The effect of sedimentation on rocky shore communities in Otago Harbour

2016

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Abstract

Increased sedimentation as a result of dredging activity within Otago Harbour may pose a significant threat to rocky shore communities which are common and form productive habitat within the harbour. This study quantified current sediment cover and the biological community at mid and low tide across nine sites. It was found that animal and macroalgal richness was negatively correlated with sediment cover, with lower species richness being found in sites with high sediment cover. Sediment cover was highly variable within the harbour but there was trend of greater sediment cover among sites close to the turning basin at Port Chalmers. Due to the short duration of this study it could not be determined whether sediment cover was changing over time. Continued monitoring on a seasonal basis is recommended to better understand the sediment dynamics of Otago Harbour and to determine whether increased dredging activity is affecting the productivity and structure of valuable rocky shore habitat.

Aims and objectives

Phased dredging activity within Otago Harbour is currently occurring and will continue, at least, until December 2017. The consent granted to Port of Otago Limited allows for the removal of 7.2 million m^3 of substrate for the purpose of deepening and widening both the shipping channel and the berthing area (Project Next Generation). The dredging process involves the use of a backhoe dredge and suction hopper dredge, the former removes larger material by scouring the bottom with a digger bucket, while the latter uses suction to remove finer material. Both practices result in the disruption of the seafloor and have the ability to re-suspend fine sediment into the water column. Otago Harbour experiences strong diurnal tidal currents and often strong wind driven water movement, which means sediment may be retained in suspension and transported throughout the harbour. Also typical in Otago Harbour is rocky reef habitat where the substrate fringing the harbours edge is dominated by consolidated reef or large boulders. This particular habitat provides a substrate for the attachment of macroalgae which are important primary producers and form further three dimensional habitat. Associated with these ecosystems is a plethora of animals that rely directly on the presence of hard substrate for attachment, or are associated with the habitat and food source provided by macroalgae. These ecosystems also contribute directly and indirectly to important fisheries. Increased sedimentation upon rocky reef habitat can have the effect of reducing the area of hard substrate available for attachment, smothering

macroalgae and animals, and reducing the amount of light available for photosynthesis. All of these outcomes reduce productivity and diversity and alter the way these valuable ecosystems function.

The aim of this study was to quantify the current level of sediment on rocky reef habitat within Otago Harbour and to quantify the biotic communities associated with these habitats. The objective was to establish an understanding of the current state of rocky reef habitat within Otago Harbour which can be used to determine if future dredging activity is having a negative effect on these ecosystems.

About this project

This project was conducted in collaboration with the New Zealand Marine Studies Centre, the University of Otago and eight primary and two secondary schools from around Dunedin. It also involved members of the community who expressed an interest. The project was funded through the Otago Participatory Science Platform (Ministry of Business, Innovation and Employment, Curious Minds Project).

Methodology

Study sites Nine sites were selected within Otago Harbour, these were chosen based on the presence of hard rocky substrate which consisted of reef, boulders or a combination of both (Figure 1). Four sites were selected on the southeast side of the harbour, four on the northwest, and one in the middle. The spatial configuration of sites surrounded the main dredging activity in the turning basin at Port Chalmers and the channel extending toward the harbour mouth (Figure 1). All sites, with the exception of Wellers Rock, had a gentle sloping shore gradient which resulted in a large portion of substrate being exposed at low tide (Figure 2).

