Sediments and Seashores: Looking Deeper 2017

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Abstract

With growing pressure being imposed on the environment, as a result of increased human activity, more natural resources are becoming at risk. This has caused concern about what may happen to these natural environments and so there is more push for localised environmental monitoring. One solution is to engage with citizen scientists, usually member of the general public without a scientific background, to assist with monitoring. An example of this is the ‘Sediments and Seashores: Looking Deeper’ project in the Otago Harbour, Dunedin, New Zealand. This project was established in response to the ‘Next Generation’ dredging project in the Otago Harbour when concerns about the impacts on the flora and fauna in the harbour arose. This project is in its second year and works with local schools to monitor sediment and biodiversity along the rocky intertidal zone within the harbour. Sediment cover generally was higher in areas closer to the location of the dredging in the major shipping channel. It was also found that many species in the harbour could be classified as vulnerable to changes in sediment loads. Scientists also collected data along the rocky shore using similar methods as used by the students and it was found that there was no statistically significant difference between the student’s data and the scientist’s data. The number of species was found to be negatively correlated with the amount of sediment (i.e. there was a lower number of species found with more sediment), however this was a weak correlation and further exploration is needed. As there is only limited data available, this study needs to be continued to establish a long-term dataset to have a better understanding of the health of the harbour.

Introduction

Increasing demand for natural resources, a result of growing global populations and expansion of trade networks, has caused changes in the way that humans use the environment. Typically, this involves altering landscapes/geography to accommodate for greater rate of production which in turn can lead to increased profit, benefiting the economy for a local to a national scale.

However, human activity can have an impact on the environment. To investigate the extent of this, regular monitoring is needed to gather information on if and how an area is changing over time. This can be used to inform local managers as well as provide details on the state of the ecosystem. A lack of information may result in management decisions that are not appropriate to what is actually occurring to an environment in 'real-time'. Monitoring can be an intensive process – both financially and time-wise- when employing trained personnel, which are not always available. This can cause delays in collecting data and incomplete or rushed datasets. Therefore, many whom are concerned of environmental management, are turning to the idea of involving volunteers (often without a science background) in the data collection process, termed as citizen science. This can reduce project costs, encourage stewardship for the environment, educate local communities and obtain a larger dataset. Despite incorporating citizen scientists in data collection since the early 1900s, it has only been in between the past 10-20 years that citizen science has begun to be utilised.

Involving citizen scientists in projects has shown to have multiple benefits to both scientists and non-scientists (Conrad & Hilchey, 2011; Bird et al., 2014; Gray et al., 2017). These include; lowering the total cost of the project through volunteer input, increasing public education and scientific literacy, obtaining a larger dataset (increasing statistical power), and encouraging local stewardship of the environment (Silvertown, 2009; Conrad & Hilchey, 2011; Gillett et al., 2012; Cooper et al., 2014; Cigliano et al., 2015; Ballard et al., 2017; Gray et al., 2017; van der Velde et al., 2017).

Increasing loads of sediment (defined as fine particles of fine sand, clay and silt by Asselman and Middelkoop, 1995) is a major stressor in aquatic environments (Jackson et al., 2010; Clapcott et al., 2011; Desmond et al*.,* 2016). Sediment can be released into the marine environment via; clearing land for forestry, agriculture and developing areas for urban uses, including the expansion of harbours/artificial ports and land reclamation (Clapcott et al., 2011; Chew et al., 2013; Pirotta et al., 2013; Environment Foundation New Zealand 2015; Ministry for the Environment & Statistics New Zealand 2016). In a coastal setting, one of the largest growing anthropogenic changes is the expansion of harbours and artificial ports, driven by increased trade and tourism, population growth, and expansion of defence forces (Jackson et al., 2010; Chew et al., 2013; Pirotta et al., 2013). As a result, dredging activity to maintain ports and shipping channels has increased up to 75% since 2000 with approximately 1481 operating vessels worldwide (Pirotta et al., 2013).

A local example of harbour expansion is the on-going deepening and widening of the shipping channel in the Otago Harbour, Dunedin (Desmond et al*.,* 2016; Port Otago Ltd 2016). Although the Otago Harbour has been dredged intermittently since 1877 to maintain the shipping channel, the intensity of dredging activity has increased recently with the establishment of the 'Next Generation Port Otago' project (Smith et al., 2010; Chew et al., 2013). 'Next Generation Port Otago' allows Port Otago Limited to remove 7.3 million cubic metres of substrate from the channel and dispose of it in offshore waters past the Otago Peninsula (Jackson et al., 2010; Chew et al., 2013; Port Otago Ltd, 2016). In response to the 'Next Generation Port Otago' capital dredging project, the 'Sediments and Seashores' project was jointly established in 2016 by the New Zealand Marine Studies Centre (NZMSC) and the University of Otago (Desmond et al., 2016). This year, the project has been continued as 'Sediments and Seashores: Looking Deeper' to extend the duration of data collection of quantifying the amount of sediment accumulating along rocky reef habitats, which are typical in the harbour. The project 'Sediments and Seashores: Looking Deeper' also included an element of quality control which was provided by scientists (defined as a tertiary student with at least three years education studying science) who completed surveys in the same areas as the students as well as following the same basic methodology. The purpose of this was to 'ground truth' the data,

Sedimentation can cause disruption to organisms residing in the harbour in a manner of ways, including blocking light (thus reducing photosynthesis), covering surfaces that organisms would normally attach to and clogging fine structures used for feeding and breathing. The implications of increased sediment on normal functioning for local organisms may cause a reduction in the biodiversity of the harbour or changes in community structures as species more tolerant of sediment are favoured over species that are intolerant. Due to the connective nature of ecosystems, there may be flow-on effects in terms of the productivity and ecosystem functioning of the Otago Harbour.

The purpose of this study was to collect data on the flora and fauna communities that reside along the rocky intertidal of the Otago Harbour. It was hoped that this data could be used to investigate biodiversity as well as changes in the structure of the communities residing in this area. Estimations of the percentage of substrate cover were also collected to investigate the amount of sediment being collected along the rocky intertidal and whether this has changed compared to last year (2016).

This project was conducted in collaboration with New Zealand Marine Studies Centre (NZMSC), the University of Otago and local schools including students, parent helpers and teachers. Seven schools (six primary schools and one secondary school) were involved as well as interested members of the community including support from Port Otago Ltd. The project was funded through the Otago Participatory Science Platform (Ministry of Business, Innovation and Employment, Curious Minds Project).

Methods

Study locations

Figure 1: Map of the Otago Harbour, Dunedin with study locations (shown by yellow stars).

Seven locations within the Otago Harbour with a rocky shoreline (which was accessible during the tidal cycle) were selected to be part of this study (Fig 1). Four locations were on the northwest side (Port Chalmers side) of the harbour and three locations were on the southwest side (Portobello side) as well as one location in the centre at Quarantine Island. Each of the following sites was allocated to a school: Dowling Bay (St Brigid's School), Acheron Point (St Leonards School), Rocky Point (Abbotsford School), Back Beach (Sawyers Bay School), Quarantine Island (Otago Girls High School), Yellow Head (Broad Bay School) and Portobello (Portobello School).

Preparation

Prior to the first data collection session, each school was also provided an hour-long introduction session. This included discussions on; the purpose of the project and how it may relate to the students involved as well as the wider community, the research question, data collection methods and gear needed and finally how to keep the marine life and themselves safe.

