

Figure 35. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Euechinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for site groups at Charles and Doubtful Sound within the Fiordland bioregion.

### **Preservation Inlet**

Two sites were sampled at Preservation Inlet, one very sheltered site in the inner fiord (Weka Point) and one more exposed site at the fiord entrance (Sandfly Point). Reef communities varied considerably between these two sites (Fig. 36A). Large brown algae (*Xiphophora gladiata*, *C. flexuosum* and *C. retroflexa*) were restricted to the shallow stratum at Weka Point and CCA dominated at greater depths. The biomass and cover of other groups was low at these depths (Fig. 36C). *Evechinus chloroticus* was abundant across all depths sampled and *Cellana stellifera*, *Patriella* spp., *Maoricolpus roseus* and *Stichopus mollis* were also common (Fig. 36B). The mussel *Mytilus* sp. was also a dominant component in the shallow stratum.

Sandfly Point was more similar to other outer Fiordland sites with *X. gladiata*, red foliose algae and coralline turf dominating the shallow strata (0–2 m and 4–6 m) and *Landsburgia quercifolia* and *Caulerpa brownii* dominating at 7–9 m (Fig. 36A). The deepest stratum (10–12 m) was dominated by *C. brownii* (> 50% cover). *Ecklonia radiata*, *Marginariella* spp., *Lessonia variegata* and *C. platylobium* were notably absent. Bryozoans, ascidians and sediment were an important component in the deeper strata (Fig. 36C). *Evechinus chloroticus* was recorded in relatively high numbers at 4–6 m and 7–9 m where it occurred in large patches. Other mobile macroinvertebrates were rare at all depths (Fig. 36B).

#### **3.4.11 Stewart Island bioregion**

The sites sampled in the Stewart Island bioregion spanned a large environmental gradient, from sheltered reefs inside Paterson Inlet to offshore islands and the highly exposed southern coast of the South Island. Based on algal community structure, sites were divided into six groups which broadly corresponded to this gradient (Fig. 37A). The sites from inside Paterson Inlet (excluding Octopus Island) formed one group (termed 'very sheltered') and were separated from the remaining more open coast sites at the 55% similarity level. The remaining sites were divided among five groups that broadly corresponded to differences in wave exposure. The most sheltered of these included sites on the northeastern coast of Stewart Island (termed 'sheltered'), while the most exposed sites sampled at Green Islets formed their own group ('Green Islets'). Three highly exposed sites formed another group and these were characterised by large *Durvillaea willana* forests and have been termed the 'Durvillaea' group. The remaining sites were divided among two groups: one including moderately exposed sites from Titi Islands, Port Adventure, Ruapuke Island and Codfish-Ruggedy (termed 'moderately exposed') and the other group included the more exposed sites from Bluff, Codfish-Ruggedy, Ruapuke and Titi Islands (termed 'highly exposed'). Fetch and Sediment were strongly correlated with PC1 and each explained 20% of the variation among sites (Fig. 37B, Table 4). These two variables were inversely correlated and sediment cover was typically highest at the most sheltered sites. *Macrocystis pyrifera* and *Carpophyllum flexuosum* were positively correlated with PC1 and more common at more sheltered sites, while *Lessonia variegata*, *Landsburgia quercifolia*, red foliose algae and coralline turf were negatively correlated and more abundant at exposed sites (Fig. 37C). *Evechinus* was positively correlated with PC2 and both *Ecklonia radiata* and *Marginariella* spp. were negatively correlated. *Evechinus*, Sediment and Fetch were all significantly related to algal community structure and explained 32% of the variation among sites (Table 4).

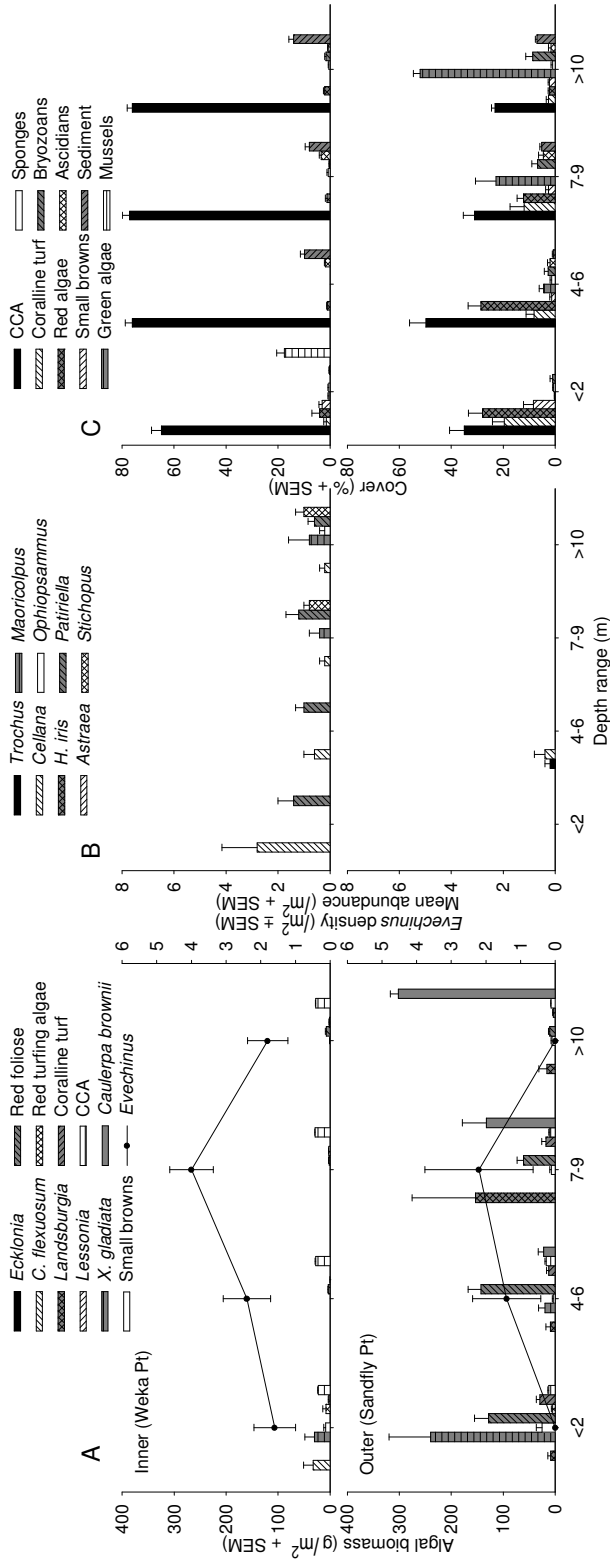
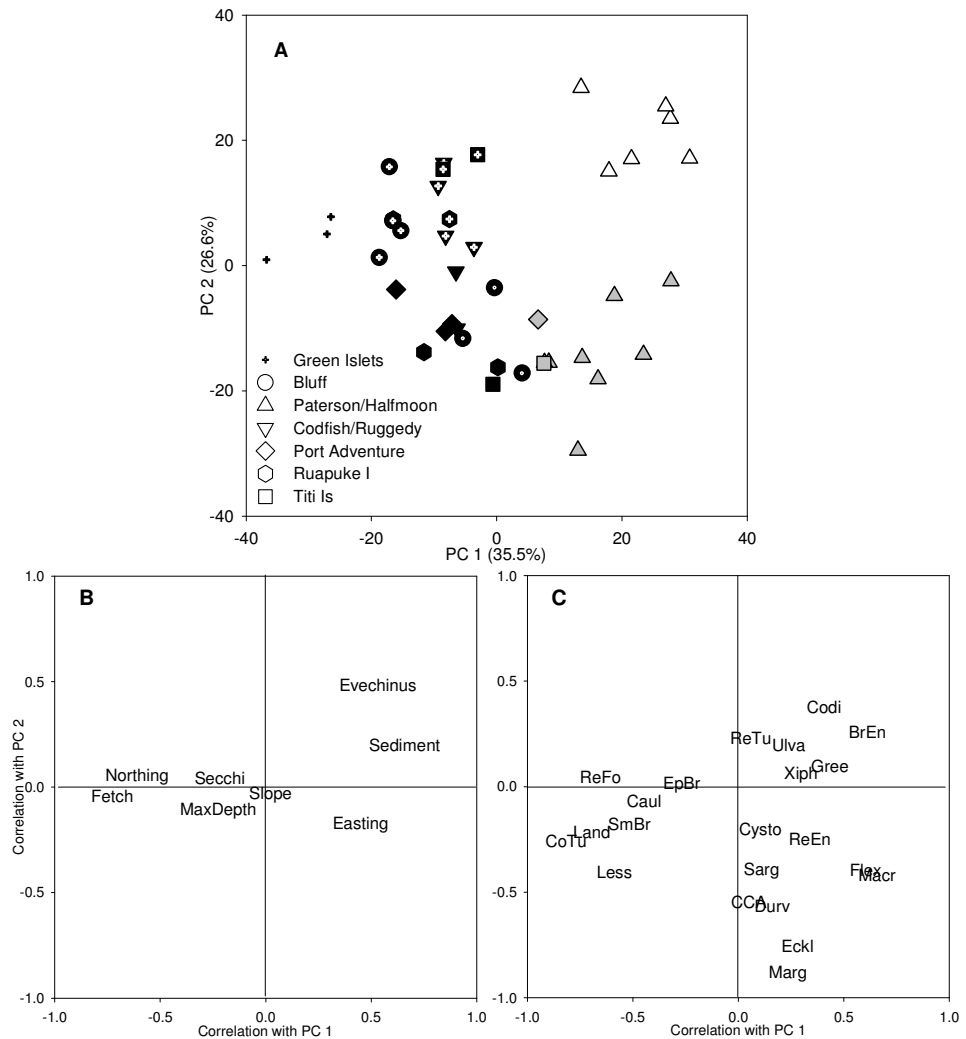


Figure 36. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evecchinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for site groups at Preservation Inlet within the Fiordland bioregion.

