TAHUNA WASTEWATER TREATMENT PLANT

(ORC Consent 2002.623, Condition 6c):

Rocky Shore Ecological Monitoring 2016

Prepared by

ryderconsulting

environment + planning + project management

February 2016

TAHUNA WASTEWATER TREATMENT PLANT (ORC Consent 2002.623, Condition 6c): Rocky Shore Ecological Monitoring 2016

Prepared for

Dunedin City Council

By

Brian Stewart

February 2016

Cover Photo: Rocky shore survey site at Victory Beach – Nicola Pyper

Ryder Consulting Ltd.
PO Box 1023
Dunedin
New Zealand
Ph: 03 477 2119

Fax: 03 477 3119

EXECUTIVE SUMMARY

- As a condition of the consent to discharge treated effluent from an outfall off St Kilda Beach the Dunedin City Council has undertaken to monitor rocky shore communities at six sites along the Otago coast.
- For the 2016 survey invertebrate and algal communities were reasonably diverse at all sites, results that are consistent with previous studies. Abundance of animals and algal cover was variable at both control and impact sites and fell within the range observed during past surveys.
- Intertidal communities at the surveyed beaches shows no significant different in community structure this year, despite a build up of sand at some locations.
- As in previous years there appeared to be no readily discernible pattern to either diversity or abundance in relation to direction or distance from the Tahuna outfall.
- Second Beach exhibited the highest community diversity this year. The least diverse site is Victory Beach followed closely by Black Head. Lawyers Head, closest to the outfall, has moderate diversity. The loss of taxa and reduced abundance usually seen around wastewater outfalls were not observed at any site.
- Community composition assessed at each site during the 2016 survey was very similar to compositions found during previous surveys, and although there were some significant changes to diversity and/or abundance at some sites through time, these changes showed no linkage with location (upstream or downstream) or distance from the outfall.
- There is no evidence of environmental damage that may be attributed to wastewater discharges from the Tahuna outfall. Any effects of wastewater are no more than minor and are insignificant in comparison to the natural variation among sites and from year to year.

Table of Contents

1. Introduction

1.1 Background

On 6 October 2004, the DCC was granted a consent to discharge treated wastewater from the Tahuna Wastewater Treatment Plant via an extended outfall off St Kilda Beach. Construction of this new extended outfall off St Kilda Beach has been completed and the outfall began operation on 23 January 2009.

Condition 6(c) of resource consent 2002.623 states: "The consent holder shall undertake biological rocky shore monitoring annually, at Blackhead, Second Beach, Lawyers Head Beach, Boulder Beach, Allans Beach and Victory Beach. Monitoring methods shall be consistent with the methods employed under Coastal Permit 97530."

This report presents the findings of the latest round of rocky shore assessment. Such assessment aims to gauge environmental impacts resulting from the discharge of wastewater off St Kilda Beach from the Tahuna Wastewater Treatment Plant.

1.2 The Otago Coastal Environment

The Otago coast is characterised by the northward flow of the subtropical Southland Current interacting with the inflow of major rivers (Clutha and Taieri), tidal currents and wind along the indented coastline. The Southland Current veers off-coast at Cape Saunders, and flows in the direction of the Chatham Islands. In the vicinity of the Tahuna Wastewater Treatment Plant outfall, the inshore current generally flows northward at around 0.06 m/s. However the speed and direction of the current are affected by weather conditions. At times, during strong nor-east winds and when particular patterns of high and low pressure systems exist across southern New Zealand, the current may turn and flow in a south-westerly direction down the coast.

The Otago coastline receives a variety of wave patterns. Wave patterns include southerly swells, which originate from westerly wind patterns south of New Zealand, and locally generated southerly and northerly storm waves. Tidal patterns are semi-diurnal, with an average range for spring tides of approximately 1.7 metres. Due to the weather, wave and current patterns along the Otago coast, the rocky shore sampling sites are relatively exposed to wave action and current influences from the south.

2. Sample location

The program includes three 'impact' sites (Second Beach, Lawyers Head and Boulder Beach) that are located relatively close to the discharge. Although down-current, Victory Beach is some 25 km distant from the nearest outfall and it is probable that effluent does not reach it. In the unlikely event of effluent being conveyed that far, it is expected that the effluent will be extremely dilute. Such distant sites may be considered 'control' sites. The remaining site, Allans Beach is downstream of the outfall along the predominant current, but is not as distant as Victory Beach. Black Head is generally up-current from the outfall and far enough away to be considered a control. The locations of the sites are shown in Figure 1, with representative photos of each site shown in Figure 2.

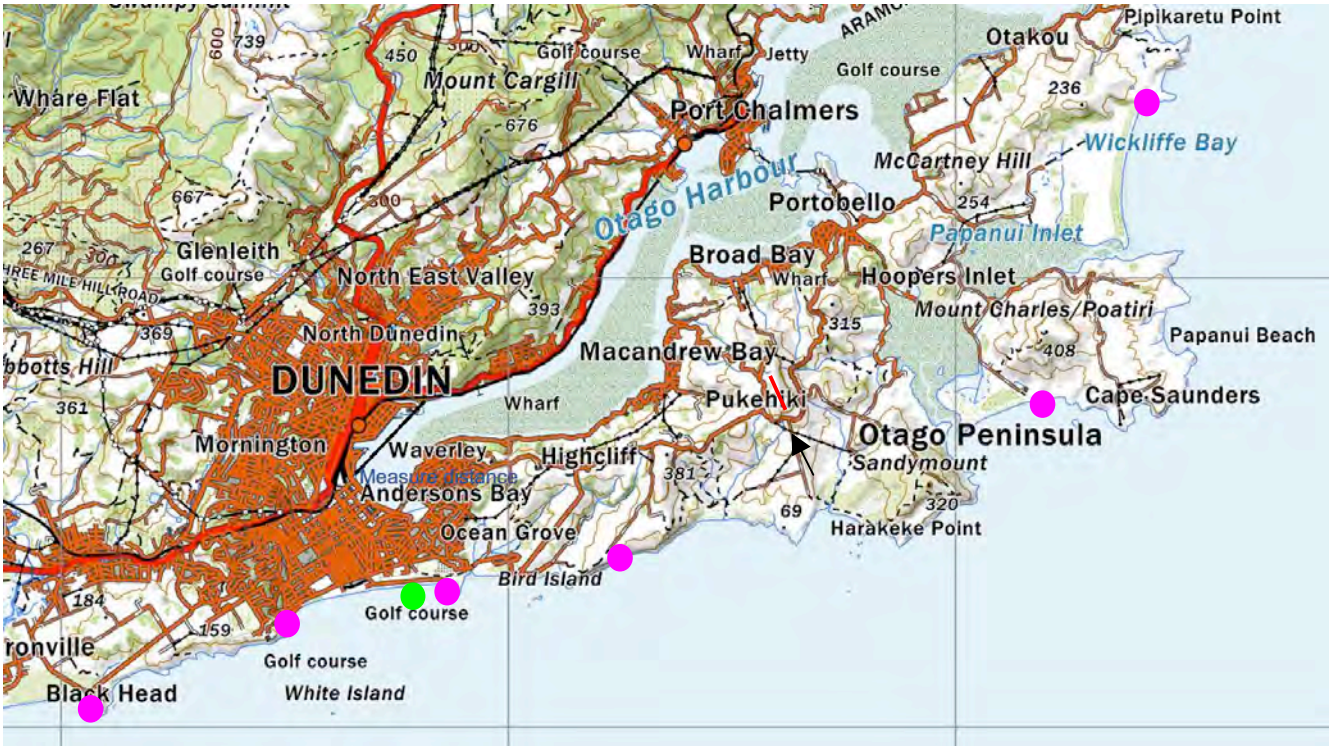

Figure 1. *Map showing location of rocky shore monitoring sites (pink dots) in relation to sewage outfall (green dot). Sites are, from left to right, Black Head, Second Beach, Lawyers Head, Boulder Beach, Allans Beach, Victory Beach.*

2.1 Black Head

The Black Head site is located on the west side of Black Head promontory amongst the boulder reef area at the eastern end of the beach. Broken boulders of columnar basalt dominate this site. These boulders have relatively smooth surfaces and the available niches differ from those found at other sites (i.e. organisms are more likely to be under rocks and boulders than in crevices and guts). Quadrats were positioned

within the boulder reef area close to the seaward edge at the bull kelp fringe. This area is exposed to strong wave action. Black Head has been monitored annually since 1996.

2.2 Second Beach

Second Beach is more similar to Black Head than other sites. It is mostly dominated by moderately sized smooth boulders, but is more sheltered from the southerly swell. The site is on, and adjacent to, a rocky promontory near the western end of the beach, and has been monitored annually since 1996.

2.3 Lawyers Head

The area surveyed is located on a rocky promontory approximately 60-80 metres west of the westernmost of the two disused effluent outfalls. The site is characterised by rough irregular basalt rock and large, smooth ledges, each of which provides the resident species with a variety of niches. Quadrats were placed as close as practicable to the bull kelp along the south-western edge of the reef. Monitoring at Lawyers Head commenced in 1999.

2.4 Boulder Beach

Boulder Beach is a rocky reef habitat 6-7km to the north-east of Lawyers Head. Habitat consists of very large irregular boulders with guts and pools incised into the basement rock. The sampling site is situated at the northern end of the beach, and has been monitored annually since 1996.

2.5 Allans Beach

Allans Beach is a rocky reef habitat similar to Boulder Beach and Victory Beach, with large boulders amidst rocky guts. The sampling site is at the northern end of the beach at the seaward base of a tall rocky pinnacle. 2004 was the first year of monitoring at this site.

2.6 Victory Beach

Victory Beach is a rocky reef habitat similar to Boulder Beach, with very large irregular boulders amidst rocky guts. The sampling site is at the northern end of the beach and is home to a thriving New Zealand fur seal (*Arctocephalus forsteri*) colony. The site was first monitored in 2003 (Thompson and Ludgate 2003).

Figure 2. *Intertidal areas sampled in 2014. (a) Black Head, (b) Second Beach, (c) Lawyer's Head, (d) Boulder Beach, (e) Allans Beach and (f) Victory Beach.*

3. Methods

3.1 General

The sampling protocol used since 1997 is based on other regional monitoring programmes operating in the Bay of Plenty, Southland and Taranaki. The method of sampling investigates species richness and diversity within and between rocky shore

sites to establish any impacts of the sewage discharges. Mussel size and frequency are also examined as a further indicator of environmental impacts.

The use of replicate samples enables the detection of uncommon taxa and, taking account of the natural variability often exhibited by rocky shore communities, allows the determination of significant variations within and among sites.

3.2 Macroalgae and Macroinvertebrate Monitoring

At each site a random block sampling design was used. Macroalgae and macroinvertebrates were identified and recorded from five randomly placed quadrats ($0.25m^2$) within each of four blocks, giving a total of 20 samples at each site. Each of the four blocks covered approximately $6m^2$ and was randomly positioned at low tide as near as practicable to the waters edge, within the macroalgal zone.

