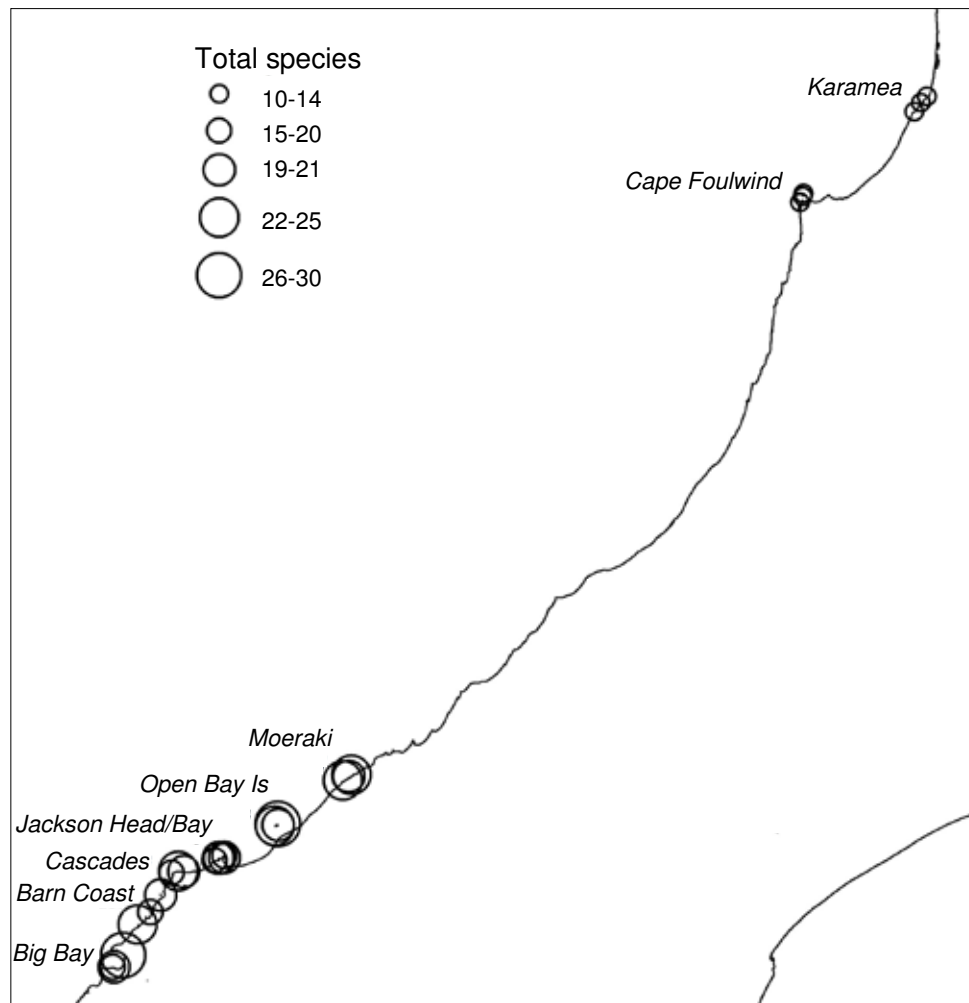


Figure 10. Macroalgal species richness. Total number of macroalgal taxa recorded at each site.