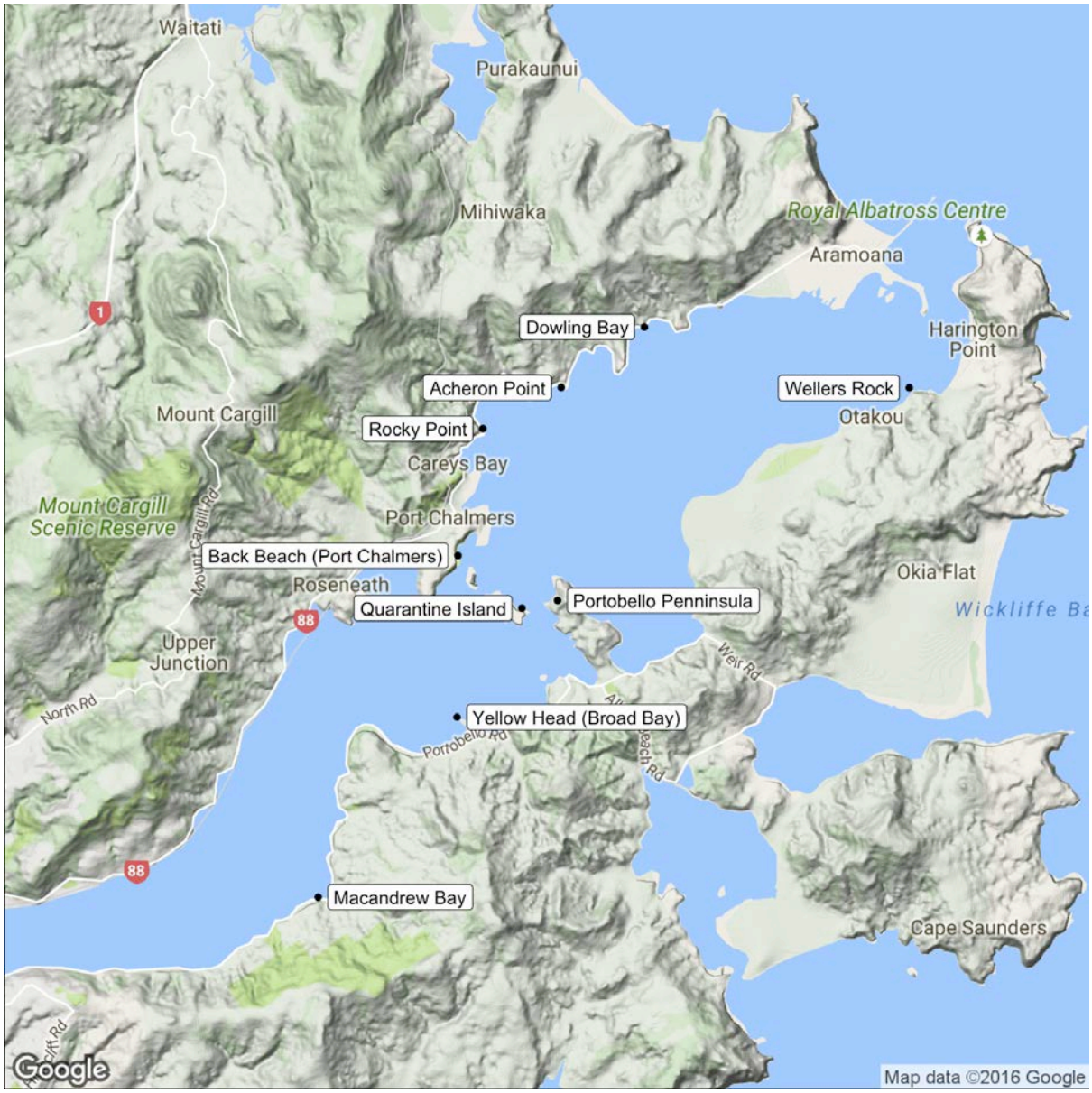

Figure 1. Map of study sites.

Study design At each site, a 30 m fixed transect was established by marking either end of a tape measure laid parallel to the waters edge with epoxy cement above the high water mark. On return visits to each site a 30 m tape was laid at the mid-tide and low-tide level based on the reference points of the permanent markers (Figure 2). During each sampling trip, five replicate one square metre quadrats were randomly placed along the transect line at both mid-tide and low-tide (Figure 2). The random placement of quadrats along each transect was achieved by computer generation of five unique random numbers between 0 and 30. Within each quadrat, percent cover of substrate type was estimated for the seven categories of: Reef, Boulder, Cobble, Gravel, Sand, Sediment and Mud. Percent cover all seaweed species was then estimated and all other living organisms were counted.

