

Baseline Benthic Survey: Areas adjacent to proposed channel dredging footprint, Whangarei Harbour Entrance

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Cover Photo: The sand dollar *Fellaster zelandiae* as seen at sample location T16B, at the outer edge of the harbour entrance ebb tide delta.

For: Chancery Green on behalf of the New Zealand Refining Company

Report by: V.C. Kerr B.Sc., Roger Grace PhD.

Kerr and Associates, Whangarei

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Table of Contents

1	Summary	5
2	Introduction.....	5
3	Methods.....	6
3.1	Selection of sample sites	6
3.2	Soft sediment sampling.....	8
3.2.1	Special habitat: <i>Sabella</i> fan worm bed.....	9
3.3	Hard shore subtidal rocky reef habitats	10
3.3.1	Sponge gardens and rocky reef encrusting communities monitoring outside of the Marine Reserve.....	10
3.3.2	Sponge gardens and rocky reef encrusting communities monitoring inside of the Marine Reserve.....	11
3.3.3	<i>Ecklonia radiata</i> canopy monitoring	12
3.4	Navigation.....	12
3.5	Sediment sampling.....	12
4	Results.....	13
4.1	Soft sediment habitats particle size analysis	13
4.2	Soft sediments benthic invertebrate communities	15
4.2.1	Intertidal benthic invertebrate communities – Inner Harbour.....	16
4.2.2	Benthic soft bottom subtidal invertebrate communities - Inner Harbour survey area	20
4.2.3	Photographic descriptions of benthic environments sampled.....	26
4.2.4	Photographic description of sampled habitats Inner Harbour.....	26
4.2.5	Benthic invertebrate communities - Outer Harbour survey area	30
4.2.6	Photographic description of sampled habitats Outer Harbour	35
4.2.7	Special site <i>Sabella</i> fan worm monitoring	36
4.3	Hard shores rocky reef communities	37
4.3.1	<i>Ecklonia radiata</i> canopy monitoring	37
4.3.2	Sponge gardens and subtidal rocky reef encrusting communities outside Motukaroro Marine Reserve.....	40
4.3.3	Sponge gardens and subtidal rocky reef encrusting communities inside Motukaroro Island Marine Reserve	49

5	Discussion	55
6	Acknowledgements	56
7	References	56
8	Appendix 1 GPS coordinates for sample locations.....	58
9	Appendix 2 Rocky Reef Transect location maps.....	59

1 Summary

A survey of hard shore shallow rocky reef habitats and a wide range of soft sediment habitats were undertaken in the Whangarei Harbour entrance area in March-May 2016. These survey results form part of body of information collected to evaluate the feasibility of the proposed dredging operation at the Whangarei Harbour entrance by the New Zealand Refining Company. At 38 sample locations spread across the harbour entrance subtidal rocky reefs and soft bottom benthic habitats were investigated. On rocky reef habitats a diver crew established permanent photo quadrats and undertook algal forest monitoring. For soft bottom benthic communities a dive team collected core samples for invertebrate community and particle size analysis. Photographic imagery was collected at all sampling locations to assist with the characterization of surface sediments and observe epibenthic organisms present at the sites. Results of this survey are presented in the body of this report and in accompanying field and lab data.

2 Introduction

Refining NZ is proposing to carry out dredging work to deepen and re-align the Whangarei Harbour entrance channel. In preparation for this work a series of studies have been commissioned to look at the feasibility of the proposed operations and to define the ‘existing environment’.

The survey methodology followed in this study has been described and explained in the context of the overall project in detail in a report by Brian Coffey (2016b). This report includes a table of information summarising the habitats of the 18 transects. The general aim of the program of work is to gather sufficient habitat and biological community information to adequately describe the areas of interest. Additionally, the aim was to set up a quantitative biological monitoring system to serve as a baseline for the areas, and provide for future monitoring needs if the dredge disposal activity proceeds. Survey work was carried out between mid March and early June 2016.

The survey approach of this study was largely informed by a pilot study completed in December 2015 and January 2016, (Kerr and Grace 2016). In this study, eighteen transects were located in the areas of interest adjacent to the proposed dredging footprint. Basic descriptive habitat and biotic community information was collected and assembled to provide the basis for the design of this current study. Diver photos, a drop video camera and a box dredge for characterisation of benthic invertebrate communities were the methods used for the pilot study.

The scope of this report is confined to presenting the methodology used and reporting and summarising the results of the fieldwork.

3 Methods

3.1 Selection of sample sites

From the work presented in the Coffey report (2016b) on the recommended methodology for this study, 38 sample locations were selected. In most cases the sample location arrangement retained the spatial coverage of the pilot study transects (Kerr and Grace 2016a). Labelling of the permanent sample locations for this current study retained the ‘original’ transect number in the name. Three new sample locations were created in the Motukaroro Marine Reserve area to better cover and satisfy replication requirements of two special habitats there; sponge garden and encrusting invertebrate communities and a fan worm *Sabella sp.* site. Repositioning of some sample locations from the pilot study transect locations were done for the purpose of depth stratification of sample locations to be regarded as a data series in analysis.

The 38 permanent sample locations were made up of six subtidal rocky reef sponge garden and encrusting invertebrate ‘special habitat’ locations (Kerr and Grace, 2016a), five *Ecklonia radiata* canopy monitoring locations, 26 soft sediment benthic invertebrate sampling locations and one special habitat location which is a soft sediment habitat colonised by a *Sabellid* fan worm. Of the 26 soft sediment locations, five were intertidal locations at Marsden Cove (a cockle bed *Austrovenus stutchburyi*) and Mair and Marsden Bank (pipi beds *Paphies australis*). In total five of the sample locations listed above are in the marine reserve, (three subtidal rocky reef sponge garden sites, one *Ecklonia radiata* canopy site and the one *Sabella* tube worm soft bottom site).

In order to visualise the relationship between the pilot study transects and the permanent sampling locations of this study both maps are presented here in Figures 1 and 2.

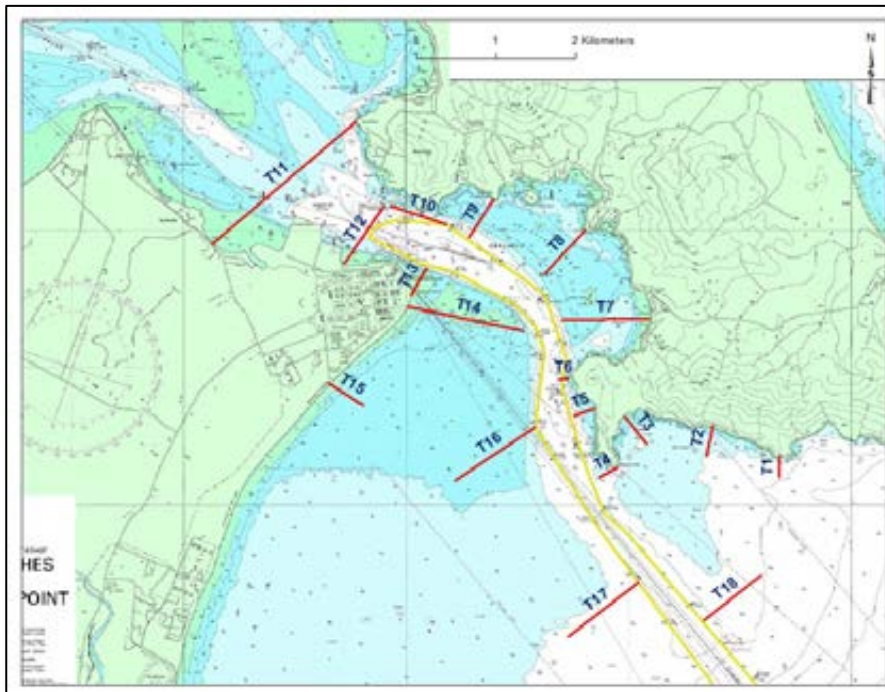


Figure 1 Map of pilot study (Kerr and Grace 2016)

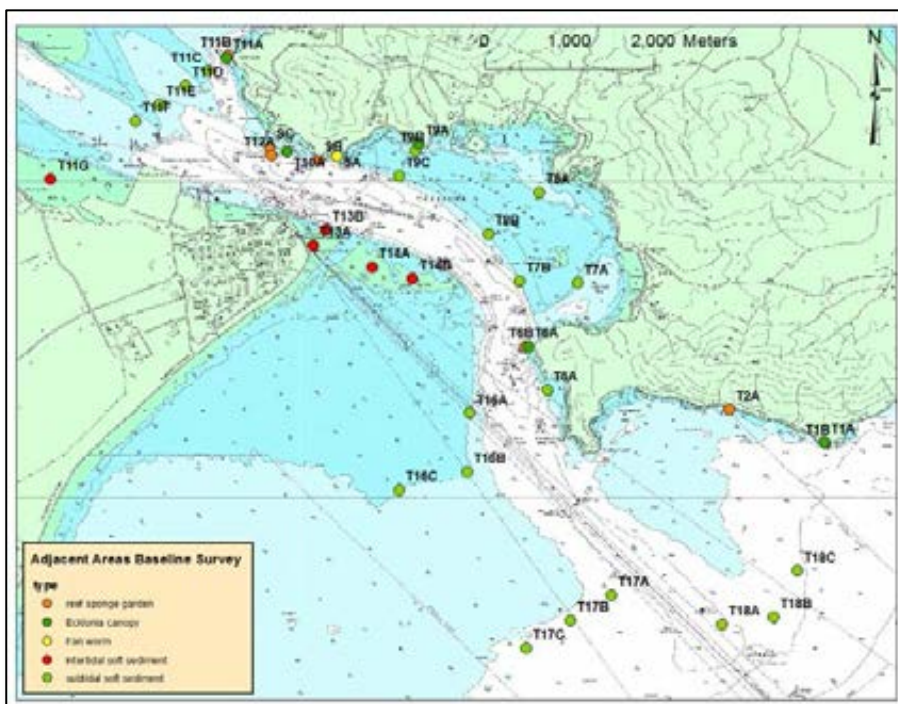


Figure 2 Map of 38 permanent sampling locations of this study shown in relation to the proposed channel dredging area.

3.2 Soft sediment sampling

Five replicate core samples were taken from each soft sediment sample location for analysis of benthic invertebrate community composition and abundance. The samples were taken with a hand-coring device operated by two divers for subtidal sites. Figure 3 below shows the coring device used in this survey. The dimensions of the coring tool are 138mm in diameter with a coring depth of 150mm. Once samples were taken on the seabed, the divers immediately transferred the contents of the corer to a sieve bag which was sealable on both ends. The sieve bag was made of flexible material in all but a central area which had a plastic scientific-quality 500-micron mesh. The samples were then transported to the surface where the cleaning and sieving process was completed. The remaining substrate material >500 microns and all biological components were placed in a plastic 1 L jar and immediately fixed with a solution of 70% ethanol, 2% glycol and the remainder seawater. Samples were then stored and later sent to the Cawthron Institute where a specialist taxonomy team sorted, identified and counted all organisms present to the lowest practical taxonomic level.



Figure 3 (Right) The hand-coring tool used in this survey, (Left) soft sediment benthic core samples ready for transfer to the lab for further analysis of invertebrate species.



Figure 4 Diver forcing the coring tool into the substrate, note red sample sieving bag to the right ready for loading with the sediment sample, photo taken at sample location T17C.

3.2.1 Special habitat: *Sabella* fan worm bed

Although a soft sediment habitat, this community was sampled with the photo quadrat method adopted for sample sites in the marine reserve described below in section 3.3.2., with the exception that a larger quadrat (0.5m^2) was used. This worm species is useful for a photographic survey approach. They have a habit of extending a considerable length of their body tube upwards from the seafloor, as well as having their feeding ‘fans’ extended. Analysis of the fan worm density was done by drawing a $100\text{mm} \times 100\text{mm}$ grid over the images and then selecting three representative squares to count. Selection of the counting squares was based on quality of the image and attempting to spread the sampling squares around quadrat haphazardly. This method is designed to allow an estimate of population density for the worms and was deemed suitable for the purpose of describing the habitat and community. Unfortunately using permanent markers to fix photo quadrats was not possible due to delays in obtaining a research permit to operate in the marine reserve. Once this is done with permanent quadrats a more rigorous counting methodology can be used to assess population density more accurately over time.

3.3 Hard shore subtidal rocky reef habitats

3.3.1 Sponge gardens and rocky reef encrusting communities monitoring outside of the Marine Reserve

Sample location target points were established from the previous pilot study and focussing on a depth range of 6-11m where encrusting sponge communities dominated the benthic community. Because four locations in this group were located in the marine reserve a method was sought that would involve the least possible disturbance and still provide a quantitative time series measurement of community health, in the form of percentage cover. To achieve this, at each site two concrete markers with stainless eye bolts and a short (1.5m) rope attached to a float were positioned in a suitable place on the bottom to create a transect where five replicate photo points could be permanently fixed. Measurement and position on this transect line were recorded at the time the photos were taken to allow for future surveys to relocate the permanent photo quadrats. Once the transect end-point blocks were positioned, a temporary float line was attached to the zero end. The survey boat took a final GPS waypoint from this line at the surface with the float line held taught to accurately fix the location for further surveys. An example of one of the zero point blocks is pictured in Figure 5 below. Also see Appendix 2 for maps of the four rocky reef transect located outside of the Motukaroro marine reserve.

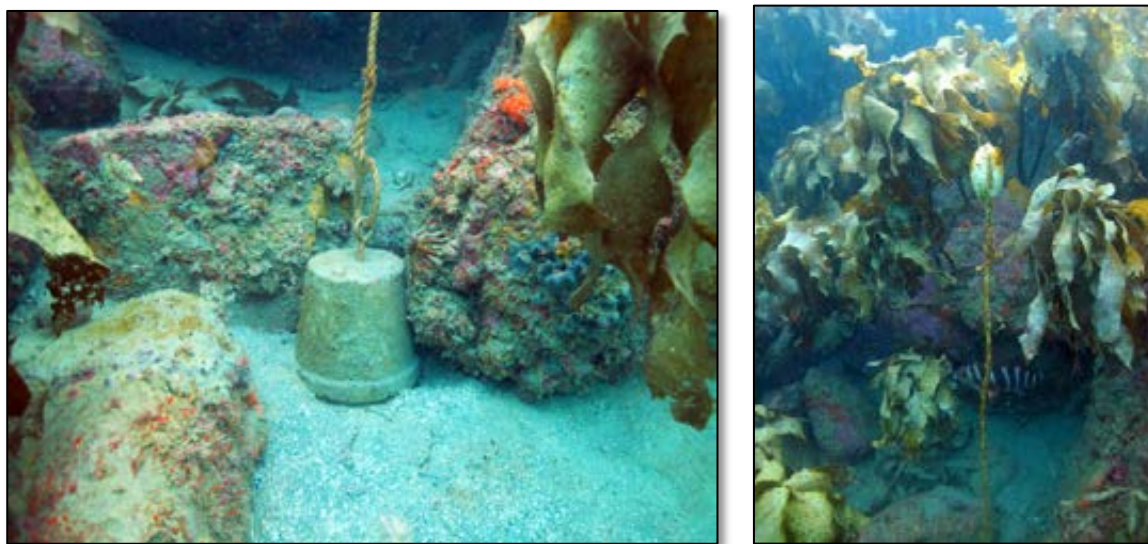


Figure 5 The zero point marker for sample location T2A taken two months after establishment.

The photo frame used for this method is pictured below in Figure 6. The camera is a Cannon G12 in an Ikelite housing. The apparatus frame base dimensions are 360mm by 260mm which is an area of 0.0936m².

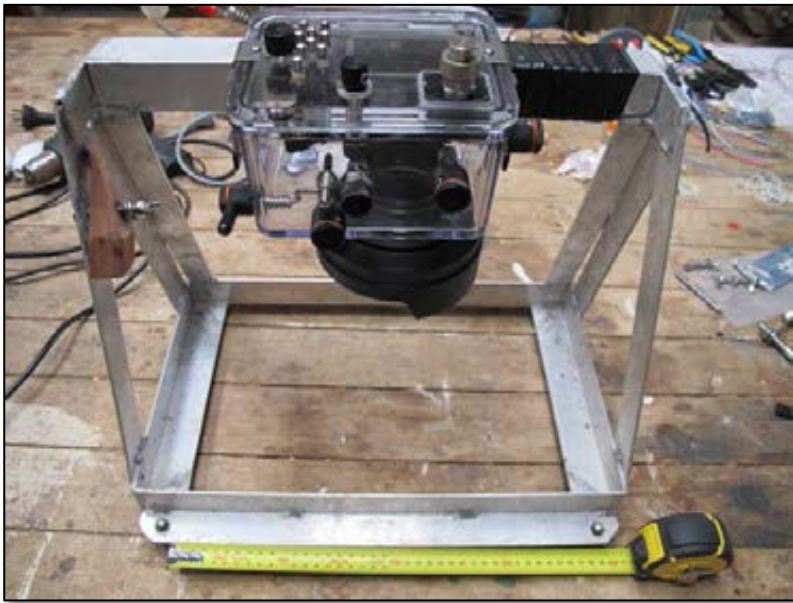


Figure 6 Camera and photo frame used for rock reef survey.

In a post-processing Photoshop procedure, photos had a 5 x 4 grid placed over them which divided the picture into 20 equal sections, each section being approximately 72mm x 72mm, (actual size on the substrate). A second routine placed five circles randomly in each grid, 100 circles, each 4mm in diameter, (actual size on substrate). A first order analysis to major taxonomic groups was then done of the encrusting organisms which cover the reef substrate within each circle. Where there was more than one organism in a circle the 'cover' score was split as a fraction of 10. From this data, a percentage cover value was generated for each of the taxonomic groups. In addition to the percentage cover estimates for each photo quadrat a provisional species list was made of the conspicuous organisms (greater than 10mm diameter approximately) to the lowest practical taxonomic level.

3.3.2 Sponge gardens and rocky reef encrusting communities monitoring inside of the Marine Reserve

It was not possible to complete processing of a research permit to carry out the planned work of establishing permanent transects within the marine reserve. It was decided to modify the method stated in Section 3.3.1 by not fixing permanent transect endpoints with markers on the sea bottom. The remainder of the method was similar to the other sites outside the marine reserve, producing five replicate photo frame quadrats. The difference is that quadrats are not likely to be able to be re-located accurately. As such, these results are valuable in describing the communities present but they will not afford the opportunity to carry out quantitative change over time comparisons. It is intended that additional

permanent photo quadrats and markers will be set up for this purpose once the research permit is granted by the Department of Conservation.