Data collection

There were two data collection periods between 26th-30th June and 22nd-25th August (with an additional collection on 20th September). At each location, a 30-metre transect line was laid out at both low tide and mid tide. 4-6 quadrats were randomly placed along the transect line using random numbers between 0-30 generated using R Studio software (version 1.0.136, R Core Team 2017). The number of quadrats surveyed varied as to how many groups each school had. Students worked in groups between 2-6, often assisted by a parent helper/teacher. The following information was recorded on a data sheet for each quadrat: estimated substrate percentage coverage (adding to 100%), species present (both flora and fauna) and the number of fauna species present and percentage cover for seaweeds. Seven substrate types were available to choose from; reef, boulder, cobble, gravel, sand, sediment and mud. As this was a facilitated citizen science project, two scientists were present during both data collection periods as were parent helpers (ranging between 1-6) and teachers.

Post data collection

The week after each data collection session, students were assisted with entering their data into the online database (www.mm2.net.nz) during a one-hour session. This also involved some reflection on the data collection sessions (for example sharing highlights found on the shore, things the students had learnt during the data collection). There were also opportunities to complete visual representations (graphs, informative posters) of their data as well as compare data collection sessions after their second visit to the shore. A final summary session was presented to each school to show how their study site compared to the other sites in the Otago Harbour as well as discuss concluding thoughts on the projects.

Reliability

Throughout the project, there were multiple occasions where the data was checked for errors in order to make it reliable resource. On the shore during data collection, the NZMSC 'Rocky Shore' guide for common intertidal species was readily available and distributed to groups. NZMSC staff and the scientist were also available for any queries that students may have had. Before the data entry session, the data sheets were screened for inconsistencies such as spelling errors, unidentifiable species (that were then identified post collection) or providing the scientific name to a description in order to make entering the data into the online database easier. Before the data was analysed, a thorough 'clean-up' of the data was undertaken. This included; consistency in grammar, replication of species and surveys entered, correct entry as count (animals) or cover (plants), updating scientific names of species.

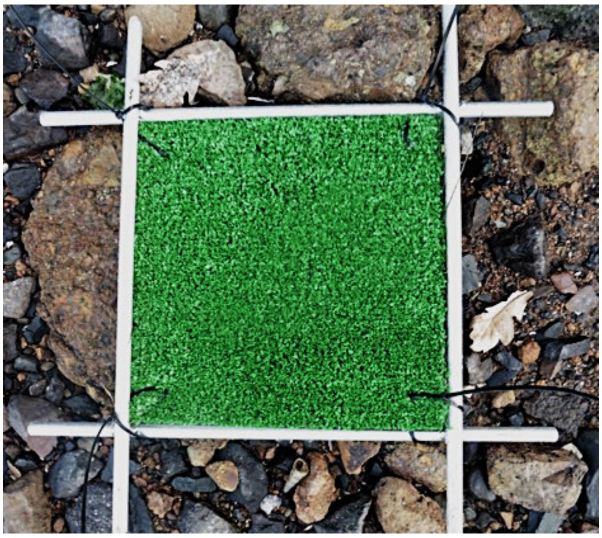

Figure 2: Sediment trap design that was used throughout this study (dimensions 250 x 250 x 5 millimetres, excluding metal frame). Sediment traps were comprised of AstroTurf glued onto a PVC plastic base and attached to a metal frame with four cable ties.

Sediment measurements

Quantitative measures of sediment were collected using sediment traps (250 x 250 x 5 millimetres (mm), excluding metal frame; Fig 2). The flat bottom design and use of AstroTurf was decided upon from preliminary work completed in the 'Sediment and Seashores' project last year and from supporting literature (Asselman & Middelkoop, 1995; Steiger et al., 2003). There were some differing methods between the students and the scientists.

Student's sediment methods

Six traps were placed out at Rocky Point on the 24th August 2017 underwater at mid tide across a 30 metre transect. Traps were placed out for 24 hours then collected by each of the six groups from Abbotsford School (Fig 3a). Traps were cut from the metal frames then were placed into a bucket to be washed (Fig 3b). Each group collected water from an undisturbed area of the shoreline, as to not collect extra sediment (Fig 3c). Water was continuously poured over the trap as to wash out all the sediment from the trap and was collected in the bucket (Fig 3d). Once no sediment remained in the traps, the sediment in the bucket was left to settle for approximately 5 minutes. Excess water was poured off then the remained sediment was poured into a 100 millilitre (mL) cylinder, which was also then left to settle (Fig 3e). This process was repeated again, however the sediment was poured into a 50mL cylinder (Fig 3e). After the sediment settled again a volumetric reading was taken by each group (Fig 3e).

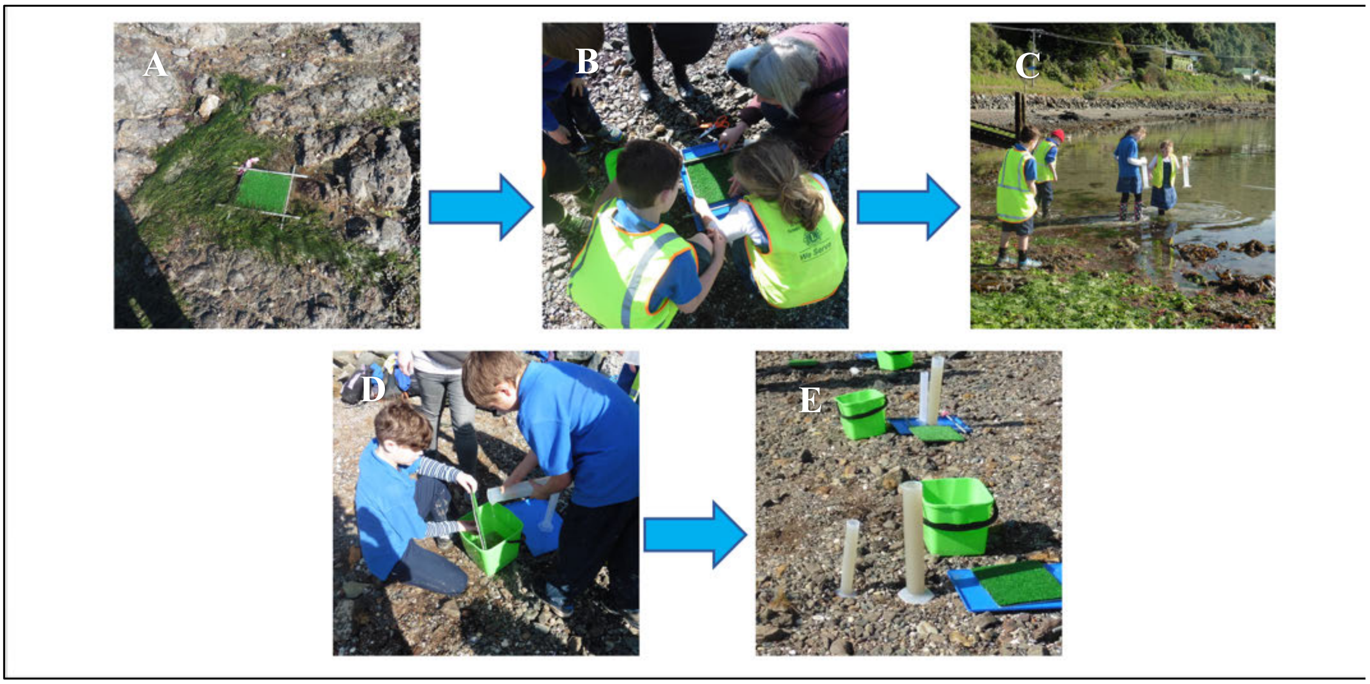

Figure 3: Pictorial step-by-step guide of collecting sediment traps with Abbotsford School at Rocky Point

In order to evaluate their own estimations of the percentage cover of substrate in their quadrats, students were provided a photograph of their mid-tide quadrat on an A3 sheet of paper. The paper was divided into 100 squares, scaled to equal 1cm2 of their quadrat, and were given instruction to re-assess the different substrate types using the photographs. This was then compared to what they estimated whilst on the rocky shore and they were encouraged to comment how and why their estimations differed or not.