Within each quadrat, algal species were recorded as percentage cover. In many cases, blades of the large bull kelp *Durvillaea antarctica* or other large foliose species overlaid other, smaller algae. The percentage cover of *D. antarctica* or other large algae was noted and the blades were then pulled aside. Algae occurring beneath this initial layer were then also recorded. Thus, cover of algae could exceed 100%.

The diversity and abundance of all visible animals were then recorded for each quadrat.

> Note: There are several species of chiton and limpets that inhabit the Otago coast. Field identification of some species can be difficult due to coralline algal growth on the animal's shell and naturally occurring shell colour variation. Furthermore, it is neither practical nor desirable to remove every animal for closer inspection in the laboratory. Therefore, in some cases, similar species such as *Notoacmea pileopsis* and *Notoacmea daedala* have been grouped together under the genus name, *Notoacmea*. Similarly, some macroalgae (e.g. *Gigartina* species) can be hard to distinguish due to age, reproductive status, or amount of damage caused by wave action and macroinvertebrate grazing. When this occurred, macroalgae species were grouped under the genus name. In 2003 the publication of superior keys and availability of taxonomic

training meant that the detail of seaweed taxonomy could be increased. For that reason some sites have shown an increase in the level of taxonomic detail since 2003.

3.3 Mussel Monitoring

Green lipped mussels (*Perna canaliculus*) are the most likely shellfish to be harvested from the intertidal rocky platforms by recreational fishers. Because of such recreational harvesting for human consumption, size/frequency data for green-lipped mussel are potentially not robust enough to determine possible environmental impacts of the sewage discharges. Previous surveys have shown that both blue (*Mytilus galloprovincialis* [formerly *Mytilus edulis aoteanus*]) and ribbed mussels (*Aulacomya ater maoriana*) are particularly abundant on Otago's rocky coastline. Since 1995, therefore, the size and frequency of all three mussel species have been recorded.

At each sampling location the number of green-lipped, blue and ribbed mussels in each of the 20 quadrats were recorded according to the following size classes:

0-2 cm
2-4 cm
4-8 cm
> 8 cm

3.4 Data Analysis

Taxonomic richness (the number of different species per sampling unit) and taxonomic abundance (the number of individual plants or animals per unit area) have long been the most significant environmental indicators used to assess change in inter-tidal communities.

In contrast to surveys prior to 2001, when data has only been able to be analysed descriptively, or on a species by species basis, the development of new statistical tools (specifically multivariate statistics based on randomisation procedures (Clarke and Gorley 2001)) allows more sophisticated analysis of the more recent data. Multivariate statistical analyses look at the entire inter-tidal community as a group, rather than on a species by species basis. Although these techniques are complex, they have been shown to be the best way of detecting the effects of pollutants on marine communities (Bayne *et al.* 1988). The approach adopted here is to use

summary values, such as number of species and density, in the same way as years prior to 2001, but to also use multivariate techniques to gain an overview of the data. Results were analysed to ascertain whether inter-tidal communities within sites that were closer to the outfall displayed any clear differences from those that were further away. This was analysed for in a number of ways:

1. Locations, and analysing changes through time.
2. Comparing animal abundances at the different sites, and ascertaining whether abundances are changing through time.
3. Analysing community patterns at the different sites and comparing communities in terms of dominant species, variability and community structure.
4. Describing the size/frequency distribution of mussel species and comparing these among sites and through time. Comparing the number of algal and animal species present at the different sites.

Marine communities can be expected to respond in any one of a number of ways when affected by pollutants. The most noticeable effects are:

(i) Marine habitats in areas that are severely impacted tend to have communities that are different from areas that are not impacted, in terms of the species present, and in terms of which species are dominant (Warwick *et al.* 1990).

(ii) Communities in areas that are impacted tend to display more variability over time and space than communities in areas that are not impacted (Warwick and Clarke 1993).

In order to ascertain whether those effects are visible for rocky shore communities along the Otago coast on either side of the sewage outfall, several multivariate statistical techniques were used. To show the data visually, ordinations have been calculated and are presented. In such procedures the invertebrate abundance data and algal percentage cover data were first transformed (log [x+1]) to overcome the large numbers of zeros in the data. Bray-Curtis similarity between samples was then calculated. This was used to create a multi-dimensional scaling (MDS) ordination of the data. In these plots, how close the samples, or locations, appear to each other reflects how similar they are in terms of taxonomic composition and patterns of abundance. Stress values indicate how well the diagram represents the data (<0.20 is

considered satisfactory; Clarke and Gorley 2001).

Although the statistics underlying multivariate analysis are complex, interpretation of the results is simple. An ordination is just a picture that shows how similar the communities from each sample are to each other. If sites are very similar, then they are close to each other in the picture.

Similarity between the communities at the different locations was analysed by calculating the percentage similarity in species lists between locations. High percentage similarity between two locations indicates that the same species are dominant at both locations. This procedure also identifies which species are contributing to the differences between locations.

Percentage similarity values show how similar two locations are in terms of the species present and in how abundant the species are.

A further possible measure of pollution impacts is the Index of Multivariate Dispersion (IMD) (Warwick and Clarke 1993). This was used to compare how variable the inter-tidal communities were at different locations. Higher values of the IMD indicate higher variability and potentially higher environmental impacts.

To interpret IMD values, compare the values from year to year or location to location. A higher IMD value indicates more variability in the community.

To analyse changes in numbers of species and animal abundances since 1998, univariate statistics were used. One-factor analysis of variance (ANOVA) (using year as a covariate) was used to see whether numbers of species or animals were different among locations. For the 2015 data in isolation, one-factor ANOVA was used to test for differences among sites. For the abundance analysis Bonferroni post-hoc tests were used to ascertain which sites were different from which other sites.

To interpret ANOVA and Bonferroni test results, look at the 'p' value. If this value is less than 0.05, then the two groups of data are significantly different from one another.

4. Results & Discussion

Sampling in 2016 was carried out over the days of 8th January to 26th January. This time period is two weeks earlier than the time period in which sampling occurred last year, but falls within the timeframe over which sampling has occurred in previous surveys. As such the 2016 results are generally comparable to previous years.

4.1 General observations

The period preceding and during sampling was typified by moderate to low swells, with generally light winds. Tides during the sampling period were moderately low, so access down the intertidal zone was similar to in 2011 and somewhat more limited than 2015, 2014, 2013 and 2012 when tides were very low. The sand build up that had buried some of the lower intertidal zone in 2013 was once again present this year, and had covered a considerable portion of the intertidal zone, especially at Black Head, Second Beach and Allans Beach. All of the sites were typified by clean rock surfaces (Figure 2).

4.2 Species Richness and Abundance

4.2.1 Taxonomic Richness

Taxonomic richness (number of distinct taxa) reflects the health of the intertidal community through a measurement of the variety of taxa present (both flora and fauna). Taxonomic richness generally increases with better water quality, greater habitat diversity and greater habitat stability.

Taxonomic richness at all sites was generally similar to previous surveys, with the total number of algae showing little difference to past surveys. Numbers of animal taxa, however, show a small decrease over the results from last year, but are within the range of values observed during previous surveys (Table 1, Figure 3).

The overall diversity (mean number of both algal and animal taxa per square metre) remains within the range of variability for all sites this year (Table 1). Algal taxa have ranged from 8 to 33 across the various sites through time while animal taxa have ranged from 10 to 44. This suggests that variability in floral and faunal diversity is not uncommon.

Despite the relatively close proximity of Black Head, Lawyers Head and Boulder Beach to the Tahuna outfall (Figure 1), overall diversity (animals and algal species combined) at these sites is not obviously different to other sites. Other sites have total taxa ranging from 37 to 56 with Black Head, Lawyers Head and Boulder Beach diversities falling within the range (17 to 68 taxa) seen at other sites over past years (Table 1).

Table 1. *Taxonomic richness and animal abundance at monitoring sites 1996-2016.*

	Total no. of taxa per site	Algal taxa per site	Animal taxa per site	Mean taxa per quadrat	Mean animal abundance (m2)
Black Head					
1996	23	9	14	14	
1997	29	12	17	16	
1998	43	16	27	12	2840
1999	48	16	32	13	7812
2000	53	23	30	12	7247
2001	38	17	21	10	27649
2002	40	17	23	20	27513
2003	57	29	28	14	5368
2004	48	21	27	20	8796
2005	59	22	37	18	1066
2006	51	22	29	13	853
2007	46	16	30	13	19208
2008	55	27	28	16	221
2009	55	25	30	15	11197
2010	58	34	24	16	3061
2011	56	25	31	19	4128
2012	51	25	26	17	7954
2013	77	33	44	17	7342
2014	60	29	31	17	5982
2015	50	20	30	13	4781
2016	35	20	15	11	5959
Second Beach					
1996	32	16	16	11	
1997	30	15	15	13	
1998	44	21	23	15	11890
1999	43	17	26	12	15936
2000	47	20	27	15	6870
2001	43	18	25	14	19964
2002	49	21	28	17	20262
2003	45	18	27	10	33808
2004	40	16	24	15	26652
2005	55	17	38	18	6110
2006	55	22	33	19	6683
2007	50	17	33	14	10779
2008	47	18	29	17	8504
2009	55	22	33	20	8850
2010	46	25	21	15	14606
2011	51	22	29	19	15031
2012	54	27	27	21	6092
2013	66	29	37	18	13980
2014	68	31	37	12	12433
2015	56	19	37	19	11531
2016	43	25	18	16	16283
Lawyers Head					
1999	35	11	24	13	19505
2000	47	23	24	14	4442
2001	39	18	21	16	26707
2002	45	18	27	18	16741
2003	49	24	25	16	28216
2004	50	19	31	16	25354
2005	42	14	28	19	7039
2006	50	20	30	17	11192
2007	42	14	28	19	5905
2008	39	16	23	13	14868
2009	44	19	25	18	3085
2010	44	25	19	13	4650
2011	38	13	25	17	3216
2012	48	19	29	18	2688
2013	42	19	23	18	3914
2014	49	21	28	15	4493
2015	44	19	25	18	5154
2016	38	23	15	11	4276

Table 1. continued….

	Total no. of taxa per site	Algal taxa per site	Animal taxa per site	Mean taxa per quadrat	Mean animal abundance (m2)
Boulder Beach					
1996	17	7	10	7	
1997	24	9	15	12	
1998	32	7	25	15	13106
1999	37	13	24	13	11581
2000	37	16	21	12	19198
2001	46	18	28	13	16863
2002	36	12	24	23	34706
2003	40	17	23	12	25717
2004	42	13	29	16	9351
2005	40	10	30	19	1469
2006	43	13	30	19	19254
2007	41	16	25	14	9377
2008	46	18	28	13	2309
2009	49	18	31	18	4260
2010	33	17	16	13	3330
2011	48	17	31	21	2747
2012	45	20	25	14	3633
2013	30	10	20	14	7644
2014	47	18	29	16	4417
2015	37	14	23	14	5132
2016	32	17	15	11	5353
Allan's Beach					
2004	40	13	27	17	7527
2005	31	11	20	14	4050
2006	49	13	36	16	10080
2007	42	17	25	13	4145
2008	54	20	34	16	4383
2009	60	23	37	20	4919
2010	55	28	27	16	4446
2011	53	19	34	19	4159
2012	51	19	32	19	6148
2013	52	18	34	16	4319
2014	65	28	37	18	3298
2015	52	21	31	20	4540
2016	36	21	15	15	3920
Victory Beach					
2003	40	15	25	14	28093
2004	37	13	24	17	10393
2005	28	8	20	16	4316
2006	42	15	27	15	5390
2007	40	17	23	11	3085
2008	47	21	26	13	2214
2009	47	20	27	17	3067
2010	47	24	23	18	2436
2011	47	23	24	19	2007
2012	45	23	22	17	4099
2013	34	14	20	17	2476
2014	57	27	30	16	2817
2015	45	17	28	21	1659
2016	27	16	11	11	6003

The analysis of variance results for 1996-2016 (Table 2) shows that there are significant differences in taxonomic richness and abundance for animals at the various sites since surveys began.

