Project Next Generation

Offshore benthos baseline survey

Prepared for Port Otago Ltd

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Authors/Contributors:
Graham Fenwick

For any information regarding this report please contact:
Graham Fenwick
Assistant Regional Manager
Marine Biodiversity & Biosecurity Group
+64-3-343 8051
graham.fenwick@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
10 Kyle Street
Riccarton
Christchurch 8011
PO Box 8602, Riccarton
Christchurch 8440
New Zealand

Phone +64-3-348 8987
Fax +64-3-348 5548

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Contents

Tables

Figures

Reviewed by

Donald Morrisey

Approved for release by

Charles Pearson

Executive summary

This survey comprised a baseline survey of marine benthos within a monitoring zone and two control areas (off Shag and Pipikaretu points) as required by Port Otago Ltd's consent for harbour dredge spoil disposal off Blueskin Bay.

Benthic communities were sampled at 28 stations on a grid over the monitoring zone, plus four stations at each control area. An anchor-box dredge sampled infauna and an epibenthic sled collected other invertebrates at selected stations. Sediments were sampled using a van Veen grab. Bottom images and side-scan sonar supplemented direct sampling of benthos and revealed further detail of sediments and sediment structures at 17 stations within the monitoring zone.

Analyses confirmed statistically significant differences in sediments (mostly in grain size compositions) between each control area and the monitoring zone. Sediments differed with distance from shore, but not with distance from the proposed spoil disposal site, area A0.

Benthic infauna densities (mean = 4595/m^2) varied between stations and areas, with highest densities (due to very abundant juvenile bivalve molluscs) at Pipikaretu Point and lowest densities at Shag Point.

The infauna comprised 165 species across all stations and areas, 91 of which were relatively abundant and widespread. Analyses based on these species grouped stations from each area and showed significant infauna differences between the controls and the monitoring zone, as well as distinguishing the infauna at some offshore stations from that at inshore stations within the monitoring zone.

The percentage of fine-very fine sand in sediments was the primary determinant of infauna composition at each station. The coarse sand-gravel fraction also correlated strongly with infauna composition.

Low densities of large invertebrates occurred in the area. Burrows, apparently inhabited by a large mantis shrimp, occurred at c. 2-3 /m^2 across the monitoring zone. There was no evidence of horse mussels (*Atrina zealadica*) in this area.

The sparse epibenthos added a further 43 species to the survey's total number of species. Analyses of data for the more abundant 19 species identified differences between control areas and the monitoring zone.

Sediment characteristics and infauna abundance, richness and composition in the monitoring zone were very similar to those described by previous surveys. Higher abundances and species richness in the present survey probably resulted from the more robust approach (sampler penetrated further into seabed, larger area/sample, better identification capabilities) used here.

Clear differences in bottom sediments and infauna show that stations at neither Shag Point nor Pipikaretu Point are suitable as controls for monitoring any changes within the monitoring zone.

The sampling plan and methods used in this study provide a robust design for monitoring any effects of dredge spoil sediments deposited and potentially dispersing from the proposed

deposition site, A0. Sampling at all five stations in rows A and G is recommended to enhance the sampling plan’s robustness and statistical power to detect any effects of sediment disposal and dispersal across the monitoring zone.

1 Introduction

Port Otago Limited (POL) plans to deepen and widen the shipping channel in Otago Harbour to safely accommodate the new generation of larger container vessels. Following several specific impact assessments, consultations with affected parties, completing an overall assessment of environmental effects and resource consent hearings, POL received consents to dredge the shipping channel between Port Chalmers and the harbour entrance. These consents included approval to deposit up to 7.2 million m^3 of dredged material offshore (at site A0), some 6.3 km north-east of Taiaroa Head. In granting these consents, Otago Regional Council imposed conditions on the various consents, including a condition under Consent 2010.198 (offshore disposal) requiring biological monitoring of area A0 and control sites at Shag Point and Pipikaretu Point.

This project provides a baseline biological survey of the disposal site (A0), plus control sites, to monitor any changes in species diversity, abundance, community composition and sediment grain size composition (key environmental factor vulnerable to change from spoil disposal). A statistically robust sampling plan was developed in consultation with Aquatic Environmental Sciences Ltd (AES) and POL. The sampling plan is intended to be sufficiently sensitive to distinguish dredging and disposal-induced changes in benthic communities from their natural variability. Details of this baseline survey plan are to be included in an environmental management plan, developed by AES and POL, before being submitted to the consent authority.

2 Methods

The sampling plan comprised a grid of sampling stations over and north of the proposed disposal site. This consists of a series of intersecting west-east rows and north-south lines of stations. Western and eastern most lines (lines 1 and 5, Figure 2-1) were located c. 1 km outside the proposed monitoring zone, and extended well north (down current) of the proposed spoil disposal site (area A0). Northern and southern most rows of stations (B and F, respectively) were situated c. 1 km inside the monitoring zone, and one additional northern and two southern stations (A3 and G2, G4, respectively) were positioned c. 1 km outside the zone (Figure 2-1).

One set of four stations was also established at 25-30 m depth of each of Shag Point and Pipikaretu Point to serve as controls (Figure 2-1). Map reference co-ordinates (WGS84) were created for all stations to facilitate reliable location of stations. Thus, the 36 sampling stations comprised four from each control area, 15 inside the potential impact and monitoring zone, and a further 13 located 1 km outside its boundaries.

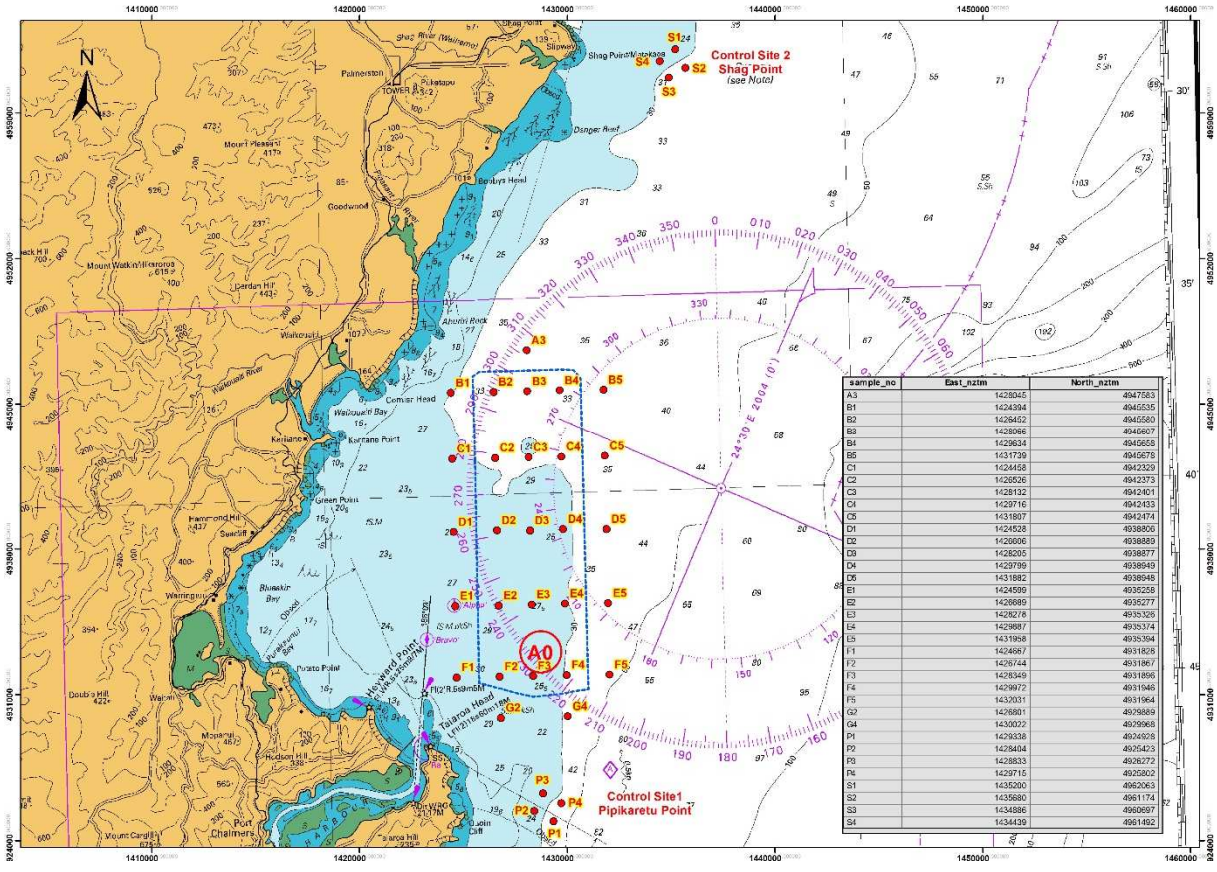


Figure 2-1: Locations of sampling stations within each of the three areas: Shag Point (S1-S4), monitoring zone off Blueskin Bay (A-G), and Pipikaretu Point (P). Grey panel (right) lists station co-ordinates (WGS84 format) for each station.

This sampling grid was oriented so that north-south lines were at transverse to distance from shore, a known environmental gradient on such coasts, and rows perpendicular to the prevailing currents and to any spoil dispersing from area A0. Consequently, stations on each row or line served as effective replicates, especially because the benthos over the entire monitoring zone was largely homogenous (Willis et al. 2008, Paavo 2011).

Previous surveys (notably Willis et al. 2008, Paavo 2011) reported that benthos[1] across the proposed monitoring zone and beyond differed little (all >50% similarity in classification analysis), with the sites showing no clear differences in environmental variables or in benthos composition. This absence of marked differences across the site in both physicochemical factors (e.g., depth range c. 28-33 m) and biota indicated a relatively uniform habitat and benthic community. From a sampling perspective, a single sample from any point within the monitoring zone essentially serves as a replicate for any other equivalent sample taken in the area.

Infauna sampling

A single sample was taken at each station to optimise spatial coverage, statistical power to detect change and resources. An anchor-box dredge was used because it generally collects large volume samples, provides for quantitative abundances (e.g., Probert 1984), is easy to use and is not prone to mis-fires. It also has proven reliable when sampling very firm sand bottoms characteristic of shallow, exposed open coast habitats (e.g., Fenwick 2002).

Infauna sampling was completed over 10-12 July 2013 from FV Sirocco. The volume of sediment taken in each sample was measured, before washing through nested sieves (1.0, 0.5 mm mesh), and each fraction preserved separately. The clean, labelled contents were preserved in 5 % formalin-seawater in the field. Subsequent processing involved washing in freshwater before preserving in ethanol. Each sample was carefully sorted into major taxonomic groups and identified as far as practical by experienced marine invertebrate technicians or taxonomists. Identified specimens were counted and the resulting data compiled into an Excel file of species by station abundances. These were then standardised to numbers/m^2 for detailed analysis and graphing using Excel and PRIMER routines.

Data analysis focused on confirming the relative homogeneity of sediments and benthos within and about Area A0, as well as establishing that the fauna and sediments at control sites 1 and 2 are similar to those within the disposal area. Faunal analyses focused on species diversity, invertebrate abundance and community composition.

A small van Veen grab was used in tandem with the anchor-box dredge to obtain an undisturbed profile of the upper 50 mm of bottom sediments. Three small samples of undisturbed surface (0-25 mm depth) sediments were frozen for subsequent particle size frequency analysis and organic content (see below).

Note, a navigational error resulted in benthic samples being taken 218- 820 m northwest of their intedned locations (Appendix B). This made no material difference to the survey results.

Epifauna sampling

A 400 mm wide Ockelmann detritus (epibenthic) sled fitted with a 2 mm mesh bag was deployed at selected central monitoring zone station (Figure 2-2). Sampling was undertaken over 10-12 July 2013 whilst completing the infauna survey. Prevailing weather, sea conditions and currents compromised tow directions, durations and, hence, distances (actual tow distances, 161-1138 m), so species abundances were standardised to numbers per 500

[1] Benthos includes all biota (plants and animals/fauna) inhabiting the bottom. It comprises infauna (species living within the bottom sediments) and epifauna (species living on the bottom), but some species variously inhabit both surface and subsurface habitats. In practice the distinction here is somewhat arbitrary, being based more on the sampling device than on the true habitat because sampling for infauna inevitably captures some strictly epifaunal species and the converse.

m. The epifauna was fixed, preserved and analysed in the same way as the infauna, before being identified and counted by the same researchers.

Bottom imagery

A minimum of ten still images was collected from 17 stations spread throughout the monitoring zone to quantify sparse or elusive fauna in the area, notably the large burrows created by a mantis shrimp (Paavo 2011). A small, tethered ROV (remotely operated vehicle: VideoRay Pro 4) was deployed at each station on 8 August 2013 to obtain standard images for comparative purposes. Subsequently, ten images (area imaged c. 50 x 30 cm) from each station were each scanned carefully and numbers of small burrow, large burrows and any other structures (including ripples) and organisms recorded.

Side-scan sonar imagery of the seabed at 17 stations (Figure 2-2) over 1 September 2013 was used to detect any differences in seabed habitats, especially changes from fine to very coarse sediments and surface structures. A single c. 400 m long and 60 m wide (30 m each side of the tow path) swath was completed using a high-frequency (675 kHz) Tritech tow-fish.