Scientist's sediment methods

Traps were placed out twice during the weeks of the 17th-24th June 2017 and 13th-21st August 2017. Two sediment traps were placed at each site, excluding Rocky Point, approximately 30m apart. These traps were placed out one week prior to collection in approximately 20 centimetres (cm) of water with rocks placed on the metal frame to weigh the traps down. Upon collection, traps were rinsed, and sediment and excess water were collected in large buckets (approximately 20 litres). Buckets were left for approximately 30 minutes to allow the sediment to settle then excess water was poured from the container slowly and carefully as to avoid sediment loss. When little or no water remained, the sediment was scooped out of the bucket using a spatula and placed in a small aluminium pie tray (volume=150 mL). The sediment was weighed in the pie tray before being placed in a drying oven, and dried for approximately 36 hours, after which it was re-weighed to investigate the ratio between wet weight and dry weight. The weight of the pie tray was subtracted from the total weight to obtain an accurate reading of the sediment weight.

Scientists also completed an exercise on the accuracy of the estimations of percentage substrate cover between photographs and at the time of data collection. This was completed using Coral Point (Kohler & Gill 2006: Fig 4). 64 quadrats were randomly selected from the students second trip (in August) and the scientist's sampling trip in May/June 2017. The boundary of the quadrat shape was outlined in Coral Point then 15 points were laid randomly on top of this (the photo was divided into three columns with five points in each third of the photo) (Drummond & Connell, 2005; Fig 4). These points were classified as; reef, boulder, cobble, gravel, sand, sediment, mud, seaweed (if unable to see the substrate cover because it was covered by seaweed) or quadrat (on the outside or the edge of the quadrat frame). This data was put into an Excel spreadsheet (version 15.35) and the percentage cover of each category was calculated. The average percentage cover across the 64 quadrats for each category was then calculated (seaweed and quadrat percentages were ignored). The substrate cover estimates recorded in the field were then compared to those calculated on Coral Point.

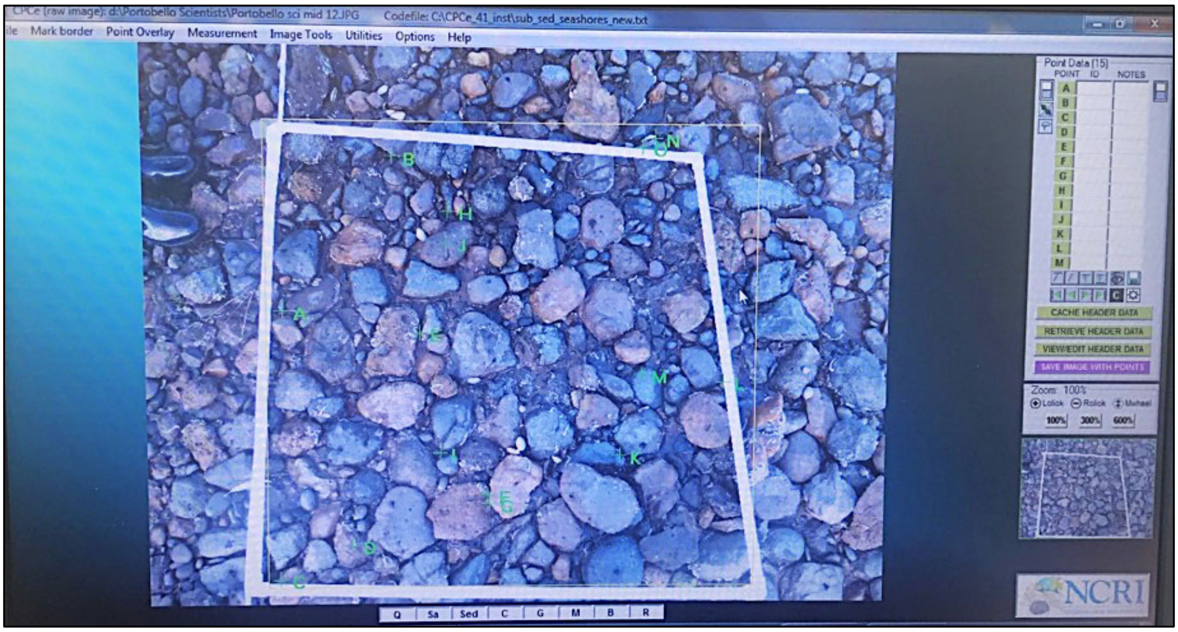

Figure 4: Screenshot of a quadrat uploaded onto Coral Point to re-evaluate estimates of percent substrate cover. The yellow square shows the outline of the quadrat area to be analysed. 15 points to be analysed (A-O) are shown in green. At the bottom of the figure are the 9 possible substrate options for the points (7 substrate types; reef, boulder, cobble, gravel, sand, sediment, mud as well as quadrat or seaweed).

Data analysis

Sediment

Sediment and mud were combined as these substrates were often difficult to differentiate from one another in the field. Mean sediment cover was calculated by using the estimates of percentage cover for both mud and sediment at low and mid tide over both sampling trips (number of quadrats = 4-6 for each shore height). A mean percentage of sediment and mud was calculated for each study location for both 2016 and 2017 and the means were compared (± SE) A mean was also calculated for the whole harbour at both low and mid tide to be used to display as the mean percentage difference (± SE) of sediment and mud from the harbour mean. This was done for all of the study locations at low and mid tide.

Abundance of turret snails

The number of turret snails (*Maoricolpus roseus*) found were used to compare abundances in 2016 and 2017. Turret snails were chosen as a species of interest as they are a sediment tolerant species and often found in sandy/muddy environments. Abundances were calculated for each study location, regardless of shore height.

Number of species

Number of species, or species diversity, was calculated using the number of species found over both sampling trips at each study location at low and mid tide (number of quadrats=4-6 for each shore height). Each species was only counted once per study location to calculate a mean for both shore heights at each study location. A median was also calculated for the whole harbour. Data is displayed as the mean difference (± SE) in the number of species found at each location from the harbour mean. A Pearson product-moment correlation was used to investigate the correlation between the number of species and the amount of sediment. This was done using R Studio (version 1.0.136, R Core Team 2017).