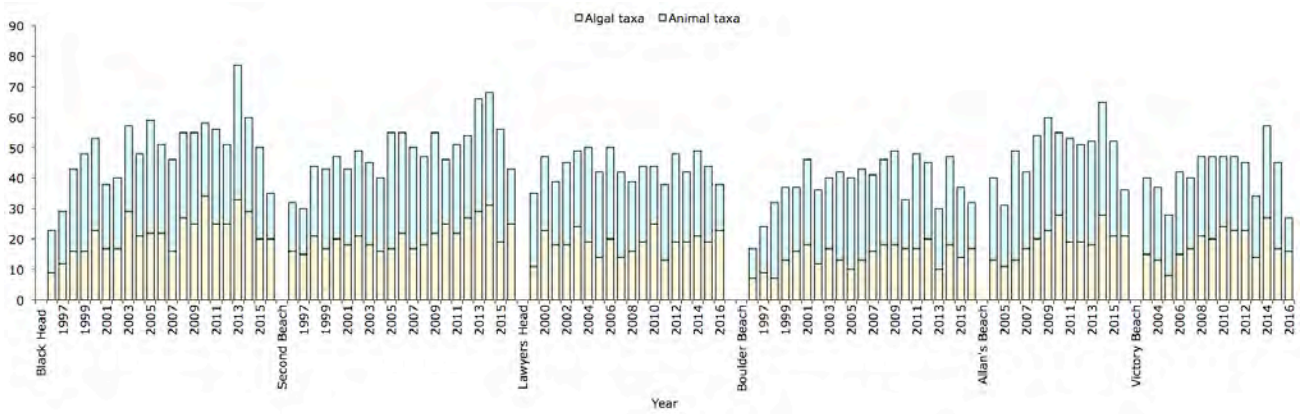

Figure 3. *Taxonomic richness for Dunedin City Council rocky shore monitoring sites 1996-2016.*

This does not remain true for abundance since 2004, when actual numbers were counted rather than percentage cover for some species, nor since 2007 (Table 2). While algal richness has changed significantly through time (shown by significant p value for 'All Years' in Table 2, the changes are somewhat less significant since 2007 (Table 2). Abundance of different species has not changed significantly since 2004 or from site to site. These results need to be viewed cautiously as some of these differences are likely due to different intertidal levels being available at different surveys due to varying tide heights.

Table 2. *Analysis of variance (ANOVA) results for algae and animal taxonomic richness and animal abundance for Dunedin City Council rocky shore monitoring sites over differing timeframes. 'p' values <0.05 indicate a statistically significant result.*

Factor		Algae	Animals	Abundance
All Years 1998-2016	$F_{20,87}$ p	3.76 <0.001	6.07 <0.001	7.05 <0.001
Sites through time	$F_{5,96}$ p	5.35 <0.001	2.35 0.05	2.37 0.05
Post 2004 data				
Years since 2004	$F_{12,65}$ p	3.68 <0.001	5.11 <0.001	1.92 0.05
Post 2007 data				
Years since 2007	$F_{9,50}$ p	2.49 0.019	6.54 <0.001	0.41 0.92

The fluctuations in algal taxonomic richness at the study sites over time can be readily seen in Figure 3. It should be recalled, however, that the availability of new and improved taxonomic keys is likely the most significant reason for the higher taxonomic diversity at all sites after 1997. Since 2004 overall diversity has continued to fluctuate (Figure 3).

There are no apparent significant differences in animal diversity closer to, or further away from, the outfall ($F_{1,4}$ = 1.37; p = 0.306). It is suggested, therefore, that any variability seen through time is most likely the result of natural variation within the communities, and the high degree of variability of substrata within sites, rather than as a result of effluent discharged from the outfall.

The overall numbers of algal taxa at each site has not changed significantly from 2013 to 2016 ($F_{3,20}$ = 1.94, p = 0.16). For animal taxa, however, there are significantly fewer taxa this year ($F_{2,15}$ = 9.92, p = <0.001), likely due to the large amount of sand present on beaches at the time of this sampling round.. Through time the only real change in algal diversity had been the relatively low diversity encountered at three sites (Boulder Beach, Allans Beach and Victory Beach) in 2005. Such low diversity had not been encountered since.

There was no clear pattern for the number of algal taxa per quadrat in 2016. Control site and impact sites all had similar numbers of algal taxa this year albeit slightly fewer than in previous years. Boulder Beach once again showed low diversity, with Victory Beach being equally low. Second Beach this year showed the highest algal diversity (Tables 1 and 3). Algal diversity at Lawyers Head is slightly higher than it was last year, but falls about midway with respect to diversity. Likewise, both animal diversity per quadrat, and total animal diversity showed no definite pattern that could be related to the location of the outfall (Tables 1 and 3). Any differences in animal diversity and/or abundance have consistently been variable through time and do not show any discernible trends. It is most likely that the small differences that do exist among sites (Tables 1 and 3) are due to differences in micro-habitat and tide height at the time of each survey.

Table 3. ***(a)*** *Average number of species found per quadrat and* ***(b)*** *total number of species found per site for the eight beaches in 2003 to 2016. Green columns are algae, plain columns are animals.*

a

	Mean no. species/quadrat																									
	2003		2004		2005		2006		2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	
	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals
Black Head	4.6	7.9	8.4	11.4	7.1	10.9	7.7	5.8	5.85	7.95	9.5	8.75	7.1	8.4	5.8	7.2	8.2	11.4	8.0	9.2	8.0	9.1	8.8	8.0	5.7	7.8	3.9	6.9
Second Beach	4.9	7.6	5.6	9.5	5.6	12.4	7.2	11.8	6.2	12.9	5.5	9.05	8	12.2	6.5	6.1	7.5	13.1	7.4	13.1	7.0	10.9	7.5	9.9	5.9	13.5	8.6	7.0
Lawyer's Head	6.7	6.2	5.6	10.6	5.8	12.9	4.9	11.9	5.8	7.8	4.25	10.45	7.1	11.1	7.5	7.2	5.5	13.7	6.0	12.4	6.0	12.3	5.7	9.4	7.2	11.2	6.5	4.5
Boulder Beach	8.3	5.6	4.6	11.7	4.4	14.4	5.2	14.1	4.5	8.85	4.5	6.15	5.4	13.1	9.9	5.9	6.8	14.1	4.8	9.3	4.1	10.2	5.2	10.9	4.6	9.6	5.4	5.7
Allan's Beach			4.4	12.3	4.7	9.6	3.7	12.0	5.15	5.8	5.45	8.7	7.1	13	7.4	5.0	6.1	14.9	5.9	15.1	4.6	11.1	7.0	11.4	7.2	13.0	7.5	7.6
Victory Beach	4.9	9.1	5.8	11.3	3.9	11.9	5.0	10.2	6.7	8.55	5.85	11.55	7	9.8	7.0	7.7	7.5	11.3	7.6	12	7.1	12.5	7.3	9.0	6.7	14.2	5.0	6.0

b

	Total no. species/quadrat																									
	2003		2004		2005		2006		2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	
	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals	Algae	Animals
Black Head	29	28	21	27	22	37	22	29	16	30	27	28	25	30	34	24	25	31	25	26	33	44	29	31	20	30	20	15
Second Beach	18	27	16	24	17	38	22	33	17	33	18	29	22	33	25	21	22	29	27	27	29	37	31	37	19	37	25	18
Lawyer's Head	24	25	19	31	14	28	20	30	14	28	16	23	19	25	25	19	13	25	19	29	19	23	21	28	19	25	23	15
Boulder Beach	17	23	13	29	10	30	13	30	16	25	18	28	18	31	17	16	17	31	20	25	10	20	18	29	14	23	17	15
Allan's Beach			13	27	11	20	13	36	17	25	20	34	23	37	28	27	19	34	19	32	18	34	28	37	21	31	21	15
Victory Beach	15	25	13	26	8	20	15	27	17	23	21	26	20	27	24	23	23	24	23	22	14	20	27	30	17	28	16	11

4.2.2 Dominant Taxa

(i) Seaweeds (macro-algae)

Surveys since 2003 have used revised and updated algal keys (e.g. Seaweeds of New Zealand – an illustrated guide, by Nancy Adams, 1994), which have allowed a greater degree of taxonomic detail and accuracy. Therefore, the major taxa present at the study sites differ slightly from those found in surveys prior to 2003.

As in previous surveys *Durvillaea antarctica* (bull kelp) and coralline algae (encrusting pink and white algae such as *Lithothamnion* spp. and articulated corallines such as *Corallina officianalis*), covered significant areas at most sites (Appendix 1). The red algae *Pachymenia lusoria* was also common at most of the sites (Appendix 1). *Ulva lactuca,* a green alga, was present at all sites, albeit sparsely at Boulder Beach, Allans Beach and Victory Beach. *Ulva* was less abundant than in 2011 - 2014 overall and was certainly not as abundant as in 2005 when the summer was particularly warm. *Codium fragile* and *Xiphophora gladiata* were less common at Black Head than last year, with neither being abundant, even outside the survey area. A diverse range of algal species was found, with many being ubiquitous (Appendix 1). *Enteromorpha* sp.*,* which was found at just Boulder Beach and Allans Beach last year, was present at all but Victory Beach this year.

(ii) Animals (Figure 4)

Once again barnacles and mussels were the visually dominant animal taxa at most sites with the small honeycomb barnacle, *Chamaesipho columna* being the most numerically dominant species. Limpets were also very common and diverse at the majority of sites. As in previous surveys, small gastropods (*Austrolittorina* spp.) were present in moderate numbers at all sites (Appendix 1) but were not as abundant at Victory Beach and Lawyers Head as elsewhere. Chitons, especially *Sypharochiton pelliserpentis,* were ubiquitous with moderate abundances at all sites. Anemones were also present at all sites, but with diversity and abundance at Allans Beach being lower this year than last year.

As for last year, ascidians were uncommon and bryozoans were rare at all but Boulder Beach. Bryozoans were, however, observed outside quadrats at Victory Beach, Second Beach and Black Head. Highly mobile taxa, such as fish, shrimps and crabs, were seen at some sites but were under-sampled because they were often observed but

tended to seek refuge at our approach and were not encountered in most of the quadrats.