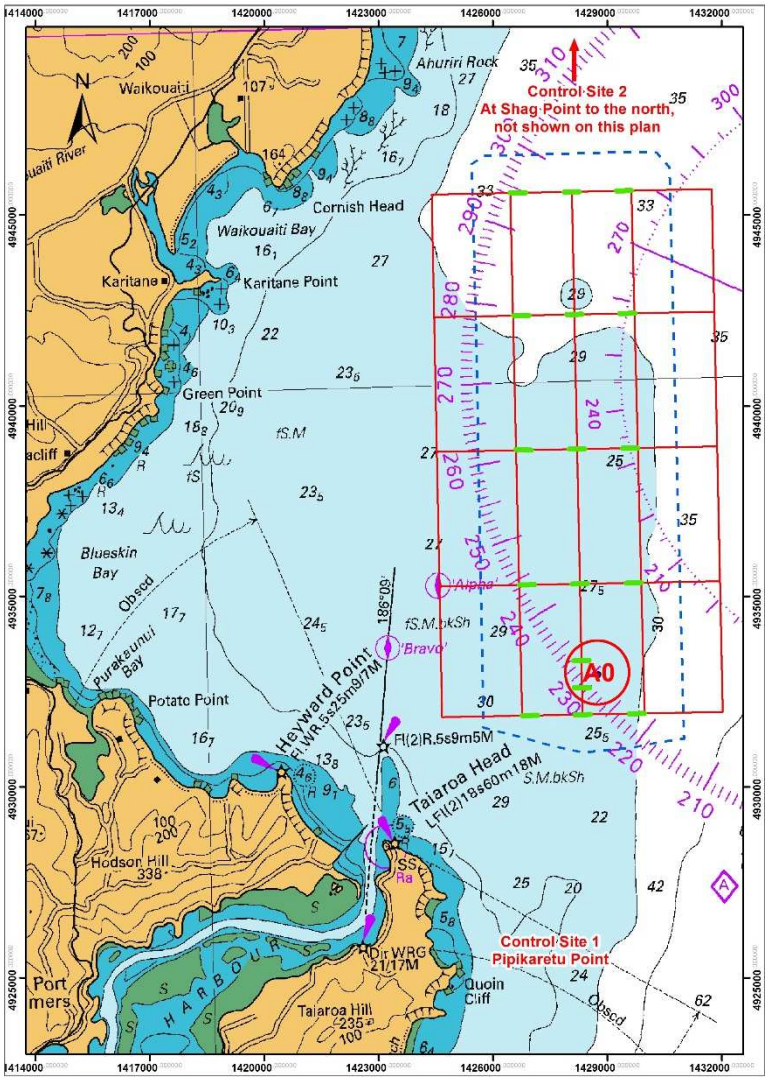


Figure 2-2: Locations (green bars) of drop-camera and sidescan images across the monitoring zone off Blueskin Bay. Red circle shows spoil disposal area (A0); broken blue line encircles monitoring zone. No bottom imagery undertaken at either Shag Point or Pipikaretu Point.

The tow-fish's position was automatically recorded every two seconds along each swath and saved with the digital sonograph image. GPS position data from the towing vessel adjusted for distance between the boat and the tow-fish. Subsequently, both the digital side-scan images and the GPS positions were used to geo-reference the resulting side-scan tracks, for importing into GIS applications (ArcMap v.10) to determine the locations of any features of interest.

Sediment analyses

Sediment particle size analysis followed the standard methods (e.g., Folk 1968, Lewis & McConchie 1993), including pipette analysis to resolve silt and clay fractions. Grain size terminology used in this report follows Wentworth, as defined by Folk (1968). Organic content of bottom sediments was determined using the Loss On Ignition (LOI) method. A representative sub-sample for each station was freeze-dried, oven-dried and weighed, before ashing at 500 °C for 4 hours and re-weighing.

Graphical presentations of results

To facilitate spatial understanding and interpretation of results, graphs for several variables consistently show stations arranged in east-west rows and north-south lines (e.g., Figure 3-1) and viewed from the west. Stations for each control site are presented in single rows, one to the north of the sampling grid for Shag Point control stations, and another to the south for Pipikeratu stations. Differing distances between rows and lines of stations are ignored to facilitate comparisons within each graph and compass quadrants are labelled in each figure to ease orientation.

3 Results

3.1 Physical environment

Depths across the study and control areas varied from 26 to 41 m, averaging 31 m below mean sea level (MSL) (Figure 3-1). Note, control stations are graphed in rows to facilitate presentation and interpretation. Depths generally increased slightly from south to north and west to east (with distance from shore), but north to south for the seaward row of stations.

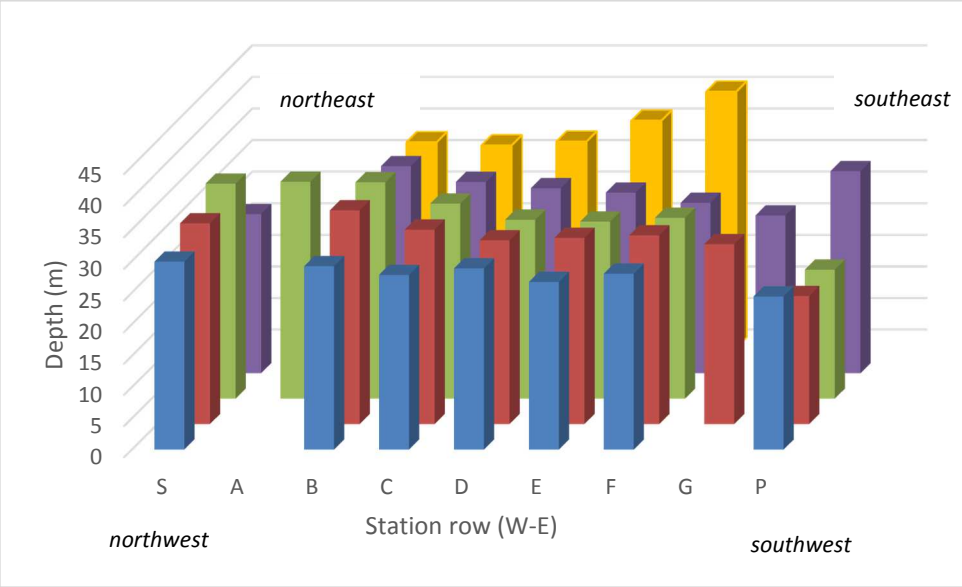


Figure 3-1: Water depths at each of the 36 stations off Blueskin Bay. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right); monitoring zone stations (rows A-G) (blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

3.1.1 Sediment grain size composition

Mud content was generally low (5-16%, Figure 3-3), but higher (21-33%) at five stations, notably A3, B2-3, D3 and F1, and lowest (0-8%) at the northern Shag Point and southern Pipikaretu Point control stations (S1-4). No pattern is apparent in mud distribution with either depth or distance from shore. Stations differed most markedly in fine-very fine sand, medium or medium sand and coarse sand-gravel compositions. Sediments at the Shag Point control stations were dominated (78-97%) by the coarsest fraction, with minimal mud and almost no fine sands (Figure 3-3), indicating high energy hydrodynamic conditions. Sediments off Pipikaretu Point contained very little coarse sediment or mud, instead being dominated by medium sand (30-77%). These sediment characteristics indicate that this location is intermediate between Shag Point and the main study area off Blueskin Bay in terms of hydrodynamic energy.

3.1.2 Organic content (LOI)

Sediments across all stations were typically low (0.5-2.6%) in organic content (Figure 3-2), although one station (S4) exceeded this range with 7% organic matter. Apart from this anomalously high value, the only apparent pattern is for lower organic content (0.5-0.6%) at all four Pipikaretu Point control sites.

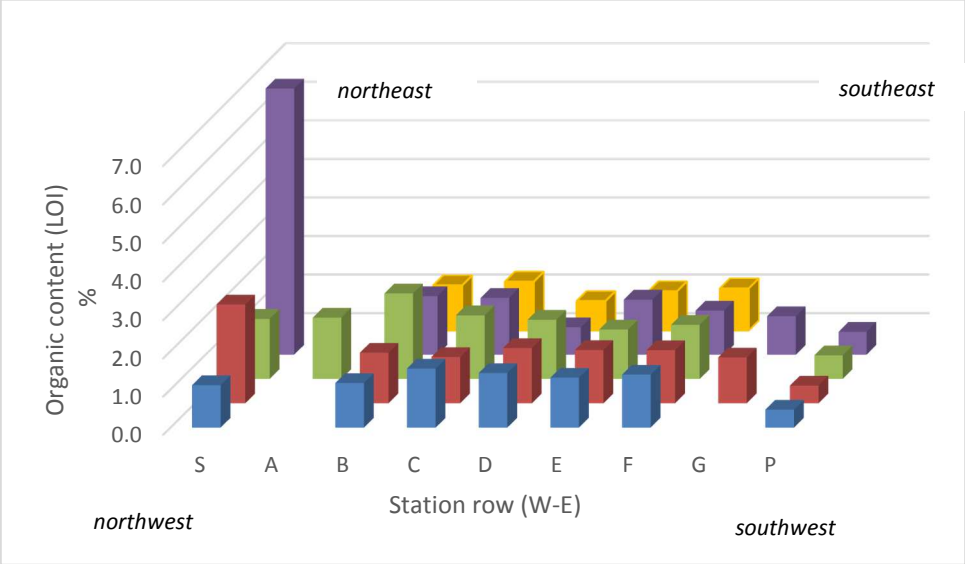


Figure 3-2: Sediment organic content across the 36 stations off Blueskin Bay. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right); monitoring zone stations (rows A-G) (blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

3.1.3 Sediment structure

Sediment profiles revealed no sediment structure or stratification (e.g., Figure 3-4) within the upper 50 mm. Certainly, there was no evidence of any anoxia or a redox potential discontinuity characteristic of many finer-grained shallow marine sediments. Shag Point bottom sediments were unconsolidated, proving impractical to view in profile (i.e., not photographed). The lighter colour of Pipikaretu sediments (Figure 3-4, P4) reflects their coarser nature, low mud content and the paucity of organic matter. Also, sediments from station F5 appear quite different: the sample shown is much drier, indicating coarser sediments with scant organic matter that drain very freely.

3.1.4 Seabed surface structure

Seabed surface images revealed sediment ripples (c. 80-230 mm trough to trough) at all stations, but nothing to distinguish the sediments and sediment structures of monitoring zone stations from each other (e.g., see Figure 3-16; no images taken at control areas).

Detailed examination of the side-scan images determined that the seabed within the monitoring zone comprises a uniform sandy bottom with very few features (Figure 3-5). Certainly, it appears devoid of any rock or reef structures. Mega ripples were a consistent feature, although variously apparent, on images from most stations. These features are conspicuous when the ripples presented a surface that reflected its signals (i.e., when the side-scan was towed parallel to the ripples), but usually apparent to the trained observer in other traces.

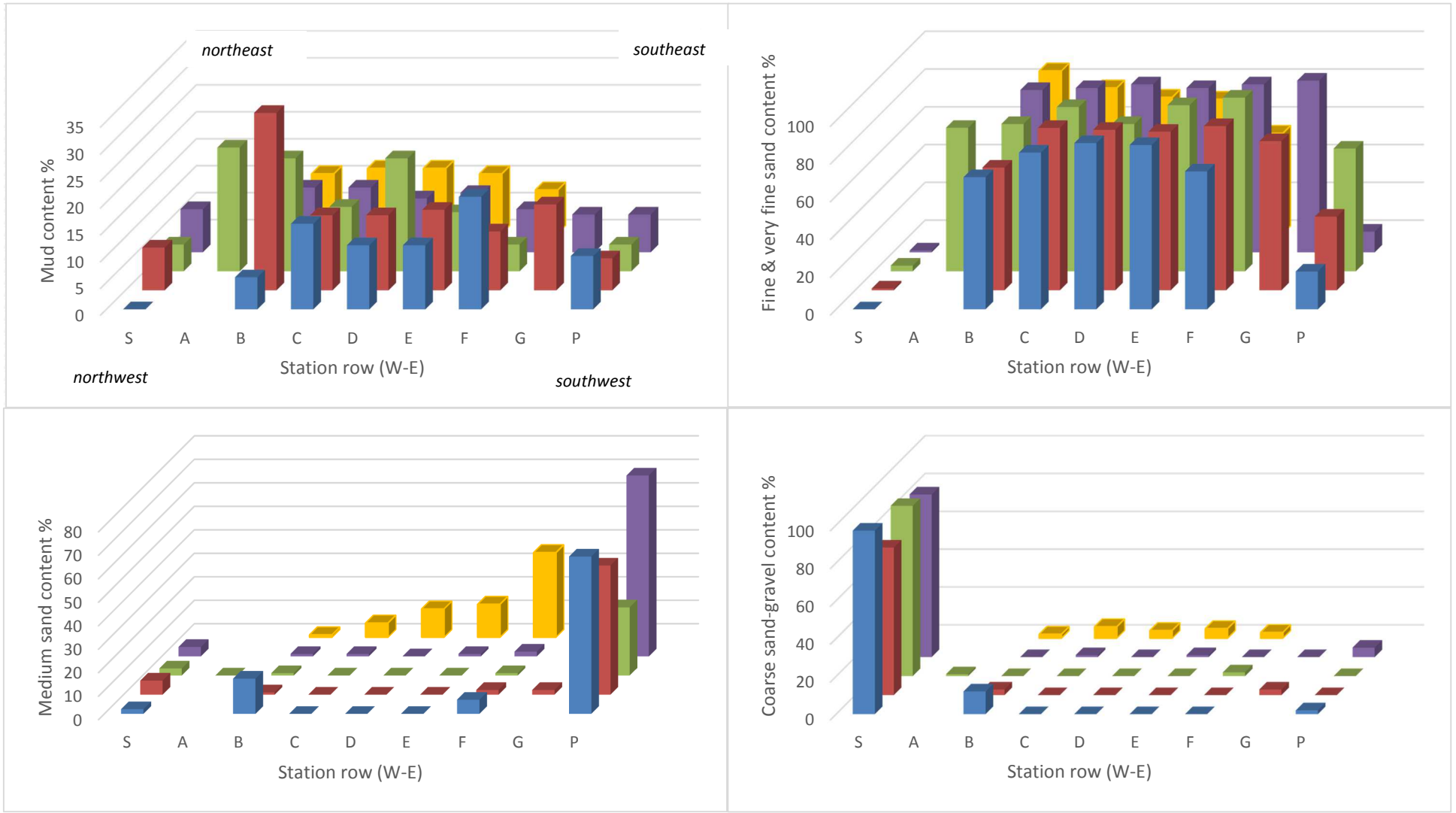


Figure 3-3: Sediment particle size composition (Wentworth scale) across the 36 stations between Shag Point and Pipikaretu Point. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right); monitoring zone stations (rows A-G) (blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

