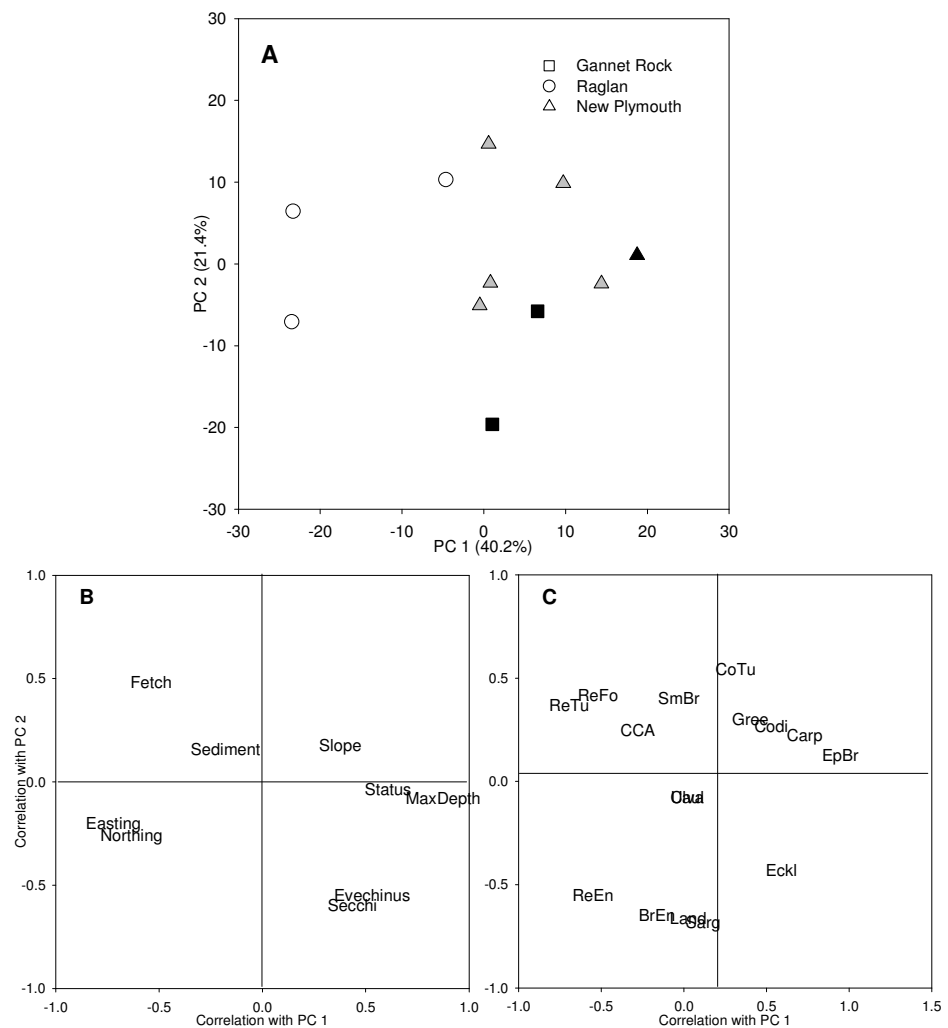


*lucida* and *Plocamium* spp. The substratum was dominated by crustose coralline algae at both locations and the percentage cover of sediment increased with depth (Fig. 15C). Few mobile macroinvertebrates were recorded at both locations (Fig. 15B), with only low numbers of *Haliotis australis*, *Cantharidus purpureus*, *Cookia sulcata*, *Trochus viridis* and *Modelia granosa* being present. *Haliotis iris* was not recorded at the sites surveyed.

### 3.4.3 Raglan bioregion

Algal communities at all Raglan, Gannet Rock and New Plymouth sites were characterised by a shallow band of *Carpophyllum maschalocarpum* and a general lack of deeper macroalgal forests. These sites were divided into three groups at the 65% similarity level: Raglan sites, offshore island sites (including both Gannet Rock sites and one site from New Plymouth (Seal East)), and the remaining New Plymouth sites (Fig. 16A). These groupings generally reflected the large-scale differences in environmental conditions among the three locations. Raglan sites were located on the mainland coast, had shallow reefs (maximum depth of c. 6 m) that were highly exposed and were turbid, whereas Gannet Rock is located c. 28 km offshore, has steep, sloping reefs and is bathed in clear oceanic water. New Plymouth sites were somewhat intermediate along this onshore-offshore gradient, being located on

Figure 16. Principal coordinates analysis of sites sampled in the Raglan 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 65% similarity level.



rockstacks located 1–2 km offshore. The associated gradient in algal community structure was reflected by strong correlations between Fetch, Secchi and MaxDepth, and PC1 (Fig. 16B). Algal species variables that were strongly correlated with PC1 include red turf and red foliose algae, which dominated Raglan sites, and *Carpophyllum maschalocarpum* and ephemeral brown algae (e.g. *Glossophora kunthii* and *Dictyota* spp.), which were more common at New Plymouth sites (Fig. 16C). The abundance of *Evechinus chloroticus* was low at coastal sites and high at offshore sites. PC2 also reflected a gradient from coastal (Raglan) to offshore locations (Gannet Rock). *Ecklonia radiata*, *Landsburgia quercifolia* and *Sargassum sinclairii* were more common at Gannet Rock (Appendix 5) and negatively correlated with PC2.

### **Raglan**

The shallow reefs at Raglan were relatively devoid of large brown algae except for small amounts of *Carpophyllum maschalocarpum* interspersed with red foliose algae (*Pterocladia lucida*, *Osmundaria colensoi* and *Melanthalia abscissa*) in the shallow stratum (Fig. 17A). *Zonaria* spp. and *Endarachne binghamiae* were also common (Appendix 5). At 4–6 m crustose coralline, red foliose and red turfing algae dominated and there was a relatively high percentage cover of sponges, bryozoans, mussels (*Xenostrobus pulex*, *Perna canaliculus*), bare rock and sediment (Fig. 17C). The red algal species *Gymnogongrus humilis* and *Lophurella hookeriana* were also present. Mobile macroinvertebrates such as *Evechinus chloroticus* and *Haliotis iris* occurred in low numbers, but the starfish *Stichaster australis* was relatively abundant (Fig. 17B).

