Appendix G:

NIWA Report on Effects of Dredge Disposal on Benthic Fauna in Offshore Disposal Ground

NIWA
Taihoro Nukurangi

Effects of Dredge Spoil Disposal on Benthic Fauna of the Eastland Port Offshore Disposal Ground

Prepared for Eastland Ports Limited

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Executive summary

A survey of 71 sites in and around the 'offshore disposal ground' in Poverty Bay was carried out for Eastland Ports Ltd to assess the impacts of dredge spoil disposal on benthic soft-sediment communities. The survey was carried out using the same methodologies as in previous surveys (Cole et al. 1996, 1999; Halliday et al. 2008).

- The offshore disposal site and surrounding areas were found to contain 79 distinct macrofaunal taxa. These taxa included 32 Polychaeta, 10 Bivalvia, 4 Gastropoda, 10 Amphipoda, 8 Eucarida, 3 Cumacea, 3 Ostracoda, 1 Holothurian and 8 other taxa.

- Statistical analysis of the fauna inside, outside and on the edge of the disposal area revealed no differences in taxonomic diversity, abundance, evenness or number of rare species present.

- Results from the present survey were comparable to those from the 1996 and 1999 surveys. Differences between the present survey and the 2008 survey were limited to the abundances of a few taxa (notably, two species of Cumacea).

- The sampling design was not optimal for detecting impacts from dredge spoil disposal, particularly given the physical conditions in this coastal setting. However, changes in community composition since 1996 have been minimal, and impacts of associated with the disposal of dredge spoil at this location do not appear to be significant.

1 Introduction

The Port of Gisborne is located on the east coast of New Zealand, and is a major component of the regional infrastructure. During the port company's 2013 financial year, over 2,000,000 tonnes of exports passed through the port, which caters for vessels up to 200 m in length drawing 10.2 m of water (Eastland Ports, 2014). The Turanganui River, which flows through the port has a high sediment load that, coupled with longshore drift, is causing infilling of more than 50,000 m^3 of sediment per year to the port and navigation channel (Mitchell, 2008). As a consequence, dredging of the port's main navigation channel and berthing area is required on a regular basis in order to maintain access for large vessels. Eastland Ports Ltd have a resource consent to dispose of dredged material in a 3 km^2 'offshore disposal ground' (Figure 1-1). The offshore disposal ground is located in approximately 20 m of water in Poverty Bay, in an area of mainly sandy muds with high wave energy. In addition, Poverty Bay receives sediments discharged from the nearby Waipaoa River, which is estimated to deliver 15,000,000 tonnes per annum to the area (GDC, 2014). Cole et al. (1996) suggested that because of these features, any fauna present in the offshore disposal ground (ODG) would be able to cope with high levels of disturbance.

Dredging has been described as one of the largest (localised) anthropogenic impacts on the seafloor (Lohrer and Wetz, 2003; Bolam, 2011; Bolam et al. 2011). The ecological impacts of dredge material deposition are generally perceived to be negative, however previous studies have shown the results to be highly context dependent (Bolam et al. 2011). For example, impacts can depend on the local physical conditions at the disposal site, the frequency and quantity of dredge material delivery, the types of sediments deposited (muds vs sands, contaminated vs uncontaminated), and the sensitivities of the resident organisms. Some organisms will be better adapted to frequent burial and high rates of bedload transport than others. If dredge spoil disposal is having marked effects, there will be changes in the abundances and types of species present when moving from the centre of the disposal area to distances further away.

In September 2013, Eastland Ports Ltd contracted the National Institute of Water and Atmospheric Research Ltd (NIWA) to carry out a survey of the Poverty Bay offshore disposal ground to assess the impacts of dredge spoil disposal on the benthic macrofauna. This follows on from previous surveys of the area (Cole et al. 1996, 1999; Halliday et al. 2008). The studies carried out in 1996 and 1999 occurred before the dumping of dredge spoils began at the outer disposal ground; dredge spoil disposal began in 2003 (Mitchell, 2008).

In order to maintain as much continuity as possible with previous surveys in the area, the same basic sampling design was employed. This involved collecting benthic macrofaunal samples at numerous stations inside the dredge disposal area (a trapezoid shaped polygon of 3 km^2), along the edges of the polygon, and outside of it (Figure 1-1). As discussed by Halliday et al. (2008), the positioning of the samples in this way is not the most sensitive design for detecting the environmental effects of the spoil deposal activities, mainly because all of the 'outer' samples are less than 1 km from the edge of the disposal ground. Given the hydrodynamics in the area, fine sediments associated with the dredge spoils may be dispersed well beyond this distance, which would leave the design without good controls (i.e., sites unequivocally unaffected by dredging).

According to Halliday et al. (2008), effects of dredge spoil disposal may manifest themselves as:

- Lower macrofaunal diversity in the samples collected inside the disposal area than outside.
- Higher macrofaunal richness outside the disposal area, including higher numbers of long-lived taxa and sensitive species.
- Fewer rare taxa inside the disposal area, as their low numbers may make their populations more vulnerable.
- Increased density of a few opportunistic, fast-reproducing taxa inside the disposal area. This may lead to higher total macrofaunal abundance inside the disposal area.
- Greater variation in macrofaunal density inside the disposal area than outside of it (as the spoils and their effects are patchily distributed in space and time).

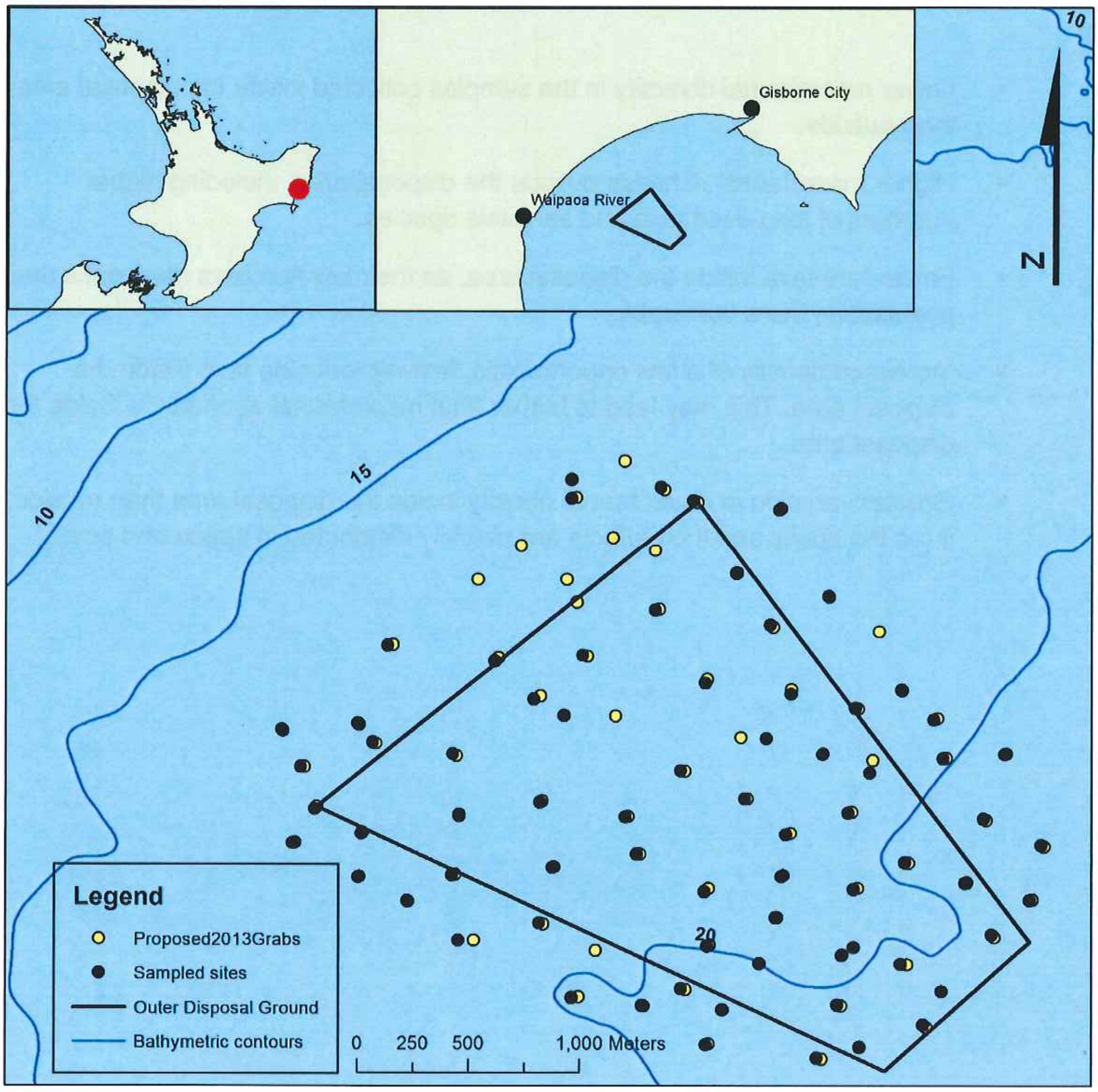

Figure 1-1: Location of offshore disposal area and sampling points (proposed and collected).

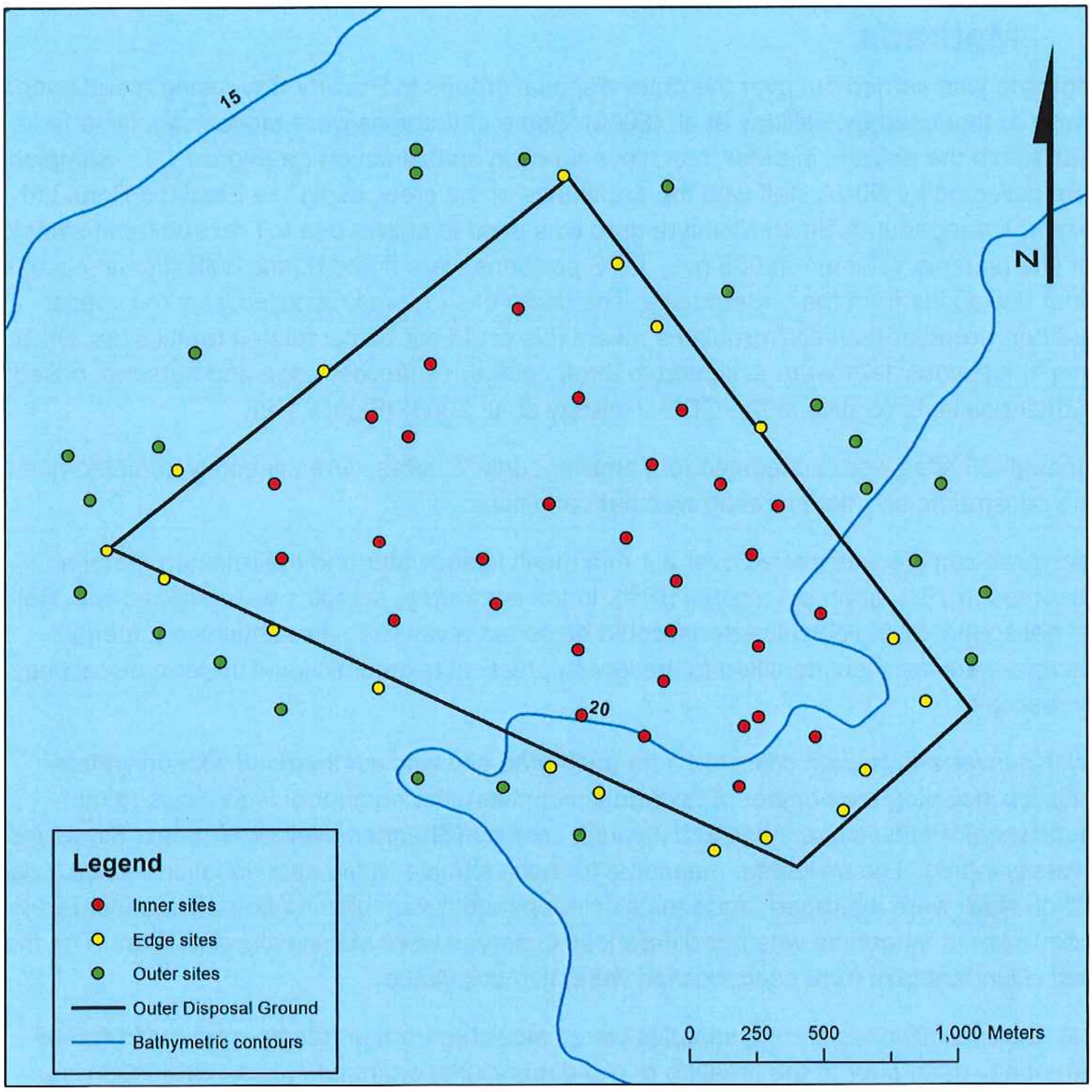

Figure 1-2: Inner, edge and outer sampling sites.

2 Methods

Sampling was carried out over the outer disposal ground in Poverty Bay, using a grid pattern similar to that used by Halliday et al. (2008). Some of the sites were moved slightly to fill in gaps within the pattern, in order to achieve an even spatial coverage (Figure 1-1). Samples were collected by NIWA staff with the assistance of the crew, using the Eastland Ports Ltd vessel, Turanganui. A Smith-McIntyre grab was used to collect one 0.1 m^2 sediment sample per site (sample volume = 0.005 m^3). GPS positions were noted during collection in case of minor deviations from the targeted site. The depth of sites was recorded from the vessel sounder, however technical problems meant this could not be completed for all sites. Grab sample locations 1-71 were assigned to three categories (inside, edge and outside), based on their positions relative to the ODG (Halliday et al. 2008) (Figure 1-2).

Although 80 sites were scheduled for sampling, only 71 sites were ultimately sampled due to time constraints and deteriorating weather conditions.

Each grab sample was sieved over a 1 mm mesh in seawater and the retained material preserved in 70% isopropyl alcohol (IPA). In the laboratory, samples were stained with Rose Bengal so that all biological material could be sorted away from the remaining material. Macrofauna were then identified to the lowest practical taxonomic level under a dissecting microscope.

Benthic invertebrate data collected from each grab site was summarised with univariate statistics including the number of taxa (total richness), the number of individuals (total abundance), Pielou's evenness and diversity metrics (Shannon-Weiner *H'* index, Simpsons Diversity index). The univariate measures for each sample within each location (inside, edge and outside) were averaged, and t-tests of independent variables (unequal variances) were undertaken to determine whether differences observed were statistically significant. The five most abundant taxa from each location were also calculated.

Bray-Curtis similarities among samples were calculated from untransformed macrofaunal community data, prior to the creation of two-dimensional ordination plots. Ordination is a technique used to visualise the relative similarities and differences among samples containing multiple species in varying abundances, with the samples positioned nearest to each other in ordination spaces being the most similar to each other. Ordination of the multivariate macrofaunal community data was performed using non-metric multidimensional scaling (MDS, PRIMER v 6) to compare the community composition of samples collected inside, on the edge of and outside the disposal area (Clarke 1993). Additionally, various transformations of the raw data were used (e.g., log(x+1), square root and conversion to presence/absence) in an attempt produce a clearer differentiation of the data in the ordination plots. However stress values of >0.2 where obtained for all transformations, indicating that the ordinations did not represent the data in two dimensions better than the untransformed data did. The ANOSIM procedure was used to determine the statistical significance of the differences between sampling areas (inner, edge, outer), and the SIMPER procedure was used to identify the taxa primarily involved in driving the discrimination between areas.

Rare taxa are likely to be excluded from ecologically stressed environments, due to their low resilience and intolerance to disturbance, for example increased levels of fine sediments (Ellingsen et al. 2007). The number of rare taxa within each grab sample were calculated using two methods:

1. The mean number of taxa represented by ≤ 1 individual per grab was calculated for each location (i.e., inside, edge and outside the disposal area).
2. The number of taxa occurring in only one grab per area was calculated. This was completed on 18 randomly chosen grab samples from within each location to prevent a bias from the uneven number of grabs per location.

Maps displaying interpolated abundances of organisms relative to the disposal area were created in GIS using the ArcGIS application with the 'Spatial Analyst' extension. Data were interpolated using the Tension Spline method, with 12 points and an analysis mask as per Halliday et al. (2008). The results were visually assessed for comparison with previous data. The same data were also used to produce maps showing each grab as variably sized points based on the numbers of individuals collected. This produced clearer results, as the interpolations can be distorted by points that occur close together but contain large differences for the selected values.