Vulnerability index

All species that were found during the two sampling periods were compiled into a list and each was given a score/ranking in relation to its vulnerability to sediment. Characteristics that made a species vulnerable were: photosyntheiser, filter feeding, slow-moving or sessile and needs rock to attach to. Species were categorized into low, medium, high or very high vulnerability depending on how many characteristics that the species had (low = 1 characteristic - very high =4 characteristics). The median number of species that were assigned to these categorises was calculated for each study location as well for the whole harbour. The data was displayed as the mean difference (± SE) of the number of species in each vulnerability category from the harbour mean. This was done for each of the study locations (regardless of shore height).

Results

The mean percentage of sediment or mud cover had little change between 2016 and 2017 (Fig 5). At Dowling Bay, Quarantine Island and Rocky Point, there were increases in the mean percentage of sediment or mud whereas Acheron Point, Portobello and Yellow Head decreased (Fig 5). There was no change in percentage cover of sediment or mud at Back Beach (Fig 5). Quarantine Island has the highest mean percentage of sediment or mud cover, which was over 50% for both 2016 and 2017 (Fig 5).

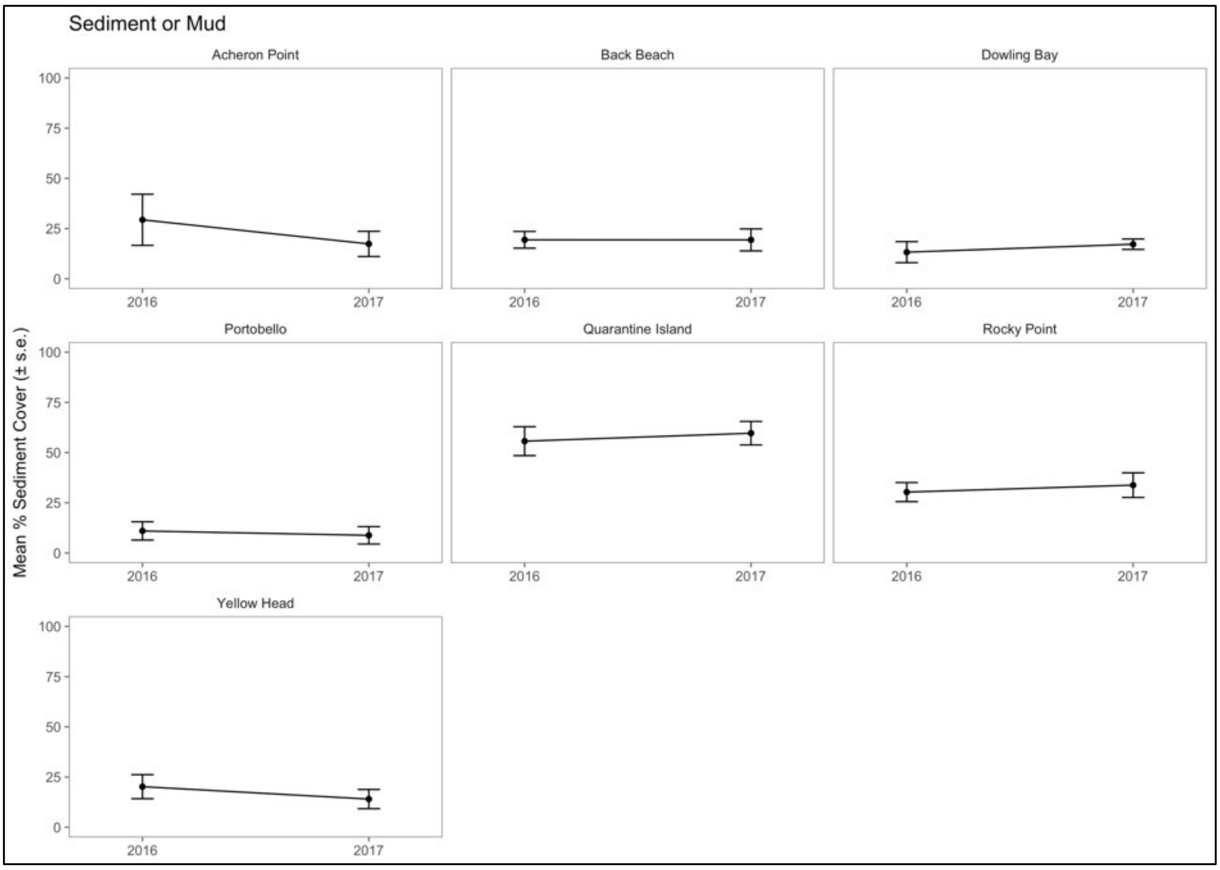

Figure 5: Mean percentage of sediment/mud cover (± standard error) estimated during both the 2016 and 2017 surveys for all seven study locations in the Otago Harbour (n=7).

At mid tide, the mean percentage of sediment or mud cover in a metre squared ranged between 0-83.5% with a mean percentage of 19.45% ± 2.8 (Fig 6). Most study locations were close to the median, however the only exception was Quarantine Island which was well above the mean percentage of sediment or mud cover (Fig 6). At low tide, all study locations were below the mean percentage of sediment or mud cover of 31.47% ± 3.70, except for Quarantine Island and Rocky Point which were higher than the mean (Fig 6).