3.3.3 *Ecklonia radiata* canopy monitoring

There were five sample locations identified for the purpose of describing ongoing health of the predominant shallow algal canopy forming species *Ecklonia radiata*. For each sample location a target GPS point was transferred to the survey boat's chart plotter. Each of these sample locations had a planned target depth of 5m. In the field the point was adjusted to be as close as possible to this intended depth. A drop line with float was put over the side and a new GPS point taken. A diver then swam around this point hovering approximately 1m above the canopy and took a series of photos from different spots around the drop line and permanent point, not more than 5m from the line. From this photo set, five representative photo quadrats were haphazardly selected and analysed for percentage cover, general health and visual presence of silt. The photographs were taken with a Cannon G12 camera in an Ikelite housing.

3.4 Navigation

Design of target points of the survey were done in a GIS project and transferred to the chart plotter on the survey vessel. The chart plotter was a Humminbird 749 sounder, (WGS 1984 coordinate system).

3.5 Sediment sampling

At each of the soft sediment sample locations an additional 150mm deep sediment core sample was taken, which the dive team placed in a plastic bag and held on the boat in a chilled condition for further processing onshore. From this homogenised sample a 300g subsample was prepared for particle size analysis. The subsample was placed in a labelled zip lock bag and frozen for transfer to the Waikato University lab for 'general purpose environmental analysis'. At the lab the samples were hand sieved at 2mm. Sample portions below 2mm were run through a Malvern Lasersizer.

4 Results

4.1 Soft sediment habitats particle size analysis

Lab analysis results for the distribution of particle sizes making up the sediments of the 26 soft sediments samples are presented below in summarised form according to predominant sediment texture classes. The size range for each sediment texture class is indicated at the top of each table in millimetres.

The particle size results in Figure 7 reveal some important patterns in the data. First the T11 sample location is the most inner areas of this survey and is a place where the main channel of the harbour entrance widens into several much shallower wide channels. There are quite strong currents running over all these sites. They are all quite shelly with a good proportion of shell hash and coarse sand, with fine sands and silts only in low proportions. Moving outwards the T8 and T9 sample locations have comparatively less shell and coarse sand with a trend towards having more shell in locations nearer the channel and less further away. Sample location T8A has more fine sand, a component of silt and a small component of clay. This pattern of coarse sediments towards the channel edge and finer sediments and presence of silt is repeated in the T7 locations. Sample location T5A has moderate currents, is located further out towards the harbour entrance and an intermediate distance from the channel edge. This sample location was chosen to provide the opportunity to monitor the indicator invertebrate species screw shell *Maoricolpus roseus*. The T5A site has an even balance of shell, coarse, medium and fine sands and a silt and clay component. The outer part of the harbour entrance has the three sets of sample locations T16, T17 and T18. Each of these series of three sample locations is depth stratified and run away from the harbour entrance channel edge. The T16 series is quite uniform in sediment make-up, comprising essentially clean fine sands with a small proportion of medium sands. The T17 series is similar but with more medium sands and some coarse sands. In addition, T17A, which is the location closest to the channel, has substantial shell hash and coarse and medium sands with only a very small proportion of fine sand. The T18 series is more uniform and has a balance between medium sand and fine sands, with the location furthest away from the channel having a proportion of fine sands.

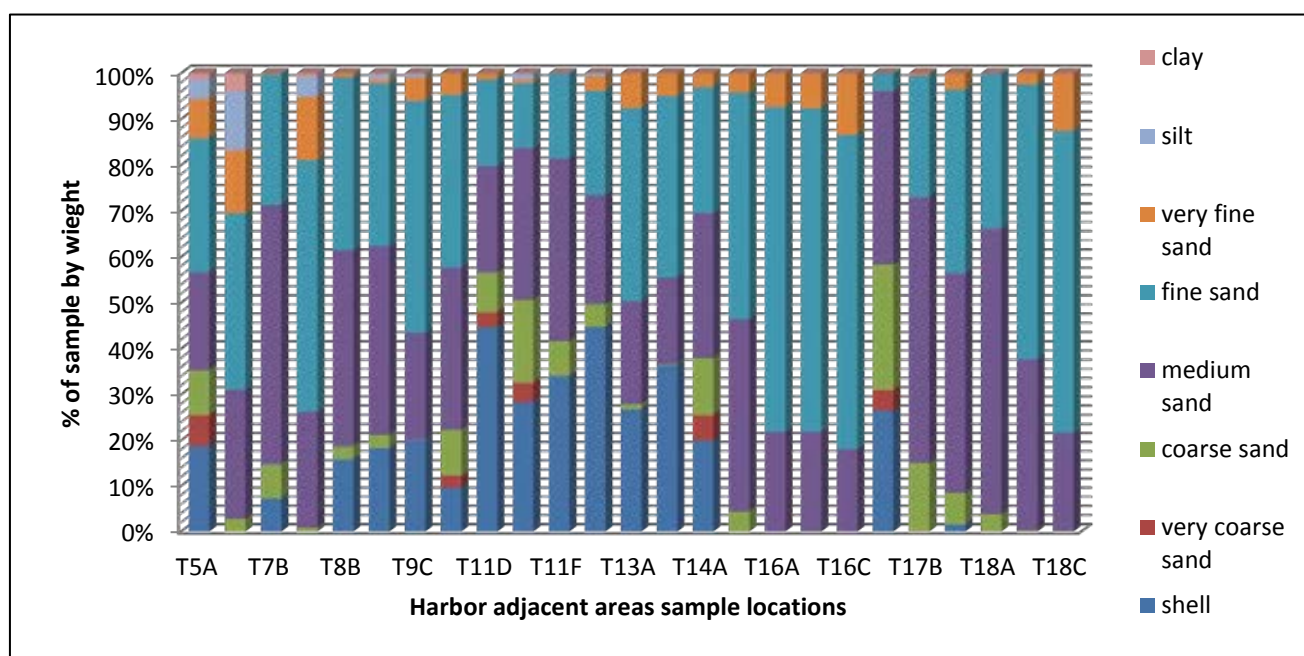


Figure 7 Percentages of particle size texture groupings for the soft sediment sample locations.

Sample	shell	very coarse sand	coarse sand	medium sand	fine sand	very fine sand	silt	clay
T5A	18.87	6.78	9.83	21.19	29.21	8.58	4.24	1.30
T7A	0.00	0.00	2.90	28.27	38.37	13.67	12.89	3.91
T7B	7.39	0.00	7.36	56.62	28.47	0.17	0.00	0.00
T8A	0.00	0.00	0.82	25.47	54.80	13.84	4.36	0.71
T8B	15.96	0.00	2.82	42.77	37.68	0.77	0.00	0.00
T9B	18.40	0.00	2.93	41.03	35.45	0.76	1.24	0.19
T9C	20.08	0.02	0.10	23.40	50.55	5.03	0.71	0.11
T11C	9.70	2.61	10.09	35.43	37.59	4.59	0.00	0.00
T11D	44.81	3.25	8.61	23.23	18.75	1.35	0.00	0.00
T11E	28.40	4.26	18.09	32.99	14.08	0.71	1.38	0.09
T11F	34.18	0.00	7.51	39.86	18.41	0.04	0.00	0.00
T11G	44.82	0.05	4.85	23.76	22.74	3.22	0.56	0.00
T13A	26.93	0.00	1.07	22.40	42.11	7.48	0.00	0.00
T13B	36.45	0.00	0.29	18.78	39.60	4.88	0.00	0.00
T14A	20.03	5.63	12.42	31.42	27.54	2.96	0.00	0.00
T14B	0.00	0.02	4.47	42.08	49.30	4.13	0.00	0.00
T16A	0.00	0.00	0.00	21.88	70.81	7.31	0.00	0.00
T16B	0.00	0.00	0.00	21.85	70.62	7.52	0.00	0.00
T16C	0.00	0.00	0.00	18.12	68.51	13.37	0.00	0.00
T17A	26.59	4.53	27.24	37.72	3.92	0.00	0.00	0.00
T17B	0.00	0.09	15.01	57.99	26.53	0.37	0.00	0.00
T17C	1.64	0.00	6.94	47.94	40.03	3.44	0.00	0.00
T18A	0.00	0.00	3.86	62.36	33.72	0.06	0.00	0.00
T18B	0.00	0.00	0.26	37.51	59.83	2.39	0.00	0.00
T18C	0.00	0.00	0.03	21.66	65.78	12.53	0.00	0.00

Table 1 Percentages of particle size texture groupings for the soft sediment sample locations.

4.2 Soft sediments benthic invertebrate communities

The results of the benthic invertebrate community analysis of the 26 soft sediment sample locations sampled are presented in this report below, (Sections 4.2.1 - 4.2.6). The level of taxonomic identification of organisms is in most cases done to family, genus or species level. The raw data is available in spreadsheet format accompanying this report. A first stage analysis of benthic community has been undertaken which provides a basic description of abundance and diversity and sampling precision. Abundance data is reported in the form of total number of individual organisms sampled and mean counts for sample locations. Community structure and diversity is presented as the number of taxa found for the main taxonomic groups at the phyla and class level reported as percentage composition of the community. There were eleven major taxonomic groups selected for this analysis.

One of the purposes of this study is to establish a baseline of community level data that could be re-sampled over time in a manner that would allow for change over time analysis. To this end at each sample location five replicate core samples were taken and analysed. For this report mean values of each set of five replicate samples are used for the analysis for abundance and diversity descriptions. An analysis was undertaken of the sampling error or variance found at each sample location, i.e. across the five replicate samples. It was decided it would be useful to report on sampling error across two important taxa groups, the Amphipoda group, (Order level) and the Polychaete worm group, (Class level). Both groups are important ecologically, diverse and abundant in terms of species counts and well distributed across the survey areas. The polychaete worms include a diverse range of functional groups including parasitic and carnivorous species, suspension, infaunal filter, infaunal deposit, epifaunal deposit, scavenger and omnivorous feeders. Amphipods are mainly epifaunal scavengers and make up an important component in most aquatic benthic communities.

For the analysis of sampling error the following calculation was preformed. For the two taxonomic groups at each sample location a standard deviation value was calculated from the sum of each of the five replicate counts and the corresponding sample location mean count for the taxa group.

4.2.1 Intertidal benthic invertebrate communities – Inner Harbour

Table 2 and Figure 8 below show abundance and diversity measures which describe the six intertidal sample locations. The method used was the same as that for the subtidal soft sediment sampling (Sec 3.2).

The five intertidal sample locations taken as a whole had 3,789 individual organisms counted and 97 species or taxa recorded. The range of total individuals counted varied between 75 (sample location T13A) to 1,526 (sample location T14B), across the five sample locations. The range of the mean counts of individual organisms for each sample location was the low count of 15 (sample location T13A) and a high count of 305 (sample location T14B). The large counts of individual organisms in sample locations T14A and T14B were primarily made up of a higher species counts and higher abundance in the Oligocheata and Polychaeta groups. The Polychaete family Serpulidae and notably the species *Hydroides norvegicus* was recorded in high numbers with mean counts of 58 and 33 individuals at sample locations T14A and T14B.

Total taxa counts were reasonably consistent across the six sample locations falling in a range of between 20 and 56. Mean taxa count values were in a range of between 8 and 28. Sample locations T14 A and B had the high taxa counts and sample location T13A had the low.

Sample location T13A was notable in that it had very low abundance and diversity counts in relation to the other locations and also compared to nearby sample location T13B suggesting that there could be a disturbance of some sort affecting this location on Mair Bank near the shore.

Sample locations	T11G	T13A	T13B	T14A	T14B
Total count individual organisms (5 samples)	568	75	293	1327	1526
Mean count individual organisms	114	15	59	265	305
Total taxa count (5 samples)	32	20	37	56	50
Mean taxa count	17	8	16	28	28

Table 2 Intertidal sample locations: abundance data; individual organisms total counts across five replicate samples for each sample location, mean values of counts for each sample location, diversity data; total taxa counted across five replicate samples and mean taxa counts for each sample location.

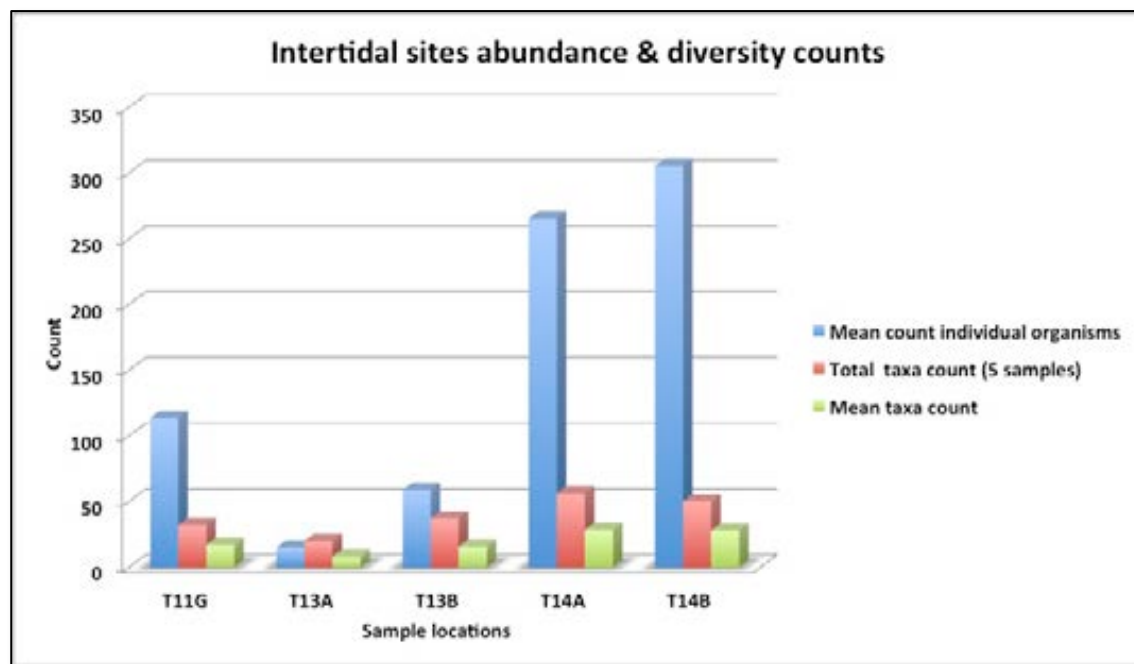


Figure 8 Intertidal sample locations: graphic illustration of abundance and diversity data shown in Table 2 above; total individuals counted, total taxa counted and mean values for individual organisms and taxa counts shown for each sample location.

Table 3 and Figure 9 below show the community composition of eleven major taxa across the five intertidal sample locations surveyed.

Polycheata, Oligocheata and the other taxa group were the most abundant of the eleven major taxa groups. They represented 37, 19 and 16 percent respectively of the invertebrate community of the intertidal sample locations taken as a whole.

The large quantity of Polycheate and Oligocheate worms making up the community of sample locations T14A and T14B can be seen clearly in the graph below and contrast dramatically with the very low diversity counts of sample location 13A.

Sample locations	T11G	%	T13A	%	T13B	%	T14A	%	T14B	%
Cnidaria	11.6	10.2%	0.0	0.0%	0.0	0.0%	1.0	0.4%	2.2	0.7%
Nematoda	0.2	0.2%	0.0	0.0%	0.0	0.0%	16.8	6.3%	44.0	14.4%
Mollusca, Polyplacophora	0.2	0.2%	0.0	0.0%	0.4	0.7%	0.2	0.1%	0.8	0.3%
Molusca, Gastropoda	6.2	5.5%	0.4	2.7%	0.2	0.3%	2.8	1.1%	5.0	1.6%
Molusca, Bivalvia	36.4	32.0%	0.6	4.0%	2.0	3.4%	0.4	0.2%	13.2	4.3%
Annelida, Oligochaeta	1.4	1.2%	0.4	2.7%	0.0	0.0%	98.0	36.9%	157.2	51.5%
Annelida, Polychaeta	43.6	38.4%	6.0	40.0%	30.4	51.9%	95.8	36.1%	59.4	19.5%
Arthropoda, Amphipoda	9.4	8.3%	2.6	17.3%	11.4	19.5%	14.4	5.4%	10.0	3.3%
Echinodermata	0.0	0.0%	0.0	0.0%	0.0	0.0%	1.2	0.5%	0.8	0.3%
Cephalocordata (lancelet worm)	0.0	0.0%	0.0	0.0%	0.2	0.3%	0.4	0.2%	0.0	0.0%
Other taxa	4.6	4.0%	5.0	33.3%	14.0	23.9%	34.4	13.0%	12.6	4.1%

Table 3 Intertidal sample locations: counts of the species or taxa making up each of the main taxonomic groups and the percentages of community represented by each group.

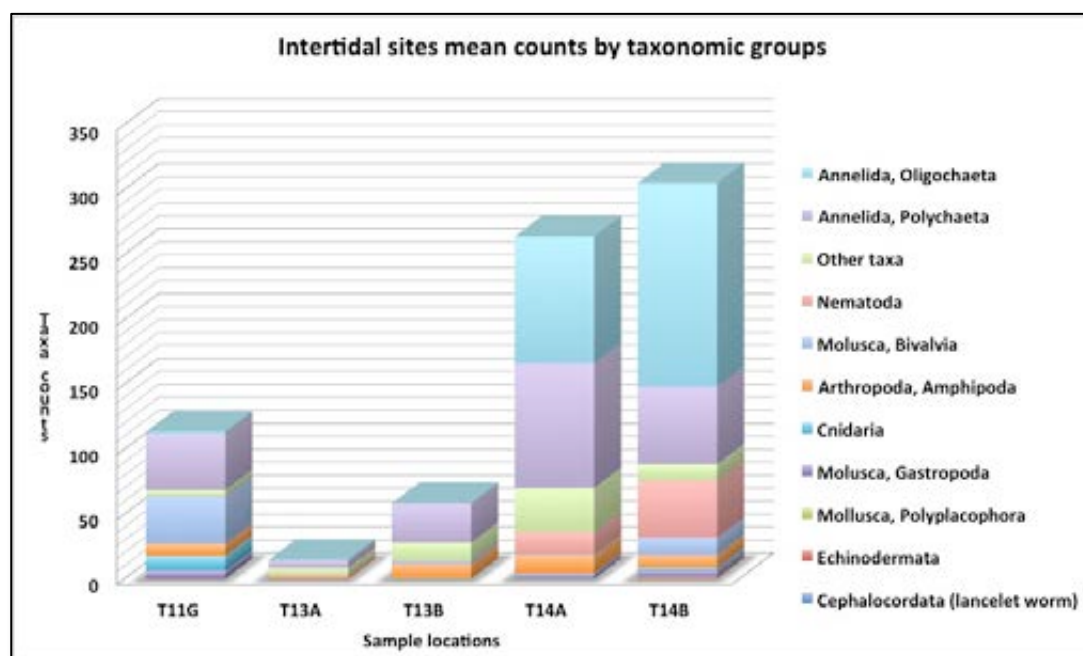


Figure 9 Intertidal sample locations: community diversity expressed as mean counts of eleven major taxonomic groups based on the data shown in Table 3 above.