### **Gannet Rock**

The two sites sampled at Gannet Rock were located on the eastern side and somewhat protected from large breaking southwesterly swells. *Evechinus chloroticus* was extremely abundant at both Gannet Rock sites (Fig. 17A), and occurred to depths greater than 25 m. *Carpophyllum maschalocarpum* was restricted to depths less than 4 m; crustose coralline algae dominated below this (Fig. 17A, C). Low numbers of *Landsburgia quercifolia* (not presented, Appendix 5) and *Ecklonia radiata* occurred amongst the *C. maschalocarpum*, along with *Osmundaria colensoi*, *Pterocladia lucida*, *Pterocladia capillacea* and *Melanthalia abscissa*. On the exposed side of Gannet Rock, *C. maschalocarpum* and *Landsburgia quercifolia* extended to depths of c. 9 m before giving way to urchin barrens (NS, pers. obs.). *Cookia sulcata* and *Dicathais orbita* were common at all depths (Fig. 17B).

### **New Plymouth**

The shallow band of *Carpophyllum maschalocarpum* extended to depths of 3–4 m, beyond which large brown algae were rare (Fig. 17A). Sea urchins were abundant at 4–6 m, and declined with depth. Crustose coralline algae were the dominant substratum cover but also declined with depth (Fig. 17C). At depths greater than 5 m there was a relatively high percentage cover of sediment, turfing algae, sponges, bryozoans and ascidians. The small cup coral *Culicia rubeola* was also common (c. 2% cover per m<sup>2</sup>) at 7–12 m. The Seal East site was grouped separately (with Gannet Rock sites), the main differences being the occurrence of low numbers of small *Ecklonia radiata* in deeper areas (> 11 m) and the high

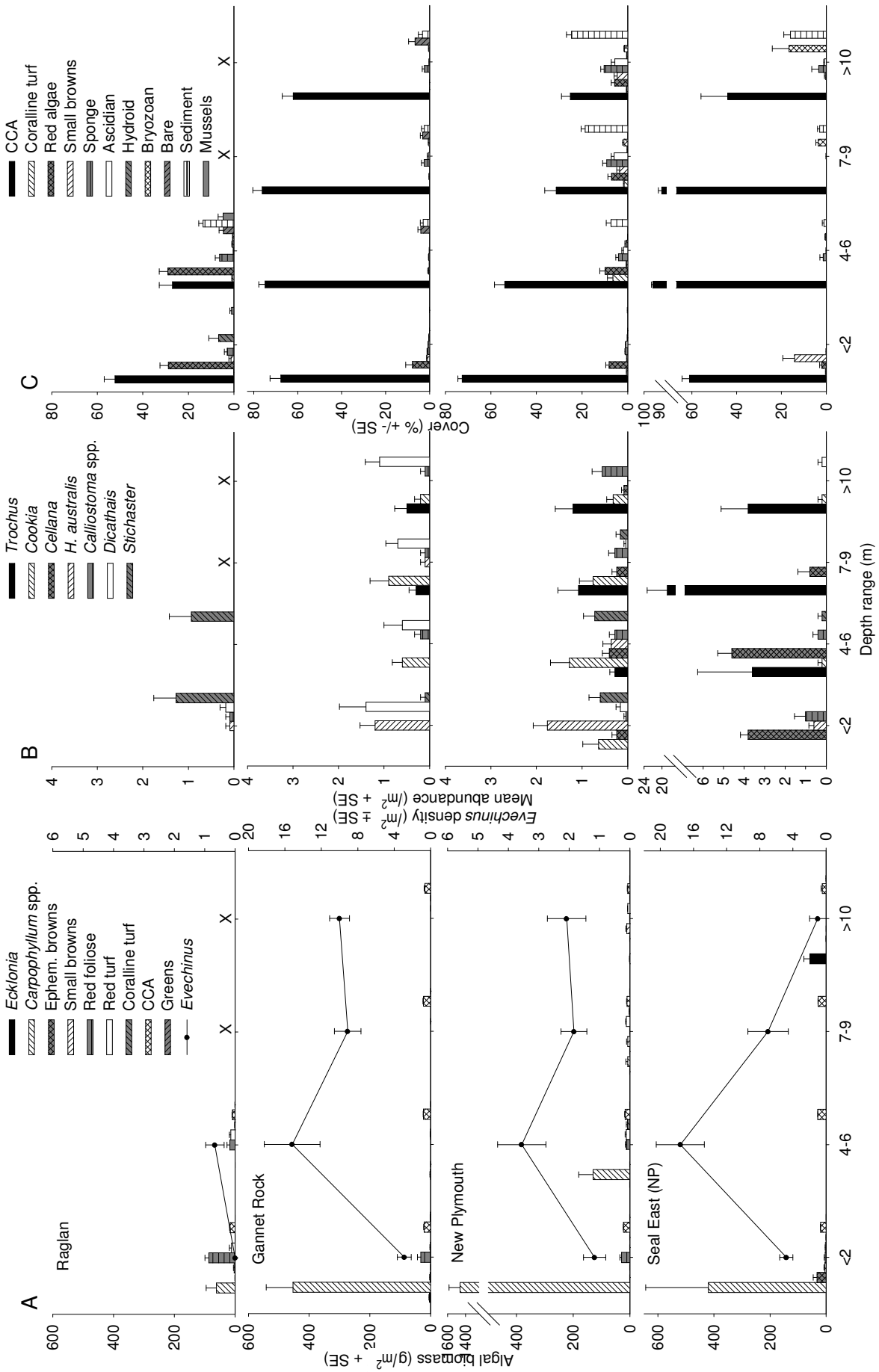


Figure 17. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evechinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for site groups within the Raglan bioregion.

cover of crustose coralline algae at all depths. Seal East also had higher densities of *Evechinus chloroticus*, *Trochus viridis* and *Cellana stellifera* (Fig. 17B). Whereas the algal community structure analysis did not separate out the three offshore sites at New Plymouth (Seal East, Seal West, Saddleback SW), these sites had higher densities of *E. chloroticus*, higher cover of crustose coralline algae and a lower cover of sediment compared to inshore sites which were dominated by turfing algae, encrusting invertebrates and sediment.

