The Final Report on the Facilitated Citizen Science Project
‘Sediments and Seashores’

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ABSTRACT

Coastal environments are under increasing pressure from human activities which are putting natural resources at risk. In order to continue to utilise these natural resources, long-term and detailed datasets need to be available to those tasked with environmental management. Gathering datasets that match this criteria can be difficult as they are often expensive to collect and funding for on-going data collection is not always available. Therefore resources managers are increasingly enlisting the assistance of the general public to record their observations then report them back to a particular department or agency. This process has been termed 'citizen science'. After public concern surrounding the dredging project in the Otago Harbour, Dunedin, New Zealand a facilitated citizen science project – 'Sediments and Seashores' – was established in 2016 by the University of Otago to gather information on the potential impacts of sediment on the rocky intertidal. The project engaged with local schools to collect abundance and density data of the species within the harbour as well as estimating the percentage cover of fine sediment on the shore. In its third and final year, the 'Sediments and Seashores' project has collected further survey data which shows the variability in sediment and species density in the harbour. However, when looking at the harbour as a whole there has been little fluctuation in species diversity over this time. To understand the localised effects of sedimentation and diversity, more research is needed. During the three year project, the quality of the data collected by students (when assisted by scientists) has shown to be comparable to data collected by scientists. There has also been assessments completed to show the value that 'Sediments and Seashores' has to science education. This project has provided information on the harbour that otherwise would not have been collected as well as provides baseline information at the beginning of the dredging project. After three years, 'Sediments and Seashores' has provided insight into running a successful facilitated citizen science projects for schools along with ideas for further development of citizen science. Despite the end of the project, it is hoped that schools that have engaged with 'Sediments and Seashores' will continue monitoring in some form.

INTRODUCTION

Coastal Ecosystems and Humans

One of the most significant environmental issues in New Zealand coastal and estuarine systems is sedimentation (Chew et al., 2013; Ministry for the Environment & Statistics New Zealand, 2016; Morrison et al., 2009; Schwarz et al., 2006). Excess sedimentation can result in the clogging of fine breathing or feeding structures (Schönberg, 2016), change behavioural responses (Chew et al., 2013), reduce light for photosynthesis (Desmond et al., 2015) and bury and scour organisms (Airoldi, 2003; Schönberg, 2016). This can reduce both biodiversity and critical habitat essential for valuable species such as paua, shellfish and rock lobster (Cussioli et al., 2015; Morrison et al., 2009; Schwarz et al., 2006).

Coastal ecosystems are particularly vulnerable due to the interaction of impacts from both land-based and marine-based human activities (Brown et al., 2018; Crain et al., 2009; Morrison et al., 2009). Most research on coastal sedimentation focusses on terrestrially sourced sedimentation (Schwarz et al., 2006; Walling, 2006; Morrison et al., 2009), however, there is a growing need to assess marine sourced sedimentation as dredging and mining activity increases worldwide (Brown et al., 2018).

Environmental Monitoring

Most monitoring regimes start in response to environmental change, increased anthropogenic disturbance or assessing management actions and is invaluable for detecting change over time (Holland et al., 2012; Lindenmayer & Likens, 2009). Knowledge from monitoring can be useful for informing management decisions (Oakley et al., 2003; Wolfe et al., 1987) as well as determining the effectiveness of management decisions (Borja et al., 2016). Gathering information for ecosystem management can be challenging as long-term monitoring schemes can be expensive (Agardy et al., 2005; Galloway et al., 2006; Magurran et al., 2010) and long-term funding is not always available (Lohner & Dixon, 2013; Sergeant et al., 2012). Long-term monitoring is also time-consuming (Magurran et al., 2010; van der Velde et al., 2017), requires suitably qualified personnel (Cox et al., 2012; Galloway et al., 2006) and can require expensive/technical equipment (Bates et al., 2007). Therefore, long-term monitoring projects are not always completed (Agardy et al., 2005; Holland et al., 2012; Magurran et al., 2010), may lack direction (Holland et al., 2012) or are terminated before long-term relationships can be identified (Lohner & Dixon, 2013) which can result in ill-informed decision making (Lohner & Dixon, 2013; Sergeant et al., 2012).

Citizen Science as a Solution?

Resource managers are increasingly utilising alternative sources of gathering long-term data (usually 10 years or more – Wolfe et al., 1987) by accessing information collected, analysed or transcribed by the public (Cigliano et al., 2015; Conrad & Hilchey, 2011). This is collectively known as citizen science collected data (Hidalgo-Ruz & Thiel, 2013; McKinley et al., 2017; Todd et al., 2016). "Citizen science" is a process where members of the general public, usually with non-scientific backgrounds, voluntarily collaborate with scientists or participate in scientific research (Silvertown, 2009; Ballard et al., 2017; van der Velde et al., 2017). Citizen science has the capacity to provide data to inform management decisions (Danielsen et al., 2014; Dean et al., 2018). This could benefit resource managers by reducing project costs (Conrad & Hilchey, 2011; Ellwood et al., 2017; Vann-Sander et al., 2016), allowing for a larger sampling size (increasing statistical power) (Devictor et al., 2010; Gray et al., 2017; Silvertown, 2009), covering larger sampling areas (Bonney et al., 2009; Devictor et al., 2010) and collecting data over greater timeframes (Bonney et al., 2009; Conrad & Hilchey, 2011).

Citizen science can be limiting as it often engages with people of a particular demographic profile (Eastman et al., 2014) and has been identified to under-represent youth (under 18 years of age). This projected chose to target engaging with youth and so collaborated with local schools. Working with schools also allowed for the engagement with the wider community as parent helpers were required to come and assist students on the shore. Schools provide an excellent opportunity to engage with under-represented groups in citizen science through both students and their parents whilst providing unique yet relevant educational experiences.

Dredging in the Otago Harbour

Many ports and harbours are under-going intensive modifications driven by increased trade and tourism (Chew et al., 2013; Pirotta et al., 2013; Port Otago Limited, 2010), population growth (Chew et al., 2013; Pirotta et al., 2013), and expansion of defence forces (Pirotta et al., 2013; Firth et al., 2014; Brown et al., 2018).