Table 4 and Figure 10 below show the results of analysis of two major taxonomic groups and the sampling variation within the five replicate samples taken at each sample location. Mean counts for the number of species found in Amphipoda and Polychaeta groups are shown along with the calculated standard deviation across the five replicate samples for each sample location of the intertidal group.

The sampling error or variance observed is what could be expected for this type of survey.

Sample locations	T11G	T13A	T13B	T14A	T14B
Polychaeta group count	43.6	6.0	30.6	95.8	59.4
Polychaeta group std.dev.	17.3	4.2	12.2	58.1	27.5
Amphipoda group count	9.4	2.6	11.4	14.4	10.0
Amphipoda group std.dev.	6.8	1.3	6.1	8.9	2.1

Table 4 Intertidal sample locations: sampling variation expressed as standard deviation of the species counts calculated across the five replicate samples for each sample location at the taxa group level. Group counts are mean values of the sum of the group counts.

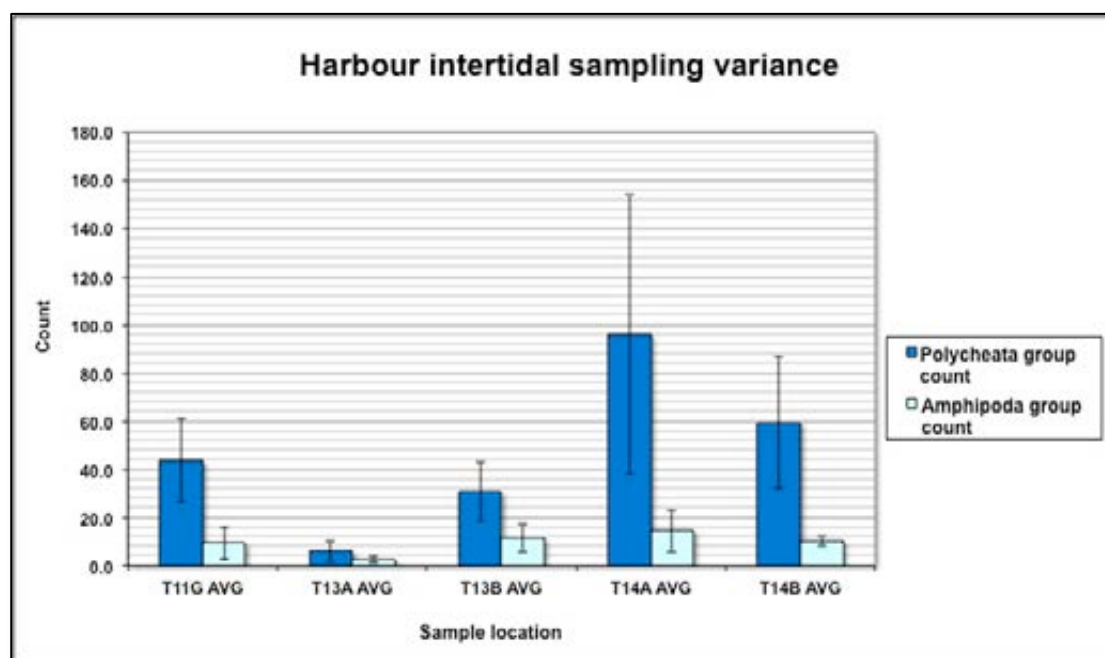


Figure 10 Intertidal sample locations: sampling variation, graphic presentation of the data shown in Table 4 above. Sampling variation is expressed as standard deviation values (error bars) calculated across the five replicate samples for each sample location at the taxa group level. Group counts are mean values of the sum of the group counts.

4.2.2 Benthic soft bottom subtidal invertebrate communities - Inner Harbour survey area

Table 5 and Figure 11 below show abundance and diversity measures describing the eleven inner Harbour sample locations surveyed.

The Inner Harbour sample locations taken as a whole had 8,534 individual organisms counted and 191 species or taxa recorded. The range of total individuals counted varied between 102 (sample location T11F) to 1,498 (sample location T5A), across the eleven sample locations. The range of the mean counts of individual organisms for each sample location was the low count of 20 (sample location T11F) and a high count of 300 (sample location T5A). Sample locations T5A and T7A had very high counts of individual organisms with the Polychaeta and Amphipoda groups accounting for much of the abundance. The Polychaeta families, Spionidae, Maldanidae, Syllidae, Ophiuridae, and Serpulidae were well represented. Both these sample locations were situated at the southern end of Caliope Bank. Across all the Inner Harbour sample locations counts were relatively high with the lowest count of 102 recorded at sample location T11F.

Total taxa counts were reasonably consistent and were generally high with the exception of sample location T11F. The range of counts was between 10 and 91. Mean taxa count values were in a range of between 3.8 and 50.

Sample locations	T5A	T7A	T7B	T8A	T8B	T9B	T9C	T11C	T11D	T11E	T11F
Total count individual organisms (of 5 replicate samples)	1498	2010	309	857	1131	716	267	248	954	442	102
Mean count individual organisms	299.6	402	61.8	171.4	226.2	143.2	53.4	49.6	190.8	88.4	20.4
Total taxa count (of 5 replicate samples)	91	89	54	57	68	77	47	38	64	56	10
Mean taxa count	50	46.2	20.8	28.4	32	40.4	19.8	16.2	32.6	26.2	3.8

Table 5 The Inner Harbour sample locations: abundance data; individual organisms total counts across five replicate samples for each sample location, mean values of counts for each sample location, diversity data; total taxa counted across five replicate samples and mean taxa counts for each sample location.

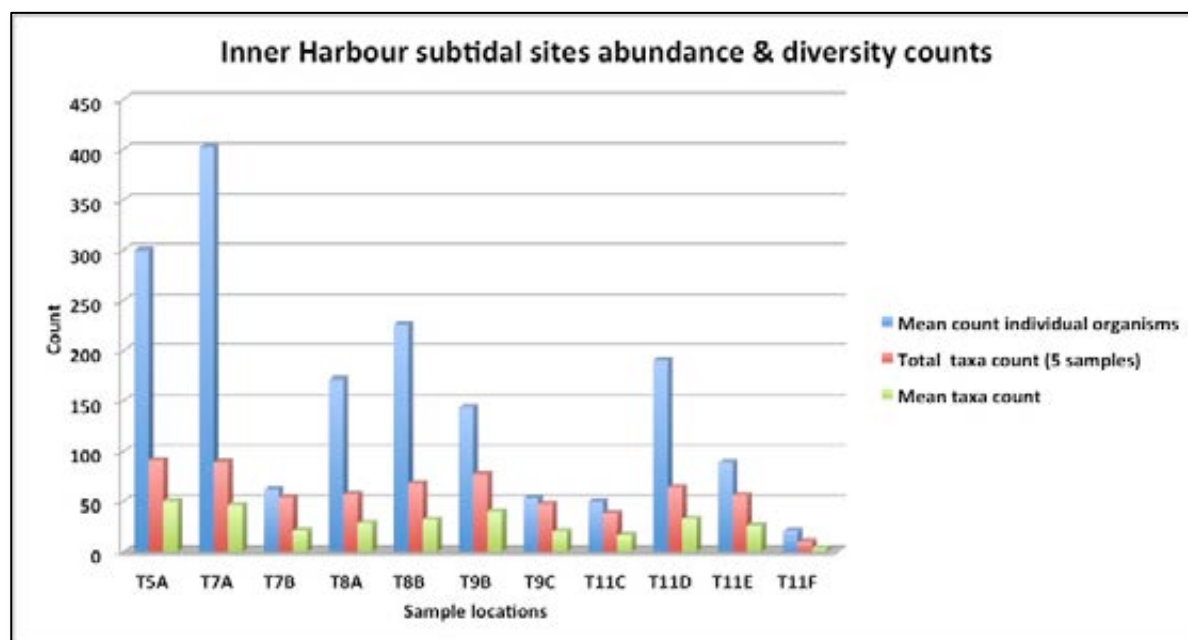


Figure 11 The Inner Harbour sample locations: graphic illustration of abundance and diversity data shown in Table 5 above; total individuals counted, total taxa counted and mean values for individual organisms and taxa counts shown for each sample location.

Table 6 and Figure 12 below show the community composition of eleven major taxa across the eleven Inner Harbour sample locations:

Polychaeta, other taxa and Amphipoda were the most abundant of the eleven major taxonomic groups. They represented 41, 25 and 11 percent respectively of the invertebrate community of the inner Harbour sample locations taken as a whole.

The taxa grouped together as ‘other taxa’ consist mainly of Nemerta and the Crustacea Orders; Copepoda, Isopoda, Decapoda, Ostracoda and Cumacea. In addition there were small numbers of Platyhelminthes (flatworm) Bryozoa, Hemichordata, Chaetognatha (arrow worms), Ascidians, Rhodophyta (algae) and two small fish species.

The large quantity of Polychaete worms making up a substantial part of the community at all sample locations can be seen clearly in the Figure 12 graph below.

Sample locations	T5A	%	T7A	%	T7B	%	T8A	%	T8B	%	T9B	%
Cnidaria	0.6	0.2%	0.8	0.2%	0.2	0.3%	0.8	0.5%	0.4	0.2%	2	1.4%
Nematoda	3.2	1.1%	6.4	1.6%	0.4	0.6%	0.8	0.5%	0.8	0.4%	7.5	5.2%
Mollusca, Polyplacophora	0.0	0.0%	0.0	0.0%	0.2	0.3%	0.0	0.0%	2.0	0.9%	2	1.4%
Molusca, Gastropoda	19.6	6.5%	5.6	1.4%	2.0	3.2%	0.4	0.2%	71.0	31.4%	6.3	4.4%
Molusca, Bivalvia	5.2	1.7%	2.0	0.5%	7.2	11.7%	4.0	2.3%	25.2	11.1%	10.8	7.5%
Annelida, Oligochaeta	30.4	10.1%	8.6	2.1%	1.0	1.6%	0.8	0.5%	3.0	1.3%	0.6	0.4%
Annelida, Polychaeta	78.6	26.2%	250.0	62.2%	29.2	47.2%	84.8	49.5%	66.0	29.2%	59.8	41.4%
Arthropoda, Amphipoda	104.8	35.0%	70.8	17.6%	4.4	7.1%	22.2	13.0%	14.2	6.3%	15.6	10.8%
Echinodermata	3.8	1.3%	1.6	0.4%	0.0	0.0%	0.8	0.5%	0.2	0.1%	1.8	1.2%
Cephalocordata (lancelet worm)	0.4	0.1%	0.4	0.1%	0.2	0.3%	1.4	0.8%	0.2	0.1%	1.2	0.8%
Other taxa	53.0	17.7%	55.8	13.9%	17.0	27.5%	55.4	32.3%	43.2	19.1%	36.85	25.5%

Sample locations	T9C	%	T11C	%	T11D	%	T11E	%	T11F	%
Cnidaria	3.2	6.0%	0.0	0.0%	1.6	0.8%	2.0	2.3%	0.0	0.0%
Nematoda	0.8	1.5%	1.8	3.6%	17.0	8.9%	19.6	22.2%	4.8	23.5%
Mollusca, Polyplacophora	0.0	0.0%	0.2	0.4%	6.8	3.6%	2.4	2.7%	0.0	0.0%
Molusca, Gastropoda	1.4	2.6%	0.6	1.2%	1.0	0.5%	0.6	0.7%	0.0	0.0%
Molusca, Bivalvia	3.2	6.0%	2.6	5.2%	15.0	7.9%	9.4	10.6%	0.0	0.0%
Annelida, Oligochaeta	3.4	6.4%	4.2	8.5%	4.6	2.4%	1.8	2.0%	1.2	5.9%
Annelida, Polychaeta	22.2	41.6%	19.2	38.7%	103.4	54.2%	30.6	34.6%	4.6	22.5%
Arthropoda, Amphipoda	3.2	6.0%	2.6	5.2%	12.6	6.6%	2.8	3.2%	1.4	6.9%
Echinodermata	0.2	0.4%	0.0	0.0%	0.8	0.4%	0.4	0.5%	0.0	0.0%
Cephalocordata (lancelet worm)	0.2	0.4%	0.2	0.4%	1.2	0.6%	0.4	0.5%	0.0	0.0%
Other taxa	15.6	29.2%	18.2	36.7%	26.8	14.0%	18.4	20.8%	8.4	41.2%

Table 6 The Inner Harbour sample locations: counts of the species or taxa making up each of the main taxonomic groups and the percentages of community represented by each group.

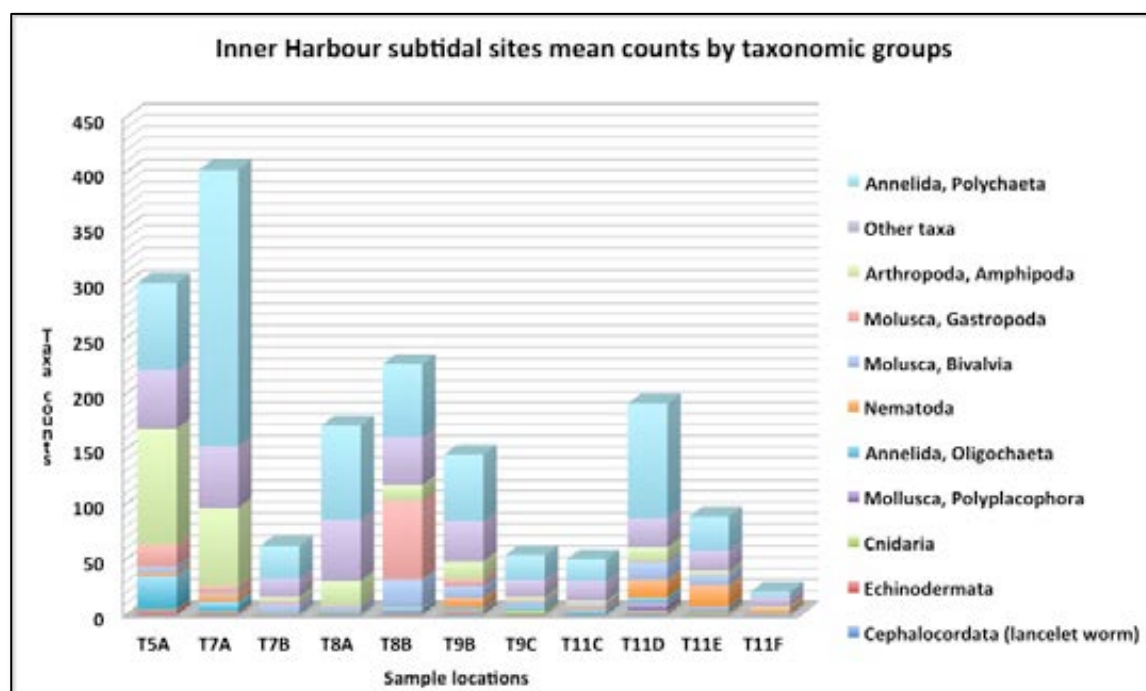


Figure 12 The inner Harbour sample locations: community diversity expressed as mean counts of eleven major taxonomic groups based on the data shown in Table 6 above

Table 7 and Figure 13 below show the results of analysis of two major taxonomic groups and the sampling variation within the five replicate samples taken at each sample location. Mean counts for the number of species found in Amphipoda and Polychaeta groups are shown along with the calculated standard deviation across the five replicate samples for each the Inner Harbour sample locations.

The sampling error or variance observed is what could be expected for this type of survey with some exceptions. Sample locations T11C, T11D, T11E and T11F had low counts for the Amphipoda group and standard deviation values near or exceeding these mean count values. This resulted from a number of zero counts recorded across the replicate samples. Sample location T11F also a low mean count and high standard deviation for Polychaete worms, again this was the result of recording numerous zero counts across the replicate samples.

Sample locations	T5A	T7A	T7B	T8A	T8B	T9B	T9C	T11C	T11D	T11E	T11F
Polycheata group count	78.6	250	29.2	84.8	66.0	59.8	22.2	19.2	103	30.6	4.6
Polycheata group std.dev.	39.0	94.6	19.8	21.4	37.0	36.4	14.5	12.6	59.2	17.4	7.1
Amphipoda group count	105	70.8	4.4	22.2	14.2	15.6	3.2	2.6	12.6	2.8	1.4
Amphipoda group std.dev.	58.6	50.6	1.9	10.4	4.5	7.2	1.3	2.7	10.5	2.4	1.9

Table 7 The Inner Harbour sample locations: sampling variation expressed as standard deviation of the species counts calculated across the five replicate samples for each sample location at the taxa group level. Group counts are mean values of the sum of the group counts.

