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Estuarine Research Report 47

Recreational Survey and Evaluation of Cockle (Tuaki) Resources in the Avon-Heathcote Estuary/Ihutai, Summer 2017-2018

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Report prepared for the Avon-Heathcote Estuary Ihutai Trust
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Executive Summary

1. The present study was undertaken in response to public concern regarding the collecting of the cockle or Tuaki *Austrovenus stutchburyii* on low tide mudflats on the Redcliffs side the Avon-Heathcote Estuary/Ihutai. There was concern whether the Tuaki population could sustain current and increased levels of harvesting. Using a mixed methods approach, standard scientific methods were used to evaluate Tuaki abundances and a survey using a questionnaire used to assess recreational activites, estuary values and current management practices.

2. Ten sites were selected to investigate Tuaki populations between the Heathcote bridge, along the McCormacks Bay causeway to Monks Bay. Four replicate 50 x 50 cm^2 quadrats were excavated to assess abundance and determine the size structure of the population. Abundances were site specific, highest at Monks Bay (850 m^{-2}) and some west sites on the causeway (314 m^{-2}) and lowest in the causeway channel (29 m^{-2}). Since 2012, Tuaki abundances have reduced considerably in the causeway channel. Populations of Tuaki from all sites comprised individuals of a wide size range suggesting regular recruitment. Apart from Monks Bay, all sites had large cockles (>30mm shell length) of harvestable size.

3. Wet weight biomass m^{-2} was highest on the city side of causeway (3000g m^{-2}) and lowest at the Mt Pleasant and Christchurch yacht clubs (270g m^{-2}). Wet weight biomass values were also low on the eastern part of the causeway sandbank (567 g. m^{-2}) and channel (453g. m^{-2}).

4. The Tuaki dry weight tissue values g. m^{-2} were site specific, highest on the west or city side of the causeway and for individuals collected from Monks Bay (78 g. m^{-2}). Values were however considerably reduced compared with previous studies. The dry weight tissue values were not related to the distance from the estuary mouth.

5. Condition index (dry weight of tissue/ shell dry weight) was generally low (<3) for most sites. Highest values (>6) were from Monks Bay near the mouth of the estuary where the population was dominated by smaller length individuals. The poor condition of some large Tuaki within the estuary suggests that they had spawned.

6. The abundance of birds on the mudflats at low tides at each site was assessed as a potential indicator of estuary health. Oyster catchers were the most common species at all sites with highest numbers on the west side of the causeway, where there was also a large number of gulls. There was no relationship between the total number of birds or individual species groups with Tuaki abundance or tissue dry weight biomass m^{-2}.The lack of godwits at some sites most likely reflects the lack of suitable food resources.

7. A recreational survey of 101 Estuary users, included 31 people who were targeted because they were observed digging on the mudflats. Most respondees were from local suburbs and more than 40% of people visited the specific area frequently, more than once a week. Most (>80%) rated the estuary fair to good in terms of estuary health. Common indicators of good estuary health were presence of birds, water clarity and wildlife such as fish. Poor indicators included pollution, rubbish, smell, slime and a reduction in wildlife. Seaweed was listed amongst the good indicators but too much nuisance seaweed such as sea lettuce was listed as an indicator of poor environmental health. Generally people were unaware of current management practices in the estuary and many had noticed changes after the Canterbury earthquake sequences between 2010 and 2012. Few people including those collecting knew what the bag limit was for Tuaki.

8. The sustainability of Tuaki populations in the study area was assessed in the light of current and potential increase in recreational harvesters. The 700 m length of mudflats along the causeway contains about 1.5 million harvestable size Tuaki. Collecting was observed mainly in a smaller area on a sandbank west of a channel close to the Beachville Rd jetty. Based on preliminary information harvesting within this small restricted area of mudflats could remove 26% of harvestable size Tuaki annually. This research found thriving Tuaki populations in some locations but it is uncertain whether the mudflats could sustain current or increased collecting in the future.

9. Recommendations were made for future management of shellfish resources in Ihutai. These included estuary wide scientific investigations, education, signage and an accurate assessment of the Tuaki recreational shellfish catch.

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1. Introduction

The Avon-Heathcote Estuary/Ihutai is a small (880 hectare) shallow inlet situated 12 Km from the centre of Christchurch City. Te Ihutai is home to numerous organisms from different trophic levels including birds, fish, invertebrates, as well as algae. There is a long history of human settlement in the estuary. Waitaha were amongst the first inhabitants, building whare in the area in the mid 1600s. Moving from site to site the people were hunter gatherers and the estuary was part of a network of waterway and a source of abundant tuna (eels), kakakana (lamprey), inanga (whitebait), patiki (flounder) and pipi (shellfish). Early European settlers, arriving in the 1850s, used the estuary as an important place for trading ships to bring resources and machinery as well as new settlers in to the area. Later on as Christchurch developed, the Avon and Heathcote rivers were used as recreation spots and means of travel, boats taking passengers into the city (Harris, 1992). One species that has been collected, used as a food resource and valued for over 600 years is *Austrovenus stutchburyi*, or Tuaki commonly referred to as the little- neck or estuarine cockle.

Over the past 60 years the estuary has seen many anthropogenic changes due to the enlargement of Christchurch City and in the 1950s, the development of a sewerage treatment systems (Marsden et al 2004). Over time the discharge systems improved and from 2010 treated sewage was no longer discharged into the estuary and the ocean pipeline was used to discharge treated waste some 3km off shore. The Christchurch earthquake resulted in changes in elevation within the estuary, regions sinking in areas close to the Avon Otakaro and elevated in areas close to the Heathcote. Large disturbances were seen on the mudflats, saltmarshes and seagrass areas and while some of the areas such as the mudflats appeared to recover quickly (Zeldis et al., 2011), others have been slow (Reid et al., 2012) . Post earthquake studies on some specific estuarine habitats has suggested that biodiversity remained high in selected bird feeding and shellfish habitats (Gwatkin and Marsden, 2014). Traditionally shellfish gathering for human consumption has been discouraged in the estuary due to high levels of pathogens. There is signage but largely this is overlooked and certain places especially along the McCormacks Bay causeway are now favoured for Tuaki collection.

1.2 Previous studies.

There has been extensive research undertaken within Te Ihutai over the past 25 years. This has included regular monitoring by the Christchurch City Council and Environment Canterbury as part of coastal management, the Healthy Estuary and Rivers programme, food safety, swimming and water quality. There have also been food gathering surveys (Fisher and Valance, 2010), cultural evaluations (Pauling et al. 2007, Lang et al. 2012) and scientific research on biomonitoring, shellfish biology and trophic relationships (Robertson et al. 2002, Marsden, 1998, 2012, Marsden et al. 2013). Postgraduate and other research within Te Ihutai has looked at many different aspects of the estuary, from the sediment composition, hydrography and percentage of contaminants within the sediments. This information has been compiled within a biography of research by Corliss P. (2018).

1.3 Research objectives

This research arose because of public concern regarding the numbers of people observed collecting shellfish in Te Ihutai. At times up to 20 people had been seen digging and collecting shellfish into buckets and containers close to the causeway separating McCormacks Bay with the main estuary mudflats. We were interested in finding out the abundance and health of Tuaki within the southern parts of the estuary and whether it is a sustainable resource. We also wanted to find out how often people collected shellfish and whether they knew about the regulations regarding collecting. Finally, because there had been many changes in the estuarine ecosystem following the earthquake (Measures et al. 2011), we also wanted to evaluate the general health of the mudflats by using birds as indicator species. Birds have been used widely as sentinels of ecosystem health especially in places where there have been changes in habitat quality (Smits and Fernie, 2013). This research that was conducted between November 2017 and February 2018 therefore included a survey of cockle abundance and biomass, an evaluation of the habitats using birds and a survey to evaluate people's collecting activities and their perceptions of the current and past health of Te Ihutai.

2. Methods

2.1 Site selection

Ten low tide sites (Fig.1, Table 1) were selected along the southern edge of the Estuary reflecting a change in environmental conditions from the more saline regions near the mouth of the estuary at Shag Rock to less saline areas close to the river mouth at the Heathcote Bridge. It was not possible to sample the eastern side of Beachville Rd opposite the end of the sandspit because of a rip rap wall which prevented safe access to the lower intertidal.

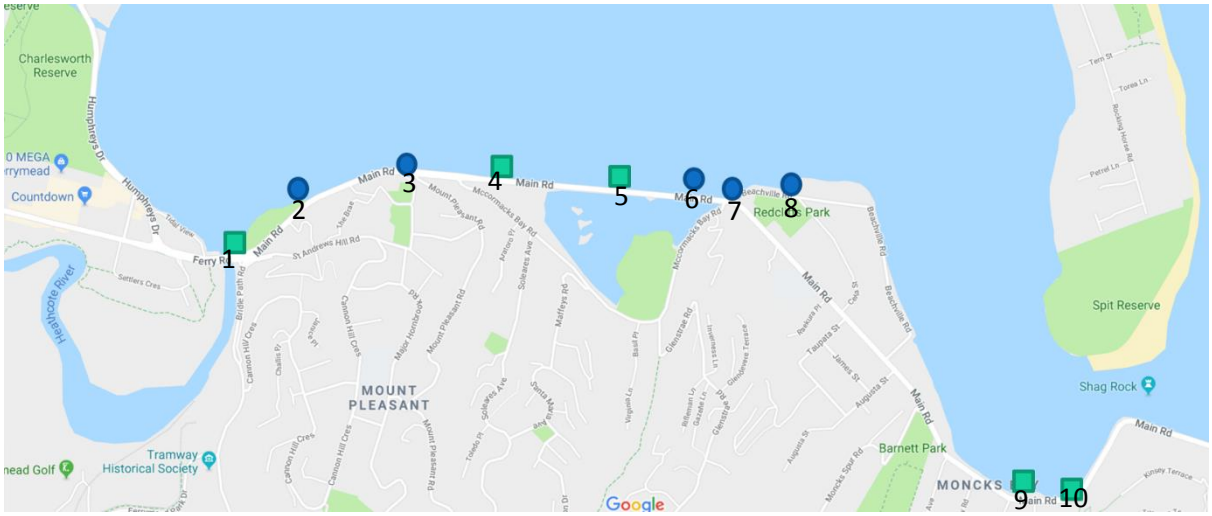


Figure 1. Sites selected for estuary sampling and bird observations: 1, Heathcote Bridge; 2, Mount Pleasant Yacht Club; 3, Bird Point; 4,Causeway; 5,Causeway Bridge; 6,Causeway Island; 7, Causeway Channel; 8, Beachville Rd; 9, Christchurch Yacht Club; 10, Monks Bay. Circles show sites sampled in November 2017, Squares those sampled in January/February 2018.

Table 1 Site numbers and names for 10 sampling sites with GPS coordinates of quadrats selected for Tuaki sampling.

1. Heathcote Bridge HB				
e1576504	e1576506	e1576507	e1576452	
n5177186	N5177220	n5177256	n5177174	
2. Mount Pleasant Yacht club – MP				
e1576883	e1576812	e1576841	e1576787	
n5477491	n517490	n5177465	n5177508	
3. Bird Point-BP				
e1577195	e1577150	e1577110	e1577058	
n5177558	n5177632	n5177571	n5177567	
4. Causeway- CW				
e1577341	e1577337	e15577456	e1577521	
n5177548	n5177544	n5177500	n5177488	
5. Causeway Bridge- CB				
e1578000	e1577964	e1578047	e1577886	
n5177400	n5177457	n5177421	n5177479	
6. Causeway Island- CI				
e1578227	e1578220	e1578180	e1578140	
n5177494	n5177466	n5177457	n5177457	
7. Causeway Channel- CC				
e1578335	e1578333	e1578306	e1578288	
n5177436	n5177427	n5177402	n5177400	
8. Beachville Rd Jetty – BV				
e1577255	e1577286	e1577320	e1578484	e1578556
n5177192	n5177166	n5177183	n5177182	e5177180
9. Christchurch Yacht club- CCYC				
e1579564	e1579555	e1579543	e1579503	
n5176297	n5176294	n5176290	n5176283	
10. Monks Bay – MB				
e1579617	e1579606	e1579598	e1579585	
n5176337	n5176329	n5176318	n5176310	

2.2 Site descriptions

Site 1. Heathcote Bridge

The closest point to the mouth of the Heathcote river. The low-tide substrate is a mix of sand and fine mud. At the top of the shore there is medium sized rocks and gravel with accumulations of drift sea lettuce. Due to its location between the river and Mount Pleasant yacht club few people visit this site.