3 Results

3.1 Spatial distribution of fauna

The offshore disposal area and surrounding areas were found to contain a moderate diversity of macrofaunal organisms >1 mm. Of the 79 taxa identified, 32 were polychaetes, 8 were crabs and shrimp, 10 were bivalves, 1 was a holothurian, and 4 were gastropods. There were also a variety of crustaceans, including 10 amphipods, 3 cumaceans, and 3 ostracods. There were 8 'others' (Table 3-1).

Table 3-1: Taxa found in the September 2013 survey of Eastland Ports Ltd offshore dredge disposal ground. Mean number of individuals per grab (± standard error) inside, on the edge and outside the disposal area.

	Taxa	Mean density/grab Inside	Mean density/grab Edge	Mean density/grab Outside
Annelida				
Polychaete	*Aglaophamus* sp.	0.67 (± 0.38)	0.78 (± 0.20)	1.22 (± 0.26)
	Ampharetidae	0.40 (± 0.22)	0.22 (± 0.10)	0.57 (± 0.26)
	Aphroditidae	0.03 (± 0.03)	0.06 (± 0.06)	0.00
	Aricidea sp	0.10 (± 0.06)	0.00	0.13 (± 0.13)
	Cirratulidae	0.03 (± 0.03)	0.00	0.13 (± 0.07)
	Cossura consimilis	0.17 (± 0.09)	0.00	0.04 (± 0.04)
	Cossura sp.	0.00	0.06 (± 0.06)	0.04 (± 0.04)
	Flabelligeridae	0.17 (± 0.07)	0.00	0.09 (± 0.06)
	Glycera lamellipodia	0.03 (± 0.03)	0.00	0.00
	Glycera sp.	0.23 (± 0.08)	0.11 (± 0.08)	0.13 (± 0.07)
	Glycinde sp. (no chevrons)	0.23 (± 0.09)	0.22 (± 0.10)	0.26 (± 0.12)
	Goniada sp. (has chevrons)	0.47 (± 0.17)	0.17 (± 0.09)	0.74 (± 0.20)
	Heteromastus filiformis	0.63 (± 0.31)	0.50 (± 0.22)	0.78 (± 0.22)
	Lumbrinereis sp.	0.03 (± 0.03)	0.00	0.00
	Macroclymenella stewartensis	0.00	0.00	0.04 (± 0.04)
	Magelona dakini	0.07 (± 0.05)	0.17 (± 0.09)	0.30 (± 0.14)
	Nereiphylla sp.	0.03 (± 0.03)	0.00	0.00
	Notomastus sp.	0.00	0.00	0.04 (± 0.04)
	Onuphis aucklandensis	0.20 (± 0.09)	0.28 (± 0.11)	0.17 (± 0.08)
	Owenia petersenae (fusiformis)	0.07 (± 0.05)	0.00	0.13 (± 0.07)
	Oxydromus angustifrons	0.03 (± 0.03)	0.00	0.00
	Paraprionospio sp.	27.43 (± 8.77)	10.83 (± 4.94)	9.39 (± 3.12)
	Pectinaria australis	0.03 (± 0.03)	0.00	0.00
	Prionospio aucklandica	0.00	0.00	0.26 (± 0.27)
	Prionospio australiensis	0.70 (± 0.33)	1.39 (± 0.61)	0.26 (± 0.16)
	Scolecolepides benhami	0.00	0.06 (± 0.06)	0.00

	Taxa	Mean density/grab Inside	Mean density/grab Edge	Mean density/grab Outside
	Scoloplos sp.	0.13 (± 0.06)	0.00	0.39 (± 0.22)
	Sigalion oviger	0.43 (± 0.15)	0.06 (± 0.06)	0.17 (± 0.08)
	Sigalionidae (median antennae)	0.90 (± 0.21)	0.39 (± 0.15)	0.52 (± 0.19)
	Sigalionidae (no median antennae)	0.50 (± 0.21)	0.44 (± 0.15)	0.26 (± 0.15)
	Spionidae sp.	0.00	0.44 (± 0.30)	0.13 (± 0.13)
	Spiophanes sp.	0.67 (± 0.47)	0.11 (± 0.08)	0.04 (± 0.04)
Crustacea				
Amphipod	*Ampelisca* sp.	0.00	0.39 (± 0.40)	0.04 (± 0.04)
	Gammaropsis spp.	0.00	0.06 (± 0.06)	0.04 (± 0.04)
	Liljeborgia sp.	0.00	0.00	0.04 (± 0.04)
	Maera sp.	0.43 (± 0.19)	0.39 (± 0.21)	0.43 (± 0.18)
	Methalimedon sp.	0.30 (± 0.12)	0.11 (± 0.08)	0.13 (± 0.07)
	Photidae	0.83 (± 0.35)	0.94 (± 0.32)	0.35 (± 0.18)
	Phoxocephalidae	0.00	0.06 (± 0.06)	0.00
	Torridoharpinia hurleyi	1.87 (± 0.33)	0.89 (± 0.37)	2.57 (± 0.73)
	Urothoidae	0.47 (± 0.18)	0.17 (± 0.09)	0.13 (± 0.07)
	Waitangi brevirostris	0.03 (± 0.03)	0.00	0.00
Crab	*Amarinus lacustris*	0.00	0.06 (± 0.06)	0.00
	Hymenosoma depressum	0.30 (± 0.16)	0.33 (± 0.20)	0.30 (± 0.16)
	Nectocarcinus sp.	0.07 (± 0.05)	0.06 (± 0.06)	0.04 (± 0.04)
	Neommatocarcinus huttoni	0.90 (± 0.29)	0.56 (± 0.17)	1.35 (± 0.36)
	Pinnotheres novaezelandiae	0.07 (± 0.05)	0.00	0.00
Shrimp	Mysidacea	0.73 (± 0.24)	0.61 (± 0.31)	0.61 (± 0.15)
	Ogyrides delli	0.50 (± 0.37)	0.28 (± 0.14)	0.17 (± 0.10)
	Philocheras australis	0.07 (± 0.05)	0.00	0.00
Cumacean	*Cyclaspis argus*	4.87 (± 1.79)	3.17 (± 0.88)	1.13 (± 0.37)
	Cyclaspis similis	0.00	0.06 (± 0.06)	0.00
	Diastylopsis crassior	88.97 (± 24.47)	87.83 (± 31.06)	130.52 (± 41.65)
Ostracod	*Diasterope grisea* (elongated ostrocod)	0.00	0.06 (± 0.06)	0.09 (± 0.06)
	Ostrocoda sp. #1 (smooth, round)	0.73 (± 0.18)	0.83 (± 0.29)	0.96 (± 0.31)
	Ostrocoda sp. #2 (humpy, ovate)	0.60 (± 0.23)	0.50 (± 0.19)	0.22 (± 0.11)
Echinodermata				
Holothurian	*Paracaudina chilensis* (coriacea?)	0.57 (± 0.16)	0.56 (± 0.21)	0.78 (± 0.17)
Mollusca				
Bivalve	*Arthritica bifurca*	0.07 (± 0.07)	0.00	0.04 (± 0.04)
	Dosinia anus	1.17 (± 0.31)	2.56 (± 1.03)	1.87 (± 0.54)

	Taxa	**Mean density/grab Inside**	**Mean density/grab Edge**	**Mean density/grab Outside**
	Mactra ordinaria	19.23 (± 4.73)	28.44 (± 20.20)	10.39 (± 4.18)
	Myllitella vivens	0.40 (± 0.17)	0.22 (± 0.10)	0.09 (± 0.06)
	Nucula nitidula	0.17 (± 0.09)	0.17 (± 0.12)	1.09 (± 0.45)
	Panopea sp.	0.07 (± 0.05)	0.00	0.00
	Rexithaerus (Tellina) spenceri	0.87 (± 0.21)	0.33 (± 0.17)	0.35 (± 0.17)
	Serratina charlottae	0.20 (± 0.09)	0.00	0.00
	Soletellina siliquens	0.00	0.06 (± 0.06)	0.00
	Theora lubrica	0.00	0.00	0.04 (± 0.04)
Gastropod	*Amalda australis*	0.00	0.06 (± 0.06)	0.09 (± 0.06)
	Philine sp.	0.03 (± 0.03)	0.00	0.04 (± 0.04)
	Rissoidae	0.00	0.06 (± 0.06)	0.00
	Xymene plebeius	0.00	0.06 (± 0.06)	0.00
Other	*Amphiura* sp. (Ophuroidea)	1.80 (± 0.43)	2.83 (± 1.06)	4.13 (± 0.1.32)
	Anthuroidea (Isopoda)	0.03 (± 0.03)	0.00	0.00
	Chaetognatha (arrow worm)	0.07 (± 0.07)	0.06 (± 0.06)	0.00
	Cirolanidae (Isopoda)	0.00	0.00	0.09 (± 0.06)
	Echiura (spoon worm)	0.00	0.06 (± 0.06)	0.00
	Edwardsia sp. (Cnidaria)	0.00	0.06 (± 0.06)	0.00
	Natatolana sp. (Isopoda)	0.27 (± 0.13)	0.00	0.30 (± 0.23)
	Nemertea (unsegmented worm)	1.07 (± 0.29)	0.83 (± 0.24)	0.52 (± 0.20)

Total macrofaunal abundance varied from 10 individuals to 805 individuals per 0.1 m^2 grab sample (Figure 3-1). The variance was predominantly caused by one species (the cumacean *Diastylopsis crassior*) that occurred in very high abundances in some areas (see Figure 3-2). Twenty of the 71 grabs contained over 200 organisms and for these, on average, *D. crassior* comprised 69% of the total abundance. Large total abundances occurred both inside and outside of the disposal area, with no obvious spatial pattern (Figure 3-1). Large differences in total abundance often occurred in grabs located close together. There appeared to be moderate diversity across the whole of the sampled area, both inside and outside the ODG.

The number of taxa did not appear to correspond with the inside, edge or outside the ODG and differences observed between areas were not significant ($p = >0.05$) (Figure 3-3 and Figure 3-4). This differs from Halliday (2008), where a statistical difference between the macrofaunal density inside and outside the ODG was observed.

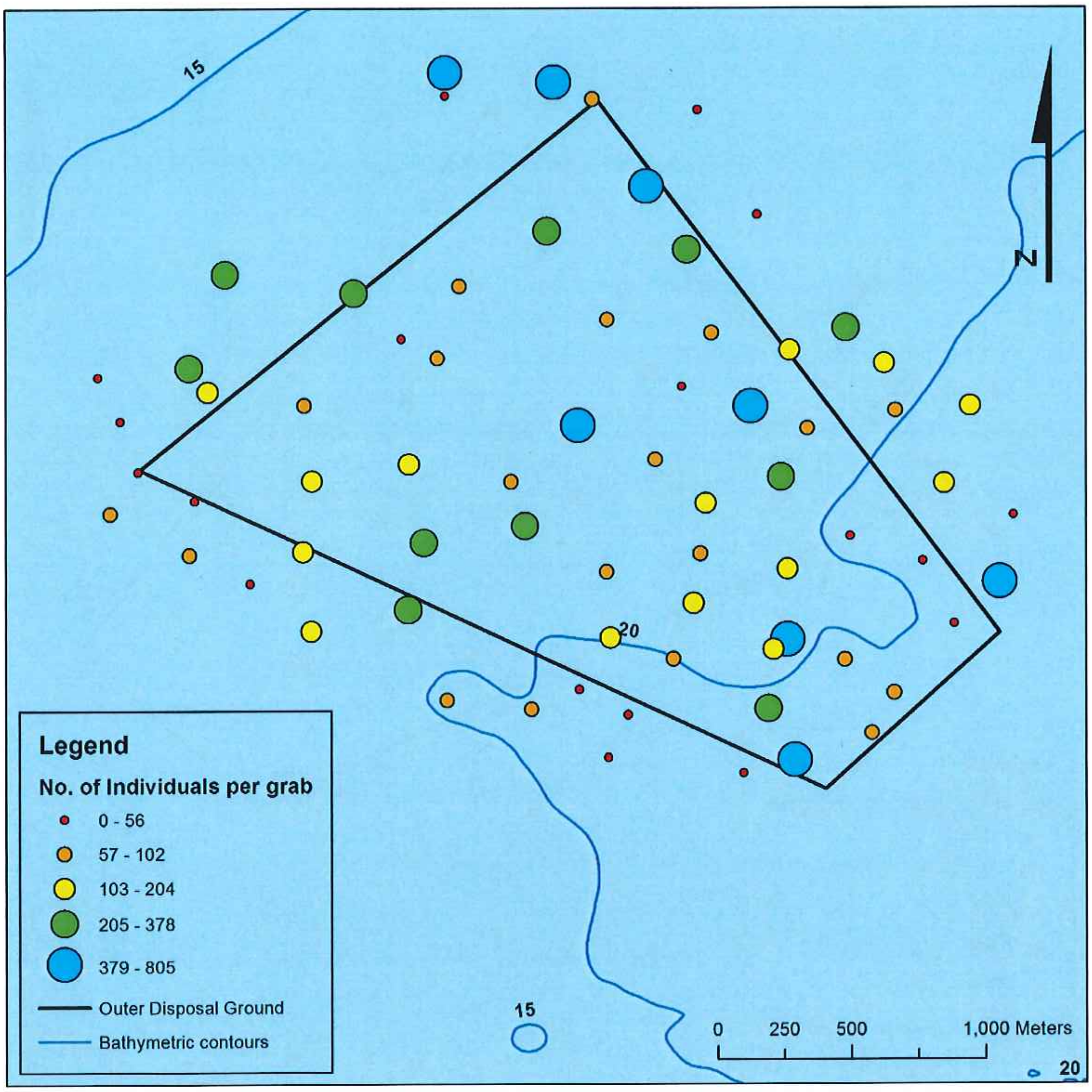

Figure 3-1: Macrofaunal total abundance per grab over the sampling area.

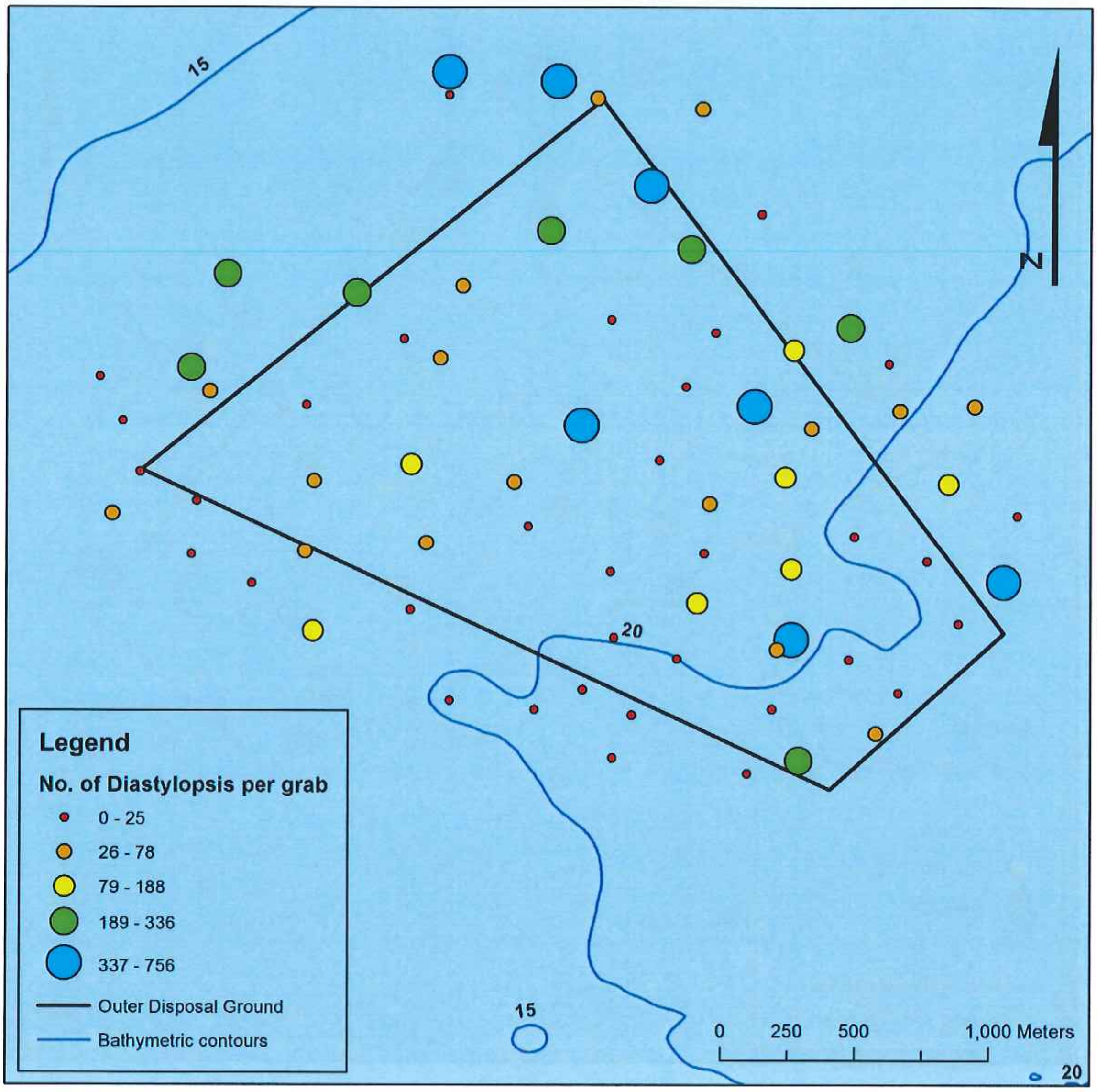

Figure 3-2: Abundance of *Diastylopsis crassior* over the sampling area.