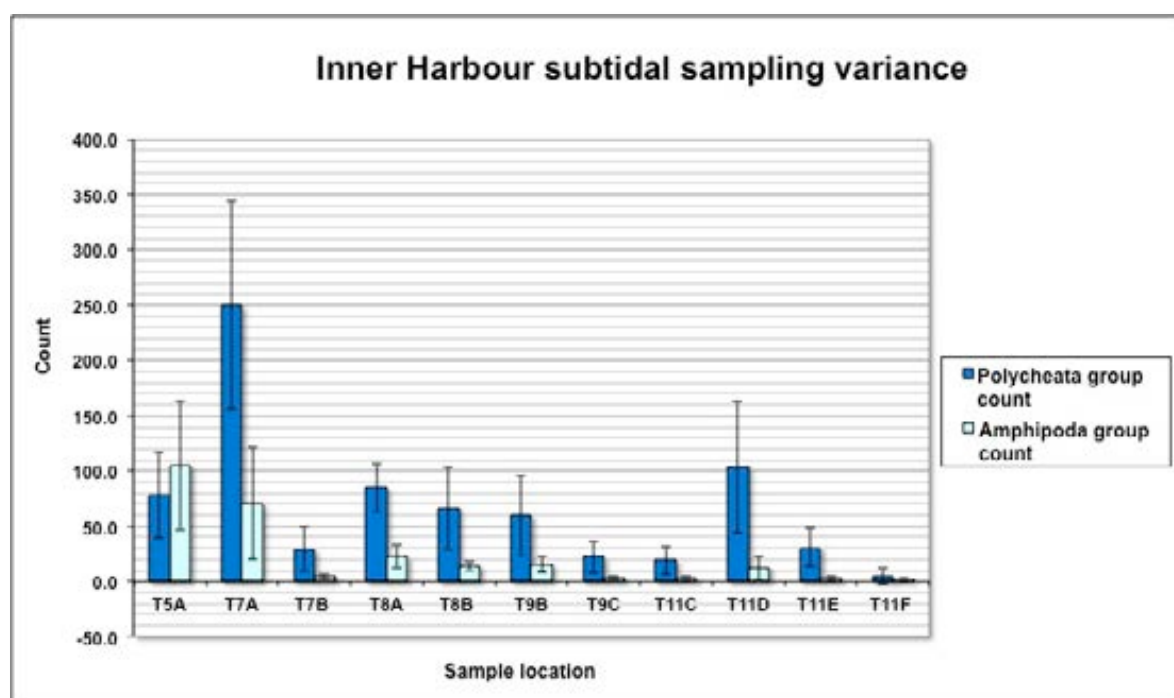


Figure 13 The Inner Harbour sample locations: sampling variation, graphic presentation of the data shown in Table 7 above. Sampling variation is expressed as standard deviation values (error bars) calculated across the five replicate samples for each sample location at the taxa group level. Group counts are mean values of the sum of the group counts.

4.2.3 Photographic descriptions of benthic environments sampled

At each of the 21 soft sediment subtidal locations where benthic core and sediment core sampling was carried out, the dive team took a series of photographs for the purpose of characterizing the substrate and recording any significant or interesting epibenthic organisms present. These photos record a range of diversity of substrates and habitats in addition to some notable taxa. The photos have been archived for future reference. A small selection from the photo archive is shown below to illustrate some of the typical substrates and taxa encountered. The photo series has been broken up in to two areas representing the inner part of the survey area (up harbour from Castle Rock and the marine reserve and down the harbour to Caliope Bank and the Home Point area) and the outer part of the survey area leaving the harbour and beyond the Frenchman and Mair Bank.

4.2.4 Photographic description of sampled habitats Inner Harbour

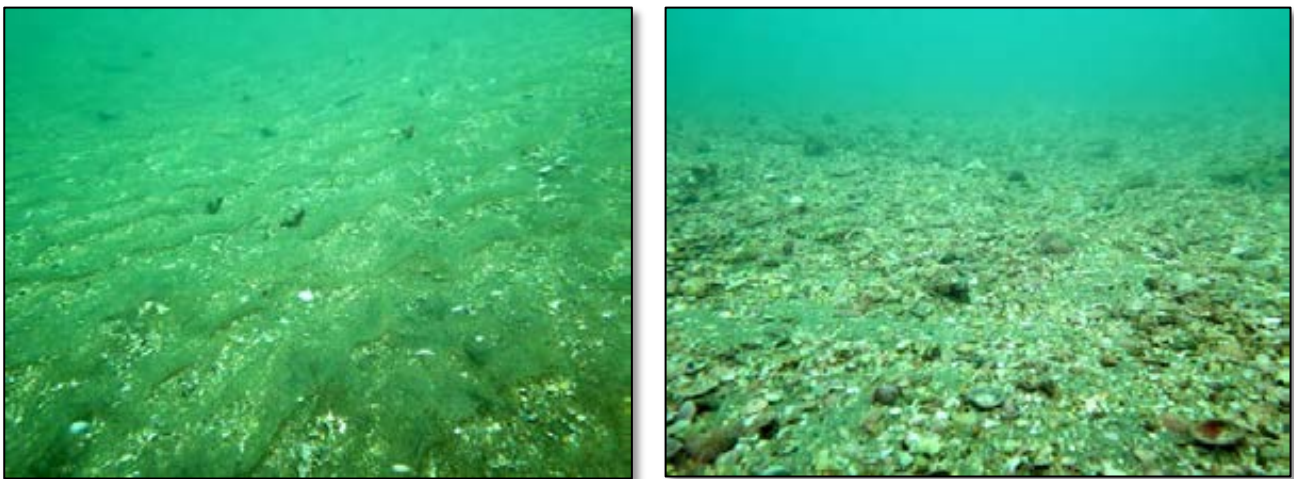


Figure 14 (Left) Sample location T11C, (Right) sample location T11D.



Figure 15 (Left) Sample location T11E, note high shell and gravel content of substrate (Right) sample location T11E, an octopus *Pinnoctopus cordiformis* is perfectly camouflaged on the shelly seafloor.



Figure 16 (Left) Sample location T11F, (Right) sample location T11F, an eleven-armed starfish *Coscinasterias muricata*.



Figure 17 (Left) Sample location T9C, (Right) sample location T9C a scallop *Pecten novaezelandiae*, half buried in the sand with a tufts of red algae growing on top shell.

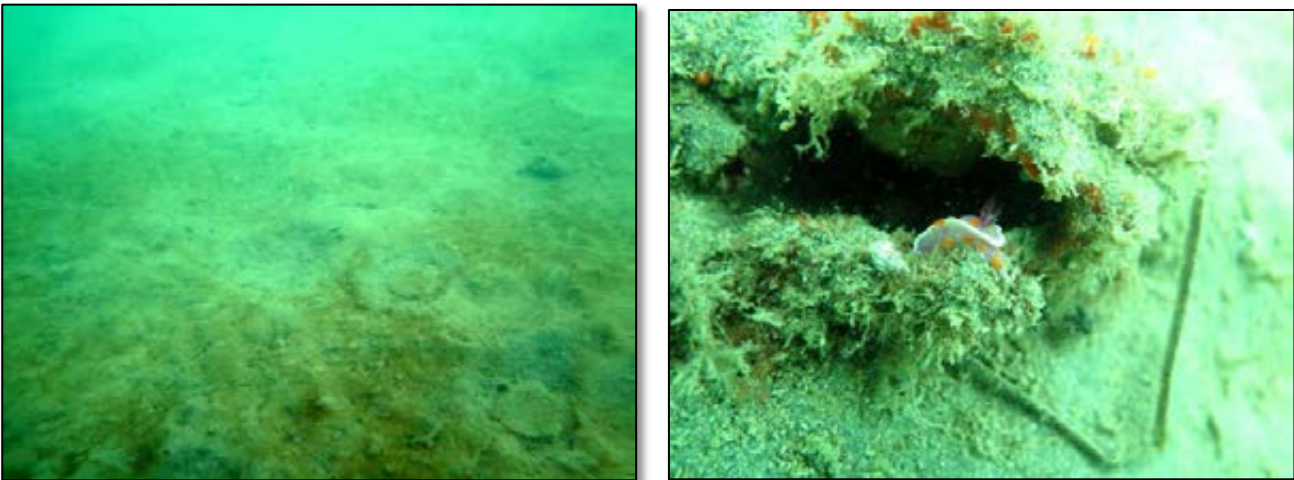


Figure 18 (Left) Sample location T8A, silty fine sand with two scallops *Pecten novaezelandiae* sitting in the sand. (Right) sample location T8A, the clown nudibranch *Ceratosoma amoena* is sitting in a dead and well-encrusted horse mussel *Atrina zelandica* shell.



Figure 19 (Left) Sample location T7B, shelly medium sand habitat, (Right) sample location T7B, two paddle crabs *Ovalipes catharus* confront our diver.



Figure 20 (Left) Sample location T5A, view of algal turf habitat over a sandy substrate, (Right) sample location T5A showing a close up of the screw shell *Maoricolpus roseus* which is abundant at this site and was selected for its value as an indicator species of environmental disturbance.

4.2.5 Benthic invertebrate communities - Outer Harbour survey area

The Table 8 and Figure 21 below show abundance and diversity measures describing the nine Outer Harbour sample locations.

The Outer Harbour sample locations taken as a whole had 828 individual organisms counted and 84 species or taxa recorded. The range of total individuals counted varied between 31 (sample location T16A) to 154 (sample location T18C), across the six sample locations. The range of the mean counts of individual organisms for each sample location was the low count of 6 (sample location T16A) and a high count of 31 (sample location T18C). The Outer Harbour sample locations as a group had pretty low abundance counts with many zero counts occurring across the replicate samples. In general these locations lack the coarse shell components and the fine silts and clay fractions that the more diverse and abundant Inner Harbour sample locations have. The Outer Harbour sites have predominantly medium and fine sand substrates.

Total taxa counts were reasonably consistent across the six sample locations falling in a range of between 13 and 36. Mean taxa count values were in a range of between 4 and 14.

Sample locations	T16A	T16B	T16C	T17A	T17B	T17C	T18A	T18C	T18C
Total count individual organisms (5 samples)	30	62	115	184	59	105	55	63	154
Mean count individual organisms	6	12	23	36.8	11.8	21	11	12.6	31
Total taxa count (5 samples)	13	23	23	33	21	28	15	22	36
Mean taxa count	4.4	7	8	14	8	11	6	8	13

Table 8 Outer Harbour sample locations; abundance data; individual organisms total counts across five replicate samples for each sample location, mean values of counts for each sample location, diversity data; total taxa counted across five replicate samples and mean taxa counts for each sample location.

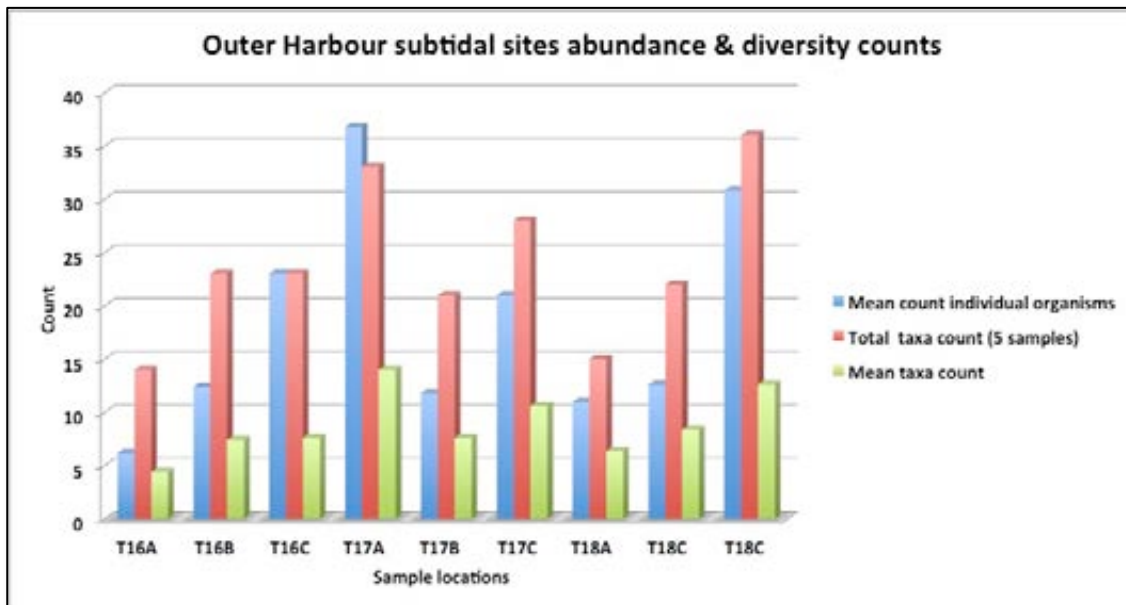


Figure 21 Outer Harbour sample locations; graphic illustration of abundance and diversity data shown in Table 8 above; total individuals counted, total taxa counted and mean values for individual organisms and taxa counts shown for each sample location.

Table 9 and Figure 22 below show the community composition of eleven major taxa across the nine Outer Harbour sample locations

The other taxa group, Polychaeta and Amphipoda were the most abundant of the eleven major taxa groups. They represented 36, 29 and 21 percent respectively of the invertebrate community of Outer Harbour sample locations taken as a whole.

The taxa grouped together as ‘other taxa’ consist mainly of Nemerta and the Crustacea Orders; Copepoda, Isopoda, Decapoda, Ostracoda and Cumacea. In addition there were small numbers of Hemichordata, Phoronida (horseshoe worm), Chaetognatha (arrow worms), Rhodophyta (algae) and a small fish species *Limnichthys polyactis*. Sample location T17A had larger numbers of Nematoda recorded as compared to the other sample locations that had very low numbers.

The large quantity of Polychaete worms making up the community of sample location 51 can be seen clearly in the Figure 19 graph below.

Sample locations	T16A	%	T16B	%	T16C	%	T17A	%	T17B	%	T17C	%
Cnidaria	0.0	0.0%	0.0	0.0%	0.2	0.9%	1.4	3.8%	0.0	0.0%	0.4	1.9%
Nematoda	0.0	0.0%	0.0	0.0%	0.4	1.7%	12.2	33.2%	0.4	3.4%	0	0.0%
Mollusca, Polyplacophora	0.0	0.0%	0.0	0.0%	0.0	0.0%	1.2	3.3%	0.0	0.0%	0	0.0%
Molusca, Gastropoda	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.2	0.5%	0.0	0.0%	0	0.0%
Molusca, Bivalvia	0.6	10%	1.2	9.7%	1.4	6.1%	1.8	4.9%	1.2	10.2%	0	0.0%
Annelida, Oligochaeta	0.0	0.0%	0.2	1.6%	0.0	0.0%	0.4	1.1%	0.0	0.0%	0.2	1.0%
Annelida, Polychaeta	1.6	26.7%	4.0	32.3%	2.8	12.2%	14.8	40.2%	3.4	28.8%	8.2	39.0%
Arthropoda, Amphipoda	0.6	10.0%	3.6	29.0%	11.4	49.6%	1.2	3.3%	2.0	16.9%	2.8	13.3%
Echinodermata	0.0	0.0%	1.0	8.1%	0.2	0.9%	0.0	0.0%	0.0	0.0%	0.6	2.9%
Cephalocordata (lancelet worm)	0.0	0.0%	0.0	0.0%	0.2	0.9%	0.8	2.2%	0.0	0.0%	0	0.0%
Other taxa	3.2	53.3%	2.4	19.4%	6.4	27.8%	2.8	7.6%	4.8	40.7%	8.8	41.9%

Sample locations	T18A	%	T18C	%	T18C	%
Cnidaria	0.0	0.0%	0.2	1.6%	0.0	0.0%
Nematoda	0.4	3.6%	0.2	1.6%	0.0	0.0%
Mollusca, Polyplacophora	0.0	0.0%	0.0	0.0%	0.0	0.0%
Molusca, Gastropoda	0.0	0.0%	0.2	1.6%	0.4	1.3%
Molusca, Bivalvia	0.2	1.8%	0.0	0.0%	1.0	3.2%
Annelida, Oligochaeta	0.0	0.0%	0.0	0.0%	0.0	0.0%
Annelida, Polychaeta	2.6	23.6%	5.4	42.9%	5.8	18.8%
Arthropoda, Amphipoda	1.4	12.7%	1.4	11.1%	12.8	41.6%
Echinodermata	0.2	1.8%	0.2	1.6%	0.4	1.3%
Cephalocordata (lancelet worm)	0.0	0.0%	0.0	0.0%	0.0	0.0%
Other taxa	6.2	56.4%	5.0	39.7%	10.4	33.8%

Table 9 Outer Harbour sample locations counts of the species or taxa making up each of the main taxonomic groups and the percentages of community represented by each group.

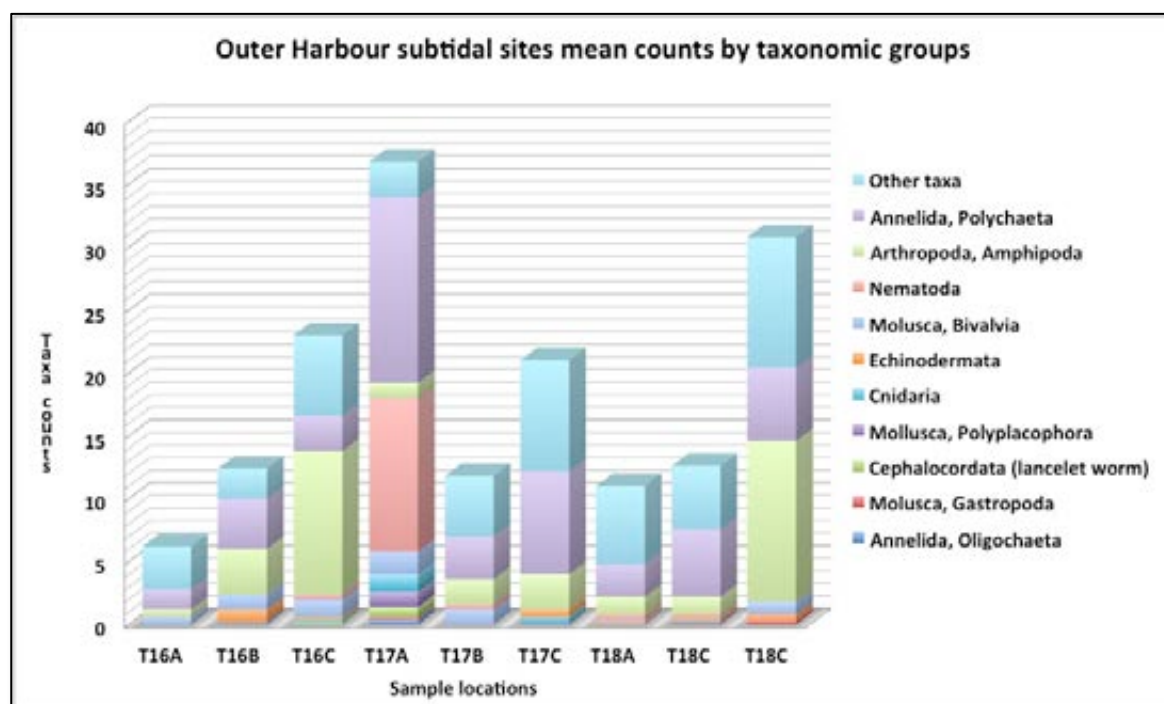


Figure 22 Outer Harbour sample locations community diversity expressed as mean counts of eleven major taxonomic groups based on the data shown in Table 9 above.

