaea* fringe and *Perna* beds, and *Ecklonia* forest and *Perna* beds, most likely because of the low numbers of samples from each of those habitats.

Constrained ordination revealed clearer groupings of samples from the different habitats (Fig. 3B) and CAP analysis found a highly significant difference between the nine habitats ( $P \leq 0.001$ ), with an overall classification success of 75.6%; i.e. 93 of the 123 quadrats analysed were correctly classified by CAP as the original habitat assigned in the field. The classification success for each habitat ranged from 0% for '*Ecklonia* forest' to 90% for 'scoured rock' (Appendix 1, Table A1.3). All '*Ecklonia* forest' quadrats were misclassified as 'mixed brown algae', suggesting there wasn't a clear distinction between these habitat types; however, only three quadrats were classified as '*Ecklonia* forest'. In general, the habitats with low numbers of samples had a low classification success, e.g. *Durvillaea* fringe, *Ecklonia* forest, *Perna* beds and *Xenostrobus* mats (Appendix 1, Table A1.3). There was a general gradient in benthic communities among IT, MT and UB and a high degree of overlap among samples based on CAP axis 1 and 2 (Fig. 3B). Subsequently, five of the IT samples were misclassified as MT (one as UB), while five of the MT samples were classified as IT and two as UB. Despite this gradient, the distinction between these habitats was clearly supported by the classification analysis, each scoring approximately 75%.

## 3.2 HABITAT DISTRIBUTIONS AND REEF PROFILES

### 3.2.1 South Westland

**Big Bay**—There was a clear difference in the distribution of habitats between Crayfish Rock on the northern side of the bay compared with Penguin Inner and Penguin Rocks on the southern side (Fig. 4A). At Crayfish Rock, shallow depths (< 6 m) were dominated by mixed brown algal habitat (MB), while mixed turfing algal habitat (MT) dominated deeper areas, with some patches of urchin barrens (Fig. 2F). In contrast, the southern sites were both dominated by MT at shallow depths, and invertebrate turf habitat (IT) below 8 m depth.

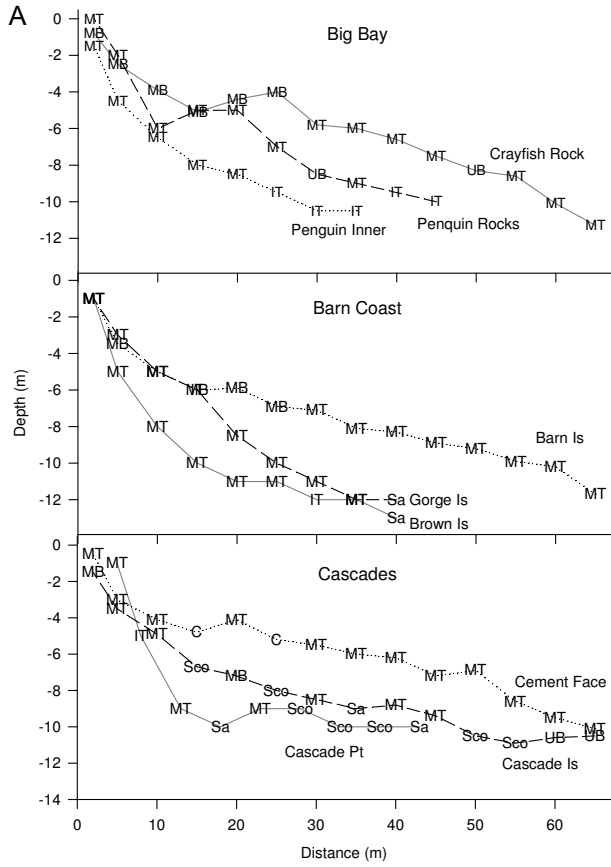
**Barn Islands**—The three sites in this area all had a similar depth distribution of habitats, with MT dominating across all depths, but with patches of MB (generally in shallow water, < 7 m). MB was not recorded at the steeper Browne Island site, but the large brown alga *Landsburgia* was present in low numbers.

**Cascades**—The reef profiles and habitat distributions were variable among the sites sampled in this area. The reef at Cascade Point was a near vertical wall classified as IT and MT to c. 9 m depth, below which it levelled out and was highly scoured and interspersed with sand (Fig. 4A). In contrast, Cement Face sloped gradually and MT dominated across all depths. The Cascade Island site was intermediate to the other sites in this area and was covered in a mosaic of habitats including Sco, MB, MT and patches of urchin barrens in the deeper areas.

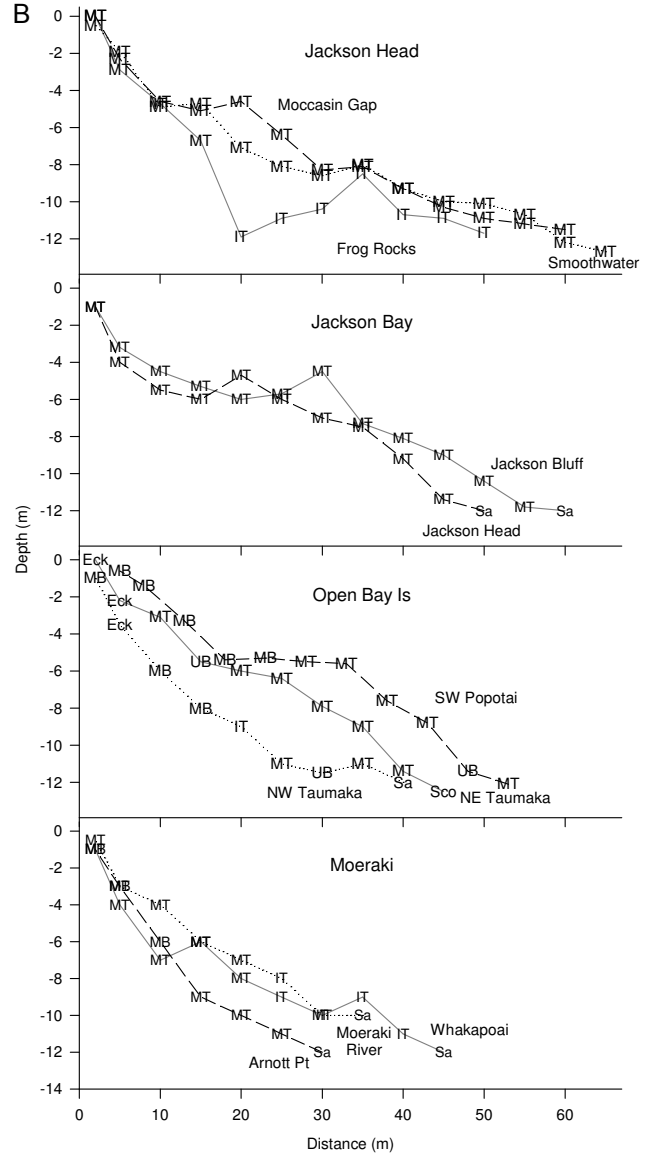
**Jackson Head and Jackson Bay**—The sites in both these areas had similar reef profiles and depth distribution of habitats with MT dominating at all depths (Fig. 4B). One exception was Frog Rocks where the reef dropped steeply to 12 m and then levelled out. At this site the reef below 10 m depth was classified as IT.



### Big Bay to Cascades



### Jackson Head to Moeraki



### Buller

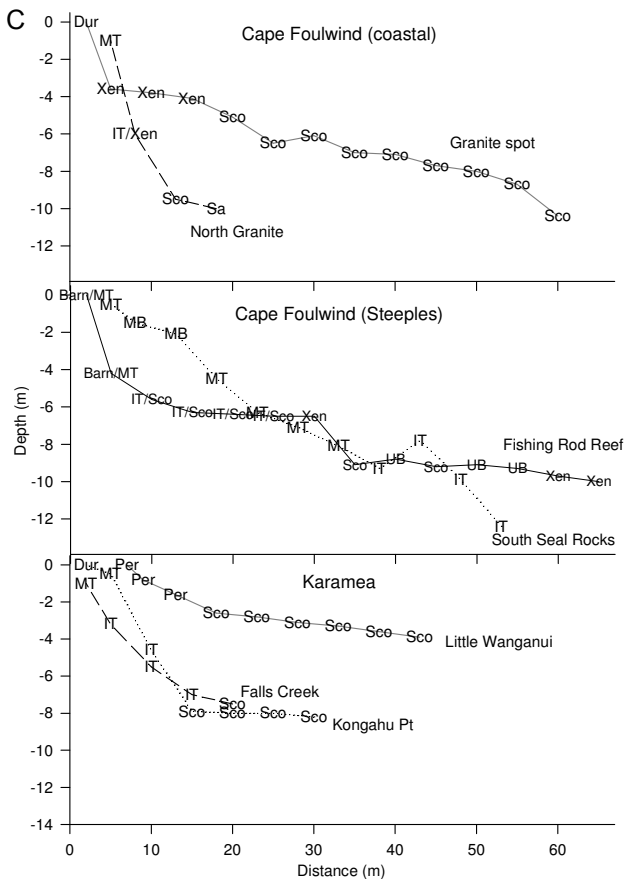


Figure 4. Depth profiles and habitat distributions at each site within each location: A. Big Bay to Cascades; B. Jackson Head to Moeraki; C. Buller. See Table 1 for habitat abbreviations. Sa = Sand, C = cobbles.

Open Bay Islands—The sites sampled at Open Bay Islands had considerably different habitat distributions to the other SIWC sites, because of the dominance of large brown algal habitat types (*Ecklonia* forest and MB) in shallow water (<8 m). Mixed turfing algae dominated the deeper water areas and patches of urchin barrens were common.

Moeraki—The Moeraki River and Whakapohai sites had similar habitat distributions with shallow quadrats (<8 m) classified as MT while deeper quadrats were IT. The Arnott Point site was considerably steeper and MB dominated shallower depths (<6 m).

### 3.2.2 Buller

Cape Foulwind—There was considerable variation among the Cape Foulwind sites (Fig. 4C) and the habitat distributions are presented separately for the coastal sites (North Granite and Granite Spot) and sites located offshore at an area known as Three Steeples (South Seal Rocks and Fishing Rod Reef). Granite Spot was a relatively gradually sloping boulder reef which was highly scoured below 4 m. *Durvillaea* fringe dominated shallow subtidal areas and 'Xenostrobus mats' covered the reef at 2–4 m depth. The reef at North Granite was near vertical, and IT and Xen covered the rock wall at 2–8 m, below which the reef was scoured and inundated by sand at 10 m. The shallow zone at Fishing Rod Reef was dominated by barnacles and MB, while the reef at greater depths was classified as a mix of IT, Sco, Xen and UB. The South Seal Rocks site was considerably different and more typical of South Westland sites, with MT and MB in shallow water (<8 m), and deeper areas of the reef were classified as IT.

Karamea—The Falls Creek and Kongahu Point sites were both steep sloping reefs that levelled out at c. 8 m depth and were highly scoured (Fig. 4C). *Durvillaea* fringe and MT dominated the shallow zone (<2 m), while IT covered the steep reef areas. The shallow reef at Little Wanganui was quite distinct from the other West Coast sites with *Perna* beds dominating the shallow zone (<2 m), while deeper areas were scoured.

## 3.3 BENTHIC COMMUNITY STRUCTURE

There was a relatively clear division in benthic community structure between Buller and South Westland sites along PC1 (Fig. 5A). ANOSIM revealed a highly significant difference in benthic community structure between sites from both regions (Global  $R = 0.885$ ;  $P = 0.001$ ); although, based on hierarchical cluster analysis, South Seal Rocks (Cape Foulwind) was clustered with the South Westland sites, which were separated from the other Buller sites at the 48% dissimilarity level. A number of macroalgal groups (red turf, red foliose, small brown, large brown and coralline turf) were positively correlated with PC1 (Fig. 5B) and these tended to have higher covers at the South Westland sites (Fig. 6A). In contrast, a number of sessile invertebrate groups (Bryozoans, Hydroids, Barnacles, Anemones and *Xenostrobus pulex*; Fig. 6B) and bare rock (Fig. 6C) were negatively correlated with PC1 and had higher covers at Buller sites.

Benthic community structure was strongly correlated with the environmental variables, which explained 54.8% of the variation among sites (Table 2A). Reefs sampled at the northern Buller sites tended to be shallower and more turbid than

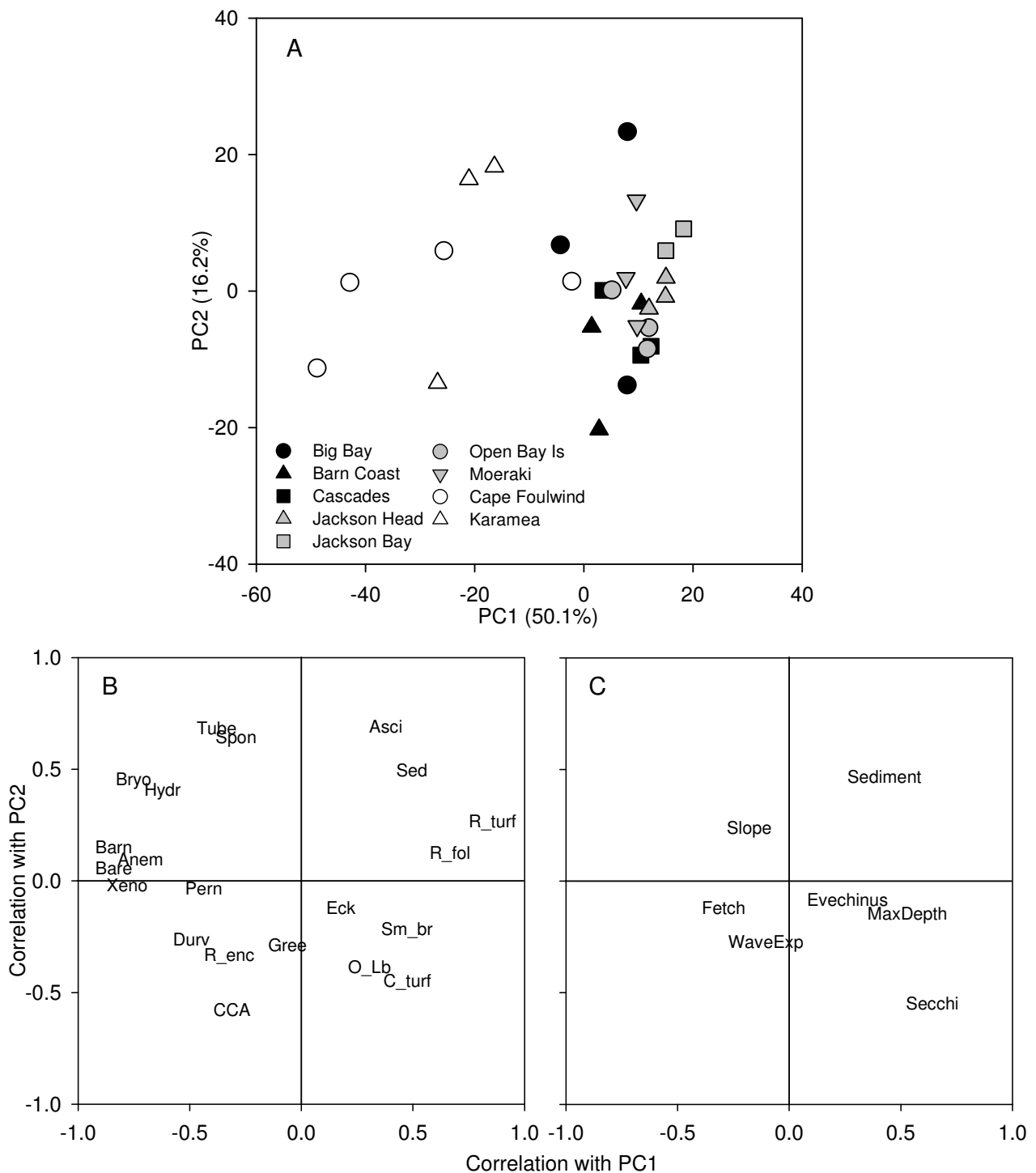


Figure 5. A—Principal coordinates analysis of benthic community structure (log(x+1) transformed percent cover data) for West Coast sites. B—Bi-plot showing correlations between principal coordinate axes and benthic group variables. C—Biplot showing correlations between principal coordinate axes and environmental variables. See Table 2 for variable codes. Buller sites—open symbols; South Westland sites—black or grey symbols (grey indicates sites in Roberts et al.'s (2005) 'Transition zone').

the South Westland sites. This was reflected by a strongly negative correlation among sites between latitude (Northing, New Zealand Map Grid) and both MaxDepth (-0.60) and Secchi (-0.64). Of the seven environmental variables, Secchi (27%) and MaxDepth (19.9%) explained the greatest variation (Table 2A). However, these two variables were also strongly correlated with each other (0.56) and when factors were fitted sequentially, Secchi (27.4%) and Sediment (15.6%)

Figure 6A. Percentage cover of dominant benthic groups for macroalgae. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.