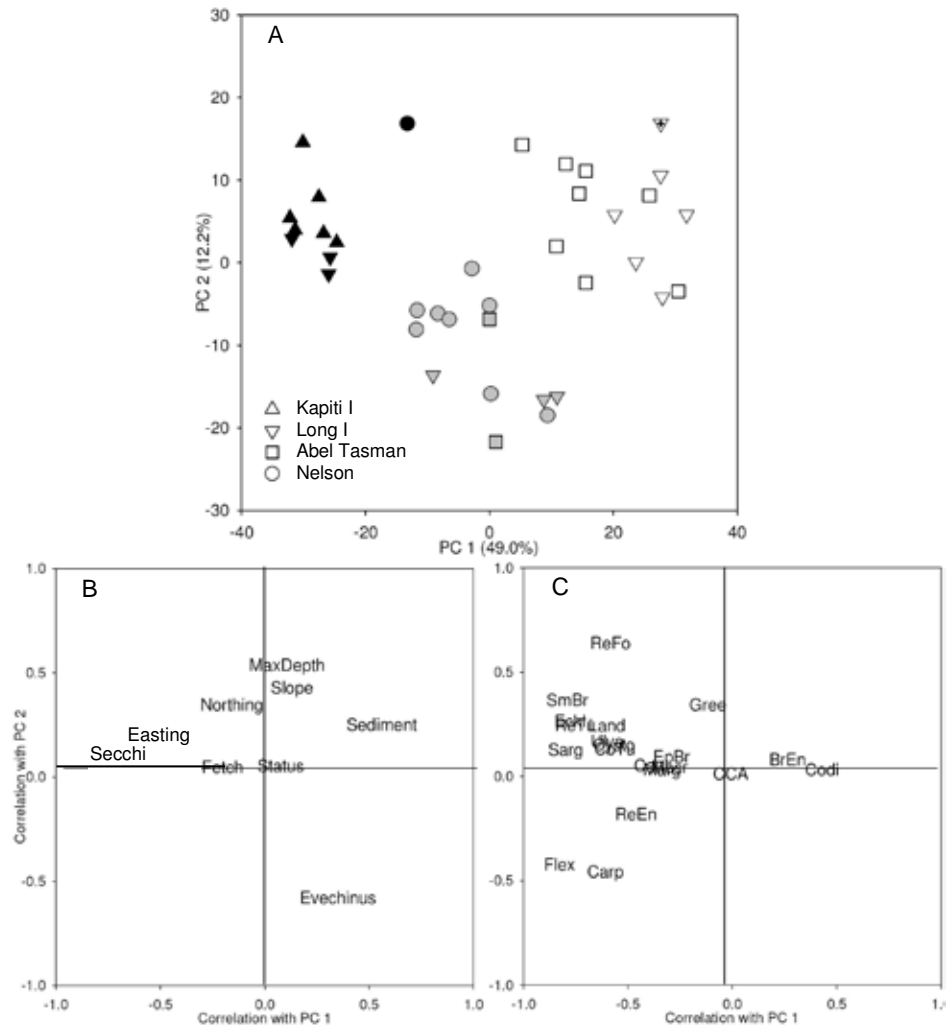
#### 3.4.4 Abel bioregion

There was large variation in algal community structure among the locations within this bioregion at the national level (Fig. 2), with Long Island, Nelson and Abel Tasman being clustered most closely to Raglan locations, and Kapiti being more like Northeastern and Portland locations. Site-level cluster analysis based on algal community structure divided Abel sites into four groups at the 60% similarity level that broadly reflected an inshore-offshore gradient along PC1 (Fig. 18). These groups were subjectively termed 'exposed-offshore', 'moderately exposed', 'sheltered' and 'very sheltered' (Blumine Island) to aid in describing the patterns within each location. Environmental variables explained 42% of the variation in algal community structure (Table 4), with Secchi (21%) and Sediment (19%) being strongly correlated with PC1 (Fig. 18B). Fetch was not strongly correlated with PC1 and only explained 7% of the variation across all sites in this bioregion; however, this was largely due to all of the sites from Kapiti (both sheltered and exposed) being grouped together (see below). Most algal species (excluding brown encrusting algae and *Codium* spp.) were negatively correlated with PC1 (Fig. 18C), which reflects their higher biomass at more exposed and offshore sites. PC2 was correlated with MaxDepth, Slope and *Evechinus*, and appears to reflect a gradient from deep, steeply sloping sites (e.g. Maheipuku at Nelson) with a higher biomass of red foliose algae to more gradually sloping sites with higher abundances of *Evechinus chloroticus* and higher biomasses of *Carpophyllum flexuosum* and *C. maschalocarpum* (e.g. Foul Point at Abel Tasman).

##### ***Kapiti Island***

All sites from Kapiti Island were grouped into the exposed-offshore group (Fig. 18); however, there were clear differences between the sites on the northwestern side of the island and the more sheltered sites on the east (Fig. 19A). Algal community structure at Kapiti was similar to that seen at Gisborne, with *Carpophyllum maschalocarpum* dominating the immediate subtidal, *Evechinus chloroticus* being rare, and extensive forests of *Ecklonia radiata* and *C. flexuosum* occurring at greater depths. At the more sheltered eastern sites *C. maschalocarpum* was restricted to the shallow depth stratum. *Ecklonia radiata* was also abundant at shallow depths, but its biomass declined markedly with depth. *Carpophyllum flexuosum* was dominant at 7–9 m, although its biomass was also reduced at 10–12 m, where the small brown algae *Halopteris* sp. (Southeast Point only), *Ulva* spp. and the red algal species *Plocamium* spp., *Rhodophyllis gunnii* and *Asparagopsis armata* were common. Crustose coralline algae were the dominant substratum cover at shallow depths but sediment dominated the deeper strata (7–9 m, 10–12 m) (Fig. 19C). Encrusting invertebrates such as sponges and ascidians covered only a small fraction of the substratum and mobile invertebrates were rare at all sites (Fig. 19B).

Figure 18. Principal coordinates analysis of sites sampled in the Abel 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 60% similarity level. Black = exposed-offshore, grey = moderately exposed, white = sheltered and cross symbol indicates very sheltered (Blumine Island).