Table 10 and Figure 23 below show the results of analysis of two major taxonomic groups and the sampling variation within the five replicate samples taken at each sample location. Mean counts for the number of species found in Amphipoda and Polychaeta groups are shown along with the calculated standard deviation across the five replicate samples for each sample location in Outer Harbour.

The sampling error or variance observed for this group of sample locations shows a mixed result. Where counts were low the error bars are close to equal to the mean count value or exceeding it. This is a result of the low counts and numerous zero counts across the replicate samples. Sample location 16C has a large standard deviation for the Amphipoda group mean count with a count in one of the replicate samples being 10x greater than all the others. Sample location T17A Polychaeta and T18C Polychaeta and Amphipoda group mean counts were within what could be described as a more even distribution of organisms.

Sample locations	T16A	T16B	T16C	T17A	T17B	T17C	T18A	T18C	T18C
Polycheata group count	1.6	4.0	2.8	14.8	3.4	8.2	2.6	5.4	5.8
Polycheata group std.dev.	2.1	1.6	3.4	5.9	2.6	6.4	1.1	3.8	1.8
Amphipoda group count	0.6	3.6	11.4	1.2	2.0	2.8	1.4	1.4	12.8
Amphipoda group std.dev.	0.5	4.3	16.5	0.8	1.2	2.9	0.5	1.1	5.9

Table 10 Outer Harbour sample locations sampling variation expressed as standard deviation of the species counts calculated across the five replicate samples for each sample location at the taxa group level. Group counts are mean values of the sum of the group counts.

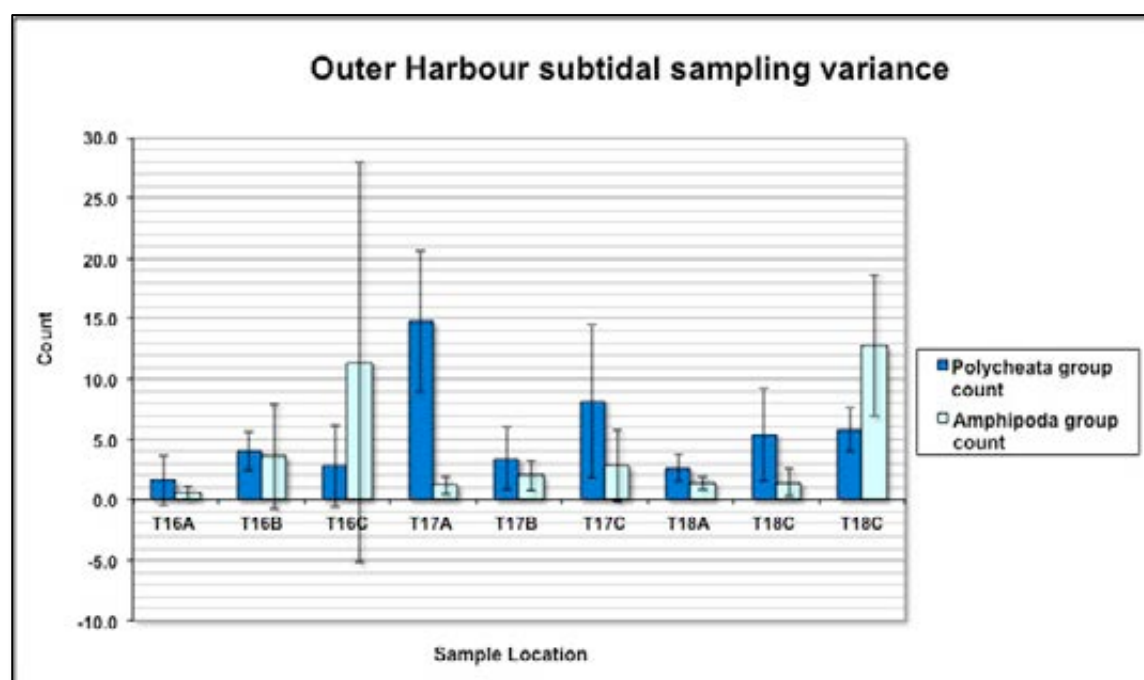


Figure 23 Outer Harbour sample locations sampling variation, graphic presentation of the data shown in Table 10 above. Sampling variation is expressed as standard deviation values (error bars) calculated across the five replicate samples for each sample location at the taxa group level. Group counts are mean values of the sum of the group counts.

4.2.6 Photographic description of sampled habitats Outer Harbour



Figure 24 (Left) Sample location T16A, fine sand and sand waves, (Right) sample location T16B, fine sand with sand dollar *Fellaster zealandiae* common.

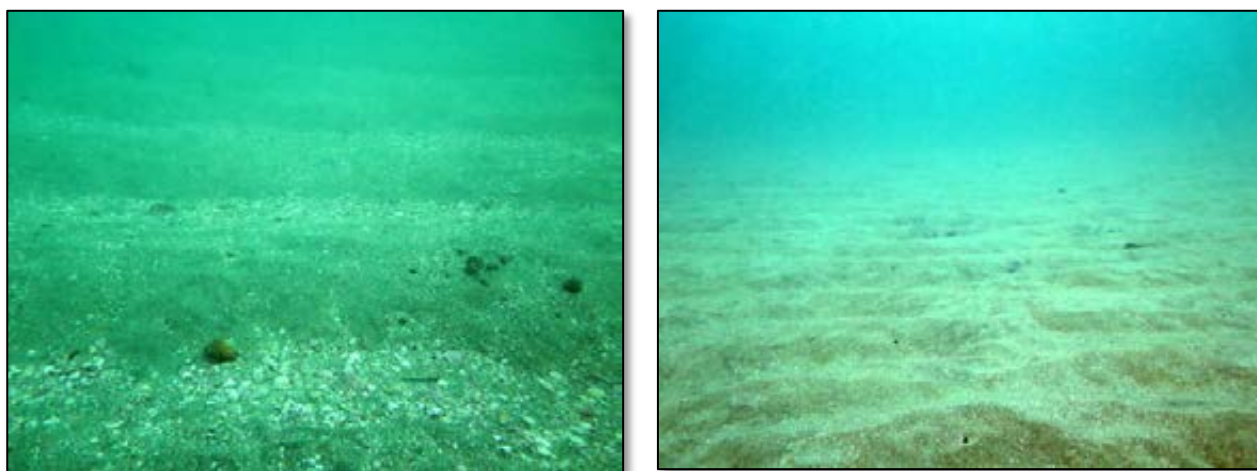


Figure 25 (Left) Sample location T17A showing medium to coarse sand with shell hash and sand wave forms, (Right) sample location T17B with medium to fine sand substrate and sand waves.



Figure 26 (Left) Sample location T18C with fine sand substrate and uneven sand wave forms, (Right) sample location T18C close up of a hermit crab *Pagurus novaezelandiae* common at this location.

4.2.7 Special site *Sabella* fan worm monitoring

The Sabellid worm site is located within the Motukaroro Marine Reserve. The method used for this survey is described in Sections 3.3.1 and 3.3.2.

The two images in Figure 27 below illustrate what this species of fan worm (*Sabella* sp.) looks like with its filter feeding fans extended and how they form dense beds. The counting square system that was used to generate the resulting estimate of population density of the community is also shown. The fan worm bed at this site is large in size; it is at least 20-30m long and at least 6-10 wide. The densities on a per meter basis counted across five replicate photo quadrats were calculated to be a low count of 3,633 and a high count of 5,467 worms per square meter.

Replicate	square 1	square 2	square 3	average count	calculated density per meter squared
A	25	39	45	36	3,633
B	54	39	53	49	4,867
C	39	40	45	41	4,133
D	28	49	42	40	3,967
E	53	64	47	55	5,467

Table 11 Counts of fan worms for three 100mm x 100mm counting squares, the average count for each quadrat and the calculated density of fan worms per meter squared.

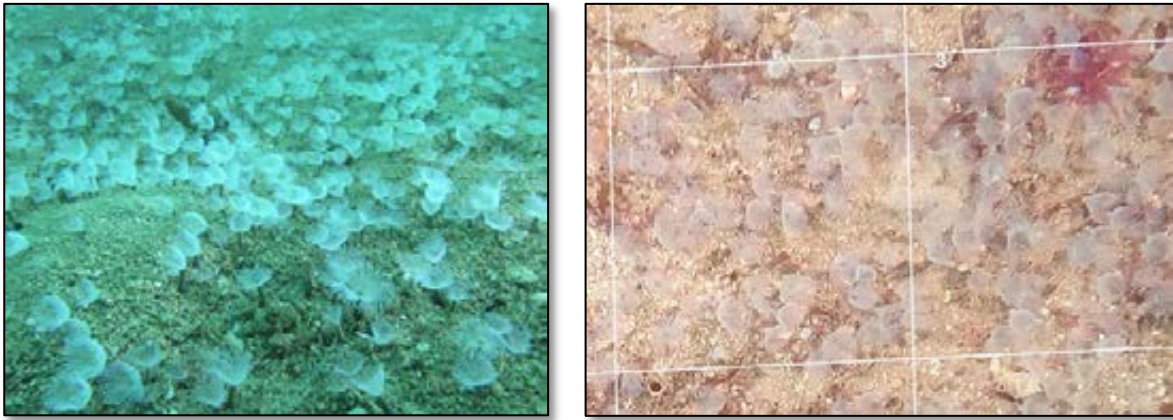


Figure 27 Sampling location SA *Sabella sp.* fan worm special site, Sample Location SA, (right) a typical view of the fan worm community at site SA, (left) a cropped image of the counting grids of photo quadrat, each counting square is 100mm x 100mm, this cropped image is taken from the replicate B photograph.

4.3 Hard shores rocky reef communities

The following sections detail the results of the specific survey investigations of this study. For a more general description and additional photographic resources of each of these sample locations readers are encouraged to refer to the pilot study completed of these areas (Kerr and Grace 2016). There is also a photo archive resource available for the previous study, as well as this current study.

4.3.1 *Ecklonia radiata* canopy monitoring

Five sites were selected to set up an ongoing monitoring site for canopy cover and health of the predominant shallow reef algal species *Ecklonia radiata*. The sites cover a range locations and distance from the proposed dredging footprint. In order from the most inner harbour site to the most outer site on the Bream Head coast.

T11A Darch Point

Marine Reserves site: T10A Motukaroro Island (east corner)

T9A Castle Rock, just east of marine reserve boundary

T6A Home Point

T1A Bream Head

At each site (target depth 5m) photos were taken from a GPS point marked by a drop line with camera hovering 1m over canopy; a minimum of five replicate photographs were taken over a 5m radius area from the drop line. Representative photos of each site are shown below.

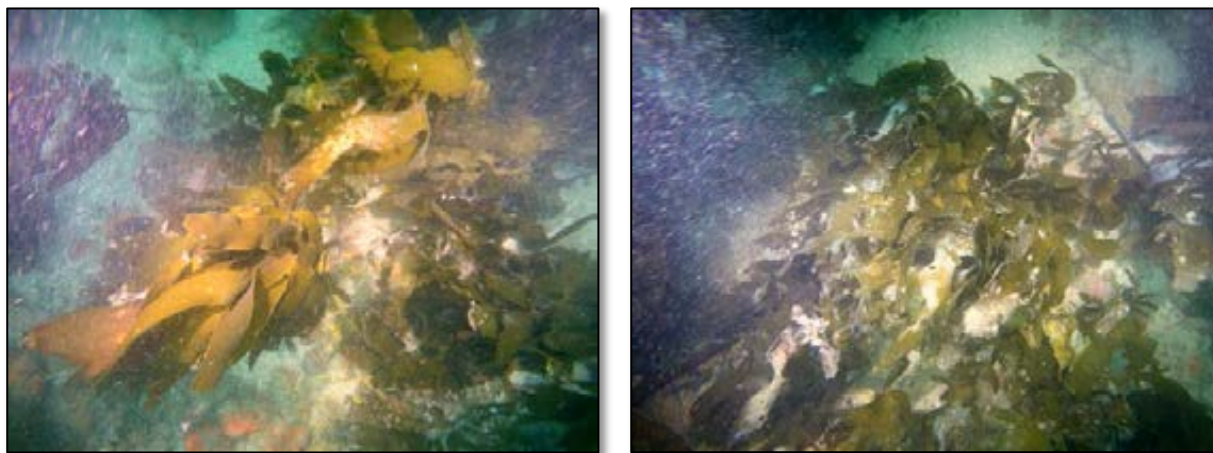


Figure 28 Darch Point, sample location T11A, representative *Ecklonia radiata* canopy photographs.

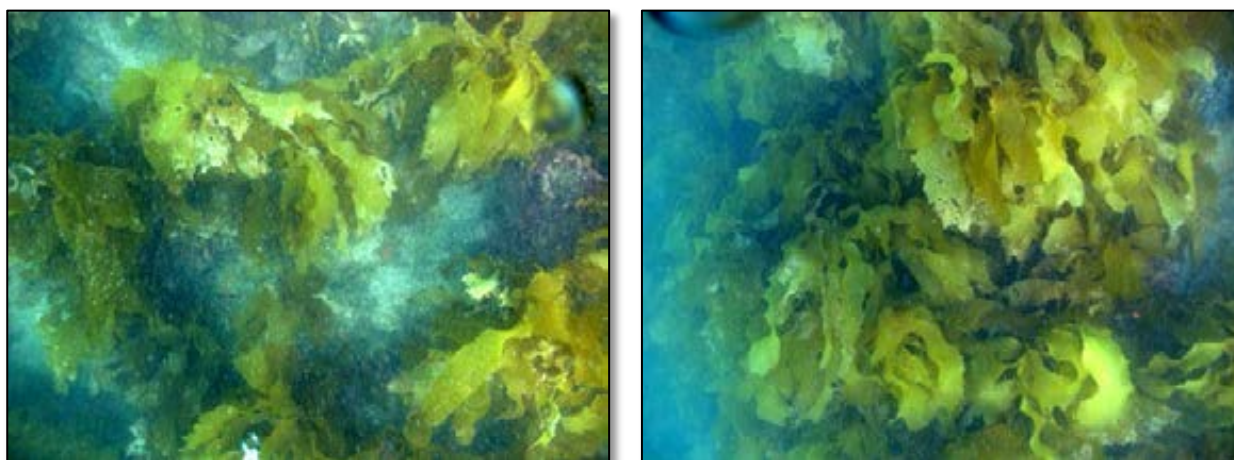


Figure 29 Motukaroro Island sample location T10A, representative *Ecklonia radiata* canopy photographs.

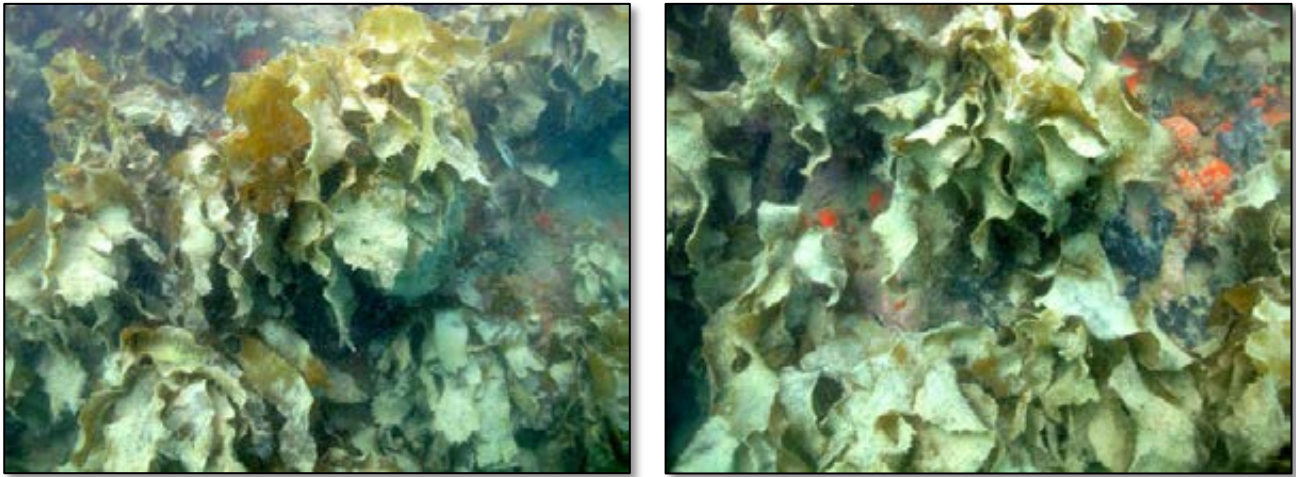


Figure 30 Castle Rock, sample location T9A, representative *Ecklonia radiata* canopy photographs

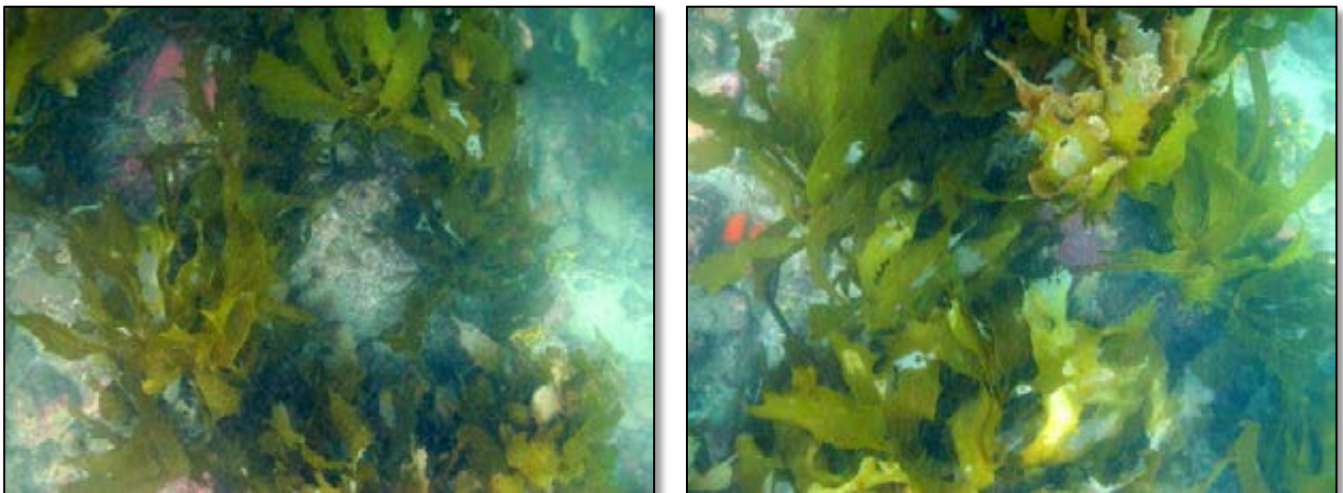


Figure 31 Home Point, sample location T6A, representative *Ecklonia radiata* canopy photographs