Figure 2. Example of a typical rocky shore within Otago Harbour, showing a gently sloping shore which is exposed at low tide. The 30 m transect can be seen along with three randomly place 1 m^2 quadrats.

Data collection Data collection was conducted twice at each site, with the exception of Acheron Point which was only sampled once, and Back Beach which was sampled four times

due to two schools being assigned to this site. The first sampling period was conducted from 8th March to 10th May 2016, and the second from 24th May to 23rd June 2016.

Data validation The validation of data occurred over three stages from the time of collection to the point of analysis. Firstly, all organisms were identified using a field guide produced specifically for southern rocky shore locations. When an organism could not be identified in the field a photograph or sample was taken for later identification. The process of data entry into the Marine Metre Squared website provided the second opportunity to validate data. This process involved selecting each species identified in the field from a drop down menu of known species found in the Otago region. When an organism was not identified to the species level, the genus name was selected. Finally, before data was analysed it was screened for inconsistencies in both species counts and identification errors. This was achieved by compiling all data into one file and then scanning the data for particularly high/ low counts of any species, this was achieved using the software package R (v. 3.0.1, R Core Team, 2013). In some cases, it was obvious that a species had been misidentified as the genus was known to exist in Otago Harbour but the particular species did not. In this case the identification was changed to the more likely species name. Observations of highly abundant species were cross checked to determine if it was an ecologically realistic observation, if it was not then the observation was discarded. By completing the three phases of data validation the majority of inconsistencies in data entry and species identification were assumed to be corrected.

Data analysis

Sediment cover. Mean sediment and mud cover was calculated at the mid and low shore levels at each site using each schools percent cover estimates from both sampling trips (n = 10 quadrats at each shore level). The harbour-wide mean was also calculated for each shore level. Data is presented as the mean percent difference (± SE) above or below the harbour mean at each site.

Species richness. Species diversity was calculated at the mid and low shore levels at each site using each schools species counts from both sampling trips (n = 10 quadrats at each shore level). The harbour-wide median was also calculated for each shore level. Data is presented as the mean difference (± SE) above or below the harbour median at each site. A Pearson's product-moment correlation was performed to test for an effect of sediment cover on species richness.

Vulnerability index. A complete list of all species identified over the entirety of this study was compiled and each species was ranked based on its vulnerability to sediment according to four characteristics; sessile, photosynthesiser, filter feeder, needs rock. If a species had, none of the characteristics its vulnerability status was low, one characteristic its vulnerability status was medium, two characteristics its vulnerability status was high and three characteristics its vulnerability status was very high. The median number of species that fell under each vulnerability ranking was calculated across the entire harbour using combined data from both shore levels and sampling trips. Data is presented as the mean difference (± SE) above or below the harbour median at each site.

All statistical analysis was performed using the software package R (v. 3.0.1, R Core Team, 2013).

Results

Sediment cover. At mid tide, mean sediment cover ranged between 0.1 – 51.8%, with an average across the harbour of 18 ± 2.7% (Figure 3). Quarantine Island, Rocky Point and Yellow Head all exhibited above average sediment cover, while at Wellers Rock, Dowling Bay and Portobello Peninsula sediment cover was below average (Figure 3). At low tide, mean sediment cover ranged between 0.7 -58.8%, with an average across the harbour of 25.5 ± 3.2% (Figure 3). Again, Quarantine Island had high levels of sediment cover, as did Acheron Point and Rocky Point (Figure 3). Wellers Rock, Portobello Peninsula and Yellow Head all exhibited below average sediment cover.