Figure 37. Principal coordinates analysis of sites sampled in the Stewart Island bioregion, based on fourth-root transformed biomass of 23 macroalgal groups (A). Bi-plots give correlations between principal coordinates axes and environmental variables (B) and original macroalgal species groups (C) (see Table 1 for macroalgal group codes). Sites shaded according to groupings identified at the 70% similarity level. White = very sheltered, grey = sheltered, black = four exposed groups (blank = moderately exposed, dots = *Durvillaea*, cross-hair = highly exposed, and Green Islets sites (+) formed their own group). See section 3.4.11 for explanation of groups.



### Very sheltered: Inner Paterson Inlet

All sites inside Paterson Inlet, excluding Octopus Island, were grouped together in the very sheltered group based on algal community structure (Fig. 37). *Evechinus chloroticus* was abundant at these sites across all depths and large brown algae (predominantly *Xiphophora gladiata* and *Carpophyllum flexuosum*) were restricted to a shallow band (< 1 m depth) (Fig. 38A). Several other species including *Cystophora scalaris*, *C. retroflexa*, *Macrocystis pyrifera*, *Marginariella boryana* and the green alga *Codium convolutum* were also common in this stratum. In the deepest stratum an assemblage of red foliose algae often occurred on the sand-reef boundary (e.g. *Dasya collabens*, *Delisea elegans*, *Adamsiella chauvinii*, *Asparagopsis armata*, *Rhodymenia* spp. and *Brongniartella australis*). Mobile macroinvertebrates were abundant, in particular *Cellana stellifera* at 0–2 m and 4–6 m, and *Maoricolpus roseus* at 7–9 m and 10–12 m (Fig. 38B). The starfish *Patriella* spp., ophiuroid *Ophiopsammus maculata* and holothurians *Stichopus mollis* and *Ocnus* spp. were common at all depths. Low numbers of *Haliotis iris* and *H. australis* were recorded at some sites. The percentage cover of crustose coralline algae declined with depth and sediment increased (Fig. 38C). Coralline turf was rare, and sponges, ascidians and bare rock were common.

### ***Sheltered***

The sites in this group were mainly situated on the open northeastern coast of Stewart Island (in the lee of the prevailing southwesterly swell) and included Octopus Island and open coast sites at Paterson Inlet and a site from both Titi Islands (Edwards Island), Port Adventure (Browns Garden) and the Codfish-Ruggedy locations (Lucky Point). These sites were dominated by large brown algae at all depths (Fig. 38A). The shallow stratum was dominated by *Marginariella urvilliana*, *Xiphophora gladiata* and at some sites *Lessonia variegata* (Native North) and *Durvillaea willana* (West Head, Bob's Point, Horseshoe). *Glossophora kunthii*, *Spatoglossum chapmanii*, *Halopteris* sp. and *Codium convolutum* were also common in this zone. The deeper strata were characterised by a mixed assemblage of *Macrocystis pyrifera*, *Ecklonia radiata*, *Carpophyllum flexuosum*, *Marginariella boryana* and *Cystophora platylobium* (Fig. 38A). The biomass of red foliose algae (e.g. *Euptilota formosissima*, *Plocamium* spp., *Delisea plumosa*, *D. elegans*, *Rhodophyllis gunnii* and *Callophyllis* spp.) tended to increase with depth and the small brown algae *Sporochnus stylosus*, *Halopteris* sp., *Carpomitra costata* and *Desmarestia ligulata* were also common. Crustose coralline algae were the dominant substratum cover at all depths, although there was also a high percentage cover of sediment at 10–12 m (Fig. 38C). Percentage cover of coralline turf was highest in the shallowest stratum, whereas the percentage cover of red algae, small browns, ascidians and sponges was greater in deeper strata. *Evechinus* were generally rare, except for the two sites located at the entrance of Paterson Inlet (Native North, Neck North) where they were abundant in the deepest strata (7–9 m and 10–12 m) and macroalgal biomass was reduced. *Opbiopsammus maculata*, *Patiriella* spp., *Stichopus mollis* and *Trochus viridis* were the most common mobile macroinvertebrate species, but overall abundance was considerably lower than at the inner Paterson Inlet sites (Fig. 38B).

### ***Moderately exposed***

This group included a selection of moderately exposed sites from Titi Islands (Herekopere), Port Adventure (Tia Island, Lords River Head, Owens Island), Ruapuke Island (North Head, Bird Rock, Caroline Bay) and Codfish Island (Codfish East, Codfish Southeast). At these sites *Xiphophora gladiata*, *Lessonia variegata* and *Marginariella urvilliana* typically dominated the shallow stratum, while *L. variegata* and, to a lesser extent, *Landsburgia quercifolia*, dominated at 4–6 m (Fig. 38A). The deeper strata were characterised by a mixed assemblage of *Ecklonia radiata*, *Carpophyllum flexuosum*, *Lessonia variegata*, *Landsburgia quercifolia*, *Cystophora* spp., *M. boryana*, *Caulerpa brownii* and red foliose algae. The biomass of *E. radiata* was generally lower than at sites in the sheltered group, while the cover of red algae was typically higher and cover of sediment lower (Fig. 38C). Patches of *Evechinus* were common in the deepest strata at most of the sites excluding the Ruapuke Island site where they were rare. Other mobile macroinvertebrate species generally occurred at lower numbers compared to sites in the sheltered group (Fig. 38B).

### ***Durvillaea***

This group included three sites at Bluff (Pig Island, Tiwai Point and Stirling Point) where *Durvillaea willana* formed large forests in the shallow subtidal to depths of

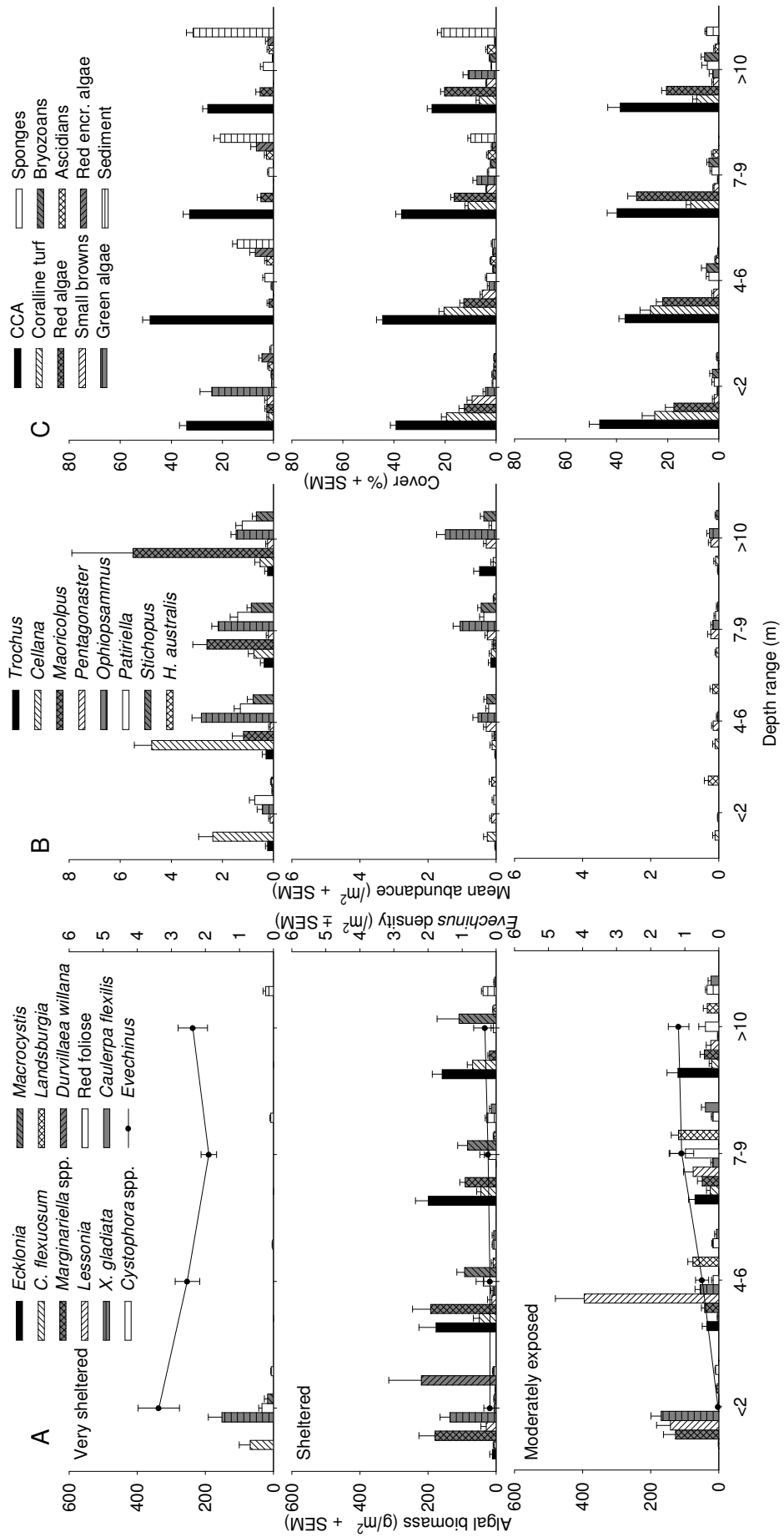


Figure 38. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evechinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for the Very sheltered, Sheltered and Moderately exposed site groups within the Stewart Island bioregion. Sites from each location are grouped according to the groups identified in Fig. 37.