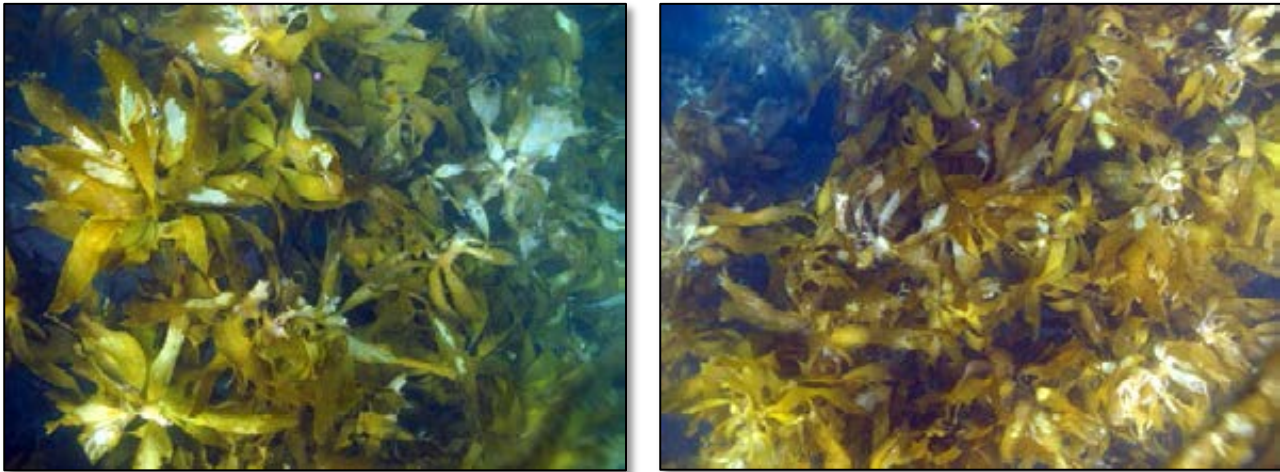


Figure 32 Bream Head, sample location T1A, representative *Ecklonia radiata* canopy photographs

4.3.2 Sponge gardens and subtidal rocky reef encrusting communities outside Motukaroro Marine Reserve

At each sample location five replicate photo quadrats were located and photographed. The photos were processed, analysed and archived as per the methodology described in Section 3.3.1 of this report. Results of this analysis are shown here in two tables for each sample location. Percentage cover of encrusting invertebrate species was calculated for each photo quadrat. Mean values of percentage cover of encrusting taxa for the five quadrats are presented for each sample location. In addition a basic taxonomic description of important taxa for each photo quadrat are presented in a second table for each sample location. Representative photos for each sample location follow the descriptions. A photo archive has been established along with detailed maps and navigational information to support relocating the photo quadrats for future surveys.

The sample location at Home Point T6A was chosen as special site where the white anemone *Actinothoe albocincta* was known to commonly occur. This anemone is present in all five replicates of the photo quadrats for this site. It is suggested that this organism would serve well as an indicator species for the examination of community structure and sensitivity to abnormal levels of siltation in the context of monitoring impacts of the proposed dredging activity.

4.3.2.1 T1B Bream Head

T1B Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
coralline paint	X	X	X	X	X
other calcareous algae	X		X	X	X
Porifera (sponges)					
encrusting sponge white, identification uncertain could be juv. ascidian				X	X
encrusting sponge orange	X		X	X	X
encrusting sponge yellow	X				
<i>Cliona celata</i>	X	X			
<i>Tethya bergquistae</i>			X		
Cnidaria					
thecate Hydrozoan				X	
Gastropoda					
Pisces					
triplefin sp.	X	X			

Table 12 Taxa recorded on the five replicate photo quadrats for the Bream Head sample location T1B (X denotes species present as a predominant specie in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology)

Taxonomic group	T1B-1	T1B-2	T1B-3	T1B-4	T1B-5	Mean
tube worm	0%	0%	0%	0%	0%	0%
Sponges encrusting	10%	5%	37%	2%	15%	14%
cup corals	0%	0%	0%	0%	0%	0%
Anenomes	0%	0%	0%	0%	0%	0%
Algae encrusting paint	30%	44%	28%	52%	40%	39%
Algae filamentous/turfing	0%	1%	0%	0%	0%	0%
Algae foliose	1%	1%	0%	0%	0%	0%
Algae calcareous	2%	0%	5%	14%	0%	4%
general encrusting community	0%	0%	0%	0%	0%	0%
Mollusca Gastropoda	0%	0%	0%	0%	0%	0%
Mollusca bivalves	0%	0%	0%	0%	0%	0%
Sponges upright	0%	0%	1%	0%	0%	0%
sand, silt, detritus, small tubes	40%	48%	28%	24%	38%	36%
shell fragments	0%	0%	0%	0%	0%	0%
thecate Hydroid	0%	0%	0%	7%	0%	1%
dead coralline paint	7%	0%	0%	1%	2%	2%
Ascidian	0%	0%	0%	0%	0%	0%
no image	10%	0%	0%	0%	5%	3%

Table 13 Bream Head, sample location T1B, summary of percentage cover of encrusting organisms on the five replicate photo quadrats.

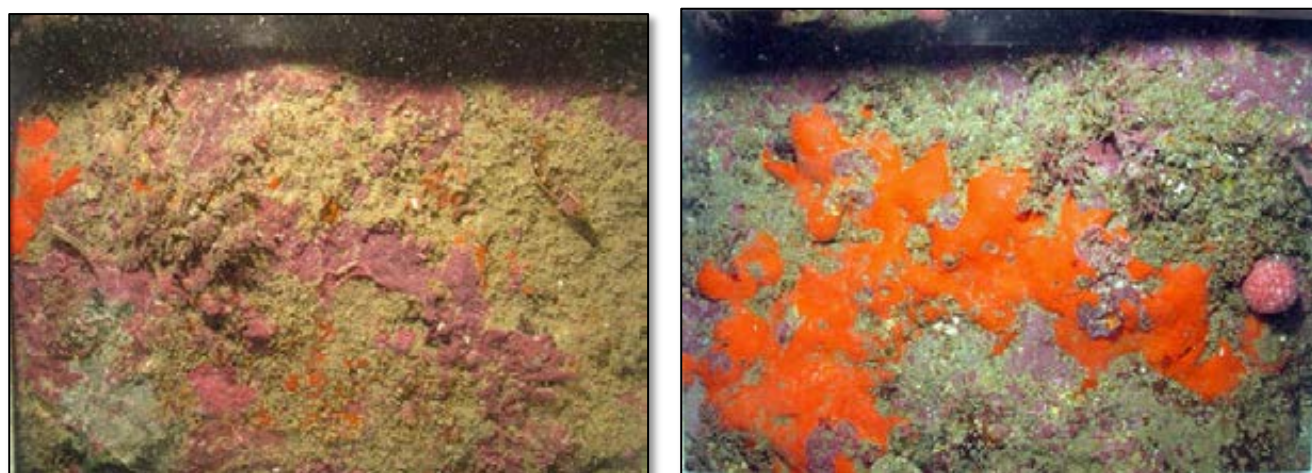


Figure 33 Bream Head, sample location T1B (Left) replicate 1, (Right) replicate 3.

4.3.2.2 Bream Head sample location T2A

T2A Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
coralline paint	X	X	X	X	
<i>Ecklonia radiata</i>	X		X	X	
Porifera (sponges)					
encrusting sponge purple		X			
encrusting sponge orange	X	X		X	
encrusting sponge yellow				X	
encrusting sponge brown				X	
<i>Cliona celata</i>	X		X		
<i>Aaptos globusum</i>	X				X
<i>Dragmaicdon australis</i>		X			
<i>Biemna rufescens</i>	X				
<i>Raspalia topsenti</i>					X
Cnidaria					
<i>Phebellum rubrum</i> (cup coral)	X				
Ascidians					
compound Ascidian		X			
Pisces					
triplefin sp.		X			X

Table 14 Taxa recorded on the five replicate photo quadrats for the Bream Head sample location T2A (X denotes species present as a predominant specie in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology)

Taxonomic group	T2A-1	T2A-2	T2A-3	T2A-4	T2A5	Mean
tube worm	0%	0%	0%	0%	0%	0%
Sponges encrusting	30%	20%	16%	19%	8%	19%
cup corals	0%	0%	0%	0%	0%	0%
Anenomes	0%	0%	0%	0%	0%	0%
Algae encrusting paint	6%	6%	37%	20%	1%	14%
Algae filamentous/turfing	0%	0%	0%	0%	0%	0%
Algae foliose	10%	0%	17%	8%	0%	7%
Algae calcareous	0%	0%	0%	0%	2%	0%
general encrusting community	0%	6%	0%	0%	0%	1%
Mollusca Gastropods	0%	0%	0%	0%	0%	0%
Mollusca bivalves	0%	0%	0%	0%	0%	0%
Sponges upright	0%	9%	0%	0%	15%	5%
sand, silt, detritus, small tubes	54%	59%	26%	53%	74%	53%
shell fragments	0%	0%	0%	0%	0%	0%
thecate Hydroid	0%	0%	0%	0%	0%	0%
dead coralline paint	0%	0%	1%	1%	0%	0%
Ascidian	0%	0%	0%	0%	0%	0%
no image	0%	0%	4%	0%	0%	1%

Table 15 Bream Head, sample location T2A, summary of percentage cover of encrusting organisms on the five replicate photo quadrats.

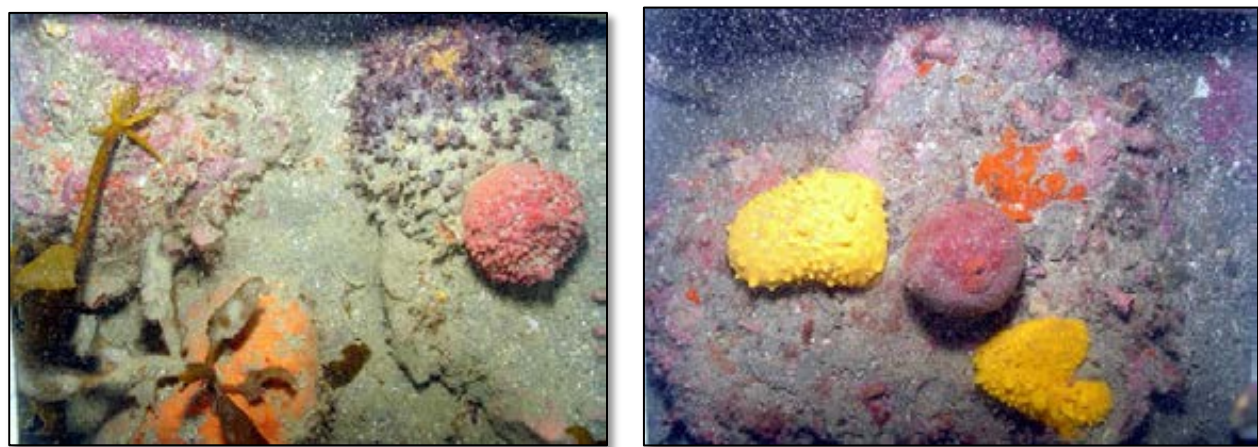


Figure 34 Bream Head, sample location T2A (Left) replicate 1, (Right) replicate 2.

4.3.2.3 Home Point, sample location T6B

T6B Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
coralline paint	X	X	X	X	X
other calcareous algae	X	X	X	X	X
red foliose algae	X		X	X	X
<i>Ecklonia radiata</i>		X	X		
Porifera (sponges)					
encrusting sponge orange	X		X	X	X
encrusting sponge yellow					X
<i>Polymastia aurantium</i>			X		X
<i>Tethya bergquistae</i>		X			
<i>Crella incrustans</i>	X				
<i>Tethya butoni</i>				X	X
<i>Darwinella oxeata</i>					
Cnidaria	X	X	X	X	
<i>Actinothoe albocincta</i>	X			X	
thecate Hydrozoan					X
Hydroids unidentified					
Annelida Polychaetes		X			
<i>Hydroides norvegicus</i>		X			
<i>Chaetopterus variopedatus</i> (parchment worm)					
Mollusca, Gastropoda			X		
<i>Ceratosoma amoenum</i> (clown nudibranch)	X				
<i>Thais orbita</i> (white rock shell)	X				
<i>Maurea punctulata</i> (tiger shell)	X				
<i>Maoricolpus roseus</i> (screw shell)				X	
<i>Sigapatella novaezelandiae</i> (circular slipper shell)	X			X	
<i>Maoricrypta costata</i> (ribbed slipper shell)	X				
limpet sp.					
Bryozoa	X			X	X
small encrusting Bryozoan					
Pisces					
triplefin sp.					

Table 16 Taxa recorded on the five replicate photo quadrats for the Home Point sample location T6B (X denotes species present as a predominant species in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology).

Taxonomic group	T6B-1	T6B-2	T6B-3	T6B-4	T6B-5	Mean
tube worm	0%	0%	0%	0%	0%	0%
Sponges encrusting	11%	4%	4%	21%	10%	10%
cup corals	0%	0%	0%	0%	0%	0%
Anenomes	3%	2%	7%	12%	12%	7%
Algae encrusting paint	37%	1%	12%	6%	7%	12%
Algae filamentous/turfing	0%	8%	19%	4%	14%	9%
Algae foliose	12%	7%	4%	0%	0%	5%
Algae calcareous	0%	0%	0%	0%	0%	0%
general encrusting community	0%	0%	0%	0%	0%	0%
Mollusca Gastropods	0%	0%	0%	1%	0%	0%
Mollusca bivalves	0%	0%	0%	0%	0%	0%
Sponges upright	4%	36%	18%	0%	11%	14%
sand, silt, detritus, small tubes	14%	6%	2%	1%	2%	5%
shell fragments	0%	36%	34%	52%	44%	33%
thecate Hydroid	18%	0%	0%	2%	0%	4%
dead coralline paint	2%	0%	0%	0%	0%	0%
Ascidian	0%	0%	0%	0%	0%	0%
no image	0%	0%	0%	0%	0%	0%

Table 17 Home Point, sample location T6B, summary of percentage cover of encrusting organisms on the 5 replicate photo quadrats.



Figure 35 Sample location T6B, Home Point, (Left) replicate 3, (Right) replicate 4

4.3.2.4 Darch Point, sample location T11B

T11B Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
coralline paint	X	X		X	X
red foliose algae	X	X			X
<i>Ecklonia radiata</i>			X	X	
Porifera (sponges)					
encrusting sponge white, id uncertain could be a juvenile ascidian					X
encrusting sponge purple	X		X	X	X
encrusting sponge orange	X	X	X	X	X
encrusting sponge yellow	X	X	X	X	X
massive grey sponge		X			
<i>Cliona celata</i>	X		X		X
<i>Titania battershilli</i>				X	X
Cnidaria					
Hydroids unidentified			X		
Ascidians					
<i>Aplidium sp.</i>					X
Pisces					
triplefin sp.	X	X		X	X

Table 18 Taxa recorded on the five replicate photo quadrats for the Darch Point sample location T11B (X denotes species present as a predominant species in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology)

Taxonomic group	T11B-1	T11B-2	T11B-3	T11B-4	T11B-5	Mean
tube worm	0%	0%	0%	0%	0%	0%
Sponges encrusting	75%	34%	49%	58%	42%	52%
Cup corals	0%	0%	0%	0%	0%	0%
Anenomes	0%	0%	0%	0%	0%	0%
Algae encrusting paint	6%	6%	0%	4%	4%	4%
Algae filamentous/turfing	0%	0%	0%	0%	0%	0%
Algae foliose	0%	3%	20%	3%	6%	6%
Algae calcareous	0%	0%	0%	0%	0%	0%
general encrusting community	0%	0%	0%	0%	0%	0%
Mollusca Gastropods	0%	0%	0%	0%	0%	0%
Mollusca bivalves	0%	0%	0%	0%	0%	0%
Sponges upright	0%	21%	4%	0%	0%	5%
sand, silt, detritus, small tubes	15%	37%	21%	29%	35%	27%
shell fragments	0%	0%	0%	0%	1%	0%
thecate Hydroid	0%	0%	0%	0%	0%	0%
dead coralline paint	0%	0%	0%	1%	2%	0%
Ascidian	0%	0%	0%	0%	8%	2%
no image	4%	0%	7%	6%	3%	4%

Table 19 Darch Point, sample location T11B, summary of percentage cover of encrusting organisms on the 5 replicate photo quadrats.

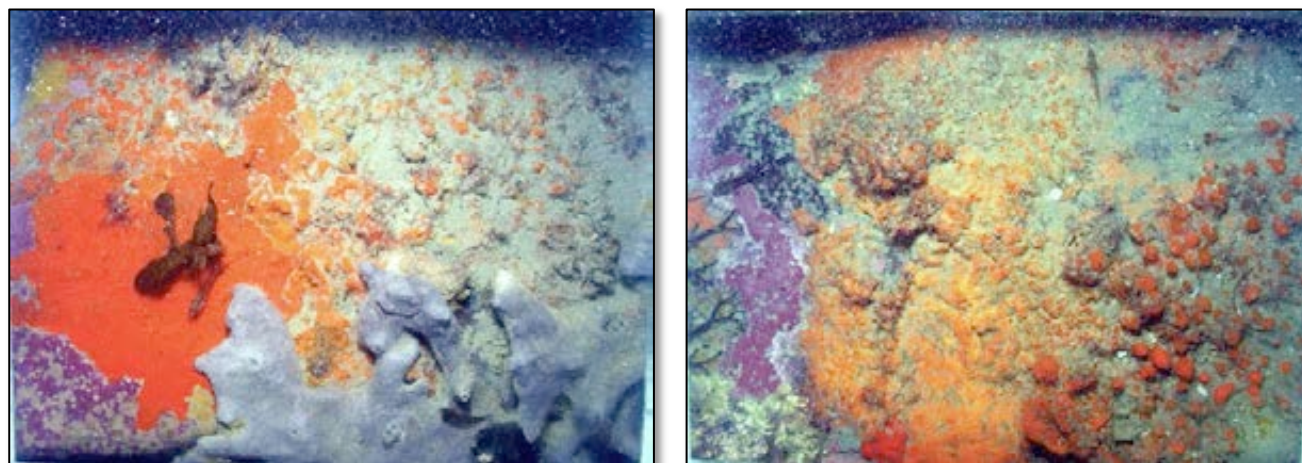


Figure 36 Sample location T11B Darch Point, (Left) replicate 2, (Right) replicate 5.