In 2014, Port Otago Limited was granted consent by the Otago Regional Council to commence a capital dredging project to remove 7.3 million cubic metres (m^3) from the main shipping channel deepening the channel to 14 m to allow larger vessels to enter the Port (Port Otago Limited 2010; Port Otago Limited, 2016). Local residents were concerned about the potential environmental impacts this may have on the harbour and approached the New Zealand Marine Studies Centre (NZMSC) – the education and outreach facility associated with the Department of Marine Science, University of Otago (Desmond et al., 2016). In response to these concerns, a facilitated citizen science project, was developed and commenced in 2016 involving local schools. The goals of the citizen science project were two-fold; first, to collect valuable scientific data about the impact of dredging on the intertidal community and second, to engage with local communities, educate them about the marine environment and encourage them to take guardianship of their local shorelines.

The facilitated citizen science project ran consecutively between 2016-2018 and involved students aged five to fifteen (though the average age of students was 9.78 years). Schools monitored six sites along the rocky intertidal within the harbour (Fig 1). The structure and methods used in the first year of the project remained consistent throughout the project (aside from some modifications to collect more data). Over the course of six months, each school was allocated approximately eight hours of contact time with the scientists which were split into six sessions. These sessions consisted of; an introduction session, two data collection sessions, two data entry sessions and a summary session. During the course of this three-year monitoring project ten schools (primary and secondary) have participated with approximately 450 students and 100 parents/teachers being involved as well as 28 scientists. This report will primarily focus on the 2018 year of sampling but will also summarise the lessons learnt from all three years of the project.

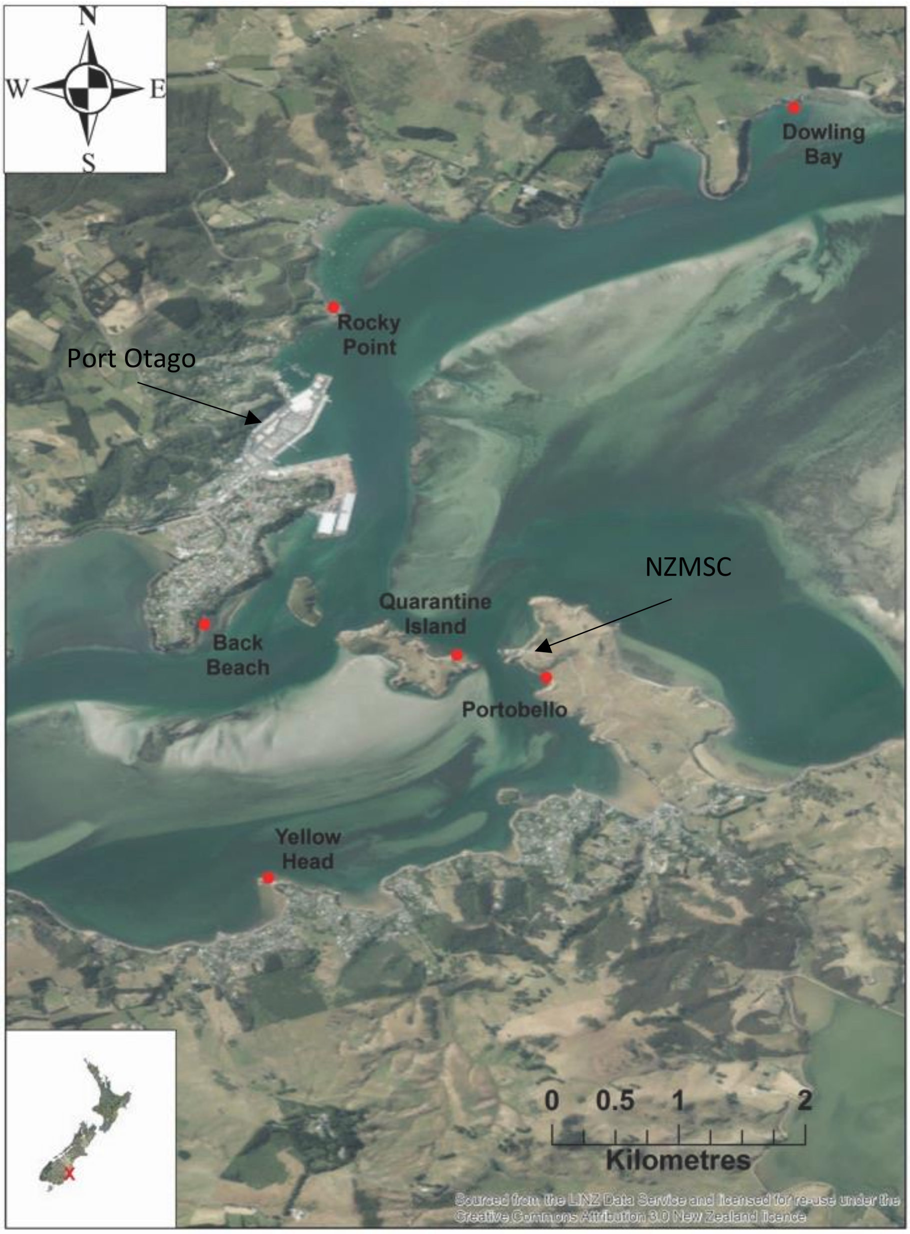

Figure 1: Map of the Otago Harbour, Dunedin. 2018 sampling sites are indicated by red circles. Red X on the inset of New Zealand indicates the location of Dunedin

METHODS

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). Three locations were on the northwest side (Port Chalmers side) of the harbour and two 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), Rocky Point (Muselburgh School), Back Beach (Ravensbourne School), Quarantine Island (Otago Girls High School), Yellow Head (Broad Bay School) and Portobello (Macandrew Bay School). Sites were selected due to their proximity to the shipping channel and the port (where dredging was occurring), providing a representative overview of the harbour ecosystem, accessibility for schools (including travelling time and ability for children to access the rocky intertidal) and slope/structure of the shoreline. All sites had a hard rocky substrate comprising of reef, boulders or a combination of both (Desmond et al., 2016)

Introduction Sessions

The purpose of this session was to introduce the scientists involved and provide students with an overview of the issue. This included background information to the issue (including environmental impacts) and an explanation of dredging (as this term was unfamiliar to most students).