Overall, a very diverse range of animal taxa was found at all sites (Appendix 1), with other taxa, such as sea stars and sponges, often seen throughout the sites but seldom falling within quadrats.

4.2.3 Animal Abundance

This years data show that there is a significant difference in the number of animal species per m^2 from 2007 to 2016 (Table 2). This differs from last year when a significant no difference was found. There is no significant difference in the overall abundance of animals from site to site. If, however, the abundance of animals at sites is compared through time since surveys began, there has been a significant change (Table 2). Second Beach continues to show high abundance (Figure 4) due to the very high densities of the barnacles *Chamaesipho columna* and *Epopella plicata* at this site. By and large, numbers are very changeable from year to year with no obvious patterns discernible. This is likely attributable to the random placement of quadrats on the highly variable substrate at the various sites. In general, however, animal numbers in 2016 show no distinct correlation with proximity to the outfall (Table 1).

The difference in numbers from year to year is quite obvious on the graph in Figure 4. The most likely explanation for the high variability at any site is that more quadrats fell within barnacle zones in years that show very high abundance. As stated in the methods, the sampling sites are chosen entirely at random with quadrats being placed randomly as close as practicable to the waters edge in the macroalgal zone. Zones where barnacles are abundant will have a marked influence on numbers due to their small size and close proximity to each other.

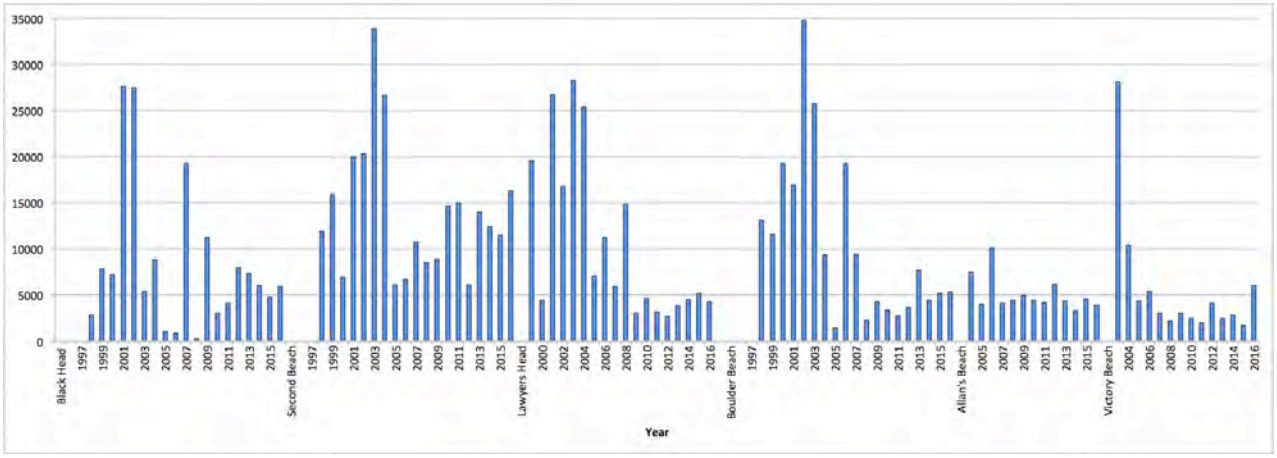

Figure 4. *Average animal abundance for each sampling location, 1996-2016.*

Looking for long-term patterns in animal abundance, the only site for which any discernible trend is apparent are perhaps Victory Beach, which shows a possible general decline in animal numbers over the years, although this year does not follow that trend. Second Beach and Boulder Beach both of show a possible slight increase in abundance over recent years.

Such trends, however, are by no means conclusive and there is no obvious reason there should be a decline or increase at these sites. Abundances at Lawyers Head and Allans Beach this year are very slightly lower than encountered last year, but those at Black Head, Second Beach and Victory Beach are very slightly higher. As already stated, the very high numbers and patchy distribution of some of the small animals confound the results somewhat. *Chamaesipho columna,* the small honeycomb barnacle, was present at every site, and, although percentage cover was quite low in many cases, when ground-truthed it was found that there was a mean of 214 individuals in each 1% of the 0.25m^2 quadrat (i.e. 8.56 per cm^2). Consequently, where the quadrat falls (in a barnacle encrusted area or not) can have an enormous bearing on the total abundance of animals at a site. This is particularly true at Second Beach where quite extensive patches of *Chamaesipho* occur. Such is the nature of random sampling.

Analysis of the 2016 data using a Bonferroni post-hoc statistical test and ANOVA confirmed that, as in previous years, Second Beach has the highest abundance (Table 4) ($F_{5,114} = 4.49$, $p = <0.001$). This is largely due to the presence of high numbers of the small barnacle *Chamaesipho columna.*

Table 4. *Bonferroni post-hoc test results for animal abundance, 2016 data. Significant differences among sites are shown, with the site having the higher abundance listed first.*

	Black H	Second	Lawyers	Boulder	Allans	Victory
Black H.						
Second B.	SB>BH					
Lawyers H		SB>LH				
Boulder B.		SB>BB				
Allans B.		SB>AB				
Victory B.		SB>VB				

4.3 Overview of Sampling Sites

4.3.3 Black Head

Black Head had a similarly diverse algal community to last year, and similar diversity to that observed in 2004, 2005 and 2006. Diversity was higher than in 2001, 2002 and 2007 (Table 1). Algae were once again dominated by articulated coralline algae, with patches of *Durvillaea antarctica Lithothamnion* and *Stictosiphonia arbuscula* also common. *Gigartina* species were also reasonably common, as they were last year. The green algae *Codium fragile* and the brown alga *Xiphophora gladiata* were less common than last year, and at lower abundances than in previous surveys. Twenty algal species were present – nine less than 2014, likely due to sand build up last year and this year. However, overall algal abundance has varied little throughout the past 12 surveys (Tables 1 and 5).

Numbers of green-lipped, blue and ribbed mussels have always been low at the surveyed site at Black Head (Figure 5). This is a function of the topography at the site and the fact that mussels here are generally in deeper water than can be easily surveyed. Numbers of green lipped and blue mussels are slightly lower than observed during last year's survey, and are at the low end of the range of variability observed since surveys began.

The remainder of the animal community was less diverse this year, but with *Chamaesipho columna* remaining the visually and numerically dominant species, followed by other barnacles (*Chamaesipho brunnea, Elminius modestus* and *Epopella plicata*). Limpets, with the exception of *Notoacmea* spp., and the small gastropod *Margarella* spp. were less common than last year. *Austrolittorina*, which was almost

completely absent in 2009 and 2010, was present in patches of reasonably high abundance on some rocks this year (Appendix 1). Anemones were observed in small, scattered clumps in pools and under rocks.

Table 5. *Total percentage of algal cover at each site from 2003 to 2016.*

	Black H	Second	Lawyers	Boulder	Allans	Victory
Algal cover/site 2003	3769	3064	3639	2676	-	2589
Algal cover/site 2004	1880	691	1421	919	1294	1432
Algal cover/site 2005	827	814	1346	1112	609	749
Algal cover/site 2006	1728	1667	1369	1379	1043	1771
Algal cover/site 2007	857	917	1390	1071	1095	945
Algal cover/site 2008	1112	819	999	1125	1200	795
Algal cover/site 2009	806	925	1055	1080	1443	966
Algal cover/site 2010	1569	959	1334	1716	1509	1229
Algal cover/site 2011	1140	952	1538	962	1395	916
Algal cover/site 2012	1015	1154	1473	1370	1326	1529
Algal cover/site 2013	1181	1081	1327	787	637	1267
Algal cover/site 2014	1123	1070	1222	1291	1405	1024
Algal cover/site 2015	1160	1048	1480	1555	1299	659
Algal cover/site 2016	441	1042	1340	999	1409	1110

4.3.4 Second Beach

Algal communities at Second Beach showed higher diversity than in 2015 with 25 taxa observed (Table 1). The algal community was dominated by *Durvillaea antarctica* but, as for previous surveys, distribution within the surveyed site was very patchy apart from in Blocks 1 and 2. As in past years, coralline algae, *Stictosiphonia arbuscula, Pachymenia lusoria* and *Ulva lactuca* were moderately common, but also rather patchily distributed (Appendix 1).

Barnacles, especially *Chamaesipho columna,* dominated the rocky shore animal community at Second Beach, with numbers exceeding four thousand per square metre in almost half of the quadrats surveyed (Appendix 1). Gastropod snails such as *Austrolottorina cincta* were also abundant and moderately widely distributed. The small black mussel, *Xenostrobus pulex,* was common in patches but has been slightly less widely distributed over the past two surveys.

Mussel numbers at Second Beach have traditionally been quite high and this year is no exception. Although less abundant than last year, numbers of large species (*Perna*) fall within the range of variability observed during previous surveys (Figure 5). Large *Mytilus* and *Aulacomya,* however, remain less common.

4.3.5 Lawyers Head

The algal community at Lawyers Head was slightly more diverse this year than last year, but typical of previous surveys, apart from 2011 when diversity was particularly low (Table 1). The community was heavily dominated by the brown alga, *Durvillaea antarctica.* This site used to be notable as being the only one where *Durvillaea willana* is found in any abundance. This year, however, *D. willana* occurred only sparsely and was observed just four quadrats. Coralline algae and *Lithothamnion* were very common, with a number of other red algal species, especially *Pachymenia lusoria* and coralline paint, also present (Appendix 1). Green algal species were again not common this year with just three taxa observed, although *Ulva lactuca* was present in most quadrats.

Numbers of *Perna canaliculus* were lower than last year and fall within the range of variability since 2004 (Figure 5). Large animals (>8cm) were still common in areas outside quadrats, especially in crevices and lower down in the intertidal zone. Numbers of *Aulacomya ater maoriana* and *Mytilus galloprovincialis* were slightly higher than last year, but much the same as in most surveys since 2007 (Figure 5).

Barnacles (mainly *Chamaesipho columna*) and the small snail, *Austrolittorina cincta,* were once again all very common at this site with patches of the small mussels, *Xenostrobus pulex* also moderately widespread. Chitons (*Sypharochiton pelliserpentis*) and limpets (*Cellana* spp*, Patelloidea corticata, Notoacmea* spp. and *Siphonaria* spp.) were all quite widespread and moderately abundant, with numbers similar to previous surveys.

4.3.6 Boulder Beach

Algal diversity was slightly higher than last year and falls within the variability observed over the past ten years. As with most other sites, the algal community at Boulder Beach was dominated by *Durvillaea antarctica, Corallina officianalis* and coralline paint, with *Pachymenia lusoria* also common throughout the site apart from at Block 4 (Appendix 1).

Perna canaliculus showed abundance slightly lower than last year, with numbers being about average for what has been observed over the past five surveys (Figure 5). Other large mussel species (*Aulacomya* and *Mytilus galloprovincialis*) also showed abundances that fell within normal variability. This beach remains closed to visitors to give yellow-eye penguin numbers a chance to recover and is not expected to be targeted by recreational shellfish gatherers.