4–5 m (Fig. 39A). These sites also had high biomasses of *Marginariella urvilliana* and/or *Lessonia variegata* at mid-depths, with *Cystophora platylobium* and red foliose algae dominating the deepest stratum. Crustose corallines were the dominant cover at shallow depths beneath the *D. willana* canopy while, in the deeper strata, red foliose algae, sediment and ascidians were also important components (Fig. 39C). *Pyura pachydermatina* was particularly abundant at Pig Island ( $25.7 \pm 6.0/\text{m}^2$ ) and Stirling Point ( $12.2 \pm 4.2/\text{m}^2$ ). *Evechinus chloroticus* was generally restricted to the deepest stratum where it was recorded in low numbers. Mobile macroinvertebrates were present in low numbers, although *Maoricolpus roseus* was common in the deepest stratum at Stirling Point (Fig. 39B). Paua (*Haliotis iris*) were generally rare but small patches of large individuals (> 150 mm) were observed at Tiwai Point.

### **Highly exposed**

The remaining Bluff sites (Oraka Point, Shag Rock, Barracouta Point, Lookout Point) and the most exposed sites from Codfish-Ruggedy (North Sealers, Ruggedy NE, Ruggedy Passage, Black Rock Point), Ruapuke Island (South Islets) and Titi Islands (Bench North, Bench SE Point) made up this group. The biomass of large brown algae was typically reduced at these sites across all depths (Fig. 39A), with *Xiphophora gladiata* and *Lessonia variegata* dominating the shallow stratum (< 2 m), and *Landsburgia quercifolia*, red foliose algae and *Caulerpa brownii* at greater depths. *Lessonia variegata*, *Marginariella* spp. and *Cystophora platylobium* also occurred at low biomasses. In general, the deeper strata at these sites were dominated by a mix of red foliose algae, *C. brownii*, ascidians, sponges and sediment (Fig. 39C). *Evechinus chloroticus* was recorded at low numbers in the deeper strata, but large patches (> 100 individuals) were observed at depths greater than 10 m at a number of sites (e.g. Shag Rock, Lookout Point). Individual *E. chloroticus* were typically large (up to 190 mm TD), and no individuals smaller than 100 mm were recorded (Appendix 6). Other mobile macroinvertebrates occurred at low numbers, e.g. *Cellana stellifera* and *Haliotis iris* in the shallow stratum and *Ophiopsammus maculata* in the deepest stratum (Fig. 39B).

### **Green Islets**

All of the sites sampled at the Green Islets were highly exposed to the south and southwest and, based on algal community structure, formed their own distinct group (Fig. 37). *Lessonia variegata* was the dominant large brown algae at each site and across all depths (Fig. 39A). *Landsburgia quercifolia* was the only other common large brown algae and typically occurred in the deeper strata. A number of common large brown algal species were notably absent from these sites, e.g. *Xiphophora gladiata*, *Cystophora platylobium*, *Marginariella* spp., *Durvillaea willana*, *Ecklonia radiata* and *Carpophyllum flexuosum*. Coralline turf and red foliose algae were a dominant component of the algal assemblages at all depths. CCA, coralline turf, red foliose algae, bryozoans and sponges were the primary space occupiers (Fig. 39C). *Evechinus chloroticus* was generally absent from depths less than 10 m, but occurred in dense patches in the deepest stratum (10–12 m) at Archway and NW Bay. All individual *E. chloroticus* recorded were > 100 mm TD (Appendix 6). *Haliotis australis*, *Ophiopsammus maculata* and *Patiriella* spp. were the most common mobile macroinvertebrates, but generally occurred in low numbers (Fig. 39B).

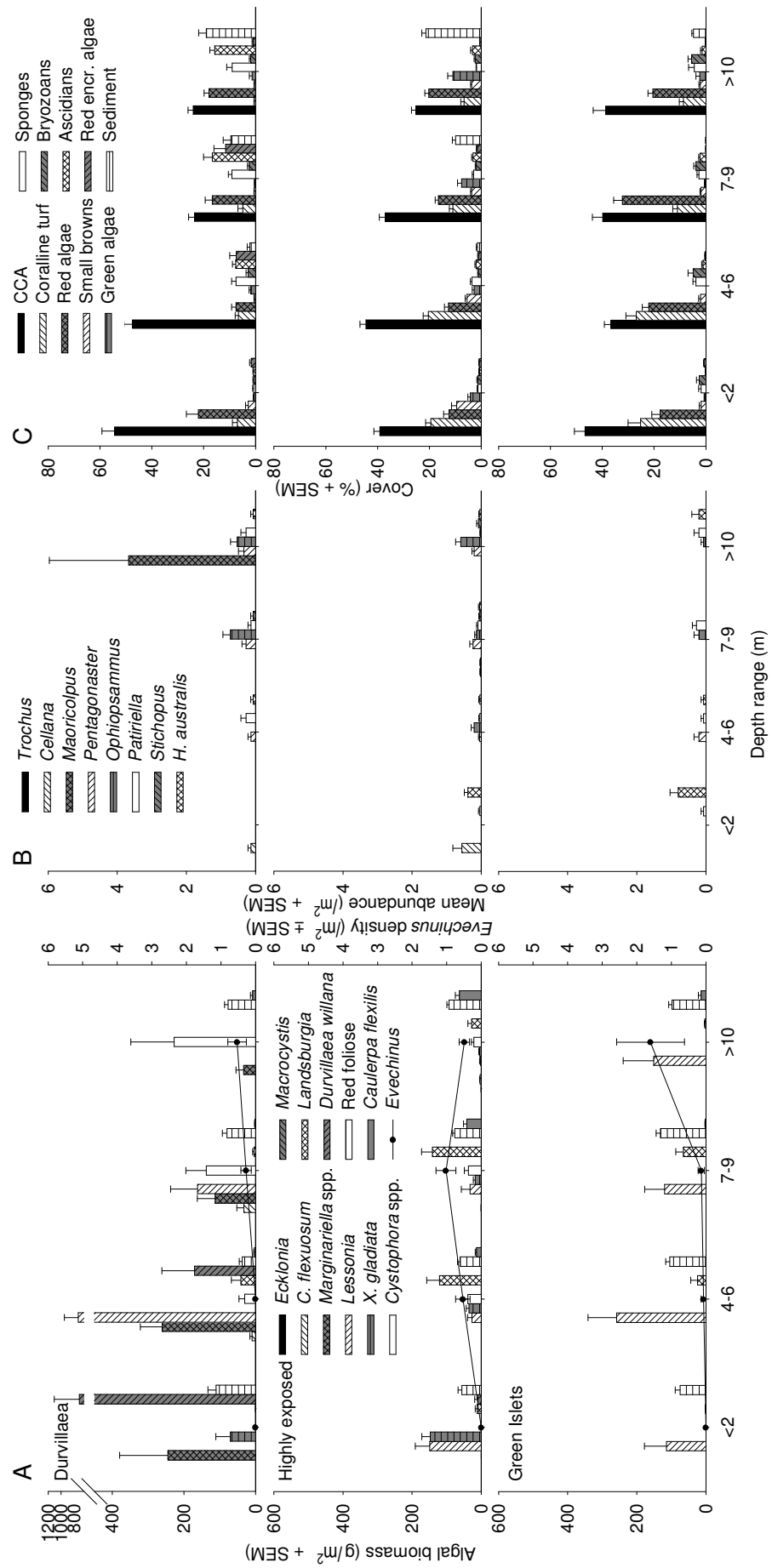


Figure 39. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evecchinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for the *Durvillaea*, Highly exposed and Green Islet groups within the Stewart Island bioregion (site groups identified in Fig. 37).



## 4. Discussion

### 4.1 BIOGEOGRAPHIC DISTRIBUTION OF KEY SPECIES

This study provides quantitative information on the distribution of a large number of shallow subtidal reef species throughout mainland New Zealand based on a consistent methodology employed across all sites. While we were unable to sample large stretches of coast (e.g. Wairarapa and the northwestern coast) and the one-off sampling procedure may have missed particular species that are present at certain sites and locations, this study provides an unprecedented quantitative description of subtidal reefs across mainland New Zealand that will provide a basis for further study of New Zealand's reefs.