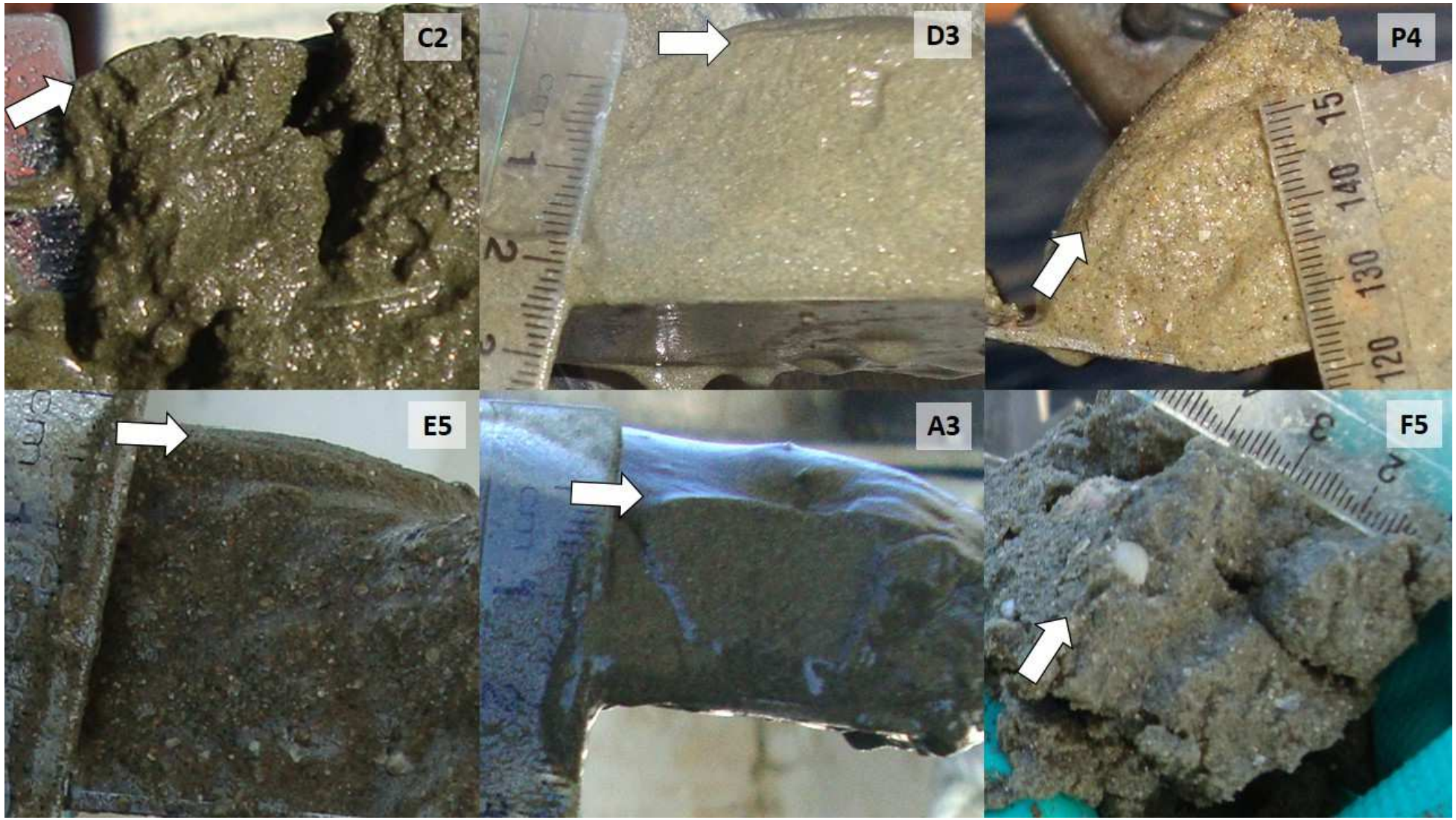


Figure 3-4: Comparison of sediment profiles at selected stations in the monitoring zone off Blueskin Bay and off Pipikaretu Point (P4), plus one outlier station (F5). White arrows indicate sediment surface and ruler is oriented perpendicular to surface.

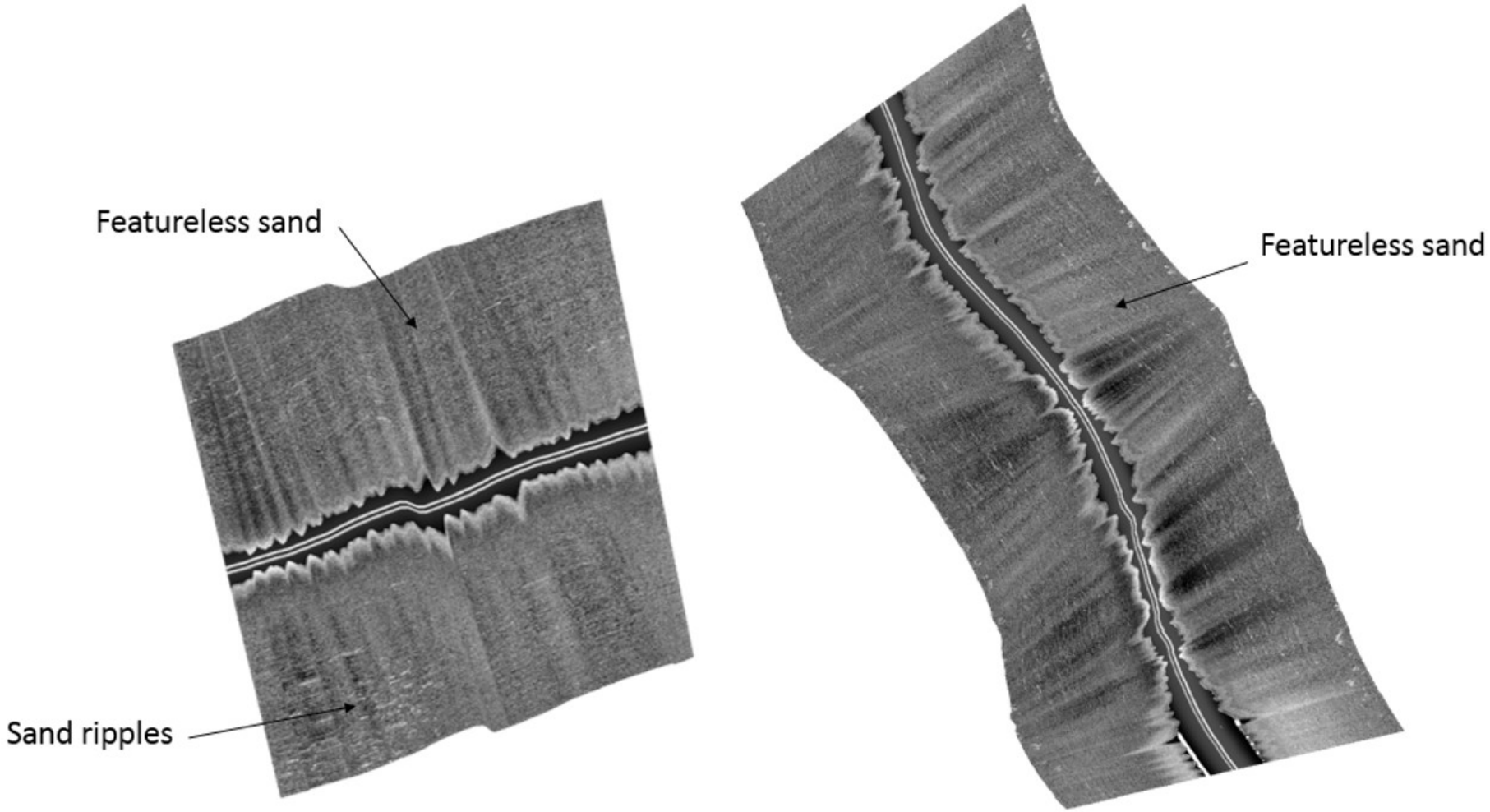


Figure 3-5: Examples of sidescan images from two stations showing vessel track (smooth centre line) and 30 m wide swaths each side. Left, a 55 x 60 m portion of sea floor from station C4; right, a larger section (120 x 60 m) at station E3. Jagged inner margin of each trace and corresponding apparent corrugations on seabed reflect sea conditions; mega ripples visible as pale bars and only when tow direction is c. parallel to them.

3.1.5 Sediment differences between stations

Cluster analysis of sediment data (grain size fractions, organic content) identified station S4 as most different from all others, that other Shag Point stations also differed from Pipikaretu Point and that both differed from all other stations off Blueskin Bay (Figure 3-6). Station F5 clearly differed, but the stations off Blueskin Bay generally shared similar sedimentary characteristics. Another three stations were separated from the other monitoring zone sediments (A3, B2, B3), indicating further heterogeneity in this area.

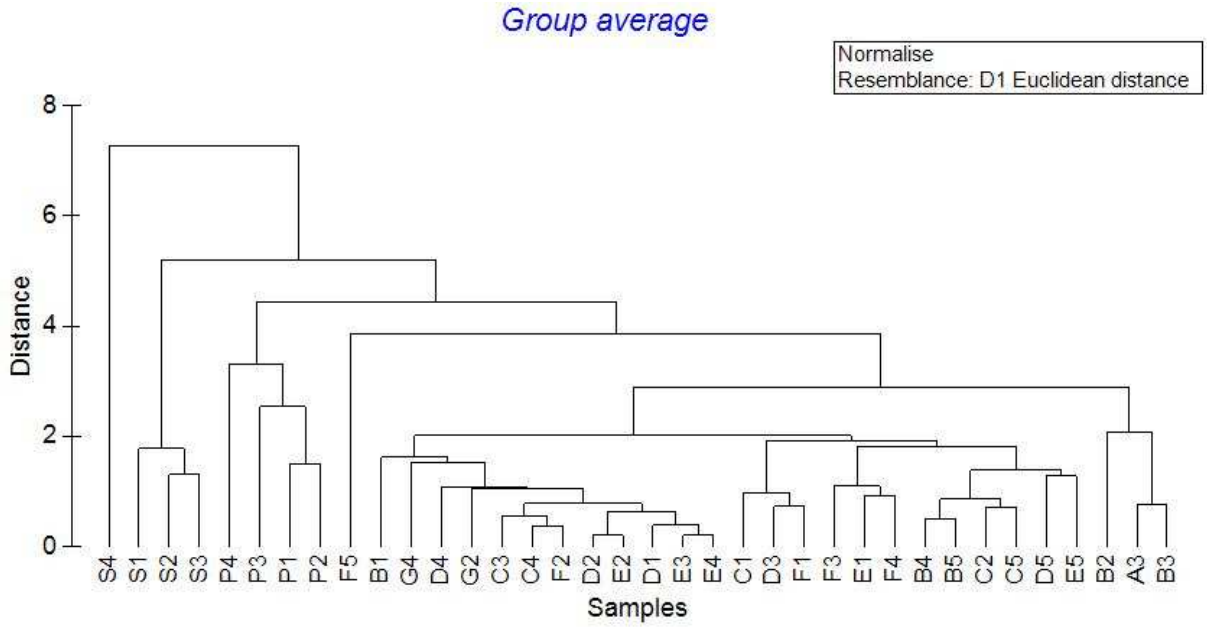


Figure 3-6: Similarities of benthic habitats within the monitoring zone off Blueskin Bay, and Shag and Pipikaretu points, based on depths and sediment characteristics.

Analysis of similarities between stations grouped by location from north to south (i.e., sampling rows A, B, C, etc., Shag Point and Pipikaretu Point each included as separate groups) showed statistically significant differences between groups based on sediment characteristics (R = 0.323, p = 0.001). Pair-wise comparisons of these groups showed that sediments at stations in the two control areas differed significantly from each other (R = 0.854, p = 0.029) and from those in other groups (i.e., monitoring zone off Blueskin Bay; R = 0.569-0.934, p = 0.008-0.024). However, there were no significant differences between pairs of station (east-west) rows within the monitoring zone (R = 0.18-0.436, p = 0.095-0.913). Equivalent tests between pairs of (north-south) lines of stations within the monitoring zone showed no significant differences between any of the three inshore lines (1-3, R = -0.045-0.045, p = 0.271-0.643), but identified significant differences between lines 1 and 4 (R = 0.272, p = 0.043), 2 and 5, and 3 and 5 (R = 0.341-0.360, p = 0.011-0.030).

In summary, Shag Point, monitoring zone and Pipikeratu sediments were distinct from each other in terms of sediment texture and organic content. There was some variation in sediment texture with distance from shore within the monitoring zone of Blueskin Bay.

3.2 Infauna

3.2.1 Infauna densities

Infauna densities ranged between 1133 and 14,732 individuals/m^2 (Figure 3-7), with an overall mean density of 4595/m^2 (SE = 514) across all stations. Highest densities (14,462-14,732/m^2) were at two southern control stations (P1-2), whereas lowest densities (1133-1182/m^2) were at two northern control stations (S1-2, Figure 3-8). Densities at most (67%) stations ranged between 2000 and 7000 individuals/m^2.

Total infaunal benthos densities were lowest at some northern control (Shag Point) stations and at some southern control (Pipikaretu Point) stations, with intermediate densities off Blueskin Bay (stations C2, C4-5; D4, E2-4) (Figure 3-8). Notably, the four southern control stations included the two with highest infauna densities and two of those with lowest densities (1842-2220/m^2, Figure 3-8). These extreme densities were due to very large numbers of juveniles of two bivalve molluscs, *Glycemeris modesta* and *Mactra ordinaria*, each contributing 91% and 89% of numbers to these densities at stations P1 and P2, respectively (Figure 3-9). Total densities at these two medium sand-dominated stations, with these species excluded, are very similar to those for the other two Pipikaretu Point stations, and to elsewhere in Blueskin Bay.

Similarly, the very high benthos density at S4 relative to other stations at Shag Point is attributable to high numbers of a few species, notably one polychaete (*Paradonereis* sp.), a species recorded only at this station, and another restricted species (two stations), the amphipod crustacean (*Gammaropsis* sp.)(Figure 3-9). Benthos at other stations with higher densities (C2, C4, C5, E3, E4) was dominated by 4-8 species, with the amphipod *Limnoporeia*? sp. A a significant contributor at stations C4 and E4.

3.2.2 Infauna diversity

A total of 166 species was identified from the 36 infaunal stations (Appendix A). Of these, 30 were found as single specimens, 12 represented by two specimens, and 60 comprised 1-5 specimens across the entire survey. Fifty-four species occurred at only one station, approximately half (75) were present at just one or two stations and half of all taxa were taken at just three stations (Figure 3-10). No species was found at all stations and just eight (4.8%) occurred at 30 or more (>83%) stations.

Species richness appears lower (but was not significantly so, t-tests) at the Shag Point control stations compared with the central Blueskin Bay stations (Figure 3-11). Richness or diversity seems similarly lower at the southern Pipikaretu stations, but this difference was not statistically significant (t-tests). There is no other pattern apparent either south to north or west to east (Figure 3-11).

The two major groups, polychaetes and crustaceans were represented by similar numbers of species in this survey (75 and 73 species, respectively). Notably, crustaceans were dominated by amphipods (32 species), mostly highly mobile, active burrowing species (e.g., Oedicerotidae, Phoxocephalidae). Molluscs contributed considerably fewer species (32 species), including bivalves (15 species), gastropods (13), chitons and scaphopods (3 and 1 respectively).