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-

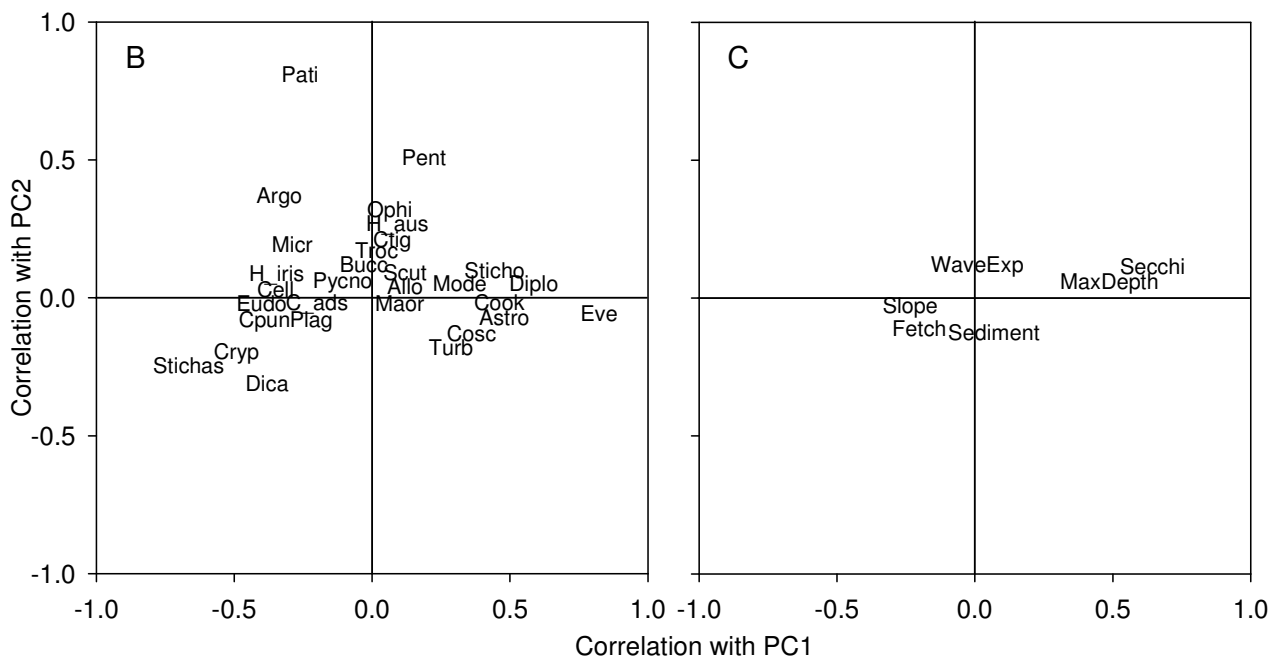
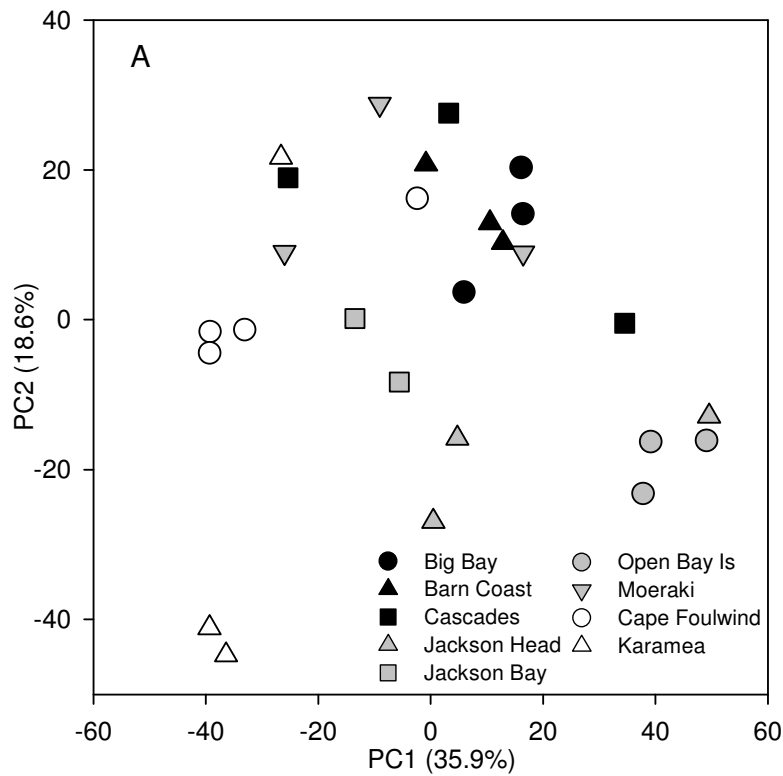


Figure 11. A—Principal coordinates analysis of mobile macroinvertebrate assemblages (log(x+1) transformed count data) for West Coast sites. B—Bi-plot showing correlations between principal coordinate axes and species variables. C— Bi-plot showing correlations between principal coordinate axes and environmental 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.