Data Collection Sessions

There were two data collection periods between 15th- 20th March, 29th March and 4thApril 2018 and 13th-18th and 27th June 2018. Data collection sessions were timed with good low-tide times that were less than 0.5 metre (most tide heights were lower than 0.4 metre) that also occurred within appropriate hours for schools, and were spaced to provide an adequate temporal gap between sampling sessions for data entry and analysis and to ensure we were sampling different seasons.

At each location, a 30m transect line was laid out at both low tide and mid tide. Four to seven quadrats were randomly placed along the transect line using random numbers. Parent helpers and teachers were present with most groups of students to help them stay on task and often recorded the findings in each quadrat. Usually two scientists (depending on group size) would be floating between groups to check on their progress and assist groups with the identification of species. Students worked in groups of three to six per quadrat (dependent on the number of students present on the data collection trips).

In each quadrat the following information was recorded onto an accompanying datasheet; the percentage cover of substrate, the number of animals and the percentage cover of macroalgae. Dead or empty organisms (often shells) were not to be counted or recorded. Substrates needed to add to 100% and were classified into six categories loosely based - reef, boulder, cobble, gravel, sand, sediment/mud (refer to Wentworth's description of silt, Wentworth 1922). Although students and scientists recorded animals as counts, if there were large aggregations of a particular species that were small (< 4 cm) within the 1 m^2 quadrat an estimate of the number of that species would be taken. This was completed by using a smaller 10 cm^2 quadrat (equating to 1% of the 1 m^2 quadrat) to estimate the cover of dense areas of algae (often turf-forming algae or holdfasts) and sessile organisms. At each data collection session some environmental parameters were also measured including salinity (measured with a refractometer in parts per thousand) and temperature of the air and the water (in degrees Celsius) and water clarity (using a 1 m long water clarity tube).

In 2017, it was found that students (aged seven to fifteen) were able to collect basic density and taxonomic data in intertidal habitats at a comparable level to that of trained scientists (refer to 2017 report for more detail, Smith et al., 2017). Therefore, in 2018 substrate data collected by students (aged five to fourteen) and trained scientists was compared. Scientists and students estimated substrate cover using three different techniques (visual percentage cover estimates, printed out photographs, volumetric measurements of sediment and) were assessed for their practicality for a citizen science project and agreeability of estimations between the two surveyors.

Visual estimates of substrate in the low tide quadrats were completed by both students and scientists during the data collection. Substrate estimates were required to add up to 100%

cover and estimates were taken of the upper most layer of the quadrat. To help with estimating cover of substrates, quadrats (1 m^2) were divided into quarters with coloured twine (50 cm^2 or 25% of quadrat) and smaller 10 cm^2 (or 1%) quadrats were also provided to place within the 1 m^2 quadrat to help aid estimation.

Photographs of all low tide quadrats were taken during the data collection session. All photographs were printed onto A3 paper and divided into a grid of 100 equal sized squares so each square would represent 1% of the photograph. In each of the 100 squares, scientists and students determined which substrate type best represented the square by writing a letter in it (e.g. R = reef, B = boulder etc.). Each of the different substrate types were then tallied so the total would add to 100. Two copies of each photograph were printed so scientists and students could do the estimates using the same photograph.

Sediment traps were made with a flat plastic PVC plate (250 mm x 250 mm x 5 mm), an AstroTurf square (glued to the PVC plate) and a galvanized reinforcing steel frame that was attached to the plate using plastic zip ties in order to weigh the trap down to prevent it from moving (Fig 2). During both data collection sessions in 2018 six sediment traps (three for scientists and three for students to collect) were placed approximately five metres apart along a 30 m transect in approximately 20 cm of water at mean low water for five days. Sediment traps were washed clear seawater and washing was ceased when the surveyors determined that sediment traps were clean (i.e. no more sediment could be seen on the trap). Next, a volumetric reading of the amount of sediment was taken using various sized cylinders. The collected sediment was dried at 35°C for a period of 36-42 hours.

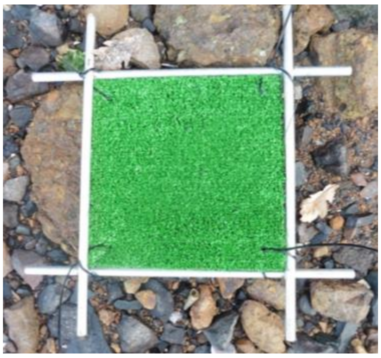

Figure 2: Image of sediment trap on the rocky intertidal (prior to deployment)

Data Entry Sessions

Data entry sessions were run in the classroom within one working week of the data collection sessions. The data entry session ran for an hour and primarily consisted of entering the data online into the nationwide database 'Marine Metre Squared' (www.mm2.net.nz).

Summary Sessions

The purpose of the summary sessions was to present the summarised data collected over their two field sessions (average number of species present) to each school and discuss what they had found, what the data meant and how it compared to the average for the whole harbour. Before showing the data, a recap discussion was held to remind students of the overall purpose of this project. To conclude the session and the project, there was a class discussion as to how they could share their data and continue collecting data beyond the scope of this citizen science project.

Investigation into Educational Components

In addition to collecting data on the rocky intertidal, the development of students' science based skills and knowledge of the scientific process during a facilitated citizen science project. Five common intertidal snail species were selected for the assessment of students' identification skills. The species were; spotted top snail (*Diloma aethiops*), horn snail (*Zeacumantus subcarinatus*), lined whelk (*Buccinulum* sp.), cats eye snail (*Lunella smaragda*) and turret snail (*Maoricolpus roseus*) (Fig 3). The identification assessment was completed using a mix and match survey. There were no identification resources available to students for this activity. To investigate students' knowledge and understanding of the scientific process, students worked in groups and recorded their ideas on how to investigate marine issues using mind maps. This was completed in both the introduction and summary sessions in a pre- and post-test format.