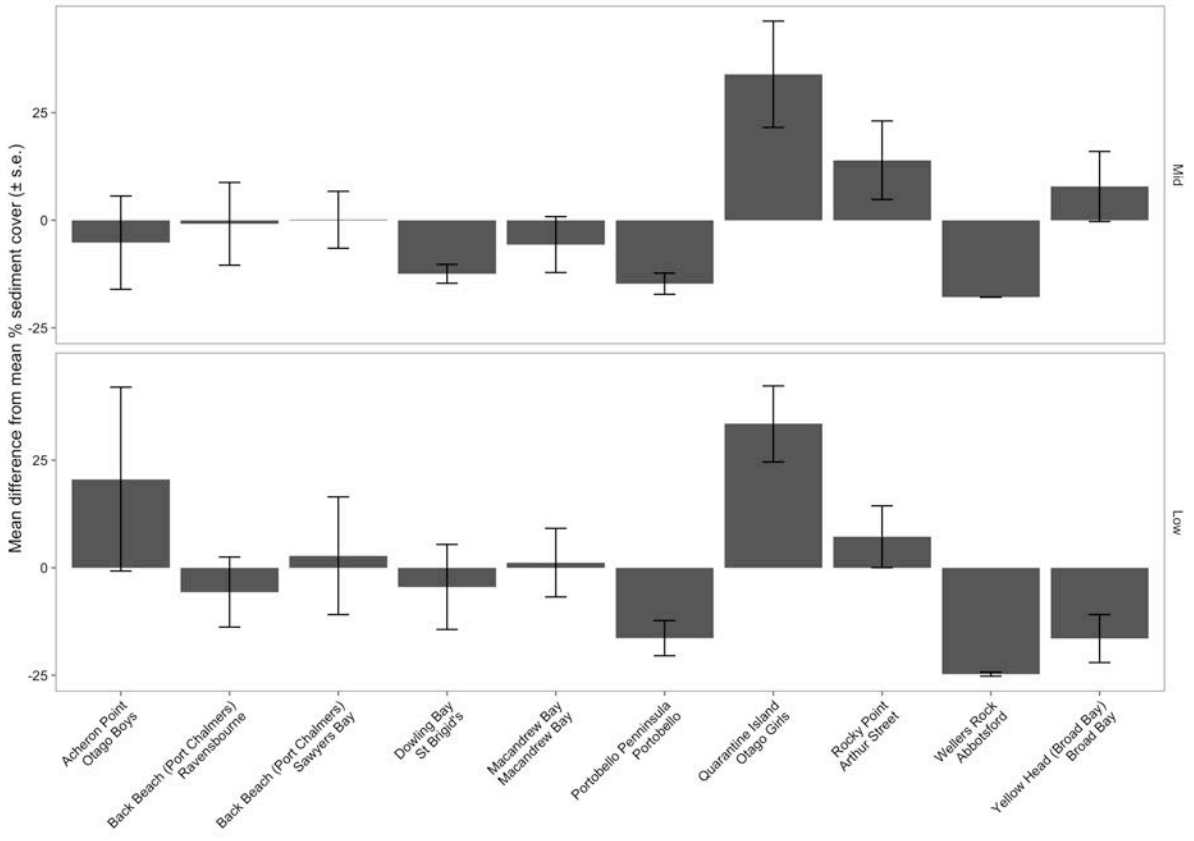

Figure 3. Difference in percent sediment cover from harbour mean per square metre at the mid tide (top) and low tide (bottom) shore level. Values represent mean difference (± SE) at each site over the two combined sampling periods (n = 10).

Species richness. At mid tide, the mean number of species per square metre within a site ranged between 8 -15, with a median across the harbour of 10 species per square metre (Figure 4). Dowling Bay exhibited particularly high species richness while Wellers Rock and Yellow head also supported greater richness than the harbour median (Figure 4). Sites that had comparatively low species richness included Back Beach, Macandrew Bay and Rocky

Point (Figure 4). At low tide, the mean number of species per square metre within a site ranged between 8 -14, with a median across the harbour of 12 species per square metre (Figure 4). Unlike at mid tide, high species richness was found at Back Beach and Portobello Peninsula while, like at mid tide, Dowling Bay showed relatively high richness at low tide (Figure 4). Acheron Point, Rocky Point and Quarantine Island all supported comparatively low species richness.