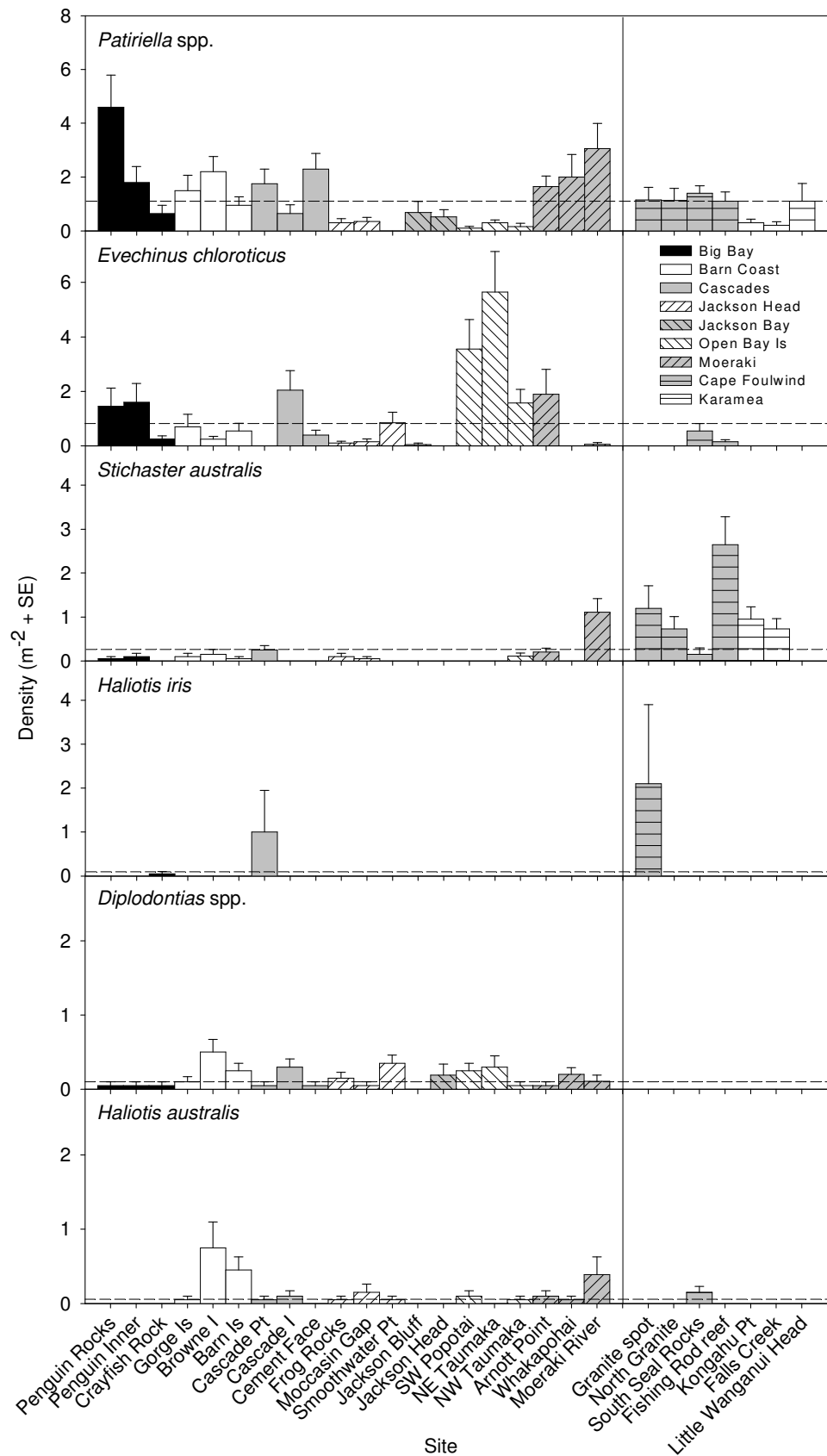


TABLE 4. CLASSIFICATION SUCCESS (PERCENTAGE OF SITES ASSIGNED TO THEIR CORRECT REGION BASED ON CAP ANALYSIS) OF PREVIOUS MARINE BIOGEOGRAPHIC CLASSIFICATION SCHEMES FOR THE WEST COAST USING MACROALGAL PRESENCE-ABSENCE DATA (THIS STUDY) AND REEF FISH PRESENCE-ABSENCE DATA (ROBERTS ET AL. 2005). *n* INDICATES 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 (%)
Roberts et al. (2005)				
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
Total		62.96		63.04
Neale & Nelson (1998)				
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
Total		92.59		82.61

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 $R = -0.110$, $P = 0.652$).