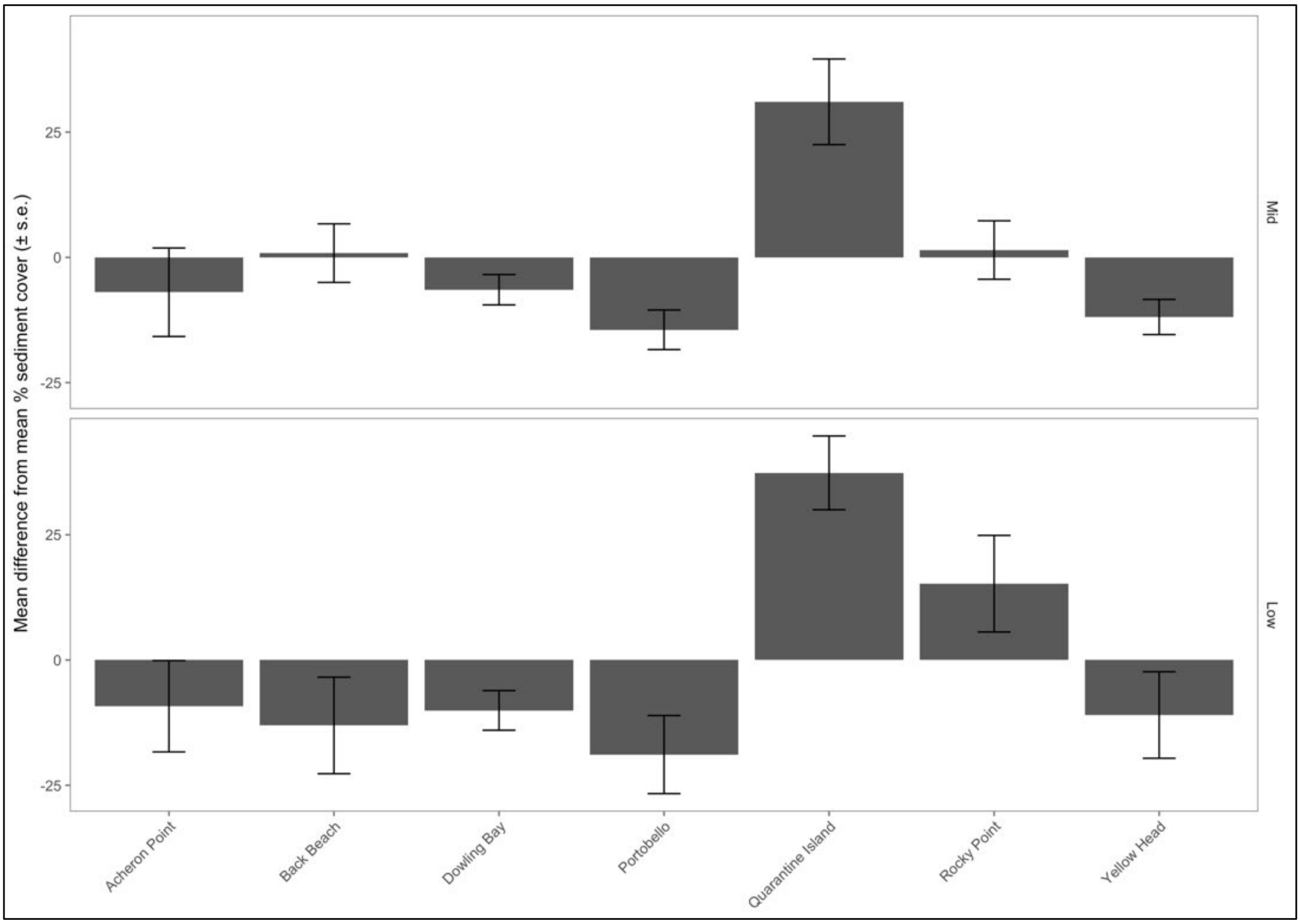

Figure 6: Mean difference from the mean percentage of sediment cover (± standard error) per metre squared at seven study locations in the Otago Harbour at mid (upper panel) and low (lower panel) tide heights. Mean percentage of sediment cover for mid tide= 19.45%, mean percentage of sediment cover for low tide= 31.47% (n=7).

There was a very small difference between species density found between the three sampling trips (one completed by scientists, two completed by students) however this was not significant ($F_{2,27}$=0.353, p-value=0.706) (Fig 7).

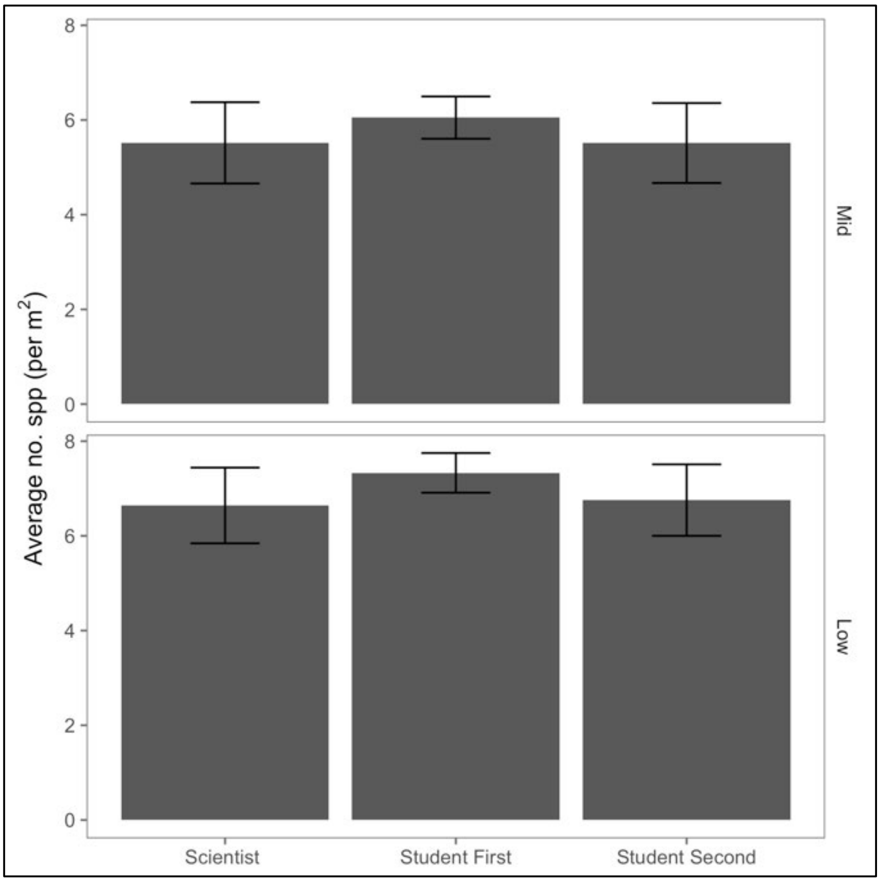

Figure 7: Average number of species found m^2 over three sampling periods for low and mid shore height ±SE ($n_{(scientists)}$=100, $n_{(student\ first)}$ =111, $n_{(student\ second)}$ =113).

Percentage of substrate cover (hence referred to as substrate cover) was not statistically different between student and scientist (p-value= 0.7) (Fig 8; Table 4). This was expected due to the temporal gaps between the two sampling trips (May/June for scientists and August/September for students) as well as slight differences in the placement of the transect line (due to slight differences in low shore height). There was a significant difference between substrate cover that was measured (visually estimated in the field) or calculated (estimated using Coral Point) (p-value <0.05) (Fig 8; Table 4). Most re-estimations of substrate cover (calculated using Coral Point) for sediment, mud and reef were under-estimated (Fig 8). There was one substrate over-estimation (cobble) in the calculated substrate cover for scientist's data (Fig 8).