Site 2. Mount Pleasant Yacht Club

The substrate comprises mostly mud with large areas of shallow sloping exposed mudflats at low tide. At the upper tidal levels there are large stones and gravel. Due to its location in front of the yacht club the site is often visited by the public.

Site 3. Bird Point

This site is located west of the start of the causeway. The area has a rocky outcrop on one side where birds often sit. The intertidal substrate is a mix of sand on the upper layer (top 5cm) and made up of mostly mud deeper down. Because of access this site has limited visitors and is favoured by birds during the time between peak high and low tide.

Site 4. Causeway

The substrate is mainly made up of sand at mid tidal levels and mud at lower tidal levels. Although it appears to be easily accessible, it is rarely visited by the public. Rocks present at upper tidal levels appear to make it unappealing to people digging for bait and cockles. At the time of sampling there was a medium layer of sea lettuce across the site.

Figure 2. Site descriptions and photos of 10 sites along the southern edge of Te Ihutai.

Site 5. Causeway Bridge

This site is where the main channel draining McCormacks Bay enters the estuary. Although it is accessible from the cycleway/ footpath by stairs, it has limited foot traffic because it is not close to a car park. The substrate is made up of mostly mud with cockle shells and rocks. Close by this site there were extensive banks of sea lettuce.

Site 6. Causeway Island

Located close to the sandbank which runs parallel to the causeway, this site is mostly sand with a large amount of cockle shells of varying sizes. The sandbanks are exposed especially during spring low tides and this is probably one of the most popular areas for shellfish gathering throughout the year.

Site 7. Causeway Channel

This site is at the southern part of McCormacks Bay where it drains into the estuary at the southern end of the causeway. It has heavy foot traffic throughout the year because it provides a route to the causeway island. The substrate is comprised of a mix of sand and mud. Although the mud appears to be a healthy there was a distinct anoxic layer just below the surface.

Figure 2 (Continued). Site descriptions and photos of 10 sites along the southern edge of Ihutai.

Site 8. Beachville Rd

This site is adjacent to the jettty on Beachville Rd and provides easy access to the estuarine mudflats. The high tide area are rip-rap, the mid tide has occasional rocks and the low-tide substrate is very sandy. Not visited as often as the causeway island or channel, it is still frequently visited by local people, often with pets.

Site 9. Christchurch Yacht Club

Next to the yacht club this site is frequently used by people as a boat ramp to access the estuary. In the summer, young people swim and jump off the jetty. At upper tidal levels there is gravel and small stones at the base of the wall and at low tide there is sandy substrate with occasional stones.

Site 10. Monks Bay

The closest point to the ocean, this estuarine site has a rock wall at upper levels, gravel and stones in the mid tide and coarse sand and shells at lower tidal levels. The site is close to a small storm water drain. There are newly established patches of seagrass with juveniles cockles. Few people visit this site perhaps due to limited tidal accessibility.

Figure 2 (Continued). Site descriptions and photos of 10 sites along the southern edge of Ihutai.

2.3 Tuaki - Cockle abundances, size distributions, biomass and health

Tuaki abundances and size distribution were measured between December 2017 and January 2018 from each of the 10 low tide sites by digging 4 replicate 50 x 50cm quadrats to a depth of 15cm The substrate was sieved through a 1mm sieve and all the bivalves counted and the shell length of each individual measured to the nearest mm. From each quadrat, 3 or 4 random individuals representing the population size range were collected to provide a sample of 15-20 individuals from each site to estimate the biomass and calculate the condition index and weight relationships and health of Tuaki. These values provide information on the stage of the reproductive cycle of the bivalve.

In the laboratory the length of the shell was measured, the live wet weight was recorded and the bivalve dissected to remove the tissues. The tissue was placed onto pre-weighed tinfoil, and these together with the shells were dried at 50^{o}C for three days to measure the dry weight. Wet weight biomass, including the shell, is used in fisheries assessments of shellfish resources and the dry weight relationships are used to assess the changes in the tissue weight over time.

Calculations

Average tuaki abundances (number m^{-1}) were estimated from the mean of the 4 replicate quadrats. The population size frequency distribution of the tuaki was estimated for each site by combining the individuals from all replicate quadrats and grouping individuals into 5mm length groups. This provided a population histogram for each site. The individual weights of tuaki from each site were used to estimate the wet weight biomass m^{-1} using regression analysis, relating the wet weight of tuaki to its shell length. Similar relationships were also plotted for the relationships between dry weight of tissue to shell length. This allowed calculation of the dry weight biomass m^{-1} for each site. Tuaki health for the subsample was estimated for each site using a dry weight condition index (Marsden,2004). This was dry weight tissue/shell dry weight x 10. The mean and SE of each sample was used to compare between sites.

2.4 Bird Observations

Bird observations were undertaken using binoculars or by eye at the mid to low tide 10 sites as in previous studies (Love, 1997; Gray, 2009). They were made between 2 hours before and 2 hrs after low tide in a predefined area 25 m each side of a specified marker point. The number of each species was recorded over a 5 minute observation period and this was repeated four times at each site ensuring a gap of at least 15 minutes between measurements so samples would be independent.

2.5 Recreational survey

The questionnaire used in the recreational survey (Appendix Table 1) included selected questions from similar assessments of shellfish resources in North Canterbury, Banks Peninsula and Te Ihutai (Mudunaivalu, 2013; Kainamu-Murchie, 2016; Kainamu Murchie et al., 2018). The survey design, information sheet and questionnaire were reviewed and approved by the University of Canterbury Human Ethics Committee. The survey was designed to gather information on the types and frequency of recreational activities including shellfish collection in the estuary, people's views on environmental health and current management practices. People were approached who were on and near the estuary in summer between November 2017 and February 2018. The aim was to gather information from general beach users and those gathering shellfish. A total of 101 surveys were assessed, and from these 31 were from people who were collecting from the estuary (Appendix 1). The

information from the questionnaires was entered in excel worksheets and summarised using tables and graphs.

2.6 Statistical analyses

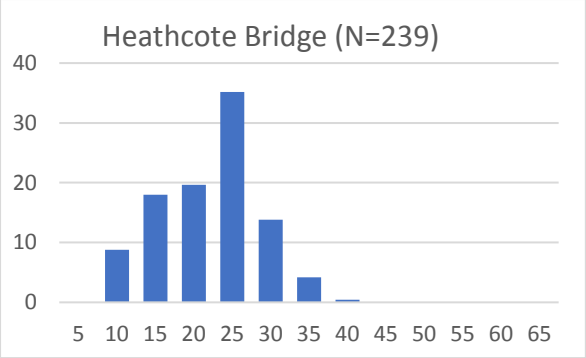
All statistical analyses were done using excel. For the cockles we calculated the dry weight condition index for a sample of 15 or more cockles from each site using the ratio dry weight/shell dry weight shell x10. Relationships between shell length and wet body weight and the population histograms were used to calculate the total biomass m^{-2}. Similar calculations were undertaken to estimate the dry weight biomass m^{-2}. Single factor ANOVA was used to test for differences in mean values amongst sites and the confidence limit was set at P =0.05.

3 RESULTS

3.1 Tuaki

3.1.1 Size frequency distributions.

The size frequency information from each site was site specific (Fig.3) The histograms were mostly unimodal with the mean and modal values increasing eastwards in populations towards the causeway. At the causeway bridge and island the individuals were larger than those elsewhere and the populations were bimodal, becoming multimodal at the yatch club. Here Tuaki had the largest size range from 5 mm shell length to 60 mm shell length. The Tuaki population nearest to the sea had the smallest modal shell length (15mm).



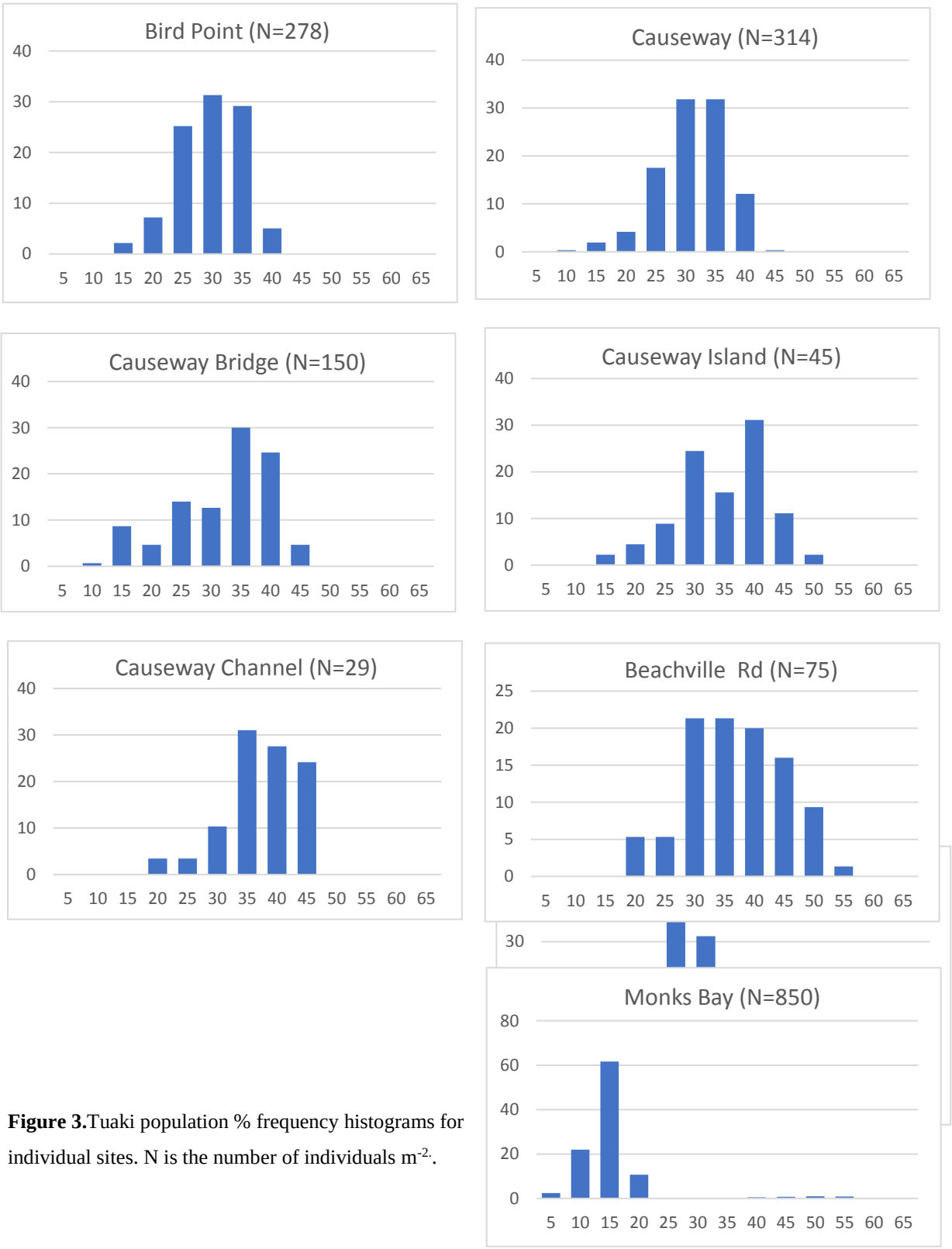
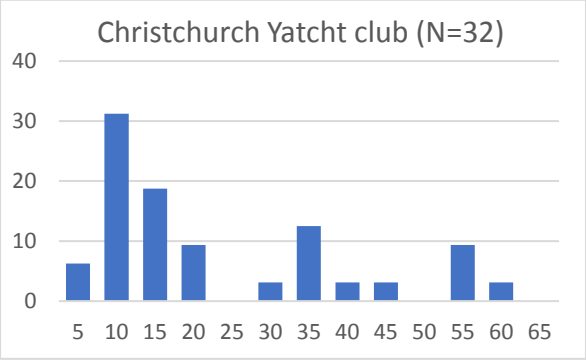


Figure 3. Tuaki population % frequency histograms for individual sites. N is the number of individuals m^{-2}.