A Pearson's product-moment correlation showed that species richness was significantly negatively correlated to sediment cover (t = -2.174, P = 0.031). This indicates that with increasing sediment cover species richness decreases.

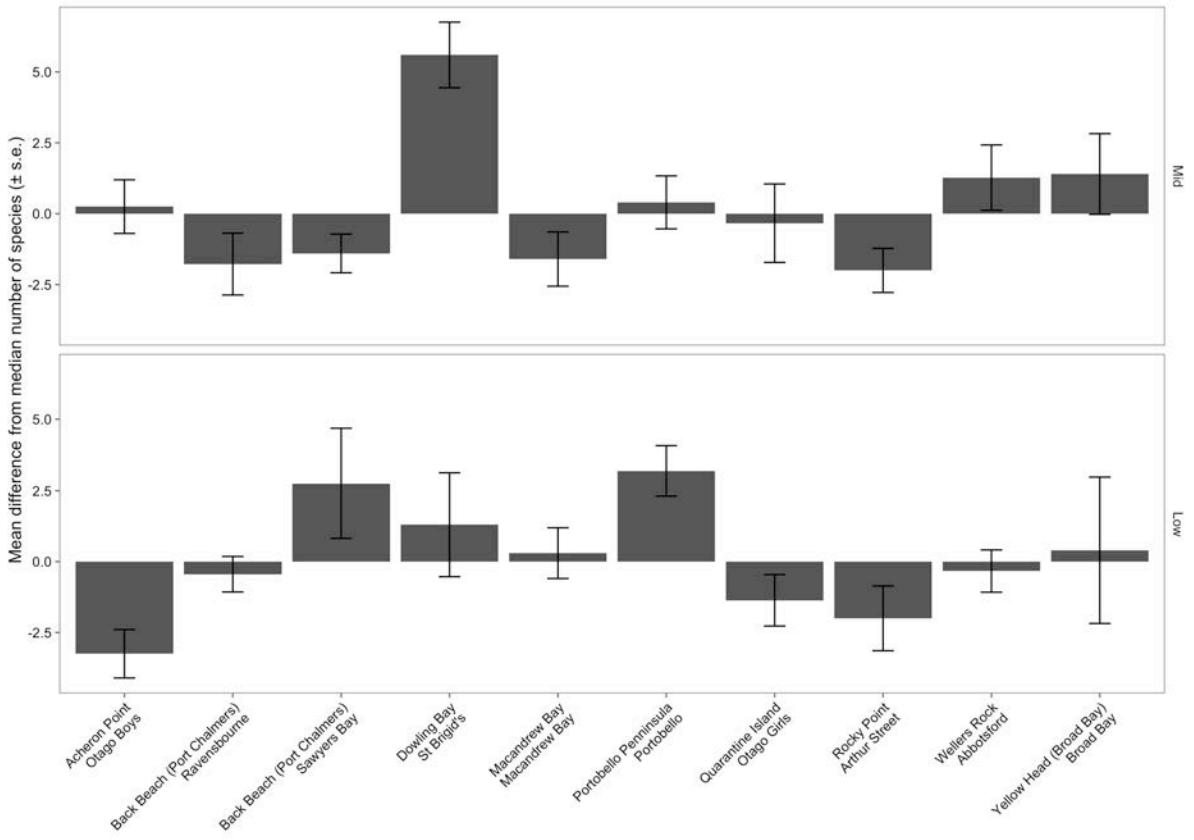

Figure 4. Difference in species richness from the harbour median per square metre at the mid tide (top) and low tide (bottom) shore level. Values represent mean difference (± SE) at each site over the two combined sampling periods (n = 10).