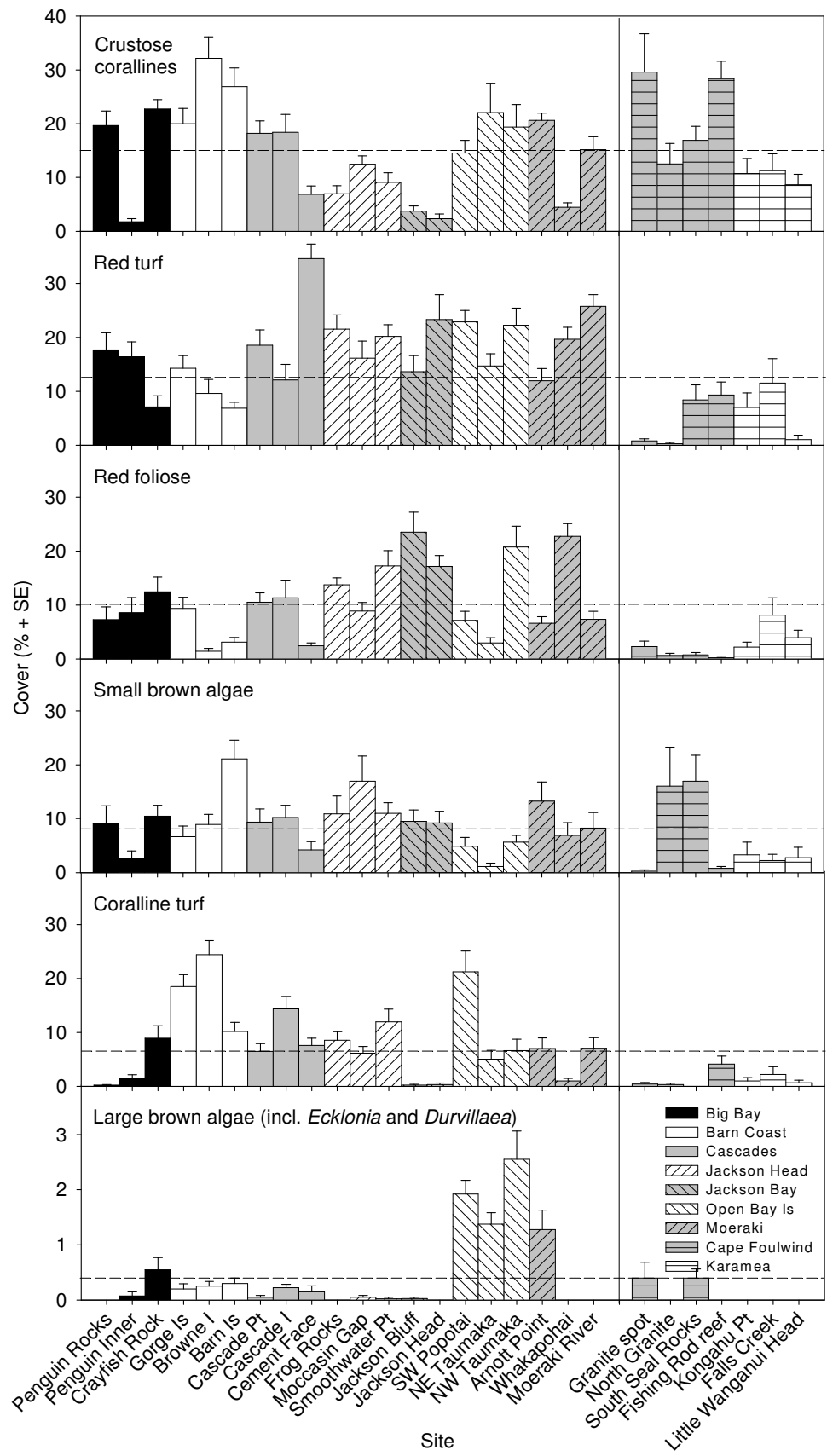


Figure 6B. Percentage cover of dominant benthic groups for sessile invertebrates. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.

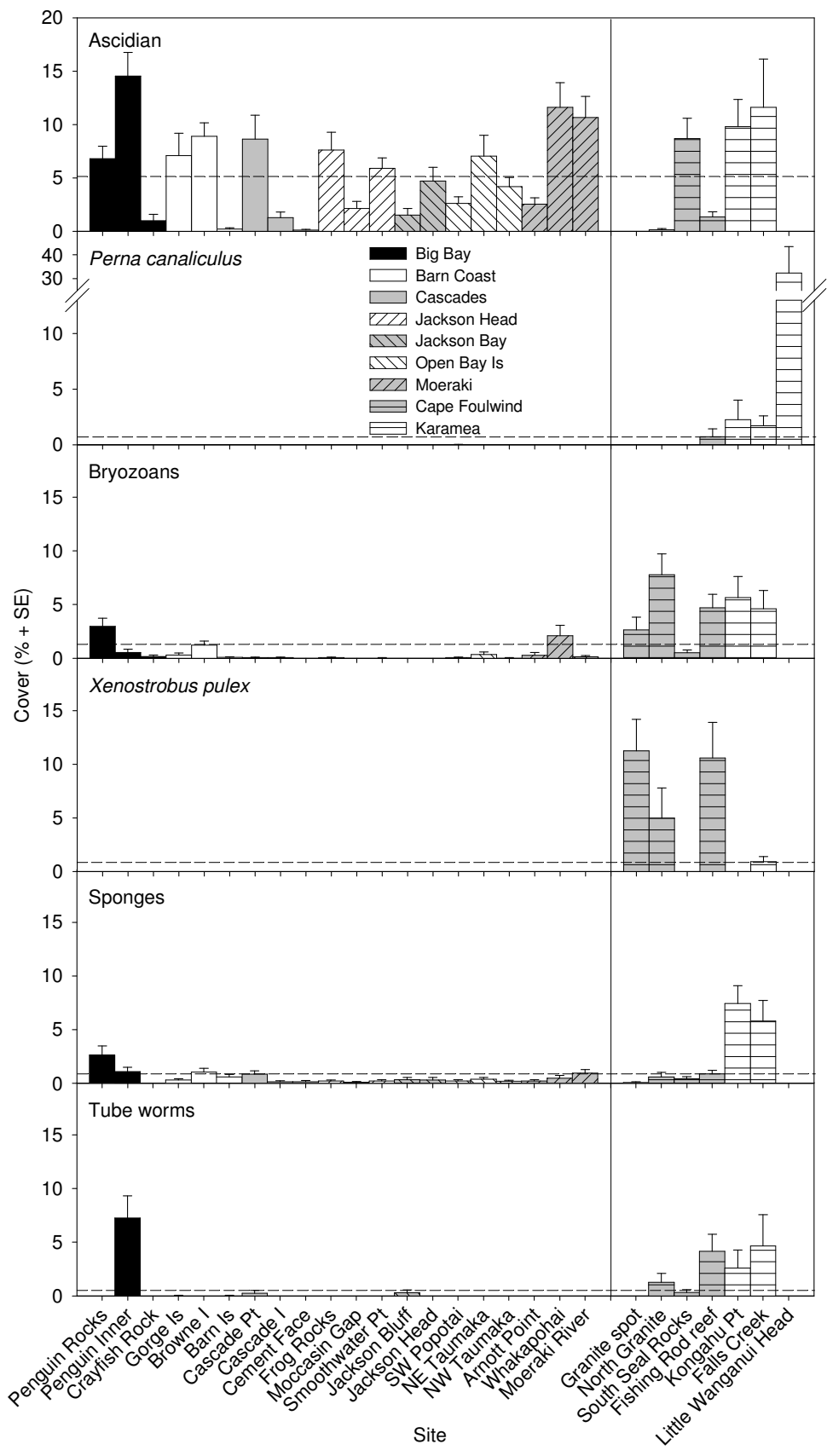
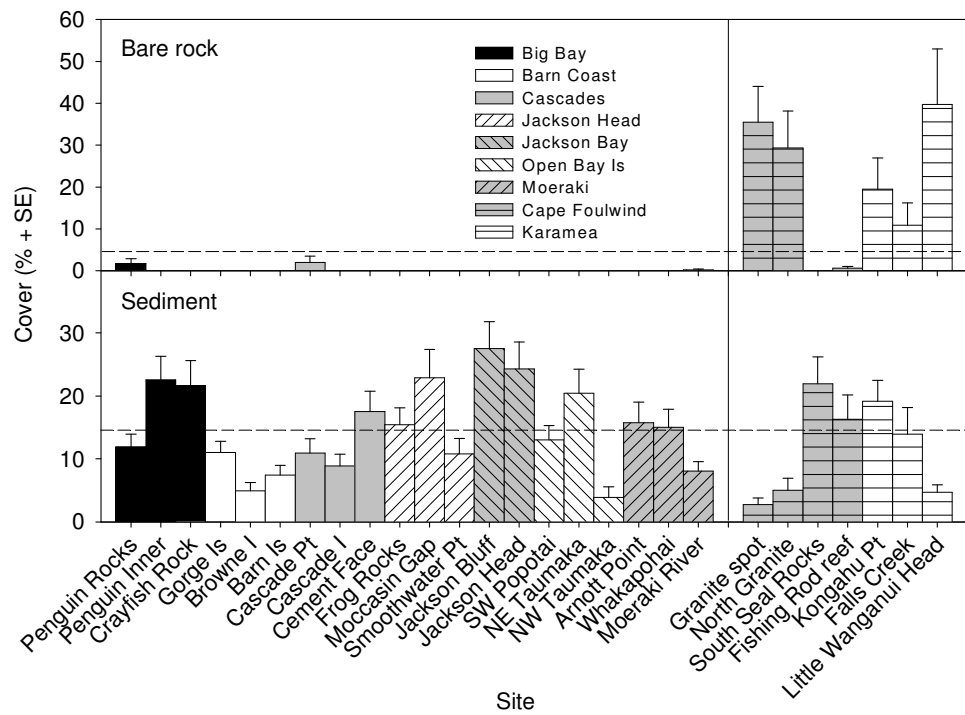


Figure 6C. Percentage cover of dominant benthic groups for bare rock and sediment. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.



were found to be significantly related to community structure. The relationship between benthic community structure and these two variables is reflected by their correlations with PC1 and PC2, respectively (Fig. 5C).

Within the Buller and South Westland regions there was no clear location-level grouping of sites; instead, variation in community structure (Fig. 5A) and key benthic groups (Fig. 6) within regions appeared to be related to differences in environmental conditions among sites. For example, the South Westland sites were spread along PC2 and this reflected a gradient from turbid sites with high sediment and ascidian cover (e.g. Penguin Inner, Penguin Rocks, Jackson Bluff, Jackson Head and Moeraki River) to sites at offshore rock-stacks or islands (e.g. Open Bay Islands sites, Barn Islands, Browne Island, Cascade Island and Crayfish Rocks) with clearer water and higher covers of large brown algae and coralline turf (Figs 5B and 6C).

The Buller sites were all highly wave exposed and the variation among sites was less clearly related to the environmental factors measured. Bare rock was a common feature at all Buller sites except for the two sites at offshore rock-stacks with moderately sloping reefs (South Seal Rocks and Fishing Rod Reef) (Fig. 6C). Benthic community structure at South Seal Rocks was more similar to South Westland sites with some large brown algae (*Sargassum sinclairii* and *Landsburgia quercifolia*) and a high cover of small brown algae, particularly *Halopteris* spp. The Kongahu Point and Falls Creek sites were distinct from the other Buller sites. These both had relatively steep sloping reefs to c. 8 m depth, with a particularly low cover of algal groups and dominance by ascidians, bryozoans, sponges and tube worms. Benthic community structure at the Little Wanganui Head site was also highly distinctive because of the dominance of *Perna canaliculus* (Fig. 6B) and bare rock (Fig. 6C).

TABLE 2. RESULTS OF NON-PARAMETRIC MULTIVARIATE REGRESSION OF BIOLOGICAL DATASETS AGAINST ENVIRONMENTAL VARIABLES.

A—BENTHIC COMMUNITY STRUCTURE. B—ALGAL SPECIES COMPOSITION.

C—MOBILE MACROINVERTEBRATE ASSEMBLAGES.

Note: The test statistics and percentage variance explained for each variable (or set) are given where variables are fitted individually (left) and for significant variables following forward selection (right) (ns = not significant).

A

	INDIVIDUAL			SEQUENTIAL		
	PSEUDO- <i>F</i>	<i>P</i>	%	PSEUDO- <i>F</i>	<i>P</i>	%
<b>Set of variables</b>						
Environmental	3.29	0.0002	54.8	3.29	0.0002	54.8
<b>Individual variable</b>						
Evechinus	1.50	0.1734	5.67	-	ns	-
Fetch	1.74	0.1364	6.5	-	ns	-
MaxDepth	6.20	0.0036	19.88	-	ns	-
Slope	1.00	0.3786	3.83	-	ns	-
Secchi	9.41	0.0002	27.35	9.4113	0.0002	27.4
Sediment	4.51	0.0048	15.28	6.5544	0.0006	15.6
WaveExp	1.07	0.3372	4.09	-	ns	-

B

	INDIVIDUAL			SEQUENTIAL		
	PSEUDO- <i>F</i>	<i>P</i>	%	PSEUDO- <i>F</i>	<i>P</i>	%
<b>Set of variables</b>						
Environmental	2.40	0.0032	46.9	2.40	0.0032	46.9
<b>Individual variable</b>						
Evechinus	3.98	0.0088	13.73	-	ns	-
Fetch	1.87	0.1224	6.94	-	ns	-
MaxDepth	7.35	0.0014	22.71	2.31	0.056	6.4
Slope	0.19	0.962	0.75	-	ns	-
Secchi	9.46	0.0002	27.45	9.46	0.0002	27.5
Sediment	1.20	0.28	4.57	-	ns	-
WaveExp	0.55	0.703	2.17	-	ns	-

C

	INDIVIDUAL			SEQUENTIAL		
	PSEUDO- <i>F</i>	<i>P</i>	%	PSEUDO- <i>F</i>	<i>P</i>	%
<b>Set of variables</b>						
Environmental	1.53	0.0488	31.5	1.53	0.0488	31.5
<b>Individual variable</b>						
Fetch	1.27	0.2564	4.83	-	ns	-
MaxDepth	2.69	0.0178	9.7	-	ns	-
Slope	1.39	0.2098	5.26	-	ns	-
Secchi	4.87	0.001	16.3	4.8674	0.001	16.3
Sediment	1.34	0.2196	5.08	-	ns	-
WaveExp	0.90	0.4868	3.49	-	ns	-

### 3.4 MACROALGAL ASSEMBLAGES

A total of 48 macroalgal taxa were recorded during quadrat sampling across the 27 West Coast sites (Table 3A; Appendix 2). Crustose corallines were the most commonly recorded group and on average were the dominant substratum cover among the sites sampled, followed by the red turfing algal species complex and articulated coralline turf. The majority of species recorded were typically short turfing or foliose species, and large brown macroalgae were generally rare and at low abundances ( $< 1/m^2$ ) (Table 2A). *Landsburgia quercifolia* and *Sargassum sinclairii* were the most common large brown algal species and were recorded in 13.9% and 10.4% of quadrats respectively.