4.3.3 Sponge gardens and subtidal rocky reef encrusting communities inside Motukaroro Island Marine Reserve

The method of surveying the three rocky reef sample locations in the marine reserve was modified so as not to permanently fix quadrat locations on the sea bottom (see Section 3.3.2). Processing and analysis of the quadrats was done using the same method as the other quadrats as per Section 3.3.1. The results of this analysis and representative photos for each sample location are below.

4.3.3.1 Lot Point location SB

SB Lot Point Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
coralline paint	X	X	X	X	X
red foliose algae	X	X	X	X	X
<i>Ecklonia radiata</i>		X			X
filamentous algae	X	X	X	X	X
Porifera (sponges)					
encrusting sponge white		X	X		X
encrusting sponge orange			X		
encrusting sponge yellow	X	X			X
encrusting sponge red	X				
massive grey sponge	X			X	
<i>Cliona celata</i>	X		X		X
<i>Clathria macrotaxa</i>	X	X	X		X
<i>Tethya bergquistae</i>	X				
<i>Darwinella oxeata</i>				X	X
Cnidaria					
Mollusca, Gastropoda					
<i>Sigapatella novaezelandiae</i> (circular slipper shell)					X
top shell unidentified		X			X
Pisces					
triplefin sp.	X		X	X	

Table 20 Taxa recorded on the five replicate photo quadrats at Lot Point, sample location SB (X denotes species present as a predominant specie in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology)

Taxonomic group	SB-1	SB-2	SB-3	SB-4	SB-5	Mean
tube worm	0.0%	0.7%	0.0%	0.0%	0.0%	0.1%
Sponges encrusting	45.0%	30.8%	45.2%	14.8%	64.6%	40.1%
cup corals	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Anenomes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Algae encrusting paint	0.0%	8.9%	3.6%	16.5%	18.7%	9.5%
Algae filamentous/turfing	5.2%	0.0%	0.0%	0.0%	0.0%	1.0%
Algae foliose	0.0%	0.8%	0.8%	16.6%	3.4%	4.3%
Algae calcareous	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
general encrusting community	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mollusca Gastropods	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mollusca bivalves	0.0%	2.4%	0.0%	0.0%	0.0%	0.5%
Sponges upright	2.0%	0.0%	0.0%	24.4%	0.0%	5.3%
sand, silt, detritus, small tubes	46.8%	46.7%	48.7%	22.5%	9.5%	34.8%
shell fragments	1.0%	6.1%	0.0%	0.0%	0.0%	1.4%
thecate hydroid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
dead coralline paint	0.0%	0.8%	0.0%	0.2%	2.5%	0.7%
drift algae	0.0%	2.8%	1.7%	0.0%	0.3%	1.0%
Asidian	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
no image	0.0%	0.0%	0.0%	5.0%	1.0%	1.2%

Table 21 Lot Point, sample location SB, summary of percentage cover of encrusting organisms on the five replicate photo quadrats.

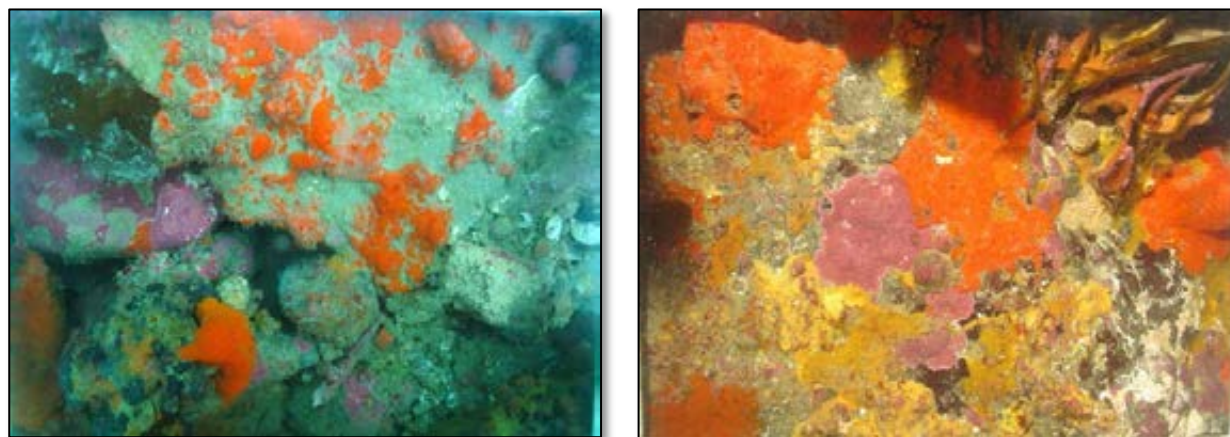


Figure 37 Lot Point, sample location SB, (Left) replicate 2, (Right) replicate 5.

4.3.3.2 Motukaroro Island northwest corner, location SB

SC Motukaroro Is. Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
<i>Codium sp.</i> (green algae)				X	
coralline paint	X	X			X
red foliose algae	X	X	X		X
<i>Ecklonia radiata</i>				X	
filamentous algae	X	X	X		X
Porifera (sponges)					
encrusting sponge white, Id uncertain could be a juvenile ascidian					X
encrusting sponge orange	X		X		
encrusting sponge yellow		X			
encrusting sponge brown	X	X			
encrusting sponge red	X	X	X		
encrusting black sponge		X		X	
massive grey sponge		X	X		
<i>Anchorina alata</i>	X	X			
<i>Cliona celata</i>		X	X		
<i>Clathria macrotaxa</i>	X	X			X
<i>Darwinella cf. gardineri</i>					X
<i>Polymastia aurantium</i>	X				
Cnidaria					
<i>Culicia rubeola</i> (cup coral)	X	X			
Hydroids unidentified	X	X			X
<i>Chaetopterus variopedatus</i> (parchment worm)	X				
Bryozoa					
small encrusting Bryozoan	X				
compound Ascidian					
Pisces					
triplefin sp.	X				

Table 22 Taxa recorded on the five replicate photo quadrats for the Motukaroro Island northwest corner sample location SC (X denotes species present as a predominant specie in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology)

Taxonomic group	SC-1	SC-2	SC-3	SC-4	SC-5	Mean
tube Worm	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sponges encrusting	21.2%	4.2%	32.3%	61.4%	18.7%	27.6%
cup corals	1.8%	2.0%	0.9%	0.0%	0.2%	1.0%
Anenomes	0.0%	0.0%	2.0%	0.0%	0.0%	0.4%
Algae encrusting paint	2.4%	0.0%	0.0%	0.0%	0.2%	0.5%
Algae filamentous/turfing	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Algae foliose	0.0%	5.9%	0.0%	9.2%	24.3%	7.9%
Algae calcareous	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
general encrusting community	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mollusca Gastropods	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mollusca bivalves	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sponges upright	43.7%	59.3%	43.7%	6.0%	11.7%	32.9%
sand, silt, detritus, small tubes	20.4%	19.6%	10.1%	16.4%	40.4%	21.4%
shell fragments	1.5%	9.0%	0.0%	0.0%	0.0%	2.1%
thecate hydroid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
dead coralline paint	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
drift algae	1.0%	0.0%	2.0%	1.0%	1.5%	1.1%
Asidian	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
no image	8.0%	0.0%	9.0%	6.0%	3.0%	5.2%

Table 23 Motukaroro Island northwest corner sample location SC, summary of percentage cover of encrusting organisms on the 5 replicate photo quadrats.

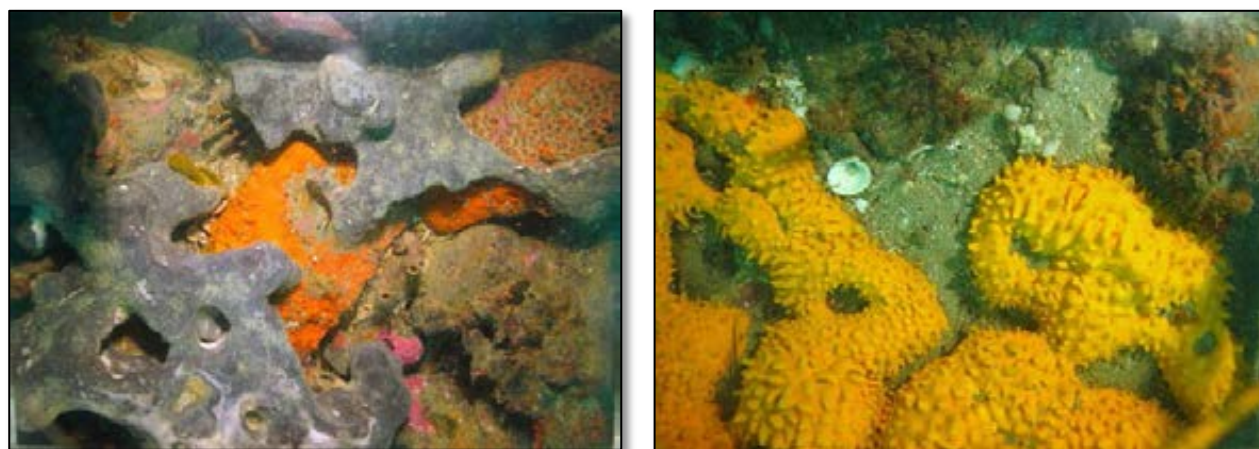


Figure 38 Motukaroro Island northwest corner sample location SC, (Left) replicate 1, (Right) replicate 2.

4.3.3.3 Motukaroro Island southwest corner, sample location T12A

T12A Motukaroro Is. Taxonomic groups	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Algae					
coralline paint	X			X	X
red foliose algae	X	X	X	X	X
filamentous algae	X	X	X	X	X
Porifera (sponges)					
encrusting sponge orange				X	X
encrusting sponge yellow		X		X	X
encrusting sponge brown	X				
encrusting sponge red	X	X			X
encrusting black sponge					X
massive grey sponge	X			X	X
<i>Cliona celata</i>			X		
<i>Clathria macrotaxa</i>			X	X	
<i>Ecionemia alata</i>					X
<i>Tethya bergquistae</i>					X
<i>Polymastia aurantium</i>		X			
<i>Biemna rufescens</i>		X			X
<i>Darwinella oxeata</i>			X	X	
Cnidaria					
thecate Hydrozoan			X	X	
<i>Solanderia ericopis</i> (hydroid tree)					X
Hydroids unidentified	X	X		X	X
Annelida Polychaetes					
<i>Chaetopterus variopedatus</i> (parchment worm)	X				X
Mollusca, Gastropoda					
<i>Calliostoma punctulatum</i> (tiger shell)					X
<i>Maoricolpus roseus</i> (screw shell)					X
Pisces					
triplefin sp.	X			X	X

Table 24 Taxa recorded on the five replicate photo quadrats for the Motukaroro Island southwest corner sample location T12A (X denotes species present as a predominant specie in terms of size or coverage of the quadrat or a species of special interest in terms of community composition and ecology)

Taxonomic group	T12A-1	T12A-2	T12A-3	T12A-4	T12A-5	Mean
tube Worm	2.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Sponges encrusting	8.0%	26.8%	54.0%	29.1%	12.4%	26.1%
cup corals	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Anenomes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Algae encrusting paint	2.6%	0.0%	0.3%	7.3%	6.5%	3.3%
Algae filamentous/turfing	0.0%	0.0%	0.0%	0.0%	1.5%	0.3%
Algae foliose	5.6%	6.0%	20.9%	36.2%	10.6%	15.9%
Algae calcareous	1.0%	0.0%	0.0%	0.0%	0.0%	0.2%
general encrusting community	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mollusca Gastropods	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mollusca bivalves	0.0%	0.0%	0.6%	0.0%	0.0%	0.1%
Sponges upright	34.4%	14.0%	0.0%	3.0%	20.1%	14.3%
sand, silt, detritus, small tubes	38.7%	50.2%	4.6%	13.6%	21.0%	25.6%
shell fragments	3.0%	0.0%	16.8%	5.3%	6.1%	6.2%
thecate hydroid	0.7%	1.0%	2.8%	4.5%	16.8%	5.2%
dead coralline paint	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
drift algae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Asidian	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
no image	4.0%	2.0%	0.0%	1.0%	5.0%	2.4%

Table 25 Motukaroro Island southwest corner sample location T12A, summary of percentage cover of encrusting organisms on the five replicate photo quadrats.

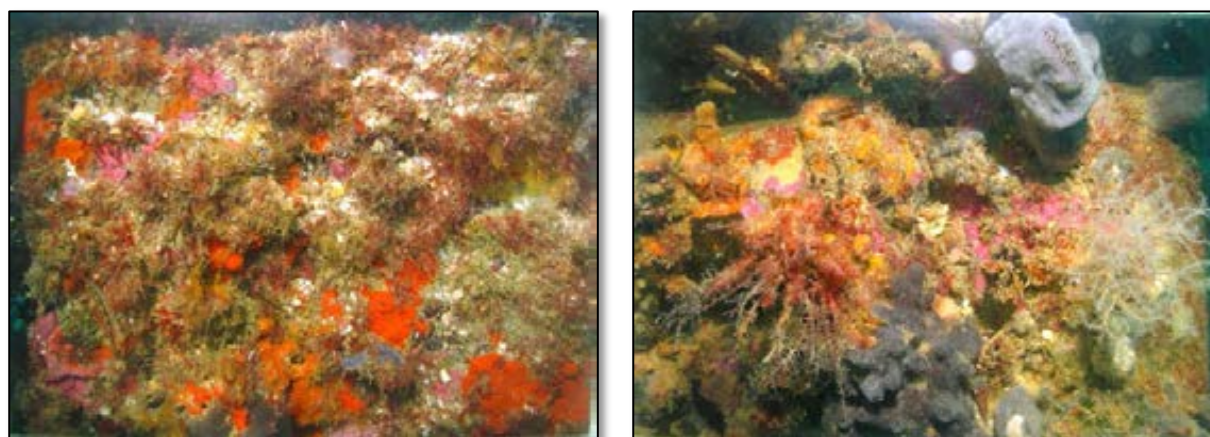


Figure 39 Motukaroro Island southwest corner sample location T12A, (Left) replicate 2, (Right) replicate 5.

5 Discussion

The results of this survey support the view that the entrance area of the Whangarei Harbour is rich in habitat diversity. The area benefits from strong tidal flows regularly bathing these habitats with oceanic and estuarine planktonic food sources. On the outgoing tide and especially at low tide these areas are bathed with waters carrying silt, nutrients and a rich diet of plankton from the middle and upper harbour. Conversely on the incoming tide these habitats are bathed by oceanic water coming in from Bream Bay bringing another source of nutrition in the form of plankton and zooplankton and pelagic ocean species. The dynamic nature of this environment brings abundant food and energy sources and allows for high productivity and diverse communities to develop.

On the shallow rocky reefs of the shoreline we see lush algal forests in the shallows. These algal forests gradually give way to a diverse and abundant encrusting invertebrate community that literally colonises all available surfaces with many species growing on top of each other. These arrays of rocky reef sites along the harbour's edge surveyed were healthy and had good diversity of species. In general, the reefs also varied a lot as we went out beyond the harbour entrance to Bream Head. These differences are due to changing conditions of tides, currents, nutrients and silt loading. Encrusting invertebrate communities are generally sensitive to these basic environmental conditions.

Soft sediments varied a great deal over the locations studied. The range included very clean fine sands outside the harbour entrance as well as very coarse shell substrates and coarse sands in the harbour. Where currents were high at channel edges and in channels substrates tended to be shelly. Conversely in sample locations further away from the channels there was a tendency for the substrates to be finer and have higher silt components. All these variations impact the composition of benthic invertebrates found in each location. Some species are specialist in terms of substrate type on which they grow, and some are more generalist. Thus each location has its own species composition reflecting the various sensitivities to the physical environment they live in.

Subtidal soft sediment communities in the inner harbour were characterised by high diversity and abundance and there were notable variations in the community structure between the sites as the position, substrate and current environment varied across the survey sites.

Subtidal soft sediment communities outside the harbour were more consistent when compared with each other but there was still variation. Overall the abundance and diversity was not nearly as high as in the inner harbour. The environments of the outer harbour area are typically not as dynamic in terms of tides and currents. The physical substrate characteristics are tend to be more uniform with a predominance of fine and medium sized sands. In contrast the inner Harbour sample sites have a diverse variety of quite shelly substrates and many mixtures of silt and clay components added to the fine and medium sands.

Intertidal sample locations at the Marsden Bank and Mair Bank were characterised by relatively low diversity and abundance results with the area on Mair Bank nearest the shore recording very low

abundance and diversity counts. It is not known what is affecting this area but there seems to be some event in recent times that has caused a significant ecological disturbance there (Williams 2014).

The soft bottom habitat substrates observed in this study have important variations noted in the amount of coarse sands, shell hash, larger shell fragments and the presence or complete absence of bedforms in the form of sand waves. The observations made in this report based on the diver notes and photographs of sediment types and ‘surface’ appearance come with the caveat that they are indications only; they should be used with the photographic examples to aid the quantitative analysis of the sediments themselves and other physical oceanographic and environmental information. That said, these actual views of the benthic environment help with description and understanding of these habitats.

Students or researchers are encouraged to utilize the photographic and survey data archive accompanying this survey to extend their understanding of this important harbour entrance area.