Figure 3 (continued). Tuaki population % frequency histograms (5mm length groups) for individual sites. N is the number of individuals m^{-2} .

3.1.2 Abundances

Tuaki abundances m^{-2} varied amongst the sites (Fig.4). Lowest values (approx. 30 m^{-2}) were recorded for the Causeway channel and Christchurch yacht club and highest abundances at Monks Bay (close to 900 m^{-2}). There were intermediate densities (between 100-300 c) for all of the western sites along the causeway. Tuaki abundances were significantly different (ANOVA F= 4.57 df =9, $p < 0.01$). When removing the Monks Bay sample (which had a much larger number of individuals found than other sites), there was still a significant difference in abundance between the sites (F= 4.16, df =8, $p<0.01$).



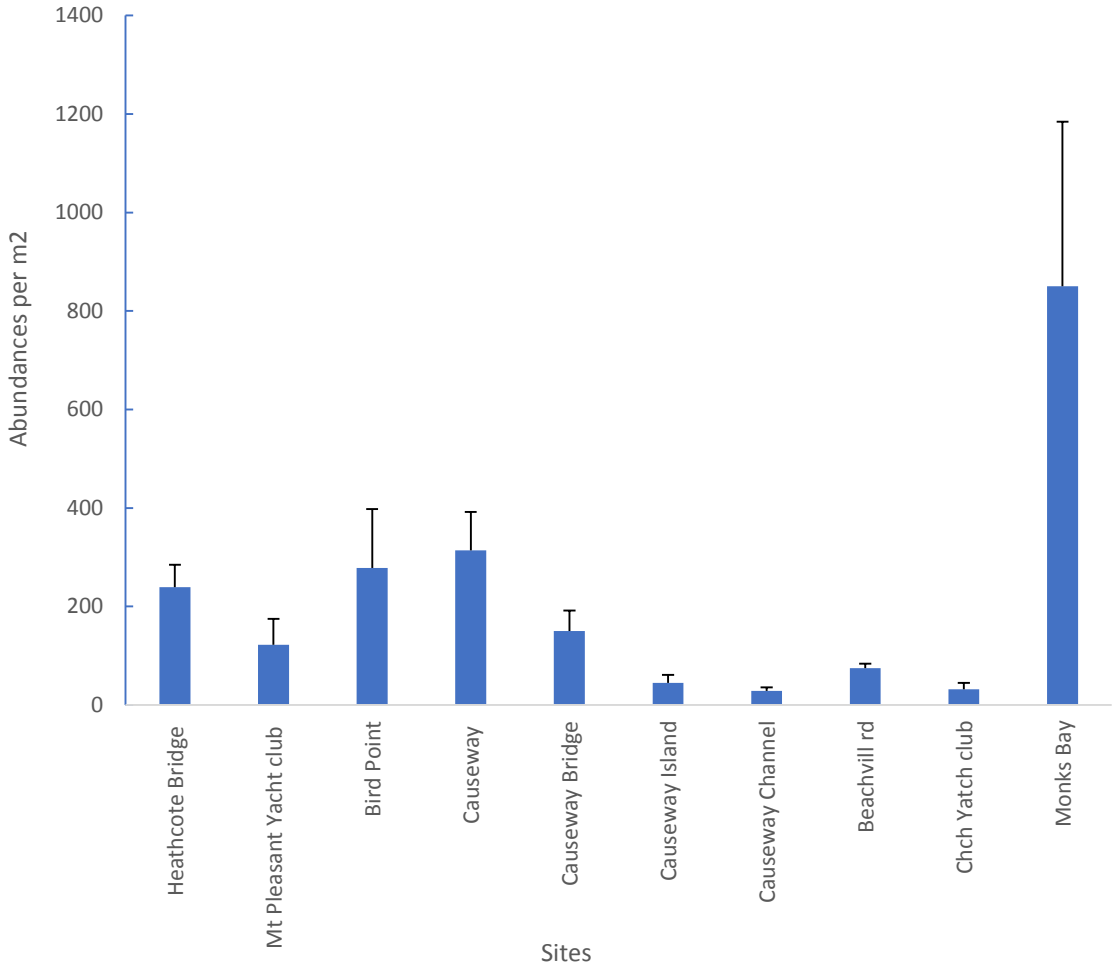


Figure 4. Tuaki mean abundance (±SE) m^{-2}

3.1.3 Wet weight Biomass (g) per m^2

Tuaki wet weight biomass was highly variable amongst sites (Fig. 5). The sites with the highest wet weight biomass were along the eastern part of the causeway with almost 3kg Tuaki m^{-2} at the most western causeway site followed closely by bird point and the causeway bridge. The site with the lowest wet weight biomass was the Christchurch Yacht club and low values (less than 500 g. m^{-2}) were recorded from the Causeway channel and Causeway island.

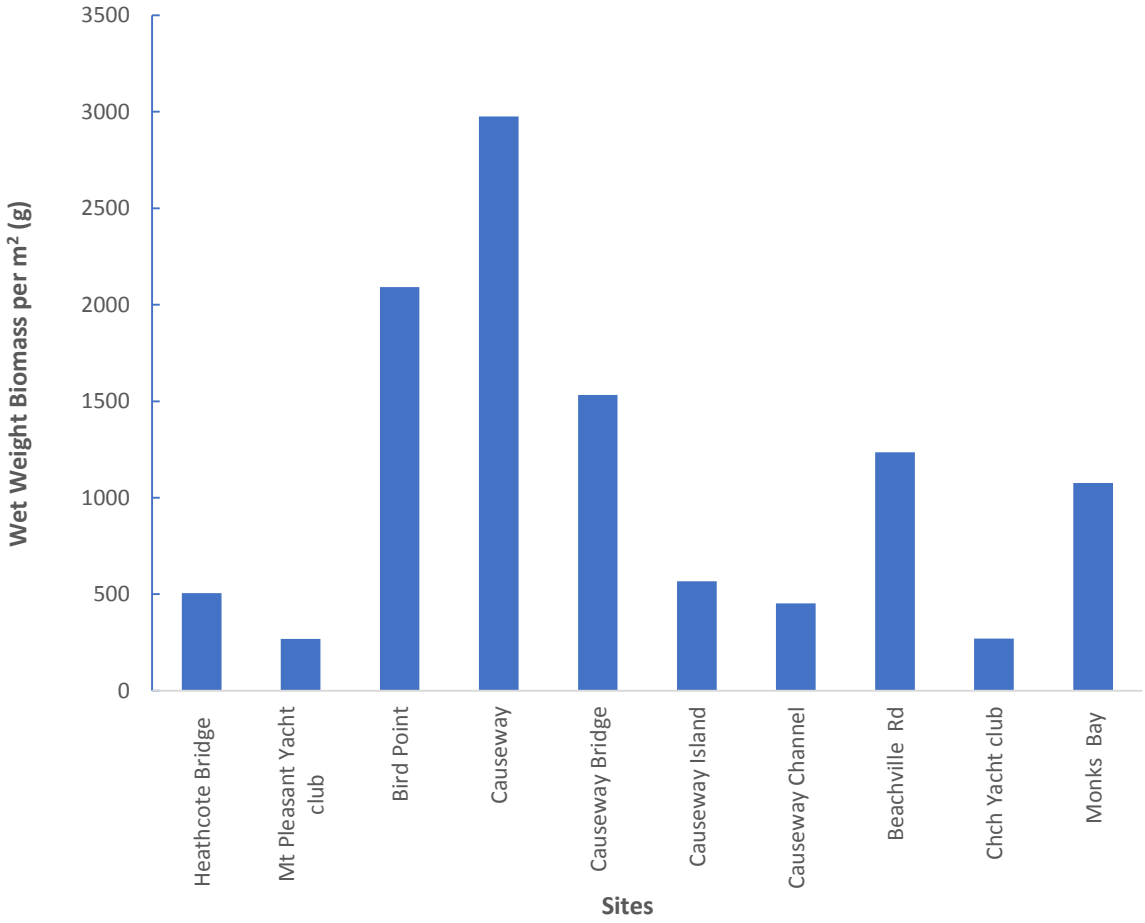


Figure 5. Tuaki, wet weight biomass g. m^{-2}

3.1.4 Dry weight biomass (g) per m^2

Dry weight tissue biomass was highly variable amongst sites (Fig. 6). The highest dry weight biomass m^{-2} were found along the western side of the causeway and at Monks Bay. The sites with the lowest dry weight biomass were the Christchurch Yacht club and the causeway channel and island. There was no consistent pattern in dry weight biomass m^{-2} with distance from the estuary mouth.

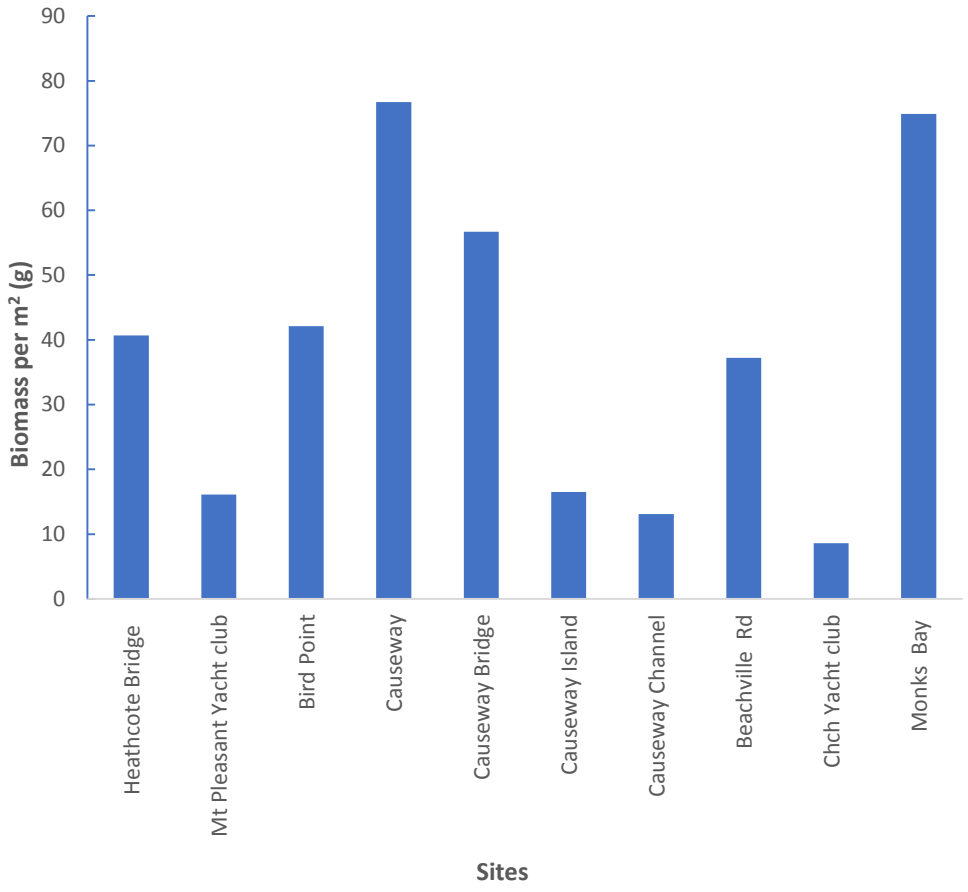


Figure 6. Dry weight tissue biomass m^{-2}

3.1.5 Condition index

Dry weight condition index of Tuaki varied significantly amongst the sites (Fig.7). The site with Tuaki with the highest condition index was Monks Bay (CI of 7), followed by Christchurch Yacht club (CI =5). The site where Tuaki had the lowest condition index, was Mt Pleasant yacht club with an index less than 1. The condition index of Tuaki from five of the 10 sites was similar (labelled b in below).