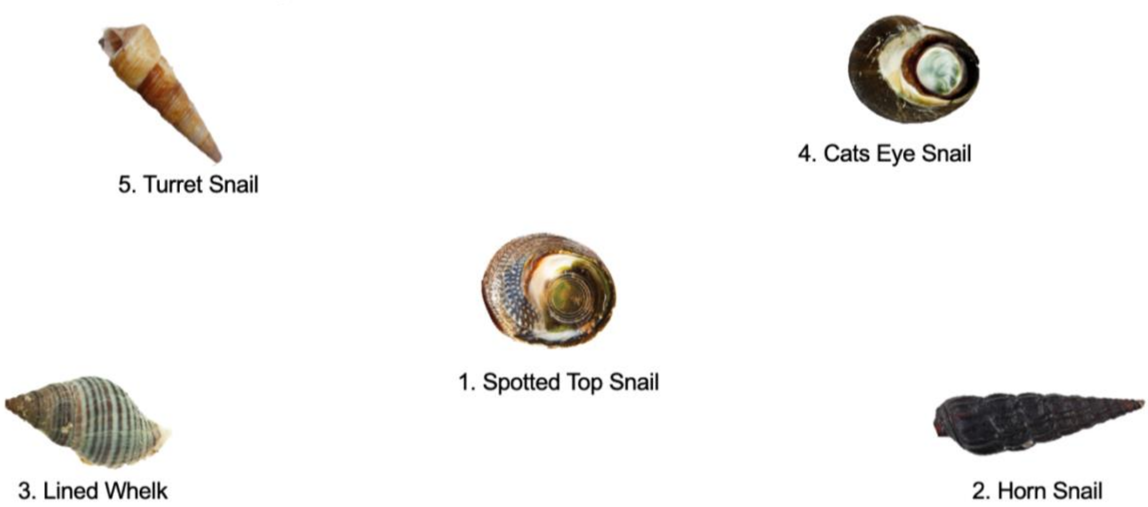

Figure 3: Images of the five species of intertidal snail used to test students' identification abilities

Analysis

Data was analysed using a combination of Microsoft Excel (version 16.18) and RStudio (version 1.1.414, RStudio Team 2016). Further investigation into differences between scientist and student collected data (see 2017 report) was completed using an ANOVA followed by a Tukey's HSD test. For the comparisons of either sediment or mean number of unique taxa, an ANOVA was run and if this identified any differences within the data then a Tukey's HSD test would follow.

RESULTS

In 2017, it was identified that students (aged 7-15) were able to identify species at a basic taxonomic level that was similar to that of (refer to 2017 report for more detail). However, as the two datasets were not exactly the same, this prompted further investigation as to where these differences may lie. It was found that there were 11 different species that were driving approximately 50% of the dissimilarity between the student and scientist datasets. Out of these 11 species, only *Austrominus modestus* (the beaked barnacle) was found to be statistically significant (p-value <0.05).

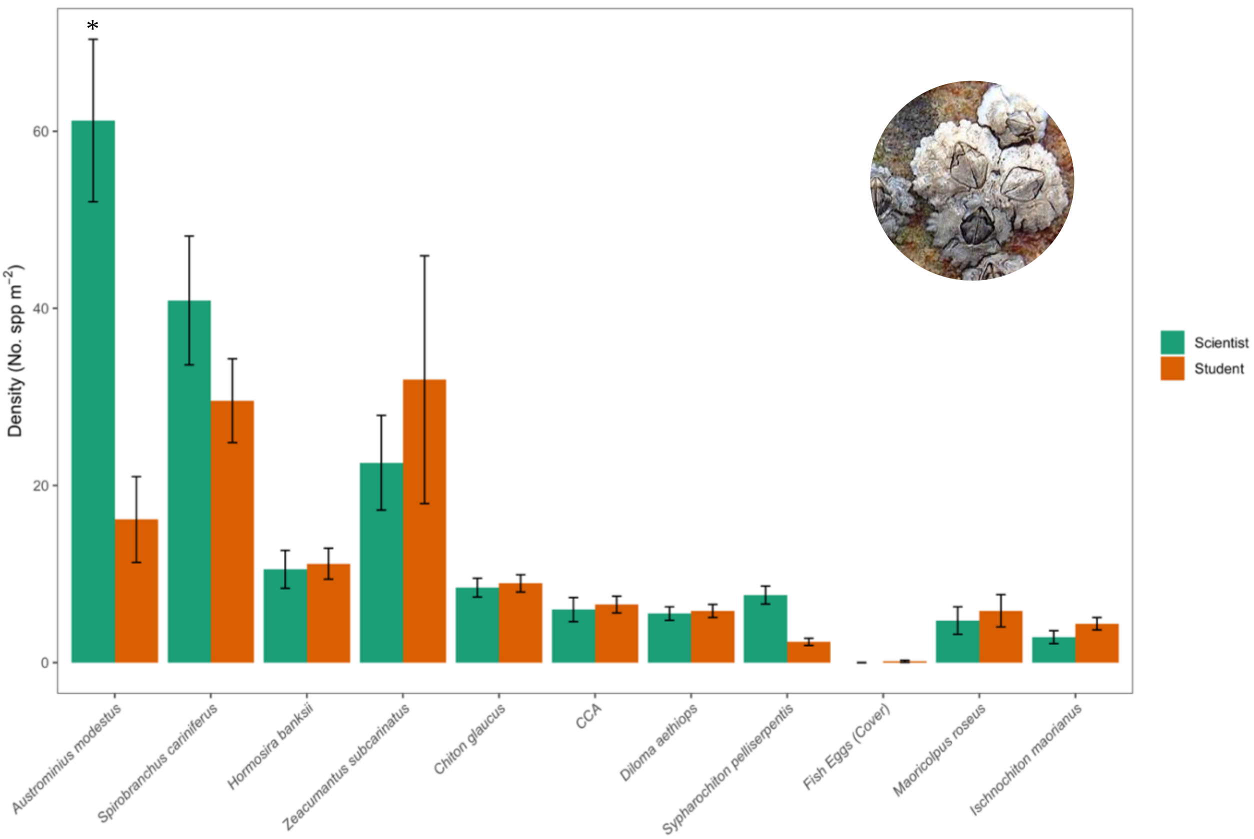

Figure 4: Densities (average number of species per m2) of 11 species that were identified as dissimilar between students (orange bars) and scientists (green bars) in 2017 using SIMPER analysis ± SE for $n_{(scientist)} = 100$, $n_{(student)} = 130$). Insert shows *Austrominius modestus* (Beaked barnacle). Asterisks represent significant differences for Tukey's HSD tests, α = 0.05

Estimates of sediment cover were significantly different between sites (Two-way ANOVA p-value <0.01; Fig 5). This prompted further investigation, which identified that Quarantine Island had significantly different values of sediment cover in 2018 compared to the previous two years (p -value <0.05 for Tukey's HSD) (Fig 5). There were no differences in sediment cover between the three years of the project nor between the interaction of study site and time (Fig).