Vulnerability index. Species that showed low vulnerability to sedimentation were relatively rare at all sites, with the median value across the whole harbour being one species per square metre (Figure 5). Species demonstrating a medium level of vulnerability were on average the second most abundant across the harbour with a median value of four per square metre

(Figure 5). Sites that demonstrated relatively high abundance of species within the medium classification were Back Beach and Dowling Bay. The only site to host fewer species than the median was Acheron Point. Due to the nature of the classification scale, very few species fell under the category of High vulnerability, those that did were found at Dowling Bay and Macandrew Bay (Figure 5). Species that showed Very High vulnerability to sedimentation were the most abundant across the harbour, with a median of five species per square metre (Figure 5). Relatively large variability in the number of Very Highly vulnerable species occurred between sites. Dowling Bay, Wellers Rock, and Portobello Peninsula all supported a high number of Very Highly vulnerable species, while Macandrew Bay, Rocky Point and Back Beach supported fewer (Figure 5).

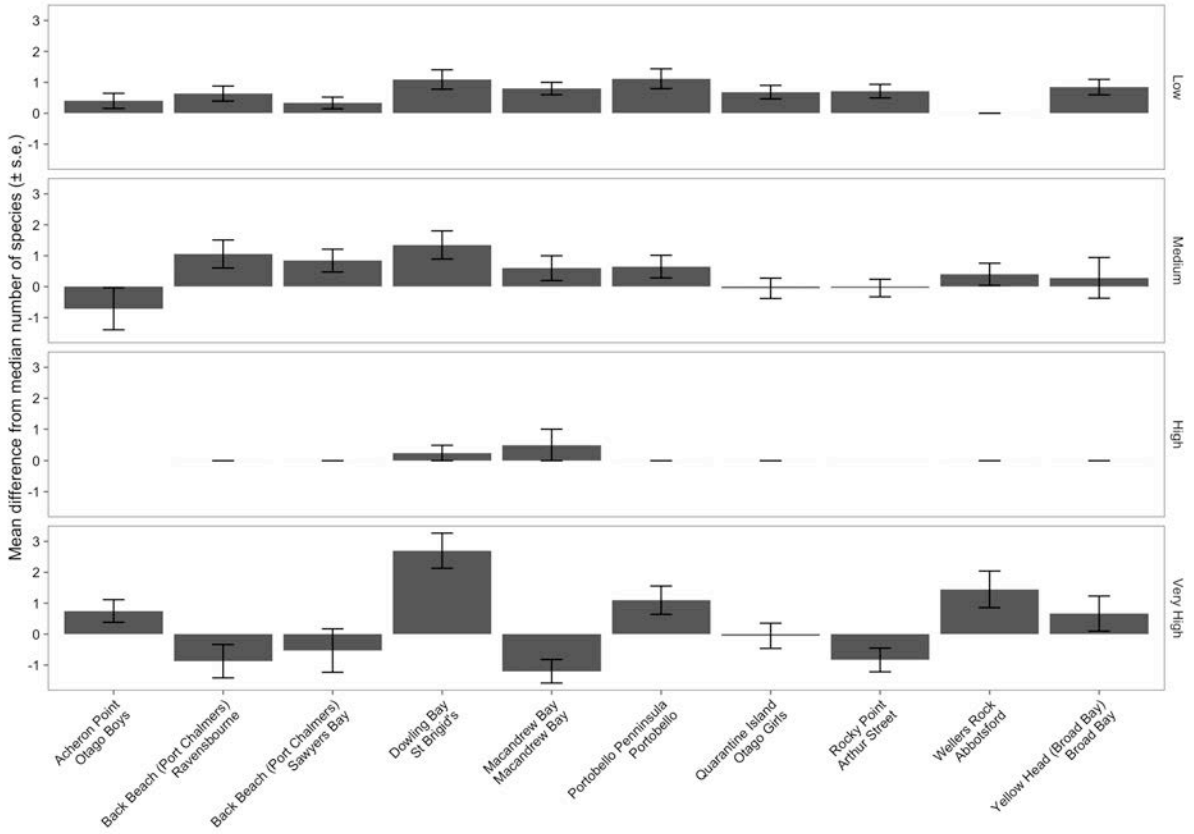

Figure 5. Difference in the number of species from the harbour median that fall under the classifications of Low (top), Medium (second), High (third) and Very High (bottom) vulnerability to sediment. Values represent mean difference (± SE) at each site over the two combined sampling periods and at both shore levels (n = 20).

Discussion.

This study is the first to assess sediment cover upon rocky intertidal shores within Otago Harbour using the Marine Metre Squared framework. It was found that the richness of species inhabiting these productive environments was significantly negatively correlated with sediment cover, meaning, as sediment cover increases a decline in the number of species present was observed. This finding demonstrates the risk of potentially increasing sedimentation within Otago Harbour and highlights the need to understand and manage processes occurring within the harbour that may increase sedimentation.

Sediment cover was typically greater at the low tide level compared to mid tide, indicating that deposition was occurring from suspended sediments carried by harbour water rather than from terrestrial sources. The cover of sediment was highly variable at different sites around the harbour but was found to be greatest at sites within close proximity to the turning basin at Port Chalmers *i.e.* Rocky Point, Acheron Point, Back Beach and Quarantine Island. However, the fact that sediment cover did not decline consistently with distance from the hypothesised source means that, even if this area is the main source of sediment, the dispersal of sediment throughout the harbour is controlled by complex hydrodynamic forces. An example is the considerably greater sediment cover observed at Quarantine Island compared to any other site. The reason for this was not able to be determined but it likely due to the hydrodynamic regime around Quarantine Island. More information is required regarding tidal and wind driven current characteristics within Otago Harbour in order to better understand the process of sediment dispersal and settlement.