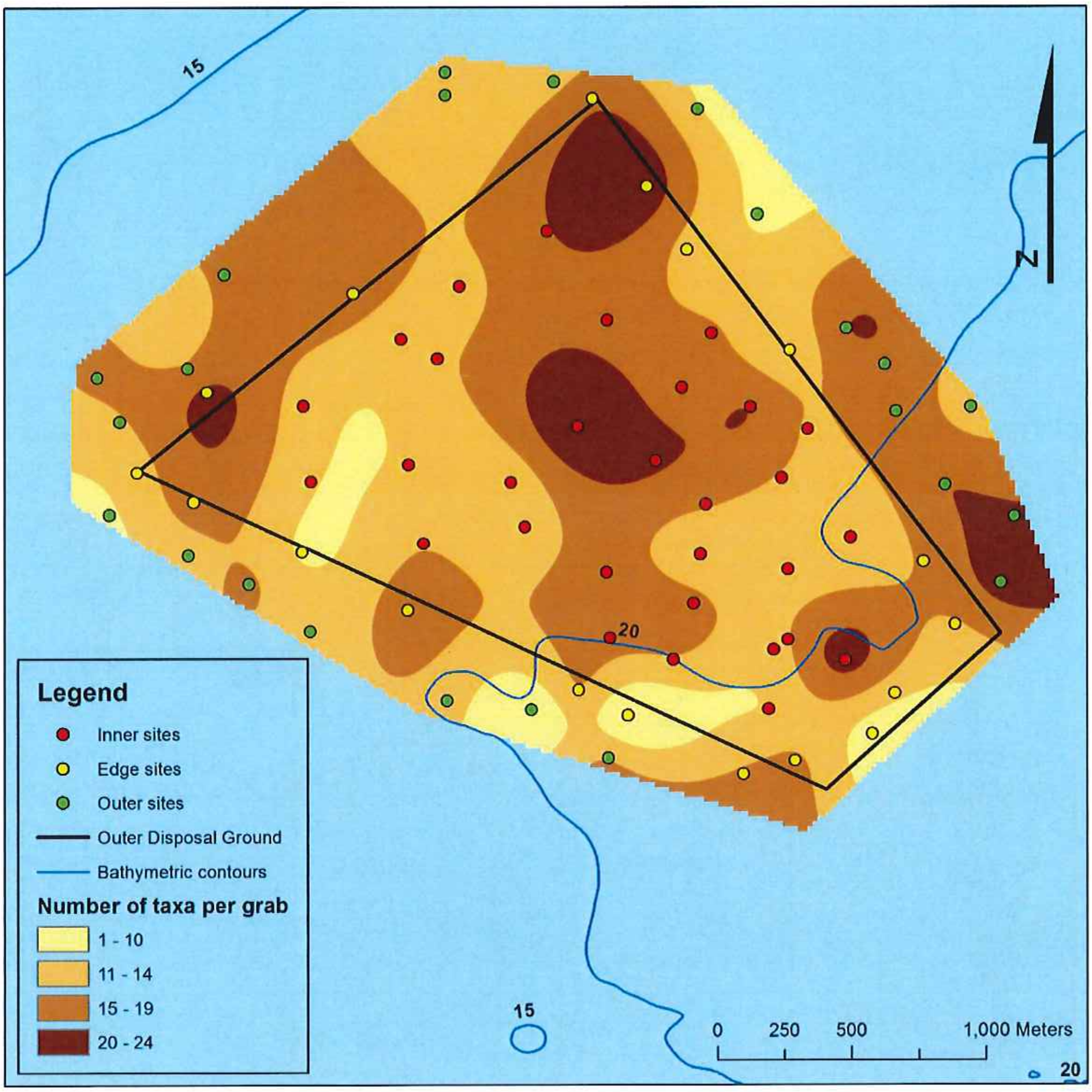

Figure 3-3: Number of taxa per grab estimated across the sampling area.

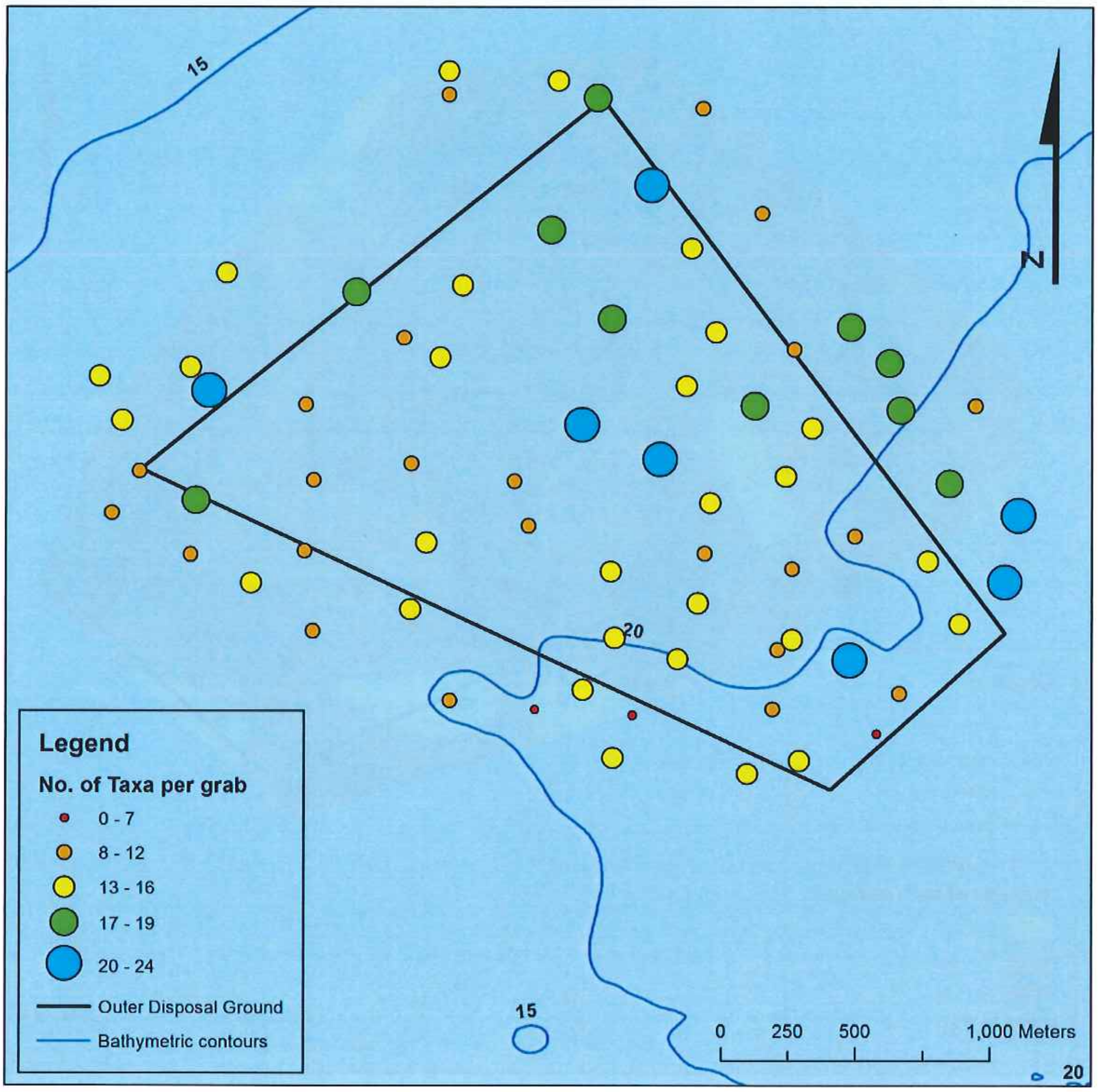

Figure 3-4: Number of taxa per grab across the sampling area.

As in 2008, *Diastylopsis crassior* (Cumacean) was the most common taxa found during the survey (Figure 3-2). The abundances found were substantially higher than in previous surveys; mean of 3, 1, 7.5 and 102 per grab sample in 1996, 1999, 2008 and 2013, respectively. Another cumacean, *Cyclaspis argus* (4th most common taxa (Figure 3-5)) was generally found with *D. crassior* and spread across the surveyed area without a strong spatial pattern. However, *C. argus* was not found in high abundance on the western side of the disposal ground. The overall abundance of polychaetes was greatest along the lower (South-Western) section of the ODG (Figure 3-6). However, as discussed in Halliday et al. (2008), because of the diversity of polychaetes found in the survey it is important to look at individual species to determine if effects due to the disposal of dredge spoil are present.

The polychaete fauna was dominated by *Paraprionospio sp.,* which dominated the patterns seen for polychaetes (Figure 3-6 and Figure 3-7). *Paraprionospio sp.* had an average of 27.43 individuals per grab within the inner disposal area, and 10.83 and 9.39 individuals per grab for the edge and outside areas, respectively (Table 3-1). These abundances were much higher than in 2008, and similar to those found in 1999. *Aglaophamus* sp. was also one of the 10 most numerically dominant taxa (Table 3-4) and, as in 2008, *Heteromastus filiformis* and *Prionospio australiensis* had mean abundances that exceeded 0.5 individuals per grab.

The highest abundance of *H. filiformis* generally occurred outside of the ODG on the north eastern side (Figure 3-8). In 2008, *H. filiformis* was found in generally higher numbers outside the disposal area, whereas in 2013, the average number found per grab was not significantly different within the disposal area and outside. However, overall abundances of this species were low (0-8 individuals per grab) so caution is required when interpreting spatial patterns. *P. australiensis* had a relatively even distribution across the inner, edge and outer areas of the ODG. *P. australiensis* was found in 2008 to show signs of being depressed in numbers within the disposal area; in 2013, its numbers were highest at the edge and within the disposal area (Figure 3-9, Table 3-1). From previous studies it has been shown that both *Heteromastus filiformis* and *Prionospio* sp. are tolerant to intermediate fine sediment deposition (Pearson and Rosenberg, 1978). Therefore, we would not expect these to show strong responses to the disposal of dredge spoil.

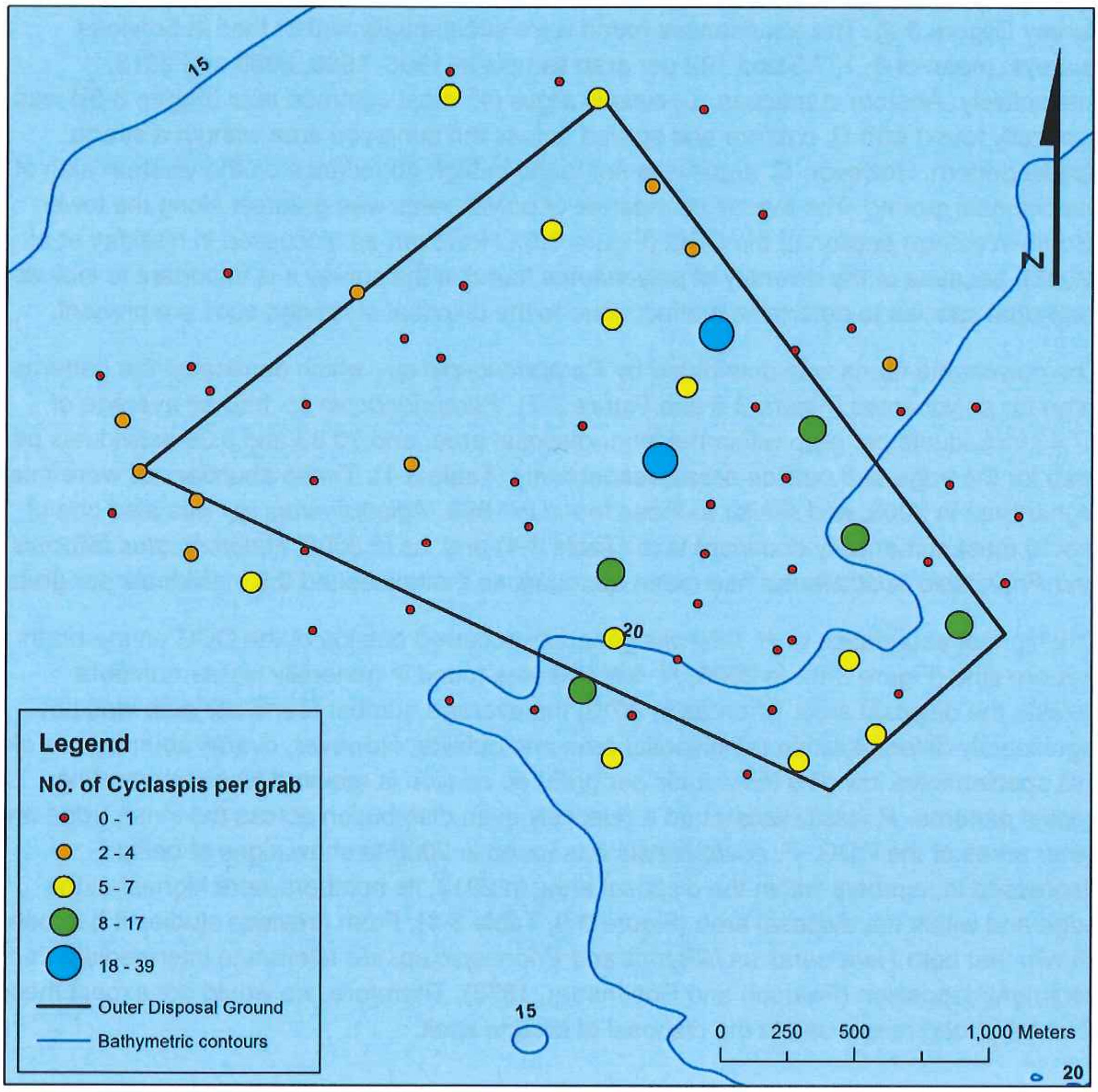

Figure 3-5: Abundance of *Cyclaspis argus* over the sampling area.

