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

Nick T. Shears

SCIENCE FOR CONSERVATION 281

Published by
Science & Technical Publishing
Department of Conservation
PO Box 10420, The Terrace
Wellington 6143, New Zealand

Cover: Shallow mixed turfing algal assemblage near Moeraki River, South Westland (2 m depth). Dominant species include *Plocamium* spp. (yellow-red), *Echinothamnium* sp. (dark brown), *Lophurella hookeriana* (green), and *Glossophora kunthii* (top right).
Photo: N.T. Shears

Science for Conservation is a scientific monograph series presenting research funded by New Zealand Department of Conservation (DOC). Manuscripts are internally and externally peer-reviewed; resulting publications are considered part of the formal international scientific literature.
Individual copies are printed, and are also available from the departmental website in pdf form. Titles are listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Science & technical*.

ISSN 1173-2946 (hardcopy)
ISSN 1177-9241 (web PDF)
ISBN 978-0-478-14354-6 (hardcopy)
ISBN 978-0-478-14355-3 (web PDF)

This report was prepared for publication by Science & Technical Publishing; editing and layout by Lynette Clelland. Publication was approved by the Chief Scientist (Research, Development & Improvement Division), Department of Conservation, Wellington, New Zealand.

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CONTENTS

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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

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*. Department of Conservation, Wellington. 53 p.

1. Introduction

As part of New Zealand's commitment to the International Convention on Biological Diversity (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) 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 Fucalean 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).

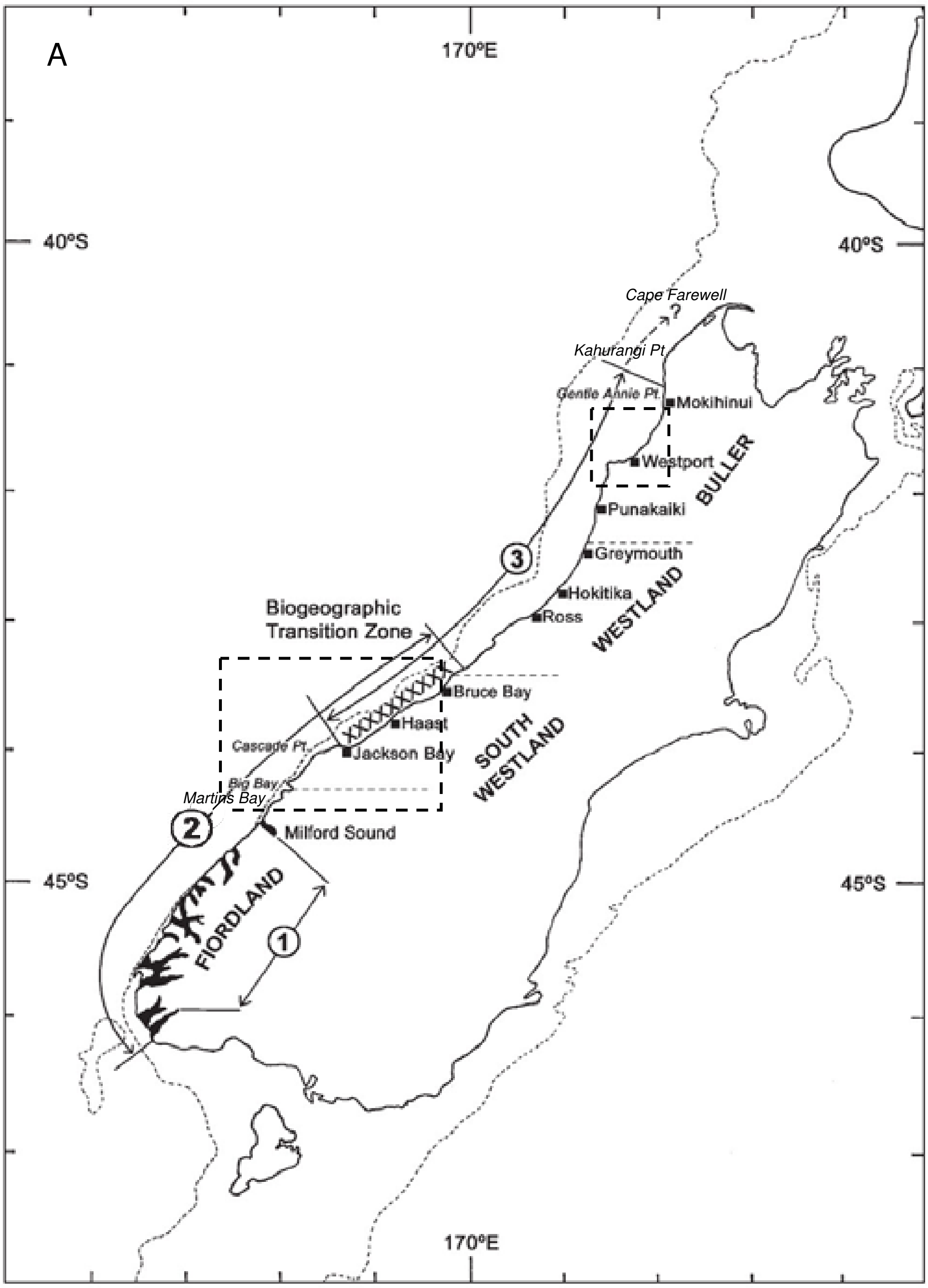
This report describes the biogeography, biological habitat types and community structure of subtidal reefs at the 27 sites surveyed by Shears et al. (in press), which span over 300 km of the SIWC (Fig. 1B, C). General descriptions of the benthic communities at these sites are provided from a national 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.