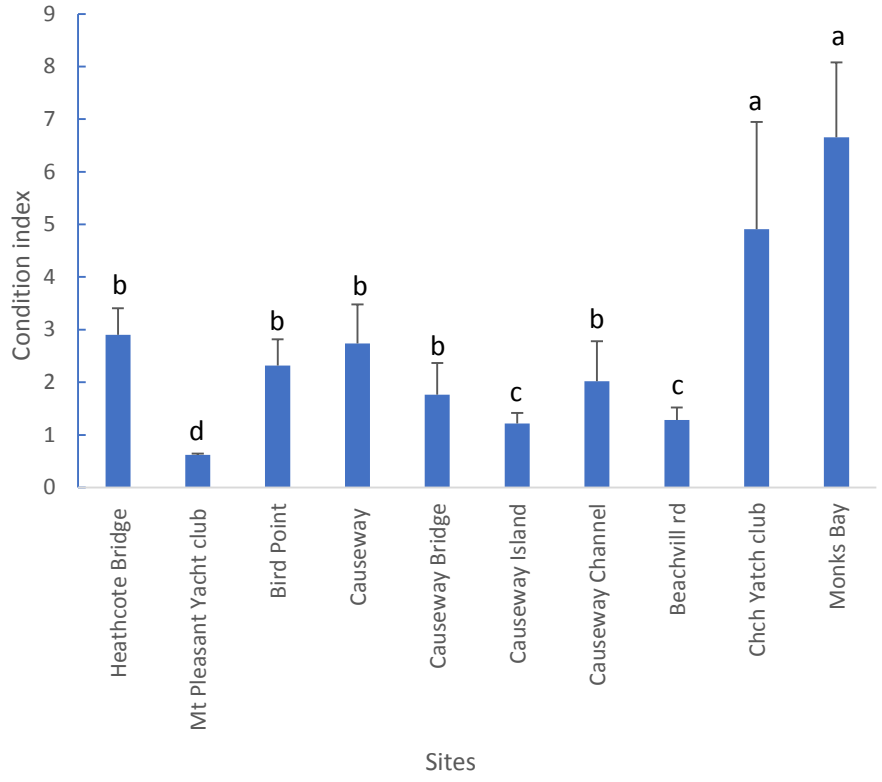


Figure 7. Average dry weight condition index (±SE). Sites shown with the same letter have CI values which are the same.

3.1.6 Tuaki Fishery Assessment

The potential area for collecting Tuaki along the causeway to the Beachville Rd Jetty is approximately 700 m in length with a beach width of approximately 20 m, with an estimated total area of 14000 m^2. Using the population structures and abundances (Figs 3 and 4), the average number of Tuaki greater than 30mm shell length was 105.5 m^{-2} with SD of 88.2. The large variance makes estimating the total number available for harvest unreliable. Using the mean value alone the estimated number of harvestable Tuaki to be approximately 1.5

million. There are fisheries modelling techniques available to estimate the allowable sustainable catch for this area but this calculation is outside the current scope of this research.

Observations within the study area confirmed that the main areas for collecting Tuaki were half way along the causeway to the southern channel draining from McCormacks Bay. Most of the shellfish collecting effort was concentrated in this 250 m strip which is approximately 20 m in width. Here the abundances were generally much lower (34.5 Tuaki m^{-2}) than further west along the causeway. The estimated number of harvestable size Tuaki for this area (5000 m^2) would be 172,500 individuals. The current regulations allow the collection of 150 Tuaki per person per day then if there were 1000 collectors per annum this resource could be totally depleted. Using a more conservative estimate of 300 collectors per annum, collectors might remove 45000 individuals. This would represent a 26% removal of this length group, from the harvestable population.

3.2 Bird Observations

At low tide birds were seen on the mudflats foraging, socially interacting or on rocks or hard edges resting or preening. At other times when benthic sampling, spoonbills and black backed gulls were seen as well as variable oystercatchers. Bird abundances were variable (Table 2) with oyster catchers being most common followed by gulls and godwits. Shags were frequently observed at Bird Point on rocks adjacent to the causeway. Highest bird numbers were recorded on the western side of the causeway (CW) where abundances exceeded 150 birds, dominated by oyster catchers and gulls but also including godwits. Lowest bird numbers were recorded from Monks Bay (MB) towards the mouth of the estuary. Godwits were not recorded at 6 out of the 10 sites. There was no significant relationship between the number of oyster catchers and either cockle abundances or dry weight biomass m^2 (Spearman Rank correlation values > P=0.05).

Table 2. Bird abundances (Average (SE) at low tides for 10 sites along the southern margin of the estuary.

	Heathcote Bridge	Mount Pleasant	Bird Point	Causeway	Causeway Bird Point

Oyster Catchers	2.5 (2.8)	17.75 (8.9)	14.3 (7.1)	95.3 (47.6)	44.3 (22.1)
Godwits	0	0	0	20.3 (10.1)	22.8(11.4)
Shags	1.3 (0.6)	0	11.8 (5.9)	0.8 (0.4)	0.3 (0.1)
Gulls	37.8 (18.9)	12.3 (7.3)	13.3 (6.6)	35.3 (17.6)	5.3 (2.6)

	Causeway Island	Causeway Chanel	Beachville Rd	Christchurch Yacht Club	Monks bay
Oyster Catchers	23.5 (11.8)	35.5 (17.8)	6 (3.0)	1.8 (0.9)	0.8 (0.4)
Godwits	0	20.7 (10.3)	0	0	0
Shags	0.8 (0.4)	0.8 (0.4)	0	2.2 (1.1)	0
Gulls	1.3 (0.6)	10.3 (5.1)	10.3 (5.1)	6.8 (3.4)	0.5 (0.3)

3.2 Recreational Survey

3.2.1 Survey Respondents

A total of 101 estuary users answered the questionnaire and this included 31 people who were actively gathering material on the mudflats. This latter group were targeted and therefore the total number does not represent the proportion of estuary users who were digging on the mudflats. Few people were walking on the mudflats and most were on the footpath or cycleway. Of all the people surveyed 51 % were male while 49% were female. This contrasted with the collectors where 69% were male while 31% were female. While interviewing groups on the mudflats, only one person from each group answered the questions and this person was more likely to be the male. For the total survey, half of the people surveyed identified themselves as being New Zealanders (Fig. 8), 17% European then 11% Māori and the remainder identifying as Fillipeno, Asian, South African or from other countries. Those who were collecting came from the same groups with slightly more Māori (23%), followed closely by Filipino (19%) then by New Zealanders (16%).

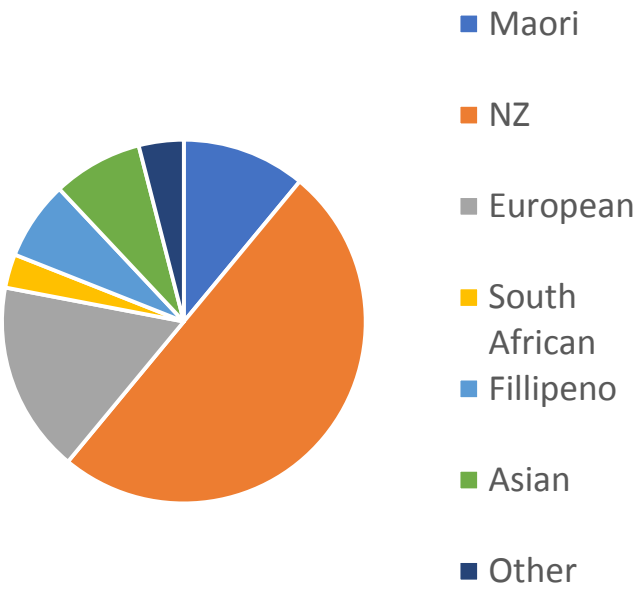


Figure 8. Ethnicity of respondents who answered the recreational survey (number =101).

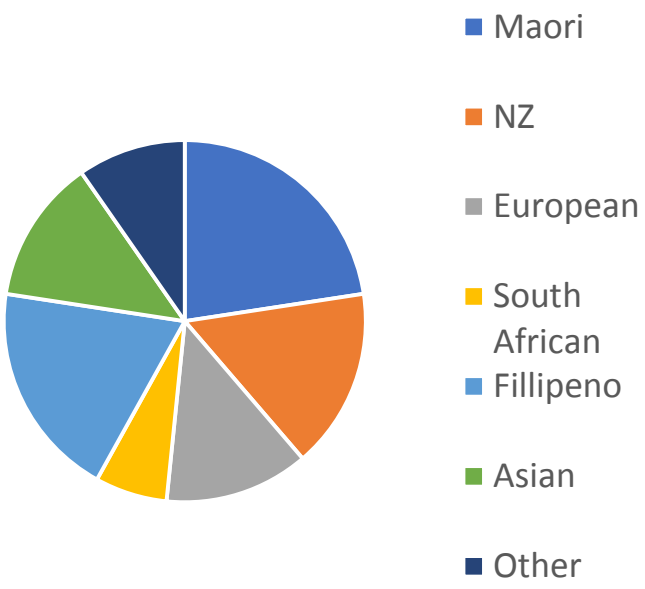


Figure 9. Ethnicity of respondents who were gathering on the estuary (number = 31).

Only adults were interviewed as part of this survey and the age distribution (Fig. 10) was approximately normal with the highest proportion between 41-50 years, followed by those aged 51-60 and 20% between 31-40 years. The smallest age group was 71+ years which comprised 9% of the sample. Of those people collecting in the estuary (Fig.11.), the

majority (39%) were aged between 31-41 years followed by 29% aged 41-50 years and 16% aged 21-30 years. There were fewer in the older age groups greater than 50.

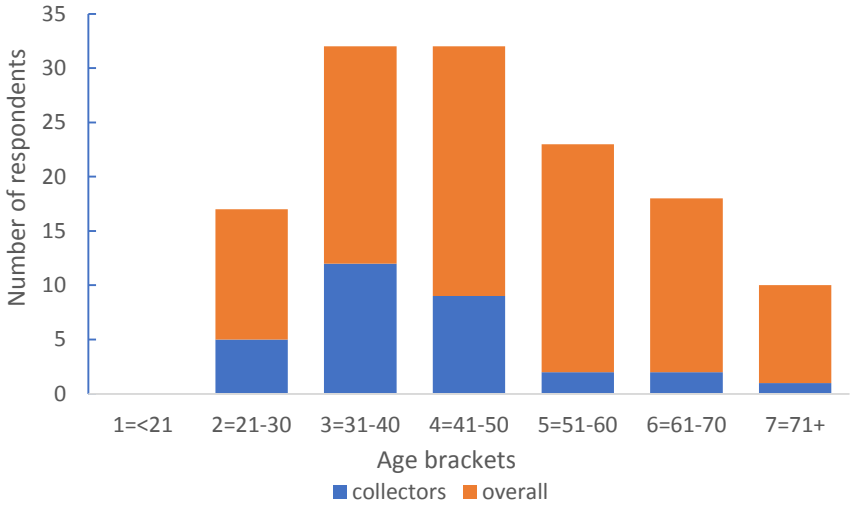


Figure 10. Age groups and number of respondents in the estuary survey (n=101). The age distribution of the collectors is shown in blue (n= 31).