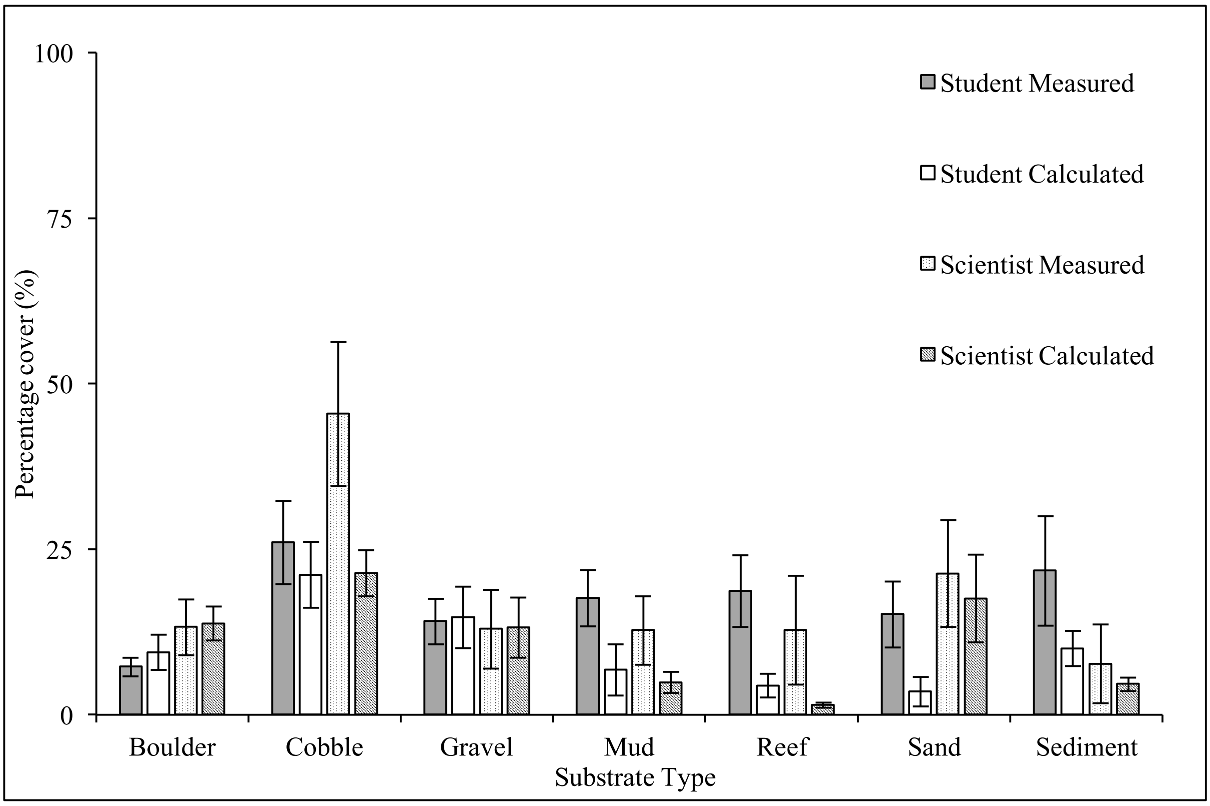

Figure 8: Percentage cover of substrate (classified as boulder, cobble, gravel, mud, reef, sand or sediment) in quadrats sampled by either students and scientists with ±SE. Measured refers to substrate percentage cover estimated in the field, whereas calculated refers to percentage of substrate cover estimated using Coral Point (n=64).

The abundance of turret snails (*Maoricolpus roseus*) generally increased at most sites in the Otago Harbour between 2016 and 2017 (Fig 9). At two study locations, Acheron Point and Yellow Head, the snail was not found in 2016 but then was found at these locations in 2017 (Fig 9). Turret snails were not found in either year at Back Beach (Fig 9).

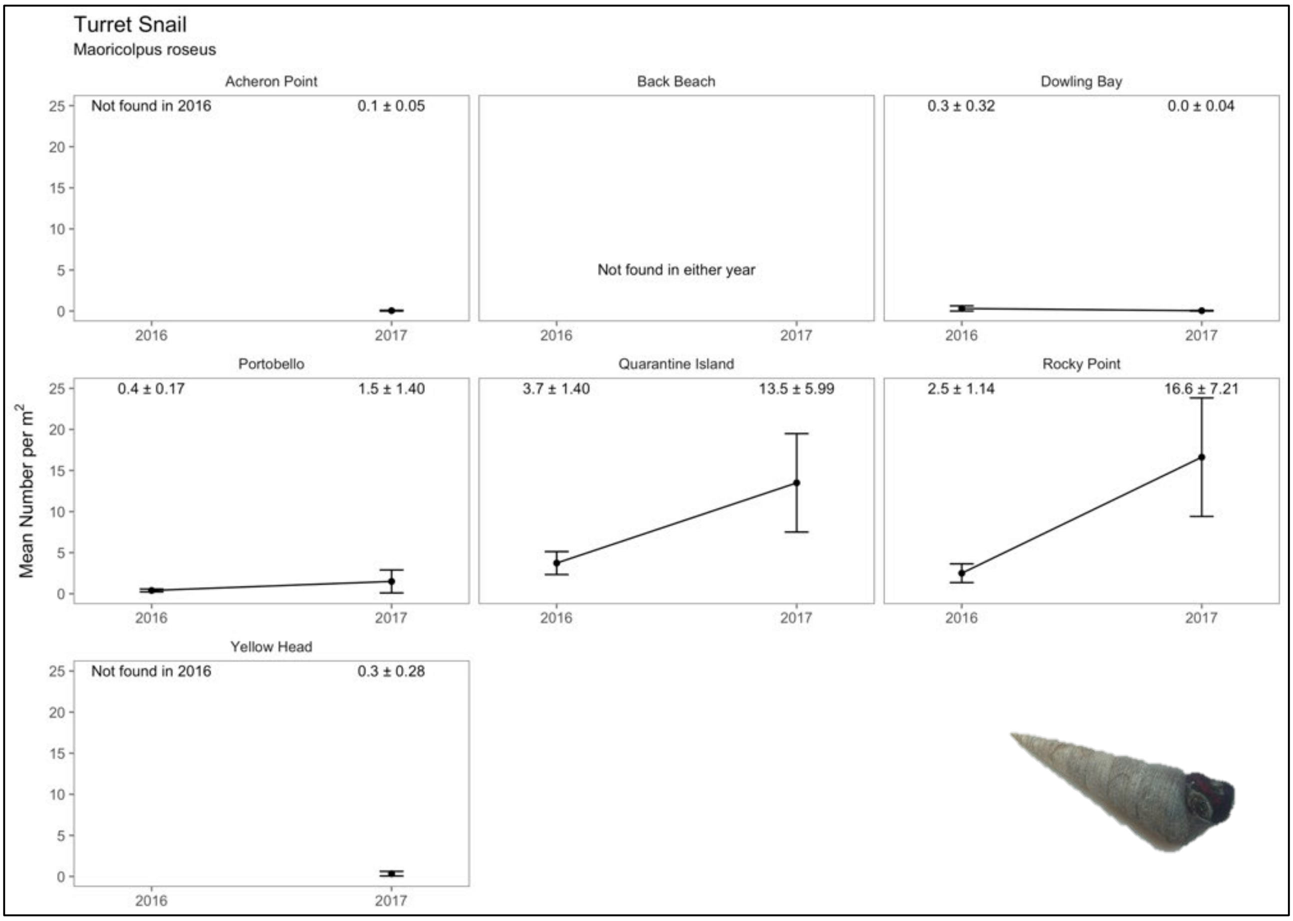

Figure 9: Mean number of turret snail (*Maoricolpus roseus*) (± standard error) estimated during both the 2016 and 2017 surveys for all seven study locations in the Otago Harbour (n=7). Insert in bottom right corner shows image of turret snail (*Maoricolpus roseus*).

At mid tide, the mean number of species per metre squared ranged between 4-20 with a median of 12 species per metre squared ± 0.51 standard error (Fig 10). Acheron Point, Back Beach and Portobello had less species found per metre squared than the median number and Dowling Bay, Rocky Point and Yellow Head had more species per metre squared than the median (Fig 10). Rocky Point being the study location with the largest positive difference from the median (Fig 10). At low tide, the mean number of species found per mere squared was 5-21 with a median of 13 species per metre squared ± 0.47 (Fig 10). Acheron Point, Portobello and Quarantine Island had less species than the median number of species per metre squared whereas the remaining study locations had more species than the median (Fig 10). At both low and mid tide, Portobello had the greatest negative difference from the median number of species found (Fig 10). A Pearson product-moment correlation found that there was a weak negative correlation between the number of species found at a location and the amount of sediment which was found to be statistically significant. (cor= -0.00857, p-value= 0.402).