The biogeographic classification of Shears et al. (in press) based on this national dataset provided a spatial framework within which to describe regional and national scale variation in communities. One of the most prevalent patterns identified by Shears et al. (in press) was a clear division in algal species composition between the Northern and Southern biogeographic provinces. In the present study we found that algal community structure based on the biomass of 23 algal species groups exhibited a similar division between provinces (Fig. 2). In general, several dominant macroalgal species had clear Northern (e.g. *C. maschalocarpum*, *C. plumosum*, *C. angustifolium*, *Osmundaria colensoi*, *Pterocladia lucida* and *Caulerpa flexilis*) or Southern (e.g. *Durvillaea willana*, *Marginariella* spp., *Macrocystis pyrifera*, *Hymenena* spp. and *Caulerpa brownii*) distributions. Few species, however, were solely restricted to either the Northern or Southern Province. For example, *Marginariella boryana* and *Macrocystis pyrifera* had Southern distributions, but both species were found at one site at Long Island (classified in the Northern Province). Similarly, while a shallow band of *Carpophyllum maschalocarpum* was a characteristic feature of locations in the Northern Province, *C. maschalocarpum* was also an important component at some locations in the Southern Province (Wellington, Kaikoura Peninsula and Banks Peninsula North). *Carpophyllum maschalocarpum* was not recorded at any of the locations on the West Coast of the South Island, despite being reported from Open Bay Islands (Neale & Nelson 1998) and Fiordland (Nelson et al. 2002).

*Carpophyllum angustifolium* and *C. plumosum* were found only at Northeastern locations, although *C. plumosum* occurs at Gisborne (Hogan et al. 1991) and on the Wairarapa Coast (Nelson 1994). *Carpophyllum angustifolium* typically dominated the sublittoral fringe on exposed reefs throughout the Northeastern bioregion, but was not recorded at Cape Karikari or Cape Reinga in this study. Moore (1961) reported the northerly range of this species to about Cape Brett (Moore 1961); however, it has been recorded from North Cape and the Three Kings Islands (Nelson 1994). At highly exposed Northern locations (e.g. Cape Reinga, Gannet Rock) *C. maschalocarpum* exhibits a long slender morphology resembling *C. angustifolium* (NS, pers. obs.). Furthermore, potential hybrids of these species may complicate these distributional patterns and additional work on the taxonomy and ecology of these species is needed to resolve these contrasting patterns.

In contrast to the other *Carpophyllum* species, which characterise the shallow subtidal fringe in Northern locations, *C. flexuosum* typically occurred in deeper water and was found throughout the country. This species formed extensive forests in areas with low wave action (e.g. Long Bay, Long Island and the eastern side of Kapiti Island) or areas with high turbidity (e.g. Banks Peninsula North and Gisborne). Schiel & Hickford (2001) found *C. flexuosum* to be the dominant fucal alga at several Southern locations, e.g. Banks Peninsula North and Fiordland. However, we found *C. flexuosum* to have a rather patchy distribution in Southern New Zealand, as it was not recorded at Otago Peninsula, Catlins, Kaikoura or several locations on the west coast (e.g. Raglan, New Plymouth, and all Buller and Westland locations except Open Bay Islands).

*Ecklonia radiata* was the most commonly recorded large brown algal species and made up 25.5% of total algal biomass. *Ecklonia radiata* occurs throughout New Zealand, but was notably absent from some locations including Otago Peninsula, Catlins, Bluff, Green Islets, Abel Tasman, Nelson and numerous west coast locations. The large mono-specific stands of *E. radiata*, typical of the Northeastern bioregion (Choat & Schiel 1982), were not observed in any other areas except Mahia, Kapiti Island and occasional sites in the Fiordland (Charles inner) and Stewart Island (Tia Island, Lucky Point and Edwards Island) bioregions. At other Southern locations (e.g. Wellington, Kaikoura, Paterson Inlet, Codfish-Ruggedy, Ruapuke Island, Titi Islands, Port Adventure and outer-fiord sites), *E. radiata* was found in a mixed assemblage with other large brown algal species, e.g. *Lessonia variegata*, *Landsburgia quercifolia*, *Cystophora* spp. and *Marginariella* spp., which is consistent with Southern sites examined by Choat & Schiel (1982) and Schiel & Hickford (2001). The absence of *E. radiata* from some locations is probably the result of a combination of factors including water temperature, high wave action, turbidity, sandscour and urchin grazing. For example, on the west coast, *E. radiata* was only found at Fiordland locations, Open Bay Islands and Gannet Rock sites, and one offshore site at New Plymouth (Seal East). It is probably absent from most other west coast coastal sites (e.g. Raglan, Karamea South, Cape Foulwind, Jackson Head and Cascades) because of extreme wave action and high levels of sandscour and turbidity. At the west coast offshore islands, *E. radiata* appeared to be restricted to either shallow (e.g. Gannet Rock) or deep (e.g. New Plymouth) water by high densities of *Evechinus chloroticus* at mid-depths. *Ecklonia radiata* does occur at some coastal sites near New Plymouth, but high turbidity limits its distribution in these areas (R. Cole, NIWA, pers. comm. 2006). High abundances of sea urchins may be responsible for the absence of *E. radiata* from some locations, e.g. Abel Tasman and Nelson, as algal assemblages in these locations were dominated by *C. maschalocarpum* and *C. flexuosum*, two species that are considerably more resistant to grazing than *E. radiata* (Cole & Haggitt 2001). Low water temperatures may also play a role in excluding *E. radiata* from some parts of New Zealand. For example, while *E. radiata* has been reported in the Otago Harbour (Batham 1956) and observed on the outer coast at Karitane (J. Fyfe, DOC, pers. comm. 2006), it was not recorded in the Chalmers bioregion in this study. *Ecklonia radiata* does occur further south, at Stewart Island and the Snares Islands, but is absent from other more southern subantarctic islands (Nelson 1994). The close proximity of the Otago coast to the subtropical convergence means that water temperatures in this area are typically colder than those at Stewart Island and the Snares Islands (Heath 1985).

Some species exhibited clear Southern distributions. For example, *Macrocystis pyrifera*, which is associated with cooler water temperatures (Hay 1990), was found only at South Island locations and at one North Island site (Palmer Head, Wellington). Although *M. pyrifera* was not recorded at Otago Peninsula or Catlins sites, extensive forests are present north of Nugget Point where there is some protection from the large southerly swell (Fyfe 1992). *Durvillaea willana* was found only at Southern New Zealand locations, being most abundant at the Catlins, Otago Peninsula and some Paterson Inlet (West Head and Bob's Point) and Bluff (Pig Island and Tiwai Point) sites. Species such as *Lessonia variegata* and *Landsburgia quercifolia* tended to achieve greatest biomasses at Southern locations, but were also common at Cape Reinga and offshore islands in Northeastern. Both *Marginariella* species were important components in the Stewart Island and Cook bioregions and had clear differences in their depth distributions with *M. urvilliana* typically occurring in the shallow depth strata (< 2 m and 4–6 m), while *M. boryana* was more abundant in the deeper strata (7–9 m and 10–12 m).

In addition to biogeographic patterns in the distributions of key algal species, there was a general increase in macroalgal diversity with latitude. This pattern is the opposite of that described for reef fish in New Zealand, where the highest diversity occurs in the north (Francis 1996). Although the mechanism for this pattern in algal diversity is unknown, algal diversity was also strongly correlated with water clarity, where highly turbid sites typically had lower algal diversity. This pattern was clearly evident within some bioregions, e.g. offshore islands in the Northeastern bioregion had low turbidity and a relatively high algal diversity compared to coastal sites.

The dominant mobile macroinvertebrate species recorded in this study also exhibited clear biogeographic patterns between Northern and Southern locations. However, there was no clear bioregional separation of locations, as has been documented for macroalgal species composition (Shears et al. in press). This was largely owing to the lower number of species recorded, and the widespread distributions of most of the dominant species (e.g. *Evechinus chloroticus*, *Trochus viridis*, *Patriella* spp., *Cellana stellifera*). Herbivorous gastropods, predominantly *T. viridis*, *Cookia sulcata*, *Cantharidus purpureus*, *Cellana stellifera* and *Turbo smaragdus*, were more abundant in the Northern Province, whereas the starfishes *Patriella* spp., *Pentagonaster pulchellus*, *Diplodontias* spp. and the ophiuroid *Ophiopsammus maculata* were more common in the Southern Province. *Evechinus chloroticus* was found to be the dominant invertebrate grazer on shallow subtidal reefs throughout New Zealand, although it was rare along large stretches of coastline, e.g. the entire east and southeast coast from Gisborne to the Catlins, including the northern shore of Cook Strait. *Haliotis iris* was generally rare but was the most common large grazer at some sites at Cape Foulwind and Banks Peninsula North. Historically *H. iris* may have been more abundant and played a greater role in structuring algal assemblages in other areas prior to the commencement of commercial harvesting (e.g. Stewart Island).