Polychaetes and crustaceans contributed similarly to species richness across most stations and areas, except that crustaceans were less diverse at the Shag Point stations (Figure 3-12). Mollusc richness was conspicuously higher at the Pipikaretu stations and lower at the Shag Point stations, compared with over the monitoring zone generally.

3.2.3 Infauna composition

Cluster analysis of stations based on species density data (Figure 3-13) separated the Shag Point stations in in one cluster at c. 18% similarity from the benthos at all other stations. The Pipikaretu Point stations were separated from most of the stations off central Blueskin Bay at 42% similarity. With the exception of two outlier stations (B2, F5) the benthos at all other stations within the monitoring zone off Blueskin Bay shared >55% similarity (Figure 3-13). A few of these were grouped in ways suggesting greater similarities within east-west rows (D1-D3, E2-E4), whereas other groupings indicate greater similarities along north-south lines (C5,D5, E5; C4, D4, E4).

Benthos density and diversity were considerably lower at the outlier station B2 (Figure 3-8, Figure 3-11; although polychaete and mollusc diversity were high), whilst that at the other outlier (F5) was higher and more diverse that at their respective neighbouring stations and most others in the monitoring zone.

A multidimensional scaling analysis replicated this clustering arrangement, with the plot presenting the inter-station similarities in three-dimensional space (Figure 3-14). As in the cluster analysis, most monitoring zone stations were very tightly clustered. Stations B2 and F5 were located outside this tight grouping. Those at Pipikaretu Point were slightly further away from those at the monitoring zone, whereas Shag Point stations were loosely grouped and well separated from all others.

These differences in benthos between these groupings of stations were statistically significant (one-way ANOSIM: R = 0.948, p = 0.001). Further tests of these differences between station groups confirmed their significance (Table 3-1). Additional tests of stations within the monitoring zone indicated that any differences between east-west rows were not statistically significant (R = -0.164-91.3, p = 0.067-0.913). Pair-wise comparisons of north-south lines of stations revealed no significant differences in benthos between the inshore four lines (R = -0.131-0.228, p = 0.760-0.974), and that benthos at the outermost line (5) was significantly different only from that at the most inshore (line 1) stations (R = 0.288, p = 0.024).

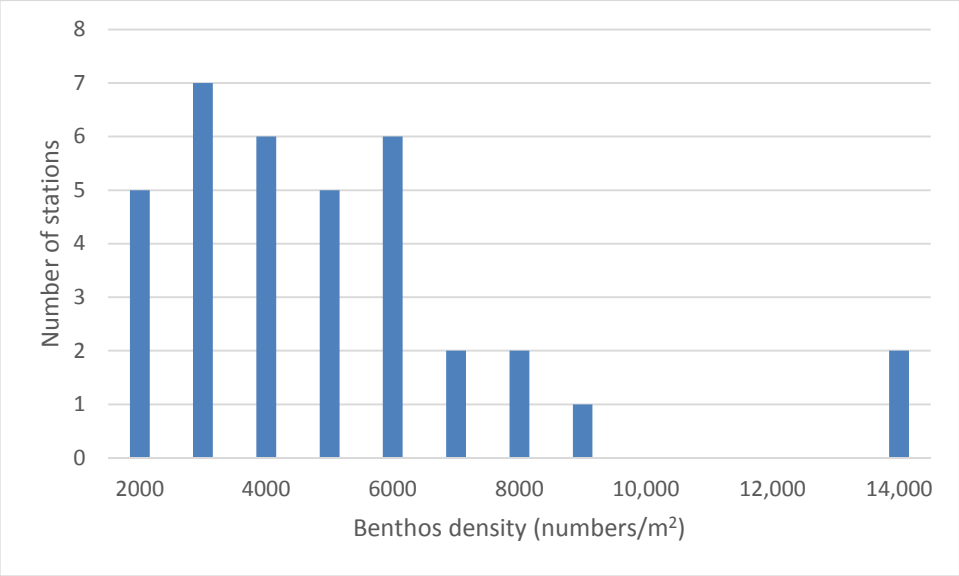


Figure 3-7: Infauna density frequencies: numbers of stations between Shag Point and Pipikaretu Point with different benthos densities.

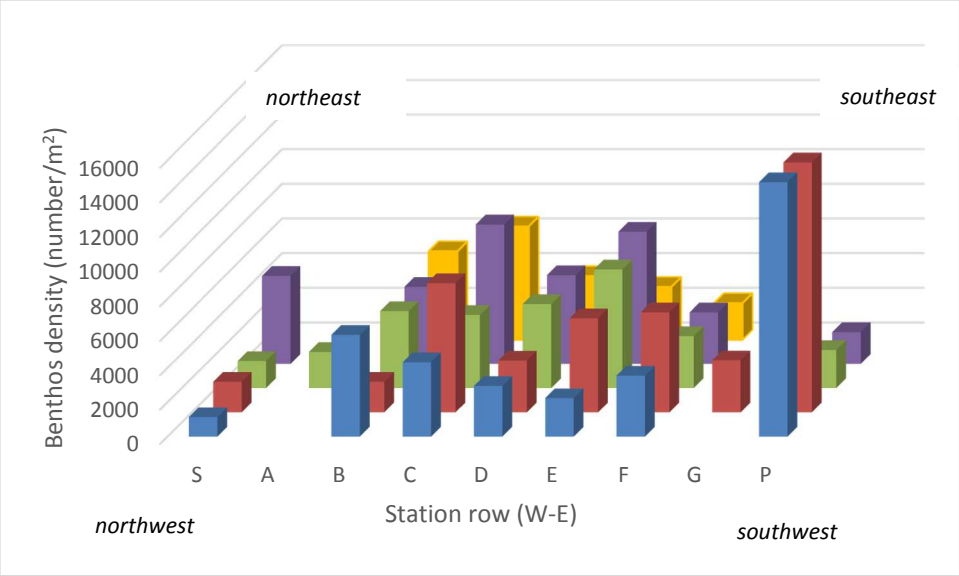


Figure 3-8: Densities of infauna at the 36 stations between Shag Point and Pipikaretu Point. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right); monitoring zone stations (rows A-G) (blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

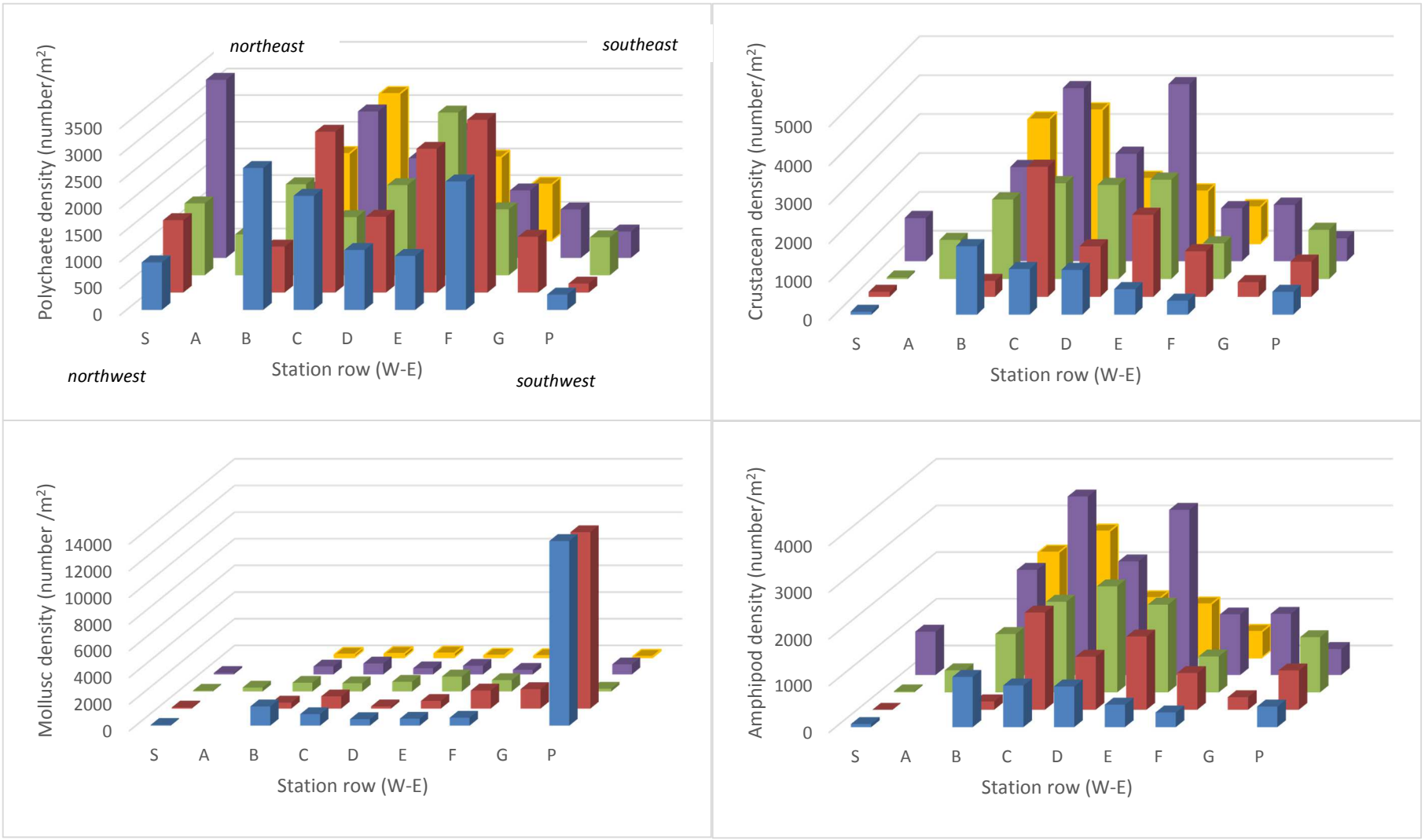


Figure 3-9: Densities of major infauna groups across the 36 stations off Blueskin Bay. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right); monitoring zone stations (rows A-G)(blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

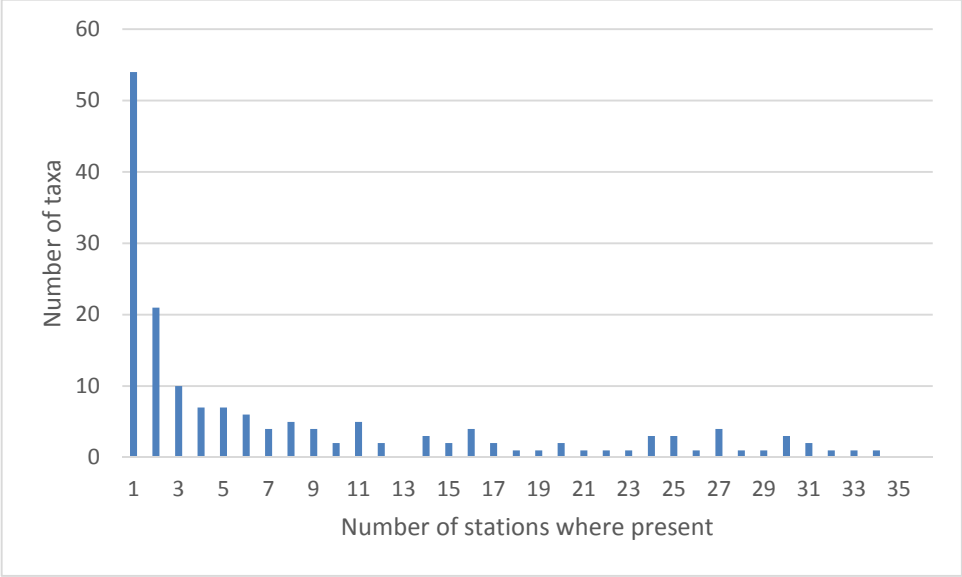


Figure 3-10: Infauna richness frequencies: numbers of taxa present at different numbers of stations between Shag Point and Pipikaretu Point.

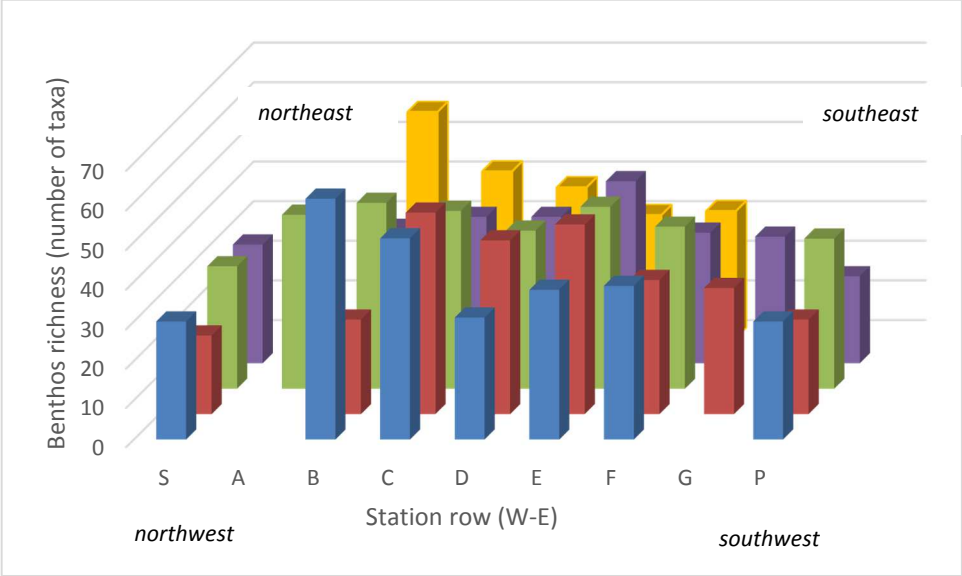


Figure 3-11: Total richness (number of taxa) of infauna at each station between Shag Point and Pipikaretu Point. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right) ; monitoring zone stations (rows A-G) (blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

Overall mean species' similarities within, and dissimilarities between each of these three areas (Primer's SIMPER analysis) are shown in Table 3-2. Mean species within similarities were highest (61.0%) within the larger monitoring zone and lowest at Shag Point (47.3%), with the Pipikaretu benthos intermediate in mean similarity (55.2%). Numbers of contributing species increased, whereas key species' contributions decreased with increasing mean similarity. Specifically, mean within similarities increased from 47% (Shag Point) to 55% (Pipikaretu Point) and to 61% in the monitoring zone as numbers of contributing species