There was a clear division in algal species composition between Buller and South Westland sites (Fig. 7A). While the South Seal Rocks site at Cape Foulwind had some similarities with South Westland sites, hierarchical cluster analysis separated all sites from the two regions at the 50% dissimilarity level, and there was a highly significant difference in algal species composition between sites from the two regions (ANOSIM, Global  $R = 0.901$ ;  $P = 0.001$ ).

The abundance of large brown algal species (Fig. 8) and cover of most other algal species (Fig. 9) was typically lower at the Buller sites compared with South Westland sites and this was reflected by the correlations between PC1 and the species variables (Fig. 7B). The majority of algal species were more common at South Westland sites and positively correlated with PC1, e.g. most large brown algal species (*Ecklonia radiata*, *Landsburgia quercifolia*, *Carpophyllum flexuosum* and *Cystophora scalaris*; Fig. 8), the small brown algae *Dictyota* spp. and *Zonaria* spp. (Fig. 9A), and a number of red algal species including *Plocamium* spp., *Anotrichium crinitum* and *Asparagopsis armata* (Fig. 9B). The green alga *Caulerpa brownii* was common at a few South Westland sites, particularly Crayfish Rocks (Fig. 9C). A low number of species were more common at the Buller sites, e.g. *Endarachne binghamiae*, *Gigartina* spp., *Gymnogongrus furcatus* (Fig. 9A, B), while others were relatively common at sites in both regions, e.g. *Halopteris* spp. (predominantly *Halopteris congesta*, which is a common component of the 'mixed turfing algal' habitat in the immediate subtidal zone), *Glossophora kuntzii*, and a number of other species that commonly occur at shallow depths—*Microzonia velutina*, *Echinothamnion* spp. and *Lophurella bookeriana*. *Durvillaea willana* was recorded at one site from each region (Fig. 8).

The environmental variables explained 46.9% of the variation in algal species composition among sites (Table 2B). As for benthic community structure, Secchi (27.5%) and MaxDepth (22.7%) were the variables most strongly related to algal species composition and these were positively correlated with PC1 (Fig. 7C). When variables were fitted sequentially, Secchi was the only significant variable, although MaxDepth was marginally significant ( $P = 0.056$ ). Unlike the benthic community structure analysis, sediment was not significantly related to algal species composition but *Evechinus* was (Table 2B).

There was no clear location-level grouping of sites within each region (Fig. 7A). All Buller sites had similar species composition, except South Seal Rocks where *Landsburgia* and *Sargassum* were present (Fig. 8), and there was a high cover of *Codium convolutum* (Fig. 9C). South Westland sites were spread out along PC2, but this did not correlate strongly with any of the physical variables measured. *Evechinus* abundance was weakly correlated with PC2 (Fig. 7C). Sites at the top



TABLE 3. MACROALGAL (A) AND MOBILE MACROINVERTEBRATE (B) TAXA RECORDED DURING QUADRAT SAMPLING.

Note: % occ. = percent occurrence, i.e. percentage of quadrats each species was recorded in ( $n = 517$ ).

% count = percentage of the total number of mobile macroinvertebrates recorded. Text in parentheses indicates species codes used in Figs 7 and 11.

A				B			
TAXA	% OCC.	MEAN COVER	MEAN COUNT	TAXA	% OCC.	MEAN COUNT	% COUNT
Crustose corallines	87.81	15.576	-	<i>Patiriella</i> spp. (Pati)	37.7	1.188	37.8
Red turf	72.73	13.277	-	<i>Evechinus cbloroticus</i> (Eve)	21.9	0.841	26.8
Coralline turf (C_turf)	56.09	6.722	-	<i>Stichaster australis</i> (Stichas)	15.3	0.317	10.1
<i>Plocamium</i> spp. (Ploc)	55.71	3.031	-	<i>Diplodontias</i> spp. (Dipl)	10.6	0.120	3.8
<i>Halopteris</i> spp. (Halop)	44.68	4.930	-	<i>Haliotis australis</i> (H_au)	6.0	0.095	3.0
<i>Microzonia velutina</i> (Microz)	36.56	2.088	-	<i>Cookia sulcata</i> (Cook)	3.1	0.041	1.3
<i>Lophurella bookeriana</i> (Loph)	26.89	1.764	-	<i>Pentagonaster pulchellus</i> (Pent)	2.9	0.029	0.9
<i>Anotrichium crinitum</i> (Ano)	25.73	1.825	-	<i>Stichopus mollis</i> (Sticho)	2.5	0.031	1.0
<i>Asparagopsis armata</i> (Asp)	25.15	0.854	-	<i>Cryptoconchus porosus</i> (Cryp)	1.9	0.023	0.7
<i>Echinobammion</i> spp. (Echino)	20.70	1.015	-	<i>Astrostole scaber</i> (Astro)	1.9	0.019	0.6
Red encrusting (R_enc)	19.92	0.760	-	<i>Cellana stellifera</i> (Cell)	1.7	0.031	1.0
<i>Glossophora kuntzii</i> (Gloss)	18.76	0.392	-	<i>Calliostoma punctulatum</i> (Cpun)	1.7	0.019	0.6
<i>Euptilota formosissima</i> (Eup)	17.99	0.616	-	<i>Micrelenbus</i> spp. (Micr)	1.5	0.112	3.6
<i>Landsburgia quercifolia</i> (Lands)	13.93	0.155	0.739	<i>Maoricolpus roseus</i> (Maor)	1.4	0.037	1.2
<i>Dictyota</i> spp. (Dicty)	13.15	0.217	-	<i>Trochus viridis</i> (Troc)	1.4	0.029	0.9
<i>Sargassum sinclairii</i> (Sarg)	10.44	0.068	0.470	<i>Haliotis iris</i> (H_iris)	1.2	0.122	3.9
<i>Carpomitra costata</i> (Carpom)	10.06	0.051	-	<i>Argobuccinum pustulosum</i> (Argo)	1.0	0.010	0.3
<i>Rhodophyllis gunnii</i> (Rgun)	7.93	0.164	-	<i>Plagusia chabrus</i> (Plag)	0.8	0.010	0.3
<i>Zonaria</i> spp. (Zon)	7.16	0.202	-	<i>Modellia granosus</i> (Mode)	0.8	0.008	0.2
<i>Ecklonia radiata</i> (Eck)	6.96	0.073	0.588	<i>Ophiopsammus maculata</i> (Ophi)	0.6	0.006	0.2
<i>Gymnogongrus furcatus</i> (Gymno)	6.96	0.199	-	<i>Allostichaster</i> sp. (Allo)	0.6	0.006	0.2
<i>Carpophyllum flexuosum</i> (Flex)	4.26	0.046	0.356	<i>Pycnogonid</i> sp. (Pycn)	0.6	0.006	0.2
<i>Ballia callitrichia</i> (Ballia)	3.87	0.263	-	<i>Turbo smaragdus</i> (Turb)	0.4	0.023	0.7
<i>Gigartina</i> spp. (Gig)	3.68	0.158	-	<i>Eudoxochiton nobilis</i> (Eudo)	0.4	0.004	0.1
<i>Spatoglossum chapmanii</i> (Spat)	3.68	0.052	-	<i>Calliostoma tigris</i> (Ctig)	0.4	0.004	0.1
<i>Colpomenia sinuosa</i> (Colp)	3.48	0.046	-	<i>Dicathais orbita</i> (Dica)	0.4	0.004	0.1
<i>Caulerpa brownii</i> (Cbrow)	3.29	0.175	-	<i>Buccinum lineum</i> (Bucc)	0.2	0.004	0.1
<i>Dictyota papenfussii</i>	3.29	0.305	-	<i>Cominella adspersa</i> (C_ads)	0.2	0.004	0.1
<i>Codium convolutum</i> (Cconv)	3.09	0.416	-	<i>Coscinasterias muricata</i> (Cosc)	0.2	0.002	0.1
<i>Hymenena durvillaei</i> (Hdurv)	2.71	0.040	-	<i>Scutus breviculus</i> (Scut)	0.2	0.002	0.1
<i>Ptilonia willana</i> (Ptil)	2.71	0.015	-				
<i>Endarachne binghamiae</i> (Endar)	2.13	0.040	-				
<i>Heterosiphonia conctinna</i> (Hetero)	2.13	0.165	-				
<i>Platybammion</i> sp. (Platy)	1.93	0.031	-				
<i>Pterocladia capillacea</i> (Pcap)	1.74	0.041	-				
<i>Cystophora scalaris</i> (Cscal)	1.35	0.011	0.046				
<i>Ceramium</i> spp.	1.16	0.020	-				
<i>Cladophoropsis berpestica</i>	1.16	0.009	-				
<i>Plocamium cirrhosum</i>	0.97	0.010	-				
<i>Pterocladia lucida</i> (Ptero)	0.77	0.005	-				
<i>Durvillaea willana</i> (Dwill)	0.58	0.019	0.044				
<i>Ulva</i> spp.	0.58	0.042	-				
<i>Bryopsis pinnata</i> (Bryop)	0.39	0.002	-				
<i>Desmarestia ligulata</i> (Desm)	0.39	0.002	-				
<i>Scoparia hirsuta</i> (Scop)	0.19	0.001	-				
<i>Lessonia variegata</i>	0.19	0.002	0.058				
<i>Sporochnus</i> sp.	0.19	0.008	-				
<i>Xiphophora gladiata</i>	0.19	0.002	0.010				

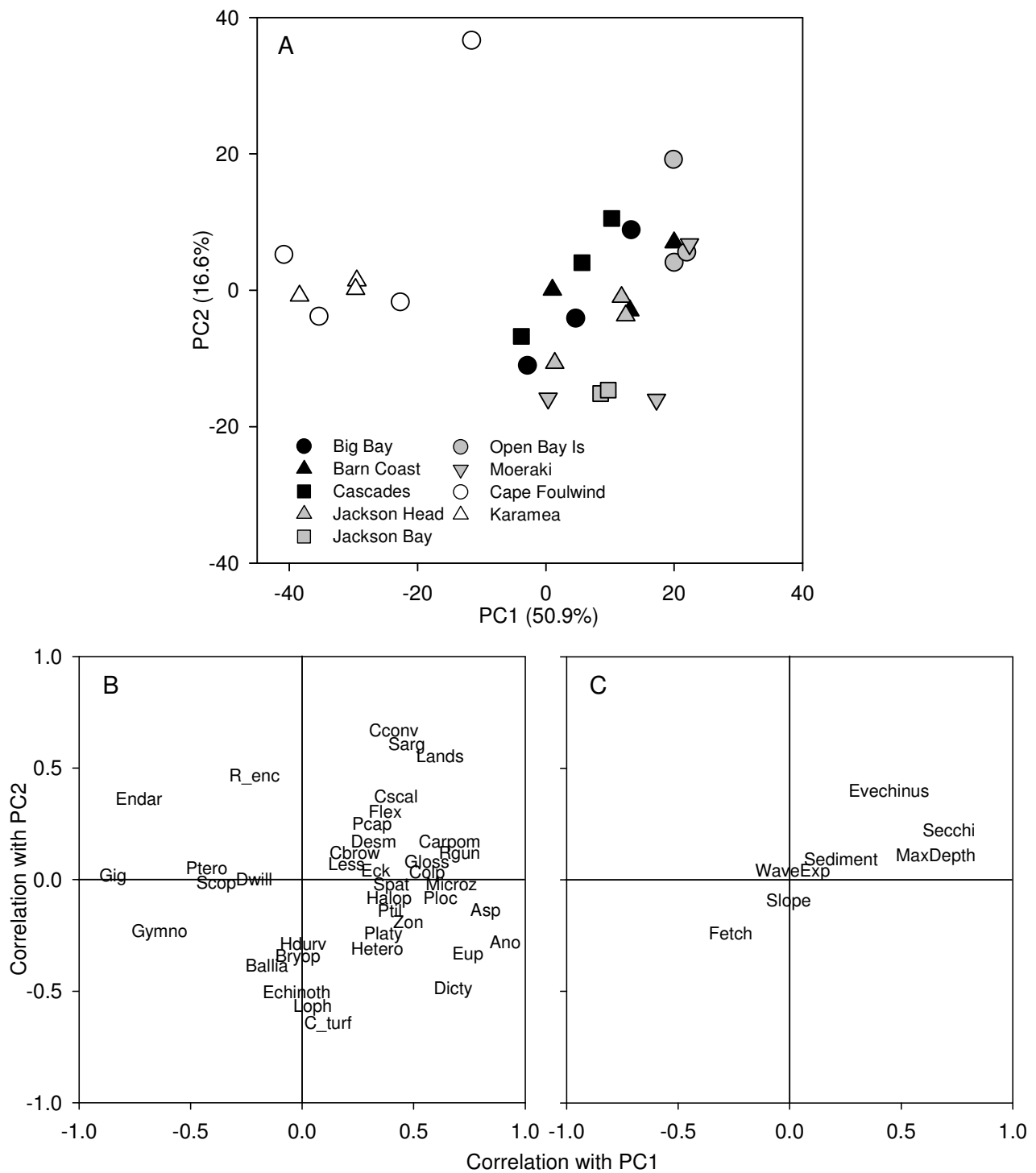


Figure 7. A—Principal coordinates analysis of macroalgal species composition (presence-absence data) for West Coast sites. B—Bi-plot showing correlations between principal coordinate axes and species variables. C— Bi-plot showing correlations between principal coordinate axes and environmental variables. See Table 2A for species codes (note: species that were weakly correlated (coefficient <0.20) with both PC1 and PC2 are not presented in C to make species codes legible). Buller sites—open symbols; South Westland sites—black or grey symbols (grey indicates sites in the ‘Transition zone’ of Roberts et al. 2005).

of the ordination (e.g. Open Bay Islands sites, Crayfish Rocks, Barn Islands and Arnott Point) tended to have higher abundances of large brown algal species such as *Sargassum* and *Landsburgia* (Fig. 8). *Ecklonia radiata* and *Carpophyllum flexuosum* were also common at Open Bay Islands only. Large brown algae were rare at the remaining sites and the algal assemblages were dominated by a variety of turfing and foliose algal species, e.g. *Plocamium*, *Echinothamnion* and *Lophurella*.

Figure 8. Mean density of dominant large brown algal species at each site. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.

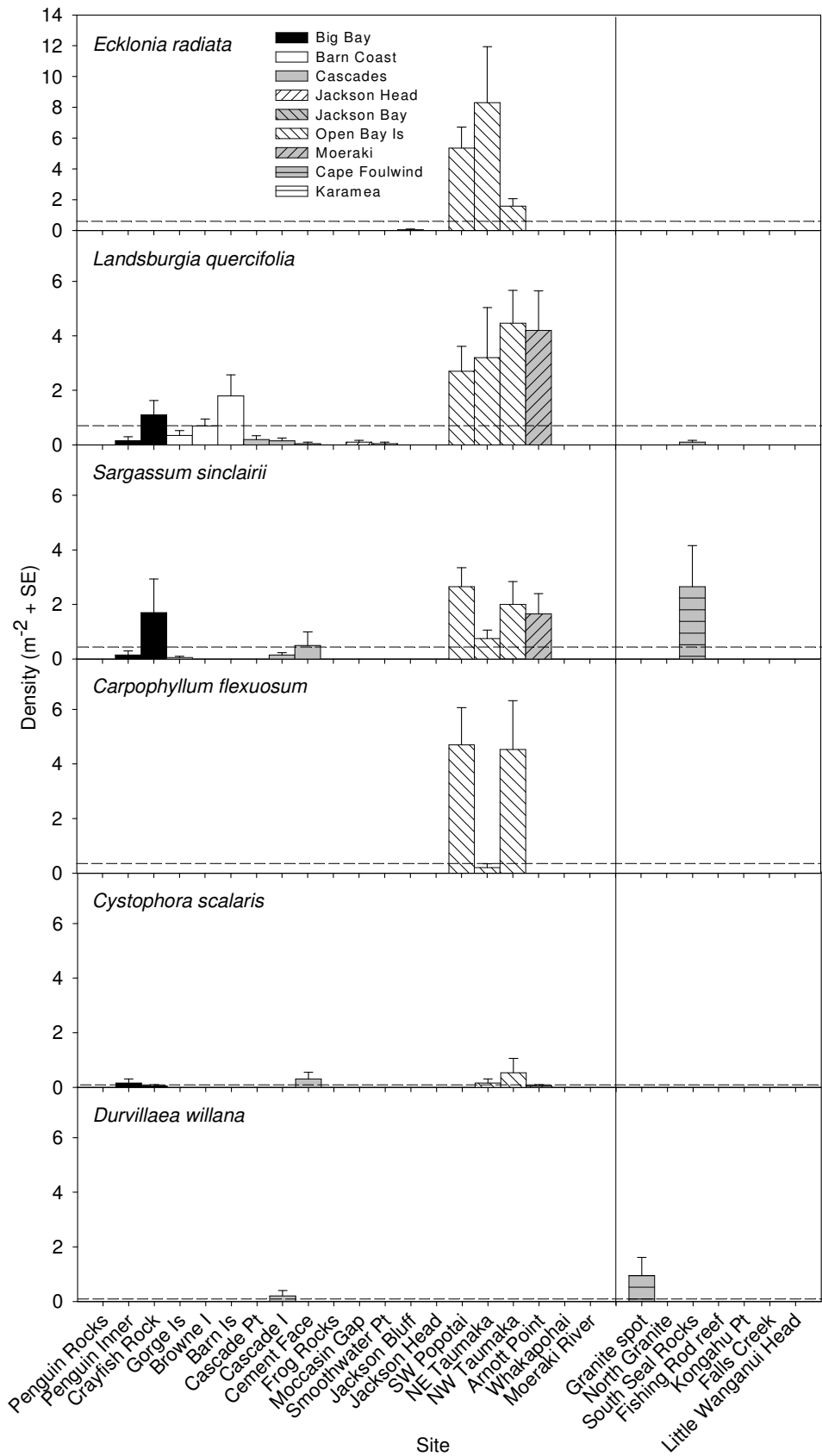


Figure 9A. Mean cover of dominant small brown algal species. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.