## 4.2 NATIONAL PATTERNS IN COMMUNITY STRUCTURE

There was a high degree of variability in benthic community structure among bioregions, among sites within bioregions, and among depth ranges within sites. There were, however, some consistent patterns in community structure at the national and bioregional levels. Overall, leathery macrophytes were the dominant component of the shallow subtidal reefs examined in this study (68% of total biomass). The leathery macrophyte group was made up of large brown algal species which were the dominant structural component of reef communities at all locations, except for Buller and West Coast locations where smaller algal groups and encrusting invertebrates dominated (also see Shears 2007). As a result, the Buller and Westland bioregions provide a unique example of temperate reef systems where both large brown algae and macroinvertebrate grazers, such as sea urchins and paua, are rare.

The immediate subtidal (<2 m depth) in most bioregions (excluding Buller and Westland) was typical of temperate reef systems worldwide in that it was characterised by high densities and biomasses of fucalean algae (Schiel & Foster 1986; Underwood et al. 1991). In Northern locations, this habitat was dominated by *Carpophyllum maschalocarpum* and/or *C. angustifolium*, whereas in most Southern locations it was occupied by varying combinations of *Xiphophora gladiata*, *Durvillaea willana*, *Lessonia variegata*, *Marginariella urvilliana* or *Cystophora* spp. At some sites, the shallow band of large brown algae was absent, e.g. at inner-fiord sites where the shallow subtidal was dominated by mussels and an assemblage of ephemeral green and red algae. This is most likely because of the presence of a low-salinity layer of surface water that may directly inhibit the recruitment of large brown algae, as well as exclude predators and grazers, and therefore allow mussels to dominate (Witman & Grange 1998). The absence of large brown algae from the shallow subtidal in many West Coast locations may be due to extreme wave action. *Durvillaea antarctica* was patchily distributed on the intertidal-subtidal boundary in these areas and potentially acts to exclude other algae from the shallow subtidal through physical abrasion.

We found large variation in the organisation of algal assemblages with depth across most sites. The bimodal depth distribution of macroalgae previously described for northern New Zealand (Choat & Schiel 1982) was recorded at some Northeastern locations and exposed sites at Kapiti Island. In the Northeastern bioregion, this bimodality is thought to be a result of high abundances of *Evechinus chloroticus* reducing algal biomass at mid-depths, whereas fucaleans dominate the shallows and *Ecklonia radiata* forests occur at greater depths (Choat & Schiel 1982). A similar bimodal algal distribution has been recorded in Dusky Sound (Villouta et al. 2001) and was recorded in this study at a few Doubtful Sound sites, where *Evechinus chloroticus* was abundant at 4–6 m. However, at the majority of sites examined algal biomass was found to decline with depth. This may be due to several factors such as high abundances of *E. chloroticus* at greater depths (e.g. Gannet Rock, Abel Tasman and Nelson) or other factors, such as low light levels (high turbidity), high levels of sedimentation, sand abrasion and low levels of propagule supply, which may prevent the establishment of deeper algal stands (Schiel & Foster 1986). For example, high turbidity appears to restrict macroalgal forests to shallow depths at the Banks sites. At these sites *Ecklonia radiata* was

rare below 5 m and *C. flexuosum* occurred at low densities. This is in contrast to Schiel & Hickford (2001) who found high densities of *E. radiata* (13–15 plants per m<sup>2</sup>) at 9–12 m of depth at Godley Head in the early 1990s. Those authors also described mixed stands of *E. radiata*, *Landsburgia quercifolia*, *Lessonia variegata* and *Marginariella* spp. at c. 8 m depth for another site nearby (Taylors Mistake), which is in stark contrast to the patterns we observed. Schiel & Hickford (2001) commented that underwater visibility tended to be better at Banks Peninsula than at Kaikoura. However, we found the opposite pattern (average Secchi disc depth during the sampling period was c. 2.5 m at Banks Peninsula North compared with c. 6 m at Kaikoura). It is unknown whether these contrasting descriptions of algal assemblages for Banks Peninsula North represent site-level variation or long-term changes. In general, little is known about the temporal variability in subtidal algal assemblages around much of New Zealand, the mechanisms responsible for variation in community structure, and the factors that potentially restrict deeper water algal assemblages in many regions.

#### 4.3 ENVIRONMENTAL CORRELATES AND STRUCTURING PROCESSES

At the national and bioregional levels, both macroalgal and mobile macroinvertebrate communities were most strongly related to turbidity (Secchi depth) and/or wave exposure (fetch). The largest variation in community structure among sites was associated with a gradient from turbid, more coastally influenced locations, to more oceanic locations with clearer water, rather than any clear latitudinal gradient. The importance of the environmental variables also increased with decreasing spatial scale, such that they explained greater variation at the bioregional level for all datasets. However, the variable that explained the greatest variation in community structure differed among bioregions. This was largely associated with the types of gradients sampled within each bioregion and how environmental variables covaried across them. For example, at the Northeastern bioregion locations, water clarity was generally lowest at the sheltered coastal sites and increased with increasing wave exposure. However, at the offshore island locations the water was clear at both sheltered and exposed sites. Furthermore, the reefs at the turbid coastal sites extended to only c. 5 m depth, whereas at the offshore islands the reefs extended beyond 12 m of depth, even at the most sheltered sites. As a result, the maximum depth sampled (MaxDepth) and turbidity (Secchi) explained the greatest variation in algal community structure among Northeastern sites and the wave exposure estimates had less explanatory power. Similar patterns were seen in the Abel bioregion where the ‘exposed-offshore’ group included both exposed and sheltered sites from Kapiti Island and wave exposure explained only 7% of the variation across all sites. While the relationships between community structure and environmental variables reflect differences in the environmental gradients sampled among sites within each bioregion, they also provide insights into the potentially important physical factors controlling community structure.

Water clarity (Secchi depth) was consistently one of the environmental variables that explained the most variation in each of the datasets examined at all spatial scales. This was particularly apparent for bioregions or locations where sites

spanned an onshore-offshore gradient, e.g. many west coast locations. The majority of the inshore sites sampled on the west coast (e.g. Raglan, Buller and Westland) were highly turbid, had shallow (< 10 m) reefs and had a high degree of sediment resuspension and abrasion associated with the high wave action. At these sites, large brown algae were largely restricted to a shallow subtidal fringe and the deeper subtidal communities were dominated by short turfing algae and sessile invertebrates such as mussels, sponges and ascidians. It is hypothesised that large brown algae are restricted to shallow depths at these coastal sites by a combination of high water motion, sandscour and high turbidity. In contrast, offshore sites had clearer water, more expansive subtidal reefs that extend into deeper water (e.g. Open Bay Islands, Gannet Rock, Sugarloaf Island at New Plymouth), less sediment and more extensive macroalgal habitats. However, sea urchins were also more abundant at these sites, compared with inshore sites, and appeared to play a role in excluding macroalgae from deep water in these environments.

In bioregions where the sites were not located across a strong turbidity gradient, wave exposure (fetch) was most strongly related to community structure, e.g. Stewart Island. In these cases, groupings of sites corresponded to broad differences in wave exposure and the relative abundance of different species varied across these gradients. For example, *Carpophyllum flexuosum* was consistently dominant at the most sheltered sites within some bioregions (e.g. Northeastern and Banks), whereas species such as *Ecklonia radiata*, *Macrocystis pyrifera* and/or *Marginariella boryana* were more typical of moderately exposed sites (e.g. those at Banks and Stewart Island), and species such as *Lessonia variegata*, *Landsburgia quercifolia* and/or *Durvillaea willana* were most typical of highly exposed sites (e.g. those at Chalmers, Stewart Island and Cook). There were, however, numerous exceptions to these general patterns; e.g. *C. flexuosum* was abundant at exposed outer-fiord sites, and also on exposed reefs at Gisborne. These findings demonstrate strong couplings between the environmental variables measured and community structure at a variety of scales, but also highlight the complex and co-varying nature of these relationships and the need for research into the mechanisms responsible for the observed patterns.

#### 4.4 THE ROLE OF SEA URCHINS

The urchin barrens habitat is generally considered to be a feature of subtidal reefs in northern parts of New Zealand (Schiel 1990), although several studies suggest urchins have important effects on algal assemblages in southern regions, e.g. Abel Tasman (Davidson & Chadderton 1994), Kaikoura (Dix 1969) and Fiordland (Villouta et al. 2001). In the present study, *Evechinus chloroticus* was abundant in Northeastern locations; however, it was also found to be abundant and to form urchin barrens habitat at numerous other locations throughout New Zealand. These locations included contrasting environments, from relatively wave-protected coastal embayments (e.g. Paterson Inlet, Nelson, Long Island, Abel Tasman and sites in Fiordland) to exposed offshore islands on the west coast (e.g. Open Bay Island, Gannet Rock and the Sugarloaf Islands at New Plymouth). At the national level, *Evechinus* explained only 4% of the variation in algal community structure, but explained up to 17% (Stewart Island) at the bioregional

level. Overall the low variation at these spatial scales is not surprising as the analysis was carried out on depth-averaged algal biomass data and the effects of grazing by *E. chloroticus* are generally restricted to specific depth ranges (Shears & Babcock 2004a).