Many of the people surveyed came from the immediate area, Redcliffs, Monks Bay and Mt Pleasant (Fig. 11). Others came from Lyttelton, within the Christchurch City boundaries and from the north and the south east of Christchurch. There were also a few people from other parts of NZ or from overseas. Shellfish collectors identified themselves as being mostly from Mt Pleasant, various parts of Christchurch and Lyttelton.

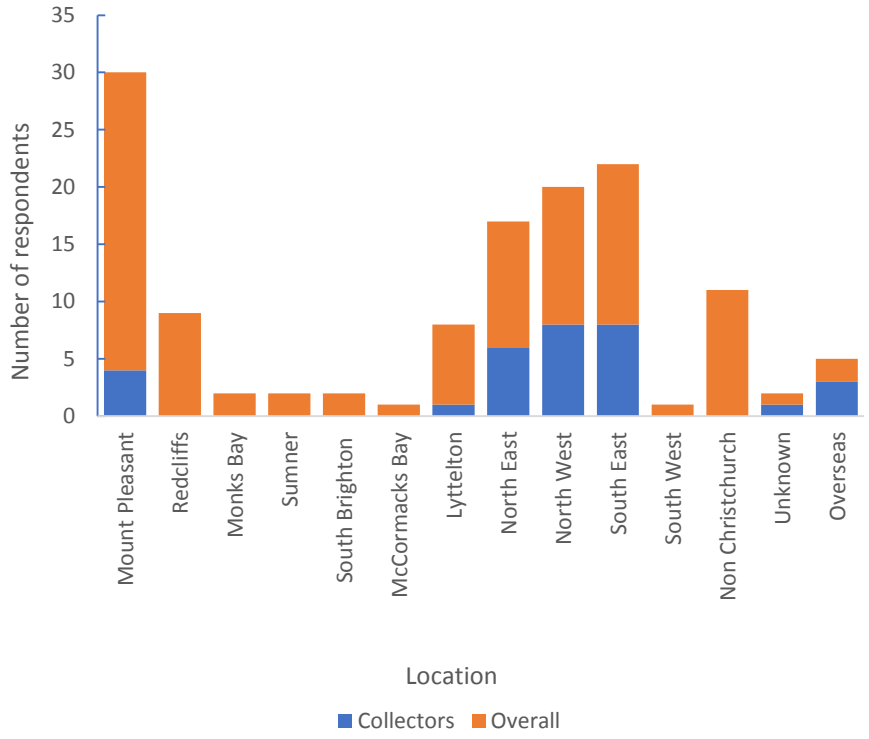


Figure 11. Residencies of estuary survey 101 respondents. Those in blue are people who were gathering on the mudflats (n=31).

3.2.2. Site information, frequency of visits

Some people visiting the estuary did so on a regular basis, ranging from every day, to once a month to their first time visiting (Fig. 12). About 26 % of people surveyed visited the estuary more than once a week, about 18% people visited daily, monthly/few times a month and yearly/ few times a year. Some 29% of people were collecting living matter. 4% were collecting non-living matter and 2% responded as other. Few were collecting shells or plant material. Most people (64%) described their visit as leisure (Fig. 13) and were admiring the estuary whilst walking or sitting along the margins (Fig.14).

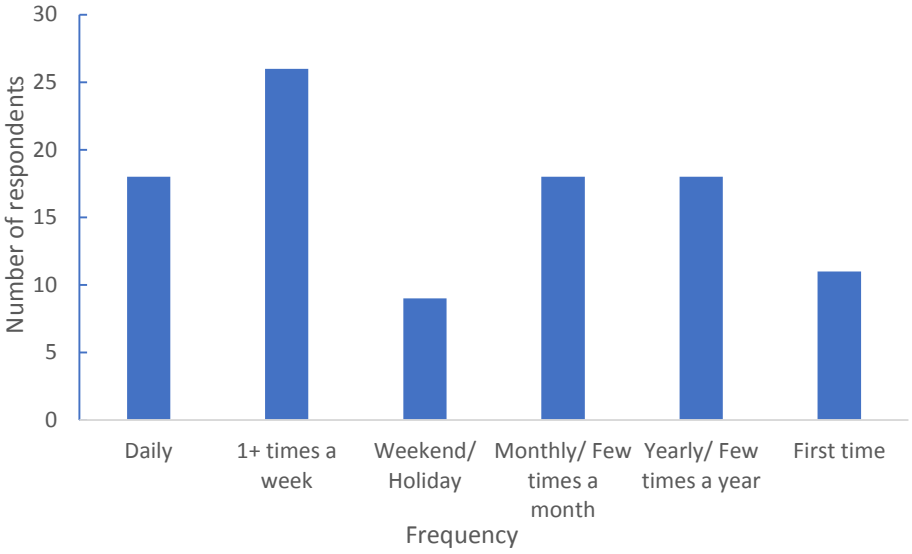


Figure 12. Frequency of visits by survey respondents (n=101).

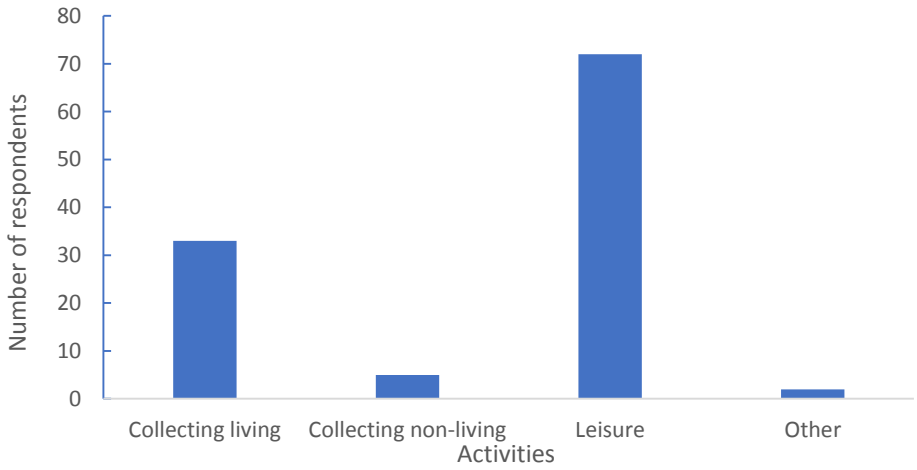


Figure 13. Activities undertaken in the survey area (n=101).

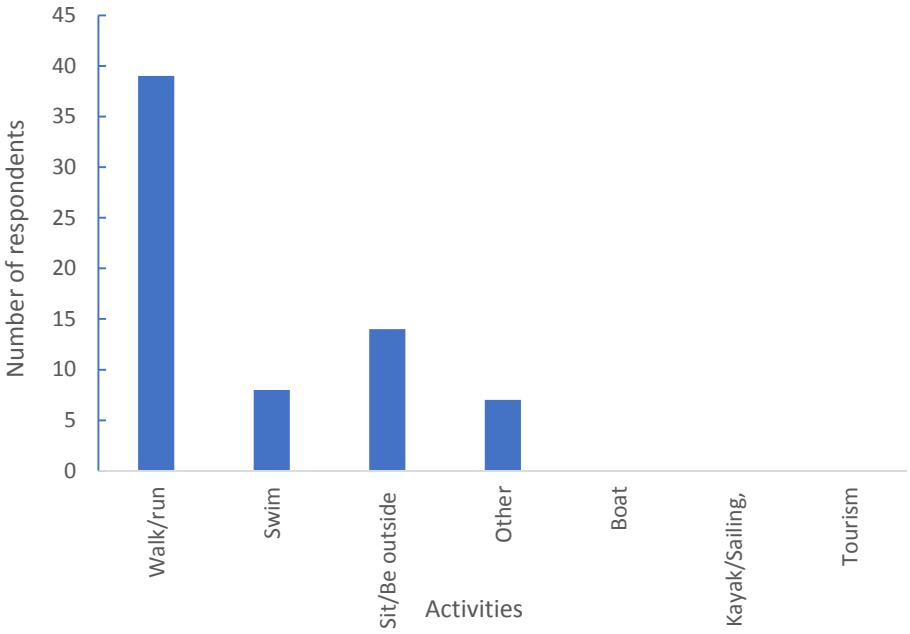


Figure 14. Leisure activities divided up into different categories (n=68)

Some of the survey participants identified as estuary collectors were visiting the site for the first time whilst others collected a few times a week or daily (Fig.15). Almost all of the people were collecting Tuaki to eat while others were collecting Tuaki or worms to use as bait or crabs as fish food.

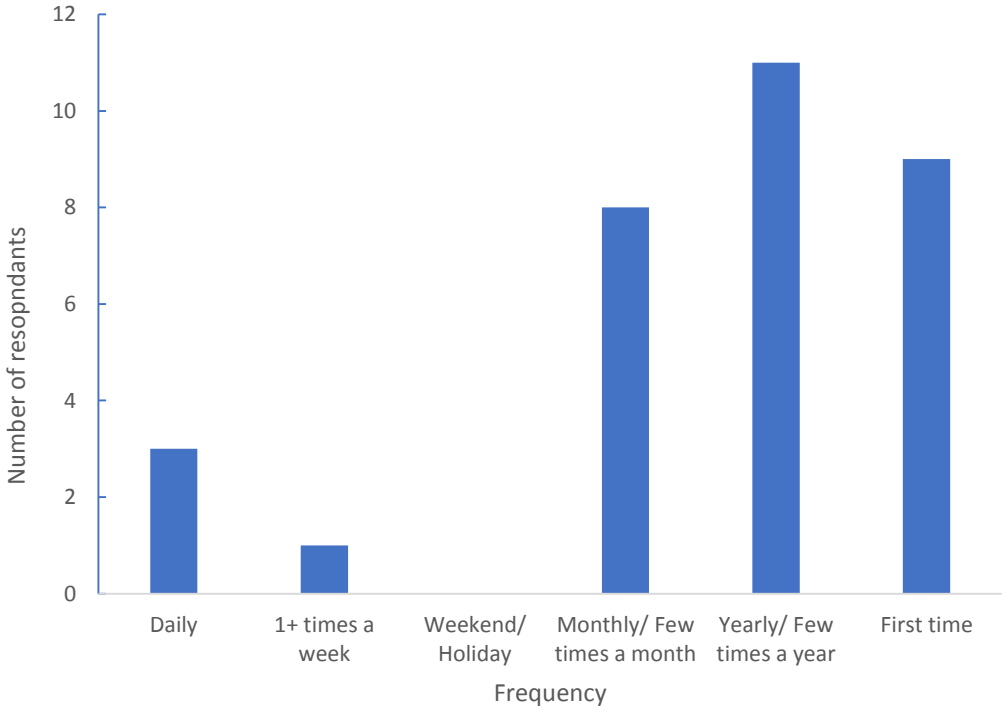


Figure 15. Frequency that estuarine collectors visited the estuarine sites.

3.2.2 Fishery and Environmental Health

People answering the questionnaire listed the main resources as cockles, fish, mussels, worms/bait, crabs and plants. Few people (21) answered this question and from the resources named 57% thought that there had been a change in the abundances in the Estuary since they first visited it. Others (38%) did not think there had been any change and 5% were unsure. For the cockle abundances, 31% responded the abundance was about the same since first collecting from the estuary, followed closely by 25% of people who thought there was only 75% of the cockles in the estuary than what was there previously. Some 25% of people were unaware of any changes. Some 13% thought there was an increase in the abundance than before and 6% responded that there was 50% less than when they first visited.