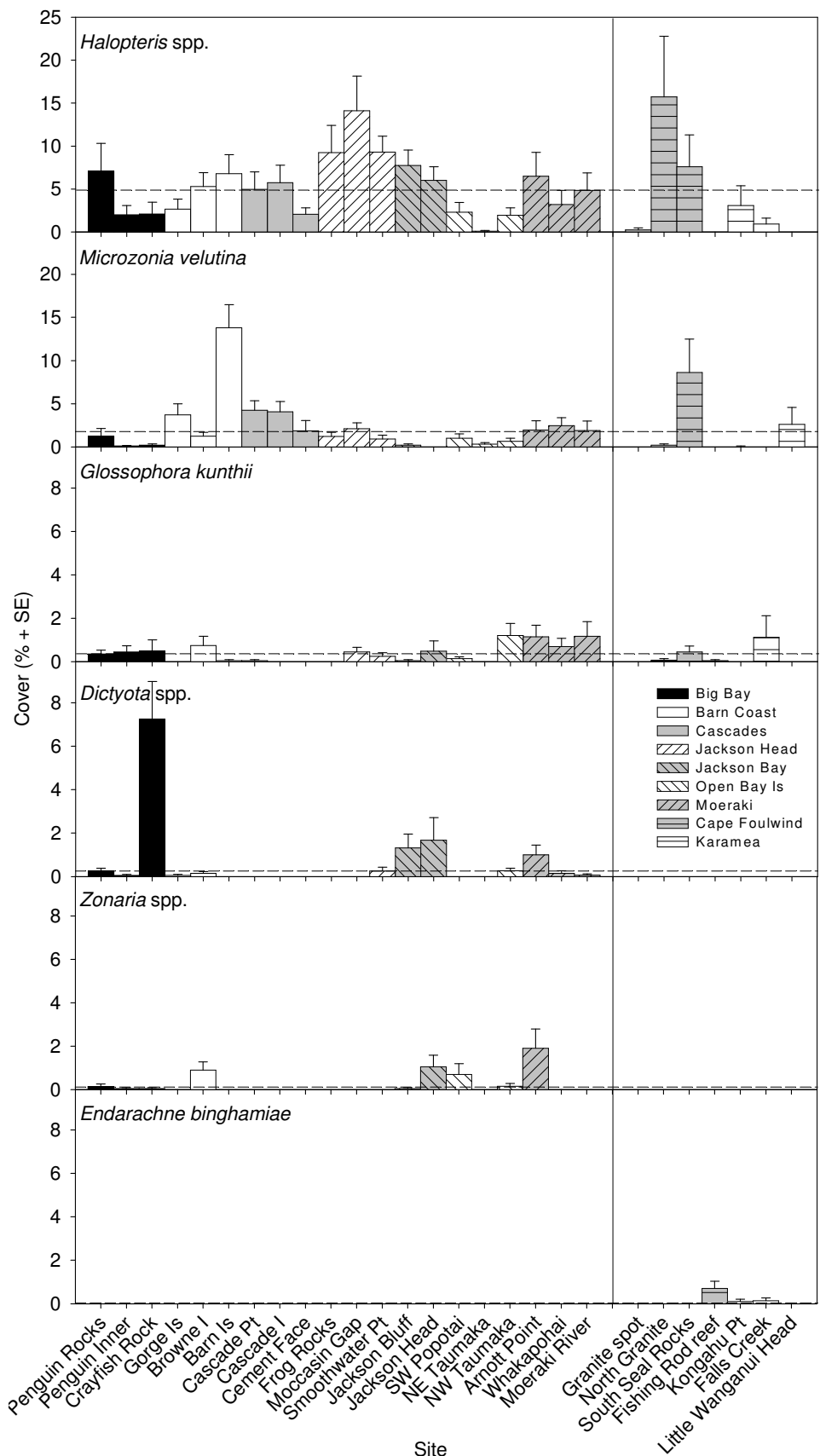


Figure 9B. Mean cover of dominant red algal species. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.

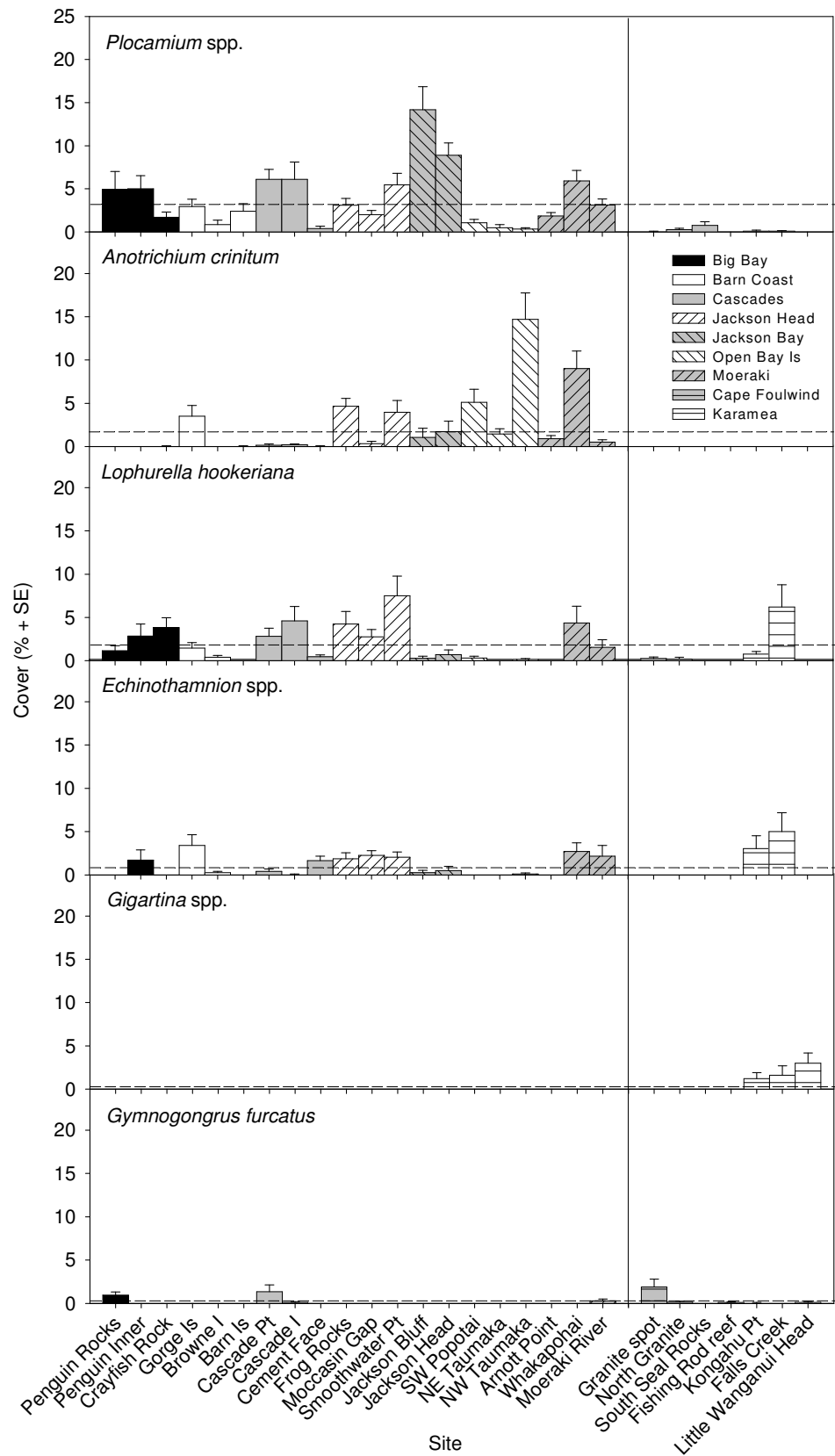
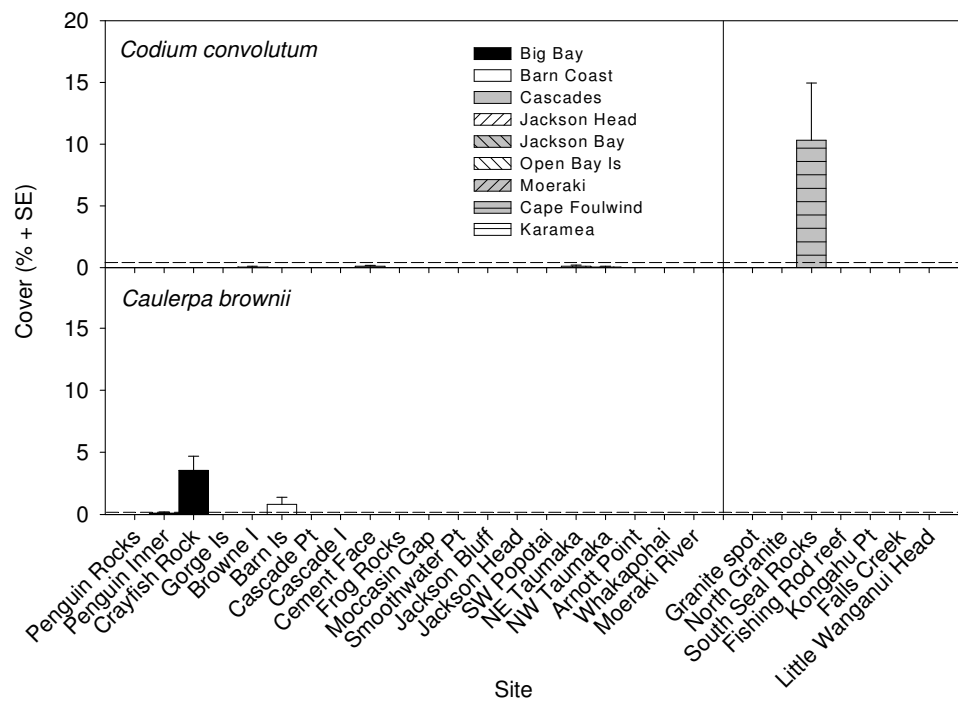


Figure 9C. Mean cover of dominant green algal species. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.



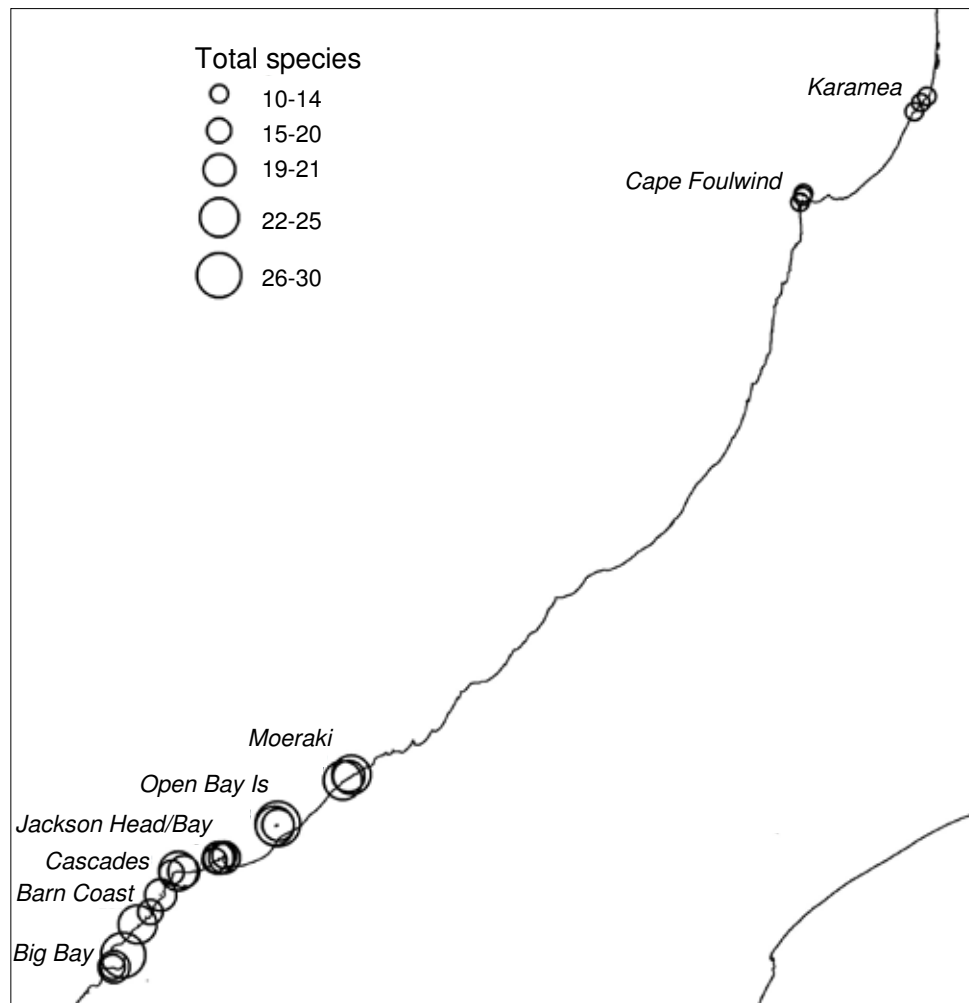
Algal species richness (total number of species recorded at each site) also varied considerably between the two regions (Fig. 10). The mean number of species recorded at South Westland sites ( $21.2 \pm 0.8$ ) was almost double the mean number recorded at Buller sites ( $11.9 \pm 0.6$ ). Consequently, species richness was strongly negatively correlated with latitude (NZ Map Grid, Northing =  $-0.77$ ) and positively correlated with Secchi ( $0.69$ ). Evecinus abundance ( $0.40$ ) and MaxDepth ( $0.40$ ) were also weakly positively correlated with algal species richness. The highest macroalgal species richness was recorded at Open Bay Islands sites, Arnett Point and Crayfish Rocks.

### 3.5 MOBILE MACROINVERTEBRATE ASSEMBLAGES

Mobile macroinvertebrate assemblages did not exhibit a clear division between Buller and South Westland sites (Fig. 11A). While ANOSIM suggested a significant difference between regions (Global  $R = 0.547$ ;  $P = 0.001$ ), this difference was less distinct compared with that seen for benthic community structure and algal species composition (as indicated by lower Global  $R$ ). Furthermore, hierarchical cluster analysis revealed no clear groupings of sites from the two regions. Environmental variables explained 31.5% of the variation in mobile invertebrate assemblages; however, the relationship was only marginally significant ( $P = 0.049$ , Table 2C). As for the other community analyses, Secchi explained the largest amount of variation (16.3%) and was positively correlated with PC1 (Fig. 11C). None of the other environmental variables were strongly correlated with PC2.