Animal diversity was lower this year, with the low diversity likely due to a build up of sand at the survey site, meaning many organisms were buried. Considerable movement of sand associated with storm events is not unusual along the peninsula coastline. Communities were dominated by a variety of barnacles (*Chamaesipho columna, C. brunnea, Elminius modestus* and *Epopella plicata*), with the small mussels *Xenostrobus pulex* and *Modiolus neozelanicus* also being very common in most quadrats. The small snail, *Austrolittorina cincta*, was once again common in many quadrats also. Limpets (*Cellana* spp., *Notoacmea* spp., *Patelloidea* spp.) and chitons were widespread, but not as abundant as in 2010, 2011 and 2012 (Appendix 1).

4.3.7 Allans Beach

Algal diversity at Allans Beach was the same this year as it was last year, but considerably lower than in 2014 and in 2010. Bull kelp (*Durvillaea antarctica*) was moderately abundant and was observed in all quadrats but those in Block 4. Coralline algae and *Lithothamnion* were very common, with the green alga, *Ulva lactuca* slightly less so. As in previous years other algae, although reasonably diverse, were quite sparse. The green algae *Codium fragile,* which appeared to be absent from quadrats in 2011, was once again observed at Block 4, as it was in the past two years, albeit in a single quadrat.

Densities of all large mussel species were very similar this year to last year, and generally fell within the variability seen in past surveys.

As in previous years the animal community was heavily dominated by barnacles, especially *Chamaesipho columna,* with *C. brunnea, Elminius modestus* and *Epopella plicata* also being present in quite high densities. The small gastropod, *Austrolittorina cincta,* and the bedding mussel *Xenostrobus* were moderately abundant this year, but patchily distributed. Chitons, limpets, and amphipods were less common this year and

patchily distributed. Anemones, especially *Actinothoe aureoradiata*, were abundant as patches in well-wetted areas.

4.3.8 Victory Beach

The algal community was similar to that at other sites, being visually dominated by *Durvillaea antarctica,* coralline algae and *Pachymenia lusoria*. However, as for the past three years, the encrusting brown alga, *Ralfsia verrucosa,* was more common here than at most other sites. Algal diversity is slightly lower than last year and much lower than in 2014. Overall, cover is within the range observed in previous surveys. Cover of bull kelp this year is slightly lower than in most previous surveys, with *Durvillaea antarctica* appearing in just nine out of twenty quadrats (Appendix 1). *Stictosiphonia arbuscula,* which was absent from surveyed areas in 2011, was once again present, although in relatively low abundance on the tops of some rocks. It should be noted that *Stictosiphonia* is quite common at higher tide levels.

Perna canaliculus, Aulacomya and *Mytilus* numbers were higher this year than last year, but none fell outside the range of variability seen in the past (Figure 5).

Animal communities were similar to those at Boulder Beach and were dominated by barnacles (*Chamaesipho columna, C. brunnea* and *Epopella plicata*), *Austrolittorina,* mussels and limpets (*Cellana* spp., *Notoacmea* spp., *Patelloidea* spp.). Overall animal diversity at Victory Beach in 2016 was considerably lower than it was last year, and lower than in all previous surveys (Table 1). This is likely a reflection of the moderate tide allowing less accessibility and a build up of sand at this site this year.

4.4 Mussel Monitoring

Size frequency distributions of green lipped (*Perna canaliculus*), blue (*Mytilus galloprovincialis*) and ribbed (*Aulacomya ater maoriana*) mussels at all eight monitoring sites since 2004 are presented in Figure 5 (see Appendix 2 for raw data).

Densities of *Perna canaliculus* showed increases at Victory Beach and Allans Beach, and slight decreases at the remaining sites (Figure 5). However, densities observed this year remain within the variability seen over the past few surveys for most sites.

The density of *Aulacomya ater maoriana* has been traditionally quite low at all surveyed beaches, this mussel being markedly less common than *Perna* or *Mytilis*. Overall, however, numbers at most sites were slightly higher than last year. There are no obvious patterns of *Aulacomya* distribution that can be related to the location of the Tahuna WWTP outfall.

Mytilus galloprovincialis abundance is generally similar to that found in previous surveys, although numbers at Black Head, Second Beach Boulder Beach and Victory Beach are a little higher than they were last year.

In summery there is no clear relationship among mussel numbers, size or species composition and the location of the outfall. Numbers of all mussel species continue to be lower at Black Head over all the years surveyed. It is believed that mussel numbers (of all larger species) are generally low at Black Head due to a lack of suitable habitat in the survey area and the very exposed nature of the shore here. There are certainly beds of *Perna* and *Mytilus* present, but, as already stated, generally in deeper water on rock pinnacles located some metres out from the shoreline making sampling both difficult and dangerous.

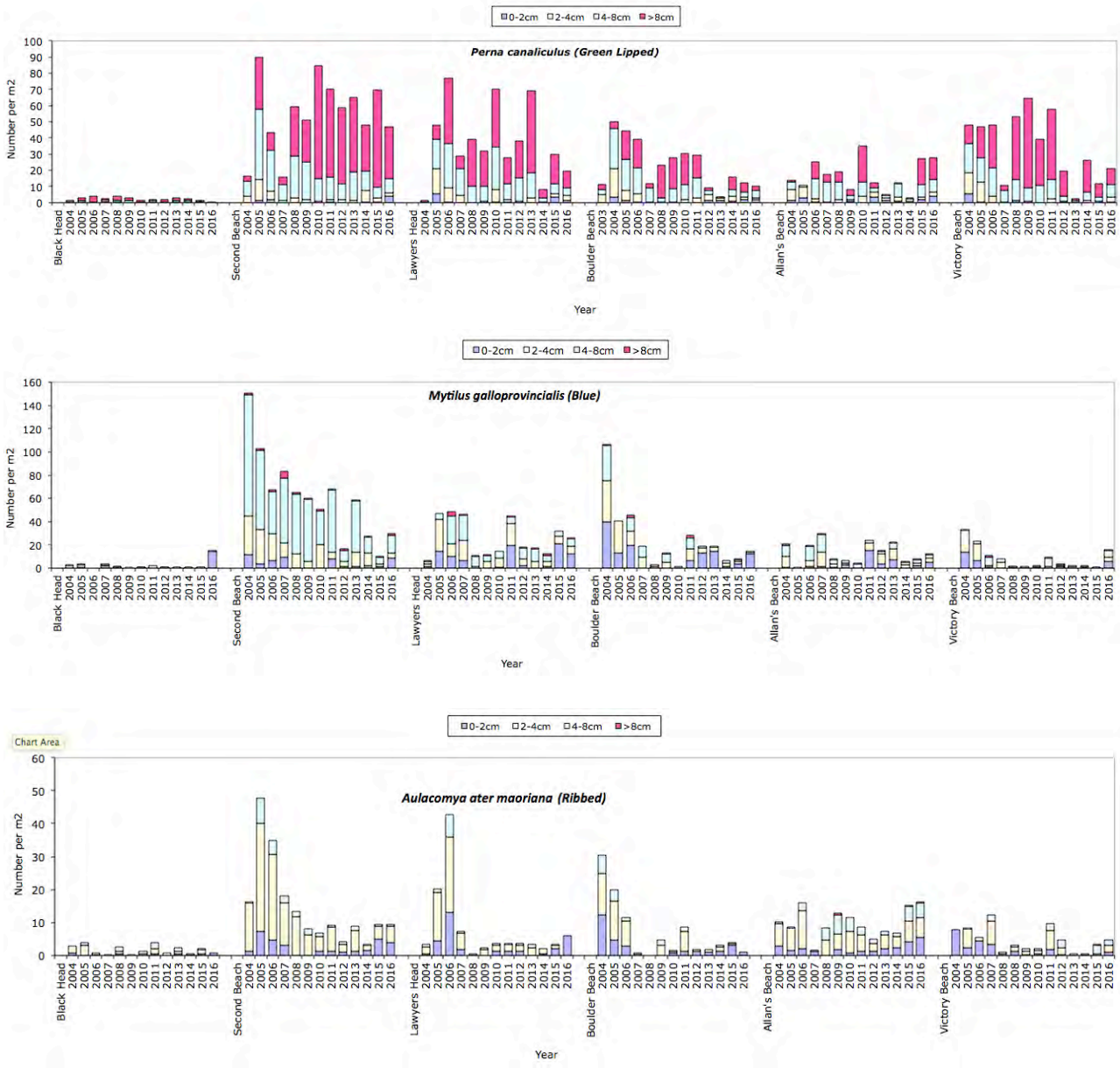

Figure 5. *Size frequency distribution data for mussels sampled during rocky shore monitoring 2016.*

4.5 Community analyses

As has been found in all previous surveys, the inter-tidal rocky shore communities were variable at most of the locations sampled (indicated by a spread of points in the ordination at particular sites) (Figure 6). All of the sites showed varying degrees of similarity within each site, as seen from the grouping of symbols in Figure 6, with Black Head arguably, showing the most intra-site similarity. Results for the ordination are similar to those seen in all surveys since 2008, apart from last year when the symbols for Second Beach formed a discrete cluster. This was likely due to

the build up of sand last year burying a high proportion of intertidal species. As a consequence, small and very abundant animals that occurred higher up in the intertidal zone (e.g. barnacles) were over represented, ensuring the community structure at Second Beach differed significantly from other sites in 2015.

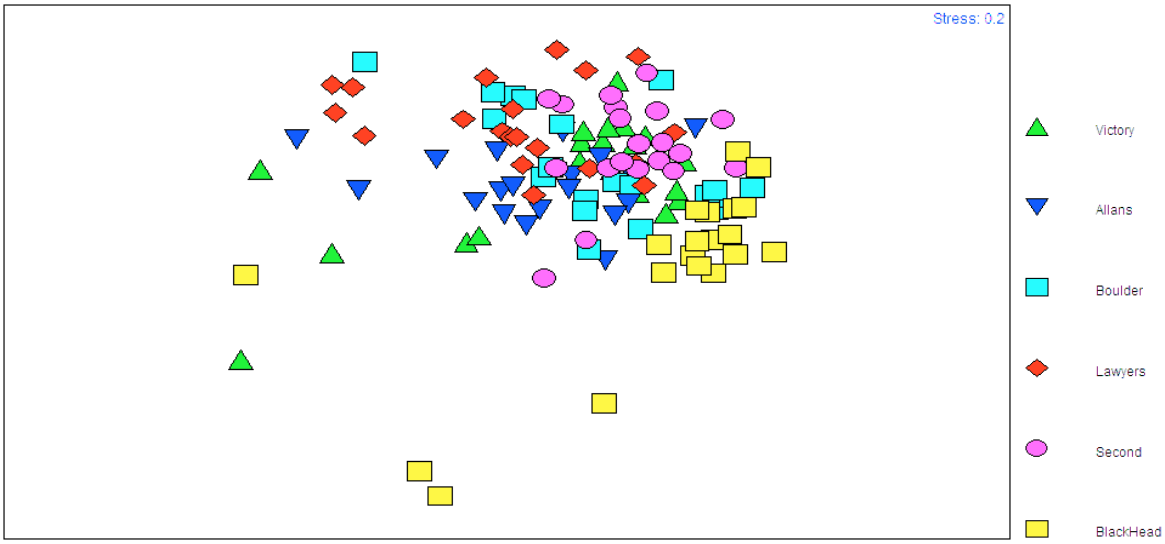

Figure 6. *Ordination of inter-tidal communities by sampling location for 2016 data.*

There was no clear pattern of community structure with proximity to the wastewater outfall. It could be argued that the symbols for Black Head, which lies up-current to the Tahuna outfall, are more separated from other sites (Figure 6), but this is likely more due to sand build up and fewer accessible mussels than proximity to the outfall. Sites downstream of the outfall (Lawyers Head, Boulder Beach) show no such separation. The percentage similarities (Table 6) suggest that no site is markedly different from any other site. Likewise, differences among quadrats within sites are similar to differences between sites. No sites this year show more intra-site similarities than inter-site similarities (Table 6).