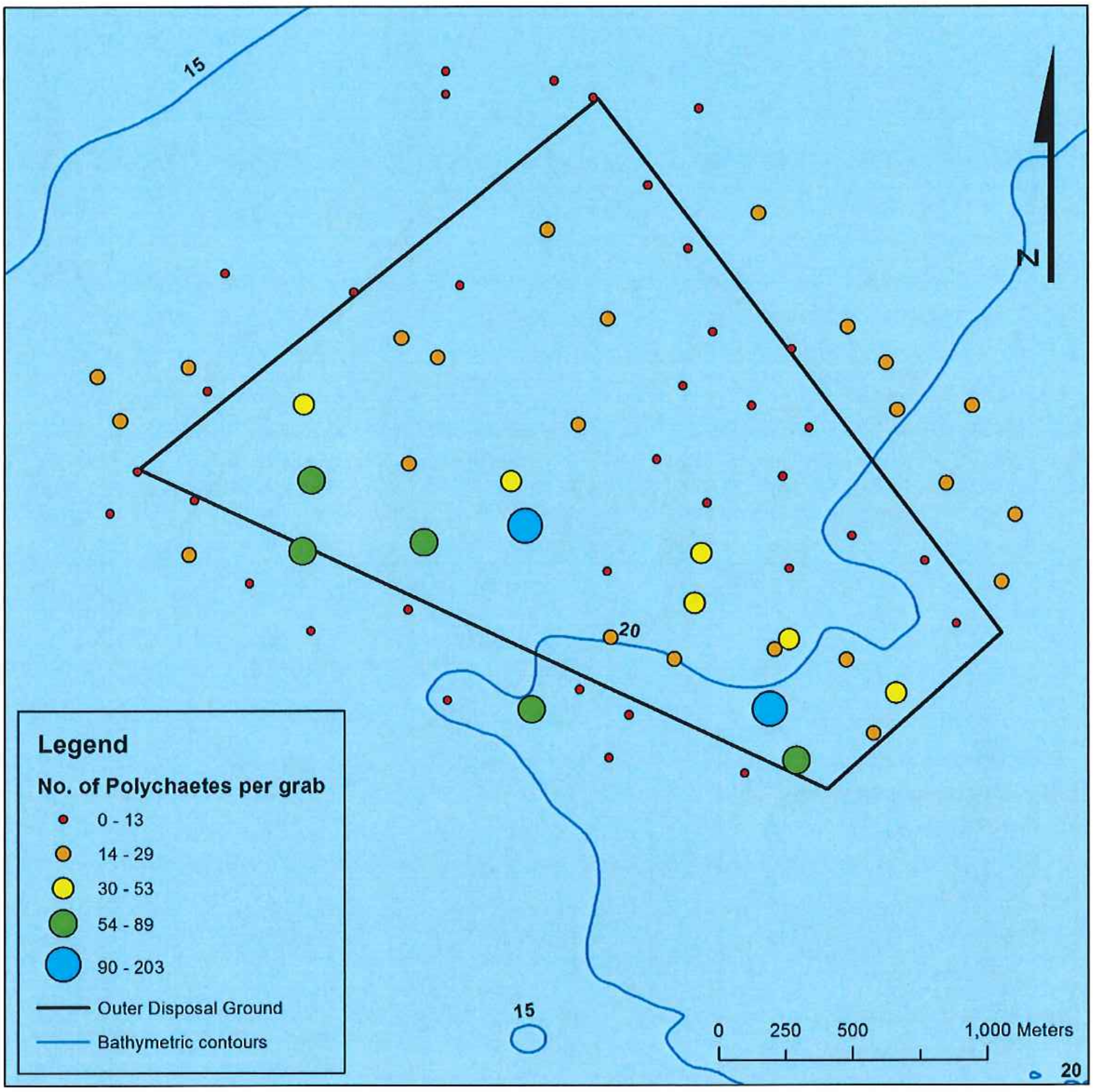

Figure 3-6: Abundance of polychaetes over the sampling area.

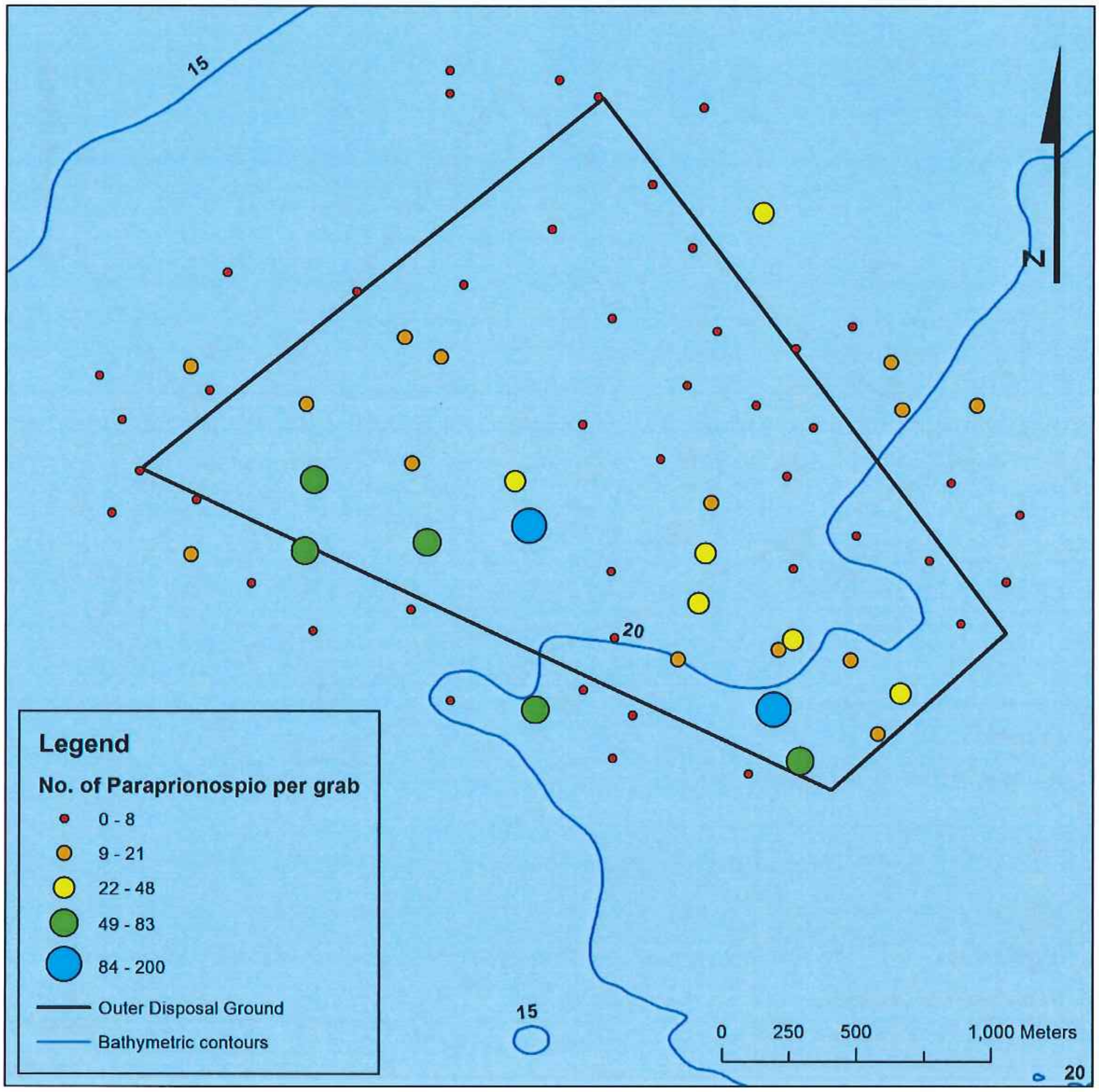

Figure 3-7: Abundance of *Paraprionospio* sp. over the sampling area.

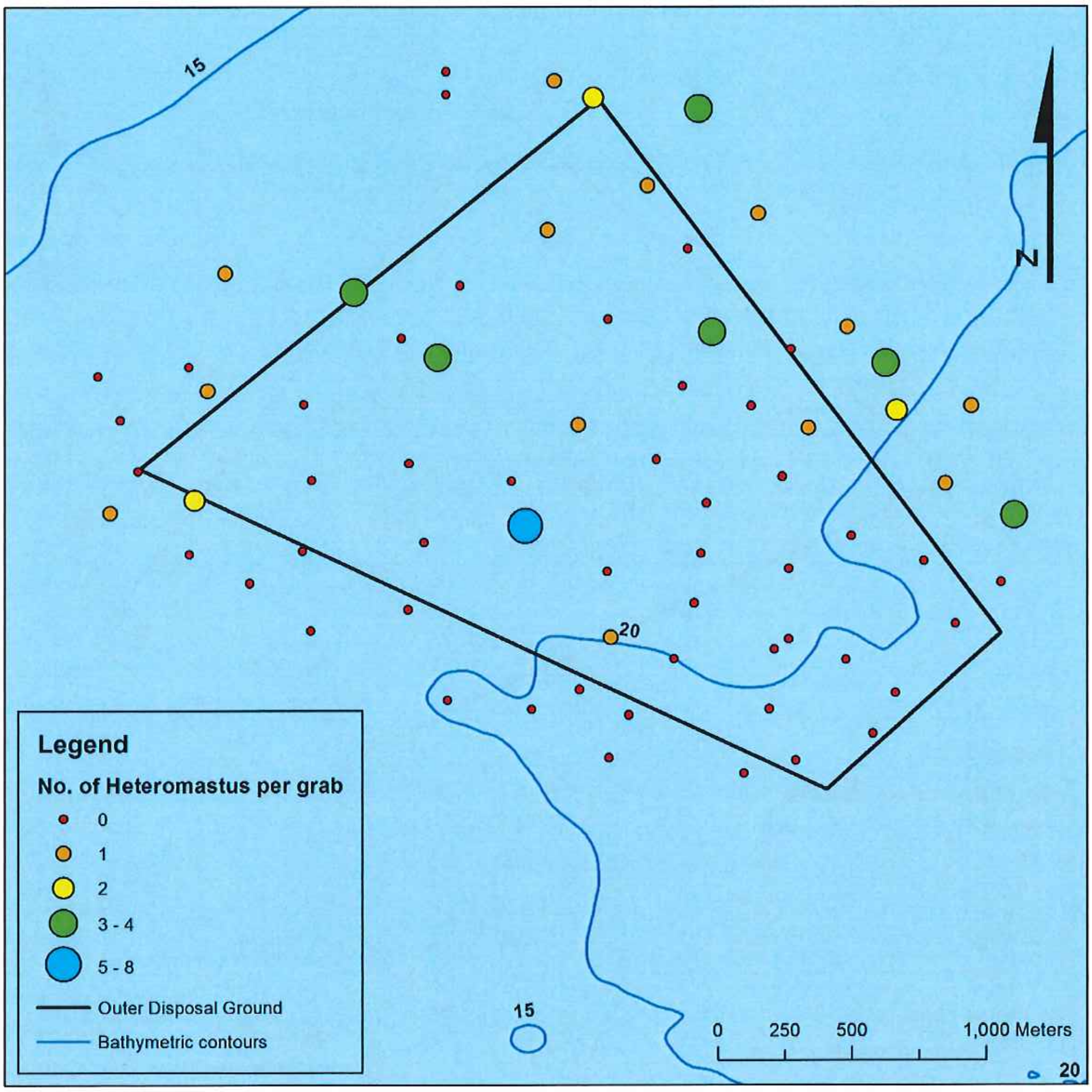

Figure 3-8: Abundance of *Heteromastus filiformis* over the sampling area.

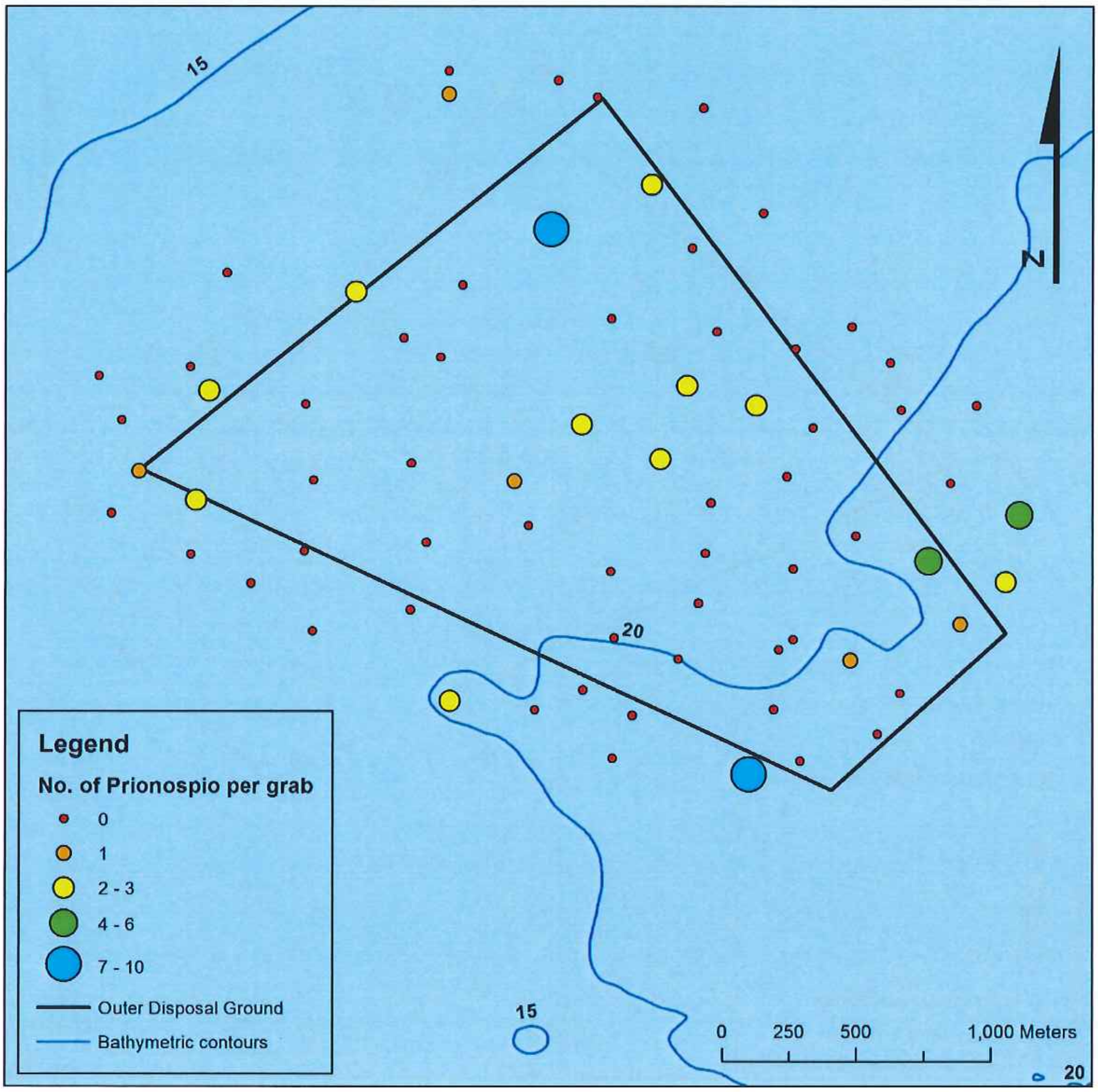

Figure 3-9: Abundance of *Prionospio* sp. over the sampling area.

In 2013, *Mactra ordinaria* (Figure 3-10) was the second most abundant species with an average of 18.7 individuals per grab across all the samples. *M. ordinaria* was found across the majority of the sampling area in high abundance, both inside and outside the disposal area but abundances were noticeably lower to the north. *M. ordinaria* was also in the top three numerically dominant species in 1996 and 1999, however in 2008 it had dropped in abundance (average of 0.87 individuals per grab).

In 2008 *Nucula nitidula* (Figure 3-11) was the most numerically dominant bivalve species found in the sampling area, however in 2013 its abundance had diminished and it was generally only found on the eastern side; predominantly outside of the disposal area.

Dosinia anus (Figure 3-12) was also one of the 10 most numerically dominant species in 2013 (Table 3-4). The distribution of *D. anus* across the sampled area was relatively even, with 'hot spots' on the western and eastern edges of the disposal area.

Paracaudina chilensisa (Figure 3-13) was one of the top 10 numerically abundant species across the sampling area in past surveys. However in 2013 it was only found in 31 of the 71 grabs with a maximum abundance of 3 individuals per grab. *P. chilensisa* is still distributed both inside and outside the disposal area, so whether this is due to dredge spoil deposition or to natural variation is unclear.

As had been the case in previous surveys, *Torridoharpinia hurleyi* (Figure 3-14) is again the most common amphipod. It is said to have similar functional characteristics to cumaceans such as *Diastylopsis crassior* in terms of their contribution to sediment re-working and turnover (Gibbs & Hewitt 2004; Thrush et al. 1988). Nine other species of amphipod were also found in 2013. *T. hurleyi* was relatively evenly spread across the disposal area, and in slightly higher numbers than in 2008.

Amphiura sp. (brittle stars) (Figure 3-15) are another species that has been commonly found across all surveys since 1996. It is consistently one of the ten most numerically dominant species found (Table 3-4) and was slightly more common outside the disposal area than inside.