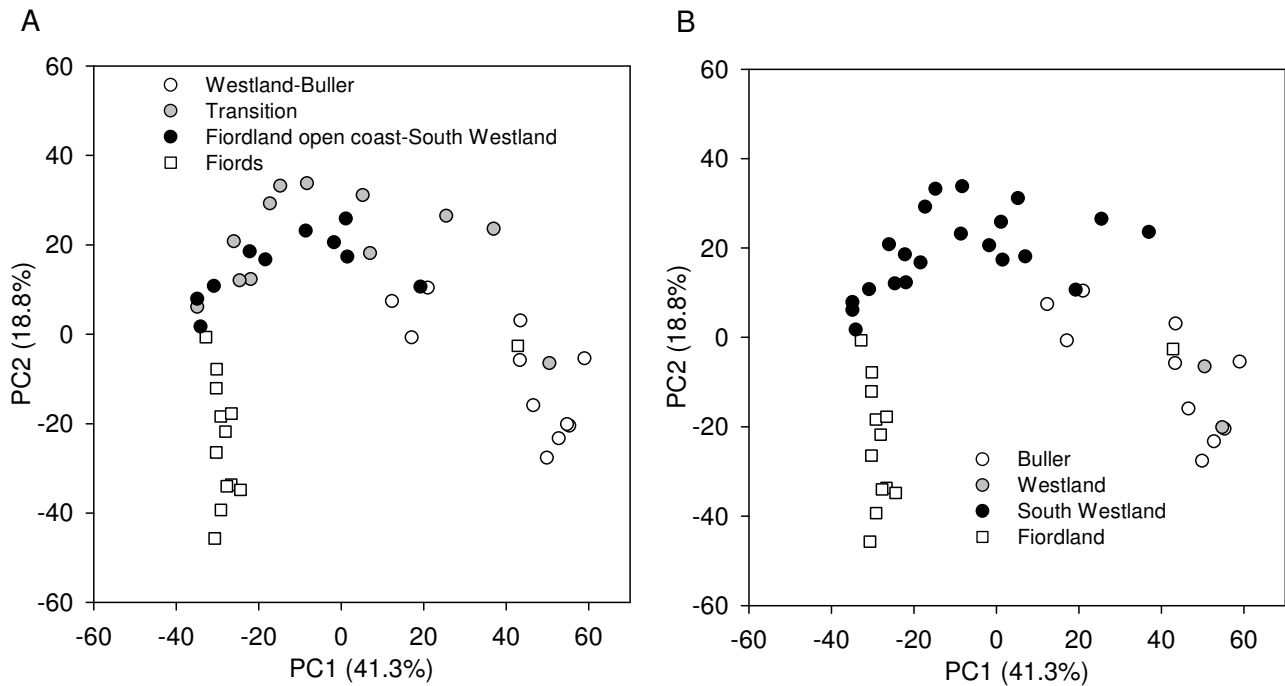


Figure 13. Principal coordinates analysis of reef fish species composition (presence-absence data for 90 species from Roberts et al. 2005) for West Coast and Fiordland sites. A—Symbols indicate regions proposed by Roberts et al. (2005); B—Symbols indicate regions proposed by Neale & Nelson (1998).

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 *Enderachne 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.

6. Acknowledgements

This study was funded by Science & Research Division (now Research, Development & Improvement Division), DOC (Science Investigation No. 2481) and West Coast/Tai Poutini Conservancy, DOC. Additional post-doctoral support was provided by the University of Auckland. I am extremely grateful to the divers who bravely took their quadrats where no ecologists have been before: Clinton Duffy, Don Neale, Phil Ross, Mark Martini and Helen Kettles. Thanks also to Kina Scollay for gallantly skippering the *Taku Hoa* with impeccable judgement and confidence, and also to Don Neale for initiating this work, and providing local knowledge, information and advice throughout. Thanks to Wendy Nelson (NIWA) for assistance with seaweed identifications, Eduardo Villouta (DOC) for software for calculating wind fetch, and Richard Gorman (NIWA) for modelled wave exposure estimates.

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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 m²), 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 barrrens (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	Mocassin 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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	X	X
<i>Ecklonia radiata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<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	X	X
<i>Carpophyllum flexuosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<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	X	X
<i>Gigartina</i> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<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	X
<i>Colpomenia sinuosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<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	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	X
<i>Codium convolutum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hymenena durvillaei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ptilonia willana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Heterosiphonia conchma</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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.