The more exposed western sites at Kapiti had a distinct pattern in algal community structure in that *E. radiata* was abundant, and achieved high biomasses at 4–12 m of depth (Fig. 19A). The biomass of *E. radiata* was reduced in the shallow stratum (< 2 m), where *C. maschalocarpum* dominated, but co-occurred with *C. maschalocarpum* and *Cystophora retroflexa* at 4–6 m, and with *C. flexuosum* at 7–9 m and 10–12 m depths. Low numbers of *Landsburgia quercifolia* also occurred at some of these sites and the red algal species *Plocamium* spp., *Anotrichium crinitum*, *R. gunnii* and *Asparagopsis armata* were common. Crustose coralline algae were the dominant substratum cover at all depths, although small brown algae (*Zonaria* spp., *Carpomitra costata* and *Halopteris* spp.) dominated the understory (Fig. 19A). Red algae, predominantly *Pterocladia lucida* and red turfing algae, were abundant in the shallow stratum, and *Ulva* spp. were also common. The cushion star *Patiriella* spp. was the most abundant mobile macroinvertebrate and low numbers of *Cookia sulcata*, *Trochus viridis* and *Cantharidus purpureus* were recorded (Fig. 19B).

### Long Island

The sites sampled at Long Island spanned a large gradient from inner Queen Charlotte Sound to more exposed outer parts of the Sound and the sites fell into all of the exposure groups identified for the Abel bioregion (Fig. 18). The inner-

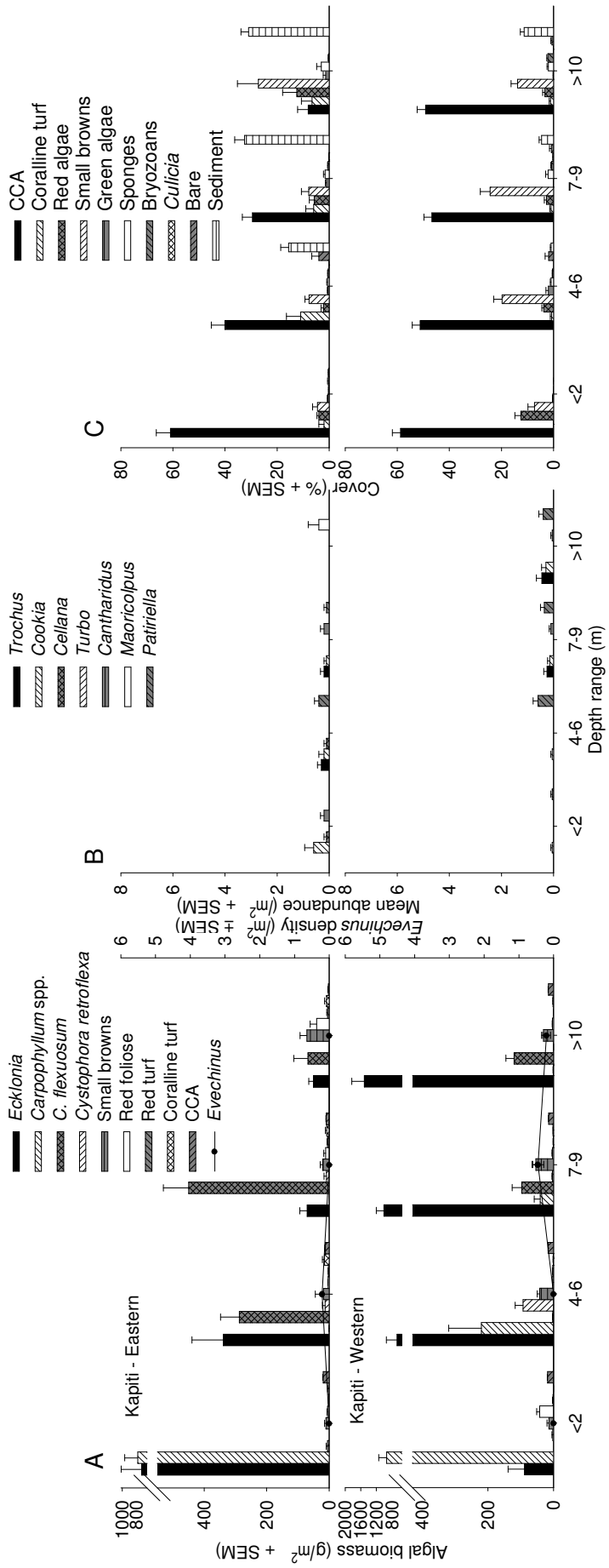


Figure 19. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evecchinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for sites on the eastern and western side of Kapiti Island sites (Abel bioregion). Note: all Kapiti sites were grouped in the Exposed-offshore group (Fig. 18).

most site, Blumine Island, formed its own very sheltered group and was the only site sampled in the entire Northern Province that completely lacked a shallow band of *Carpophyllum maschalocarpum* (Fig. 20A). Large brown algae were absent at this site and crustose coralline algae were the dominant algal group at all depths. Small amounts of filamentous and turfing algae (e.g. *Polysiphonia* sp. and *Chondria* sp.) were present at shallow depths. *Evechinus chloroticus* occurred at moderately low densities (c. 1/m<sup>2</sup>) across all depths. *Turbo smaragdus* occurred at high densities in the shallow stratum (< 2 m), *Cellana stellifera* was abundant at mid-depths, and *Maoricolpus roseus* was abundant in the deepest strata (4–12 m) (Fig. 20B). Crustose coralline algae dominated the shallow stratum, but at greater depths sediment was the dominant cover (Fig. 20C). Bare rock also made up an important component of the substratum.

Large brown algae were also scarce at sites in the sheltered group, except for *C. maschalocarpum* in the immediate subtidal (< 2 m deep). Moderate densities of *E. chloroticus* occurred at shallow depths and densities tended to decline with depth (Fig. 20A). Mobile macroinvertebrates and substratum cover showed similar patterns to those of Blumine Island, although the numbers of *Patiriella* spp. and percentage cover of the cup coral *Culicia rubeola* were higher (Fig. 20B, C). Moderately exposed sites mainly differed in the occurrence of *C. flexuosum* at 4–6 m. The numbers of *E. chloroticus*, *Trochus viridis*, *Cantharidus purpureus*, *Cookia sulcata* and *Patiriella* spp. also tended to be higher than at the sheltered sites. Consistent with increasing wave exposure and/or water movement, the percentage cover of crustose coralline algae was higher in the deepest strata, and the cover of sediment was lower, compared to the more sheltered sites (Fig. 20C).