Mobile macroinvertebrate species generally occurred in low numbers on West Coast reefs with the mean abundance being  $< 1/m^2$  for all species except *Patiriella* spp. (Table 3B). In total, 24 of the 30 species recorded occurred in less than 3% of the quadrats sampled. *Patiriella* was the most common and numerically abundant species (Table 3B), and was found at all sites except Smoothwater

Figure 10. Macroalgal species richness. Total number of macroalgal taxa recorded at each site.



Point (Fig. 12). *Patriella* tended to occur in lower numbers around the Jackson Head, Jackson Bay and Open Bay Islands areas and was positively correlated with PC2 (Fig. 11B). *Evechinus* and *Stichaster* were also relatively common (Table 3B) and were strongly correlated with PC1 (Fig. 11B). *Evechinus* was rare at the Buller sites (only occurring at the two offshore sites: South Seal Rocks and Fishing Rod Reef) and, in general, was more common at the South Westland sites, particularly Open Bay Islands, Cascade Island and Arnott Point. *Diplodontias* spp. and *Haliotis australis* were also more common at South Westland sites and rare at Buller sites. In contrast, *Stichaster* was generally more abundant at the Buller sites and rare at most South Westland sites (Fig. 12). *Haliotis iris* was locally abundant at Cascade Point and Granite Spot.

### 3.6 BIOGEOGRAPHIC ANALYSIS

According to the scheme proposed by Roberts et al. (2005), twelve of the sites sampled in the present study were in the 'Fiordland open coast-South Westland' region, seven in Westland-Buller, and eight in the Transition zone (Table 4). Overall, there was a significant difference in algal species composition among these regions (ANOSIM: Global  $R = 0.567$ ,  $P = 0.001$ ) and there was a clear division in algal assemblages between Westland-Buller and the other regions (Fig. 7). However, there was no clear division between sites in Fiordland open coast-

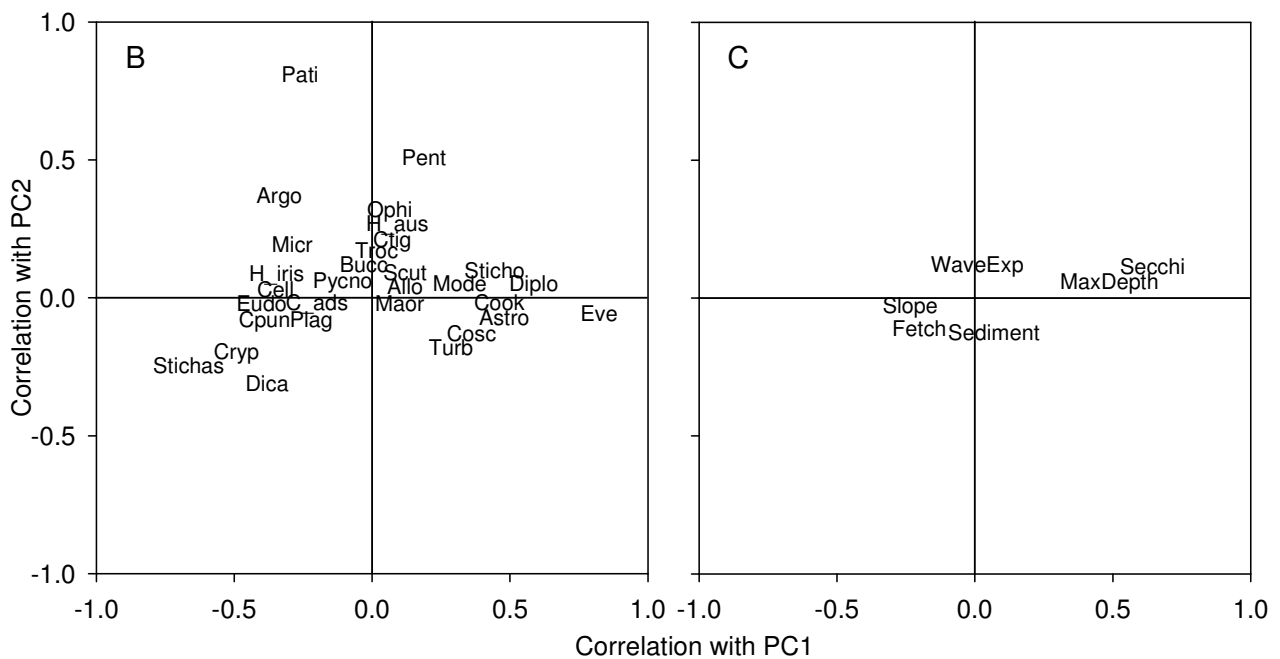
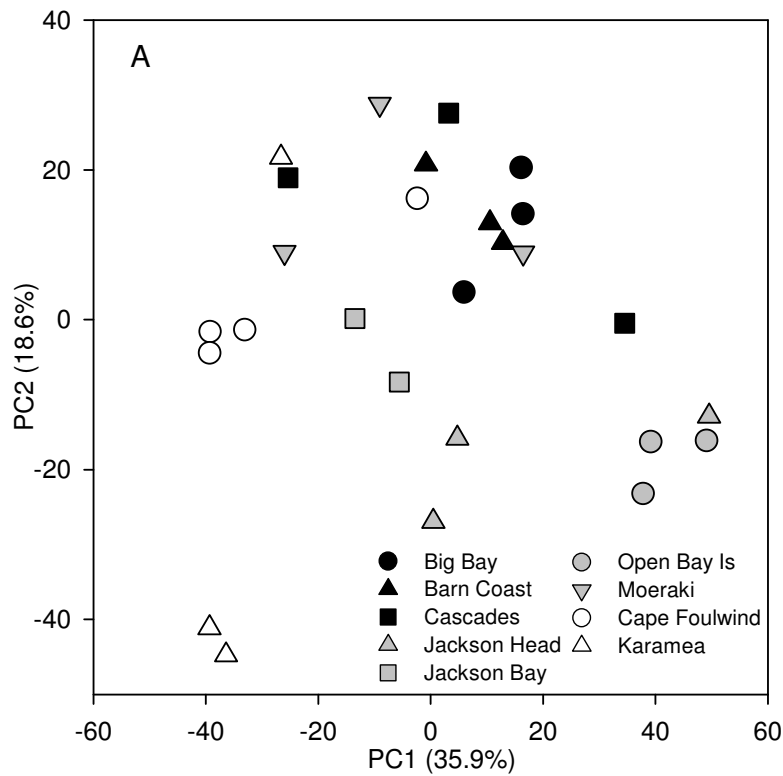


Figure 11. A—Principal coordinates analysis of mobile macroinvertebrate assemblages (log(x+1) transformed count data) for West Coast sites. B—Bi-plot showing correlations between principal coordinate axes and species variables. C— Bi-plot showing correlations between principal coordinate axes and environmental variables. See Table 2B for species codes. Buller sites—open symbols; South Westland sites—black or grey symbols (grey indicates sites in Roberts et al.'s (2005) 'Transition zone').

South Westland region and the Transition zone and there was only a marginally significant difference between these two regions (Global  $R = 0.177$ ,  $P = 0.036$ ). Classification success was low for the Roberts et al. (2005) scheme (63.0%) and seven out of eight sites in their proposed Transition zone were misclassified as being in the Fiordland open coast–South Westland region. Three of the Westland–Buller sites were also misclassified as Fiordland open coast–South Westland. Based on the scheme proposed by Neale & Nelson (1998), twenty of the sites sampled



Figure 12. Mean density of dominant mobile macroinvertebrate species at each site. Horizontal lines indicate global means across all sites and vertical line indicates division between South Westland (left) and Buller (right) sites.

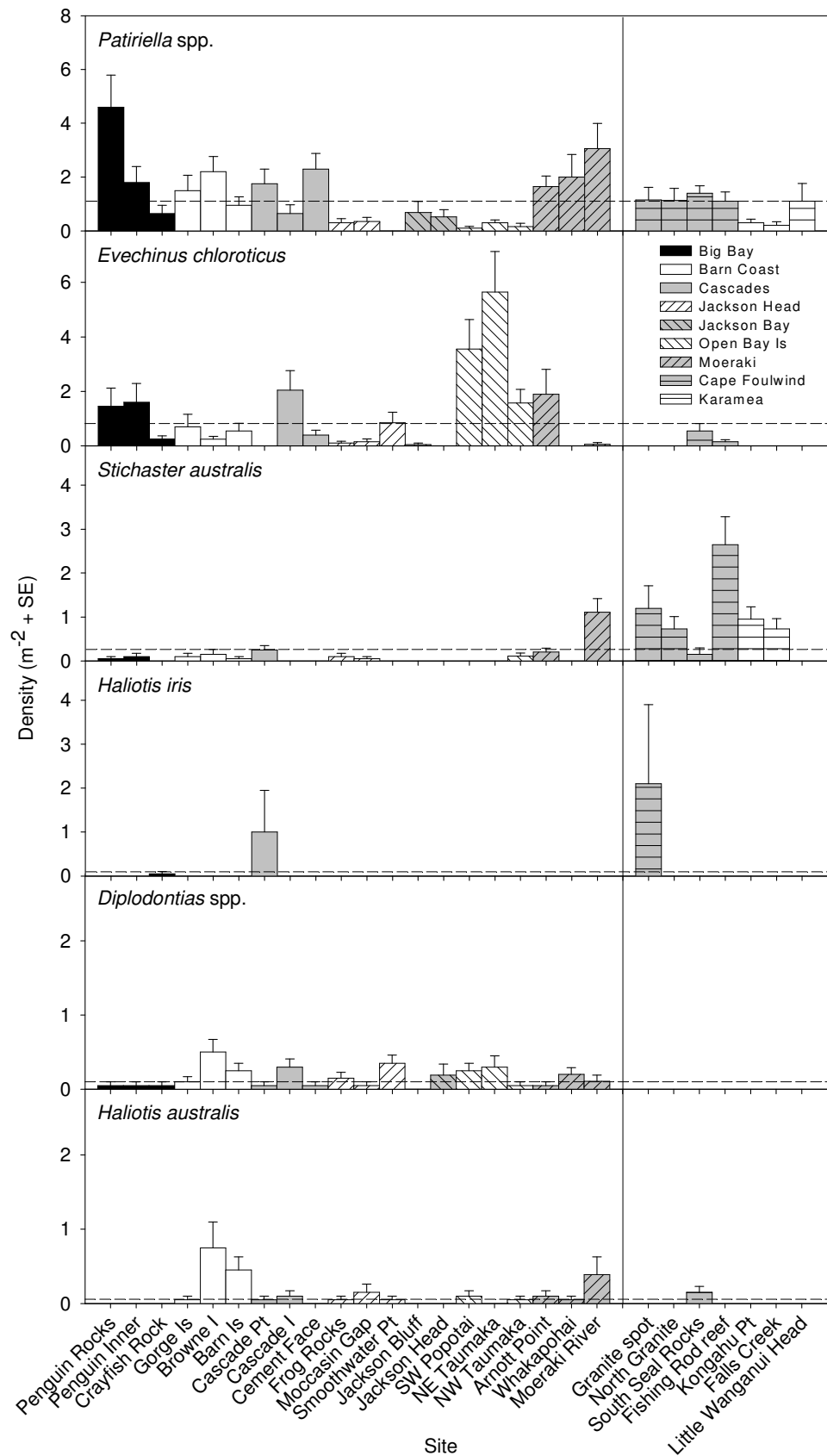


TABLE 4. CLASSIFICATION SUCCESS (PERCENTAGE OF SITES ASSIGNED TO THEIR CORRECT REGION BASED ON CAP ANALYSIS) OF PREVIOUS MARINE BIOGEOGRAPHIC CLASSIFICATION SCHEMES FOR THE WEST COAST USING MACROALGAL PRESENCE-ABSENCE DATA (THIS STUDY) AND REEF FISH PRESENCE-ABSENCE DATA (ROBERTS ET AL. 2005). *n* INDICATES THE NUMBER OF SITES SAMPLED WITHIN EACH OF THE PROPOSED REGIONS FOR EACH STUDY.

	MACROALGAE		REEF FISH	
	<i>n</i>	CLASSIFICATION SUCCESS (%)	<i>n</i>	CLASSIFICATION SUCCESS (%)
<b>Roberts et al. (2005)</b>				
Westland-Buller	7	57.14	11	72.73
Transition	8	12.50	12	33.33
Fiordland open coast-South Westland	12	100.00	10	80.00
Fiordland	0	-	13	69.23
<b>Total</b>		<b>62.96</b>		<b>63.04</b>
<b>Neale &amp; Nelson (1998)</b>				
Buller	7	71.43	10	60.00
Westland	0	-	2	0.00
South Westland	20	100.00	21	100.00
Fiordland	0	-	13	84.62
<b>Total</b>		<b>92.59</b>		<b>82.61</b>

were in the South Westland region and seven in the Buller region. There was clear separation in algal species composition between these regions (Fig. 7, Global  $R = 0.901$ ,  $P = 0.001$ ) and CAP analysis revealed a 92.6% classification success (Table 4) (two 'Buller' sites were misclassified as South Westland).

The reef fish data of Roberts et al. (2005) exhibited similar patterns in species composition, with an overall significant difference in fish assemblages among their proposed regions (Global  $R = 0.519$ ,  $P = 0.001$ ) but a high degree of overlap (Fig. 13A), and no significant difference (Global  $R = -0.003$ ,  $P = 0.444$ ), between sites located in the 'Fiordland open coast-South Westland' region and the 'Transition zone'. The reef fish assemblages at sites sampled in both 'Fiordland' (Milford Sound: 13 sites) and 'Westland-Buller' were relatively distinct, although one Fiordland site (St Anne Bay) was grouped with Buller sites. The St Anne Bay station was, however, the only rockpool station sampled in Fiordland and had a comparatively low diversity (7 species) compared with the other Fiordland stations (13-22 species). The overall classification success was 63.0% for the Roberts et al. (2005) regions, with 7 out of 12 sites in the proposed 'transition zone' misclassified as 'Fiordland open coast-South Westland'. The reef fish assemblage data conformed more closely with the regions proposed by Neale & Nelson (1998) (Fig. 13B), with highly significant differences among regions (Global  $R = 0.667$ ,  $P = 0.001$ ), and an overall classification success of 82.6%. All 21 'South Westland' sites were classified correctly and 84.6% (11/13) of 'Fiordland' sites were classified correctly (two were misclassified as 'South Westland'). The two sites sampled in the 'Westland' region, however, were misclassified as 'Buller', and three 'Buller' sites were misclassified as 'South Westland'. There was no significant difference between the two Westland sites and Buller sites (Global  $R = -0.110$ ,  $P = 0.652$ ).