6 Acknowledgements

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8 Appendix 1 GPS coordinates for sample locations

Wpt	Type	Depth	Longitude	Latitude
T9C	subtidal soft sediment	5.0	174.510627	-35.83277755
T9B	subtidal soft sediment	5.0	174.5124048	-35.83009688
T9A	<i>Ecklonia</i> canopy	6.4	174.51274	-35.82939
T8B	subtidal soft sediment	5.0	174.5201291	-35.83898714
T8A	subtidal soft sediment	5.0	174.5254668	-35.83451172
T7B	subtidal soft sediment	5.0	174.5234247	-35.84394832
T7A	subtidal soft sediment	5.0	174.5295861	-35.84414138
T6B	reef sponge garden	14.1	174.52397	-35.85086
T6A	<i>Ecklonia</i> canopy	6.6	174.52431	-35.85084
T5A	subtidal soft sediment	6.0	174.5263	-35.85550336
T2A	reef sponge garden	9.5	174.54565	-35.85756
T1B	reef sponge garden	7.7	174.55573	-35.86109
T1A	<i>Ecklonia</i> canopy	5.3	174.55572	-35.86106
T18C	subtidal soft sediment	14.5	174.5528125	-35.87461575
T18B	subtidal soft sediment	14.5	174.5502999	-35.87952758
T18A	subtidal soft sediment	14.5	174.5448371	-35.8802634
T17C	subtidal soft sediment	10.5	174.5240646	-35.88284083
T17B	subtidal soft sediment	10.5	174.5287614	-35.8798672
T17A	subtidal soft sediment	10.5	174.5331012	-35.87714485
T16C	subtidal soft sediment	5.0	174.5105877	-35.86605653
T16B	subtidal soft sediment	5.0	174.5178403	-35.86411489
T16A	subtidal soft sediment	5.0	174.5180892	-35.85794664
T14B	intertidal soft sediment	Intertidal	174.5120461	-35.84364088
T14A	intertidal soft sediment	Intertidal	174.5077773	-35.84244877
T13B	intertidal soft sediment	Intertidal	174.5027873	-35.83851186
T13A	intertidal soft sediment	Intertidal	174.501501	-35.84021056
T12A	reef sponge garden	8.1	174.49711	-35.83064
T11G	intertidal soft sediment	intertidal	174.4736852	-35.83314927
T11F	subtidal soft sediment	7.0	174.4826352	-35.82699219
T11E	subtidal soft sediment	7.0	174.4851593	-35.82523831
T11D	subtidal soft sediment	7.0	174.4879738	-35.82329786
T11C	subtidal soft sediment	7.0	174.4903847	-35.82163566
T11B	reef sponge garden	4.5	174.49248	-35.82005
T11A	<i>Ecklonia</i> canopy	7.1	174.49231	-35.82027
T10A	<i>Ecklonia</i> canopy	5.8	174.4987	-35.83024
SC	reef sponge garden	7.0	174.49691	-35.82978
SB	reef sponge garden	10.5	174.50211	-35.8312
SA	Fan worm	5.0	174.5040533	-35.83073104

Note: tide depths are not tide level corrected to chart datum, but are typically high near high tide levels

9 Appendix 2 Rocky Reef Transect location maps

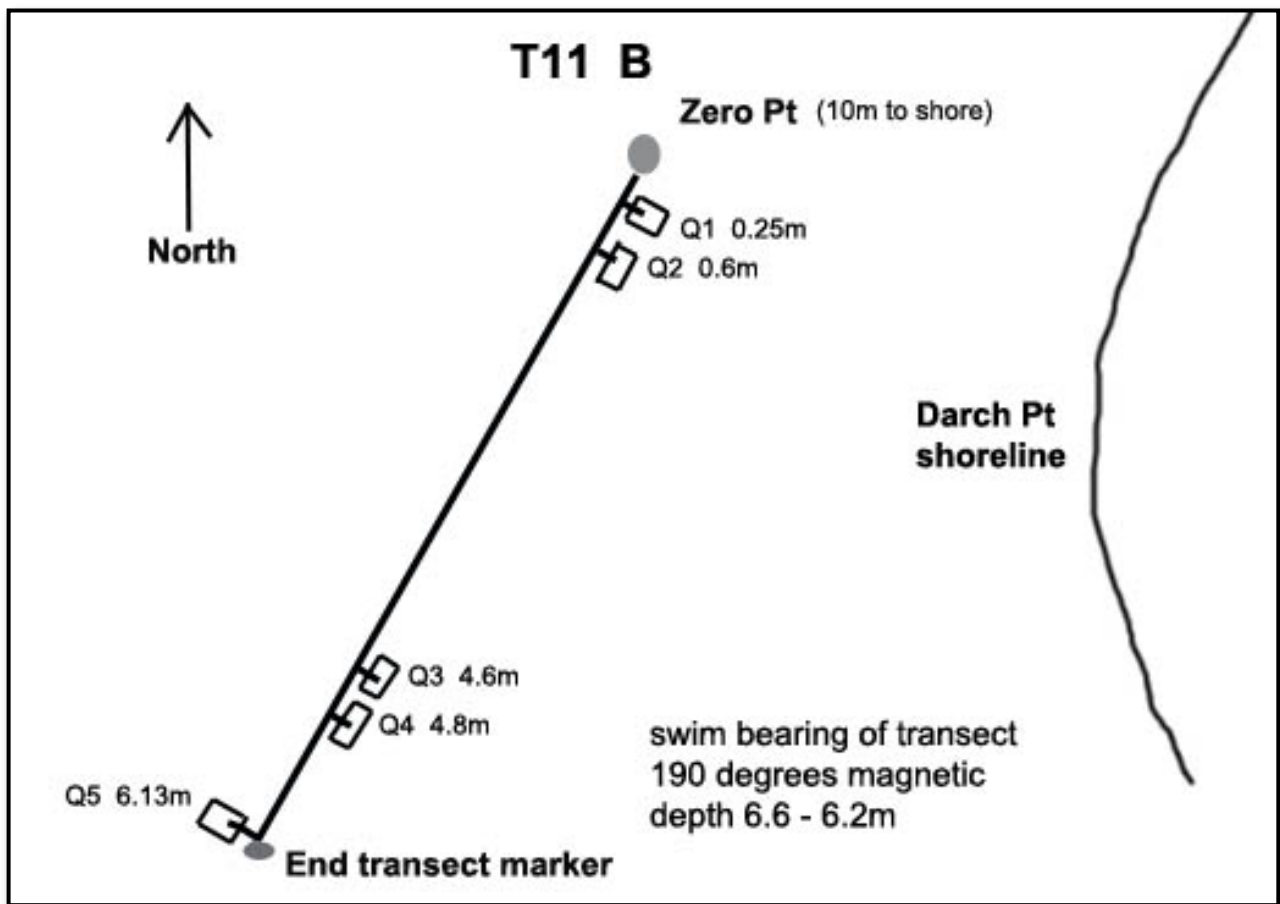


Figure 40 Location map for rocky reef site T11B at Darch Point, showing location of permanent photo quadrats. Swim bearing and distances indicated start from zero point which is the T11B waypoint. Markers are placed on the bottom at both the zero point and the end of the transect

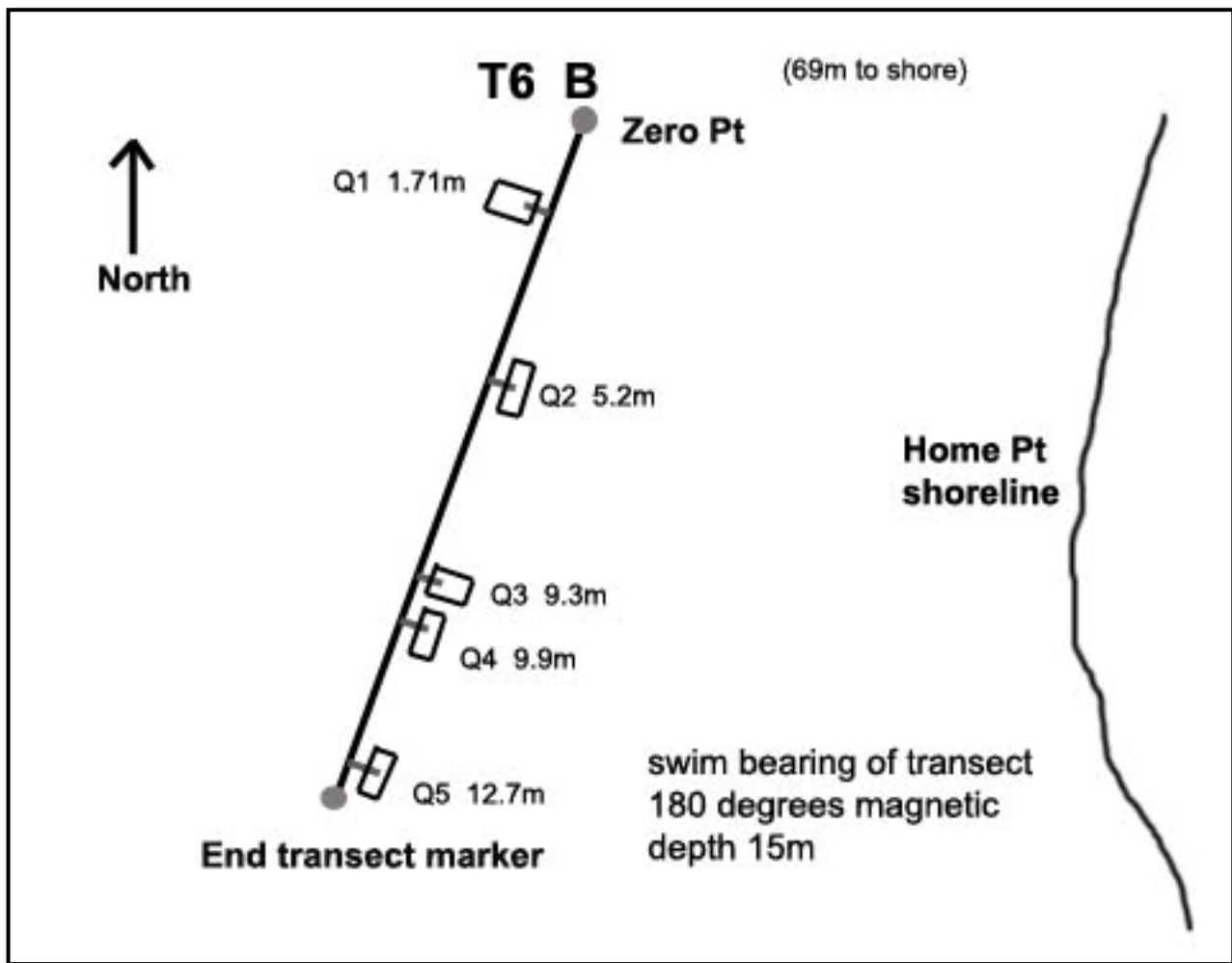


Figure 41 Location map for rocky reef site T6B at Home Point., showing location of permanent photo quadrats.. Swim bearing and distances start from zero point which is the T6B waypoint. Markers are placed on the bottom at both the zero point and the end of the transect.

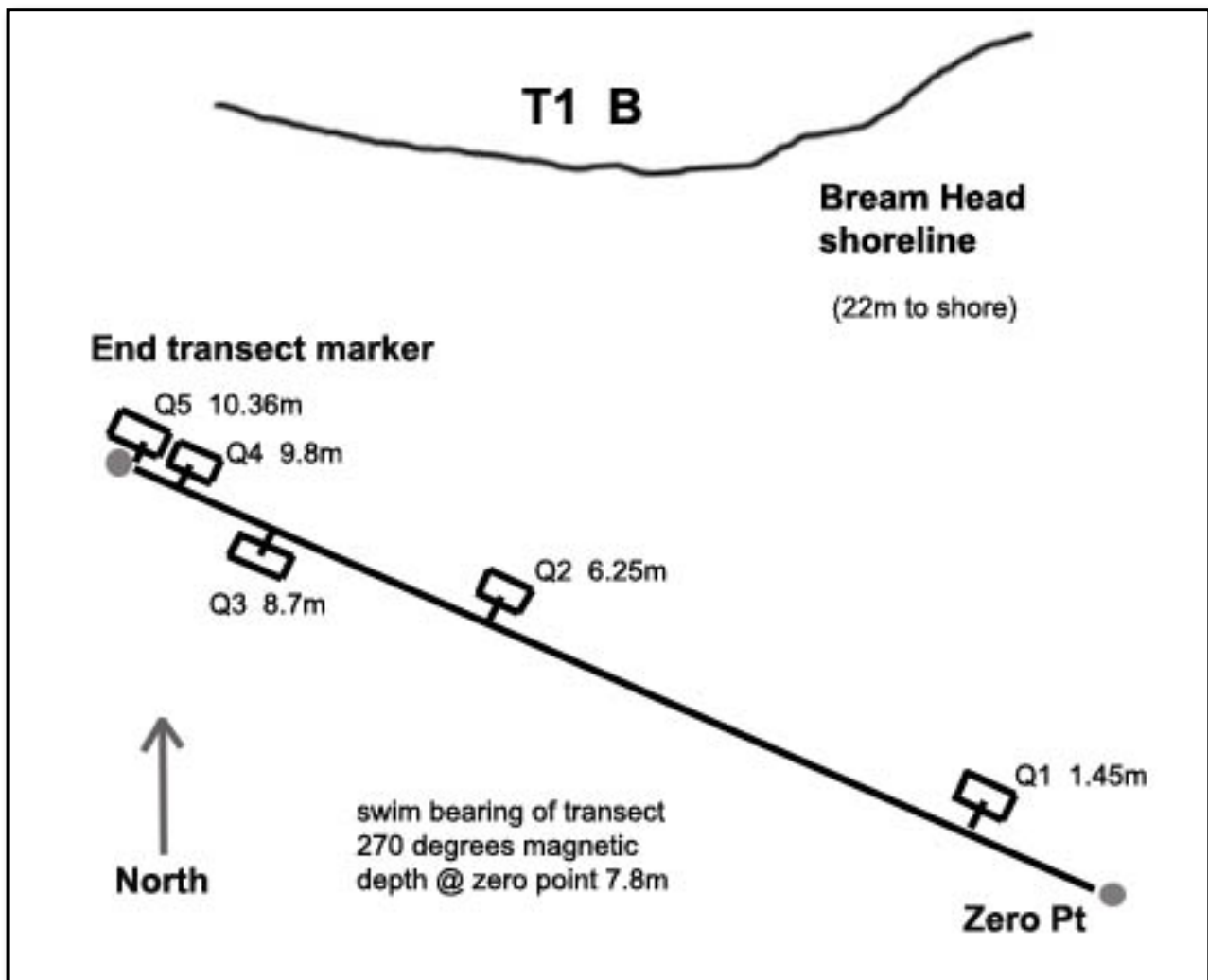


Figure 42 Location map for rocky reef site T1B at Bream Head, showing location of permanent photo quadrats. Swim bearing and distances start from zero point which is the T1B waypoint. Markers are placed on the bottom at both the zero point and the end of the transect.

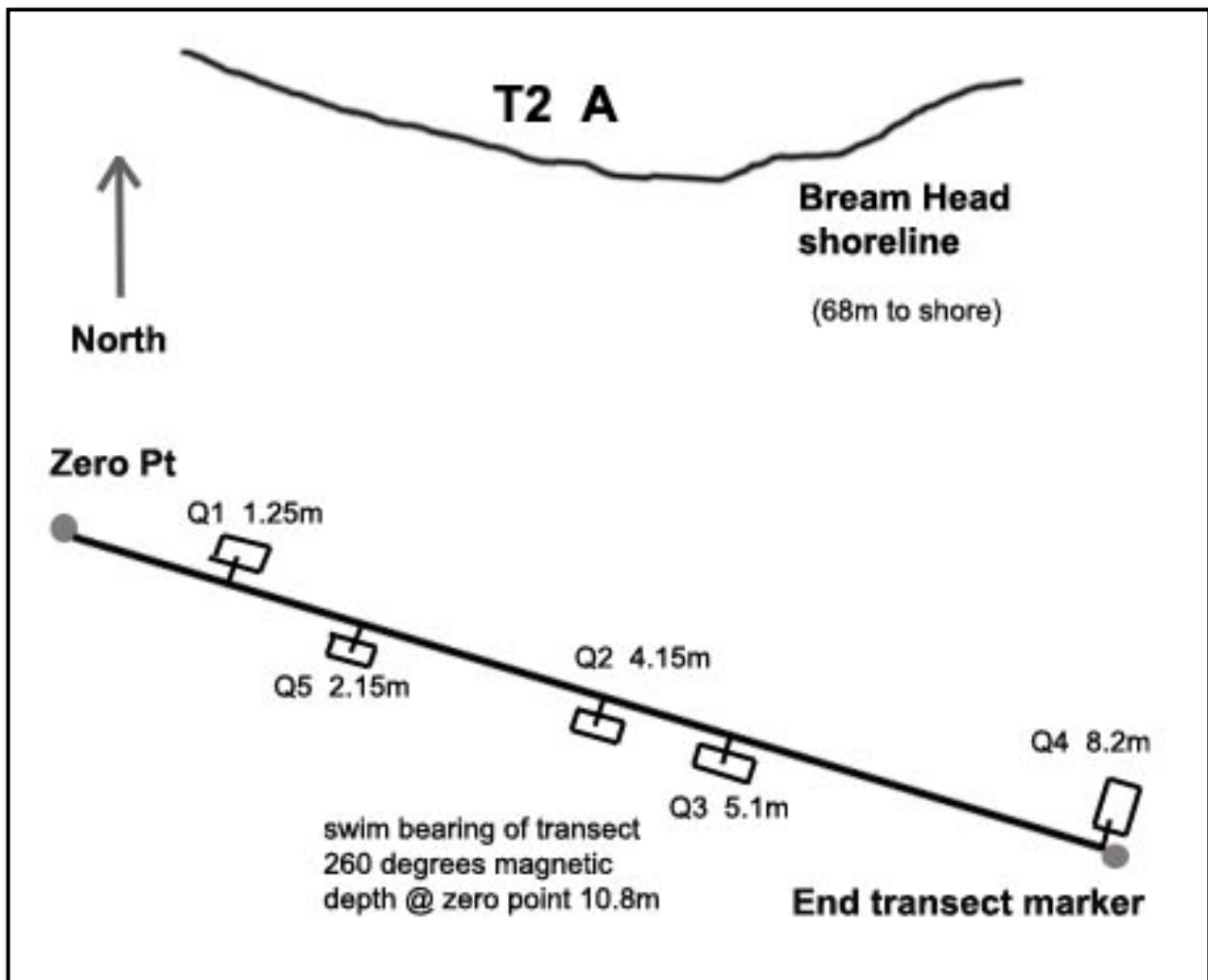


Figure 43 Location map for rocky reef site T2A at Bream Head, showing location of permanent photo quadrats. Swim bearing and distances start from zero point which is the T2A waypoint. Markers are placed on the bottom at both the zero point and the end of the transect

Note: Maps of transects are drawn to scale, distance from shore is not drawn to scale. Outline of photo transect is not drawn to scale but note orientation of the frame which is shown. There is no GPS bearing for the end marker of the transect but it can be found by swimming the bearing from zero point. A laminated photo of each quadrat will be used to help precisely relocate the photo quadrat on the transect line.