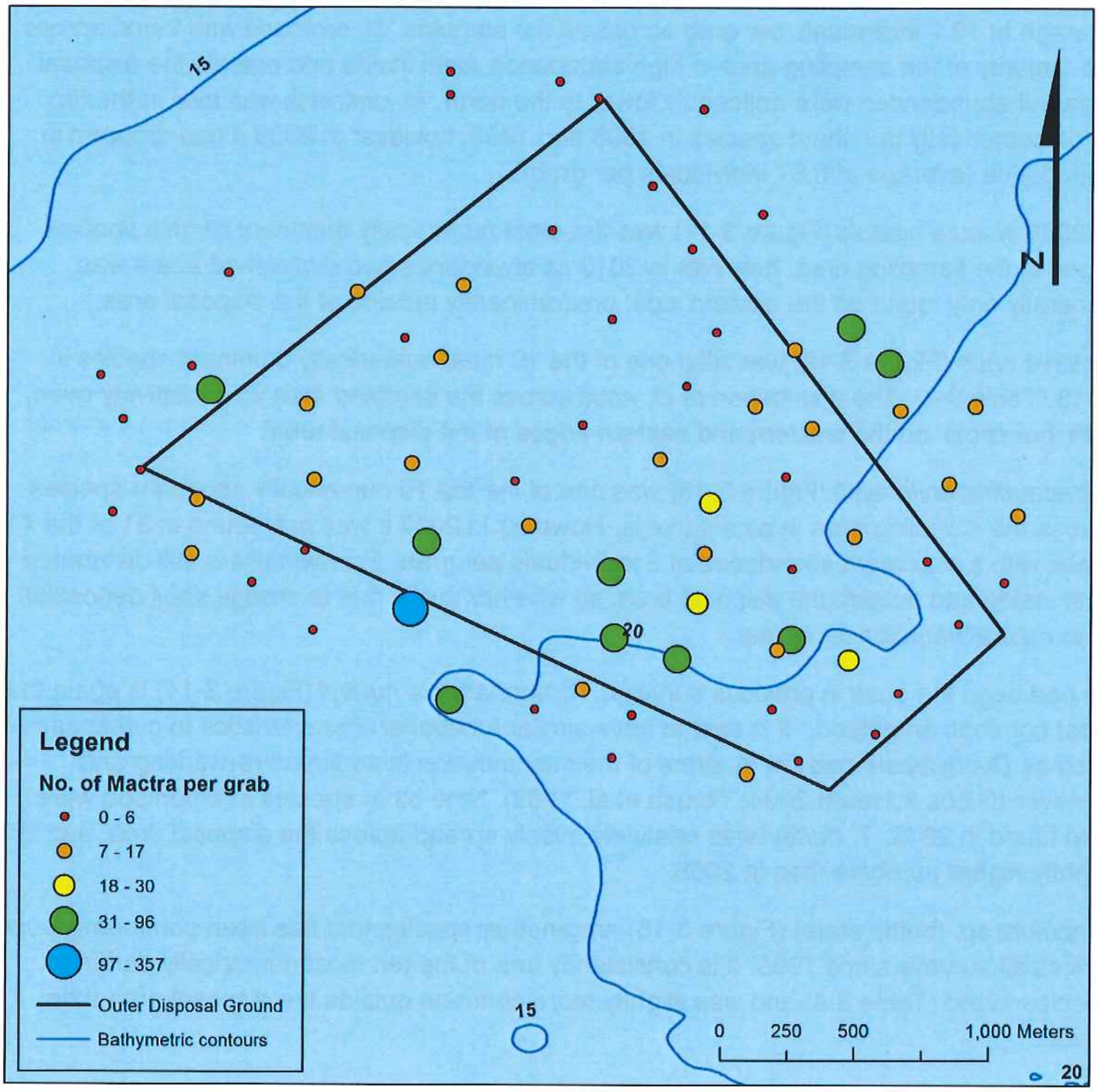

Figure 3-10: Abundance of *Mactra ordinaria* over the sampling area.

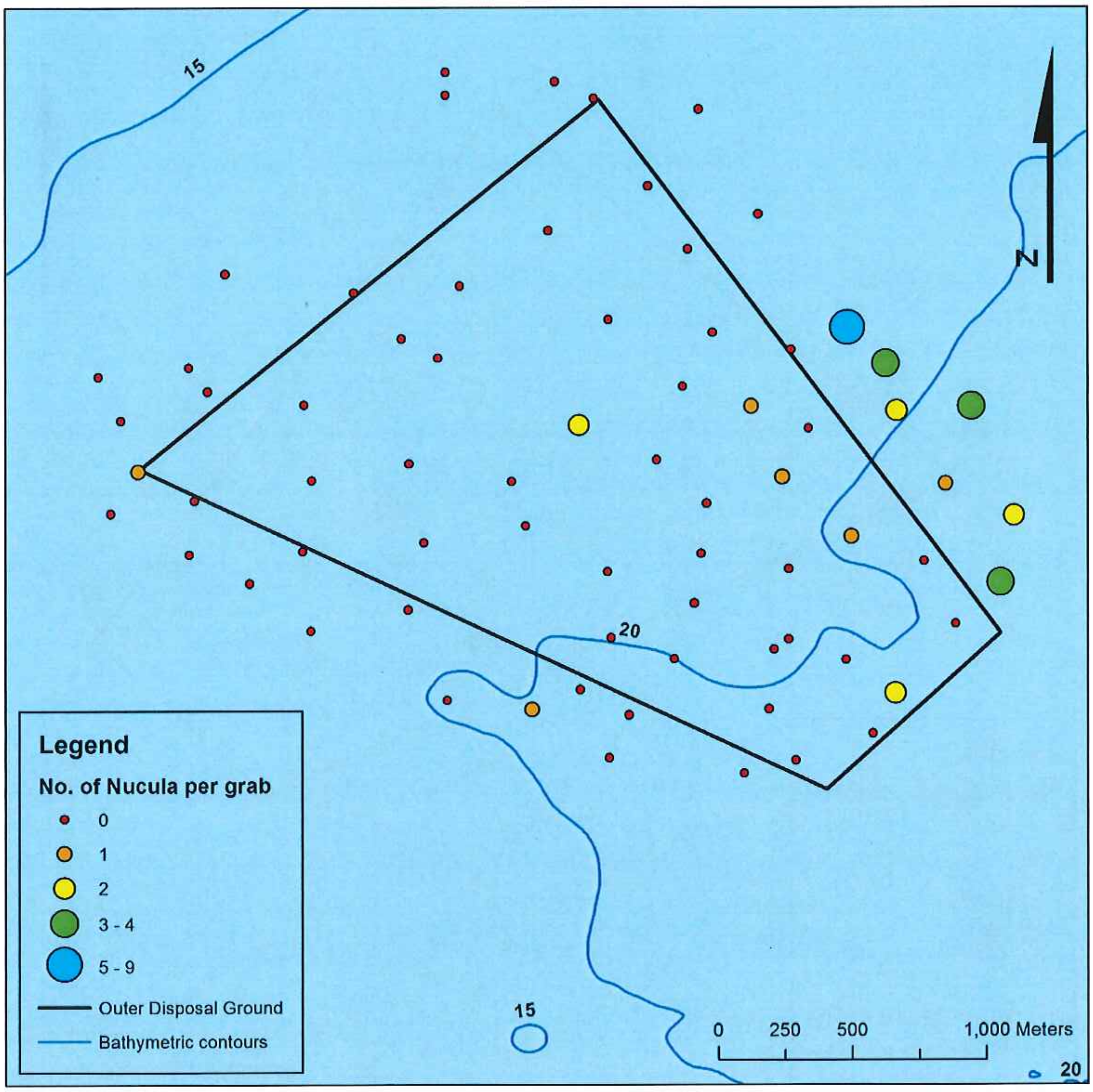

Figure 3-11: Abundance of *Nucula nitidula* over the sampling area.

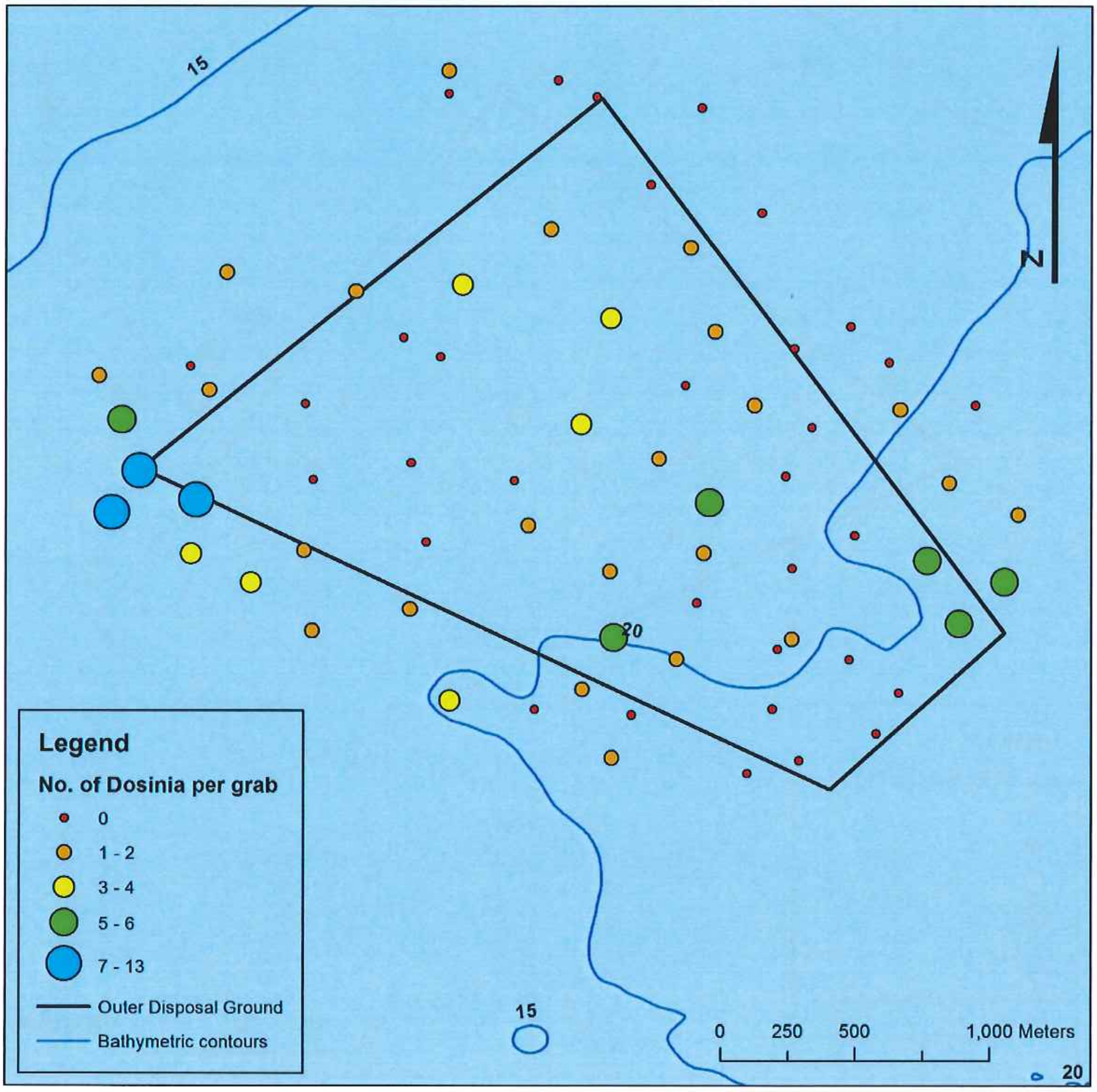

Figure 3-12: Abundance of *Dosnia anus* over the sampling area.

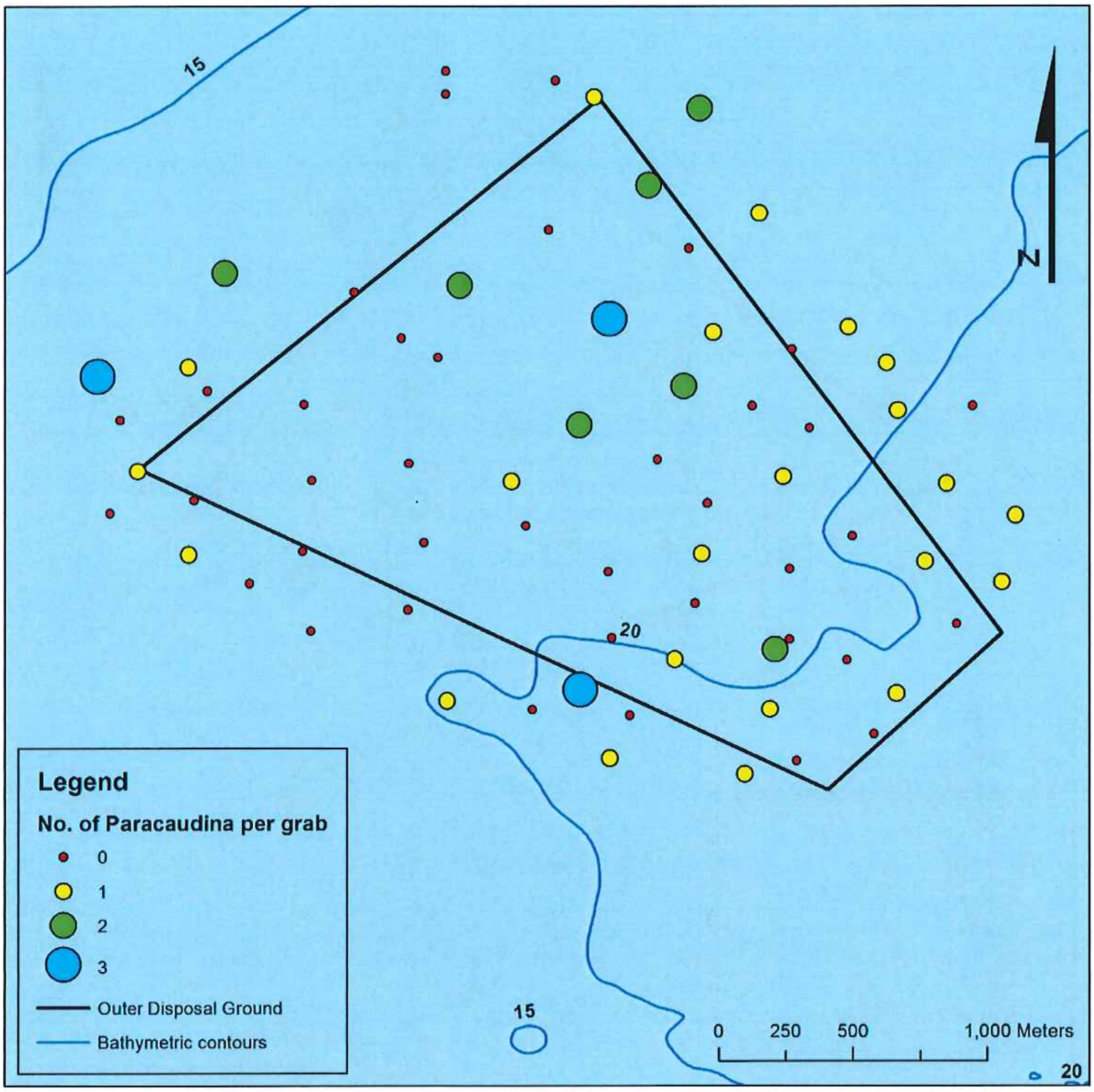

Figure 3-13: Abundance of *Paracaudina chilensisa* over the sampling area.