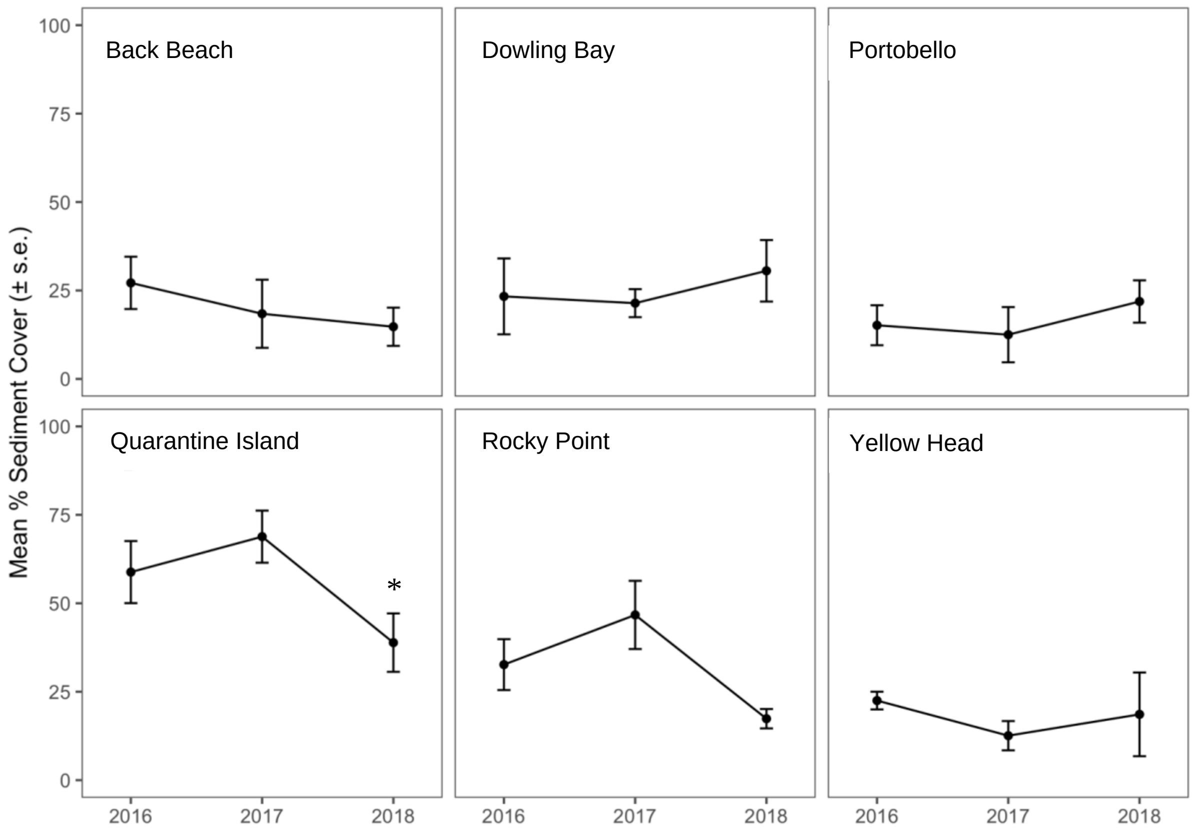

Figure 5: Mean percentage cover of sediment (± SE) visually estimated at low tide by students for each of the six study sites over a three-year facilitated citizen science project (2016-2018). Significant results are indicated by asterisk above the data points ($n_{(2016)} = 50$, $n_{(2017)} = 63$, $n_{(2018)} = 46$)

Although number varied between the study sites, there was no significant differences in the mean number of unique taxa found at low tide between the different study sites or between the years of the 'Sediments and Seashores' project (Fig 6). This can be seen in the relatively consistent number of unique taxa found within the whole harbour (Fig 6). This was also the case for the mean number of taxa found at mid tide (Fig 7).