At the exposed-offshore sites, *Carpophyllum flexuosum* stands were present at depths of 4–9 m, and sea urchins were abundant only in the deepest stratum (10–12 m) (Fig. 20A). *Carpophyllum flexuosum* exhibited a sheltered morphology (Cole et al. 2001) and formed forests typical of sheltered sites in other parts of the country, e.g. Long Bay. *Ecklonia radiata* was also present at 10–12 m interspersed with *C. flexuosum*. *Macrocystis pyrifera*, *Marginariella urvilliana* and tall *Sargassum sinclairii* plants (> 2 m length) also occurred at the Motuara Island site, which was subject to strong currents. In general, the biomass of red foliose algae, e.g. *Rhodomenia* sp. and *Asparagopsis armata*, increased with depth. Crustose coralline algae dominated the substratum at shallow depths and declined with depth. Coralline turf was also a dominant cover at shallow depths, whereas sediment dominated the deepest stratum (Fig. 20C). Mobile macroinvertebrate species were not as common as at the other sites (Fig. 20B), although *Cantharidus purpureus* tended to be more abundant, possibly associated with the higher biomass of *E. radiata*.

### ***Abel Tasman***

Two sites at Abel Tasman (Foul Point and Isol Rock) were grouped in the moderately exposed group whereas the others were classified as sheltered (Fig. 18). Algal and invertebrate assemblages were similar to those seen in equivalent groups at Long Island. At sheltered sites, the shallow band of *Carpophyllum maschalocarpum* extended to depths less than 2 m and *Evechinus chloroticus* occurred at moderate–low densities across all depths (Fig. 21A). Intermediate exposure sites were characterised by stands of *C. flexuosum* at mid-depths

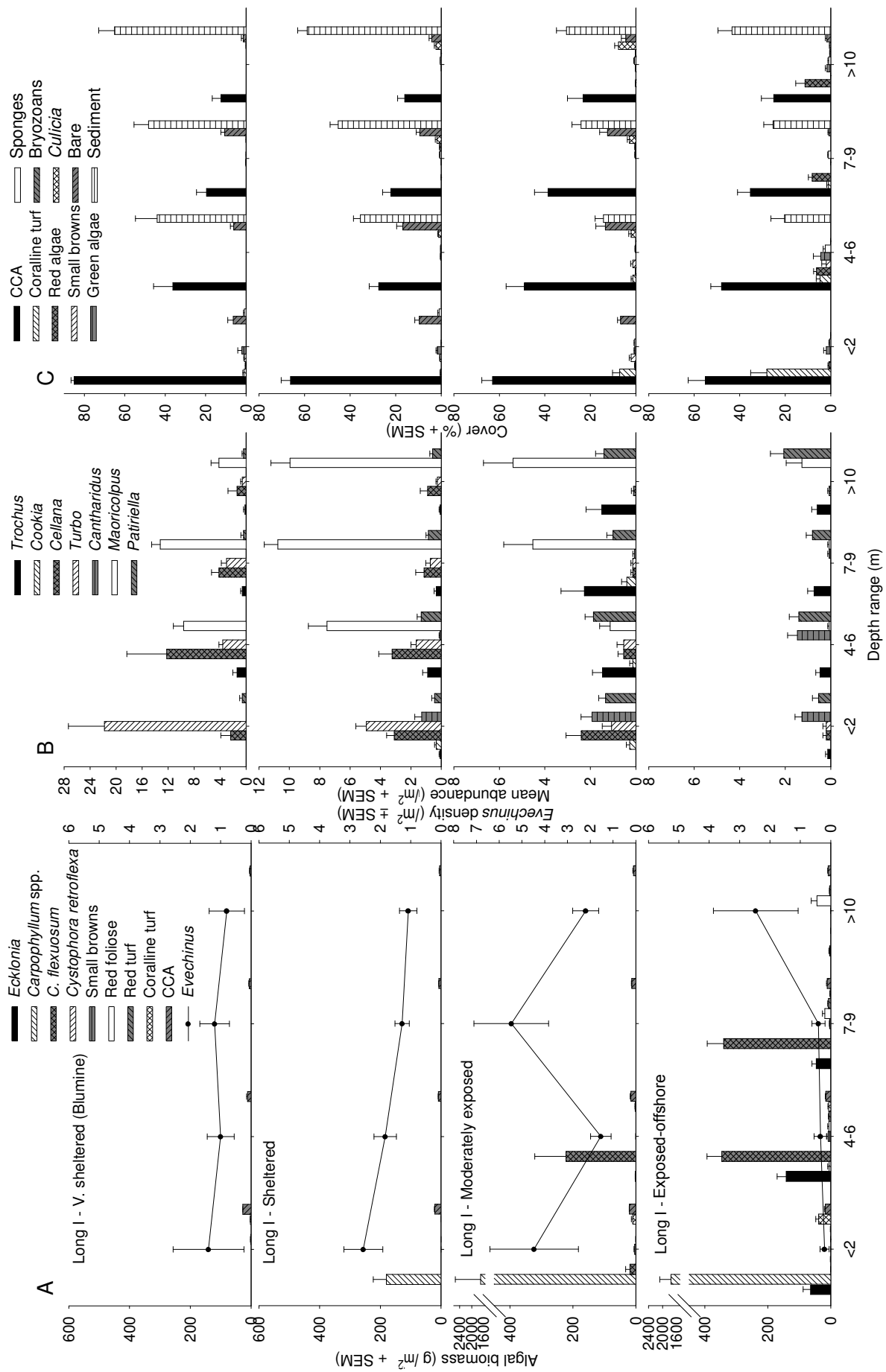


Figure 20. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evechinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for Long Island sites (Abel bioregion). Sites are grouped according to the exposure groups identified in Fig. 18.