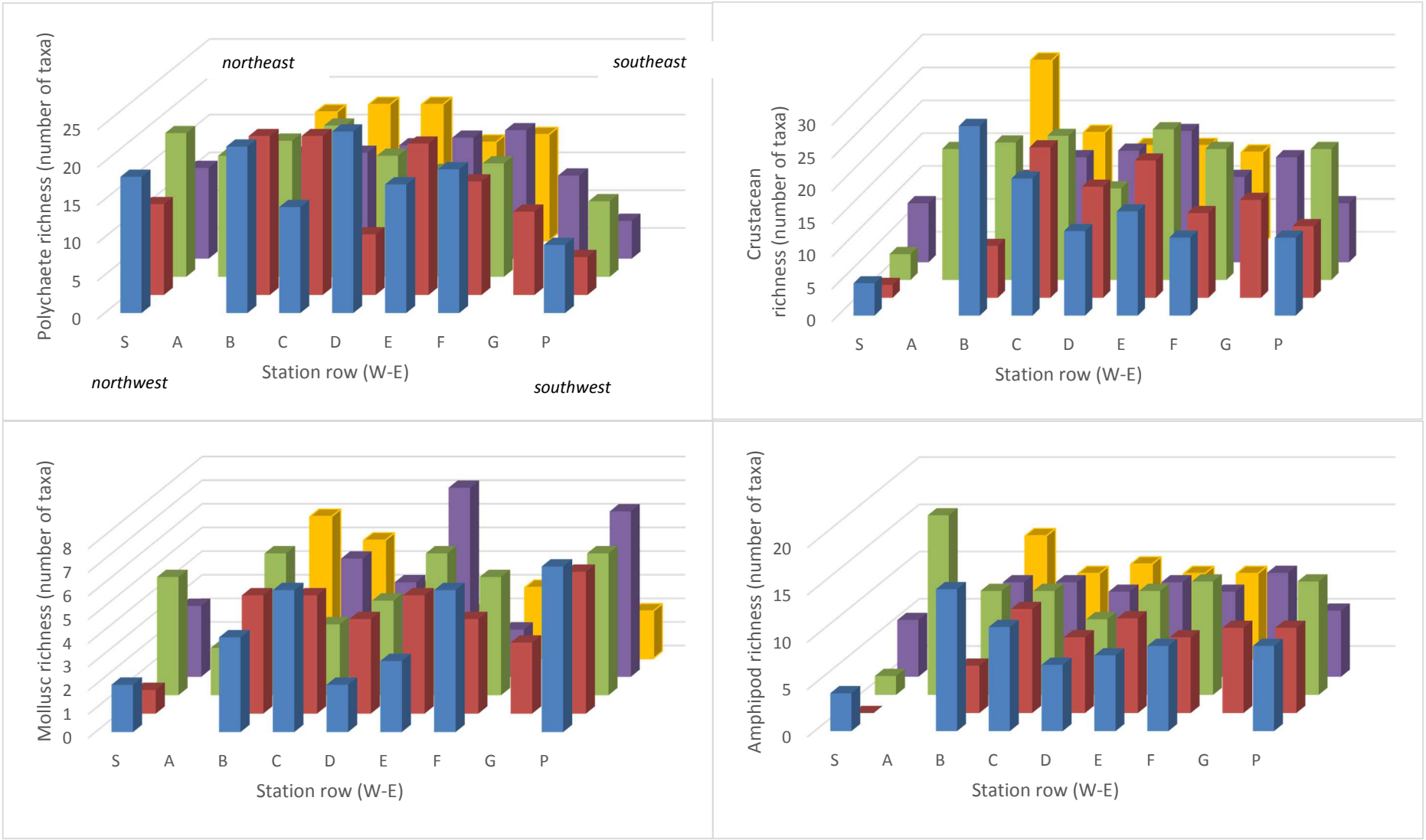


Figure 3-12: Richness (number of taxa) of major infauna groups across the 36 stations off Blueskin Bay. Stations arranged north (S, Shag Point controls, left) to south (P, Pipikaretu Point controls, right); monitoring zone stations (rows A-G), (blue bars, western line; brown, mid-west line; green, mid line stations; purple, mid-east line; yellow, eastern line).

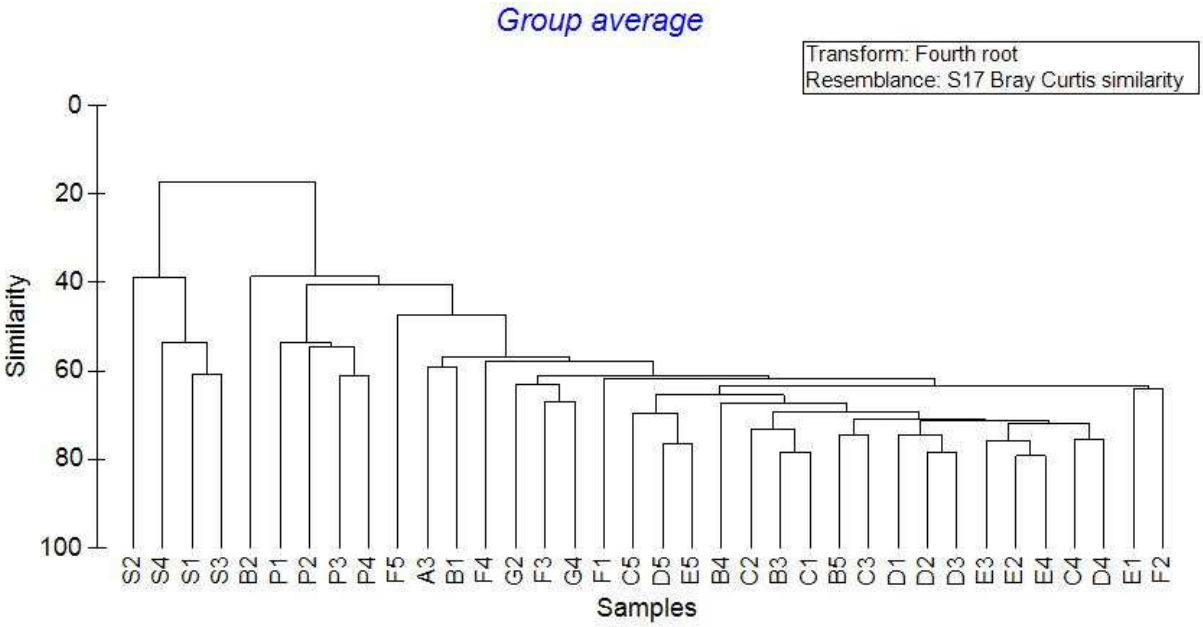


Figure 3-13: Cluster analysis dendrogram showing levels of similarity (%) between infauna at all sampling stations: Shag Point (S1-S4), monitoring zone off Blueskin Bay (A-G), Pipikaretu Point (P1-P4).

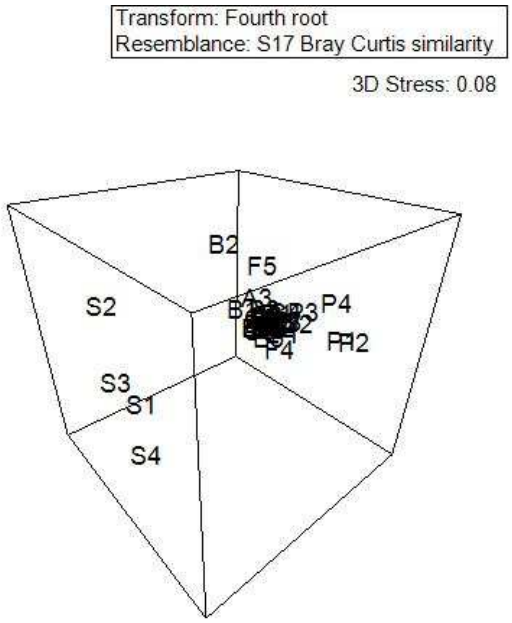


Figure 3-14: Multidimensional scaling plot of relationships between infauna at all sampling stations at Shag Point (S1-4), Pipikaretu Point (P1-P4) and the potential impact zone off Blueskin Bay.

Table 3-1: One-way ANOSIM (analysis of similarities) between stations grouped by area (Shag Point, Pipikaretu Point, monitoring zone off Blueskin Bay).

Differences between groupings	R statistic	Significance
All groups of stations	0.948	0.001
Monitoring zone, Pipikaretu Point	0.897	0.001
Monitoring zone, Shag Point	0.999	0.001
Pipikaretu Point, Shag Point	1.000	0.029

increased from 14 to 18 to 33, respectively, and contributions by the most influential species decreased from 16% to 7.8% to 6.7%, respectively (Table 3-2). These key species tend to be most abundant within their respective areas or their distributions are otherwise distinctive from those of others (Figure 3-15).

The percentage of very fine and fine sand in the sediment appears to be the main determinant of differences in benthos between stations (Table 3-3). Coarse sand-gravel also was strongly associated with the benthos, and together these two factors (not strictly independent) appear strongly correlated with the benthos. Adding more environmental factors did not increase the strength of correlations and, hence, variance explained. Note, this analysis (using Primer's BIOENV routine) is an indirect correlation that determines correlation between a faunal similarity matrix and an environmental factor similarity matrix. Thus, although the correlation is strong and ecologically logical, this analysis provides evidence for, rather than proving, a causal relationship.

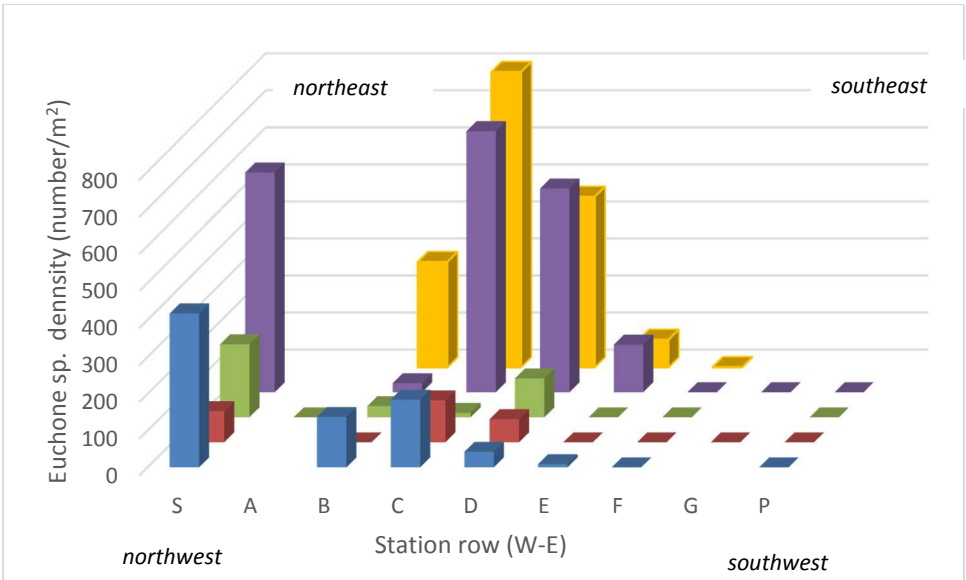
3.2.4 Elusive fauna

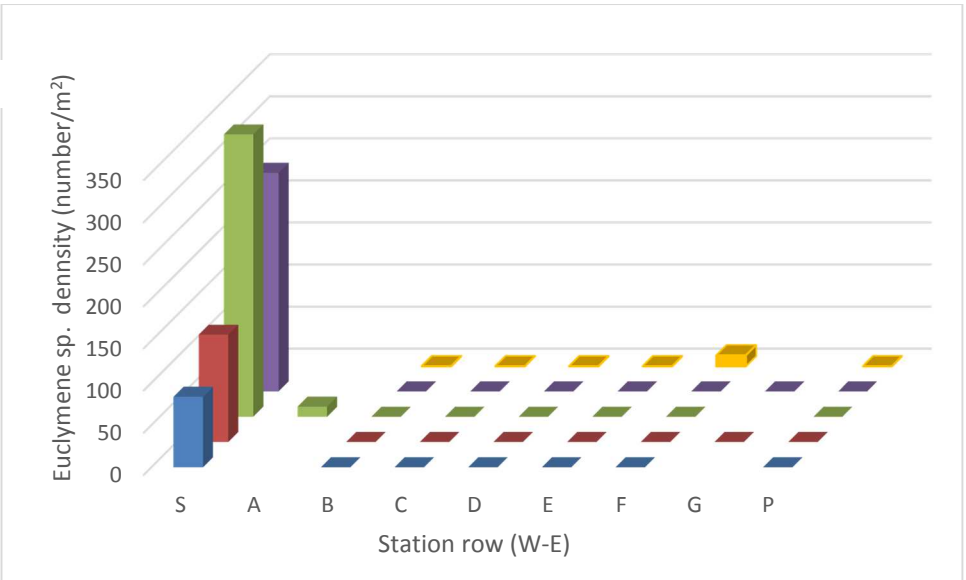
Surface structures resulting from infauna activities and the presence of some larger epifaunal species were assessed from seabed images for 17 central monitoring zone stations (note, includes two extra stations within the proposed disposal zone (A0)). Identifiable epifaunal species were too scarce for meaningful analysis, but the rippled sand bottom, frequently with shell fragments in ripple troughs, burrows of two sizes, constructed and maintained by benthic invertebrates, were obvious (e.g., Figure 3-16). These invertebrates (including the large mantis shrimp, *Heterosquilla* sp. cf. *tricarinata* (see Paavo 2011), were not captured via other sampling means. Horse mussels (*Atrina zelandica*) were reported from the area in a previous study (Willis et al. 2008) and, as large ecological architects that influence sediment characteristics and other species' abundances, some assessment of their densities was important. We found no evidence of horse mussels (*Atrina zelandica*) in these images or elsewhere in this study.