Few species that had Low vulnerability to sedimentation were found during this study *i.e* those that are unaffected by high levels of sediment. This is due to the shores sampled being rocky habitat that typically experiences little sediment cover, and are therefore inhabited by species that are not resilient to high levels of sediment. It follows that species with Very High vulnerability to sediment were the most abundant but their presence was highly variable across sites. Typically, sites that had low sediment cover had a greater richness of species that were categorised as having Very High vulnerability to sediment, these were; Wellers Rock, Dowling Bay, Portobello Peninsula and Yellow Head. This method of quantifying the richness of species based on their vulnerability to sediment provides a means to assess any future changes in community structure that are the result of increased sedimentation. If

sedimentation increases it would be expected that the richness of vulnerable species would decline while the richness of those not vulnerable would increase.

Human activity has influenced the sediment regime within Otago Harbour for hundreds of years and dredging activity has occurred within the last 150 years, therefore the ability of the results from this study to represent a true baseline is significantly compromised. This study also commenced after a large portion of the dredging associated with Project Next Generation had occurred, further compromising the ability to detect an effect of increased dredging activity. The value of these results still remains extremely high and they hold potential to act as a key reference point for future comparisons as dredging activity continues to occur.

Recommendations

Future work should focus on maintaining a monitoring program that uses the same methods and study sites established in this study. It is important to quantify temporal variability in sediment cover and deposition, as well as the structure of the biological community, in order to determine whether increased sedimentation is affecting these important habitats. It is recommended that seasonal sampling is undertaken in order to achieve this. A comprehensive understanding of the hydrodynamics within Otago Harbour would help determine where the most likely points of sediment deposition are and should be a focus of further work. Finally, access to information regarding the timing and magnitude of future dredging activity, as well as turbidity information, which is currently being measured at seven fixed sites within the harbour, is needed in order to better understand if dredging activity is increasing sedimentation.