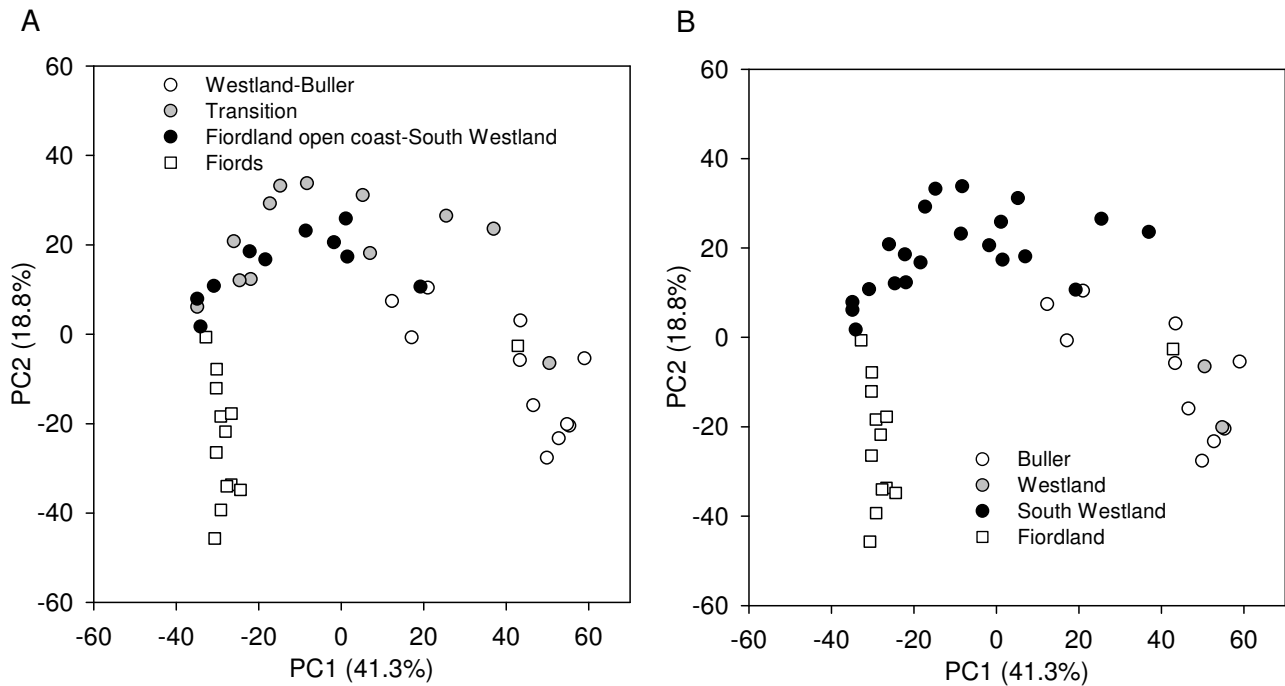


Figure 13. Principal coordinates analysis of reef fish species composition (presence-absence data for 90 species from Roberts et al. 2005) for West Coast and Fiordland sites. A—Symbols indicate regions proposed by Roberts et al. (2005); B—Symbols indicate regions proposed by Neale & Nelson (1998).

## 4. Discussion

### 4.1 HABITAT CLASSIFICATION

The biological habitat types identified on South Island West Coast (SIWC) reefs provide a stark contrast to those described from other parts of New Zealand, e.g. northeastern (Shears et al. 2004) and Kaikoura (Schiel & Hickford 2001). While some of the same habitats found in northern New Zealand were recorded during the survey (e.g. ‘*Ecklonia* forest’, ‘mixed brown algae’ and ‘urchin barrens’), these were generally rare. Furthermore, the *Ecklonia* forest described from Open Bay Islands was restricted to shallow water and comprised short *Ecklonia* plants with other large brown algae interspersed. This is in contrast to the deep water (> 5 m depth) monospecific stands of tall *Ecklonia* plants found in northern New Zealand. The most common SIWC habitats recorded were ‘mixed turfing algae’, ‘invertebrate turf’ and ‘scoured rock’. The ‘mixed turfing algae’ habitat represents a mix between the ‘turfing algae’ and ‘red foliose algae’ of Shears et al. (2004) and was typically characterised by a variety of turfing and foliose algal species (e.g. *Lophurella*, *Anotrichium* and *Asparagopsis*). The ‘invertebrate turf’ habitat is somewhat analogous to the ‘encrusting invertebrate’ habitat of Shears et al. (2004), being dominated by encrusting ascidians, sponges, hydroids, and bryozoans. However, in northeastern New Zealand, the ‘encrusting invertebrate’ habitat is typically found on vertical walls, whereas the ‘invertebrate turf’ habitat at West Coast sites also occurred on flat and sloping areas of reef with high sediment cover. Similar habitats dominated by filter feeders are typical of sites with high turbidity in many areas throughout New Zealand (e.g. Banks Peninsula, New Plymouth, Raglan) (Shears & Babcock 2007).

The 'scoured rock' habitat represents a habitat that is symbolic of the SIWC's extreme physical conditions and was particularly common at sites in the Buller region. Reefs in this habitat were predominantly bare, presumably because of high levels of sand scour. Crustose coralline algae were the dominant encrusting form in this habitat and most other encrusting groups were rare. This habitat was typically found at the sand-reef interface, but at some sites, e.g. Granite Spot (Cape Foulwind), the majority of the reef (5–10 m) was classified as 'Scoured rock'. At Granite Spot, the abalone *Haliotis iris* (paua) also appeared to be highly abraded by sand, as the outside of their shells were highly eroded, with the blue-green nacre being visible (pers. obs.). The 'scoured rock' habitat was rare at sites with steeper sloping reefs, where the effect of sand-scour appeared to be reduced, e.g. at headlands, offshore islands and rock stacks.

Two mussel-dominated habitat types were also identified ('*Xenostrobus* mats' and '*Perna* beds') that are generally atypical of subtidal habitats in New Zealand. '*Perna* beds' were only recorded at Little Wanganui Head at the entrance of Little Wanganui Inlet, but similar *Perna*-dominated subtidal reefs also occur on offshore reefs at Raglan, on the northwestern coast of the North Island (pers. obs.) and some other parts of the SIWC (D. Neale, pers. comm. 2007). '*Xenostrobus* mats' were recorded in shallow water (< 7 m) at a number of Buller sites. While *Xenostrobus pulex* is typically an intertidal species (Morton 2004), it also appears to be common on shallow subtidal reefs (< 5 m depth) in certain parts of New Zealand's west coast, e.g. Shears & Babcock (2007) also found *X. pulex* to be common on subtidal reefs at Raglan.

The bull kelp *Durvillaea antarctica*, another typically intertidal species, was an important component of the '*Durvillaea* fringe' habitat. While this habitat was often associated with *D. willana*, which occurs in shallow subtidal areas, the influence of sweeping by *D. antarctica* blades also appears to extend into these areas. Beneath the *Durvillaea* canopy, the substratum was predominantly covered in crustose corallines and other groups that were resistant to the sweeping action of *Durvillaea*, e.g. encrusting bryozoans. However, this habitat was rarely encountered in these surveys, as it is generally restricted to very shallow water (< 1 m depth and low intertidal) and is characteristic of very exposed points and headlands. In most cases, sampling was carried out in the lee of such physical features.

Classification analysis indicated distinct differences in communities among the nine reef habitats identified, providing strong support for their use in classifying and mapping shallow subtidal reefs along the SIWC. One exception, however, was '*Ecklonia* forest', which could not be statistically distinguished from 'mixed brown algae' habitat. '*Ecklonia* forest' was very rare at the sites sampled and only three samples (at the Open Bay Islands) were classified as this habitat. In general, the most common habitats had the highest classification success and it appears that the low sample sizes for some habitats ( $n < 10$ ) compromised the overall classification success. While additional sampling in these habitats is required to provide a more robust test of their classification success, the communities found in these habitats all appear relatively distinct. Furthermore, as discussed in Shears et al. (2004), the classification technique used (CAP) may also underestimate an observer's ability to categorise habitats, as it doesn't take into account differences in size or morphology of key species. Regardless, 76% of the samples were classified correctly, based on counts of dominant habitat-

forming species and covers of dominant benthic groups, indicating that these reef habitat types can be reliably identified visually in the field. While this habitat classification scheme will also be suitable for use with other habitat mapping techniques (e.g. aerial photography, drop camera and towed video survey methods), the average sea conditions and water clarity on the SIWC potentially pose severe limitations to such studies.

#### 4.2 FLORAL AND FAUNAL CHARACTERISTICS OF SIWC SUBTIDAL REEFS

The macroalgae recorded during quadrat sampling (48 taxa) represent a relatively small subset of the flora of the West Coast region, primarily because crustose corallines and red turfs (< 5 cm height), which are the dominant macroalgal forms on many SIWC reefs, were not identified to species level. Furthermore, many other larger common species such as *Plocamium* spp. and *Halopteris* spp. could not be identified to species level in the field. Based on museum collections, Neale & Nelson (1998) recorded more than 175 macroalgal taxa for the SIWC, but also noted that this was most likely an underestimate of the region's flora. One of the characteristic features of the SIWC flora is an absence of many species found throughout New Zealand. For example, New Zealand's dominant kelp *Ecklonia radiata* (Shears & Babcock 2007) was only recorded at Open Bay Islands. The extreme physical conditions along the SIWC may be responsible for the absence or low numbers of many species common to both the north and south.

Fucal species are rare along much of the SIWC. *Landsburgia quercifolia* and *Sargassum sinclairii* were locally abundant at some South Westland sites and also South Seal Rocks, Cape Foulwind. These algae were found, typically, at sites on offshore islands or rock-stacks with deeper, clearer water where the effects of sand-scour were reduced. *Cystophora* species common to southern New Zealand (Nelson et al. 2002) were rare at the sites examined, although *Cystophora scalaris* was recorded in low numbers at six of the South Westland sites. *Carpophyllum flexuosum* was the only *Carpophyllum* species recorded and was common at Open Bay Islands (OBI). *Carpophyllum maschalocarpum*, which has also been recorded at OBI (Neale & Nelson 1998), was not recorded in this study. Similarly, *Marginariella boryana* and *Xiphophora gladiata*, which have been recorded at OBI in the past, were not recorded at sites in this location in the present study. *Xiphophora gladiata* was, however, recorded in the lee of Gorge Is. The two kelp species *Lessonia variegata* and *Ecklonia radiata* were both recorded at OBI, but were absent from all other sites. A variety of smaller brown algal species were common across all locations on the reefs examined, e.g. *Halopteris* spp., *Glossophora kunthii* and *Microzonia velutina*. *Halopteris congesta* was particularly common and formed a short turf (< 5 cm height) in the shallow subtidal zone at many sites. The small brown algal species *Endarachne binghamiae* was only recorded at Buller sites.

Green algae (Chlorophyta) were generally rare on the subtidal reefs sampled on the SIWC and are potentially limited by high wave action, turbidity and sand-scour. *Caulerpa brownii*, which had not been recorded on the SIWC previously (Neale & Nelson 1998), was common at Big Bay sites and was also recorded at Barn Islands. The prostrate *Codium convolutum*, which appears more resistant to

high wave action than other species, was commonly recorded in South Westland but was rare at most Buller sites. One exception was South Seal Rocks, Cape Foulwind, where *C. convolutum* was highly abundant in the shallow subtidal zone. *Ulva* spp. were rare at all sites except Little Wanganui Head where they were recorded growing on mussels (*Perna canaliculus*).

Red algae (Rhodophyta) were the most diverse algal group among SIWC sites, and most of these were more common in South Westland than Buller. However, a few species that appear more tolerant of sand and gravel abrasion were more common in the northern Buller region e.g. *Gymnogrongrus furcatus* and *Gigartina* spp. Species of Gigartinaceae were also found by Neale & Nelson (1998) to be a conspicuous part of the flora in the intertidal zone from Karamea in the north to about Okarito in the south, but the taxonomy of this group is poorly understood. Some more northern species such as *Pterocladia lucida* were also found to extend down to Karamea, but were sparse. At most South Westland sites, the shallow subtidal fringe was dominated by a red turfing assemblage with *Echinothamnion* spp., *Plocamium* spp., *Lophurella bookeriana*, *Hymenena durvillaei*, crustose corallines and articulated coralline algae. More delicate species such as *Anotrichium crinitum*, *Asparagopsis armata*, *Euptilota formosissima* and *Rhodophyllis gunnii* were more common in deeper water.

Macroalgal species richness tended to increase with latitude, being higher in the southern part of the SIWC. This pattern has been reported at a national scale for New Zealand (Shears & Babcock 2007) and also regionally among northern and southern Fiords (Nelson et al. 2002). Not surprisingly, there is a clear gradient in mean SST temperature along the SIWC (strongly positively correlated with northing among sites, 0.93), but the annual range in temperature is also strongly correlated and declines with latitude (strongly positively correlated with northing among sites, 0.99), i.e. reefs in the northern SIWC are subjected to a greater annual range in SST (NZMEC).

The overall abundance and diversity (28 species) of mobile macro-invertebrates was considerably lower than that observed for macroalgae. *Patiriella* spp. were the most abundant mobile invertebrate species and were found at all sites, except Smoothwater Point. The actual species of *Patiriella* were not recorded in the field, but appear to have predominantly been *P. regularis*. As for macroalgae, the majority of species were more common at the South Westland sites, e.g. *Evechinus chloroticus*, *Haliotis iris*, *Pentagonaster pulchellus* and *Diplodontias* spp. Only the starfish *Stichaster australis* was more common at Buller sites. This species is typically an intertidal species around most of the New Zealand coast 'on wave-beaten shores, particularly west coasts with the green mussel *Perna canaliculus*' (Morton 2004); however, in this study it was recorded in subtidal areas at high abundances associated with the mussel *Xenostrobus pulex*.

The diversity of sessile invertebrates and encrusting fauna was not investigated at the SIWC sites examined in this study. Instead, species were grouped into general benthic groups (e.g. ascidians, bryozoans, sponges, anemones, tube worms and hydroids). In many cases, these groups were dominant components of the reef communities, particularly at the Buller sites, and much of the diversity of the SIWC reefs is encompassed in these broad groupings. In addition, numerous species of bryozoans, ascidians and tube worms observed appeared to be unique at the national level (pers. obs.). Further investigation of the encrusting fauna

on these highly exposed and turbid invertebrate-dominated reefs is necessary to better understand the nearshore biodiversity of this coast.

### 4.3 COMMUNITY STRUCTURE AND PROCESSES

The structures of shallow subtidal reef communities on the West Coast of the South Island are atypical at a national scale (Shears & Babcock 2007). The reef communities along the entire Buller coast are exposed to extreme wave action, high sand scour and high turbidity. Large brown algae (*Durvillaea* spp.) were found to be largely restricted to shallow depths (< 2 m), where the reef is covered by a mixture of crustose coralline algae and algal turfs. At greater depths, the reef is predominantly bare or covered in a suite of encrusting invertebrates (e.g. mussels, sponges, ascidians and bryozoans). Reefs in South Westland tend to have a higher cover of macroalgal groups, although large brown algae are generally restricted to headlands and offshore islands, e.g. Open Bay Islands, and sea urchins occur at low numbers. While the South Westland coast is also subject to high wave action, it does not appear to be as impacted by sand scouring and high turbidity as sites in the Buller region. The covers of bare rock and most encrusting invertebrate groups in South Westland are much lower than at Buller locations and the substratum is generally covered by crustose corallines and a suite of short turfing algal species. At Open Bay Islands, *Ecklonia*, *Landsburgia*, *C. flexuosum* and *Sargassum sinclairii* are common at shallow depths, while red foliose algae and *Evechinus* are abundant at depths greater than 7 m. In general, Open Bay Islands are regionally unique, with a number of species being found there that are rare or absent at other SIWC sites.

The clear differences in benthic community structure between the two regions appear to be related to major differences in their physical characteristics. The two regions span a large latitudinal gradient and while factors such as sea surface temperature and solar radiation vary among sites, many other environmental parameters also vary, e.g. turbidity, sand-scour, sedimentation, depth of coastal waters, extent of rocky reef and reef slope. These factors are all highly interrelated and turbidity, as measured by Secchi depth, was found to be the single environmental variable that explained the greatest variation among sites. In most cases, sites with clearer water are located on offshore islands or rock-stacks and/or have extensive reefs extending into deeper water. High turbidity potentially restricts most macroalgal species (particularly large brown algae) to shallow water and in this study large brown algae (with the exception of *Durvillaea* spp.) were rare at highly turbid sites and most common offshore (e.g. at Open Bay Islands) or in areas with relatively high water clarity (e.g. Crayfish Rocks, Big Bay). High wave action, sedimentation and sand-scour are also likely to restrict many species from coastal sites where the reefs were typically dominated by short turfing algal species or encrusting invertebrates. Overall, the sites surveyed in the Buller region were more turbid, had shallower reefs and appear to have higher levels of sand-scour. Roberts et al. (2005) suggested similar mechanisms were important in explaining variation in reef fish assemblages among regions, and suggested the low diversity on the northern SIWC (Buller) was most likely due to low habitat diversity and high exposure. In this study there was no clear difference in wave exposure between the two regions, with all sites being highly exposed (wave exposure between 1.4 and 2.3 m), except Jackson Bluff at the

entrance of Jackson Bay (0.5 m). This is likely to explain why there was no significant relationship between community structure and wind fetch or wave exposure (Table 2) among the sites examined. However, both methods used to estimate wave exposure were not sensitive to small-scale topography that may affect wave force at sites. There were some differences among sites that appeared to be related to wave exposure, e.g. *Ecklonia* was more abundant and found at larger sizes at the most sheltered Open Bay Islands site (NE Taumaka) compared with the more exposed sites at Open Bay Islands.