Data from past surveys suggest that the composition of species across sites is not significantly different from year to year and the fact that there is considerable overlap of symbols in Figure 6 shows that differences in community composition are generally slight. The highest percentage similarity (i.e. quadrats within the site mostly containing similar species) is at Second Beach, reasonably close to the outfall, but at Boulder Beach and Allans Beach, both much further from the outfall, quadrats also show considerable similarity (Figure 6, Table 6).

Table 6. *Percentage similarity in species lists between sites in 2016. Internal similarities are shown shaded in grey. Higher values indicate that the same species are dominant at both locations assessed.*

	Black Head	Second Beach	Lawyers Head	Boulder Beach	Allans Beach	Victory Beach
Black	43.80					
Second	40.21	57.65				
Lawyers	29.78	45.40	50.11			
Boulder	38.29	47.17	44.72	53.97		
Allan's	36.02	49.18	47.75	46.12	53.31	
Victory	36.51	46.54	43.10	47.29	45.59	48.21

In general, similarities in species composition between sites other than Second Beach surveyed in 2016 were moderate, ranging from 29.78% overlap in species (Black Head and Lawyers Head) to 49.18% (Second Beach and Allans Beach) (Table 6). Overall, similarity in community structure is much that same as it has been during past surveys.

At all sites the dominant species were similar, with differences in species composition being mainly due to differences in abundance or cover of species that represented only a minor component of the communities. While the 'impact' sites (Second Beach, Lawyers Head and Boulder Beach) were distinguished by higher densities of some species, Black Head also showed high densities of some animals. None of the surveyed sites had any species that were found nowhere else, nor were they missing species that were ubiquitous elsewhere. As in previous years, the green alga *Ulva lactuca* was moderately common at Lawyers head and Second Beach, but was also common at Allans Beach. Second Beach, as usual, had the highest density of the small barnacle, *Chamaesipho columna,* but there were also very high densities of this species to be found at Victory Beach.

Internal similarities (number of species shared between quadrats within a site) ranged from 43.80% to 57.65%. As in 2015 Second Beach and Boulder Beach were the least variable sites while Black Head and Allans Beach were the most variable (Table 6). Victory Beach and Black Head showed somewhat more variability (Table 6).

It could be argued that there is a pattern of variability in communities close to or far from the outfall with Second Beach having a lower index of multivariate dispersion (IMD) than Victory Beach, Allans Beach and Black Head, but Victory Beach, the

most distant site, shows an IMD lower than at Lawyers Head and Boulder Beach (Table 7).

Table 7. *Changes in the index of multivariate dispersion (IMD) for inter-tidal communities through time. A higher IMD value indicates more variability in the community and potentially lower environmental impact.*

Site	IMD 2004	IMD 2005	IMD 2006	IMD 2007	IMD 2008	IMD 2009	IMD 2010	IMD 2011	IMD 2012	IMD 2013	IMD 2014	IMD 2015	IMD 2016
Black Head	1.133	1.342	1.395	0.876	1.005	0.639	1.060	0.841	0.777	1.145	1.027	1.286	1.145
Second Beach	0.971	1.358	1.181	1.129	0.756	0.842	0.472	0.867	0.725	1.109	1.024	0.761	0.803
Lawyer's Head	1.302	0.576	0.919	1.103	0.779	0.948	1.184	0.917	0.962	0.802	0.995	0.974	1.245
Boulder Beach	0.981	0.665	0.656	0.621	0.998	0.626	0.851	0.624	0.989	0.623	0.861	0.826	1.259
Allans Beach	1.123	0.791	0.91	0.848	1.237	1.298	1.136	1.173	1.029	1.404	1.195	1.096	1.518
Victory Beach	0.975	0.485	0.65	1.144	1.333	1.336	0.790	0.627	0.931	0.917	0.897	1.057	1.062

It is interesting to note the changes in variability from year to year (Table 7). There is no obvious pattern to this change, which suggests that differences are due to natural variability and patchiness in the distribution of species at each site, rather than effects from the outfall. Indeed, there is no significant difference in variability through time ($F_{12,65} = 0.79$; $p = 0.651$). Boulder Beach, however, traditionally shows slightly lower diversity to the other sites.

5. Conclusions

The 2016 rocky shore intertidal survey revealed diverse and healthy ecological communities along the Otago coast that are consistent with those observed in other studies along the Otago coastline (e.g., Morton & Millar 1968, Probert 1988, Gerring 1990). The communities observed this year did not differ significantly in terms of the species present or their relative abundance and cover from those observed in past surveys.

The number of species found continues to be higher than found in years prior to 2004, reflecting increased effort put into taxonomy of both algae and animals, and, more specifically, the use of actual numbers rather than percentage cover in the case of some species of small animals. Overall numbers of animals this year were not significantly different to those found last year ($F_{1,10} = 0.42$; $p = 0.531$). As in previous surveys, analysis of species patterns through time shows high variability, but there are no clear trends that can be related to the presence of the Tahuna WWTP outfall.

As in previous surveys, analysis of size frequency data and abundance of the three major species of mussels found on local rocky shores reveals no clear patterns of distribution, either through time, or with proximity to the outfall. Overall, mussel numbers this year are similar to those observed at most sites in previous surveys, with numbers not falling outside the range seen since surveys began except at Black Head. Changes observed are likely due to natural variability and patchiness of distribution, random quadrats occasionally falling on locations where mussels are absent. All mussel species remain scarce at Black Head and have traditionally been low there since surveys began (Stewart 2004 – 2015). *Aulacomya* remain the least common of the three species at all sites. Overall, there are no clear patterns in mussel abundance at either of the sites closest to the outfall, or at sites located far from the outfall.

Detailed analysis of the whole community using multivariate techniques suggests that any differences between possible impact sites (Lawyers Head and Boulder Beach) and the other sites is statistically insignificant and there is considerable overlap in community structure among all sites (Figure 6). Unlike last year, when Second Beach showed significant differences due to the very high percentage of barnacles encountered in quadrats, this year second Beach shows now significant difference in community structure. The build up of sand at the site last year made accessibility to the usual low intertidal zone impossible and it is believed that that was the most likely explanation for the difference in community structure observed in 2015.

Lawyers Head and Second Beach usually show a slightly higher percentage algal cover than other sites, a possible indication of nutrient enrichment. This year, however, the highest percentage algal cover was observed at Allans Beach (Appendix 1) suggesting that if any enrichment is occurring it is likely unrelated to the Tahuna WWTP outfall. In addition, high algal diversity is to be found at Black Head, Second Beach, Lawyers Head and Allans Beach. It should be pointed out here, however, that no clear relationship between nutrient enrichment and seaweed species has been established for New Zealand conditions. Overall, no clear relationship exists for algal cover or richness in relation to the Tahuna outfall. Generally, the differences in macro-algal species dominance from site to site are subtle, and there do not appear to be any clear-cut trends through time.

As observed in previous surveys, there are very subtle differences between inter-tidal communities at the impact sites and at other sites. However, the overall similarity in community composition and species abundance between sites is high. As in previous years variation between samples collected from within individual sites was often greater than the variation between sites, emphasising the natural variability present. Natural variability is due to a number of factors, not least of which are nature of substrate, aspect, and exposure to wave action.

In conclusion, there is no compelling evidence of environmental damage at any site that may be attributed to wastewater discharges from the Tahuna Wastewater Treatment Plant outfall. Any effects of wastewater are no more than minor and are insignificant in comparison to the natural variation among sites and from year to year.

6. References

Adams, N.M. 1994. *Seaweeds of New Zealand*. Canterbury University Press.

Bayne, B.L., Addison, R.F., Capuzzo, J.M., Clarke, K.R., Gray, J.S., Moore, M.N. and Warwick, R.M. 1988. *An overview of the GEEP workshop.* Marine Ecology Progress Series 46: 235-243.

Clarke, K.R. and Gorley, R.N., 2001. *Primer v5 - User manual/tutorial.* Primer-E, Plymouth.

Gerring, P. 1990. *Biological survey of rocky shores at Black Head and Brighton*. Zenith Technology.

Gerring, P. 1991. *Biological survey of rocky shores at Black Head and Brighton*. Zenith Technology.

Morton, J E. & M. C. Miller. 1968. *The New Zealand Sea Shore.* Collins Press, London. Great Britain.

Probert, P.K. 1988. *Biological survey of rocky shores*. Zenith Technology.

Probert, P.K. 1989. *Biological survey of rocky shores*. Zenith Technology.

Stewart, B. 2004. Green Island Wastewater Treatment Plant (ORC Consent 97530, Condition 8): Rocky Shore Ecological Monitoring 2004. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2005. Green Island Wastewater Treatment Plant (ORC Consent 97530, Condition 8): Rocky Shore Ecological Monitoring 2005. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2006. Green Island Wastewater Treatment Plant (ORC Consent 97530, Condition 8): Rocky Shore Ecological Monitoring 2006. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2007. Green Island Wastewater Treatment Plant (ORC Consent 97530, Condition 8): Rocky Shore Ecological Monitoring 2007. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2008. Green Island Wastewater Treatment Plant (ORC Consent 97530, Condition 8): Rocky Shore Ecological Monitoring 2008. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2009. Green Island Wastewater Treatment Plant (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a): Rocky Shore Ecological Monitoring 2009. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2010. Green Island Wastewater and Tahuna Wastewater Treatment Plants (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a):

Rocky Shore Ecological Monitoring 2010. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2011. Green Island Wastewater and Tahuna Wastewater Treatment Plants (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a): Rocky Shore Ecological Monitoring 2011. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2012. Green Island Wastewater and Tahuna Wastewater Treatment Plants (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a): Rocky Shore Ecological Monitoring 2012. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2013. Green Island Wastewater and Tahuna Wastewater Treatment Plants (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a): Rocky Shore Ecological Monitoring 2013. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2014. Green Island Wastewater and Tahuna Wastewater Treatment Plants (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a): Rocky Shore Ecological Monitoring 2014. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Stewart, B. 2015. Green Island Wastewater and Tahuna Wastewater Treatment Plants (ORC Consent 97530, Condition 8 and ORC Consent 2006.553, Condition 7a): Rocky Shore Ecological Monitoring 2015. Report to the Dunedin City Council prepared by Ryder Consulting Limited.