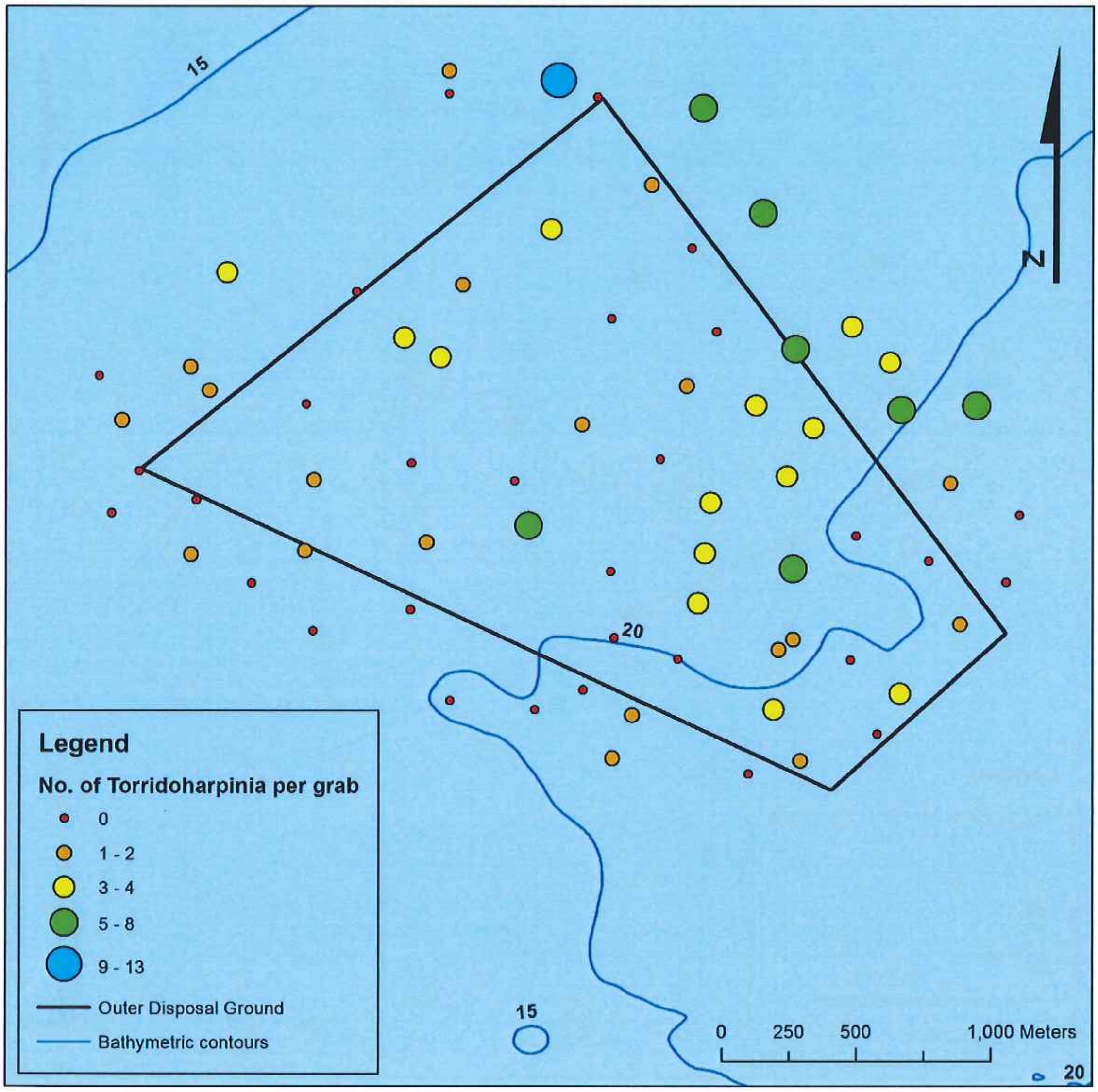

Figure 3-14: Abundance of *Torridoharpinia hurleyi* over the sampling area.

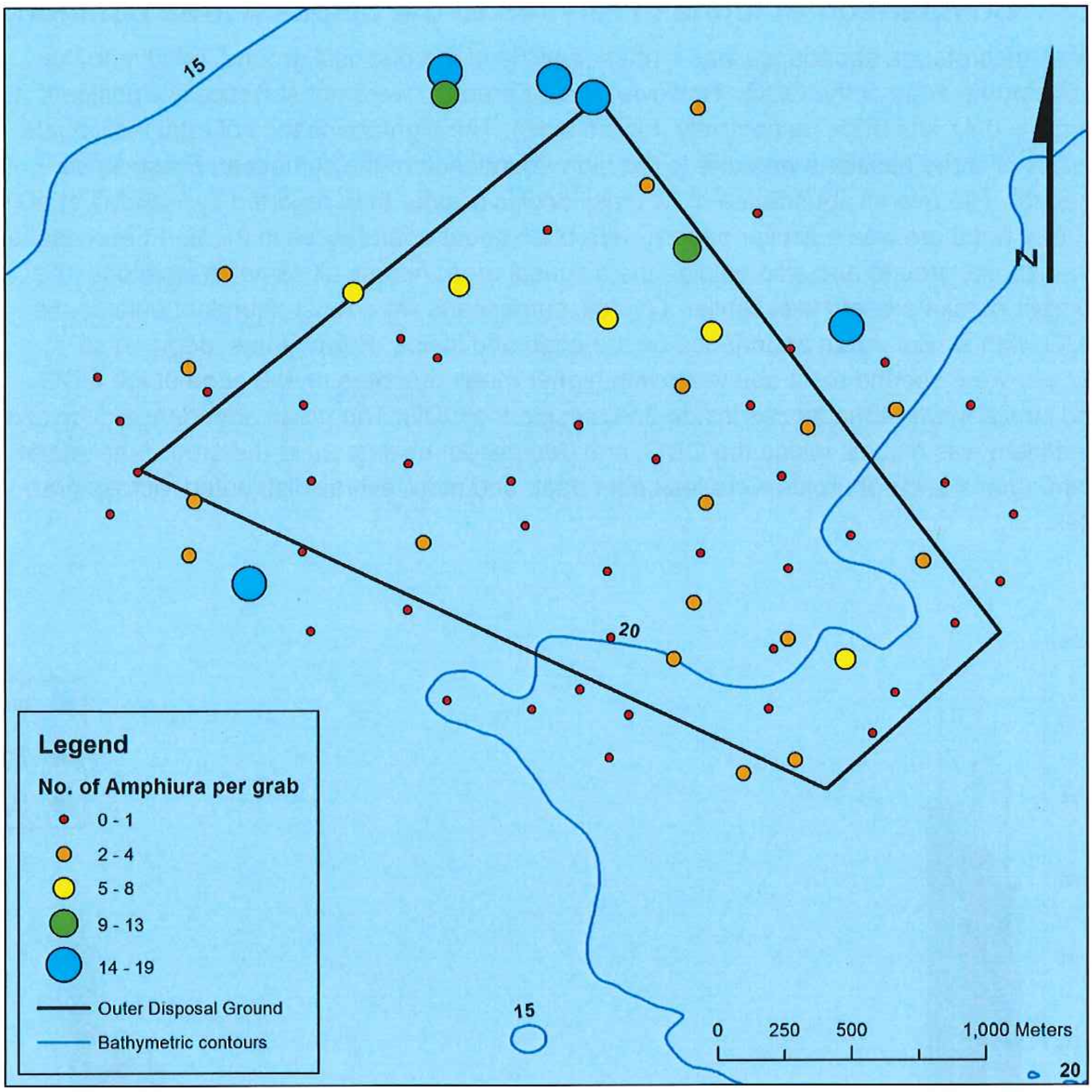

Figure 3-15: Abundance of *Amphiura* sp. over the sampling area.

3.2 Comparison of fauna in relation to the disposal area position.

Mean macrofauna abundance was highest outside of the disposal ground, relative to the inside or the edge of the ODG. However, the differences were not statistically significant (t-test; p = 0.41 and 0.35, respectively; Figure 3-16). The high abundance of total individuals across all three positions was due to the high abundance of the cumacean *Diastylopsis crassior*. The overall abundance of *D. crassior* was greater than reported by Halliday et al. (2008), but there was a similar pattern, with the highest abundances in the north and east of the disposal ground and also outside the disposal area. Across all sampled locations, the number of taxa present was similar. Overall, cumaceans were most abundant outside the ODG, with similar mean abundance on the edge and inside. Polychaetes (segmented worms) were second most abundant with higher mean numbers on the edge of the ODG, and similar lower abundances inside and outside the ODG. The mean abundance of bivalves (shellfish) was highest inside the ODG, and decreased moving out of the area. Amphipods, holothurians and ophuroids were less abundant, and more evenly distributed, across grab sites.

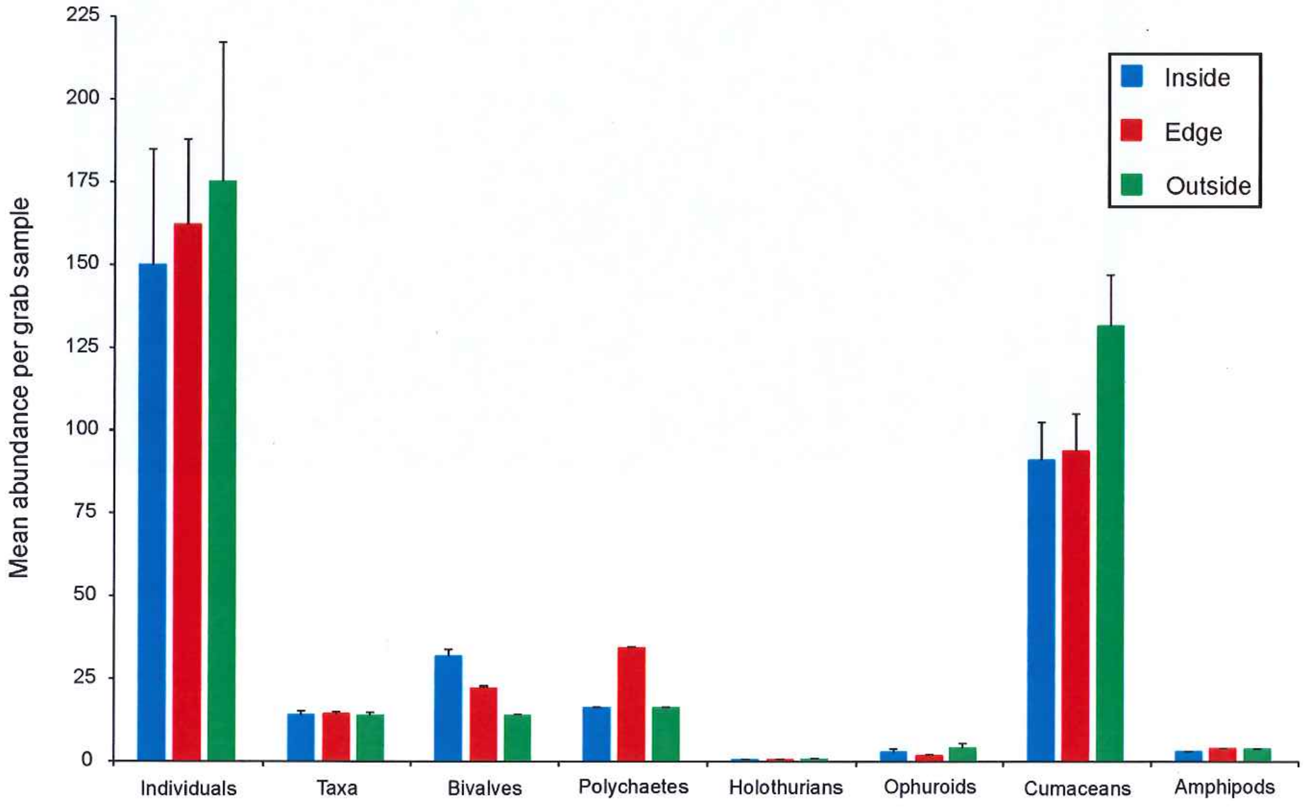

Figure 3-16: Comparison of the mean abundance of all individuals, the number of taxa and bivalve, polychaete, holothurian, ophuroid, cumacean and amphipod abundances per grab (0.1m^2) inside, on the edge and outside the disposal area (+standard error).

There was no apparent distinction between inside, edge and outside of the disposal areas with respect to taxa group richness or evenness (p = 0.34-0.43 for both indices; Figure 3-17 and Figure 3-18). Both measures show variability across the site and there appears to be no distinct difference between inside the disposal area and outside. Both the Shannon-Weiner Diversity H' Index and the Simpsons index were very similar, and neither index showed an effect that would point to impacts from dredge spoil disposal within the sampled area (Figure 3-19 and Figure 3-20).

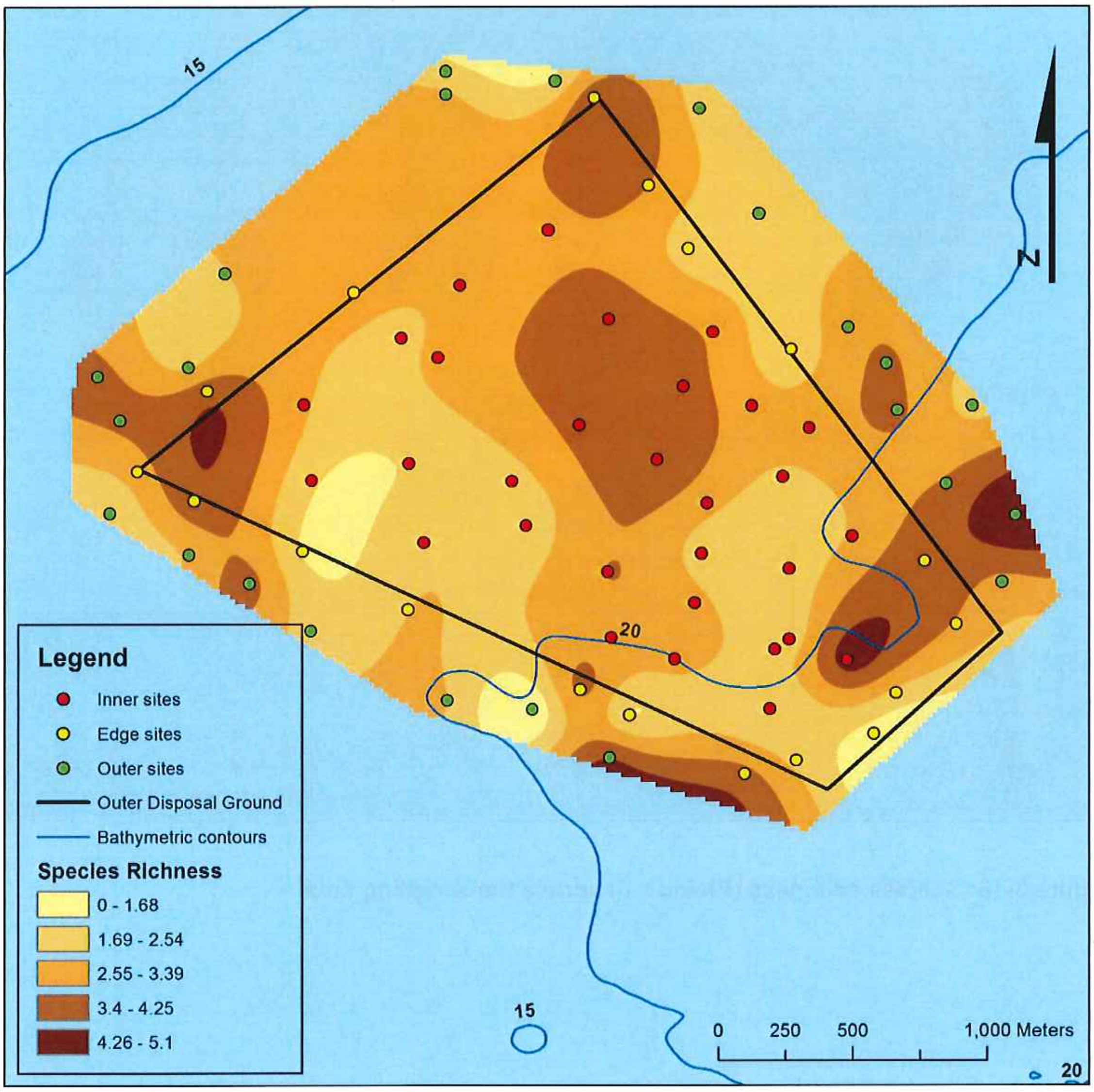

Figure 3-17: Taxonomic richness (Margalefs d) estimated over the sampling area.