Grazing by sea urchins is generally considered to be a key structuring process on temperate reefs (Steneck et al. 2002); however, the sea urchin *Evechinus chloroticus* was generally very rare at most of the sites examined. Large aggregations of urchins occurred at a few sites, forming patches of 'urchin barrens' habitat devoid of large brown algae (e.g. at Open Bay Islands sites and Crayfish Rocks, Big Bay). However, the effect of urchin grazing at these sites appeared relatively localised and the barrens habitat not extensive, unlike other parts of New Zealand (Shears & Babcock 2007). At Open Bay Islands, *Evechinus* appeared to play some role in restricting large brown algae from depths greater than c.7 m. However, the relative roles of grazing, turbidity and sedimentation in restricting large brown algae from these depths are unknown. In general, sea urchins were most abundant at sites with the highest abundances of large brown algae and high species richness. It therefore appears that urchins are restricted from the turbid coastal sites by the same mechanisms that restrict kelp, e.g. wave exposure (Siddon & Witman 2003) and sedimentation (Phillips & Shima 2006; Walker in press). Paua *Haliotis iris* were also rare at most sites, but found in dense patches on crustose coralline algae and also bare rock at some sites around Westport and Cascades. This species was potentially more abundant historically on the SIWC and may have played a greater role in structuring reef assemblages.

Research on intertidal reef habitats on the SIWC suggests that intermittent upwelling on the West Coast provides high levels of subsidies (nutrients, particulates and propagules) to nearshore areas, ultimately determining the intensity of species interactions and, subsequently, community structure (Menge et al. 1999; Menge et al. 2003). These authors found higher levels of predation by the starfish *Stichaster australis*, grazing by limpets, and recruitment of mussels and barnacles on the SIWC, compared with the east coast of the South Island where upwelling was thought to be less prevalent. In most cases the species composition on SIWC subtidal reefs is considerably different to that in the intertidal zone, so it is only possible to draw comparisons at the functional level. However, one exception was *S. australis*, which was relatively common at most Buller sites and Moeraki River in South Westland (Fig. 12). Interestingly, the highest abundances of *S. australis* were found at sites where the mussel *Xenostrobus pulex* occurred (Fig. 6B). This is broadly consistent with the patterns described by Menge and his colleagues. Shears & Babcock (2007) also found *S. australis* and *X. pulex* to be common in the subtidal zone at Raglan on the west coast of the North Island, where upwelling may also be a common feature of the coastal oceanography (Stanton 1973). However, as Schiel (2004) points out, the oceanography along the SIWC, and around New Zealand in general, is highly complex and the relative importance of pelagic-derived (upwelling) and terrestrial-derived (freshwater) nutrients to nearshore benthic processes needs further work.



At most of the SIWC sites examined, invertebrate predators, herbivores (e.g. urchins and herbivorous gastropods) and kelp were rare. This contrasts with the patterns described in the intertidal zone by Menge and colleagues and suggests that oceanographic processes such as upwelling are not as important as other processes in 'setting the pace' of community dynamics on subtidal reefs (*sensu* Menge et al. 2003). While processes such as upwelling may still be important in driving nutrient and propagule supply to subtidal reefs, it appears that abiotic factors associated with the harsh physical environment are largely determining the structure of reef communities. The low numbers of herbivores recorded on most of the reefs surveyed suggest that grazing does not play as important a role in structuring assemblages as it does on many other subtidal reefs throughout New Zealand. Under such circumstances, the removal or recovery of predators such as lobster is not likely to result in community-wide changes as have been observed in other parts of New Zealand (Babcock et al. 1999; Shears & Babcock 2002). Overall, the observed patterns along much of the SIWC are broadly consistent with Menge & Sutherland (1987), whereby the importance of trophic interactions are reduced in high-stress environments. However, at locations such as the Open Bay Islands where environmental stress associated with turbidity and sand-scour appear reduced, trophic interactions between predators, urchins and kelp may be more pronounced.

#### 4.4 BIOGEOGRAPHY OF THE SIWC

Currently, the draft inshore biogeographic classification system for New Zealand (Marine Protected Areas—Draft Classification and Protection Standards, June 2007; DOC & MfE 2007) proposes an SIWC biogeographic region from Cape Farewell in the north to Jackson Head in the south. There is clear evidence from both macroalgal (Neale & Nelson 1998; Shears et al. *in press*) and reef fish (Roberts et al. 2005) distributions that this single region does not adequately represent the biogeographic variation along this coast. Furthermore, from the analyses carried out in the present study, there is limited evidence for a biogeographic boundary at Jackson Head, as South Westland sites both to the north and south of Jackson Head had similar macroalgal and reef fish assemblages. Instead, there was a clear division in algal species composition, species richness, benthic community structure, mobile macroinvertebrate assemblages and reef fish assemblages (based on the data of Roberts et al. 2005) between sites sampled in South Westland and those sampled around Buller (Westport and Karamea). This provides support for a further biogeographic division within the larger SIWC region.

Roberts et al. (2005) proposed three biogeographic regions for the SIWC—Westland-Buller, Fiordland open coast-South Westland, and the inner Fiords. In addition, the area from approximately Jackson Head in the south to Bruce Bay in the north was proposed as a Transition zone between the Fiordland open coast-South Westland and Westland-Buller biogeographic region on the basis that reef fish communities in this area are intermediate between sites to the north and south (Roberts et al. 2005; Fig. 1). Using the reef fish species composition data of Roberts et al. (2005) and macroalgal species composition data from the present study to test these regions, I found an overall classification success of 63% for both datasets. Based on these analyses, there was no clear division in algal and reef fish assemblages between sites in the Fiordland open coast-South Westland region and the Transition zone. The majority of sites in the Transition zone (87.5% for reef fish and 75% for macroalgae) were misclassified as being in the

Fiordland open coast–South Westland zone. Instead, the reef fish and macroalgal data conformed more strongly (had higher classification success) to the regions proposed by Neale & Nelson (1998), with an overall classification success of 83% for reef fish and 93% for macroalgae. These results are consistent with Shears et al. (in press) in that classification analyses based on groups of taxa with short dispersal distances (e.g. macroalgae) exhibit clearer biogeographic disjunction and greater classification success than wider dispersing taxa (e.g. fishes). For both datasets, sites between Big Bay and Bruce Bay (the South Westland region) formed a relatively clear grouping (100% classification success), distinct from sites from Fiordland and sites to the north (Westland and Buller). Only two sites were sampled in the Westland region (Greymouth to Bruce Bay) by Roberts et al. (2005), and these were both misclassified as Buller. It therefore remains unclear whether the Westland area proposed by Neale & Nelson (1998) forms a distinct biogeographic region. The reefs in this area are generally limited in extent and seldom extend into subtidal zones (Rilov & Schiel 2006), and it appears that the physical setting, along with an absence of many species, are what characterises this area as a distinct biogeographic region (Neale & Nelson 1998).

The analyses carried out in this study provide further support for the separation of Fiordland and South Westland into two distinct regions. While the Fiordland flora is considered to be most closely related to the flora of the West Coast of the South Island (Nelson et al. 2002), the national analysis of Shears et al. (in press) clearly demonstrates a division in algal species composition between South Westland and Fiordland. The reefs on the outer coast of Fiordland are dominated by *X. gladiata*, *Ecklonia*, and *C. flexuosum*, and other more ‘southern’ species such as *Marginariella* and *Cystophora* spp. are also common (Shears & Babcock 2007). The southern boundary between South Westland and Fiordland was proposed as being at Awarua Point (the northern point of Big Bay) by Neale & Nelson (1998), but the present study suggests this boundary lies to the south of Big Bay, based on the similarity in algal assemblages between Big Bay and sites to the north. Both Moore (1949) and Knox (1975) proposed the area around Milford Sound as the northern boundary of a *Forsterian* province, while King et al. (1985) (shelf ecological regions) placed biogeographic boundaries in the vicinity of Big Bay/Martins Bay. It is possible or even likely that the boundary is best described not by a single point along the coast, but by an area several kilometres or tens of kilometres in length. A relative lack of biological survey sites south of Big Bay makes it difficult to precisely define the location and extent of this boundary.

## 5. Summary and conclusions

- Nine commonly occurring biological habitat types were identified on the SIWC subtidal reefs examined in this study. Some of these habitat types have not previously been described from New Zealand’s subtidal reefs and some appear unique to west coast locations (e.g. *Xenostrobus* mats and scoured rock). The reef communities within these habitats were biologically distinct and classification analysis revealed an overall classification success of 76%, supporting the use of these habitat descriptions in future classification and mapping studies of SIWC reefs.

- Large differences were found in reef community structure and diversity between Buller and South Westland sites and these differences were strongly related to differences in turbidity and depth of the reefs. Buller sites were generally shallow and highly turbid, and were dominated by encrusting invertebrates, crustose corallines and bare rock. In contrast, other algal groups were more common at the South Westland sites, which tended to have higher water clarity and reefs that extended into deeper water. Extreme physical conditions appear to be the key factor controlling reef community structure, and the influence of sea urchin grazing appears minimal. Only at a few offshore locations (e.g. Open Bay Islands), and coastal sites with high water clarity (e.g. Crayfish Rocks, Big Bay) were both sea urchins and subtidal kelps common. Such locations are rare on the SIWC and should be given priority for marine protection.
- Macroalgal and reef fish species distribution data provided strong support for the SIWC biogeographic scheme proposed by Neale & Nelson (1998), which included South Westland, Westland and Buller regions. There was, however, limited support for their Westland region (between Greymouth and Bruce Bay), which may need to be incorporated into the Buller region. There was considerably less support for the scheme proposed by Roberts et al. (2005), which proposed a broad biogeographic transition zone from Bruce Bay to Jackson Head, between a Fiordland open coast–South Westland and a Westland–Buller region.
- For the purposes of assessing representativeness for the protection of marine habitats, it is recommended that the proposed SIWC region be divided into two biogeographic regions: Buller (Cape Farewell to Bruce Bay), and South Westland (Bruce Bay to Martin’s Bay). However, additional sampling is needed to determine whether a third biogeographic region is warranted between Bruce Bay and Greymouth (Westland), and further sampling is needed between Milford Sound and Big Bay to determine the biogeographic boundary between Fiordland and South Westland.

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## 7. References

- Anderson, M.J. 2002: DISTLM v2: a FORTRAN computer program to calculate a distance based multivariate analysis for a linear model. Department of Statistics, University of Auckland, 9 p.
- Anderson, M.J. 2003: PCO: a FORTRAN computer program for principal coordinate analysis. Department of Statistics, University of Auckland, New Zealand. Available from [www.stat.auckland.ac.nz/~mja](http://www.stat.auckland.ac.nz/~mja) (accessed September 2006). 7 p.
- Anderson, M.J.; Willis, T.J. 2003: Canonical analysis of principal coordinates: an ecologically meaningful approach for constrained ordination. *Ecology* 84: 511-525.
- Andrew, N.L.; Choat, J.H. 1982: The influence of predation and conspecific adults on the abundance of juvenile *Evechinus chloroticus* (Echinoidea: Echinometridae). *Oecologia* 54: 80-87.
- Ayling, A.M. 1981: The role of biological disturbance in temperate subtidal encrusting communities. *Ecology* 62: 830-847.
- Bustamante, R.H.; Branch, G.M. 1996: Large-scale patterns and trophic structure of southern African rocky shores—the roles of geographic variation and wave exposure. *Journal of Biogeography* 23: 339-351.
- Choat, J.H.; Schiel, D.R. 1982: Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand. *Journal of Experimental Marine Biology & Ecology* 60: 129-162.
- Clarke, K.R.; Warwick, R.M. 1994: Change in marine communities: an approach to statistical analysis and interpretation. Natural Environment Research Council, UK. 144 p.
- Commonwealth-of-Australia 2006: A Guide to the Integrated Marine and Coastal Regionalisation of Australia Version 4.0. Department of the Environment and Heritage, Canberra, Australia. [www.environment.gov.au/coasts/mbp/publications/pubs/imcra4.pdf](http://www.environment.gov.au/coasts/mbp/publications/pubs/imcra4.pdf).
- Connor, D.W. 1997: Marine Biotope Classification for Britain and Ireland. Joint Nature Conservation Review, Peterborough, UK.
- DOC (Department of Conservation); MfE (Ministry for the Environment) 2000: The New Zealand Biodiversity Strategy: our chance to turn the tide. Department of Conservation and Ministry for the Environment, Wellington, New Zealand. 145 p. Available from [www.biodiversity.govt.nz](http://www.biodiversity.govt.nz) (accessed September 2006).
- DOC (Department of Conservation); MfE (Ministry for the Environment) 2007: Marine Protected Areas—draft classification and protection standard. [www.biodiversity.govt.nz/pdf/MPA-Draft-protection-and-classification-system.pdf](http://www.biodiversity.govt.nz/pdf/MPA-Draft-protection-and-classification-system.pdf) (accessed October 2007).
- Edgar, G.J.; Banks, S.; Farina, J.M.; Calvopina, M.; Martinez, C. 2004: Regional biogeography of shallow reef fish and macro-invertebrate communities in the Galapagos archipelago. *Journal of Biogeography* 31: 1107-1124.
- Edgar, G.J.; Moverley, J.; Barrett, N.S.; Peters, D.; Reed, C. 1997: The conservation-related benefits of a systematic marine biological sampling programme—the Tasmanian reef bioregionalisation as a case study. *Biological Conservation* 79: 227-240.
- Gorman, R.M.; Bryan, K.R.; Laing, A.K. 2003: Wave hindcast for the New Zealand region: nearshore validation and coastal wave climate. *New Zealand Journal of Marine and Freshwater Research* 37: 567-588.
- King, K.J.; Bailey, K.N.; Clark, M.R. 1985: Coastal and marine ecological areas of New Zealand: a preliminary classification for conservation purposes. Department of Lands and Survey, Wellington, New Zealand. Information Series No 15/1985. 47 p.
- Knox, G.A. 1975: The marine benthic ecology and biogeography. Pp. 353-403 in Kuschel, G. (Ed.): Biogeography and ecology in New Zealand. Monographiae Biologicae, Dr W. Junk, The Hague.