(4–6 m and 7–9 m) and variable densities of *E. chloroticus*. *Ecklonia radiata* was absent from all Abel Tasman sites (but see Davidson & Chadderton 1994). There was little difference in mobile macroinvertebrates between the two groups (Fig. 21B), except *Turbo smaragdus* was more abundant at the sheltered sites. *Cookia sulcata*, *Trochus viridis* and *Maoricolpus roseus* were common at all sites. Crustose coralline algae were the dominant substratum cover at all depths, except for at 10–12 m, where sediment was the dominant cover (Fig. 21C). The percentage cover of sponges and bryozoans was notably higher than that recorded at Long Island sites.

### **Nelson**

All of the Nelson sites were grouped into the moderately exposed group, except for Maheipuku (exposed-offshore group). *Carpophyllum maschalocarpum* was the dominant large brown algae at all the sites sampled and was generally restricted to the shallow depth stratum (<2 m), where it formed dense stands (Fig. 21A). *Glossophora kunthii*, *Sargassum sinclairii*, *C. flexuosum*, *Cystophora retroflexa* and *C. torulosa* were also occasionally found in this shallow zone. *Ecklonia radiata* was absent from all sites. For the moderately exposed sites, depth distributions of large browns and *Evechinus chloroticus* were consistent with those seen for this group at Long Island. *Carpophyllum flexuosum* and *Sargassum sinclairii* were common at 4–6 m, although most of the *C. flexuosum* was short (<0.5 m long) and appeared to be grazed by sea urchins. With increasing depth (7–9 m and 10–12 m), the density of *E. chloroticus* tended to decline and large brown algae became rare, with the exception of a few sparsely distributed *C. flexuosum*. The substratum was dominated by crustose coralline algae at all depths, but the percentage cover of sediment, sponges and bryozoans increased with depth (Fig. 21C). Mobile macroinvertebrates were present in moderate numbers, with *Cellana stellifera* and *Patiriella* spp. being the most abundant at all depths (Fig. 21B). The ambush star *Stegnaster inflatus* was also common at some sites.

Algal community structure at Maheipuku was considerably different from that of other sites within the exposed-offshore group. The reef at this site consisted of a relatively steep wall sloping to 13 m deep. *Carpophyllum maschalocarpum* dominated the shallow depth stratum and large brown algae were rare at greater depths where red foliose and red turfing algae dominated (e.g. *Asparagopsis armata*, *Anotrichium crinitum* and *Plocamium* spp.) (Fig. 21A). *Carpophyllum flexuosum* was not recorded at this site, but other brown algae including *Sargassum sinclairii*, *Demarestia ligulata*, *Carpomitra costata* and *Halopteris* sp. were common. *Evechinus chloroticus* occurred at lower numbers compared with other Nelson sites, and the percentage cover of crustose coralline algae was low. Dominant percentage cover categories were red turfing and foliose algae, sediment, bryozoans and sponges (Fig. 21C). Mobile macroinvertebrates were rare, except for *Patiriella* spp., which was found at all depths (Fig. 21B).

### **3.4.5 Cook bioregion**

All sites sampled at Wellington and Kaikoura were relatively exposed to the open sea and there was little variation in algal community structure, with sites from the two locations separated at the 75% similarity level (Fig. 22A). There