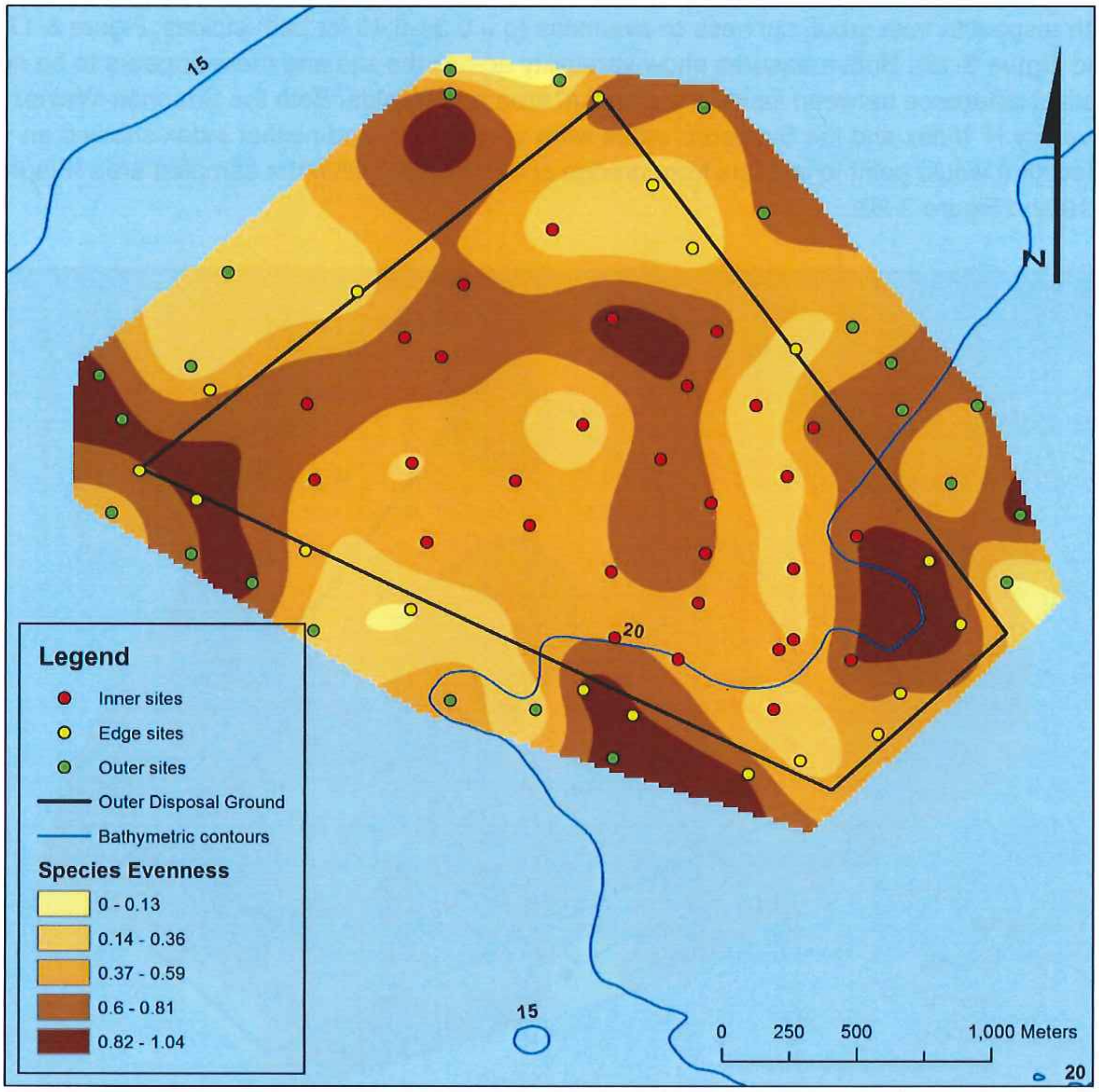

Figure 3-18: Species evenness (Pielou's J) across the sampling area.

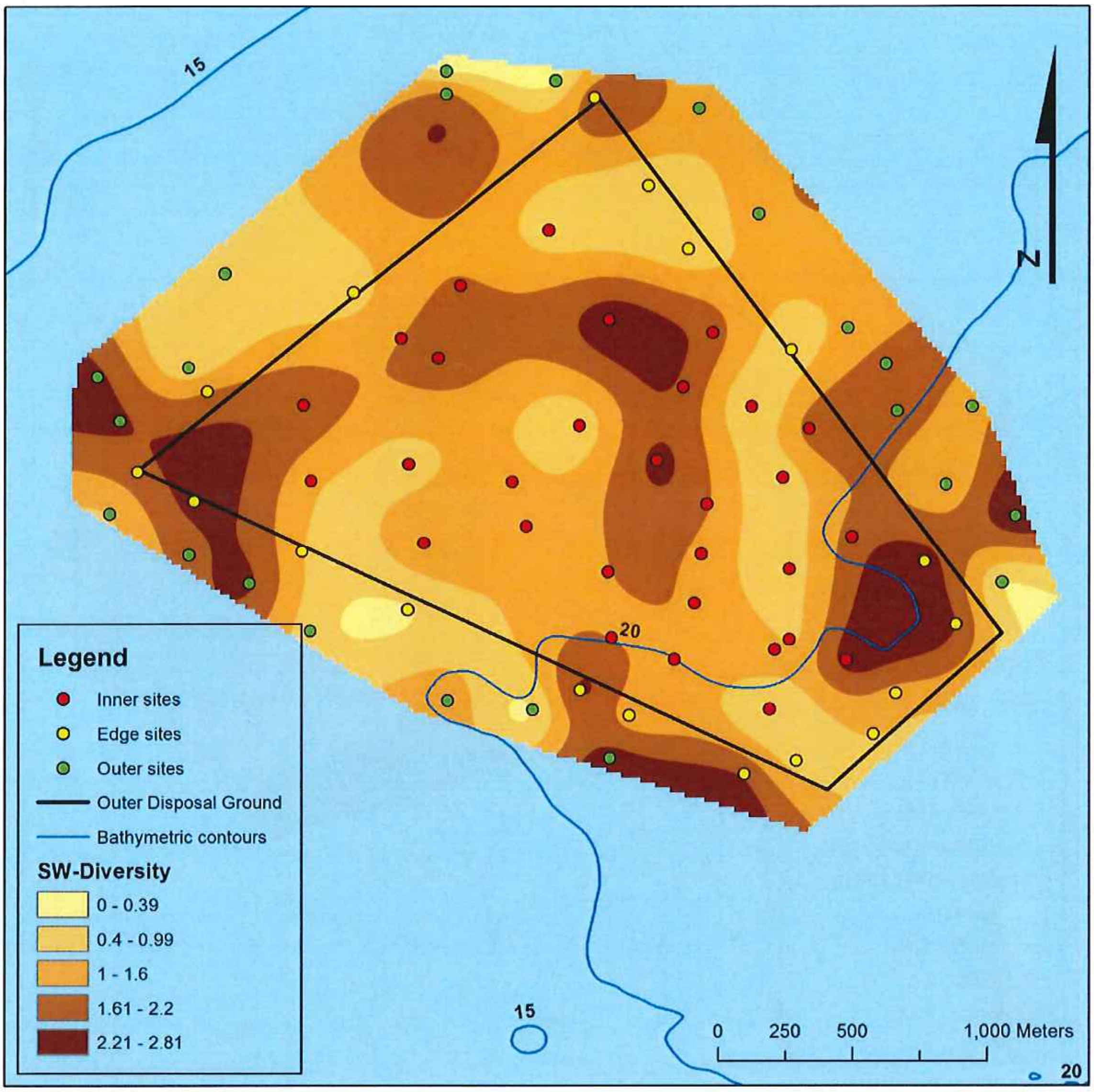

Figure 3-19: Shannon-Wiener Diversity Index H' across the sampled area.

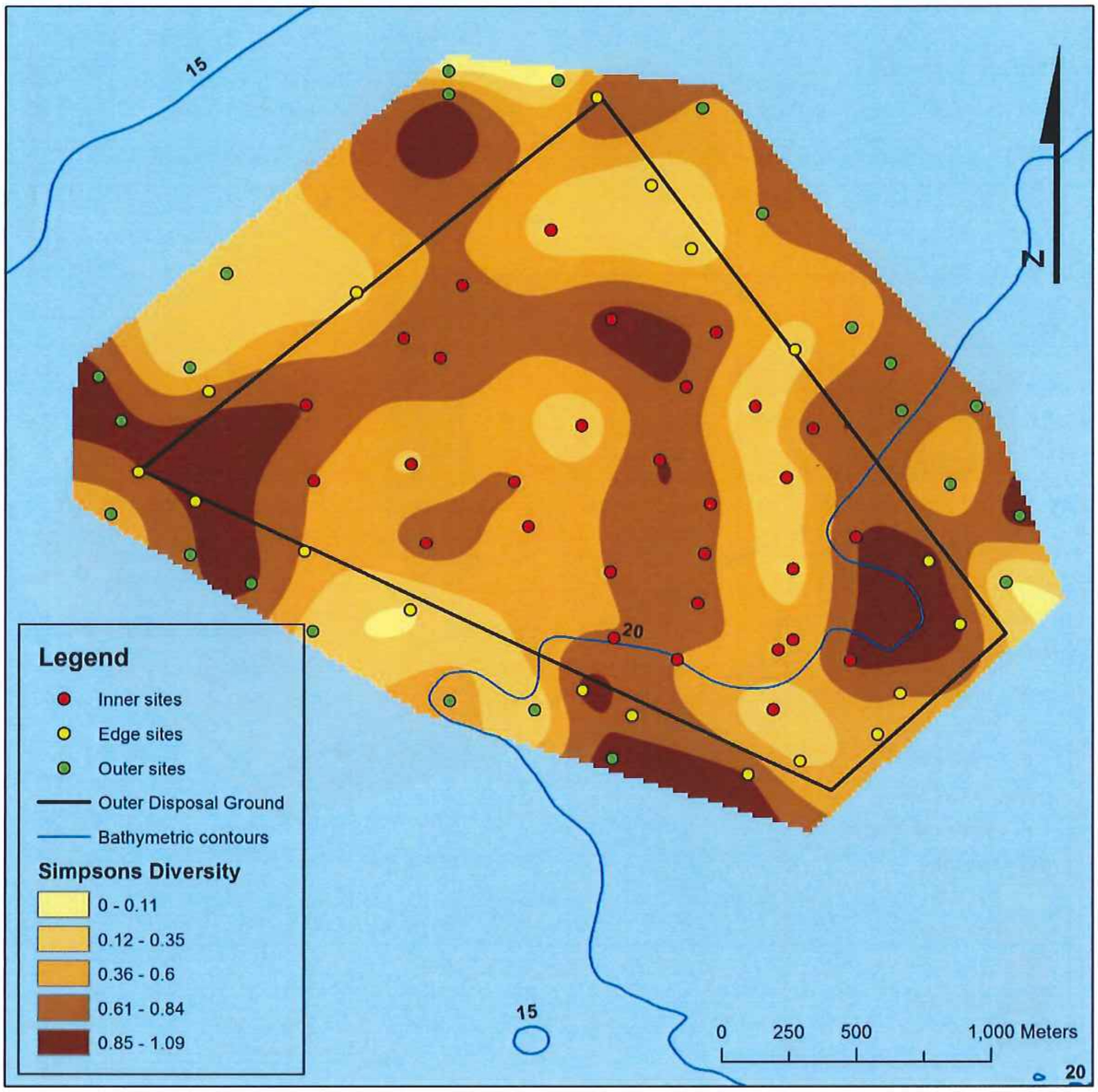

Figure 3-20: Simpsons Diversity Index across the sampled area.

Figure 3-21 demonstrates the similarity of the faunal communities in ordination space for the outside, edge and inside locations. If the disposal of the dredge material strongly effected the community structure at the sites in the same way, we would expect to see grouping of site communities based on their relative exposure i.e., grouping of inside sites, edge sites and outside sites. Figure 3-21 displays no evidence of grouping based on disposal ground position. There appears to be no obvious similarities of communities sampled from each location and therefore, it appears that community composition is either not effected by the spoil disposal, or that the spoil materials are being distributed far from the disposal site in all directions (and that all communities are being equally affected).

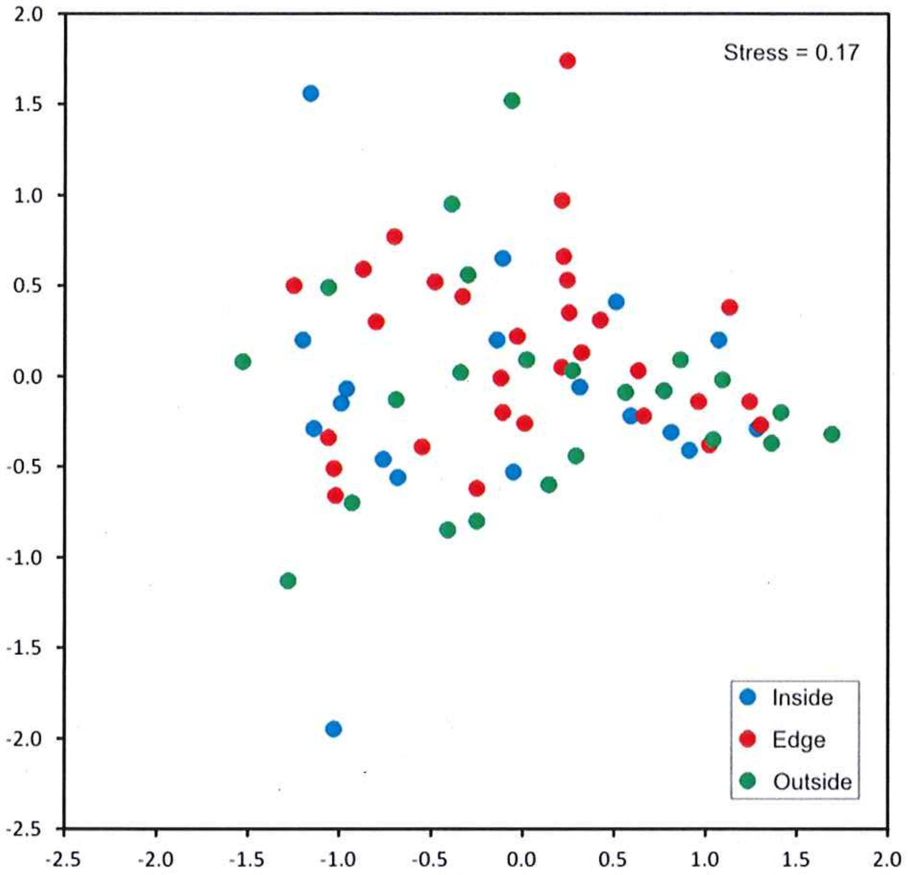

Figure 3-21: Non-metric Multi-dimensional Scaling plot (MDS) of untransformed data using Bray Curtis similarities, displaying grab sample communities inside, on the edge and outside the disposal area.

An ANOSIM (Analysis of Similarities) confirmed that there were no significant differences between communities sampled between inside and outside ($p = 0.10$); inside and edge ($p = 0.13$) and edge and outside ($p = 0.61$) the disposal area.

The SIMPER analysis was conducted to determine the taxa most responsible for the community differences outside and inside the disposal area (Table 3-2). The taxa identified were similar to those reported by Halliday et al. (2008). However, the most noticeable difference was *Diastylopsis crassior,* which tended to be more abundant outside the disposal area.

Table 3-2: Results of SIMPER analysis displaying which taxa are most responsible for significant community differences between the inside and outside the disposal area.

Common Taxa Inside Disposal Area	Common Taxa Outside Disposal Area
Paraprionospio sp. aff *P. pinnata*	*Diastylopsis crassior*
Mactra ordinaria	*Amphiura* sp.
Cyclapsis argus	*Torridoharpinia hurleyi*
Nemertea	*Dosinia anus*
Sigalionidae	*Neommatocarcinus huttoni*
Rexithaerus (*Tellina*) *spenceri*	*Aglaophamus* sp.
Spiophanes sp.	*Heteromastus filiformis*
	Ostrocoda sp.1
	Paracaudina chilensis

The mean number of rare taxa within each area (Method #1, Table 3-3), was fairly consistent between areas, with outside of the disposal area having only 5 fewer rare taxa than the inside of the disposal area. Method #2 (Table 3-3) showed the number of taxa occurring in only one grab sample (in each zone), and indicated that the edge zone had the most rare taxa while the inside had the least number of rare taxa. The total number of rare taxa observed in 2013 was higher than that last reported by Halliday et al. (2008).

Table 3-3: Number of rare taxa calculated using two methods.