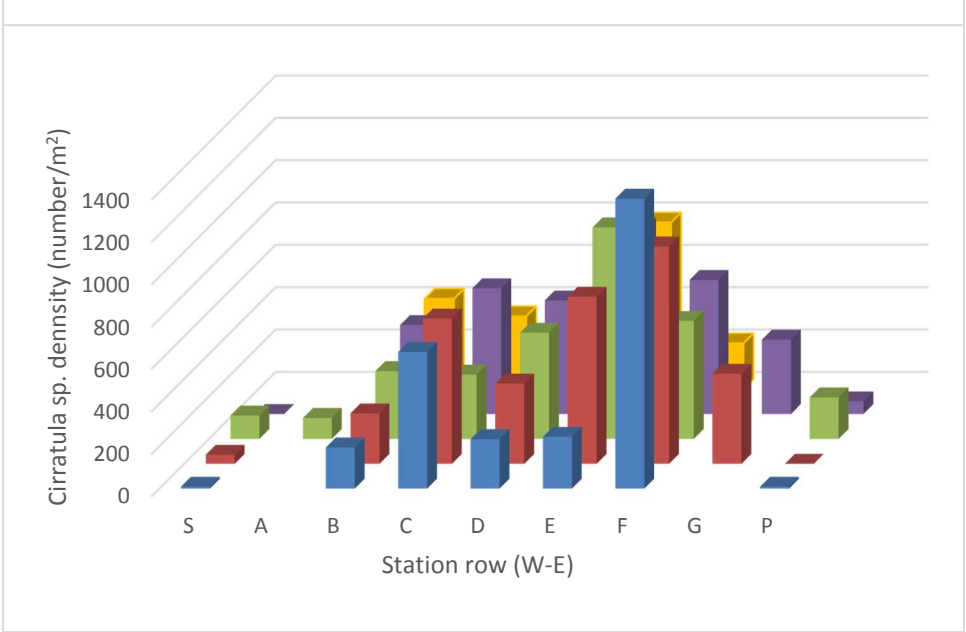
Densities of burrows (Figure 3-17) were generally low and varied with no clear pattern. There is some evidence of increased densities towards the middle of the monitoring zone for small burrows. Large burrows were less frequent, but more frequent at two central stations.

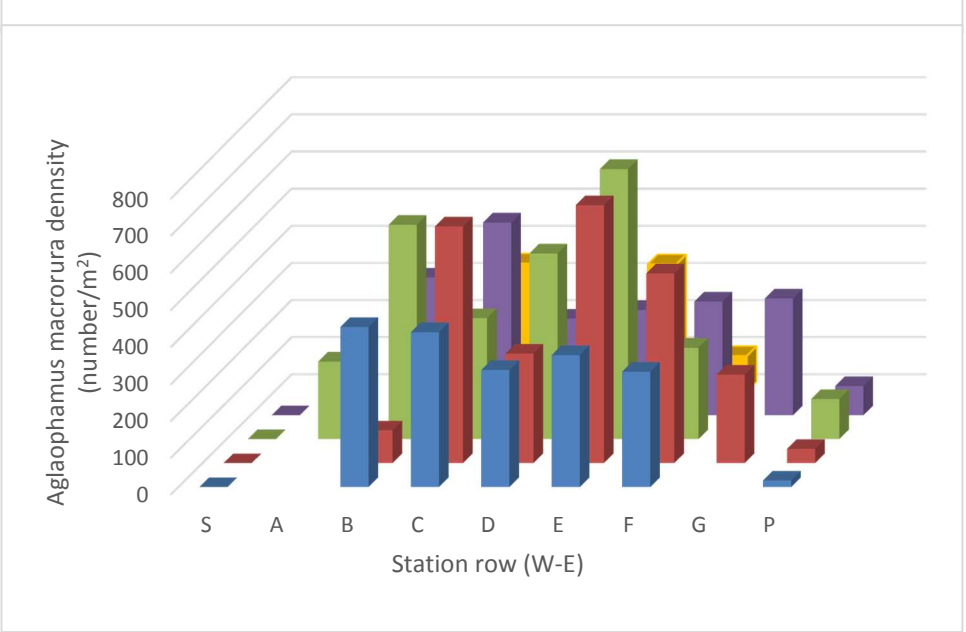
Table 3-2: Mean similarity between pairs of species contributing to the distinctiveness within and between each area, numbers of contributing species and contribution of most important species to average similarities within areas and to average dissimilarities between areas. Bold values indicate the three species contributing most; blanks signify very minor contributions.

	Similarity within area			Dissimilarity between areas		
Species	**Shag Point**	**Monitoring zone**	**Pipikaretu Point**	**Monitoring x Pipikertu**	**Monitoring x Shag**	**Pipikaretu x Shag**
Overall mean similarity/dissimilarity	47.3	61.0	55.2	60.0	82.1	87.7
Number of contributing species	14	33	18	61	61	46
Cirratula sp.	4.81	**6.73**	2.67	1.51	1.83	1.26
Aglaophamus macroura		**6.27**	6.17	0.90	**2.85**	2.34
Antisolarium egenum		**5.40**	5.57	1.11	**2.76**	2.13
Hippomedon sp.		3.28	**9.11**	0.81	1.80	3.77
Urothoidae		4.18	**8.37**	0.66	2.28	2.91
Glycymeris modesta			**7.82**	**2.90**		**3.88**
Euchone sp.	**15.99**	1.41		1.12	1.65	**3.55**
Euclymene sp.	**15.12**				**2.37**	3.18
Ampharetidae	**10.63**				1.93	2.48
Mactra ordinaria				**2.50**		**4.02**
Goniodiastylis sp.				**1.60**	2.15	


northeast
southeast
Euchone sp. dennsity (number/m²)
800
700
600
500
400
300
200
100
0
S A B C D E F G P
Station row (W-E)
northwest
southwest


Euclymene sp. dennsity (number/m²)
350
300
250
200
150
100
50
0
S A B C D E F G P
Station row (W-E)


Cirratula sp. dennsity (number/m²)
1400
1200
1000
800
600
400
200
0
S A B C D E F G P
Station row (W-E)


Aglaophamus macrorura dennsity (number/m²)
800
700
600
500
400
300
200
100
0
S A B C D E F G P
Station row (W-E)

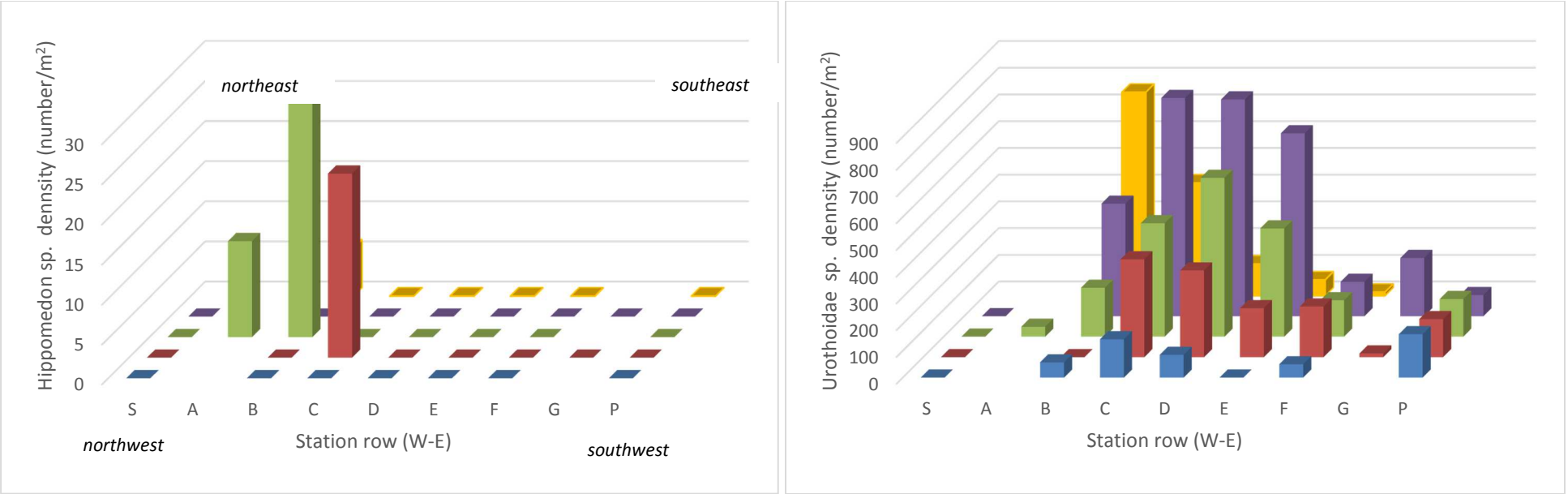


Figure 3-15: Densities of the two species contributing most to similarities of within areas (Table 3 2): *Euchone* sp. and *Euclymene* sp. (Shag Point (S)); *Cirratula* sp. and *Aglaophamus macrorura* (monitoring zone (stations A-G)); *Hippomedon* sp. and Urothoidae sp. (Pipikaretu Point (P)).

Table 3-3: Combinations of abiotic factors most strongly correlated with benthos distribution (Primer's BIOENV routine; Spearman correlation coefficients).

	Best variable combination		
Number of factors	**Best combination**	**Second best combination**	**Third best combination**
1	Very fine & fine sand 0.795	Coarse sand-gravel 0.623	Medium sand 0.446
2	Very fine-fine sand + coarse sand-gravel 0.842	Very fine-fine sand + organic content 0.796	Very fine-fine sand + medium sand 0.791
3	Very fine-fine sand + coarse sand-gravel + medium sand 0.829	Mud + coarse sand-gravel + medium sand 0.814	Very fine-fine sand + coarse sand-gravel + organic content 0.813

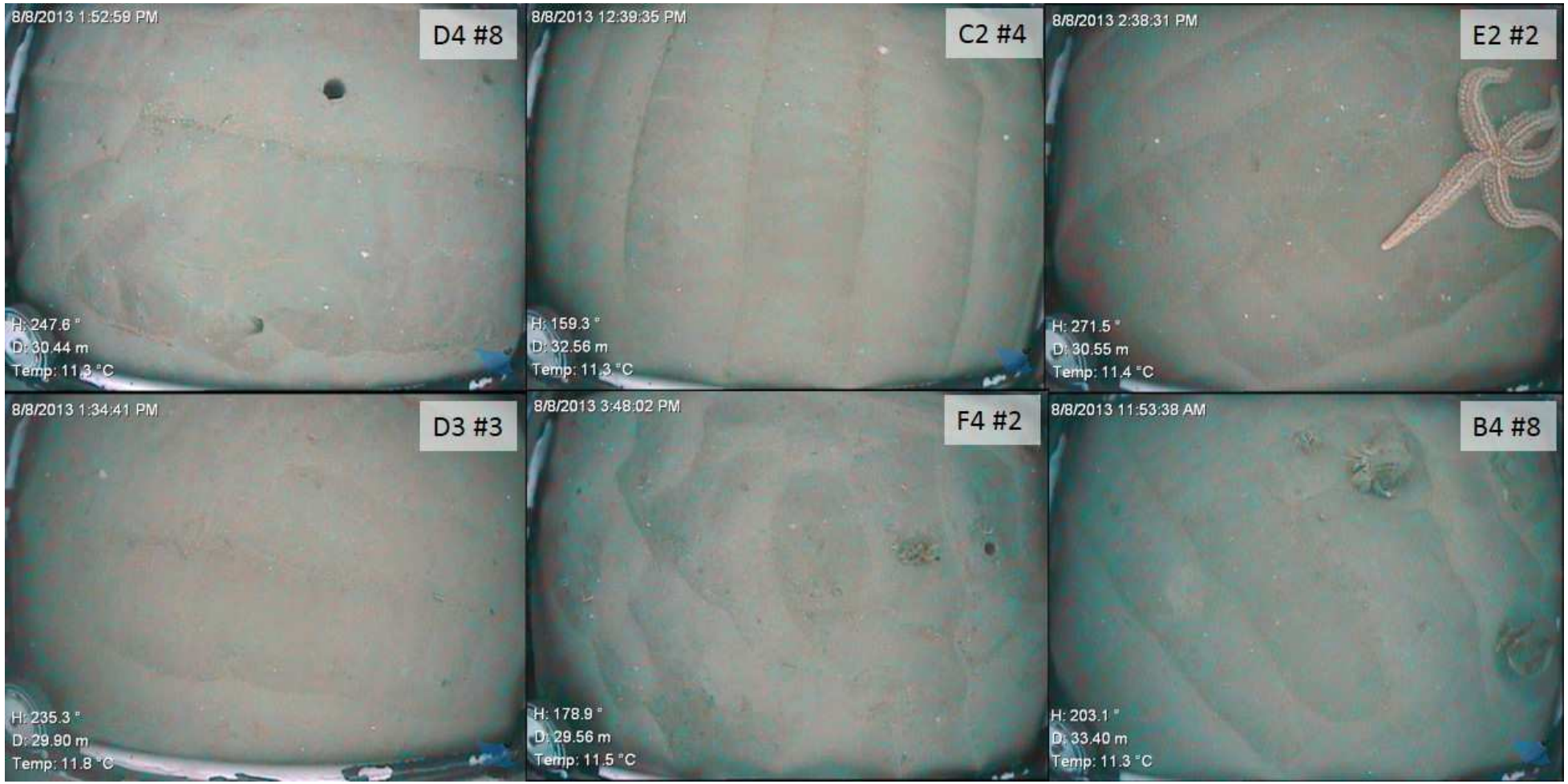


Figure 3-16: Images of bottom sediments from stations within the monitoring zone off Blueskin Bay, showing sediment heterogeneity, shell, ripples, epifauna and burrows.