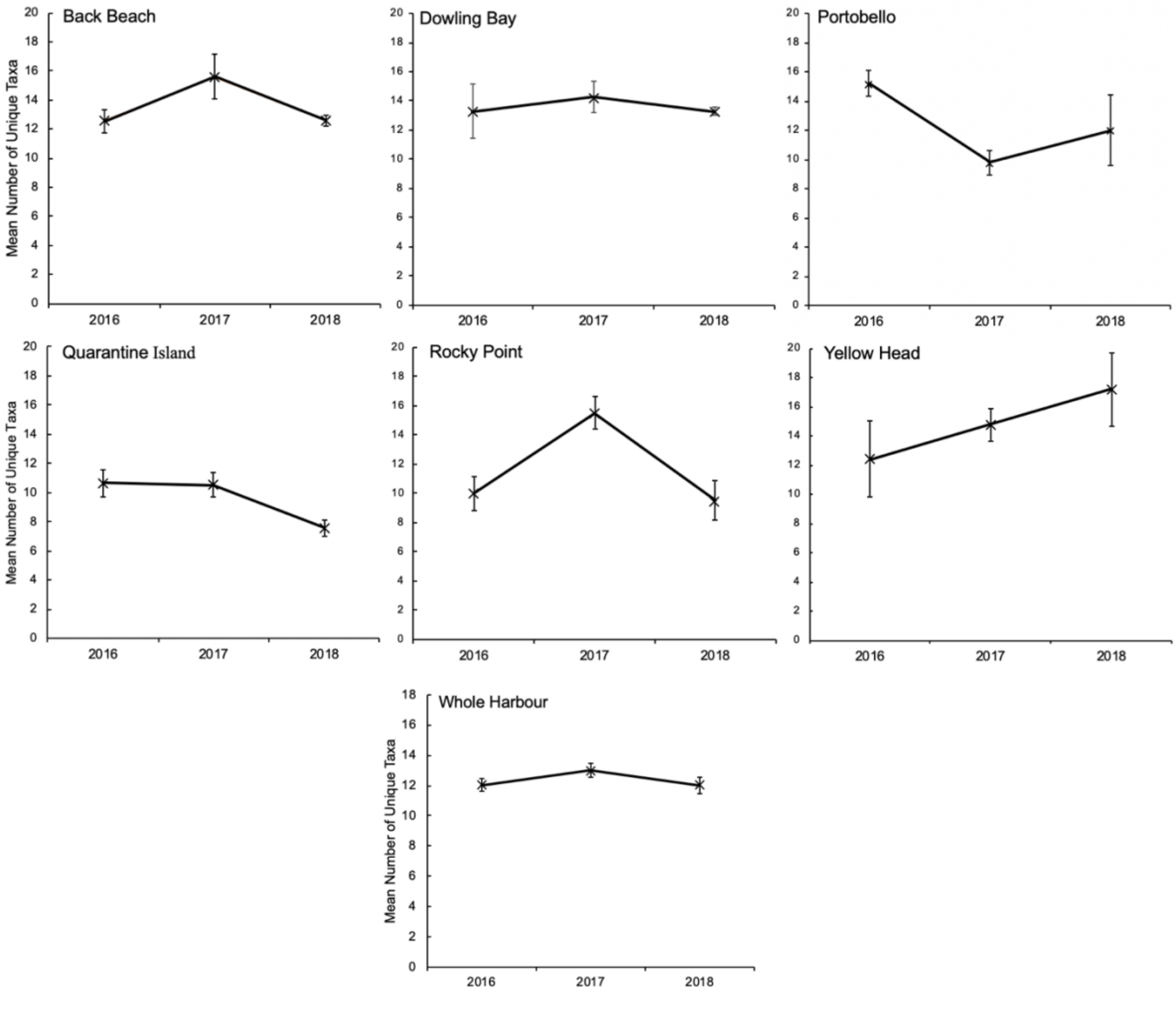

Figure 6: Mean number of unique taxa (± SE) found at low tide for the six study sites monitored as part of the 'Sediments and Seashores' project from 2016 to 2018. The mean number of unique taxa found (± SE) at low tide for the Otago Harbour between 2016 and 2018 is also shown at the bottom ($n_{(2016)} = 68$, $n_{(2017)} = 65$, $n_{(2018)} = 62$)