There was large variation in the relationship between *E. chloroticus* abundance and environmental variables among bioregions. At the national level, *E. chloroticus* was most strongly related to water clarity (Secchi) and was rare at the most turbid locations (e.g. Long Bay, Raglan, Gisborne, Karamea, Cape Foulwind, Banks Peninsula North, Flea Bay and the Catlins), and abundant at locations with high water clarity (e.g. Gannet Rock, Poor Knights Islands, Mokohinau Islands and Tuhua Islands). These patterns were most evident in bioregions where sites were located across an onshore–offshore gradient, e.g. those in Northeastern, Raglan, Buller and Westland bioregions. In all cases, offshore islands with higher water clarity supported greater abundances of urchins. The estimate of water clarity used in this study, however, was based on a one-off field measurement of Secchi depth and it is proposed that better information on national patterns in ambient turbidity (suspended sediment) would explain a higher proportion of the variation in the abundance of *E. chloroticus*. A potential mechanism excluding *E. chloroticus* from turbid areas is the adverse effect of suspended sediments on larval survival (Phillips & Shima 2006), settlement success and the survival of juvenile *E. chloroticus* (Walker 2007). The percentage cover of sediment on the reef, however, was not a good predictor of the abundance of *E. chloroticus* at a national scale and, in some bioregions, *E. chloroticus* was actually positively associated with sediment cover (e.g. Paterson Inlet, Nelson and Long Island).

*Evechinus chloroticus* exhibited contrasting relationships with wave exposure among bioregions. In the Northeastern bioregion, *E. chloroticus* was generally positively associated with wave exposure, although the species was rare at the most exposed sites at Cape Reinga. However, as mentioned above this wave-exposure gradient also corresponded to a gradient in water clarity from turbid sheltered coastal sites where *E. chloroticus* was rare to exposed and offshore island locations that have clear water and abundant *E. chloroticus* (Grace 1983; Shears & Babcock 2004b). In the Abel and Stewart Island bioregions, however, this pattern in the abundance of *E. chloroticus* was reversed, with the species being abundant at sheltered sites (e.g. Paterson Inlet, Long Island, Nelson and Abel Tasman) and rare at more exposed open coast sites (e.g. Titi Islands, and exposed Kapiti Island and Long Island sites). However, water clarity at these sheltered sites was considerably higher (Secchi depth 5–10 m) than at sheltered Northeastern sites and did not appear to limit the distribution of *E. chloroticus*.

The apparent decline in the abundance of *E. chloroticus* with increasing exposure at sites in the Abel and Stewart Island bioregions is consistent with increasing wave action preventing the species from overgrazing, as has been suggested for the most exposed locations in the Northeastern bioregion (e.g. Cape Reinga; Shears & Babcock 2004b). However, exposed sites at Titi Islands, Kapiti and Long Island had only moderately high wind fetch values. In other parts of New Zealand, *E. chloroticus* is abundant at sites with similar or even higher wave-exposure estimates (e.g. Gannet Rock, New Plymouth and some Northeastern sites). Furthermore, algal assemblages at these sites suggested they are not subjected to extreme wave action. For example, at ‘exposed-offshore’ sites at Long Island, *C. flexuosum* plants were tall (total length > 1 m) and exhibited a

sheltered morphology (Cole et al. 2001). Similarly, on the western side of Kapiti Island, *Ecklonia radiata* occurred at high biomasses at shallow depths suggesting these sites were not exposed to large swell waves. These observations suggest that other mechanisms are excluding *Evechinus chloroticus* from these sites. Individual *E. chloroticus* at these sites were also large (> 100 mm TD), present at the bottom of the reef (10–12 m), and juveniles were rare, suggesting low recruitment into these habitats. In Doubtful Sound, Wing et al. (2003) suggest that low settlement of *E. chloroticus* at the entrance of the fiord is due to the loss of larvae to the open ocean. Furthermore, in such situations where kelp dominates, negative feedback effects may further reduce settlement and prevent the species from establishing in these areas (Andrew & Choat 1985; Rowley 1990; Konar & Estes 2003). The high abundances of both adults and juveniles in the relatively sheltered embayment locations (e.g. Paterson Inlet, Long Island, Nelson and Abel Tasman) may result from a high retention of larvae owing to high residence times and stratification of the water column in summer. This has been shown to occur in Doubtful Sound, where the greatest abundance and settlement of *E. chloroticus* occur at mid-fiord sites (Wing et al. 2003). More research into urchin recruitment and larval urchin dispersal is needed to better understand the distribution patterns of urchins and the occurrence of urchin barrens habitat.

#### 4.5 CONSERVATION AND MANAGEMENT IMPLICATIONS

With increased awareness of the potential effects of land-based activities on coastal ecosystems, there is a growing literature in New Zealand on the effects of various components of sedimentation on reef-associated species (e.g. Phillips & Shima 2006; Schiel et al. 2006; Steger & Gardner 2007; Walker 2007). All of these studies show negative effects of sediment on survival, settlement or metabolic rates of different life history stages. High turbidity is generally associated with high levels of sedimentation and we found that turbidity (Secchi) was consistently important in explaining variation in algal community structure among sites at all spatial scales examined. While this suggests that sedimentation may play a fundamental role in structuring New Zealand's reef communities, it is important to note that gradients in water clarity and, potentially sedimentation, may largely be natural (e.g. coastal-offshore), with certain parts of the New Zealand coast naturally having larger sediment inputs (Carter 1975) and higher turbidity, e.g. Portland, Banks and locations on the West Coast. Furthermore, while such areas of high turbidity had distinctive attributes or community structures, we demonstrate complex associations between water clarity and a variety of other physical (wave exposure) and, potentially biological processes (phytoplankton productivity). Identifying the actual mechanisms responsible for these patterns and separating anthropogenic from environmental variation is necessary to inform management and remains the challenge to ecologists.

The effects of fishing are also likely to have influenced the patterns in algal and invertebrate communities described in this study both directly and indirectly. For example, the low numbers of paua recorded throughout the country are likely to be a direct result of overfishing of this species. In contrast, the prevalence



of *Evechinus chloroticus* in many areas may be an indirect effect of overfishing of sea urchin predators. Such effects have been shown through comparisons of marine reserves and fished sites in parts of Northeastern (Babcock et al. 1999; Shears & Babcock 2002, 2003), but these trophic cascade effects have not been demonstrated in other parts of the country (Shears & Babcock 2004a). However, the establishment of networks of marine reserves throughout the country, and continued monitoring of existing reserves, will allow broader generalisations about where these effects occur. While trophic cascade effects are likely to occur following the recovery of predator populations in areas where *E. chloroticus* is abundant, in parts of the coastline where urchins are not common more subtle and potentially more complex interactions may occur as a result of the cessation of fishing.

The biogeographic classification for mainland New Zealand based on the dataset analysed here (Shears et al. in press) provides a large-scale spatial framework for further ecological study and systematic conservation planning. The description of 11 major bioregions has important implications for any conservation effort that aims to protect New Zealand's coastal marine biodiversity through the establishment and management of a comprehensive system of adequate and representative marine reserves (Day et al. 2002). The analyses and descriptions in the present report demonstrate how the structure of algal and invertebrate assemblages on shallow reefs vary greatly across environmental gradients within bioregions. It is important that this variation is represented in the design of no-take marine reserve networks within bioregions. Although we were only able to sample large environmental gradients in a few bioregions, similar variation in community structure is expected to occur in all bioregions should such gradients exist.

## 5. Conclusions

This study provides the first quantitative description of subtidal habitats for many of the areas examined. Both national and regional patterns in community structure, and their associations with environmental variables, were complex and multidimensional largely owing to the highly complex nature of the New Zealand coast and the inter-related nature of the environmental variables examined. However, some general relationships between biological pattern and environmental variables were apparent. Firstly, the proportion of variation explained by a local-scale environmental variable tended to increase with decreasing spatial scale for all biological datasets. The structure of algal and benthic communities was most strongly associated with water clarity, suggesting that community structure varies most strongly across a gradient from coastally influenced sites (e.g. shallow areas or embayments) with high turbidity to more oceanically influenced locations (e.g. offshore islands). The effect of wave exposure did not vary consistently across these gradients and water clarity was a better predictor of community structure and species composition.

The abundance of *Evechinus chloroticus*, the dominant invertebrate grazer, also varied considerably around New Zealand. The environmental variables that were found to be correlated with the abundance of *E. chloroticus* varied among bioregions, and the species was found to be abundant in contrasting environments, demonstrating a complex association with environmental conditions. Water clarity explained the greatest variation in the abundance of *E. chloroticus*, its abundance being low in highly turbid areas (e.g. southeastern coast). While there is much we still need to understand about the processes driving variability at the local and regional level, we can see similarities in the relationships between environmental factors and marine community structure around the entire country.