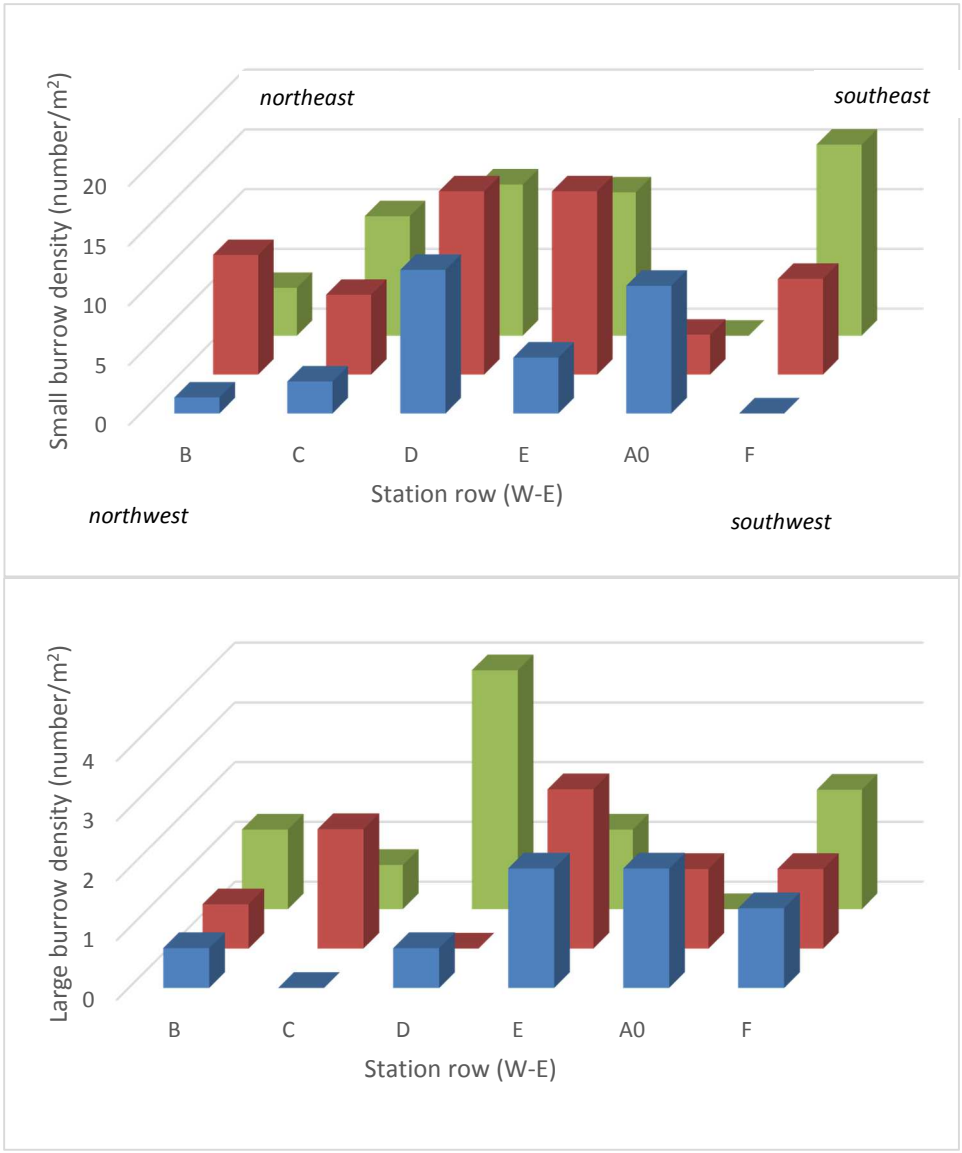


Figure 3-17: Mean (n = 10) densities of small (top) and large (bottom) burrows at central stations within the monitoring zone off Blueskin Bay.

3.3 Epifauna

Epifauna[2] was collected from all stations at both control areas, as well as 19 of the 28 monitoring zone stations (no fauna was taken in tows at the other stations). These yielded 95 species in total, adding 43 species taken only in the epibenthic sled and bringing the total species richness for the three areas to 209. Fifty-two of the species were also present within infaunal samples. Seventy-five of the epibenthic species occurred at just one or two stations. Individual sled tows generally yielded few individuals (range 1-200, mean = 10) and up to 17 species. Individual tows traversed 150-1140 m of bottom, accounting for some of the variability in abundance and richness.

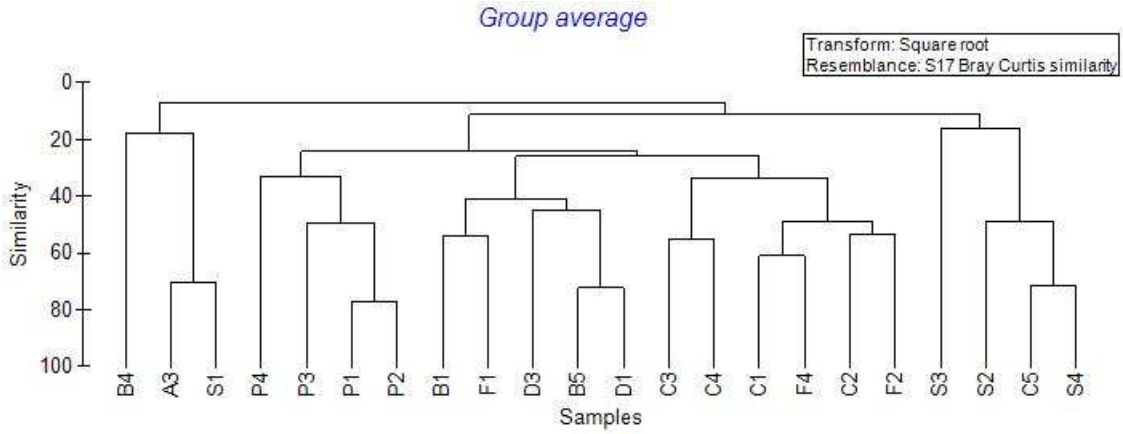


Figure 3-18: Cluster analysis dendrogram showing levels of similarity (%) between epifauna at all sampling stations: Shag Point (S1-S4), monitoring zone stations (A-F) and Pipikaretu Point (P1-P4). Stations with <4 individuals and species occurring at 1-2 stations only excluded.

Community analysis of key species (19 species present at >2 stations) at stations with at least four individuals present (22 stations) using abundances standardised to numbers per 500 m provided a loose clustering of stations (a similar arrangement with lower similarities resulted from using presence-absence data). The resulting grouping of stations (Figure 3-18) is broadly similar to that for the more rigorous infaunal benthos analysis (Figure 3-13). Pipikaretu Point stations comprised a distinct, albeit loose, cluster. Three Shag Point stations are grouped along with C5, whilst the fourth Shag Point station was widely separated. Most of the monitoring zone stations grouped at c. 30% similarity.

[2] As noted above, the practical distinction between infauna and epifauna is based on the gear used. Sampling of one habitat inevitably captures some species from the other because many species spend time in both habitats and the gear is not exclusive in its sampling. This means that many of the species counted here as epifauna also were included under infauna.

4 Discussion

Comparison with previous surveys

Previous surveys in the area each described the benthos, detailing dominant taxa and reviewing previous investigations. Willis et al. (2008) completed a more extensive survey of the sediments and benthos of Blueskin Bay extending from c. 7 to >30 m depth (November 2008), whereas Paavo's (2011) investigation more intensively surveyed disposal area A0 and a southern portion of the monitoring zone (May 2010). No detailed description is repeated here because this survey's primary objective was to establish a set of detailed baseline data for monitoring potential changes arising from the proposed dredge spoil discharge at A0. These data are held in NIWA's secure project data system and an electronic copy was provided to Port Otago Ltd, along with this report.

Sediment characteristics determined during the present survey confirm findings made by previous investigations in the area, notably Willis et al. (2008) and Paavo (2011). Most importantly, the sediments over the monitoring zone tend to be well sorted sands, indicating a hydrodynamically active environment that is likely to disperse finer sediments from any dredge spoil that extends beyond the disposal site. The increasing dominance by finer sediment fractions with increasing distance from shore noted here was consistent with Willis et al's findings, although that survey reported a more complex sedimentary picture further to seaward. There is no evidence of any surface or reef structures, other than consistent ripples that enhance habitat and species diversity.

Organic content of sediments within the monitoring zone were low (<2.0%), but three times higher at one Shag Point station. Results for the monitoring zone agreed closely with those reported previously (Willis et al. 2008), but the zone of elevated sediment organic content across at least the western part of the monitoring zone (see Willis et al's Figure 10) was not apparent. The elevated levels shown reflect c. 1% differences in organic content, perhaps within the margin of error for loss on ignition measurements.

This survey identified a total of 209 taxa, 166 found in infauna samples and 95 taken as epifauna, although inevitably there is no clear distinction between faunas found in these two inter-linked habitats. Thus, the total benthos is considerably richer than determined by Willis et al. (2008) and Paavo (2011), who reported 120 and 97 taxa, respectively. The same species dominated in all three surveys, with comparable densities. Previous total benthos density estimates were 800-8060/m^2 (Willis et al. 2008) and 391-2161/m^2 (Paavo 2011), compared with 1133-14,772/m^2 (median 4000-5000/m^2) in this survey. Both Willis et al. (2008) and Paavo (2011) used Ponar grabs, one sampling c. 0.05 m^2 (bite depth of c. 50 mm), whilst the latter's one sampled 0.087 m^2. In comparison, the anchor-box dredge sampled to c. 105 mm deep and samples taken during this survey were calculated (based on sample volume and depth) to cover c. 0.027-0.222 m^2 (only two samples were less than 0.05 m^2). This deeper penetration, the usually larger area sampled, plus the sampling of more diverse habitats (Shag and Pipikaretu points) probably explains the larger number of taxa sampled here. Additional factors conceivably contributing to this study's higher species number include analysing all fauna retained on 0.5 mm sieves and better taxonomic resolution of crustaceans. Each survey was completed in a different season, conceivably

contributing to the reported faunal differences, although many of the species either are perennial or their populations are relatively persistent between years.

The close similarities of benthos and sediments from this survey with those of the two previous investigations confirm the robustness and suitability of methods used for this baseline survey. This investigation used a small anchor-box dredge to quantify benthos following demonstrations of its utility for this purpose, especially on hard sand and gravelly bottoms (Probert.1984; Probert & Grove 1998; Fenwick 2002, 2004).

Analyses of sediments and benthos indicated stations B2 and F5 differed appreciably from others in the monitoring zone off Blueskin Bay. These stations had lowest total densities (1783-2092/m^2 cf. 2237-14,732/m^2) and amongst the lowest diversities (24-32 cf. 31-57 species). Sediments at station B2 differed from other monitoring zone stations in their high mud content (33% cf. 5-23%), whereas those at F5 differed in their high medium sand content (36% cf. 0-15%) and greater depth (41 m cf. 27-36 m). These differences in benthos and physical attributes, apparently driven by hydrodynamics, indicate real differences between these stations and others in the monitoring zone. They further indicate the natural heterogeneity in benthos over the wider area off Blueskin Bay.

The only evidence that the large, habitat modifying bivalve mollusc *Atrina zelandica* in the area comes from Willis et al.'s (2008) reported large shell fragment in one sample, plus poorly resolved bottom images with indistinct shapes interpreted as this shellfish. Paavo (2011) noted this, but found no further evidence of this species in the general area. The only further evidence located during this survey was a single large shell fragment from one station, even though we examined >16 images from each of these 17 stations. Overall, therefore, there is no evidence that *Atrina* populations occur in this area, certainly not in any abundance over the wider monitoring zone.

Control areas

This survey provides a robust baseline for comparison with any effects of the proposed increased dredge spoil within the disposal site at A0. Notably, the two proposed control areas, Shag Point to the north and Pipikaretu Point to the south, are identified as quite different and, thus, unsatisfactory to serve as controls. Water depths across the control areas are similar to those within the monitoring zone, but sediment characteristics differ appreciably. Pipikaretu differed from the other areas in its sediment having lower organic content and very fine to fine sand fractions, whilst medium sand was the dominant size fraction. At Shag Point, sediments were predominantly coarse sand-gravel, contained almost no very fine-fine sands. Sediments across the monitoring zone contained intermediate organic loads, mostly included >10% mud and >60% very fine-fine sands, and very little medium sand or coarse sand-gravel. These characteristics, along with the pronounced surface rippling and paucity of subsurface sedimentary structures indicate strong hydrodynamic forcing across all three areas.

These sedimentary (and, by inference, hydrodynamic) differences in benthic environments between the three areas are reflected within the benthic fauna. Groupings of stations based on sedimentary and faunal compositions via cluster analysis were remarkably consistent. In both analyses, Shag Point and Pipikaretu Point areas were separated from each other at low similarities and these differences were statistically significant. Clearly, benthic sediments, in

tandem with hydrodynamics, exert a strong influence on benthic community variation across the three areas and all stations.

More importantly for this investigation, neither the Shag Point area nor the Pipikaretu Point area is suitable as a control for assessing impacts of any dredge spoil disposal at area A0 (although they may be valuable for assessing any far-field impacts). Differences of their sediments and biodiversities from those of the monitoring zone are such that no meaningful, valid comparisons will be possible. Furthermore, no other site well clear of potential impacts from spoil deposition seems likely to replicate the monitoring zone's hydrodynamic and sedimentary conditions sufficiently to serve as meaningful controls. Instead, the array of stations over the monitoring zone seems ideal for monitoring and assessing any impacts. In particular, the grid provides coverage over a large area and includes five rows of stations oriented transverse to the predominant gradient (south-north currents and sediment movement; one row is presumed to be up-gradient of area A0) and five lines of stations transverse to depth or distance from shore, the second potentially significant biophysical gradient.

The lack of a suitable control area is less than ideal and not readily solved by choosing another site. This is best addressed by sampling a full row of five stations at A, instead of the single station A3 included in this survey, plus a full row up-gradient of A0 in row G (instead of the two stations G2 and G4). A sixth full comparison set of stations further down-gradient than the northern-most full row (B1-B5) is likely to enhance any impact-related differences with benthos closer to area A0. Expanding row G (presumed up-gradient) to five stations seems likely to further enhance the statistical resolution and power to detect any changes attributable to sediment disposal across these stations.

Sampling plan suitability for monitoring

Importantly, this study found no statistically significant differences in sediments and infauna north to south (i.e., between rows of stations at differing distances from A0), the most obvious test for any future impacts from sediment disposal at area A0. Sediments did change with distance from shore, with the two offshore lines of stations differing from the inshore ones. Similarly, the benthic infauna changed with distance from shore, but the difference was significant only between the most inshore (western) and offshore (eastern) lines of stations.

Based on these results, the sampling grid used in this investigation provides a robust baseline and framework for monitoring the effects of proposed future dredge spoil disposal at area A0. For the first monitoring re-survey, we strongly recommend expanding row A from one to five stations and row G from two to five stations enhance this sampling grid's statistical power and ability to detect and monitor change in the absence of meaningful control sites. There is no evidence suggesting that benthos at these additional stations differs appreciably from that at adjacent stations at this time (i.e., pre-impact). Thus, sampling them now would be ideal, but pragmatically unnecessary. We further recommend that sampling for repeat surveys should be completed at about the same time of year (July-August) to minimise any potential seasonal differences in benthos.

5 Acknowledgements

Special thanks to Mike Page who led the fieldwork for this project, and to Megan Carter, for assistance in the field, completing sample sorting, identifications of molluscs and various other invertebrates, operating the side-scan and scoring the seabed images. Both of their contributions were substantial and hugely appreciated. Derek Kater and Dan Cairney assisted with different components of the fieldwork, frequently under difficult conditions and with long hours. My thanks to you both. Martin Finnie (skipper of *Sirocco*) and his crewman worked hard to accommodate our needs and timetable, for which I am most grateful. Barry Greenfield did a fantastic job identifying and counting polychaete worms from the samples under a tight deadline. Thank you for your conscientious and efficient efforts, Barry.

Thanks also to Helena Campbell, Ken Grange and Don Morrisey. Helena completed the challenging task of grain size analysis, distinguishing silt and clay fractions via the mysteries of pipette analysis with her usual good humour and efficiency. Ken processed the side-scan data and reviewed the images. Don gave his precious time for a very helpful review of the draft report.