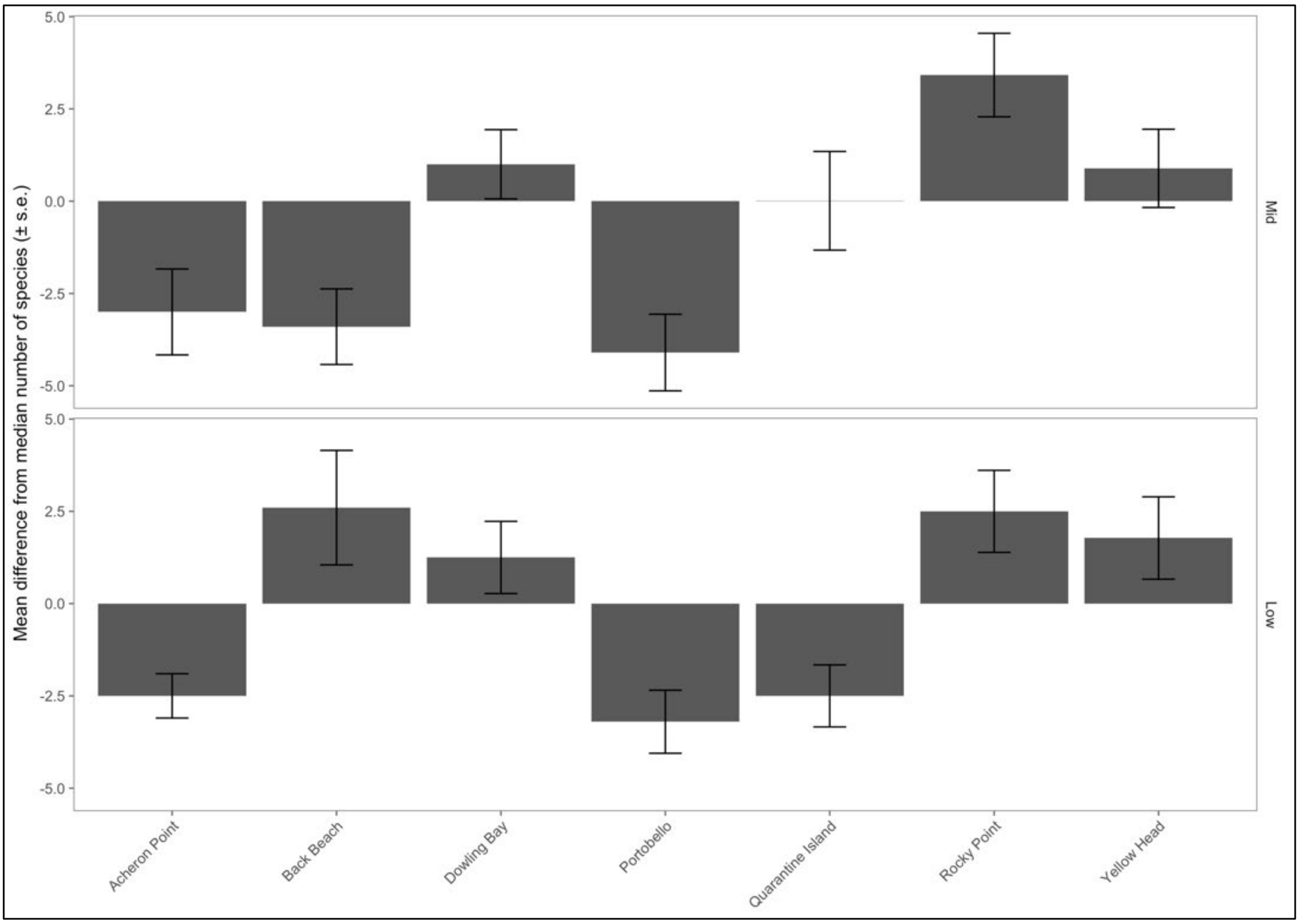

Figure 10: Mean difference from the median number of species found per metre squared (± standard error) at seven study locations in the Otago Harbour at mid (upper panel) and low (lower panel) tide heights. Median number of species found at mid tide= 12, median number of species found for low tide= 13 (n=7).

Species that were classified as having low vulnerability to sediment were found at all study locations in number that were close to the median of 2 (Fig 11). Species that were classified to have medium vulnerability to sediment were the second most abundant in the harbour, with Back Beach and Rocky Point having abundances higher than the median number of 4 and Acheron Point and Quarantine Island having lower abundances (Fig 11). All study locations had small abundances of highly vulnerably species, close to the median of 0 (Fig 11). For species that were considered to have very high vulnerability to sediment, there was a greater range amongst the study locations - Portobello had less than the median of 6 as well as Back Beach (Fig 11). Dowling Bay, Rocky Point and Yellow Head had higher abundances of very high vulnerability species compared to the median (Fig 11).