Most of the collectors favoured Tuaki as food but some collected for bait. Most people answered that the cockles were now smaller than they used to be and there were less of them. One respondent said that there was approximately 25% more fish than in previous years.

Most people rated the Estuary health between 2-3 fair and good (Fig.16) and almost everyone stated that they would return to visit in the future. There was a similar response from those collecting in the estuary.

Many people struggled with what they thought were indicators of the estuaries health. Most could name just 1 or 2 indicators of good estuarine health. Common indicators that people thought showed that the estuary was in good health were the presence of birds, water clarity and wildlife such as fish and seaweed Common bad indicators were pollution rubbish, smell, slime and foam (Table 3). Also noticing a decline in wildlife was rated as an indicator of poor environmental health. Sea lettuce was listed as an indicator of both good and poor estuarine health. Some people thought that there shouldn't be any in the estuary and some thought that the more sea lettuce, the better the health of the estuary.

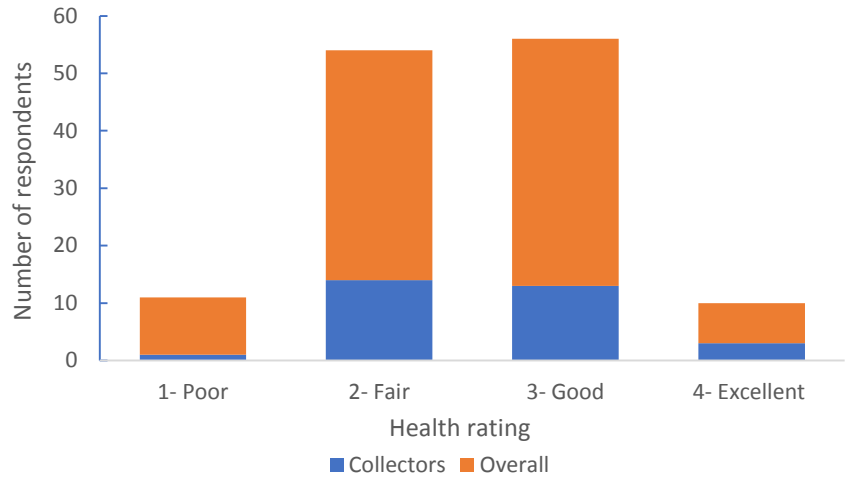


Figure 16. Assessment of Estuary health (n = 101). Area in blue shows the information for collectors (n=31).

Table 3. List of indicators representing good and poor estuary health

Indicators of good health	**Number of times suggested**	**Indicators of poor health**	**Number of times suggested**
Sea lettuce/ algae	5	Sea lettuce/ algae	23
Sea lettuce amount	2	Rubbish	22
No nuisance algae	6	Pollution/slime/sludge/foam	29
Plants	7	Unpleasant smell	24
No pollution	12	Water murky	12
No smell	6	A decline in wildlife	27
Smell	2		
Foam	3		
Water quality	5		
Water clarity	22		
Safe water testing results	2		
Water/wild life	24		
Cockles (big/more)	13		
People/recreational activities	9		
Birds	41		
Fishing	4		
Swimmers	3		
Sandier/ Clearer sand	2		
Others suggested	12		
Total	180	**Total**	137

3.2.4. Management

Just over half of the people surveyed (62%) said that the land use had changed since the 2011 earthquakes. Other common observations were an increase in people walking and biking around the estuary and more building being constructed in the immediate area surrounding the estuary. Some people (61%) commented on water flow in the estuary, some have not seen noticeable change during the time they have been using the estuary. Those that responded that the flow had changed, commented that there was more water contained in the estuary than when they first visited the estuary. About half (54%) of the respondents suggested that there had been a change in the overall water quality. Most of these respondents said that the water had become clearer than in previous years.

Over half (61%) of the respondents said that there has been no change in the sediment condition. However, of those who noted that the sediment had changed, some mentioned that the sediment had become more sandier over time. Some people (7%) also noticed other changes and those included smell, storm water clearance improvement, more sandbanks and that the tide stays out longer than before the quakes.

People were generally unaware of any current management regulations. About half of the people surveyed were aware of some but most could only name one of the agencies involved. Most people thought that the current management was effective and heading in the right directing but could still improve.

When asked about the maximum numbers of shellfish which could be taken from the estuary many people didn't know. Those that could answer (about half), suggested approximately 50 cockles per person, which is under the current limit, a few suggested an extremely high limit (300 per person) while others were vague ("about a bucket full").

Further comments for improvements to the estuarine environment included more plants, to improve the visible biodiversity, more signage explaining things such as the estuaries history and rules (such as the area allowed for motorised water sports), more bins/ increased rubbish collection and more shading and seats along the walkway for people to admire the estuary.

4 Discussion

The present study was undertaken in response to public concern regarding the collecting of cockles on the mudflats along McCormacks Bay causeway. People were concerned whether the current population could sustain the present and increased levels of harvesting. A mixed methods experimental design and standard scientific methods were used to evaluate Tuaki abundances. A survey was conducted to assess recreational activites, estuary values and current management practices. These studies suggest thriving Tuaki populations in some locations but it is uncertain whether the mudflats could sustain current or increased collecting in the future.

4.1 Assessment of Tuaki abundances

There have been numerous studies on Tuaki populations in Ihutai. They include studies undertaken as part of regular monitoring and early studies by Knox summarised in Marsden and Knox 2008, EOS reports, and those undertaken as part of Environment Canterbury consultancy reports, Todd et al. 2008, Gwatkin and Marsden 2011/2012 and PhD studies by Adkins 2012, Adkins et al. 2014, Kainamu- Murchie 2017). Some of these included investigation into the current area of interest but none examined in detail the current study area along the causeway. In 2008 Tuaki abundances were less than 100 m^{-2} at eastern part of the study site, increasing to abundances up to 200 m^{-2} west of the causeway and some patches of higher densities, up to 400 m^{-2} (see maps included in Marsden and Gwatkin, 2013). Post the 2011 earthquake sequences, Gwatkin and Marsden (2013) targeted known hotspots of cockle abundances in the summer of 2011/12 and found densities up 400 m^{-2} at Beachville Rd in the channel and shell bank. These high abundances are no longer present in this area. Abundances in the present study were in the range 50 to 300 m^{-2} and therefore within the range recorded in previous years.

Many factors are known to affect Tuaki abundances. Large individuals may reach the end of their life span of 7-12 years (Pilkington 1992) and post-spawning mortality can be high. Excessive sand deposits may bury individuals below the depth where they can uncover themselves (Thrush et al. 2003). There may also have been post-earthquake disturbances which may have affected growth and reproduction (Baxter 1971). Finally in many parts of

the world including New Zealand, over fishing has resulted in population declines in many shellfish species such as cockles, pipis, scallops and mussels.

Highest population abundances (800 m^{-2}) in the present study were found at Monks Bay, an area which had not been intensively sampled previously. Similar densities have been previously recorded in 2008 at the mouth of the Heathcote River and at the estuary mouth. These areas characteristically have coarser sand sediment and some freshwater and nutrient inputs and these are consistent with the Monks Bay site. It will be of interest to follow the survival of these individuals over the next few years.

Although shellfish abundance is a good tool for monitoring shellfish, wet weight biomass and dry tissue weight biomass are more useful for fishery assessments. Some populations may be dominated by small individuals and therefore the biomass can be low. In the present study highest wet weight biomass (including shell) was found along the eastern side of the causeway and lowest values in sites close to the channel at Beachville Rd.

The dry weight biomass values representing the tissue weight m^{-2} was greatest at the Causeway and Monks Bay with dry weight tissue biomass of 75 and 90g respectively. All of the values in the present study were below those previously recorded in 2008 and 201/2012 (Marsden and Gwatkin 2013). They are however similar to those recorded previously from intertidal sites at Tern St (own data). In summary, while the abundance appears to have remained constant over time in some locations, wet weight and dry weight biomass at sites close to the channel at Beachville Rd appears to have declined since the summer of 2011/12.

4.2 Tuaki populations

Tuaki population structures in the southern part of Ihutai were site specific, demonstrating a wide range of individual lengths within populations at a particular location. All populations had representatives from the immature length group less than 15 mm shell length, characteristic of recruitment from the previous year. The growth rate of Tuaki is rapid over the first 2 to 3 years, then slows with individuals reaching maximum length in about 6 to 11 years (Marsden and Pilkington 1995, Marsden 2004). Because of variations in individual growth the population histograms of individual year classes merge so that the overall population histogram can look unimodal as newly established populations such as those at

Monks Bay, or those at Mount Pleasant yacht club, trimodal as in populations from the causeway and multimodal as in the Christchurch yacht club. At this latter site there were low Tuaki abundances indicating good recruitment over the past two years and this was the site where the largest Tuaki, up to 60 mm shell length were collected. Individuals of this length had disappeared from places along the causeway where they previously had been found.

4.3 Tuaki health

Tuaki are filter feeders, obtaining food by feeding usually around the time of the high tide (Marsden and Knox 2008). The energy obtained in this way can be allocated towards shell growth and tissue growth. In juveniles tissue growth is rapid and the condition index can be high. As bivalves reach maturity excess resources are allocated towards both tissue growth and the development of gonad tissue. Shellfish health can be measured in several ways, by cultural or visual assessments and by standard weight related methodologies. The dry weight condition index (CI) is a simple ratio of the dry weight of the tissue and the shell, which remains relatively constant over time. As the gonad develops the dry weight increases often doubling the weight of the tissues. Once the gonad is mature then male and female Tuaki spawn and there is often a dramatic loss of gametes and a fall in the condition index. Spawning usually occurs annually but can occur twice a year if growth conditions over winter are good. Previous records from Ihutai (Marsden 2004) suggest that over winter when temperatures are low the condition index would be low increasing rapidly during spring as a result of the spring bloom and increased food availability. The condition index of Tuaki can also be low where individuals are stressed. In the present study CI values were highly variable, with very low values from Mount Pleasant Yacht club and low values at the causeway island and Beachville Rd. Higher values were recorded closer to the estuary mouth and this would be consistent with growth studies suggesting that exposure to reduced salinity can impair growth in this species (Marsden and Pilkington 1995, Marsden 2004). Variation of CI with location is expected because of the differing conditions at each location in the estuary and individuals at different stages in the reproductive cycle . After spawning, Tuaki may have low resistance to stressors and there may be mass mortalities as seen in other sand beach bivalves such as Tuatua.

4.4 Habitat health using birds

Estuarine mud flats provide feeding areas for a variety of wading birds which feed on benthic invertebrates. While godwits and gulls feed on a wide range of invertebrate prey items including polychaetes and molluscs, oyster catchers are specialised shellfish predators feeding mainly on the smaller bivalves on the estuarine mudflats between 2h before and 2h after the low tide. Highest abundances of oyster catchers and godwits were seen at the causeway sites where there was an abundance of suitable prey items. Neither the total number of birds or the numbers of oystercatchers correlated with either the abundance or dry weight tissue biomass m^2 of Tuaki. The presence of birds successfully feeding, however is an indicator of potentially productive mudflats and this most likely reflects the availability of preferred prey (Wakeling 2011, Marsden and Gwatkin, 2013). The absence of godwits from many of the sites most likely reflects the lack of preferred prey in the form of polychaetes.

4.5 Estuarine activities and usage

Visitors to the estuary were mostly between 30 and 50, were mainly local and made multiple visits, mainly for leisure including walking and relaxing outside. These results are consistent with previous studies (Xayasenh, 2015) where post earthquake, these were the favoured activities. Of the total number of people visiting the estuary relatively few were observed collecting shellfish on the mudflats. This group were therefore targeted to obtain information. Most of these respondents were in the 31-40 age group and the largest group was 23% who identified themselves as Māori followed by Filipino and New Zealanders. Importantly, about 25% of the collectors visited the area for collecting 1 or more times a week. Shellfish collecting is an important social, economic and cultural practice undertaken in many parts of the world and the results presented here are in line with casual conversations with beach goers over the years. They highlight the importance to Māori of this resource, which is a similar finding to that reported by Kainamu- Murchie et al. (2017, 2019). This research showed the deep connection that people have with traditional shellfish gathering areas around Te Ihutai.