	Outside	Edge	Inside
Method #1	49	51	54
Method #2	16	19	10

3.3 Comparison with pre-dump fauna

When comparing the total number of macrofaunal individuals observed in 1996, 1999, 2008 and 2013, a large increase in total number of individuals was detected in 2013 (Figure 3-22 and Figure 3-23). This increase was largely due to the high numbers of cumaceans and, to a lesser extent, bivalves, with other taxa numbers remaining fairly consistent throughout the four sampling times. However, polychaete abundances decreased in the 2008 sampling relative to before and after.

Total mean macrofauna abundance had declined between 1996 and 2008, and natural variability at this location appears to be high. Discounting the high numbers of cumaceans in 2013, there appears to be no variation in numbers between this and previous years that could be attributed to the effects of dredge spoil disposal. Examining the ten most numerically dominant taxa across all four surveys (Table 3-4), it can be seen that although there have been changes in many species, there have also been many species that are relatively stable across the sampled area.

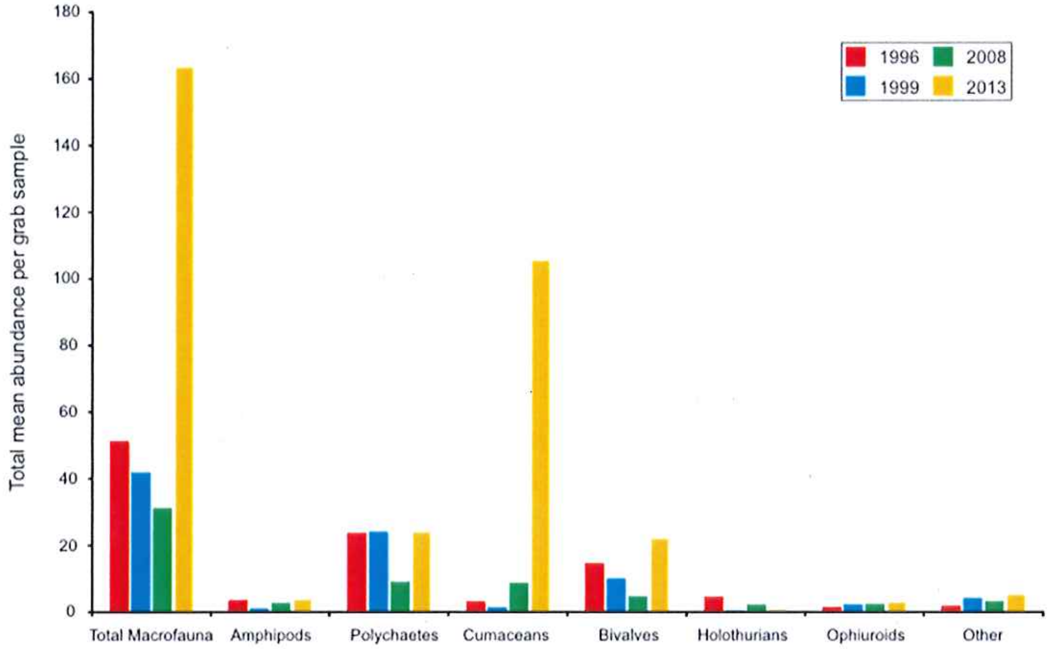

Figure 3-22: Total mean abundance of macrofaunal individuals, amphipods, polychaetes, cumaceans, bivalves, holothurians, ophiuroids and other taxa per grab in 1996, 1999, 2008 and 2013.

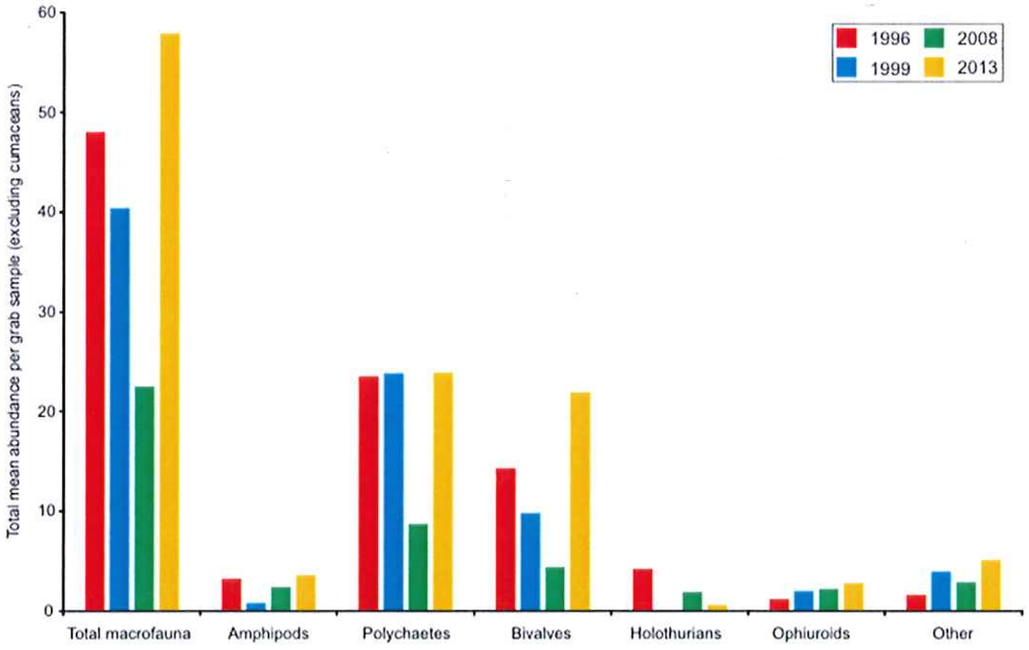

Figure 3-23: Total mean abundance (excluding cumaceans) of macrofaunal individuals, amphipods, polychaetes, bivalves, holothurians, ophiuroids and other taxa per grab in 1996.

Table 3-4:.Ten most numerically dominant taxa (1-10) across all grab samples for the 1996, 1999, 2008 and 2013 surveys.

Rank	1996	1999	2008	2013
1	*Nerinopsis* sp. (Polychaete)	*Anobothrus* aff. *Patagonicus* (Polychaete)	*Diastylopsis crassior* (Cumacean)	*Diastylopsis crassior* (Cumacean)
2	Capitellid sp. (Polychaete)	*Paraprionospio* sp. aff. *P. pinnata* (Polychaete)	*Nucula nitidula* (Bivalve)	*Mactra ordinaria* (Bivalve)
3	*Mactra ordinaria* (Bivalve)	*Mactra ordinaria* (Bivalve)	*Amphiura* sp. (Ophiuroid)	*Paraprionospio* sp. (Polychaete)
4	*Paracaudina chilensis* (Holothurian)	*Nucula nitidula* (Bivalve)	*Prionospio tridentate* (Polychaete)	*Cyclaspis argus* (Cumacean)
5	*Tellina spenceri* (Bivalve)	*Amphiura* sp. (Ophiuroid)	*Paracaudina chilensis* (Holothurian)	*Amphiura* sp. (Ophiuroid)
6	*Diastylopsis crassior* (Cumacean)	*Paracaudina chilensis* (Holothurian)	*Heteromastus filiformis* (Polychaete)	*Torridoharpinia hurleyi* (Amphipod)
7	*Ampharete* sp. (Polychaete)	Isopod red eye (Isopod)	*Aglaophamus verrilli* (Polychaete)	*Dosinia anus* (Bivalve)
8	*Nucula nitidula* (Bivalve)	*Diastylis* sp. (Cumacean)	*Cyclaspis argus* (Cumacean)/*Torridoharpinia hurleyi* (Amphipod)	*Neommatocarcinus huttoni* (Crustacean: Crab)
9	*Arthritica bifurca* (Bivalve)	*Tellina edgari* (Bivalve)	*Mactra ordinaria* (Bivalve)	*Aglaophamus* sp. (Polychaete)
10	*Amphiura* sp. (Ophiuroid)	Amphipod sp.1 (Amphipod)	*Goniada echinulata*/*Paraprionospio* sp. aff. *P. pinnata* (Polychaetes)	Octrocoda sp. #1 (Ostrocod)/Nemertea (Unsegmented annelid)

4 Discussion

The disposal of dredge spoils is often considered to be one of the major anthropogenic impacts on coastal ecosystems (Bolam et al. 2011), yet depending on the prevailing physical conditions (e.g., waves, sediment inputs) there may be little impact observed on the ecosystem. Various studies (e.g., Bolam and Rees, 2003) have been conducted to test for the effects of dredge spoil disposal on benthic macrofauna communities, and in many cases there have been few effects detected. Bolam et al. (2006) notes that the perception that dredged material disposal results in ecological harm is due largely to historical mistakes rather than current findings. Fredette and French (2004) reviewed the changes that have occurred in dredging practice over more than 30 years and found that there are often minimal impacts environmentally, if careful management is undertaken. In shallow areas where the seabed is influenced by wind and waves (i.e., Poverty Bay), there is often very little effect at a broad scale due to the speed with which the environment naturally changes.

In 2013, no difference was observed in benthic macrofauna community composition across the ODG. Taxa present were similar to those found in previous years, however, a large increase in cumaceans was observed. Halliday et al. (2008) noted that cumaceans are opportunistic, rapid colonists following disturbance and commonly found in areas exposed to high waves. They can be resilient to the effects of dredge spoil disposal and respond quickly to changes in environment. These high numbers were seen across all sampling positions. No significant differences were observed inside and outside the ODG for any of the other taxa identified.

As noted in Halliday et al. (2008) the sampling design used was not optimal for detecting changes between the disposal ground and the surrounding areas. The prevailing physical conditions are likely to spread some of the dredge spoil material outside the sampled area, which decreases the ability of these surveys to detect any differences from the surrounding habitat. However, as noted by Cole (1999), the variability between species in the 1996 and 1999 surveys in the absence of dredging indicate that this area undergoes substantial temporal variation. This needs to be taken into consideration before drawing conclusions about the possible impacts of dredge spoil disposal.

Future studies could incorporate measurement of the physical oceanographic processes present in the ODG, and modelling of these would allow inferences to be made on the likely fate of the dumped material. Likewise, sampling an array of sites at increasing distances away from the disposal ground (e.g., upstream and downstream of the disposal area, in parallel with the direction of prevailing longshore drift) would be beneficial. However this is outside of current resource consent requirements.

If a local impact within the ODG was occurring, we would expect to see community differences between the inside and outside zones, and transitional effects along the edge. Sensitive taxa would decrease in density or disappear, and we would expect the more robust taxa to dominate, in the middle of the dredge spoil disposal zone. However, we found no statistical differences ($p > 0.05$ for all tests) in community composition, richness, evenness, and two diversity indices that we were able to relate to the disposal of dredge spoils in Poverty Bay.

5 Acknowledgements

Samantha Parkes (NIWA Hamilton) for carrying out the fieldwork. James Evans and the crew of the Pilot Vessel Turanganui (Dave Daniel, Andrew Williams and Tony Abbot) for assistance with the sampling.

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Appendix A Proposed and Actual sampling locations.

Site	Proposed Latitude	Proposed Longitude	Actual Latitude	Actual Longitude	Depth (m)
001	-38.70007	177.98860	-38.70002	177.98843	18.5
002	-38.70876	177.98530	-38.70873	177.98320	-
003	-38.70203	177.98690	-	-	-
004	-38.70441	177.98706	-38.70445	177.98690	17.3
005	-38.70414	177.98372	-	-	-
006	-38.70633	177.98415	-38.70630	177.98395	18.2
007	-38.70795	177.98226	-38.70807	177.98198	-
008	-38.71039	177.97886	-38.71030	177.97872	18.8
009	-38.70988	177.97558	-38.70983	177.97547	18.3
010	-38.71245	177.97318	-38.71253	177.97312	19
011	-38.71353	177.97500	-38.71350	177.97503	18.1
012	-38.71520	177.97880	-38.71522	177.97867	19.3
013	-38.71787	177.97955	-38.71788	177.97893	20
014	-38.71722	177.98237	-38.71717	177.98220	22.4
015	-38.71828	177.98448	-38.71817	177.99497	22.4
016	-38.72017	177.98379	-38.72020	177.98352	-
017	-38.71987	177.98815	-38.71983	177.98797	19.8
018	-38.72070	177.98965	-38.72070	177.98962	-
019	-38.72053	177.99446	-38.72050	177.99432	19.9
020	-38.72270	177.99368	-38.72265	177.99348	-
021	-38.72142	177.99792	-38.72132	177.99780	-
022	-38.71888	177.99715	-38.71885	177.99688	-
023	-38.71777	178.00068	-38.71765	178.00057	-

Site	Proposed Latitude	Proposed Longitude	Actual Latitude	Actual Longitude	Depth (m)
024	-38.71553	177.99956	-38.71555	177.99950	22.7
025	-38.71057	177.99577	-38.71108	177.99563	20.3
026	-38.70516	177.99171	-38.70507	177.99158	-
027	-38.70297	177.99019	-38.70295	177.99025	-
028	-38.70033	177.99201	-38.70038	177.99195	-
029	-38.70727	177.98902	-38.70743	177.98893	-
030	-38.71213	177.99065	-38.71213	177.99053	21.7
031	-38.71354	177.99241	-38.71360	177.99222	-
032	-38.71577	177.99513	-38.71580	177.99497	-
033	-38.71847	177.99452	-38.71850	177.99448	-
034	-38.71695	177.99185	-38.71695	177.99180	-
035	-38.71577	177.98907	-38.71590	177.98890	-
036	-38.71437	177.98628	-38.71437	177.98615	-
037	-38.71222	177.98233	-38.71227	177.98223	-
038	-38.70768	177.99245	-38.70787	177.99242	-
039	-38.70965	177.99040	-38.70968	177.99142	19.3
040	-38.71102	177.98813	-38.71098	177.98793	20.1
041	-38.71285	177.98580	-38.71287	177.98568	19.6
042	-38.71490	177.98278	-38.71492	177.98273	19.1
043	-38.71807	177.98910	-38.71810	177.98902	20.1
044	-38.71525	177.99212	-38.71528	177.99203	-
045	-38.71267	177.99490	-38.71272	177.99475	-
046	-38.71473	177.99721	-38.71472	177.99707	20.8
047	-38.71030	177.99373	-38.71033	177.99372	-

Site	Proposed Latitude	Proposed Longitude	Actual Latitude	Actual Longitude	Depth (m)
048	-38.71030	178.00117	-38.71033	178.00110	-
049	-38.71407	178.00267	-38.71402	178.00255	-
050	-38.71623	178.00220	-38.71625	178.00210	-
051	-38.71300	178.00035	-38.71295	178.00023	-
052	-38.70773	177.99695	-38.70770	177.99693	20
053	-38.70393	177.99397	-38.70390	177.99395	22.6
054	-38.70847	177.99516	-38.70845	177.99505	-
055	-38.70887	177.99838	-38.70892	177.99823	22.5
056	-38.71048	177.99873	-38.71050	177.99860	22.4
057	-38.70535	177.99602	-	-	-
058	-38.69838	177.98565	-38.69913	177.98348	18.2
059	-38.69957	177.98727	-38.69945	177.98713	18.4
060	-38.69988	177.98367	-38.69992	177.98348	18.2
061	-38.70150	177.98518	-	-	-
062	-38.70183	177.98147	-	-	-
063	-38.70322	177.98330	-	-	-
064	-38.70322	177.97970	-	-	-
065	-38.70640	177.98054	-38.70653	177.98038	-
066	-38.70587	177.97628	-38.70590	177.97607	19.6
067	-38.70910	177.97490	-38.70905	177.97485	-
068	-38.70932	177.97177	-38.70935	177.97180	18.7
069	-38.71083	177.97268	-38.71083	177.97255	18.9
070	-38.71392	177.97230	-38.71393	177.97222	18
071	-38.71530	177.97490	-38.71532	177.97487	-
072	-38.71627	177.97687	-38.71628	177.97688	21.9

Site	Proposed Latitude	Proposed Longitude	Actual Latitude	Actual Longitude	Depth (m)
073	-38.71276	177.97897	-38.71283	177.97897	-
074	-38.72053	177.98642	-38.72052	177.98637	21.8
075	-38.72208	177.98907	-38.72212	177.98895	-
076	-	-	-38.71882	177.99113	-
077	-	-	-	-	-
078	-	-	-38.72222	177.99522	20.2
079	-	-	-38.71997	177.99855	-
080	-	-	-	-	-