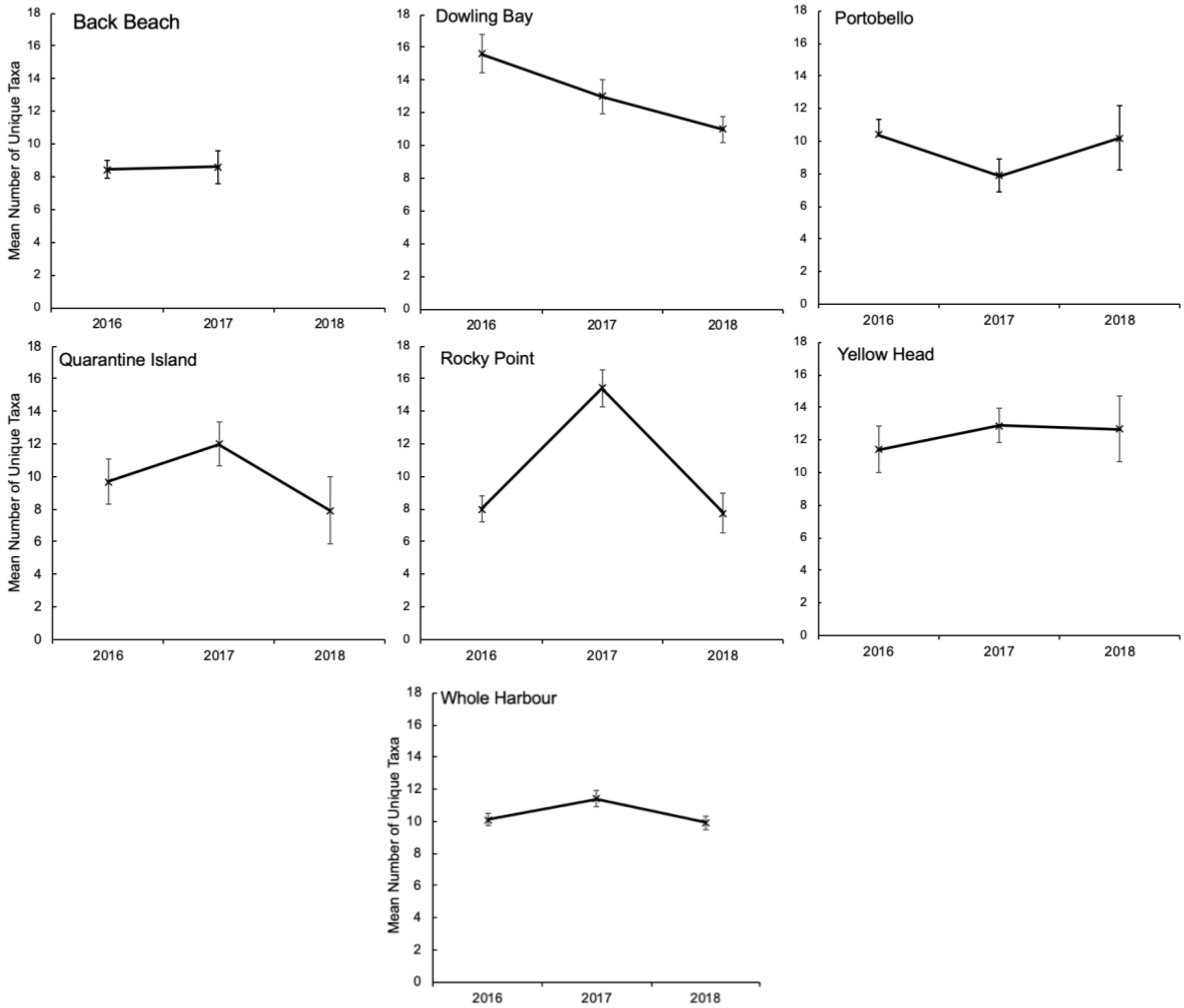

Figure 7: Mean number of unique taxa (± SE) found at mid tide for the six study sites monitored as part of the 'Sediments and Seashores' project from 2016 to 2018. The mean number of unique taxa found (± SE) at mid tide for the Otago Harbour between 2016 and 2018 is also shown at the bottom ($n_{(2016)}$ = 84, $n_{(2017)}$ = 65, $n_{(2018)}$ = 52)

DISCUSSION

Learnings from the 'Sediments and Seashores'

Estimating Small Organisms

When comparing scientists collected data to student collected data in 2017, it was identified that there was difference in the densities recorded for the beaked barnacle (*Austrominius modestus*). Beaked barnacles are common on the rocky intertidal (Carson & Morris, 2017) and often reside in clusters of multiple individuals in densities of 100 or more per 10cm^2 (O'Riordan & Ramsay, 2013). Counting all these individuals can be seen as tedious for students which may result in unreliable estimates of species density or no record of the species at all. Other research has shown that citizen scientists can have selective bias to focus on large, colourful or charismatic species (Parrish et al., 2018). In the context of this project, was often species of crabs, sea stars or intertidal fish (pers. observation). Therefore, to encourage counting of species that are small (less than 2 cm), sessile or slow-moving and have dense patchy distributions, sub-sampling by moving the smaller quadrat (10cm^2) around the 1m^2 quadrat was an option to estimate species density. This method of estimating density was regularly adopted by students whereas scientists would be more likely to take the time to count all the individuals. The differences in the approach could explain how students and scientists calculated different densities of *A. modestus*. This explanation could also be applied to *Spirobranchus cariniferus* (blue tube worms), which although was not found to be statistically significant between surveyors, still showed some differences in density. *S. cariniferus* is similar to *A. modestus* in the sense they are small (up to 40 mm), sessile and can be in aggregations of 1000 individuals per m^2 (Carson & Morris, 2017) therefore were likely to be counted using subsampling.

Species Over Time

Within each of the study sites, there was a range of unique taxa identified between the three years of the project. However, when looking at the data for the harbour as a whole, there was very little variation in the number of taxa found during the project. This relative consistency in the number of taxa found on the rocky intertidal may imply that there has been little impact of sediment on this environment when we look at the harbour as one system. It should also be of note that the number of organisms classed as highly or very highly sensitive to sediment (see 2016 and 2017 reports for more information) have remained relatively stable over the past three years.

When looking at the variability of taxa found at a site level, it appears that there may be more localised effects of sediment and that these effects could be delayed. Many sites, as well as the values for the harbour, all went down slightly in 2018. In 2017, there was a large amount of material removed from the harbour and this is likely to have stirred up fine particles that may be transported towards the shoreline and eventually settle there. To find more information about the potential of localised impacts from excess sedimentation and to also better understand the diversity of the intertidal in Otago Harbour, regular monitoring (as has been achieved as part of this project) is highly recommended.

Sediment Cover Over Time

Mean percentage cover of sediment estimated by students differed significantly between study sites. Quarantine Island had the highest cover of sediment estimated over the course of monitoring compared to the other study sites. In 2017 Quarantine Island was estimated to have 60% mean sediment cover. This was the year in which the capital dredging project removed the largest amount of material from the harbour within the sampling area. The amount of sediment estimated at Quarantine Island in 2018 was significantly lower to that estimated in 2017. Interestingly 2018 had the least amount of material dredged from the harbour since dredging project commenced in April 2015 due to technical issues with the primary dredging vessel and the completion of the first phase of the dredging in the lower harbour. The changes seen at Quarantine Island are similar to the changes in the amount of material dredged.

Quarantine Island, Rocky Point and Back Beach were the study sites closest to the port and the channel. During the data collections these locations were observed to have settled sediment on shallow subtidal macroalgae as well as along the intertidal. This was particularly apparent during sampling on Quarantine Island in 2017. Despite these observations at Back Beach (where sediment was clearly observed settling macroalgae) there was low coverage of sediment estimated. Unlike Quarantine Island and Rocky Point, the shoreline at Back Beach was narrow and made of up predominantly boulders therefore there may have been fewer places for sediment to settle and build up over time. In contrast, Portobello and Yellow Head – which were on the other side of the harbour – had similar trends in estimated mean sediment cover. The variability of estimated mean sediment cover between sites suggests that proximity to the shipping channel may influence sediment accumulation on the rocky intertidal however, this would need more monitoring and greater information of the hydrology in the harbour to further investigate this relationship.

Difficulties of Set Tasks

Assigning tasks that are suitable to the level of those involved has been identified as important for reliable data collections by citizen scientists (Kosmala et al., 2016; Parrish et al., 2018). Younger students did not have the skills or understanding to complete some tasks, such as estimating percentage cover of substrates, without adult support. In contrast older students (aged 13-14) were able to complete their surveys on the rocky intertidal more independently in comparison to the younger students involved and often had less adult support (two to three teachers for 25 students). This could prompt further investigation into age and amount of support on the ability to complete tasks assigned in a monitoring project. Therefore, future projects need simplification of some tasks to be more inclusive or more selective criteria for participants to be involved in future projects are needed. An example of simplifying tasks could be getting students to identify fewer squares using the photographic methods as opposed to all the squares. This would require less time and would be more comparable to other studies that use point-intercept analysis.