Mark James (Aquatic Environmental Sciences Ltd) and Lincoln Coe (Port Otago Ltd) provided several comments that helped to improve clarity and readability of the final version of this report. Thank you both.

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Appendix A Species identified.

			Number of stations	
Phylum	**Major group**	**Species identity**	**Infauna**	**Epifauna**
Annelida	Polychaeta	Aglaophamus macroura	32	1
Annelida	Polychaeta	Ampharetidae	4	0
Annelida	Polychaeta	Aonides trifida (oxycephala)	3	0
Annelida	Polychaeta	Aphroditidae	7	0
Annelida	Polychaeta	Aricidae sp.	16	0
Annelida	Polychaeta	Armandia maculata	27	1
Annelida	Polychaeta	Asychis theodori?	1	0
Annelida	Polychaeta	Bispira manicata	0	1
Annelida	Polychaeta	Boccardia accus	0	1
Annelida	Polychaeta	Capitella sp.	1	0
Annelida	Polychaeta	Ceratoneris sp.	1	0
Annelida	Polychaeta	Cirratula sp.	34	1
Annelida	Polychaeta	Diopatra sp.	2	0
Annelida	Polychaeta	Dispio sp.	1	0
Annelida	Polychaeta	Dorvillea sp.	0	1
Annelida	Polychaeta	Dorvillea sp. A	2	0
Annelida	Polychaeta	Dorvillidae sp. B	1	0
Annelida	Polychaeta	Euchone sp.	21	1
Annelida	Polychaeta	Euclymene sp.	6	1
Annelida	Polychaeta	Eunice sp. australis?	0	1
Annelida	Polychaeta	Exogoninane	1	0
Annelida	Polychaeta	Flabelligeridae sp. A	17	0
Annelida	Polychaeta	Flabelligeridae sp. B	2	0
Annelida	Polychaeta	Glycera americana	8	1
Annelida	Polychaeta	Glycera lamelliformis	1	0
Annelida	Polychaeta	Glyceridae	1	0
Annelida	Polychaeta	Glycinde trifida (Goniada emerita)	1	0
Annelida	Polychaeta	Goniada echinulata?	1	0
Annelida	Polychaeta	Goniada with stripes	6	2
Annelida	Polychaeta	Goniadidae	14	0
Annelida	Polychaeta	Harmothoe sp?	0	1
Annelida	Polychaeta	Hemipodus simplex	4	0
Annelida	Polychaeta	Heteromastus filiformis	15	0
Annelida	Polychaeta	Levinsenia gracilis	9	0
Annelida	Polychaeta	Lumbrineridae (Lumbriconereid) sp. A	22	1
Annelida	Polychaeta	Lumbrineridae (Lumbriconereid) sp. B	9	0
Annelida	Polychaeta	Magelona dakini	26	0
Annelida	Polychaeta	Micropodarke? sp.	3	0

Annelida	Polychaeta	Nereiphylla? sp.	3	0
Annelida	Polychaeta	Nereis falcaria	0	1
Annelida	Polychaeta	Nicon aestuarinensis	1	0
Annelida	Polychaeta	Notomastus zeylanicus	1	0
Annelida	Polychaeta	Ophiodromus angustifrons	1	0
Annelida	Polychaeta	Ophiodromus sp.	1	0
Annelida	Polychaeta	Owenia petersonae (fusiformis)	24	1
Annelida	Polychaeta	Paradoneis lyra	1	0
Annelida	Polychaeta	Paradoneris sp.	1	0
Annelida	Polychaeta	Perineris vallata	1	0
Annelida	Polychaeta	Philine aperta	1	0
Annelida	Polychaeta	Phyllodoce - Umida sp.	5	3
Annelida	Polychaeta	Phyllodoce sp.	1	0
Annelida	Polychaeta	Platynereis australis	0	2
Annelida	Polychaeta	Polydora sp.	8	0
Annelida	Polychaeta	Polydora tough tube	0	1
Annelida	Polychaeta	Pomatoceros sp.	0	1
Annelida	Polychaeta	Prionospio australiensis	29	1
Annelida	Polychaeta	Prionospio cirrifera (Minuspio)	2	0
Annelida	Polychaeta	Prionospio ehlersi?	7	0
Annelida	Polychaeta	Prionospio tridentata	24	1
Annelida	Polychaeta	Sabellidae	0	2
Annelida	Polychaeta	Scalibregmatidae	4	0
Annelida	Polychaeta	Scoloplos sp. ohili?	6	0
Annelida	Polychaeta	Sigalionidae - Labiosthenolepis sp.	17	0
Annelida	Polychaeta	Sosanides?	27	0
Annelida	Polychaeta	Sphaerosyllis semiverrucosa	4	1
Annelida	Polychaeta	Spiophanes cf. bombyx	30	1
Annelida	Polychaeta	Spirobidae	1	0
Annelida	Polychaeta	Terebellid - Streblostoma sp.	11	2
Annelida	Polychaeta	Travisia olens	18	0
Annelida	Polychaeta	Trichobranchidae	2	0
Annelida	Polychaeta	Trichomusculus barbatus	0	4
Annelida	Polychaeta	Trypanosyllis sp.	0	1
Annelida	Polychaeta	Trypanosyllis zebra?	1	0
Annelida	Polychaeta	Typosyllis sp.	1	1
Annelida	Polychaeta	Typosyllis? sp.	16	0
Brachiopoda	Brachiopoda	Notosaria nigricans	0	1
Bryozoa	Bryozoa	Bryozoa	7	1
Chordata	Ascidiacea	Cnemidocarpa drygalskii	0	1
Chordata	Ascidiacea	Didemnum lithostrotum	0	1

Chordata	Ascidiacea	Molgula sp.	0	3
Chordata	Ascidiacea	Pyura pilosa	0	2
Chordata	Ascidiacea	Pyura pulla	0	1
Cnidaria	Actinaria	Anemone (on hermit crab)	0	1
Cnidaria	Hydroida	Hydroid	6	1
Cnidaria	Zoantharia	Zoids (on hermit shell)	0	2
Crustacea	Amphipoda	Ampelisca sp.	24	0
Crustacea	Amphipoda	Amphilochus sp.	4	0
Crustacea	Amphipoda	Eusiridae	1	0
Crustacea	Amphipoda	Gammaropsis sp.	2	3
Crustacea	Amphipoda	Hippomedon sp.	30	2
Crustacea	Amphipoda	Ischyroceridae	8	1
Crustacea	Amphipoda	Lembos sp.	27	1
Crustacea	Amphipoda	Leucothoe sp.	2	0
Crustacea	Amphipoda	Liljeborgia sp.	25	1
Crustacea	Amphipoda	Limnoporeia sp. A	28	0
Crustacea	Amphipoda	Limnoporeia sp. B	1	0
Crustacea	Amphipoda	lysianassoid sp.	1	0
Crustacea	Amphipoda	Metaceradocus? sp.	0	1
Crustacea	Amphipoda	Oedicerotid sp.	25	0
Crustacea	Amphipoda	Otagia sp.	3	3
Crustacea	Amphipoda	Palabriophoxus? sp.	25	1
Crustacea	Amphipoda	Paracentromedon? sp.	3	0
Crustacea	Amphipoda	Paradexamine pacifica	3	0
Crustacea	Amphipoda	Parawaldeckia sp.	6	0
Crustacea	Amphipoda	Patuki sp.	5	3
Crustacea	Amphipoda	Peltopes sp.	2	0
Crustacea	Amphipoda	Photis nigrocula	5	4
Crustacea	Amphipoda	Phoxocepahlus regium	1	0
Crustacea	Amphipoda	phoxocephalid sp. A	1	0
Crustacea	Amphipoda	phoxocephalid sp. C	2	0
Crustacea	Amphipoda	Polycheria obtusa	0	4
Crustacea	Amphipoda	Protophoxus australis	31	1
Crustacea	Amphipoda	Ringaringa sp.	5	0
Crustacea	Amphipoda	Stegocephalidae	1	0
Crustacea	Amphipoda	Stenothoidae	2	0
Crustacea	Amphipoda	Syndexamine carinata	1	0
Crustacea	Amphipoda	Torridoharpinia hurleyi	11	1
Crustacea	Amphipoda	Urothoidae	30	0
Crustacea	Amphipoda	Waitangi sp.	9	1
Crustacea	Copepoda	copepod	2	0

Crustacea	Copepoda	Copepoda	0	1
Crustacea	Cumacea	Ceratocumidae	1	0
Crustacea	Cumacea	Colurostylis sp.	16	0
Crustacea	Cumacea	Cyclaspis sp.	20	0
Crustacea	Cumacea	Diastylis? sp.	12	0
Crustacea	Cumacea	Diastyplopsis sp.	8	0
Crustacea	Cumacea	Gynodiastylis sp.	27	1
Crustacea	Cumacea	Leucon sp.	1	0
Crustacea	Cumacea	Nannoniscidae	1	0
Crustacea	Decapoda	Callianassa?	1	0
Crustacea	Decapoda	hermit crabs	12	0
Crustacea	Decapoda	Nectocarcinus integrifrons	1	15
Crustacea	Decapoda	Notomoithrax sp.	0	5
Crustacea	Decapoda	Ogyrides sp.	10	1
Crustacea	Decapoda	Pagurus sp.	0	9
Crustacea	Decapoda	Periclimenes (Harpilius) sp.	0	1
Crustacea	Decapoda	Petrolisthes elongatus	0	4
Crustacea	Decapoda	Pontophilus sp.	9	13
Crustacea	Euphausiacea	Euphausid	2	1
Crustacea	Isopoda	Anthuridae	1	0
Crustacea	Isopoda	Eurydice sp.	1	0
Crustacea	Isopoda	Ianira sp.	2	0
Crustacea	Isopoda	Macrochiridothea uncinata	4	1
Crustacea	Isopoda	Munna sp.	10	0
Crustacea	Isopoda	Paramunna? serrata	14	0
Crustacea	Isopoda	Plakarthrium typicum	3	1
Crustacea	Isopoda	Sphaeromatidae	0	1
Crustacea	Mysdidacea	mysid	3	1
Crustacea	Nebaliacea	nebalian sp.	7	0
Crustacea	Ostracoda	Cypridinodes concentrica	20	0
Crustacea	Ostracoda	Diasterope grisea	15	0
Crustacea	Ostracoda	Leuroleberis sp.	11	0
Crustacea	Ostracoda	Myodocopida indet. gen. et sp.	1	0
Crustacea	Ostracoda	Podocopida sp.	1	0
Crustacea	Tanaidacea	tanaid sp. A	14	2
Crustacea	Tanaidacea	tanaid sp. B	5	0
Crustacea	Tanaidacea	tanaid sp. C	5	0
Crustacea	Thoracica	Elminius modestus (on hermit shell)	0	2
Echinodermata	Asteroidea	Patiriella sp.	0	1
Echinodermata	Asteroidea	Sclerasterias mollis	0	1
Echinodermata	Echinoidea	Evechinus chloroticus	0	5

Echinodermata	Holothuroidea	Neocucumella sp.	1	0
Echinodermata	Holothuroidea	Neothyonidium armatum	1	0
Echinodermata	Holothuroidea	Neothyonidium dearmatum	1	0
Echinodermata	Holothuroidea	Paracaudina sp. (juv)	2	0
Echinodermata	Holothuroidea	Trochodota dendyi	2	0
Echinodermata	Ophiuroidea	Amphiura sp. A	23	1
Echinodermata	Ophiuroidea	Amphiura sp. B	1	0
Echinodermata	Ophiuroidea	Ophiopeza cylindrica	1	0
Echinodermata	Ophiuroidea	Ophiopsammus maculata	1	3
Mollusca	Bivalve	Atrina zelandica	0	1
Mollusca	Bivalve	Dosina mactracea	0	1
Mollusca	Bivalve	Modiolus areolatus	0	3
Mollusca	Bivalve	Ostrea chilensis (on hermit crab)	0	1
Mollusca	Bivalvia	Dosinia sp. (juv)	2	0
Mollusca	Bivalvia	Gari sp.	5	2
Mollusca	Bivalvia	Glycymeris modesta (incl. juv)	6	5
Mollusca	Bivalvia	Hiatella sp (juv)	1	0
Mollusca	Bivalvia	Mactra ordinaria (incl. juv)	11	1
Mollusca	Bivalvia	Myodora sp.	3	0
Mollusca	Bivalvia	Nucula dunedinensis (incl. juv)	33	2
Mollusca	Bivalvia	Nuculana bellula	1	0
Mollusca	Bivalvia	Scalpomactra scalpellum	19	5
Mollusca	Bivalvia	Tawera spissa	16	1
Mollusca	Bivalvia	Zethalia zelandica	2	0
Mollusca	Gastropod	Austrofusus glans	0	1
Mollusca	Gastropod	Calliostoma sp.	0	1
Mollusca	Gastropod	Sigapatella novaezelandiae	0	1
Mollusca	Gastropod	Struthiolaria papulosa	0	2
Mollusca	Gastropoda	Alcithoe sp.	1	0
Mollusca	Gastropoda	Antisolarium egenum	31	1
Mollusca	Gastropoda	Eatonilla sp.	2	0
Mollusca	Gastropoda	Maoricolpus roseus	1	3
Mollusca	Gastropoda	Sigapatella tenuis	1	0
Mollusca	Gastropoda	Tanea zelandica	11	2
Mollusca	Gastropoda	Turbonilla sp.	2	0
Mollusca	Gastropoda	Zeacolpus pagoda	1	0
Mollusca	Gastropoda	Zeacolpus symetricus	1	2
Mollusca	Polyplacophora	Notoplax mariae	1	0
Mollusca	Polyplacophora	Parachiton sp.	1	0
Mollusca	Polyplacophora	Rhyssoplax canaliculata	2	0
Mollusca	Scaphopoda	Scaphapoda	1	0

Nematoda	Nematoda	Nematode	3	0
Nemertea	Nemertea	Nemertean	8	0
Porifera	Porifera	Sponge	2	1
Sipuncula	Sipuncula	Sipunculid sp.	4	0
Sipuncula	Sipuncula	Sipunculid sp. 2	0	1
Vertebrata	Pisces	Creediidae	0	1
Vertebrata	Pisces	Tripterygiidae	0	1

Appendix B Infaunal sampling location offsets.

Vessel navigational error resulted in infaunal samples taken at red points, instead of planned stations (green points). Offsets ranged between 218 and 820 m.