4.6 Estuary health and management practices

Most people recognised resources such as shellfish, fish and bait, including worms and crabs but many were uncertain about whether these had changed over time. Some people mentioned changes in Tuaki and fish but there were few consistent responses. Both collectors

and recreational users rated the health of the estuary as fair to good and most said they would visit the estuary again. These findings reflect information from water samples from recreational surveys and improved water quality following the removal of waste water from the estuary along the ocean outfall. The public perceptions about the sediment in the estuary were varied, some people noted that the sediment had become sandier and that there were new sandbanks. Such observations have been noted post earthquake by the public, especially in areas close to the Christchurch yacht club.

When asked about indicators of either good or poor estuary health, people named water clarity, wildlife including fish and birds as indicators of good health and poor health indicated by a decline in wildlife, pollution, rubbish and increased presence of sea lettuce. These answers indicated quite a high level of understanding about estuarine processes. Many people noted changes post-earthquake both in the estuary itself or an increased presence of construction, or people walking and biking. The findings from the present study confirm that people visiting the Estuary have a wide appreciation of its recreational, ecological and cultural values and such values can be important in assessments of environmental health in estuarine ecosystems. Recent research (Chang et al. 2013, Zsuffa et al. 2014, Flint et al. 2017) suggests that holistic assessments including both scientific and other values can be useful in assessing change and evaluating the effectiveness of management practices.

When asked about improvements that might be made to improve the estuary, the suggestions included increasing plants to improve the diversity, seats and shading and more rubbish bins. Some of these suggestions have been implemented as part of the new cycleway but a lack of signage remains a problem.

In general there was not good knowledge about who manages the estuary and of the fisheries regulations associated with it. While many of the respondents recognised that there may be limits on the number of shellfish which are allowed, about half thought that the limit was about 50. Some people thought the limit was 300 per person while others represented the number as about a bucket. Most people collecting shellfish were in groups made up of people collecting as families, or couples. No detailed assessment was made on the numbers of shellfish collected by respondents in this survey. The Tuaki were in put in buckets and none of the groups appeared to exceed the current limit of 150/day /person. Most were collecting Tuaki for eating or bait and most intended to cook them. This might avoid potential food poisoning by bacteria. There are health risks associated with eating raw shellfish, including

the presence of bacteria and viruses and normally shellfish collection in an estuary with storm water and river inputs would be discouraged.

4.7 Sustainability of Tuaki populations

The present study supports the view that Tuaki populations in some parts of Ihutai are stable with regular recruitment such that populations might be expected to expand in the future. The sediment conditions and water quality have improved post earthquake and there are new recruitment areas in localities where populations had declined prior to the earthquake.

Tuaki along the McCormacks Bay causeway include individuals of shell length greater than 30mm shell length favoured by harvesters. As people drive over the causeway at low tide the mudflats are exposed and people are visible, collecting on the mudflats. There is easy access to the mudflats across a small channel. During summer at the weekends and over the Christmas holidays during low spring tides up to 20 people have been seen on the mudflats. Between November 2017 and the end of February 2018 there were approximately 54 days when low tides were 0.5 or below during daylight hours. If on average there were 5 collectors per day or 300 over the summer season, and, if collecting was generally confined to a small area then an unacceptably large proportion of the population would be removed. Although most collectors did not appear to be exceeding the regulatory limit, our research suggests that harvesting has the potential for local adverse effects on the Tuaki population close to the Beachville Rd Jetty. As catch rates decline, harvesters may then move west along the causeway to collect shellfish.

In a study prior to the earthqauakes Fisher and Vallance (2010) suggested that there were likely to be about 4,000 people who routinely collected seafood (shellfish and fish, including kahawai, elephant fish and red cod) from the Estuary. There was also a larger latent population of up to 24,000 who collected in the past but may not have been collecting at the time because of perceived contamination. These authors suggested that once the ocean outfall was established and environmental conditions improved these latent collectors have the potential to become active.

If collecting pressure was to increase from the present low levels and the largest individuals were removed from the population it might take 4-6 years for the populations to recover. These large individuals most likely contribute most to successful spawning. Stopping

harvesting, however may not lead to rapid recovery which will depend on recruitment and settlement.

It is not known whether there are large size harvestable Tuaki post-eathquake elsewhere in the Estuary. Immediately post earthquake Tuaki abundances of more than 1200 m^2 were recorded for the channel at Tern St (Marsden and Gwatkin 2013) and dry weight biomass was 700g m^{-2}. If shellfish beds with large individuals have survived then they are relatively inaccessible and protected against harvesting. It is therefore important to determine the extent of the shellfish beds especially in the central parts of the estuary and measure the availability of harvestable size shellfish. Post earthquake there was high sediment input into the estuary and new bare areas of sandbanks established. By now these areas may be suitable for reseeding purposes. Procedures for doing this have been established by Henry Couch Whakaraupō Mātaitai Tangata Tiaki/ Kaiktiaki. Reseeding of Tuaki in suitable areas might increase the productivity of shellfish in the estuary and there would be ongoing improvements in estuarine services including increased biodiversity (Marsden and Adkins, 2010).

Finally one of the threats to sustainability of Tuaki in Ihutai is the presence of sea lettuce. Despite the removal of treated waste water from Ihutai this nuisance algae continues to thrive and cover the mudflat surface. This stops birds actively feeding on the mud flats and if the sea lettuce accumulates on the surface the sediment can become anoxic. This can kill polychaete worms, result in shellfish moving to the surface where they might be eaten by birds or in extreme cases after long exposure they might die (Marsden and Bressington, 2009). Previous large scale mortalities have been recorded in Ihutai, for example outside the treatment ponds (Adkins 2012) when the sediments have become anoxic. Similarly in spots directly following the earthquake when raw sewage had been released in the estuary (own data). Although Tuaki are regarded as relatively tolerant of environmental stressors, combinations of stressors such as high summer temperatures, increased nutrients and low water flows most likely result in reduced Tuaki survival or growth.

Management of sea lettuce with estuaries is not easy and it has been disappointing to see sea lettuce accumulating and now decaying on Te Ihutai margins despite the removal of treated waste water. Similar occurrences, however have been recorded in other areas such as Tauranga following treated sewage removal and this has been attributed to the release of accumulated nutrients in the sediments. Other factors which can promote sea lettuce growth

include unusual weather conditions, such as mild winter temperatures. It will therefore be important to understand why the sea lettuce appears to be increasing in Te Ihutai and explore options to minimise its effects in some of the more sensitive estuarine areas.

4.8 Conclusions and Recommendations

The present research confirms that people visiting the southern parts of Te Ihutai appreciate its natural values. Similarly high natural values have been reported for other parts of the estuary such as South Shore and South New Brighton (Regenerate Christchurch survey). Many people surveyed travel to the estuary from other parts of Christchurch and shellfish collecting is an important recreational and cultural activity. If Tuaki from southern New Zealand become available then this activity could be supported by reseeding into suitable transplant areas.

We identified areas in the estuary about half way along the McCormacks Bay causeway with high abundances of Tuaki. At the time of sampling these individuals had a low condition index which may be a normal part of their natural cycle. Abundances were reduced in the McCormacks bay channel and sandbank where previously there had been high population densities. This reduction may have been due to natural mortality causes due to old age but harvesting may have played a part. There is therefore a clear need for further studies to assess Tuaki abundances both in this area and elsewhere in the estuary. If possible this would be a repeat of the 2004 study undertaken by Derek Todd et al. which included water depth and sediment composition. There is also a need for fisheries modelling to determine whether these Tuaki populations can sustain regular harvesting. If Tuaki populations are shown not to be sustainable then there would be a need to regulate collecting or place a ban on collecting. This may be achieved through fisheries regulations (Ministry of Fisheries) or using special regulations such as establishing a mātaitai. Te Ihutai is of high cultural value to Ngai Tahu and local Runanga may be in a position to put a ban on collecting or rahui in place. Our study did not measure how many shellfish were being removed by collectors. During our study most people did not appear to be exceeding the bag limits for Tuaki. Our focus was on information gathering not compliance monitoring. It will, however be necessary to assess the

Tuaki recreational catch if decisions are to be made about limiting the recreational catch. In the past we have seen collectors taking away large bins of cockles from the Estuary. The public should also be encouraged to inform MAF poacher if the current regulations appear to be breached.

It is clear to many people who visit the estuary that the numbers of people collecting Tuaki has increased post earthquake. Recently there have been reports from members of the Estuary Trust of between 20 and up to 40 people seen on the mudflats and this is generating widespread local concern. The present study did not attempt to gather quantitative data on the shellfish catch because this may have limited the willingness of participants to contribute to our research. To advance the management of shellfish resources, better information is required on the number of people collecting and monitor their catch. It might be possible to do this with a fixed camera mounted above estuary and/or with the assistance of local fisheries offices and or residents.

Contaminants from the catchment, groundwater, rivers and storm water enter the estuary and potentially accumulate in the biota. Levels of trace metals in the flesh of Tuaki are usually below the levels likely to affect people and the greatest public risk is most likely from microbial contaminants, bacteria and especially viruses which can cause gastric problems and be very long lasting. There has been regular monitoring of microbial contaminants in shellfish over several summers and these have highlighted particular areas of concern. There is therefore a need to better inform the public of potential health risks associated with shellfish collecting and to improve signage. If water quality and environmental conditions in Te Ihutai improve so that there is not a health risk then there is likely to be increased harvesting pressure.

Estuarine ecosystems are amongst the most impacted ecosystems in the world and with global change many predictions have been made about their resilience to change. Organisms within estuaries are exposed to multiple stressors and increased storm surges, change in water levels and ocean acidification are all likely to play a part. Many people predict that there will be an increase in nuisance algal blooms and if they are severe then shellfish and other benthic invertebrates will be negatively impacted. There would also be ongoing effects on upper trophic levels on fish and birds. It is therefore important to understand if or how nuisance algae affect the shellfish beds and its ongoing effects on the whole ecosystem. Shellfish are important ecological engineers in mudflat community, they perform important ecological

services, transferring nutrients within the system and providing habitat for other organisms, therefore increasing the biodiversity (Lundquist et al. 2006, Thrush et al. 2006). They also provide important cultural and recreational value for the people of Christchurch and the surrounding area. It is therefore important to try to not only maintain but enhance these resources so that they can be enjoyed by future generations.

5. Acknowledgements

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6. References

Adkins, S.E. (2012). Population Biology and Restoration of Intertidal Cockle Beds. PhD Thesis in Environmental Science. University of Canterbury.

Adkins, S.E., Marsden, I.D., Pirker, J.G. 2014. Variation in population structure and density of *Austrovenus stutchburyi* (Veneridae) from Canterbury, New Zealand. Journal of Shellfish Research 33: 343-354.

Baxter, R.E. 1971. Earthquake effects on clams of Prince William Sound. In NRC, The Great Alaska Earthquake of 1964. pp 238-245. Committee on the Alaska Earthquake, National Research Council, National Academy Press, Washington, DC, USA.

Chang, H.-T., Yang, L., Yeh, S.-C., Chen, H.-W. 2013. Systematic index frame for functional assessment of constructed wetlands. Ocean and Coastal management 73: 145-152.

Corliss, P. 2018. A bibliography of the Avon-Heathcote Estuary/Ihutai. Web resource prepared for the Avon-Heathcote Estuary Ihutai Trust.