Tahuna AEE 2002. Prepared for the Dunedin City Council by Montgomery Watson Harza.

Thompson, R.M. and Ludgate, B.G. 2003. *Green Island wastewater discharge - Rocky shore monitoring*. Report to the Dunedin City Council. Ryder Consulting Limited.

Warwick, R.M. and Clarke, K.R. 1993. *Increased variability as a symptom of stress in marine communities.* Journal of Experimental Marine Biology and Ecology 172: 215-226.

Warwick, R.M., Platt, H.M., Clarke, K.R., Agard, J., Gobin, J. 1990. *Analysis of macrobenthic and meiobenthic community structure in relation to pollution and disturbance in Hamilton Harbour, Bermuda.* Journal of Experimental Marine Biology and Ecology 138: 119-142.

APPENDIX 1

ABUNDANCE & DIVERSITY DATA CORRECTED FOR PERCENTAGE COVER

SITES:
BLACK HEAD
SECOND BEACH
LAWYERS HEAD
BOULDER BEACH
ALLANS BEACH
VICTORY BEACH

Site: Blackhead 8 Jan 2016																				
Block	Block 1				Block 2					Block 3					Block 4					
Quadrat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGAL SPECIES (% cover)																				
Brown Algae (Phaeophyta)																				
Cystophora torulosa	1																			
Durvillaea antarctica									3	1	1	3	30	3						
Xiphophora gladiata		3																		
Green Algae (Chlorophyta)																				
Bryopsis plumosa		1	1			2					5		3							
Codium fragile		3			2															
Enteromorpha species					4															
Ulva species						3		3	1				15							
Red Algae (Rhodophyta)																				
Ballia hirsuita		1		2	3	1		1			2				1					
Lithothamnion													1							
Corraline paint (white)							1				2				1					
Echinothamnion lyalli								2												
Euptilota formosissima										2		1								
Gigartina clavifera										2			1							
Gelidium pusilum																3	1			
Grateloupia stipitata					1															
Nemalion helminthoides		1				1														
Pachymenia lusoria	3			10			2		1				1		2			2		3
Porphyra species	1	15		8				1		25	7	8		9	2	2	3	1		1
Stictosiphonia arbuscula	15	3	3		2	7	7	2	1						6	15	10	75	1	65
Verrucaria maura							2													2
ANIMAL SPECIES (Numbers)																				
Anthopleura aureoradiata	2	1												2						
Pyura pachydermatina										1				5						
Chamaesipho brunnea	33	66	99	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	17
Chamaesipho columna (% cover)	642	428	11775	642	214	428	428	214	214	0	0	642	0	0	428	1285	1713	642	642	1499
Elminius modestus	98	394	0	197	197	197	0	98	98	0	0	197	0	0	394	197	295	197	591	98
Epopella plicata	133	221	199	11	6	44	22	22	11	0	11	11	0	0	11	17	22	55	0	33
Mitella spinosa																			18	
Sypharochiton pelliserpentis	1					1						1								3
Diloma nigerrima								1												
Lepsithais lacunosus	1	1	1			3		2				1							1	
Austrolittorina cincta (% cover)	0	171	685	0	171	171	343	86	257	0	257	86	0	0	0	171	86	257	171	428
Nodilittorina unifasciata antipodum						171														
Margarella species			2	2	2	2	3	3	5	8	8		2	7	1					3
Melagraphia aethiops					1		1	2	2	1										
Micrelenchus tenebrosus			1																	
Number of animals per m2	910	1282	12762	852	591	1067	797	428	588	10	276	938	2	14	834	1669	2116	1151	1423	2081
Number of algal taxa per quad	4	7	2	3	5	5	4	5	4	4	5	3	6	2	5	3	3	3	1	4
Number of animal taxa per quad	8	7	8	6	7	9	7	9	7	8	6	7	6	8	6	5	5	5	7	7
Totalnumber of taxa per quad	12	14	10	9	12	14	11	14	11	12	11	10	12	10	11	8	8	8	8	11

Site: Second Beach 15 January 2016																				
Block	Block 1					Block 2					Block 3					Block 4				
Quadrat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGAL SPECIES (% cover)																				
Brown Algae (Phaeophyta)																				
Durvillaea antarctica	25	3		95	12	2			15	5		35	86	30				5		
Ralfsia verrucosa		3		4	4					3					2					
Scytothamnus australis					1			2	1		2	1	2		3		1	3	1	1
Splachnidium rugosum							1	2			2				1	1	1			1
Green Algae (Chlorophyta)																				
Bryopsis plumosa	1		5			4		2	1			2		1	1					
Chaetomorpha coliformis							2					2		1						1
Codium fragile															2					4
Enteromorpha species	1																			1
Ulva species			1		3	1	3	2	2	1	4	6	1	4	10		3	3	1	7
Red Algae (Rhodophyta)																				
Ballia hirsuita	5	2		4	3		4	1	1	1	3	2		7	2		2	4		3
Corallina officianalis	20			2	2	5	10	2	2	10	30	10	4	2	2		4			7
Lithothamnion	7			20	16			1	4				3	4						
Corraline paint (white)		2		3	2					2				2	2					
Echinothamnion lyalli							2				3	3								
Euptilota formosissima							2		3			3		3						3
Gigartina decipiens						1					3	3	1	6						2
Gigartina clavifera					2					1	5	5	2	12	2					6
Gigartina livida												1								
Gelidium pusilum			1		3															
Jania micrarthrodia												3								
Nemalion helminthoides			1					2	2					1						
Pachymenia lusoria	12	80		2			12			7			4	1	20	1		3		
Porphyra species	1		1													1		2	4	1
Stictosiphonia arbuscula	3	2	8	2		3		15	28	2	4	3	2			27	30	4	8	
Verrucaria maura		1								1										
ANIMAL SPECIES (Numbers)																				
Amphipods					1										2					2
Actinothoe albocincta	6	7				1	3		8	1	3		2	2				23		18
Anthopleura aureoradiata	3						1													
Pyura pachydermatina												1								
Chamaesipho brunnea	0	165	99	66	33	33	66	66	99	99	33	33	33	33	33	0	33	33	33	66
Chamaesipho columna (% cover)	1070	5995	18198	1499	5781	1285	1499	7493	5352	2141	642	1070	3211	1070	214	6423	5352	642	1499	2569
Elminius modestus	0	197	0	0	197	394	197	591	197	197	0	0	591	0	197	0	98	197	295	0
Epopella plicata	11	11	33	22	22	88	99	133	66	199	11	22	44	33	0	111	33	44	133	22
Mitella spinosa						1													3	1
Chiton glaucus				1																
Cryptoconchus porosus													1							
Plaxiphora obtecta						1							1							
Eudoxochiton nobilis													1							
Sypharochiton pelliserpentis	2		5	1	2	1	3	2		5						2	1		2	
Lepsithais lacunosus			1																	
Austrolittorina cincta (% cover)	86	0	257	0	0	86	0	257	171	343	171	171	257	0	0	343	171	0	171	0
Nodilittorina unifasciata antipodum									257											
Margarella species																				1
Number of animals per m2	1178	6375	18593	1589	6036	1890	1868	8542	6151	2984	861	1298	4141	1139	446	6878	5689	939	2136	2679
Number of algal taxa per quad	9	7	6	8	10	6	8	9	10	10	9	14	9	13	11	4	6	7	4	12
Number of animal taxa per quad	8	6	7	7	7	9	8	6	7	7	6	6	9	6	6	6	6	6	7	9
Totalnumber of taxa per quad	17	13	13	15	17	15	16	15	17	17	15	20	18	19	17	10	12	13	11	21

Site: Lawyers head 15 January 2016																				
Block	Block 1					Block 2					Block 3					Block 4				
Quadrat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGAL SPECIES (% cover)																				
Brown Algae (Phaeophyta)																				
Durvillaea antarctica	75	80	75	48	35	20	18	45	25	80	2	45	10	20	5					7
Durvillaea willana														10		5		20		5
Halopteris species																			2	
Ralfsia verrucosa						3				2					1		1			5
Splachnidium rugosum											2						7		1	
Green Algae (Chlorophyta)																				
Bryopsis plumosa																	5	1		
Enteromorpha species																1				2
Ulva species	5	2	1	2		2	3	1	2		4	2		3	3	1	12	1	3	3
Red Algae (Rhodophyta)																				
Ballia hirsuita											7									
Corallina officianalis	3	3	3	3	3	15	25	4	8	2	15	10	7	2	5	3		2	40	2
Lithothamnion	55		2	15	5	5	30	20	8	9	6	15	5	25	7	1		3		2
Lithophyllum		7			3					5										3
Corraline paint (white)	7	2	2	7	4	3	10	15	8	5	4	15	8	3						
Echinothamnion lyalli														3						
Gigartina decipiens																			9	
Gigartina clavifera																			7	
Gelidium pusilum														2						
Iridaea species																			4	
Jania micrarthrodia														1						
Nemalion helminthoides																	2			
Pachymenia lusoria	2	6	5		5	10	4	1			5	8	20		8		2			7
Plocamium species																				1
Stictosiphonia arbuscula																8		5		16
ANIMAL SPECIES (Numbers)																				
Amphipods		3								3				2						
Epiactus thompsoni														1						
Oulactis mucosa																1				
Actinothoe albocincta																			1	
Anthopleura aureoradiata	3		2										3	1		1	1	2		4
Chamaesipho brunnea			17		66		33				66	33		132	99	132	33		33	
Chamaesipho columna (% cover)		321	107		428	428	214	214			1498	428	428	3210	107	1712	1498	2568	1284	3210
Elminius modestus											197		99			197	99			
Epopella plicata		11	55			22	44				253	33	110		55	110	165	253		6
Acanthochitona zelandica									1											
Chiton glaucus					6										4					
Eudoxochiton nobilis	1	2			1			1												
Sypharochiton pelliserpentis	5		1		1	2	1	3	2	1			5	1	5	3		5	3	1
Austrolittorina cincta (% cover)			86			86				86	86					257	342	257	86	
Margarella species						1					2						2			
Number of animals per m2	9	337	268	0	502	539	292	218	3	90	2102	494	645	3347	270	2413	2140	3085	1407	3221
Number of algal taxa per quad	6	6	6	5	6	7	6	6	5	6	8	6	5	9	6	6	6	6	7	11
Number of animal taxa per quad	3	4	6	0	5	5	4	3	2	3	6	3	5	6	5	8	7	5	5	4
Totalnumber of taxa per quad	9	10	12	5	11	12	10	9	7	9	14	9	10	15	11	14	13	11	12	15