- Larson, G.L.; Buktenica, M.W. 1998: Variability of secchi disk readings in an exceptionally clear and deep Caldera Lake. *Archiv für Hydrobiologie* 141: 377-388.
- Lourie, S.A.; Vincent, A.C.J. 2004: Using biogeography to help set priorities in marine conservation. *Conservation Biology* 18: 1004-1020.
- McArdle, B.H.; Anderson, M.J. 2001: Fitting multivariate models to community data: a comment on distance-based redundancy analysis. *Ecology* 82: 290-297.
- Menge, B.A.; Daley, B.A.; Lubchenco, J.; Sanford, E.; Dahlhoff, E.; Halpin, P.M.; Hudson, G.; Burnaford, J.L. 1999: Top-down and bottom-up regulation of New Zealand rocky intertidal communities. *Ecological Monographs* 69: 297-330.
- Menge, B.A.; Lubchenco, J.; Bracken, M.E.S.; Chan, F.; Foley, M.M.; Freidenburg, T.L.; Gaines, S.D.; Hudson, G.; Krenz, C.; Leslie, H.; Menge, D.N.L.; Russell, R.; Webster, M.S. 2003: Coastal oceanography sets the pace of rocky intertidal community dynamics. *Proceedings of the National Academy of Sciences of the United States of America* 100: 12229-12234.
- Menge, B.A.; Sutherland, J.P. 1987: Community regulation: variation in disturbance, competition, and predation in relation to environmental stress and recruitment. *American Naturalist* 130: 730-757.
- Moore, L.B. 1949: The marine algal provinces of New Zealand. *Transactions of the Royal Society of New Zealand* 77: 187-189.
- Morton, J. 2004: Seashore ecology of New Zealand and the Pacific. David Bateman. Auckland.
- Neale, D.; Nelson, W. 1998: Marine algae of the West Coast, South Island, New Zealand. *Tubinga* 10: 87-118.
- Nelson, W.A.; Villouta, E.; Neill, K.F.; Williams, G.C.; Adams, N.M.; Slivsgaard, R. 2002: Marine macroalgae of Fiordland, New Zealand. *Tubinga* 13: 117-152.
- Parsons, D.M.; Shears, N.T.; Babcock, R.C.; Haggitt, T.R. 2004: Fine-scale habitat change in a marine reserve, mapped using radio-acoustically positioned video transects. *Marine & Freshwater Research* 55: 257-265.
- Phillips, N.E.; Shima, J.S. 2006: Differential effects of suspended sediments on larval survival and settlement of New Zealand urchins *Evechinus chloroticus* and abalone *Haliotis iris*. *Marine Ecology Progress Series* 314: 149-158.
- Rilov, G.; Schiel, D.R. 2006: Seascape-dependent subtidal-intertidal trophic linkages. *Ecology* 87: 731-744.
- Roberts, C.D.; Stewart, A.L.; Paulin, C.D.; Neale, D. 2005: Regional diversity and biogeography of coastal fishes on the West Coast South Island of New Zealand. *Science for Conservation* 250. Department of Conservation, Wellington, New Zealand. 70 p.
- Schiel, D.R. 1990: Macroalgal assemblages in New Zealand: structure, interactions and demography. *Hydrobiologia* 192: 59-76.
- Schiel, D.R. 2004: The structure and replenishment of rocky shore intertidal communities and biogeographic comparisons. *Journal of Experimental Marine Biology & Ecology* 300: 309-342.
- Schiel, D.R.; Hickford, M.J.H. 2001: Biological structure of nearshore rocky subtidal habitats in southern New Zealand. *Science for Conservation* 182. Department of Conservation, Wellington, New Zealand. 54 p.
- Shears, N.T.; Babcock, R.C. 2002: Marine reserves demonstrate top-down control of community structure on temperate reefs. *Oecologia* 132: 131-142.
- Shears, N.T.; Babcock, R.C. 2007: Quantitative description of mainland New Zealand's shallow subtidal reef communities. *Science for Conservation* 280. Department of Conservation, Wellington, New Zealand. 126 p.
- Shears, N.T.; Babcock, R.C.; Duffy, C.A.J.; Walker, J.W. 2004: Validation of qualitative habitat descriptors commonly used to classify subtidal reef assemblages in northeastern New Zealand. *New Zealand Journal of Marine & Freshwater Research* 38: 743-752.

- Shears, N.T.; Smith, F.; Babcock, R.C.; Duffy, C.A.J.; Villouta, E. in press: Evaluation of biogeographic classification schemes for conservation planning: application to New Zealand's coastal marine environment. *Conservation Biology*.
- Siddon, C.E.; Witman, J.D. 2003: Influence of chronic, low-level hydrodynamic forces on subtidal community structure. *Marine Ecology-Progress Series 261*: 99–110.
- Stanton, B.R. 1973: Hydrological investigations around northern New Zealand. *New Zealand Journal of Marine & Freshwater Research 7*: 85–110.
- Steneck, R.S.; Graham, M.H.; Bourque, B.J.; Corbett, D.; Erlandson, J.M.; Estes, J.A.; Tegner, M.J. 2002: Kelp forest ecosystems: biodiversity, stability, resilience and future. *Environmental Conservation 29*: 436–459.
- Villouta, E.; Chadderton, W.L.; Pugsley, C.W.; Hay, C.H. 2001: Effects of sea urchin (*Evechinus chloroticus*) grazing in Dusky Sound, Fiordland, New Zealand. *New Zealand Journal of Marine & Freshwater Research 35*: 1007–1024.
- Walker, J.W. in press: Effects of sediment on settlement and survival of juvenile sea urchins (*Evechinus chloroticus*). *Marine Ecology Progress Series*.
- Ward, T.J.; Vanderklift, M.A.; Nicholls, A.O.; Kenchington, R.A. 1999: Selecting marine reserves using habitats and species assemblages as surrogates for biological diversity. *Ecological Applications 9*: 691–698.
- Wing, S.R.; Gibbs, M.T.; Lamare, M.D. 2003: Reproductive sources and sinks within a sea urchin, *Evechinus chloroticus*, population of a New Zealand fjord. *Marine Ecology Progress Series 248*: 109–123.

# Appendix 1

## MEAN ABUNDANCE AND COVER OF KEY COMPONENTS OF SIWC SUBTIDAL REEF HABITAT TYPES

Three tables: A1.1, A1.2 and A1.3.

Table A1.1. MEAN ABUNDANCE OF *Durvillaea* spp., *Ecklonia radiata* (per m<sup>2</sup>), AND OTHER LARGE BROWN ALGAE, AND THE PERCENTAGE COVER OF OTHER MAECROALGAL GROUPS.

Note: Numbers in parentheses indicate minimum and maximum values recorded in each habitat. Text in parentheses indicate codes used in Fig. 3. For mixed turfing algae, 29 samples were randomly selected from a total of 112.

HABITAT	<i>n</i>	<i>Durvillaea</i> (Durv)	<i>Ecklonia</i> (Eck)	OTHER LARGE BROWNS (O_Lb)	SMALL BROWNS (Sm_br)	RED FOLIOSE (R_fol)	RED TURF (R_turf)	CORALLINE TURF (C_turf)	RED ENCrustING (R_enc)	CRUSTOSE CORALLINES (CCA)	GREEN (GREE)
<i>Durvillaea</i> fringe (Dur)	2	11.5 ± 3.5 (8,15)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	4.0 ± 1.0 (3,5)	9.0 ± 2.0 (7,11)	2.5 ± 2.5 (0,5)	8.0 ± 2.0 (6,10)	70.0 ± 5.0 (65,75)	0.0 ± 0.0 (0,0)
<i>Ecklonia</i> forest (Eck)	3	0.0 ± 0.0 (0,0)	21.7 ± 5.2 (12,30)	5.0 ± 2.5 (2,10)	6.7 ± 3.5 (0,12)	2.0 ± 1.0 (0,3)	5.0 ± 5.0 (0,15)	10.7 ± 4.7 (5,20)	0.0 ± 0.0 (0,0)	41.0 ± 7.2 (29,54)	0.7 ± 0.7 (0,2)
Mixed brown algae (MB)	15	0.0 ± 0.0 (0,0)	2.6 ± 1.3 (0,18)	11.9 ± 2.7 (5,39)	19.0 ± 6.4 (0,85)	14.7 ± 6.7 (0,88)	18.6 ± 5.7 (0,54)	17.4 ± 4.4 (0,50)	0.9 ± 0.5 (0,5)	20.4 ± 5.2 (0,75)	0.3 ± 0.3 (0,4)
Mixed turfing algae (MT)	29	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.2 ± 0.2 (0,5)	7.3 ± 2.2 (0,50)	7.9 ± 1.8 (0,30.5)	44.7 ± 5.3 (0,86)	10.9 ± 2.4 (0,50)	0.7 ± 0.4 (0,10)	11.2 ± 2.7 (0,50)	0.1 ± 0.0 (0,0.5)
Scoured rock (Sco)	29	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	1.1 ± 0.4 (0,10)	0.3 ± 0.2 (0,5)	1.6 ± 0.8 (0,20)	0.7 ± 0.4 (0,10)	2.8 ± 1.2 (0,30)	21.3 ± 4.3 (0,74)	0.6 ± 0.2 (0,5)
Invertebrate turf (IT)	27	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	1.8 ± 0.9 (0,22)	4.4 ± 1.6 (0,31)	9.7 ± 3.1 (0,50)	4.3 ± 1.7 (0,35)	0.5 ± 0.3 (0,5)	6.2 ± 2.0 (0,40)	0.0 ± 0.0 (0,1)
Urchin barrens (UB)	8	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.8 ± 0.6 (0,5)	2.2 ± 2.1 (0,17)	18.9 ± 7.2 (0,45)	3.3 ± 2.5 (0,20)	4.5 ± 3.1 (0,25)	29.9 ± 3.1 (25,50)	0.3 ± 0.3 (0,2)
<i>Perna</i> beds (Per)	3	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	1.3 ± 0.9 (0,3)	20.0 ± 0.0 (20,20)	1.0 ± 0.6 (0,2)	1.7 ± 1.7 (0,5)	0.0 ± 0.0 (0,0)	2.7 ± 1.2 (1,5)	0.7 ± 0.7 (0,2)
<i>Xenostrobus</i> mats (Xen)	7	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.1 ± 0.1 (0,1)	2.2 ± 2.1 (0,15)	0.3 ± 0.3 (0,2)	4.6 ± 1.9 (0,15)	28.7 ± 5.5 (15,55)	0.0 ± 0.0 (0,0)



TABLE A1.2. MEAN PERCENTAGE COVER OF SESSILE INVERTEBRATE GROUPS.

Note: Numbers in parentheses indicate minimum and maximum values recorded in each habitat. Text in parentheses indicate codes used in Fig. 3. For mixed turfing algae, 29 samples were randomly selected from a total of 112.

HABITAT	<i>n</i>	HYDROIDS (Hydr)	ASCIDIANS (Asci)	SPONGES (Spon)	TUBE WORMS (Tube)	BARNACLES (Barn)	BRYOZOANS (Bryo)	ANEMONES (Anem)	XENOSTROBUS (Xeno)	PERNA (Perna)
<i>Durvillaea</i> fringe (Dur)	2	0.3 ± 0.3 (0,0.5)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.3 ± 0.3 (0,0)	0.0 ± 0.0 (0,0.5)	0.5 ± 0.5 (0,1)	0.0 ± 0.0 (0,0)
<i>Ecklonia</i> forest (Eck)	3	0.0 ± 0.0 (0,0)	14.7 ± 10.1 (0,34)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	3.5 ± 2.1 (0,7)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)
Mixed brown algae (MB)	15	0.0 ± 0.0 (0,0)	1.5 ± 0.9 (0,13)	0.4 ± 0.3 (0,5)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.3 ± 0.2 (0,2.5)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)
Mixed turfing algae (MT)	29	0.1 ± 0.1 (0,2)	2.0 ± 0.6 (0,10)	0.3 ± 0.2 (0,4)	0.2 ± 0.2 (0,5)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.6 ± 0.4 (0,10)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)
Scoured rock (Sco)	29	0.3 ± 0.2 (0,4)	0.9 ± 0.9 (0,25)	0.0 ± 0.0 (0,0)	0.1 ± 0.1 (0,2)	0.3 ± 0.2 (0,5)	2.2 ± 0.9 (0,15)	0.6 ± 0.2 (0,5)	2.7 ± 0.8 (0,15)	0.1 ± 0.1 (0,1)
Invertebrate turf (IT)	27	1.3 ± 1.1 (0,30)	24.7 ± 4.7 (0,74)	2.0 ± 1.2 (0,30)	12.2 ± 3.3 (0,45)	1.1 ± 0.8 (0,20)	3.9 ± 2.0 (0,40)	2.5 ± 1.2 (0,22)	0.0 ± 0.0 (0,0)	0.3 ± 0.2 (0,5)
Urchin barrens (UB)	8	1.3 ± 1.3 (0,10)	0.9 ± 0.6 (0,5)	0.3 ± 0.2 (0,2)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	3.1 ± 1.6 (0,10)	1.5 ± 0.9 (0,7)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)
<i>Perna</i> beds (Per)	3	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.3 ± 0.3 (0,1)	0.0 ± 0.0 (0,0)	92.0 ± 6.0 (80,98)
<i>Xenostrobus</i> mats (Xen)	7	6.4 ± 3.0 (0,20)	0.0 ± 0.0 (0,0)	0.8 ± 0.7 (0,5)	0.3 ± 0.3 (0,2)	1.4 ± 0.9 (0,5)	5.6 ± 2.7 (0,20)	3.5 ± 1.0 (0,1.7)	48.4 ± 9.1 (20,80)	0.0 ± 0.0 (0,0)

TABLE A1.3. MEAN PERCENTAGE COVER OF SEDIMENT AND BARE ROCK, AND MEAN ABUNDANCE OF *Evechinus*.

Numbers in parentheses indicate minimum and maximum values recorded in each habitat. Text in parentheses indicate codes used in Fig. 3. The overall classification success for each habitat from CAP analysis is also given. For mixed turfing algae, 29 samples were randomly selected from a total of 112.

HABITAT	<i>n</i>	SEDIMENT (Sed)	BARE ROCK (Bare)	<i>Evechinus</i> (Eve)	CLASSIFICATION SUCCESS
<i>Durvillaea</i> fringe (Dur)	2	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	50.0%
<i>Ecklonia</i> forest (Eck)	3	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	1.0 ± 0.6 (0,2)	0.0%
Mixed brown algae (MB)	15	2.7 ± 2.3 (0,35)	0.1 ± 0.1 (0,2)	0.8 ± 0.4 (0,6)	80.0%
Mixed turfing algae (MT)	29	17.8 ± 3.7 (0,70)	0.2 ± 0.2 (0,6)	2.0 ± 0.7 (0,13)	75.9%
Scoured rock (Sco)	29	12.2 ± 3.2 (0,50)	49.3 ± 5.7 (0,98)	0.0 ± 0.0 (0,1)	89.7%
Invertebrate turf (IT)	27	23.5 ± 4.1 (0,69)	0.5 ± 0.4 (0,10)	0.1 ± 0.1 (0,2)	74.1%
Urchin barrens (UB)	8	15.8 ± 7.4 (0,52)	0.0 ± 0.0 (0,0)	6.0 ± 2.6 (0,22)	75.0%
<i>Perna</i> beds (Per)	3	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	0.0 ± 0.0 (0,0)	66.7%
<i>Xenostrobus</i> mats	7	0.0 ± 0.0 (0,0)	2.4 ± 2.1 (0,15)	0.1 ± 0.1 (0,1)	57.1%

# Appendix 2

## MACROALGAL TAXA

TABLE A2.1. A LIST OF MACROALGAL TAXA RECORDED AT EACH SITE WITHIN EACH REGION OF ISWC. 'X' INDICATES SPECIES PRESENT AT A SITE.

Taxa	South Westland										Buller																
	Penguin Rocks	Penguin Inner	Crayfish Rock	George Islands	Browne Island	Barn Islands	Cascade Point	Cascade Island	Cement Face	Frog Rocks	Moccasim Gap	Smoothwater Point	Jackson Bluff	Jackson Head	SW Popoai	NE Taunaka	NW Taunaka	Arnot Point	Moeraki River	Whakapohai	Granite spot	North Granite	South Seal Rocks	Fishing Rod reef	Kongahu Pt	Falls Creek	Little Wanganui Head
Crustose corallines	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Red turf	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coralline turf	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Placodium</i> spp.	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Hatopteris</i> spp.	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Microzonia velutina</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Lophurella hookeriana</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Anotrichium crinitum</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Asparagopsis armata</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Echinodammion</i> spp.	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Red encrusting	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Glossophora kuantzii</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Euphitota formosissima</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Landsburgia quercifolia</i>	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Dictyota</i> spp.	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Sargassum sinclairii</i>	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Carpomitra costata</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Rhodophyllis gunnii</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Zonaria</i> spp.	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Ecklonia radiata</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Gymnogongrus furcatus</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Carpophyllum flexuosum</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Ballia callitricbia</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Gigartina</i> spp.	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Spatoglossum chapmanii</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Colpomenia sinuosa</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Dictyota papenfussii</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Caulerpa brownii</i>	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Codium convolutum</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Hymenena durvillaei</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Ptilonia willana</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Heterosiphonia conchma</i>	-		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table A2.1 continued on next page



***Ecology of subtidal reefs on the South Island West Coast***

*This report describes the biogeography, biological habitat types and community structure of subtidal reefs on the South Island West Coast (SIWC). A biological habitat classification scheme for SIWC subtidal reefs is developed, and nine biological habitat types identified. Analyses support division of the SIWC into two biogeographic regions—northern Buller and South Westland. Abiotic factors (particularly poor water clarity and sand scour) appear to play a dominant role in shaping subtidal reef communities on the SIWC.*

Shears, N.T. 2007: Biogeography, community structure and biological habitat types of subtidal reefs on the South Island West Coast, New Zealand. *Science for Conservation* 281. 53 p.