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# Appendix 1

## DETAILS OF SAMPLING LOCATIONS AND SITES

LOCATION	SITE	EASTING	NORTHING	DATE
<b>Northeastern</b>				
Cape Karikari	Takini South	2549612	6708196	7/10/1999
Cape Karikari	CK4	2552073	6704156	8/10/1999
Cape Karikari	Koware South	2552750	6704345	8/10/1999
Cape Karikari	Whale	2545848	6712376	9/10/1999
Cape Karikari	Whangatupere	2551761	6707401	9/10/1999
Cape Karikari	Omahuri	2548866	6708787	10/10/1999
Cape Karikari	Pihoaka Point	2551727	6708248	10/10/1999
Cape Karikari	Sunburn Point	2548292	6711752	10/10/1999
Cape Reinga	Lighthouse	2481893	6753367	11/10/1999
Cape Reinga	Tapotupotu	2486322	6751851	11/10/1999
Hahei	Cooks Bluff	2757571	6483105	10/05/1999
Hahei	Sandy Cove	2758899	6482610	10/05/1999
Hahei	SE Motueka	2760416	6482908	11/05/1999
Hahei	Twin gauge	2762066	6481777	11/05/1999
Hahei	Mahurangi Pinn	2761755	6481256	12/05/1999
Hahei	Whitecaves	2761731	6479881	12/05/1999
Hahei	Mussell Rock	2756861	6482939	13/05/1999
Hahei	Razor	2760471	6483166	13/05/1999
Hahei	Mahungarape	2755919	6486296	14/05/1999
Hahei	Whitecliffs	2758466	6482784	1/05/2000
Leigh	ABC	2671853	6546767	16/12/1998
Leigh	Nordic	2673093	6543630	15/03/1999
Leigh	Rodney	2674176	6545146	15/3/1999
Leigh	Kemps	2669136	6547458	16/03/1999
Leigh	Onespot	2673503	6545795	16/03/1999
Leigh	Mathesons	2672272	6542562	17/03/1999
Leigh	Ti Point	2672136	6540956	17/03/1999
Leigh	Outpost	2673923	6544131	18/03/1999
Leigh	Schiels	2671943	6546990	23/03/1999
Leigh	Tower	2672527	6546361	24/03/1999
Leigh	Martins rock	2670741	6546565	4/05/1999
Leigh	Okakari Point	2669323	6547541	4/05/1999
Leigh	TeRere	2670114	6546945	4/05/1999
Leigh	Cape Rodney	2674152	6545535	25/05/1999
Leigh	Waterfall	2672183	6546526	25/05/1999
Long Bay	DOC sign	2667199	6499909	13/04/1999
Long Bay	Skull Rock	2667364	6499835	13/04/1999
Long Bay	Wet Rock	2666661	6501912	13/04/1999
Long Bay	Mushrooms	2667662	6498879	14/04/1999
Long Bay	Outer Tor	2667497	6498445	14/04/1999
Long Bay	Hot tub	2668514	6505648	15/04/1999
Long Bay	Matakatia	2668858	6506334	15/04/1999
Long Bay	Ritch Reef	2668964	6506036	15/04/1999
Long Bay	N-sign	2666782	6501120	12/09/1999

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Appendix 1—continued

LOCATION	SITE	EASTING	NORTHING	DATE
Long Bay	Pines	2666811	6502553	12/09/1999
Mokohinau Islands	Lizard	2701371	6585652	1/06/1999
Mokohinau Islands	Dragon	2700547	6585296	2/06/1999
Mokohinau Islands	PinnSth	2699726	6584844	2/06/1999
Mokohinau Islands	Sentinel	2700385	6584921	2/06/1999
Mokohinau Islands	Arches	2700220	6585467	3/06/1999
Mokohinau Islands	Pudding	2700557	6586008	3/06/1999
Mokohinau Islands	SW Bay	2700666	6585531	3/06/1999
Mokohinau Islands	House Bay	2701287	6586216	4/06/1999
Mokohinau Islands	Light Point	2701840	6586156	6/07/1999
Poor Knights Islands	Cleanerfish	2668059	6636866	8/06/1999
Poor Knights Islands	Skull Bay	2668289	6636118	8/06/1999
Poor Knights Islands	Frasers	2669024	6633668	9/06/1999
Poor Knights Islands	Labrid	2668543	6633083	9/06/1999
Poor Knights Islands	Rock Lilly Cove	2668741	6636787	9/06/1999
Poor Knights Islands	Bartels' Bay	2668554	6634747	10/06/1999
Poor Knights Islands	Light Bay	2668637	6637499	10/06/1999
Poor Knights Islands	Matt's Crack	2668846	6634467	10/06/1999
Poor Knights Islands	Nursery	2668452	6634558	11/06/1999
Tawharanui	Takatu	2677683	6535969	19/04/1999
Tawharanui	Twin Peaks	2678018	6535722	19/04/1999
Tawharanui	Pinnacle	2677435	6535904	20/04/1999
Tawharanui	T-Cave	2678192	6535511	20/04/1999
Tawharanui	Karamuroa	2672542	6537667	21/04/1999
Tawharanui	P-Point	2673550	6536649	21/04/1999
Tawharanui	Iguana	2677210	6535671	22/04/1999
Tawharanui	Mid-Point	2676710	6535623	22/04/1999
Tawharanui	Comet	2674920	6535612	3/05/1999
Tawharanui	North Cove	2676045	6535619	3/05/1999
Tuhua Island	Turanganui	2800918	6431404	15/03/2000
Tuhua Island	Awatukoro Point	2796796	6430789	16/03/2000
Tuhua Island	Hurihurihunga	2799367	6431942	16/03/2000
Tuhua Island	Maorichief	2798268	6431898	16/03/2000
Tuhua Island	Bait Pond	2797426	6431457	17/-3/2000
Tuhua Island	Okawa	2800838	6430305	17/03/2000
Tuhua Island	Hot Springs	2800658	6431789	18/03/2000
Tuhua Island	Te Roto	2800658	6429485	18/03/2000
<b>Portland</b>				
Gisborne	Pouawa South	2963647	6274453	16/01/2002
Gisborne	Baldy Reef	2961200	6272250	17/01/2002
Gisborne	Makorori	2958008	6269378	17/01/2002
Gisborne	Pouawa North	2963796	6274642	17/01/2002
Mahia	Black Reef	2928393	6206527	18/06/2002
Mahia	Portland South	2929760	6198616	18/06/2002
<b>Raglan</b>				
Gannet Rock	Gannets leap	2647833	6357898	22/03/2001
Gannet Rock	SE Bay	2647813	6357785	22/03/2001
New Plymouth	Seal East	2596933	6238202	18/12/2000
New Plymouth	Lion W	2598866	6238943	19/12/2000

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Appendix 1—continued

LOCATION	SITE	EASTING	NORTHING	DATE
New Plymouth	Saddleback SW	2597835	6239366	19/12/2000
New Plymouth	Seal West	2596816	6238252	19/12/2000
New Plymouth	Moa Bay	2599112	6239076	20/12/2000
New Plymouth	Shilling Rock	2597679	6237742	20/12/2000
Raglan	Raglan Island	2665705	6372184	23/03/2001
Raglan	Redline Rock	2664760	6369665	23/03/2001
Raglan	Taranaki Point	2666602	6357875	23/03/2001
<b>Cook</b>				
Kaikoura	9Pin	2568050	5866257	7/12/1999
Kaikoura	Homestead	2569415	5865337	8/12/1999
Kaikoura	Seal Reef	2569415	5864996	9/12/1999
Kaikoura	Baxters	2566040	5863924	12/12/1999
Kaikoura	Shark tooth	2567680	5863289	12/12/1999
Kaikoura	Lastone	2567234	5863346	13/12/1999
Wellington	3Peak	2658417	5982512	11/08/1999
Wellington	Durv Rocks	2658148	5982551	11/09/1999
Wellington	Sirens	2657483	5982639	11/09/1999
Wellington	Moa Point	2661443	5982971	11/10/1999
Wellington	Shark fin	2659940	5982726	11/10/1999
Wellington	Palmer	2662396	5983050	11/11/1999
<b>Abel</b>				
Abel Tasman	Foul Point	2515324	6033097	30/11/1999
Abel Tasman	Seal Colony	2515763	6035029	30/11/1999
Abel Tasman	Wharf Rock	2515494	6036413	30/11/1999
Abel Tasman	Isol Rock	2511057	6044518	1/12/1999
Abel Tasman	Nthn Boundary	2513845	6039465	1/12/1999
Abel Tasman	Separation Point	2509748	6047167	1/12/1999
Abel Tasman	Abel Head	2514836	6038883	2/12/1999
Abel Tasman	FG Rock	2515200	6037996	2/12/1999
Abel Tasman	Pinnacle Island	2515568	6030807	2/12/1999
Abel Tasman	Pitt Island	2515648	6028741	3/12/1999
Kapiti Island	Aropawaiti East	2672338	6040876	8/12/2000
Kapiti Island	Onepoto Bay	2671952	6040573	8/12/2000
Kapiti Island	Ulva Rock	2670003	6037336	8/12/2000
Kapiti Island	Tokahaki	2673377	6041217	9/12/2000
Kapiti Island	South West Point	2669541	6033916	10/12/2000
Kapiti Island	Te Rere Stream	2673278	6038374	10/12/2000
Long Island	Nob Rock	2618257	6009413	16/11/1999
Long Island	Thresher Point	2616432	6007500	16/11/1999
Long Island	Bluemine	2614507	6002125	17/11/1999
Long Island	Te Ruatarore	2614687	6008622	17/11/1999
Long Island	Landing	2619057	6010010	18/11/1999
Long Island	Ship Cove	2614745	6012282	18/11/1999
Long Island	South Beach	2616600	6007974	18/11/1999
Long Island	Motuara Island	2617543	6012835	19/11/1999
Long Island	Sleeping Man	2617956	6009865	19/11/1999
Long Island	Twin Cave	2619136	6010290	19/11/1999
Long Island	Cooper Point	2620483	6009053	20/11/1999
Long Island	Kotukutuku	2619512	6008099	20/11/1999