Site: Boulder Beach 11 Jan 2016																				
Block	Block 1					Block 2					Block 3					Block 4				
Quadrat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGAL SPECIES (% cover)																				
Brown Algae (Phaeophyta)																				
Adenocystis utricularis													25	6	7					
Durvillaea antarctica	12	10	7		4	30	30	25	35	75	12	5	4							
Green Algae (Chlorophyta)																				
Bryopsis plumosa	7	3	2	1						2	1	3	7	3	2					
Caulerpa brownii						2	4	6	5											
Chaetomorpha coliformis							2			1										
Enteromorpha species						3	2													
Ulva species		2	3	2	3							2	2	1	3					
Red Algae (Rhodophyta)																				
Ballia hirsuita	4												5		1					
Corallina officianalis	4	45	10	2	5	12	12	13		6	6	8		4	5		2			
Lithothamnion	15	15	4	1		30	25	10	43	45	40	10		2						2
Corraline paint (white)			2								1							2	2	3
Iridaea species						2														
Nemalion helminthoides													1	3	1			1		
Pachymenia lusoria		8	3		1	4	15	3	30	15	20	15	3							
Porphyra species											1					1	1	1		2
Stictosiphonia arbuscula	6	8			2										3	15	35	7	12	18
Verrucaria maura	5																			
ANIMAL SPECIES (Numbers)																				
Unidentified species		10	4	4																
Actinothoe albocincta								2	1											
Didemnum (orange) (% cover)						3	7	3	3	1										
Chamaesipho brunnea	66	0	66		33															
Chamaesipho columna (% cover)	1499	4282	2141	642	1499	1070		1070	428	642	428	642	214	428	642	856	642	642	1070	428
Elminius modestus	98	0	0	0	197	0		0	0	0	0	0	0	98	0	394	295	197	197	0
Epopella plicata	111	88	88	88	221	88	111	77	55	77	33	77	88	99	88	33	22	111	166	111
Mitella spinosa	2																	2		
Bryozoans							10													
Chiton glaucus		2									1									
Cryptoconchus porosus	1																			
Eudoxochiton nobilis	1							1												
Sypharochiton pelliserpentis	3	3			2	1		1			1		1					1	1	
Austrolittorina cincta (% cover)	257	514	0	514	685	0	0	0	0	0	257	86	343	343	0	257	0	171	257	257
Margarella species		3	4								2			1						
Number of animals per m2	2038	4902	2303	1249	2637	1163	128	1155	487	721	722	805	646	970	731	1540	960	1124	1691	796
Number of algal taxa per quad	7	7	7	4	5	7	7	5	4	6	7	6	7	6	7	2	3	4	2	4
Number of animal taxa per quad	9	9	7	5	6	6	4	8	6	5	7	4	5	5	4	4	4	6	5	4
Totalnumber of taxa per quad	16	16	14	9	11	13	11	13	10	11	14	10	12	11	11	6	7	10	7	8

Site: Allan's Beach 11 Jan 2016																				
Block	Block 1					Block 2					Block 3					Block 4				
Quadrat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGAL SPECIES (% cover)																				
Brown Algae (Phaeophyta)																				
Durvillaea antarctica	25	36	48	40	50	10	60	25	90	48	25	40	30	28	45					
Ralfsia verrucosa						1						5	1	2						1
Splachnidium rugosum																	2		1	1
Green Algae (Chlorophyta)																				
Bryopsis plumosa							3		2						1			1	2	2
Chaetomorpha coliformis			1	1			1	1		1		1			4					
Codium dimorphum							1	3												
Codium fragile																			3	
Enteromorpha species					2					1										
Ulva species	5	2			3	4	2	3		1	5	3	2	1	3			3	5	8
Red Algae (Rhodophyta)																				
Ballia hirsuita	3	1	2		3			3		3	4	4	1		2	2		2	4	
Corallina officianalis	4	6	3	12	8	18	7	15	40	18	22	11	8	8	13	5	1		10	13
Lithothamnion	8	10	30	20	30	15	38	10	25	25	50		8	9	10	2	3		3	
Corraline paint (white)		6			2			4				2			2	1				
Echinothamnion lyalli															4					
Euptilota formosissima							2	1						2	2				2	
Gigartina decipiens				1		2	2	1		3										
Gigartina clavifera		1		1			1							1					2	1
Gigartina livida																				3
Iridaea species												2								
Pachymenia lusoria	6		5	2	3			8		9	3	12	5	4			2			8
Stictosiphonia arbuscula							1				5		2			7	3	4	12	10
ANIMAL SPECIES (Numbers)																				
Unidentified species										1										
Oulactis mucosa	1								11				1	1						
Actinia tenebrosa									1				1			1		2		1
Actinothoe albocincta	28	14	6	12	5		15	8	3					14	9					
Anthopleura aureoradiata	1	21	8	6	8	12	5	9	8	12	3	2			6					5
Didemnum (orange) (% cover)	1					1		1												
Chamaesipho brunnea	33	33	0	66		0		0	0	0	0	33	66	33		66	0	66		33
Chamaesipho columna (% cover)	214	214	642	856	642	0	214	214	214	0	856	214	1712	4000	428	214	642	428	214	214
Elminius modestus	0	197	0	197	0	0	394	591	0	0	0	197	0	197	0	197	394	0	394	98.5
Epopella plicata	0	0	0	33	55	0	33	11	11		99	66	88	99	55	88	88			88
Mitella spinosa							2						2							
Eudoxochiton nobilis				1		1			1				1							
Sypharochiton pelliserpentis	1		2		1		2	3	3		2			2		2				
Austrolittorina cincta (% cover)	171	171	256	171		171		171.0			171	171		256	171	513	171	256	85.5	171
Margarella species	2	3	2			3	2	2	1				2		1	2			1	
Number of animals per m2	452	653	916	1342	711	188	667	1010	253	13	1131	683	1873	4602	670	1083	1295	752	695	611
Number of algal taxa per quad	6	7	6	7	8	6	11	11	4	9	7	9	8	8	10	5	5	4	10	9
Number of animal taxa per quad	11	8	9	8	6	9	8	10	11	5	7	6	9	8	7	8	5	5	4	7
Totalnumber of taxa per quad	17	15	15	15	14	15	19	21	15	14	14	15	17	16	17	13	10	9	14	16

Site: Victory Beach 26 Jan 16																				
Block	Block 1					Block 2					Block 3					Block 4				
Quadrat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGAL SPECIES (% cover)																				
Brown Algae (Phaeophyta)																				
Durvillaea antarctica	1	2	3	90	12	8	10	25			8									
Ralfsia verrucosa																	1		2	
Green Algae (Chlorophyta)																				
Bryopsis plumosa		2																		
Chaetomorpha coliformis										1										
Ulva species	3	3						1								2	2	1		
Red Algae (Rhodophyta)																				
Ballia hirsuita							3	2		3			1		3				1	
Corallina officianalis	12	15	3		2	25	85	35	30	90		1			2	2	6	2	1	
Lithothamnion	15	7	5	15	3	30	15	10	25		8	2			1		2	2		
Corraline paint (white)					3						4						1			3
Euptilota formosissima		3																	2	
Gigartina clavifera							3			8										
Gymnogongrus torulosus										2										
Pachymenia lusoria	5	7	4			80	25	30	85	15	15	8	2		7	12	20	12	1	6
Porphyra species				6	1								2	1						
Stictosiphonia arbuscula		4													8				1	45
Verrucaria maura		2		3	3	7				3	3		2			7	2	4		2
ANIMAL SPECIES (Numbers)																				
Amphipods						3	2	2	3											
Actinothoe albocincta		4		7																
Anthopleura aureoradiata						2			2	2						1				
Chamaesipho brunnea	0	99	0	0	66	0	0	0	0	0	0	0	0	0	99	0	0	33	0	0
Chamaesipho columna (% cover)	1070	1713	3211	4282	1499	0	214	214	0	0	1070	1713	1499	642	642	1285	1285	1070	1070	428
Elminius modestus	98	394	197	197	197	0	0	0	0	0	98	0	394	197	295	98	0	394	0	394
Epopella plicata	77	111	166	144	33	0	0	0	0	0	22	22	55	111	88	111	111	77	829	44
Mitella spinosa			4														2		2	
Sypharochiton pelliserpentis		2	3		5		2							1		1	2			
Austrolittorina cincta (% cover)	0	0	171	0	0	257	86	257	0	0	0	0	257	86	0	171	171	0	171	171
Margarella species			2																	2
Number of animals per m2	1246	2322	3754	4630	1800	262	304	473	5	2	1191	1735	2205	1036	1125	1667	1570	1575	2073	1040
Number of algal taxa per quad	5	9	4	4	6	5	6	6	3	7	5	3	4	1	5	4	7	5	6	4
Number of animal taxa per quad	5	7	8	6	6	7	7	6	7	6	5	5	5	6	5	7	7	5	6	6
Totalnumber of taxa per quad	10	16	12	10	12	12	13	12	10	13	10	8	9	7	10	11	14	10	12	10

APPENDIX 2

MUSSEL ABUNDANCE AND SIZE FREQUENCY DATA

SITES:
BLACK HEAD
SECOND BEACH
LAWYERS HEAD
BOULDER BEACH
ALLANS BEACH
VICTORY BEACH

	Species	Size class	Frequency
Black Head	*Perna canaliculus*	<2	0
		2-4	0
		4-8	0.2
		>8	0
Second Beach	*Perna canaliculus*	<2	3.8
		2-4	2.4
		4-8	8.6
		>8	32.2
Lawyers Head	*Perna canaliculus*	<2	1.4
		2-4	3
		4-8	5
		>8	10
Boulder Beach	*Perna canaliculus*	<2	1.8
		2-4	1.4
		4-8	4.6
		>8	2.6
Allan's Beach	*Perna canaliculus*	<2	4
		2-4	2.6
		4-8	7.6
		>8	13.4
Victory Beach	*Perna canaliculus*	<2	0.2
		2-4	3.2
		4-8	7.8
		>8	10

Site	Species	Size class	Frequency
Black Head	*Aulacomya ater maoriana*	<2	0.8
		2-4	0
		4-8	0
		>8	0
Second Beach	*Aulacomya ater maoriana*	<2	3.8
		2-4	5
		4-8	0.6
		>8	0
Lawyers Head	*Aulacomya ater maoriana*	<2	6
		2-4	0
		4-8	0
		>8	0
Boulder Beach	*Aulacomya ater maoriana*	<2	1
		2-4	0
		4-8	0
		>8	0
Allan's Beach	*Aulacomya ater maoriana*	<2	5.6
		2-4	5.8
		4-8	4.6
		>8	0.2
Victory Beach	*Aulacomya ater maoriana*	<2	1
		2-4	2
		4-8	1.8
		>8	0

Site	Species	Size class	Frequency
Black Head	*Mytilus galloprovincialis*	<2	14.8
		2-4	0.6
		4-8	0
		>8	0
Second Beach	*Mytilus galloprovincialis*	<2	8.8
		2-4	4.4
		4-8	15
		>8	1.2
Lawyers Head	*Mytilus galloprovincialis*	<2	12
		2-4	7
		4-8	6.2
		>8	0.2
Boulder Beach	*Mytilus galloprovincialis*	<2	12
		2-4	1.8
		4-8	0.8
		>8	0
Allan's Beach	*Mytilus galloprovincialis*	<2	5
		2-4	3.4
		4-8	3.2
		>8	0.6
Victory Beach	*Mytilus galloprovincialis*	<2	5.6
		2-4	4
		4-8	5.6
		>8	0.2