Education Outcomes

In an anonymous survey, teachers involved in the 2018 project rated how valuable they thought the project was in terms of developing the science capabilities under the topic ‘Nature of Science’. These capabilities are described as “the weaving strand” through the science curriculum in New Zealand (Ministry of Education, 2007). Most teachers thought this project was ‘valuable’ or ‘very valuable’ in meeting the five capabilities (gather and interpret data, use evidence, critique evidence, interpret representations and engage with science)

(Ministry of Education, 2014). Engaging with science being the most highly rated science capability being met by the project.

The correct identification of common rocky shore snail species increased significantly over the course of the project as was expected. A significant increase in the rate of correct identification between pre- and post-test was observed in *Z. subcarintus* (horn snails) and *Buccinulum* sp. (lined whelks). The assessment of snail identification also demonstrates retention of knowledge learnt during the project as the summary sessions were held at least five weeks after the last time the students encountered snails in their second data collection. This highlights the importance of practical learning when retaining knowledge for species identification.

There was a noticeable shift in the distribution of the students' ideas through the mind map exercise. At the beginning of the project, student responses were focussed on planning the project (background information, asking additional questions, predicting outcomes from the dredging). At the end of the project, students' ideas shifted to more specific thinking on how they would answer the question (i.e. the resources, equipment and techniques they may need to complete their research).

Future Development of 'Sediments and Seashores'

Online training could be a worthwhile investment for the future of this case study. It would reduce the scientist's time in the project but more importantly, online training would provide a resource for teachers to refer back to in the classroom. This could encourage schools to continue monitoring with less assistance from the scientists. One of the issues with this project is that it may have been 'too facilitated' and so teachers may not feel confident enough to lead any aspect of the project without the scientists present. This could potentially be an issue to the longevity of this particular citizen science project, which no longer has a source of secure funding, and so will rely on the initiation of teachers and schools to contact the scientists co-ordinating the project if they wish to continue monitoring.

Technology is an important part of society and should be utilised to increase the number of people engaging with citizen science by making it more accessible. Funding opportunities should be provided to assist in the development and maintenance of both apps and websites. Incorporating technology – particularly apps and smartphones – into citizen science has been highly recommended in other research (Shah & Martinez, 2016; Hecker et al., 2018; Peters, 2018). Examples of using robust automatic techniques to assess quality of data entered online by citizen scientists includes flagging systems for unexpected data (e.g. invasive species, species out of normal range) (Bonter & Cooper, 2012; Dickinson et al., 2012) or verification of photographs by other members in the online community (Parrish et al., 2018). There have also been discussions on the potential of automatic photo recognition technology (Wiggins et al., 2011). Adopting these mechanisms (or similar) for online citizen science projects could greatly reduce the reliance upon the scientists to complete quality control measures. Therefore, improvement and further development of the technology used in this case study is highly recommended and could reduce the time and costs to engage scientists over the long term.

Directions for Those Who Have Taken Part

As stated above, continued monitoring of the rocky intertidal is highly recommended to better understand the relationship of the diversity on the shore to the potential effects of excess sedimentation from the dredging. Ideally, schools that have participated over the past three years will take ownership of their study sites and monitor these locations. This does not have to be an entirely individual project, as the NZMSC is willing to provide support. However, this will not be as extensive as has been done in the 'Sediments and Seashores' report. The support from Port Otago Ltd. could be useful to help continue the legacy of 'Sediments and Seashores' through supporting public days where monitoring data could also be collected. This would provide an opportunity for the community to follow through with their own concerns about the dredging and contribute to the substantial dataset that has been collected through the 'Sediments and Seashores' project. It is hoped that this dataset will come in use for future monitoring endeavours within the Otago Harbour.

Additional Outcomes of the Project

The data collected during the three years of the 'Sediments and Seashores' project has been used for a master's thesis as well as presented at the Citizen Science Association (USA) conference in 2019. In addition, ‘Sediments and Seashores’ has been used as an exemplary case study for workshops and in conference presentations around New Zealand as well as Australia and the United States. ‘Sediments and Seashores’ was also the subject of a short film produced by a University of Otago Science Communication graduate student which has been well-received (to view use this link: https://youtu.be/JZigGb06Vd8) . Participating schools have used their experiences from the ‘Sediments and Seashores’ project as evidence to gain Enviroschool status. Students from multiple schools have also been awarded CREST awards from the Royal Society Te Apārangi for their participation in the ‘Sediments and Seashores’ project (see image on front page).

CONCLUSIONS

This facilitated citizen science project has succeeded in collecting scientifically validated data, engaging multiple stakeholders into a monitoring project and demonstrated educational links to the national curriculum. This project is a strong case study not only for facilitated citizen science in New Zealand but also as a marine facilitated citizen science project. The regular monitoring of this project has contributed three years' worth of regular monitoring of the rocky intertidal which otherwise would not have been collected (as scientists gathering data as required by the consent for the dredging project only assess the rocky intertidal every three years) (Port Otago Limited, 2010). Information from the project not only provides more detail to the fluctuations of sediment on the intertidal (and the short effects of this) but also contributes to knowledge of the ecology of the Otago Harbour for both scientists and the wider public involved. This project also had the opportunity to bring multiple stakeholders together – local government, the Port, scientists, and the wider community – which over time eased tensions surrounding the issue of the dredging. Support for on-going monitoring for schools that have previously been involved is available however, this will not be possible at the same intensity as provided in the first three years of the facilitated citizen science project.

Citizen science is in no way a replacement for professionally collected data but rather can complement and enhance scientific research (Dennis et al., 2017; Dickinson et al., 2010; Freiwald et al., 2018; Koss et al., 2009). As stable funding for long-term scientific research projects is highly difficult (and often rare) (Lovett et al., 2007; Müller et al., 2010), citizen science can assist in collecting data at broad and fine spatiotemporal scales which is needed for addressing large scale conservation issues (Burgess et al., 2017). Sometimes having a more simplistic monitoring approach that can be sustained over time will provide data that is more beneficial for resource managers in the long run. Ideally, resource managers would adopt the combination of consistently collected data with regular periods of intensive monitoring. This approach would work well in the continuation of monitoring the intertidal in Otago Harbour.

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