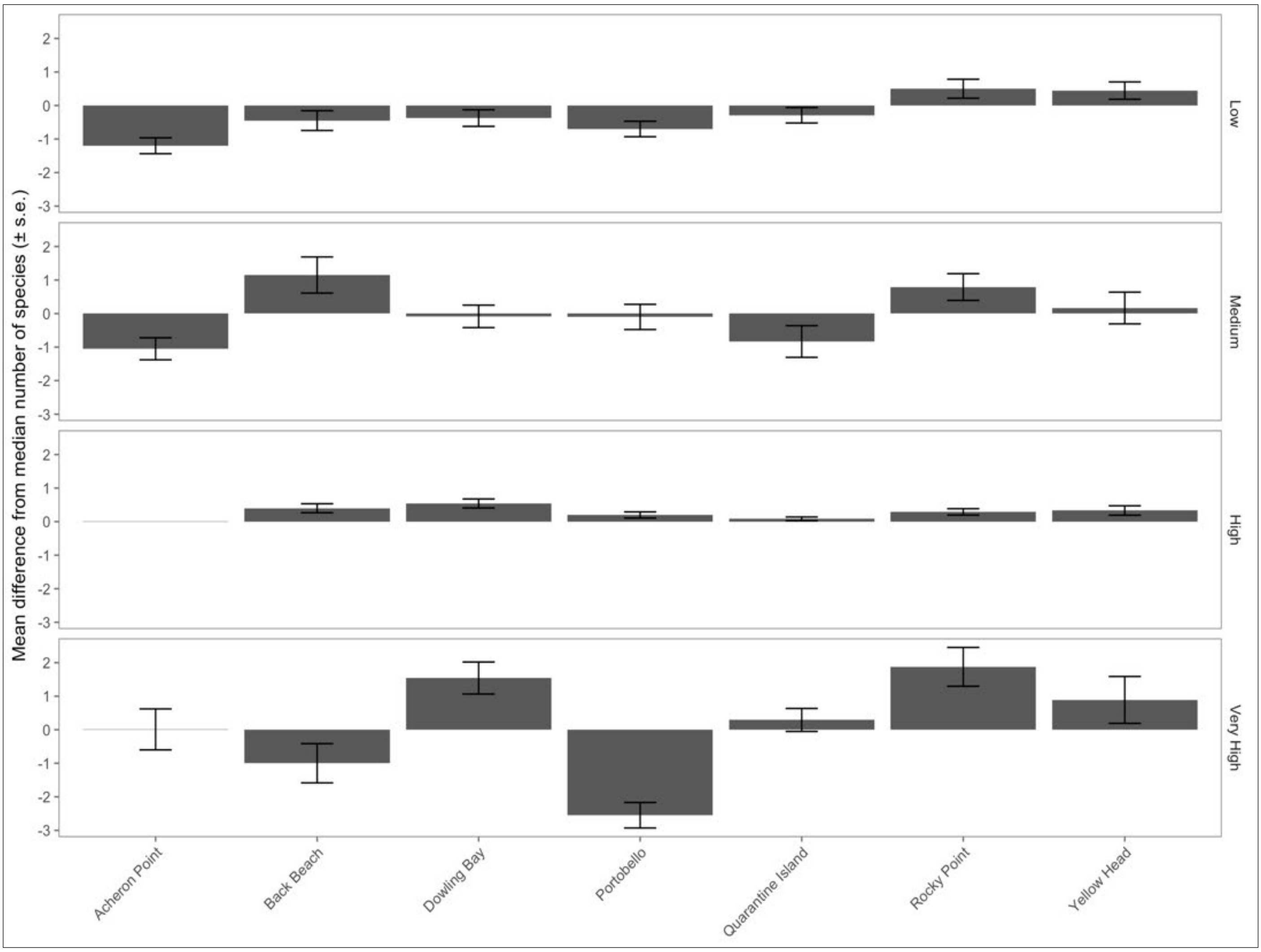

Figure 11: Mean difference from the median number of species found per metre squared at different vulnerabilities to sediment (± standard error) at seven study sites in the Otago Harbour. Vulnerabilities are classified as low (top panel), medium (second panel), high (third panel) and very high (bottom panel) vulnerability to sediment (n=7).

Discussion

This project follows on from last year's 'Sediments and Seashores' project in the hope of creating a long-term study collecting information on sedimentation levels and potential effects on the rocky intertidal ecosystem in the Otago Harbour. Using methodology from the Marine Metered Squared programme, information on the amount of sediment accumulating along the rocky intertidal as well as indications of biodiversity were collected. This was ground truthed by scientists who competed surveys at the same locations along the rocky intertidal using the Marine Metred Squared methodology. It was found that there was no statistically significant difference between scientists and students in the average number of species found per metre squared at both shore heights. To aid in gathering information about sedimentation, sediment traps were also placed out at one location to provide a quantitative/physical measurement. This is an area of research that requires further exploration.

Sediment varied between study locations and between shore height (low and mid tide heights). Quarantine Island had the most sediment out of all the study locations in 2016 and had a slight increase in mean percentage sediment cover in 2017. As this location is in the centre of the harbour, it is hypothesised that hydrography would play a role in the distribution of the sediment to this location. This could be a potential area of future research. Most study locations on the Southwest/Port Chalmers) side (Acheron Point, Back Beach, Dowling Bay, Rocky Point) of the harbour showed slight increases in the mean percentage of sediment per metre squared, the only exception being Acheron Point. This is likely to be a result of these locations being close to the site of the dredging, which is occurring in the main shipping channel which follows this side of the harbour closely.

One point of interest is the increase in the abundance of the turret snail (*Maoricolpus roseus*) throughout the harbour from 2016 to 2017. Turret snails were seen to have increased at study location that had higher amounts of sediment and mud. This is supported by the snail's habitat preferences, usually where sand/mud/sediment is present. Therefore, turret snails could be used as a biological indicator for sediment/mud in the Otago Harbour, thus abundance of this species should be carefully monitored over time.

Although this study found that the number of species found in a quadrat was negatively correlated with sedimentation levels, and this was found to be significant, as this is a weak correlation interpretation of this result should be taken cautiously. This could be achieved by collecting more data over time as the dredging persists or is completed.

More sediment was found at the low tide mark than at the mid tide mark (31.48 ± 3.7% sediment/mud at low tide compared to 19.45 ± 2.8% sediment/mud at mid tide). This was similar to last year's findings - 25.5 ± 3.2% sediment/mud at low tide and 18 ± 2.7% sediment/mud at mid tide. As was suggested from last year's data, this indicates that the sediment is likely to be from a marine source as opposed to terrestrial. It is also thought that due to the low tide mark being more or less underwater at all times, this increases the exposure time of sediment to the rocky intertidal, which with its uneven surfaces (either from biological or physical surfaces) makes it ideal to catch particles such as sediment. It should be noted that sediment is hard to distinguish from other substrates, especially mud, and therefore it was thought that it would be best to combine these two substrates for data analysis. This can be seen in the differences in the under-estimations of percentage of substrate cover for sand and mud in measured (in-the field) and calculated (using Coral Point) values.

There were not many species that were considered to have low or high vulnerability to sediment in the Otago Harbour, yet there were higher numbers of species that were considered to have medium and very high vulnerability. This demonstrates the range of species that are found in the harbour as well as their difference in tolerance to sediment. Study locations that had higher number of species than the mean of the harbour also appeared to have a higher number of very highly vulnerable species. Rocky Point and Quarantine Island had mean sediment levels that were above the mean sediment level for the harbour at both low and mid tide. Interestingly, these two locations also had a higher than average number of highly vulnerable species (in particular Rocky Point). These two locations will be important for future monitoring as they provide habitat to animals that are at risk if there are increases in sediment accumulation. Dowling Bay is another location that had a higher than average number of highly vulnerable species, but it was found to have a lower than average amount of sediment. None the less, this location could be another important location to monitor to see investigate the relationship between increasing sediment and the diversity of vulnerable species.

With increasing pressure on natural resources, and thus the environment, monitoring is needed to see the impacts that occur as a result of human activity. Projects like 'Sediments and Seashores' are an important source of environmentally monitoring which hold many benefits beyond simply collecting data. They involve local communities and in doing so engage with people from a range of difference backgrounds, encouraging them to take guardianship of their local areas whilst providing feedback to interested stakeholders on the state of the environment. This data has the possibility to be of value and could be used to further investigate and assess the effects of the dredging in the Otago Harbour.

Future Work

Although the 'Sediments and Seashores' project has now completed two years of surveys along the rocky intertidal of the Otago Harbour, this still does not provide enough information that is needed for environmental monitoring. Therefore, continuation of this project, using the same sites and methods, is needed to increase the dataset with the goal to continue this monitoring for the duration of the dredging and even beyond completion of the 'Next Generation' project. Over time, this would allow for a clearer image as to what is going on in the Otago Harbour, as seasonal 'noise' would be reduced.

It would also be of interest to expand on quantifying the amount of sediment at each location with the use of sediment traps. Further investigation as to whether the student methods are consistent to that of the scientists as well as to their own estimations in their quadrats. This project has found that the average number of species found per metre squared and so it would be interesting to see if this is also found in estimations of sediment cover.

Identifying a methodology of collecting sediment that provides the best representation of how much is accumulating in the harbour could be useful in further monitoring for the harbour with opportunity to extend into different environments. Methodology could include; drying and washing sediment traps (getting a dry weight or a volumetric reading), using photographs or visual estimations whilst in the field. Analysis of this sediment could also be of interest to help determine whether it is coming from a terrestrial or marine source. To aid this information turbidity monitoring, which was monitored for a 15-month period ending only recently, could also provide insight as to whether the sediment is a result of dredging.

The relevance of citizen science projects, such as 'Sediments and Seashores: Looking Deeper', in applying science skills and logical thinking in a real-world context is another area for investigation. A proposal to do this would be to assess how students are able to interpret problems in different environmental setting and come up with ideas as to how to approach this problem given what they've learnt during the 'Sediments and Seashores: Looking Deeper' project. For example, they might decide to survey an area, using quadrats, to gather more information.

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