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Appendix 1—continued

LOCATION	SITE	EASTING	NORTHING	DATE
Nelson	NE Beach	2544697	6006050	23/11/1999
Nelson	Pepin Cave	2544497	6007303	23/11/1999
Nelson	Cable NW	2543877	6005684	23/11/1999
Nelson	Goat Rock	2543610	6005362	24/11/1999
Nelson	Hoop	2540206	6002479	25/11/1999
Nelson	Pine/Sign	2540472	6002889	25/11/1999
Nelson	Summit	2541769	6003909	25/11/1999
Nelson	BB House	2539818	6002257	26/11/1999
Nelson	Maheipuku	2544963	6007990	26/11/1999
<b>Banks</b>				
Banks Peninsula North	Godley North	2493891	5736235	18/01/2000
Banks Peninsula North	Lubchenco	2493316	5736088	18/01/2000
Banks Peninsula North	Little Akaloa	2511739	5728539	25/02/2000
Flea Bay	Flea East	2510793	5703958	23/02/2000
Flea Bay	Outer West	2511002	5703426	23/02/2000
Flea Bay	Rockpool Point	2510731	5703669	23/02/2000
Flea Bay	Hectors Wall	2511360	5703579	24/02/2000
Flea Bay	Tern Rock	2511478	5703134	24/02/2000
<b>Chalmers</b>				
Catlins	False Islet	2260635	5409277	12/02/2000
Catlins	Hole Point	2261955	5410586	12/02/2000
Catlins	Tuhawaiki Island	2257416	5406373	12/02/2000
Otago Peninsula	Cape Saunders	2333964	5478632	19/02/2000
Otago Peninsula	Puddingstone	2335078	5479650	19/02/2000
Otago Peninsula	Sandymount	2330190	5476635	20/02/2000
<b>Buller</b>				
Cape Foulwind	Fishing Rod reef	2383024	5941736	24/02/2001
Cape Foulwind	Granite spot	2381671	5938138	24/02/2001
Cape Foulwind	South Seal Rocks	2382840	5940581	24/02/2001
Cape Foulwind	North Granite	2381700	5938290	27/02/2001
Karamea	Falls Creek	2428497	5976797	25/02/2001
Karamea	Kongahu Point	2425899	5973459	25/02/2001
Karamea	Little Wanganui	2430778	5979244	25/02/2001
<b>Westland</b>				
Barn	Barn Island	2134236	5669941	21/02/2001
Barn	Brown Island	2130224	5663309	9/12/2003
Barn	Gorge Island	2125321	5658550	9/12/2003
Big Bay	Penguin Inner	2116300	5642142	8/12/2003
Big Bay	Penguin Rocks	2115697	5642167	8/12/2003
Big Bay	Crayfish Rock	2119708	5646604	12/12/2000
Cascades	Cascade Island	2141018	5679231	21/02/2001
Cascades	Cement Face	2143307	5678981	21/02/2001
Cascades	Cascade Point	2138476	5678640	9/12/2003
Jackson Head	Frog Rocks	2155031	5683225	20/02/2001

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Appendix 1—continued

LOCATION	SITE	EASTING	NORTHING	DATE
Jackson Head	Moccasin Gap	2157047	5684270	20/02/2001
Jackson Head	Smoothwater Point	2156495	5684352	20/02/2001
Jackson Head	Jackson Bluff	2158886	5684454	12/12/2003
Jackson Head	Jackson Head	2158984	5685079	12/12/2003
Moeraki	Arnott Point	2204776	5714279	10/12/2003
Moeraki	Moeraki River	2208106	5716501	10/12/2003
Moeraki	Whakapoai	2206988	5715906	11/12/2003
Open Bay Islands	NE Taumaka	2179646	5697156	22/02/2001
Open Bay Islands	SW Popotai	2178539	5696721	22/02/2001
Open Bay Islands	NW Taumaka	2179505	5697478	11/12/2003
<b>Fiordland</b>				
Bligh Sound	Bligh OW	2071295	5589037	25/01/1999
Bligh Sound	Franzinner	2077508	5583660	25/01/2000
Bligh Sound	Chasland Head	2072478	5589151	25/01/2000
Bligh Sound	Turnaround Point	2078109	5586225	25/01/2000
Bligh Sound	Bligh IW	2075802	5583017	26/01/2000
Bligh Sound	Bligh ME	2078872	5586425	26/01/2000
Bligh Sound	Bligh ON	2074630	5591877	26/01/2000
Charles Sound	Charles inner	2048460	5551129	23/01/2000
Charles Sound	Charles outer	2045293	5554418	23/01/2000
Doubtful Sound	Hubs Spur	2029146	5533804	21/01/2000
Doubtful Sound	Hut Bay	2036333	5528325	21/01/2000
Doubtful Sound	Joseph Point	2037307	5525670	21/01/2000
Doubtful Sound	Jamieson	2030626	5528830	22/01/2000
Doubtful Sound	Renown Rock	2037523	5527670	22/01/2000
Doubtful Sound	Sail Rock	2032513	5530768	22/01/2000
Preservation Inlet	Sandfly Point	2017127	5437298	16/03/2005
Preservation Inlet	Weka Point	2020786	5438548	16/03/2005
<b>Stewart Island</b>				
Bluff	Oraka Pt	2114848	5411531	22/03/2005
Bluff	Pig Island	2123913	5410486	22/03/2005
Bluff	Barracouta Point	2147406	5392227	23/03/2005
Bluff	Lookout Point	2152629	5387851	23/03/2005
Bluff	Shag Rock	2144141	5395393	23/03/2005
Bluff	Stirling Point	2154032	5388640	24/03/2005
Bluff	Tiwai Point	2155425	5390468	24/03/2005
Codfish-Ruggedy	Codfish Southeast	2102422	5367193	14/03/2005
Codfish-Ruggedy	Ruggedy Passage	2105692	5376044	14/03/2005
Codfish-Ruggedy	Codfish East	2102363	5368359	17/03/2005
Codfish-Ruggedy	North Sealers	2100414	5370663	17/03/2005
Codfish-Ruggedy	Ruggedy NE	2106226	5376207	17/03/2005
Codfish-Ruggedy	Black Rock Point	2117548	5379304	18/03/2005
Codfish-Ruggedy	Lucky Point	2123254	5377092	18/03/2005
Green Islets	Archway	2033766	5425664	15/03/2005
Green Islets	NW Bay	2031101	5424077	15/03/2005
Green Islets	Prices Point	2041905	5424702	15/03/2005
Paterson Inlet	Octopus	2139273	5353661	31/01/2000
Paterson Inlet	Refuge Island	2138857	5351088	31/01/2000
Paterson Inlet	Neck North	2142802	5353784	1/02/2000

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*Appendix 1—continued*

LOCATION	SITE	EASTING	NORTHING	DATE
Paterson Inlet	Balancing Rock	2137416	5353010	1/02/2000
Paterson Inlet	Ulva East	2140838	5352512	1/02/2000
Paterson Inlet	Ackers Point	2140868	5356773	2/02/2000
Paterson Inlet	Native North	2141284	5354940	2/02/2000
Paterson Inlet	Iona South	2138244	5355536	2/02/2000
Paterson Inlet	Horseshoe	2139545	5359778	7/02/2000
Paterson Inlet	Tamihou Island	2137091	5352726	19/03/2005
Paterson Inlet	Ulva East2	2140763	5352545	19/03/2005
Paterson Inlet	Bobs Point	2138192	5361525	21/03/2005
Paterson Inlet	West Head	2135454	5363772	21/03/2005
Port Adventure	Browns Garden	2144760	5338590	12/03/2005
Port Adventure	Lords River Head	2140594	5332620	13/03/2005
Port Adventure	Owens Island	2142866	5331715	13/03/2005
Port Adventure	Tia Island	2146867	5337926	13/03/2005
Ruapuke Island	Bird Rock	2159992	5372755	20/03/2005
Ruapuke Island	Caroline Bay	2165302	5374494	20/03/2005
Ruapuke Island	North Head	2167810	5376729	20/03/2005
Ruapuke Island	South Islets	2166573	5368849	20/03/2005
Titi Islands	Edwards	2144826	5364838	3/02/2000
Titi Islands	Herekopere	2146140	5360395	3/02/2000
Titi Islands	Bench Nth	2147096	5356879	4/02/2000
Titi Islands	Bench SE Point	2147989	5355765	4/02/2000