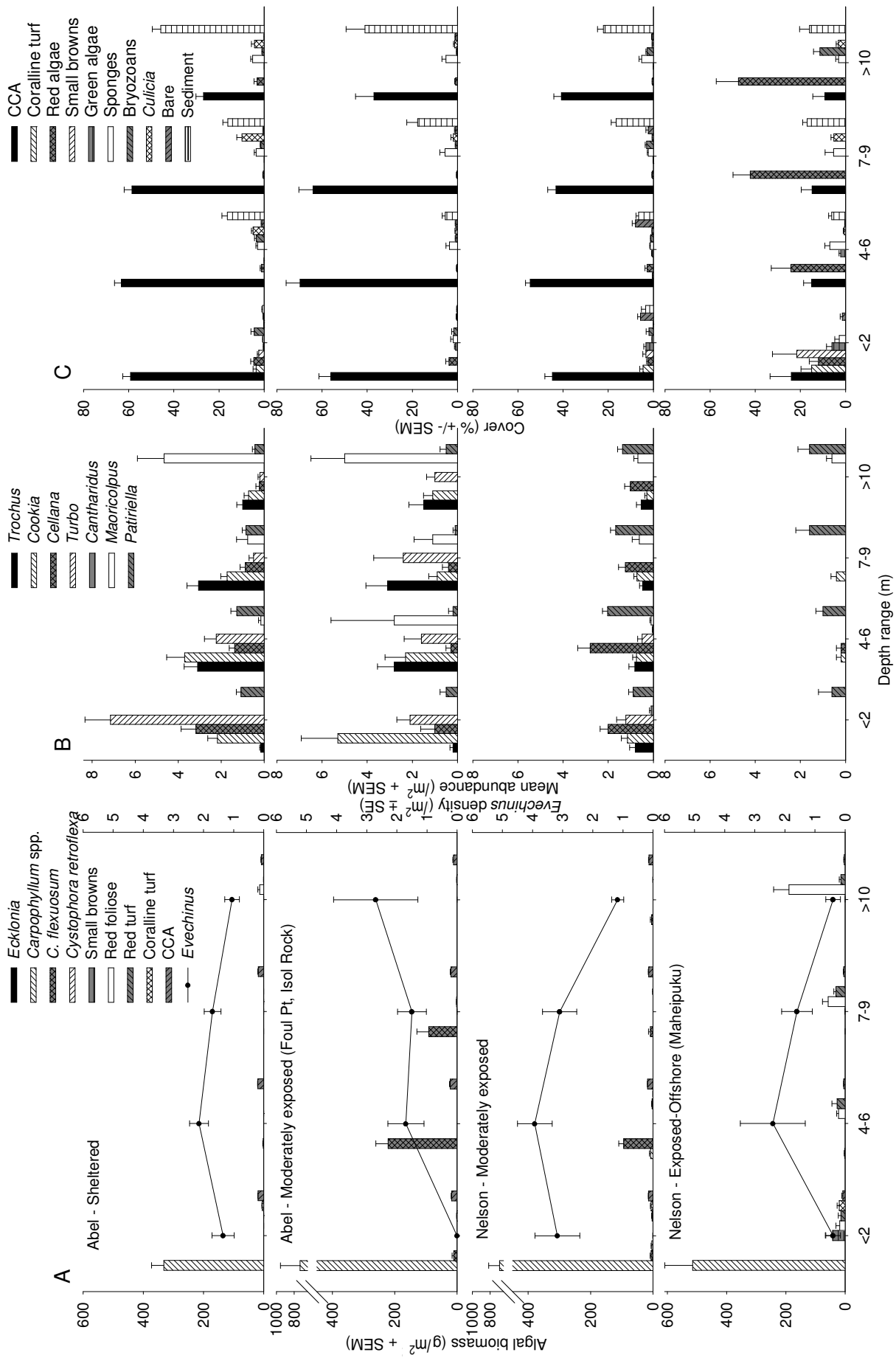


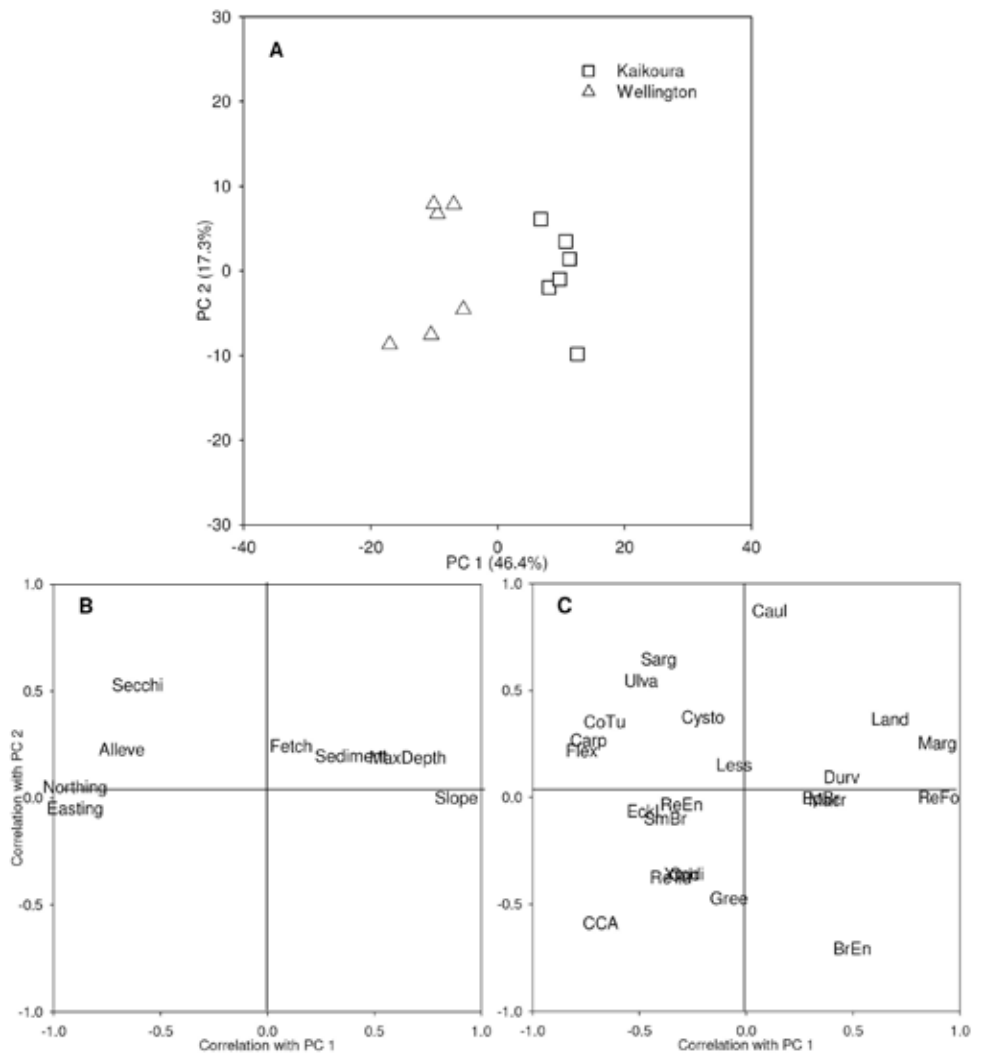
Figure 21. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Evecchinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for Abel Tasman and Nelson sites (Abel bioregion). Sites from each location are grouped according to the exposure groups identified in Fig. 18.

was no clear division between sites sampled on the northern and southern side of the Kaikoura Peninsula, or among sites at Wellington associated with any clear geographic or environmental gradients. The environmental variables Slope, Secchi and MaxDepth were strongly correlated with PC1 (Fig. 22B). Wellington sites tended to have more gently sloping reefs and clearer water than the Kaikoura sites. Differences in the dominant species between the two locations are reflected in the correlations with PC1. *Carpophyllum maschalocarpum* and *C. flexuosum* were more abundant at Wellington, whereas *Landsburgia quercifolia*, *Marginariella* spp. and red foliose algae were more abundant at Kaikoura (Fig. 22C).

### Wellington

Algal community structure on Wellington's south coast shared several similarities with both Northern and other Southern locations (Fig. 2). As in Northern locations, the immediate subtidal was dominated by *Carpophyllum maschalocarpum*, and *Pterocladia lucida* was also abundant, but species more typical of Southern locations were also abundant in this zone at some sites, e.g. *Marginariella urvilliana*, *Landsburgia quercifolia* and *Lessonia variegata* (Fig. 23A, Appendix 5). *Lessonia variegata* was dominant at greater

Figure 22. Principal coordinates analysis of sites sampled in the Cook 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 from both locations were separated at the 75% similarity level.



depths but formed mixed algal assemblages with *Ecklonia radiata*, *Landsburgia quercifolia* and *M. urvilliana*. There was a diverse understory of red algae, including *Euptilota formosissima*, *Callophyllis* spp., *Craspedocarpus erosus*, *Plocamium* spp. and *Rhodophyllis gunnii*. Large areas were also dominated by the green algae *Caulerpa brownii*, and to a lesser extent *C. flexilis* and *C. articulata*. *Carpophyllum flexuosum* was common at the most sheltered site, at the entrance to the Wellington Harbour (Palmer Head), and low numbers of both *Macrocystis pyrifera* and the exotic *Undaria pinnatifida* were recorded at this site. *Evechinus chloroticus* and other mobile invertebrates were rare, although *Haliotis australis* was common in the shallow depth stratum, and *Patriella* spp. were common across deeper strata (Fig. 23B). Crustose coralline algae were the dominant substratum cover at all depths but coralline turf was also important in the shallow stratum, whereas the green algae *Caulerpa* spp. and also *Ulva* spp. were important at greater depths (Fig. 23C).