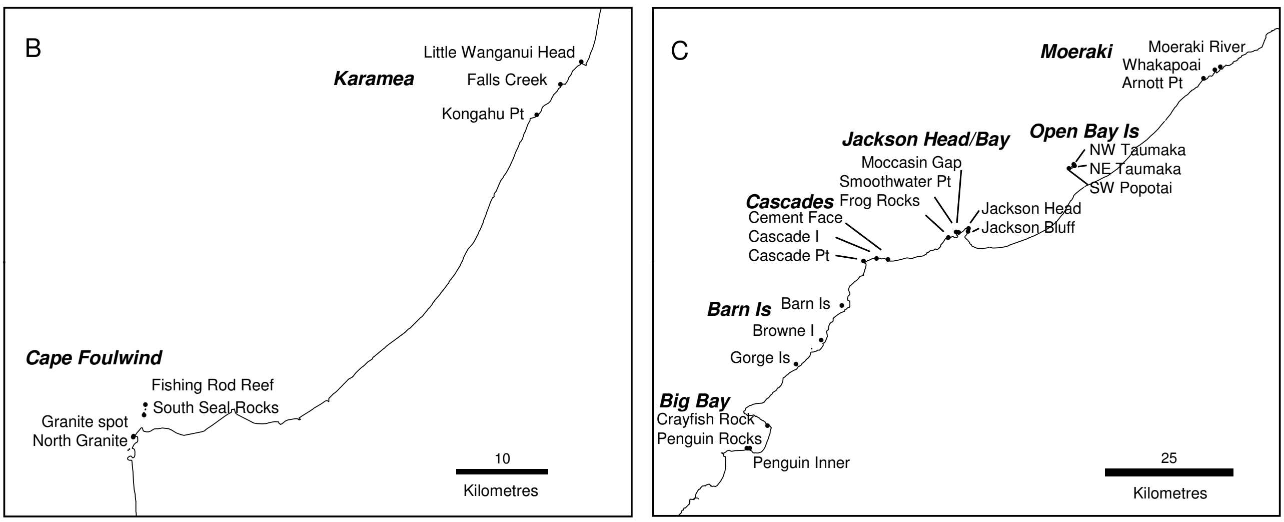
2. Methods

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^2 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
Durvillaea fringe (Dur)	<1	Shallow fringe of *Durvillaea willana* and/or *D. antarctica*. Substratum predominantly covered by crustose corallines and, to a lesser extent, red encrusting algae and red turfing algae.
Ecklonia forest (Eck)	<5	Generally monospecific stands of *Ecklonia radiata* (>4 adult plants per m^2). Urchins at low numbers (<1 exposed urchin per m^2).
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^2).
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^2) 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 *Xenostrobus* 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 *Evechinus* are generally absent.
Urchin barrens (UB)*	5–12	Very low numbers of large brown algae present (<4 adult plants per m^2), substratum typically dominated by crustose coralline algae and red turfing algae. Usually associated with grazing activity of *Evechinus* (>2 exposed urchins per m^2).
Perna beds (Per)	<3	Dominance of *Perna canaliculus*, which may be covered in a variety of encrusting flora and fauna.
Xenostrobus mats (Xen)*	2–10	*Xenostrobus pulex*, crustose corallines and the hydroid *Amphisbetia bispinosa*. 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:

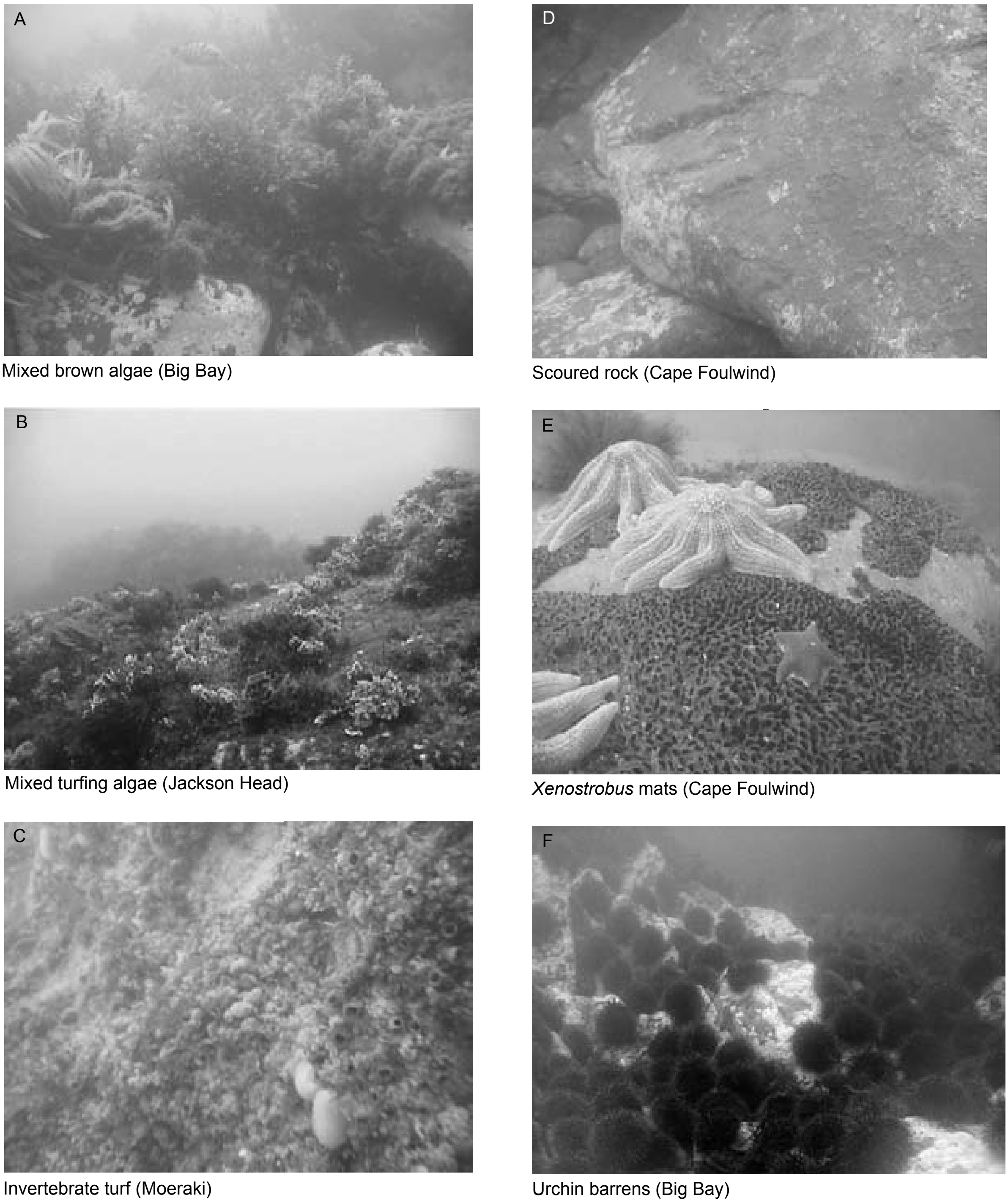
- Neale & Nelson (1998): Buller, Westland, South Westland and Fiordland (note: Fiordland was included as this was considered as a distinct region by these authors).
- Roberts et al. (2005): Fiords, Fiordland open coast–South Westland, Transition and Westland–Buller (note: the Transition zone was treated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

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