Gray, E.R., 2009. Population size, distribution, feeding behaviour and prey capture success of three wader species in the Avon-Heathcote estuary. Estuarine research report 37. School of Biological Sciences, University of Canterbury, Christchurch, NZ.

Fisher, K., Valance, S. 2010. Food gathering practices at the Avon-Heathcote Estuary Ihutai Canterbury Aotearoa/New Zealand. Summer Scholarship Report, 2009/2010 for Lincoln University, Environment Canterbury and the Avon-Heathcote Estuary Ihutai Trust. 47pp.

Flint, N., Rolfe, J., Jones, C.E., Sellens, C., Johnston, N.D., Ukkola, L. 2017. An ecosystem health index for a large and variable river basin: methodology, Challenges and continuous improvement in Queensland's Fitzroy basin. Ecological Indcators 73: 626-636.

Gwatkin, K, Marsden ID. 2014. Macrobenthic communities in the Avon-Heathcote Estuary/Ihutai following the Canterbury 2010/2011 earthquakes. Estuarine Research Report No. 43, 32pp.

Jones, M.B., Marsden, I.D. 2005. Life in the Estuary illustrated guide and Ecology. Canterbury University Press, 179pp.

Kainamu- Murchie, A. 2017. '*Ki uta ki tai*' '*Mauka makai*': The ecological and sociocultural values of estuarine shellfisheries in New Zealand and Hawai`i. PhD in Environmental Science, University of Canterbury.

Kainamu-Murchie, A. A. Marsden, I.D., Tau, R.T.M., Gaw, S., Pirker, J. 2018. Indigenous and local peoples' values of estuarine shellfisheries: moving towards holistic–based catchment management. NZ. Journal of Marine and Freshwater Research (add in volume and page numbers).

Lang, M., Orchard, S., Falwasser, T., Rupene, M., Williams, C., Tirikatine-Nash, N., Couch, R. 2012. State of the Takiwa. 2012. Te Ahutanga o Te Ihutai: cultural health assessment of the Avon-Heathcote Estuary and its catchment. Mahaanui Kurataiao Ltd Toru. 48pp.

Love, A. 1997. Food resources and habitat use by wading birds of remnant and restored wetlands at the Avon-Heathcote Estuary, Christchurch. MSc Thesis in Zoology, University of Canterbury.

Lundquist, C.J., Thrush, S.F., Hewitt, J.E., Halliday, J., MacDonald, I., Cummings, V.J. 2006. Spatial variability in recolonisation potential:influence of organism behaviour and hydrodynamics on the distribution of macrofaunal colonists. Marine Ecology Progress Series 342:67-81.

Maclaren, S., Marsden, I.D. The ecology of the Avon Heathcote Estuary : macrobenthic survey , summer 2004/5 Estuarine Research Report 33, University of Canterbury.

Marsden, I.D.1998 Benthic invertebrates of the Avon-Heathcote Estuary, December 1997. Report for Environment Canterbury.

Marsden, I.D. 2004. Laboratory and field experiments investigating the effects of reduced salinity and seston availability on growth of the little-neck clam *Austrovenus stutchburyi.* Marine Ecology Progress Series 266: 157-171.

Marsden, I.D. Adkins, S.C. 2010. Current status of cockle bed restoration in New Zealand. Aquaculture International 18: 83-97.

Marsden, I.D. Bressington, M.J. Effects of macroalgal mats and hypoxia on burrowing depth of the New Zealand cockle (*Austrovenus stutchburyi).* Estuarine and Coastal Shelf Science *v* 81, 2009: 438-444.

Marsden I. D., Knox G.A., 2008, Chapter 23. *Estuaries, Harbours and Inlets*. In Natural History of Canterbury edited by Winterbourn, M, Knox, G.A. Burrows, C. and Marsden, I.D., 735-770 University of Canterbury Press, New Zealand.

Marsden, I.D., Maclaren, S.R. 2010. Short-term study testing the resilience of an estuarine bivalve to macroalgal mats. Hydrobiologia 649: 217-229.

Marsden, I. D. & R.M. Pilkington, 1995. Spatial and temporal variations in the condition of *Austrovenus stutchburyi* Findlay, 1927 (Bivalvia:Veneridae) from the Avon-Heathcote Estuary, Christchurch. New Zealand Natural Science 22:57-67.

Marsden, I. D., Smith, B. D., Rainbow, P, S. 2013. Effects of environmental and physiological variables on the accumulated concentrations of trace metals in the New Zealand cockle *Austrovenus stutchburyi.* Science of the Total Environment 470-471: 324-339.

Measures, R., Hicks, M., Shankar, U., Bind, J., Arnold, J., Zeldis, J. 2011.Mapping earthquake induced topographical change and liquefaction in the Avon-Heathcote Estuary. NIWA Client CHC2011-066, July 2011. Report produced for Environment Canterbury, 28p.

Mudunaivalu, K. 2013. Evaluation of the customary fisheries management of shellfish in the Canterbury Region. MSc Thesis in Environmental Science 182pp.

Pauling, C., Lenihan, T.M., Tirikatene-Nash, N., Couch, R. 2007. State of the Takiwa. , Te Ahuatanga o Te Ihutai: Cultural health Assessment of the Avon- Heathcote Estuary and its catchment. Te Runanga o nagai Tahu Toru 76pp.

Pilkington, R. 1992. Spatial and temporal variation in the growth and condition of *Austrovenus stutchburyi* in the Avon-Heathcote Estuary. MSc in Zoology, University of Canterbury.

Reid, C.M., Thompson, N.K., Irvine, J.R.M. and Laird, T.E. 2012. Sand volcanoes in the Avon–Heathcote Estuary produced by the 2010–2011 Christchurch Earthquakes: implications for geological preservation and expression. New Zealand Journal of Geology and Geophysics, 55: 249-254.

Robertson, B.M.; Gillespie, P. A.; Asher, R. A.; Frisk, S.; Keeley, N.B.; Hopkins,G. A.; Thompson, S. J. & B. J. Tuckey, 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development,Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096.

Smits, J.E., Fernie, K.J. 2013. Avian wildlife as sentinels of ecosystem health. Comparative Immunology, Microbiology and Infectious Diseases 36: 333-342.

Thrush, S. F., Hewitt, J.E., Gibbs, M., Lundquist, C. & A. Norkko, 2006. Functional role of large organisms in intertidal communities: community effects and ecosystem function. Ecosystems 9: 1029- 1040.

Thrush, S.F., Hewitt, J.E., Norkko, A., Cummings, V.J., Funnell, G.A. 2003. Macrobenthic recovery processes following catastrophic sedimentation on estuarine sandflats. Ecological applications 13: 1433-1455.

Wakeling, D, 2011. Distribution of shore birds and the status of the population of the eastern bar-tailed godwit (*Limosa lapponica bauera*) at the Avon-Heathcote Estuary. B.Sc Project Report, University of Birmingham.

Xayasenh, P. 2015. Post-quake recreational opportunities in the Avon River and the Avon-Heathcote Estuary/Ihutai. M.Sc in Freshwater Management, University of Canterbury.

Zeldis, J. Skilton, J., South, P., Schiel, D. 2011. Effects of the Canterbury Earthquakes on Avon-Heathcote Estuary. NIWA consultancy report.

Zsuffa, I., Van Dam, A.A., Kaggwa, R.C., Namaalwa, S., Mahieu, M., Cools, M., Johnston, R. 2014. Towards decision support-based integrated management planning of papyrus wetlands: a case study from Uganda. Wetlands Ecological Management 22: 199-213.

7 Appendices

Appendix 1. Questionnaire information sheet

Information and Consent Sheet

The School of Biological Sciences, University of Canterbury
islay.marsden@.canterbury.ac.nz

24th August 2017

Information and Consent sheet for local recreational participants

You are invited to participate in research entitled: Sustainability and values of New Zealand shellfish. This information will contribute towards local based indicators, food safety knowledge, and future implications for coastal zones resource management. I am being assisted in this research by a summer student at the University of Canterbury.

Your participation in this project will consist of completing a questionnaire that asks you to provide fishery, land use, and management information. Question will consist of YES/NO and multiple choices. Completion of the survey will take approximately 15-20 minutes. If the questionnaire is filled out electronically, it should be sent back to the researcher by email to islay.marsden@canterbury.ac.nz.

Participation is voluntary. Participation can be withdrawn from the research including any information provided by not submitting the survey to the researcher. You will not be asked to participate in any follow-up to this investigation. In the performance of the tasks and application of the procedures, there are no risks envisaged from participating in this survey.

You can access the results of this research in a University of Canterbury Report to be written for the Estuary Trust in 2018. The results of the project may be published, but you may be assured of the completed confidentiality of data gathered in this investigation. All data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after ten years. To ensure anonymity and confidentiality, personal information will not be used during the processing of data, nor in the final report.

The research is being carried as part of a summer scholarship co-funded by the Estuary Trust under the supervision of Professor Islay Marsden (University of Canterbury), who can be contacted at islay.marsden@canterbury.ac.nz. She will be pleased to discuss any concerns you may have about participation in the project.

By participating in the study, it is understood that you have provided consent for the information to be used in the study.

This project has been reviewed and approved by the Human Ethics Committee of the University of Canterbury, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Thank you for your time.
Regards,

Islay Marsden
School of Biological Sciences,
University of Canterbury,
Christchurch.
Tel. 3695185

Cell: 0212112328

7.2: Appendix 2. Questionaire

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND
UC College of Science

School of Biological Sciences

Tel: (03) 364 2500, Fax: + 64 364 2590

Email: biology@canterbury.ac.nz

Location: _____

Date and time: _____

Project title: Sustainability of shellfish in the Avon-Heathcote Estuary/Ihutai

Questionnaire for recreational use

Ethnicity: _____

Cultural affiliation(s): _____

Sex: Female/Male Age: <21, 21-30 ,31-40, 41-50, 51-60, 61-70,71+

Your place of residence: _____

SITE INFORMATION

1. How often do you visit this site? _____
2. Have you done any of these activities here?

☐ Collect living animal/plant/other_____ ☐ to eat, bait, material, other_____

☐ Collect non-living shells/stones/plant/other_____ ☐ to eat, bait, material, other_____

☐ (Leisure) walk/run/swim/bathe/sit and be outside/boat, other _____

☐Other eg How much shellfish is taken?:

_____

FISHERY HEALTH

3. What living plants/animals/others do you favour as resource (bait, food…)? Please list these:

_____

4. In the last 10/20/30 years (circle one), have these changed in abundance? YES/NO
   a. If YES, what abundance remains today compared to the past 10/20/30 years?

Species name:	**% of the past species abundance that is available today**
1.	10%, 25%, 50%, 75%, 100% n/a
2.	10%, 25%, 50%, 75%, 100% n/a

   b. Are there any other species gathered in the past that are not available today?

_____

ENVIRONMENTAL HEALTH

5. How would you describe the general condition of the site where you do the above activity?

CONDITION SCALE:	1	2	3	4
	Poor	Fair	Good	Excellent

6. Would you return to the site in future? YES/NO, please explain:

_____

7. What are the main environmental indicators that signal good/poor waterway health for gathering natural resources, especially food and bait?

Good Indicators	Poor Indicators

MANAGEMENT

8. What main changes (if any) have you seen in this site over time in the last 10/20/30 years?

- ☐ Catchment land use Yes/No _____
- ☐ Water Flow Yes/No _____
- ☐ Sediment Yes/No _____
- ☐ Water quality Yes/No _____
- ☐ Other if YES, what are they: _____

If YES to any of the above, please explain:

_____

9. Do you know what the current management is here? YES/NO

   If YES, what are the current regulations: _____

   If YES, think the current management is effective? YES/NO

Please explain: _____

DO YOU HAVE ANY FURTHER COMMENTS?

_____

_____

_____

THANK YOU VERY MUCH - END OF QUESTIONAIRE