### **Kaikoura**

Algal assemblages at Kaikoura were dominated by a mixture of large brown and red foliose algae at all depths (Fig. 23A). *Carpophyllum maschalocarpum* was found only in the shallow stratum and mixed with *Landsburgia quercifolia*, *Lessonia variegata*, *Marginariella urvilliana* and red foliose algae. *Ecklonia radiata* was abundant in mixed stands with *L. variegata* and *M. boryana* at 4–8 m at the northern sites but was rare at southern sites, which are more exposed to the prevailing southerly swell. *Marginariella boryana* dominated the deepest strata at the northern sites, whereas *Landsburgia quercifolia* was the dominant large brown alga at these depths for the southern sites. *Sargassum sinclairii* and *Macrocystis pyrifera* were present in low biomasses at sites on the northern side of the peninsula. Some *Durvillaea willana* plants occurred in the shallow stratum at the southern sites. The Kaikoura sites had a diverse red algal flora that achieved high biomasses across all depths. At shallow depths the red algal species *Pterocladia lucida*, *Hymenocladia sanguinea*, *Cladbymenia oblongifolia* and *Rhodymenia* spp. were most common, whereas for the deeper strata *Euptilota formosissima*, *Hymenena palmata*, *Craspedocarpus erosus*, *Plocamium* spp., *Rhodophyllis gunnii*, *Schizoseris* spp., *Streblocladia glomerulata* and *Rhodymenia obtusa* were most common (Appendix 5). The green alga *Caulerpa brownii* was also common in the deepest strata (7–9 m and 10–12 m) (Fig. 23A). Mobile macroinvertebrates, e.g. the two starfish species *Diplodontias* sp. and *Pentagonaster pulchellus*, occurred in low numbers (Fig. 23B). Crustose coralline algae were the dominant substratum cover (Fig. 23C), but there was a relatively high percentage cover of other encrusting forms, in particular red foliose algae and the green algae *Caulerpa brownii*. Sites at Kaikoura generally had higher percentages cover for sponges, bryozoans and sediment than Wellington sites, which is consistent with the higher turbidity recorded at Kaikoura.

### **3.4.6 Banks bioregion**

Algal community structure at Banks Peninsula North and Flea Bay were similar to those of Northern locations (Fig. 2), largely owing to the predominance of *Carpophyllum maschalocarpum* in the shallow subtidal and *C. flexuosum* at greater depths. The Banks bioregion sites were divided into three groups at the 60% similarity level (Fig. 24A). The relationship between these groupings and

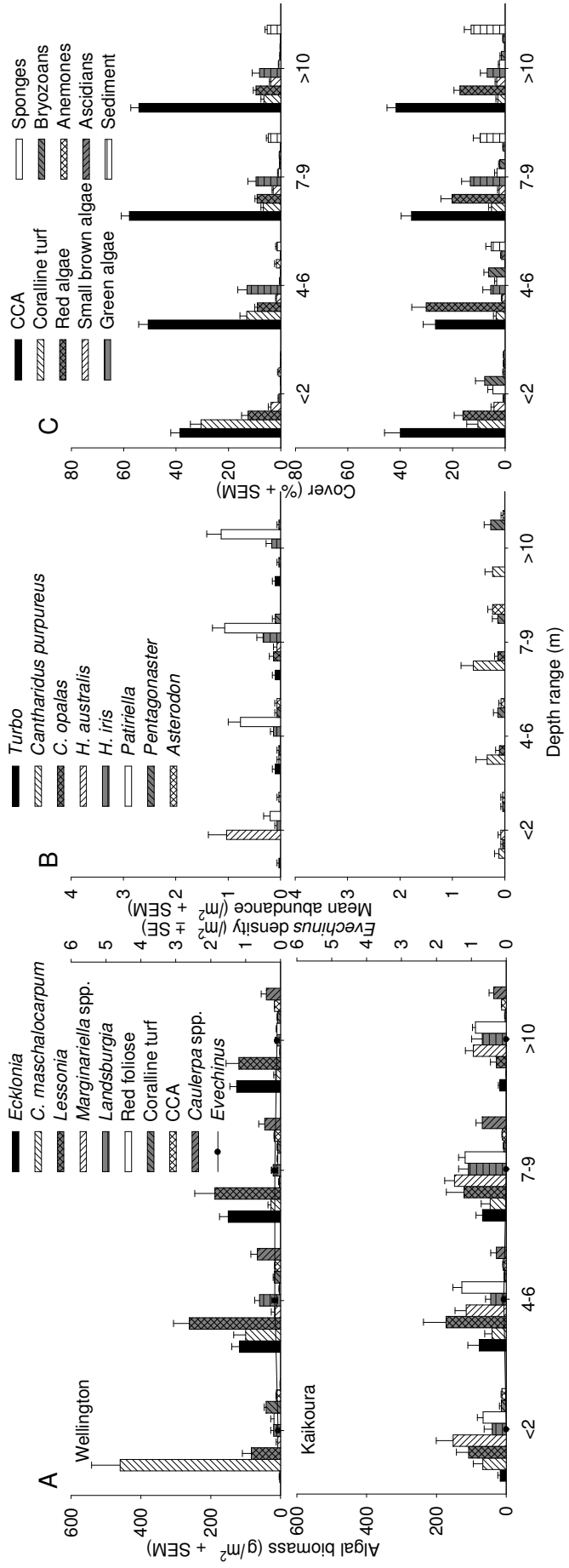


Figure 23. Depth-related patterns in biomass (g AFDW/m<sup>2</sup>) of dominant macroalgal groups and density of *Echinus chloroticus* (A), density of common mobile invertebrates (B) and cover of common encrusting forms (C) for site groups within the Cook bioregion.